Rocky Mountain Institute®

Georgia Tech Research Institute

LESSONS FROM AUSTRALIA

REDUCING SOLAR PV COSTS THROUGH INSTALLATION LABOR EFFICIENCY

1820 FOLSOM STREET | BOULDER, CO 80302

PUBLISHED JUNE 2014
DOWNLOAD AT: WWW.RMI.ORG

TABLE OF CONTENTS

AUTHORS

Koben Calhoun, Karen Crofton, Joseph Goodman (GTRI), and Robert McIntosh

** Authors listed alphabetically. All authors are from Rocky Mountain Institute unless otherwise noted.*

Editorial Director: Peter Bronski
Art Director: Romy Purshouse
Graphic Designer: Teressa Luedtke

CONTACT

For more information, please contact:
Koben Calhoun, kcalhoun@rmi.org
Robert McIntosh, rmcintosh@rmi.org

EXECUTIVE SUMMARY

After examining the installation practices in Germany and Australia—two global leaders in installed distributed solar photovoltaic (PV) capacity—we conclude that the U.S. can substantially improve its average installation efficiency. Labor hours per kilowatt have the potential to streamline from 9.4 to approximately 7 and begin approaching world-leading installation rates of 4–6, thus reducing the soft costs that today make up fully two-thirds of the installed cost of PV systems in the U.S. This high level of efficiency is possible through four critical interventions:

1. Optimizing the pre-installation process
2. Redesigning the base installation process for asphalt shingle and tile roofing applications
3. Utilizing integrated racking and mounting systems to reduce and eliminate non-value-add activities
4. Reducing the number of separate meters to monitor the PV system output

These improvements will help installers increase efficiency, reduce cost, and make one-day installations common in the U.S., resulting in additional cost reductions throughout the PV installation value chain.

INTRODUCTION

Distributed energy resources, including residential rooftop solar photovoltaics (PV), can play an integral role in the electricity system of the future. For example, Rocky Mountain Institute's analysis *Reinventing Fire* showed how the U.S. electricity system could shift from centralized fossil-fueled generation to efficiency and 80% renewables—half of them distributed—for essentially the same cost as maintaining the system we have today while improving the grid's reliability and security and decreasing carbon emissions to more than 80% below 2000 levels.[i]

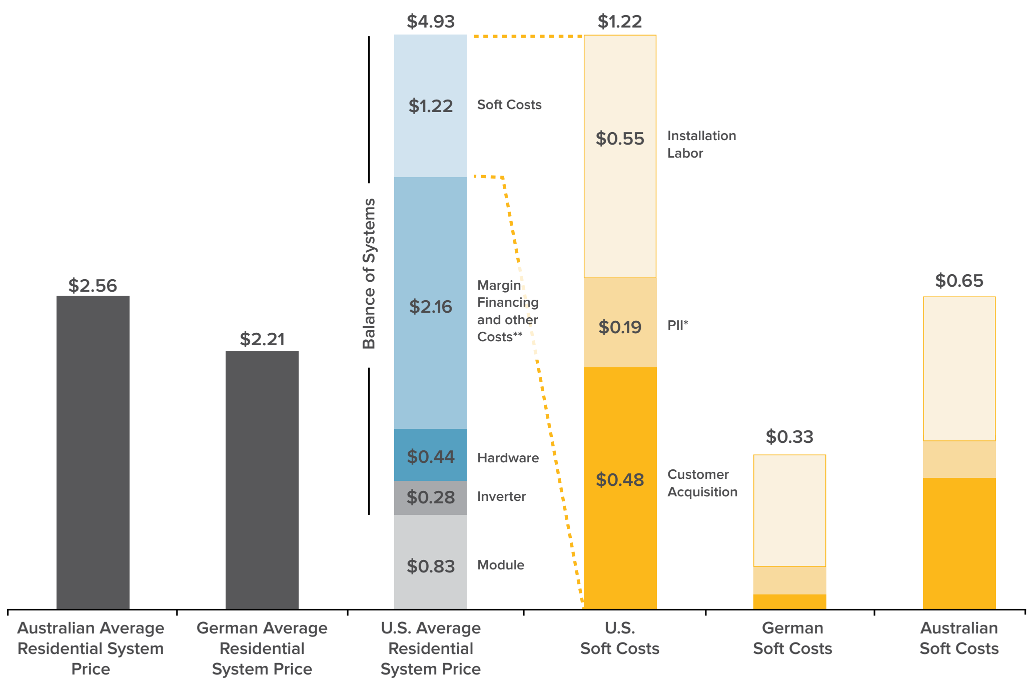
However, realizing that vision will require continued cost declines for residential rooftop solar in order to accelerate customer adoption.[ii] Between 2008 and 2012, the price of sub-10-kilowatt rooftop systems in the U.S. decreased 37%, but 80% of that cost decline was due to decreasing solar PV module costs.[iii] Total soft costs—including customer acquisition; installation labor; permitting, inspection, and interconnection (PII); and margin and other associated costs—now make up approximately 70% of the total installed priced for a U.S. residential PV system. Thus soft costs represent a land of opportunity for cost reductions.

Germany and Australia provide a unique opportunity to draw a comparison as global leaders of installed distributed PV generation. When combined, the U.S., Australia, and Germany comprise over 39%[1] of total global distributed PV generation capacity, with 6.1 GW,[iv] 3 GW,[v] and 21.4 GW[vi] of installed small-scale solar generation, respectively. Industry reports highlight the fact that Germany and Australia have total installed costs and soft costs at a fraction of what they are in the U.S. (see Figure 1).[2] In Australia and Germany, total soft costs (which include margin and other costs) comprise approximately 50% of the total cost of installation, with total soft costs of $1.20 and $0.97 per Watt installed, respectively.[3]

In the U.S., by contrast, total soft costs are $3.38 per Watt installed, and account for up to 65–70% of total installed costs.

Rocky Mountain Institute (RMI) and Georgia Tech Research Institute (GTRI) previously compared the U.S. and Germany in the December 2013 report *Reducing Solar PV Soft Costs: A Focus on Installation Labor.* Now we turn our attention to Australia, where we conducted a similar study and analysis. This report highlights our findings, including some characteristics unique to the Australian residential solar PV market as well as lessons that reinforced our findings from Germany.

FIGURE 1: RESIDENTIAL PV SOFT COSTS IN THE U.S., GERMANY, AND AUSTRALIA



*Permitting, inspection, and interconnection costs

** Includes installer and integrator margin, legal fees, professional fees, financing transactional costs, O+M costs, production guarantees, reserves, and warranty costs.

[1] Global small-scale capacity of 77.9 GW taken from *Bloomberg Global Renewable Energy Market Outlook 2013.*

[2] We use the U.S. residential PV price as stated in GTM/SEIA Q2 2013 for consistency with previous analysis in *Reducing Solar PV Soft Costs: A Focus on Installation Labor.* The current U.S. average residential PV price is $4.56/W according to GTM/SEIA Q1 2014. However, the cost breakdown has remained proportional to the total cost of the system.

[3] Throughout this report, $0.95 AUD = $1 USD. In addition, all dollars are adjusted to 2012 levels.

AUSTRALIAN PV MARKET OVERVIEW

Our recent analysis of the Australian residential PV market included direct observation data, interviews with industry professionals, and a review of industry reports. We found extensive similarities between the Australian and U.S. PV installation processes. However, we also noted a significant difference in total system costs, and particularly in the soft cost categories. Our analysis of existing industry studies found a total non-hardware cost difference of $2.19 per Watt installed between Australia and the U.S.:

- Customer Acquisition - $0.26
- Permitting, Inspection, and Interconnection - $0.05
- Installation Labor - $0.26
- Margin, Financing, and Other Costs - $1.62
- **Total Cost Difference - $2.19**

Based on our analysis, the primary difference between Australia and the U.S. stems from the way the solar market developed in Australia. Strong incentives for residential PV drove significant customer demand. Australian PV retailers and installers flooded the market to meet the growing customer demand. As a result, high market competition and transparency drove prices down and forced solar installers and retailers to lean processes so they could compete on price. One-day installs have become the norm, and installers and retailers rely more heavily on volume to create profit, especially as system prices have continued to decline.

In 2000, Australia passed the Renewable Energy (Electricity) Act stating 20% of Australia's electricity would come from renewable sources by 2020. By 2009, this led to rebates (i.e., Small-scale Technology Certificates) on solar installations, which lower the upfront cost of systems by $0.61–$0.71 AUD per Watt.[vii] Simultaneously in 2009, states in Australia began offering a feed-in tariff (FIT) to further incentivize homeowners, allowing owners to receive up to $0.60 AUD for each kWh provided to the network. In concert, retail electricity prices increased significantly during this period, more than doubling from an average of $0.10/kWh AUD in 2003 to $0.23/kWh AUD by the end of 2013.[4,viii] The strong incentives combined with increasing electricity prices led to strong demand for residential PV systems. The residential market grew from 20 MW of new capacity in 2008 to over 900 MW of new capacity installed in 2011.[ix] Today over 10% of Australian homes have PV systems.[x] Rebates have decreased from their highest levels, and the FIT has been effectively discontinued or severely reduced ($0.08/kWh AUD is now average[xi]). However, demand for residential PV systems has remained high and Australia's solar PV soft costs remain a fraction of what they are in the U.S.

Market competition has been one of the main sources of soft cost reduction. Between 2009 and 2012, the number of retailers went from 961 to 4,246, while the number of solar-accredited electrician installation companies increased from 1,300 to 4,484.[xxii,5] The high initial rebates/FITs made systems relatively affordable, limiting the need for financing and allowing the majority of Australians with rooftop PV systems to pay the full cost of the system up front.[xiii] Price competition became a primary differentiator for customers in the market for a PV system. As a result, total installed costs dropped from $12/W USD at the end of 2008 to $2.56/W USD by the second quarter of 2013.[6] But unlike in the U.S., where soft costs have remained high despite large drops in hardware costs, Australian soft costs also fell dramatically during the same period, from $5/W in 2008 to $1.20/W in 2013.

[4] Adjusted for inflation. 2003 price would be $0.13 in 2013 AUD.

[5] For comparison, the U.S. has 10,392 companies deriving at least some revenue from solar installation services. <http://www.thesolarfoundation.org/sites/thesolarfoundation.org/files/TSF%20Solar%20Jobs%20Census%202013.pdf>

[6] We focus on Q2 2013 to match the December 2013 RMI/GTRI report, *Reducing Solar PV Soft Costs: A Focus on Installation Labor.*

AUSTRALIAN SOFT COSTS

CUSTOMER ACQUISITION

With 10% of Australian homes possessing solar systems, (compared to 0.4% in the U.S.) word-of-mouth and recommendations are common pathways for rooftop PV purchasing decisions in Australia. Retailers quote referrals as their main method of acquiring business. The scale of the solar market has reached a tipping point that allows retailers to focus less on educating and convincing customers that solar is a good choice and focusing more acutely on the system type, design, and price. It is possible that as the U.S. reaches a comparable level of solar penetration, retailers will see significant reductions in customer acquisition costs as well.

PERMITTING, INSPECTION, AND INTERCONNECTION (PII)

Homeowners can easily place solar systems onto roofs due to low permitting, inspection, and interconnection requirements/costs in Australia. Permits are generally only required if a building is zoned as "heritage preservation." Inspection for rebates is provided for free by the government. Inspection/interconnection requirements from utilities are low, though some electrical retailers are now trying to establish fees. In general, however, the primary cost for PII is the time taken by retailers to fill out the forms.

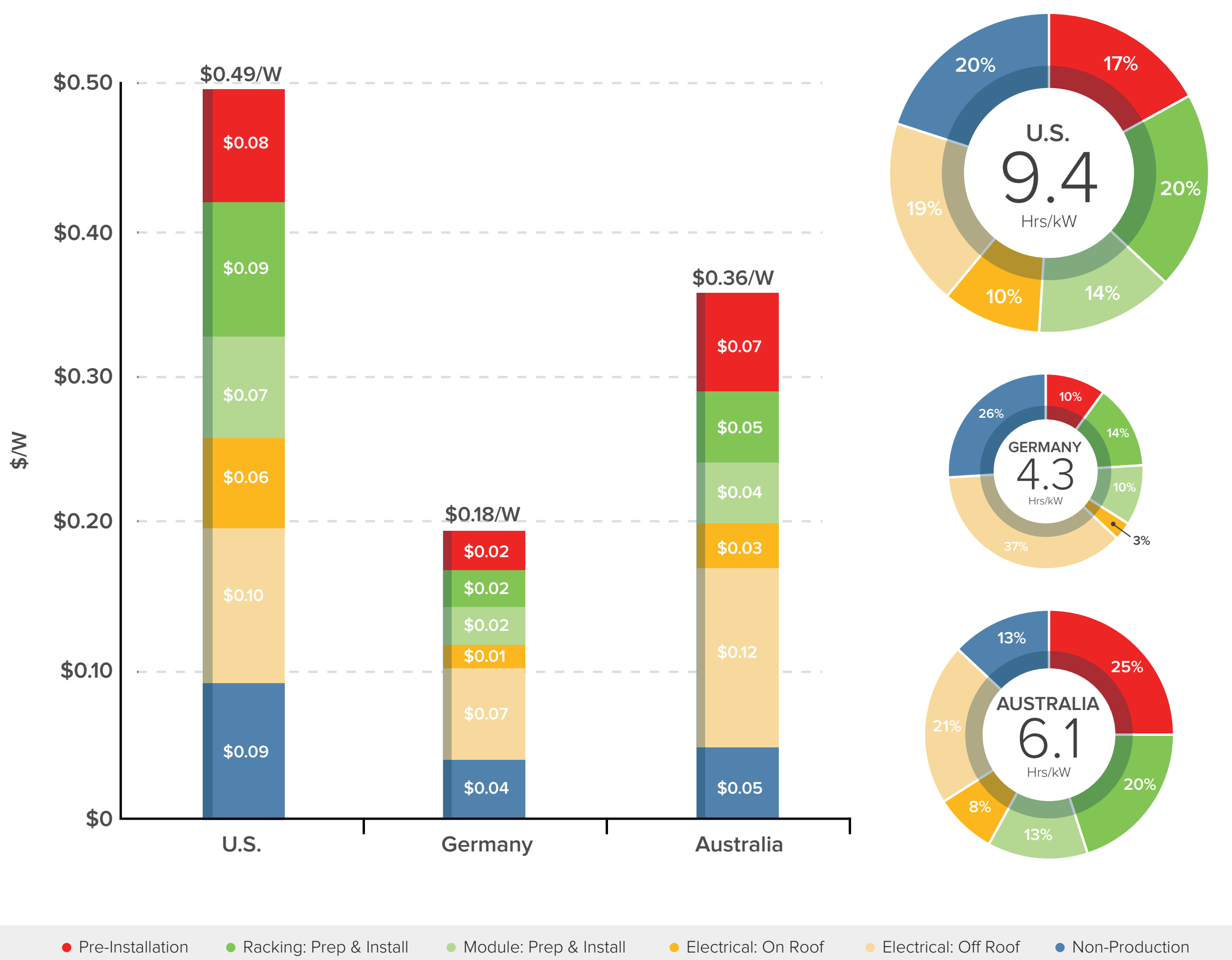
INSTALLATION LABOR

Australian installers are often paid a flat rate per system, as opposed to the hourly rate structure common in the U.S. The flat rate is determined by the average estimated time required to complete the install (including factors such as size, roof pitch, roof type, and quality of the electrical panel). The flat rate system encourages installers to lean their installation practices to maximize profit. The less time taken, the more systems can be installed and the more profit can be earned. Installers have focused on leaning processes through well-coordinated roles and reducing non-value-add activities. Beyond installation practices, the Australian market provides several opportunities for increased efficiency, including building and electric codes, as well as common Australian architecture. Also, Australian systems are generally smaller than their counterparts in the U.S., averaging 3.5 kW in Australia for benchmarked installations and 6.25 kW in the U.S., both of which are similar to industry averages.[xiv,xv]

A FOCUS ON AUSTRALIAN INSTALLATION LABOR

The Australian PV installation process closely resembles that of the U.S. and Germany, both in the components used, as well as the types of practices employed. As highlighted in our previous analysis, "observed German installers spend a proportionately similar amount of time as U.S. installers [on the PV installation process]. German installers are simply able to do each of [the] discrete activities two to four times faster than any benchmarked U.S. installer." Similarly, and consistent with industry studies (see Figure 1), our time-and-motion studies found that Australian installers spend approximately the same proportion of time on each category of installation activities as benchmarked U.S. installers, but are able to perform discrete activities significantly faster (see Figure 2).

FIGURE 2: INSTALLATION LABOR BY PRIMARY ACTIVITY VALUE STREAMS



Pre-Installation

Benchmarked Australian installers spend significantly less time on on-site pre-installation activities than U.S. installers, and in some cases, less time than even benchmarked German installers. The primary efficiency gains pertain to simplified processes for loading and unloading racking and mounting materials, and the fact that most installers pick up the system hardware components at a "company" warehouse the day of the installation. While there is some additional time required for driving to the warehouse and loading materials, this is often limited to a single person (often the crew leader) and leads to an overall reduction in total pre-installation activities. Pre-installation also includes less time spent setting up safety gear, requiring less setup time than the U.S. due to roof types and local safety requirements.

Racking Installation

The racking installation process is comprised of measuring for system placement, positioning and attaching the racking system base components, and affixing system rails to base components. Australian racking system components and the finished product are similar to the U.S. market, particularly rail-based systems. However, some meaningful differences exist in the sequence of activities and implementation of specific components. Specific activities that either take significantly less time (or in some instances are not present in the Australian process at all) include measuring and squaring the array, installing flashing and other moisture protection for the racking and mounting system base component, and preparation or adjustments to clay tiles as part of the PV system installation. The Australian racking and mounting installation process benefits from architectural, regulatory, and cultural advantages that support increased efficiency. In particular, the clay tile and open roof structure allows for visual identification of critical roof components, thereby reducing time spent on measuring for the array placement.

Similar to anecdotes from the German observations, requirements and processes to ensure moisture protection are often less stringent in the Australian market compared to the U.S. This is one important driver in the time difference associated with the base preparation process between the two countries.

Module Installation

The module installation process is quite similar to what was observed in the U.S., in both process and total time required. One noticeable advantage for Australian installers is the residential architecture, which consists primarily of lower, single-story or split-level homes that allow installers to convey modules to the roof manually, thereby limiting the need to convey via a ladder or by using module lifts.

On-Roof Electrical

The on-roof electrical installation process observed in Australia closely matches that of benchmarked U.S. installers. The most significant differences exist in the grounding and combiner box activities. The grounding process in Australia, while similar to the U.S., is simplified in regards to the number of contact points with the racking system, thereby limiting total install time. In addition, time spent installing the combiner box on observed Australian systems was about half the time dedicated to similar activities in the U.S. Drivers of the time and cost reduction are simplified component and overall system design.

Off-Roof Electrical

Compared to the U.S., benchmarked Australian electricians spend about a third less time on all off-roof electrical activities, and slightly less time than benchmarked German installers. Off-roof electrical makes up the largest percent of all activities in both Germany and Australia, and the second most in the U.S. Benchmarked Australian installers spend a considerable amount of time connecting inverters to the electrical panel. Electrical boxes in Australia are generally less organized than those observed in Germany and the U.S., adding to electrical installation time as electricians must navigate an often-crowded panel. However, the total off-roof electrical installation time is less in Australia compared to the U.S. due to the limited use of additional meters to track system output, whether for utility net metering or a financing organization.

Non-Production

Australian installers spend less than half the time on non-production activities that U.S. installers do. This was due in part to non-standardized meal or rest breaks (time was taken to eat and get water when necessary, but minimized) and fewer production delays due to excellent organizational processes. By making the one-day install standard, less time was needed for cleanup and breaks each day, resulting in less overall time spent on non-production activities.

Similar to our comparison of the U.S. and Germany, there are several enabling factors that allow observed Australian installers to install systems more efficiently and at lower cost: market structure, regulatory, legal, and architectural differences; product advantages; and installation best practices (see Table 1).

TABLE 1: ENABLING FACTORS FOR AUSTRALIAN INSTALLATION EFFICIENCY

TOTAL TIME DIFFERENCE (U.S. vs. AUS)	INSTALLATION ACTIVITY	ACTIVITY COST/TIME DIFFERENCE	AUSTRALIAN MARKET STRUCTURE, REGULATORY, LEGAL, AND ARCHITECTURAL DIFFERENCES	PRODUCT ADVANTAGES	INSTALLATION BEST PRACTICES
3.37 hrs/kW	Pre-Installation	0.14 hrs/kW	Local warehouses organize equipment by job, to be picked up by installers day of installation	Simplified racking and mounting systems enable efficient loading and unloading of the truck during pre-installation activities	Limited off-site prep: trucks are stocked with universal equipment and pick up system specific components by job
	Racking Prep and Installation	0.80 hrs/kW	Clay tile / standing seam metal roofs reduce base prep times, namely measuring and moisture barrier activities	Universal racking systems applicable to majority of roof types and pitches	Bases and rails are ready to be installed with minimal preparation
	Module Prep and Installation	0.46 hrs/kW	Low height architecture allows for easier conveyance of modules to the roof area		Modules are fully unpacked and mostly prepped before arrival on site
	On-Roof Electrical	0.79 hrs/kW	Smaller system designs simplify string and homerun installation	Lower grounding requirements, smaller systems, and less onerous safety gear mean on-roof electrical is very fast	
	Off-Roof Electrical	0.09 hrs/kW	Limited use of additional meters to track system output		
	Non-Production	1.09 hrs/kW	Looser labor requirements mean breaks, meals, and working hours are flexible. Breaks are taken during natural lulls in work and are minimal in length	Incentive for lead and crew to minimize delay in order to ensure one-day install, or else income is lost	Optimize crew size to limit waiting time; One-day installations minimize fixed costs (cleanup, meals, etc.)

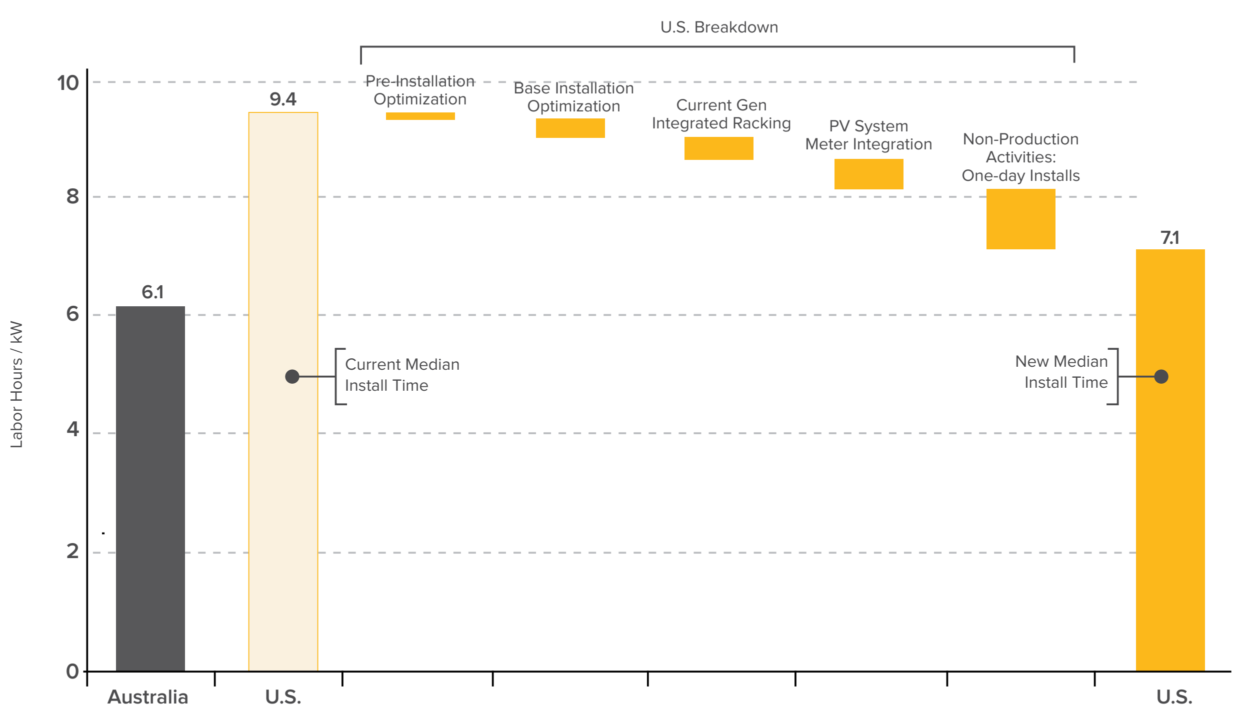
COST REDUCTION OPPORTUNITIES FOR THE U.S. SOLAR INDUSTRY

Using the time-and-motion data, we analyzed and compared data on the Australian PV installation process to existing data on U.S. and German processes. Based on benchmarked Australian installers, our analysis highlights an opportunity to reduce total installation time by nearly 2.3 labor hours per kW, thereby approaching the Australian median total install time of 6.1 labor hours per kW. Figure 3 highlights the best near-term opportunities for the U.S. PV market to adjust installation practices, encourage product innovation, or enact policy and regulatory changes that will enable the time and cost efficiencies demonstrated internationally.

The Australian data allowed for a reassessment of the recommendations identified in the U.S. and German comparison, as well as highlight new cost reduction opportunities (see Figure 4 for a full matrix of cost reduction opportunities). Based on a comparative analysis of installation processes in the U.S., Germany, and Australia, four key near-term actions will allow U.S. installers to reduce total installation time and begin approaching one-day installation levels of efficiency:

1. Pre-installation process optimization
2. Base installation optimization
3. Integrated racking and mounting solutions
4. PV meter integration

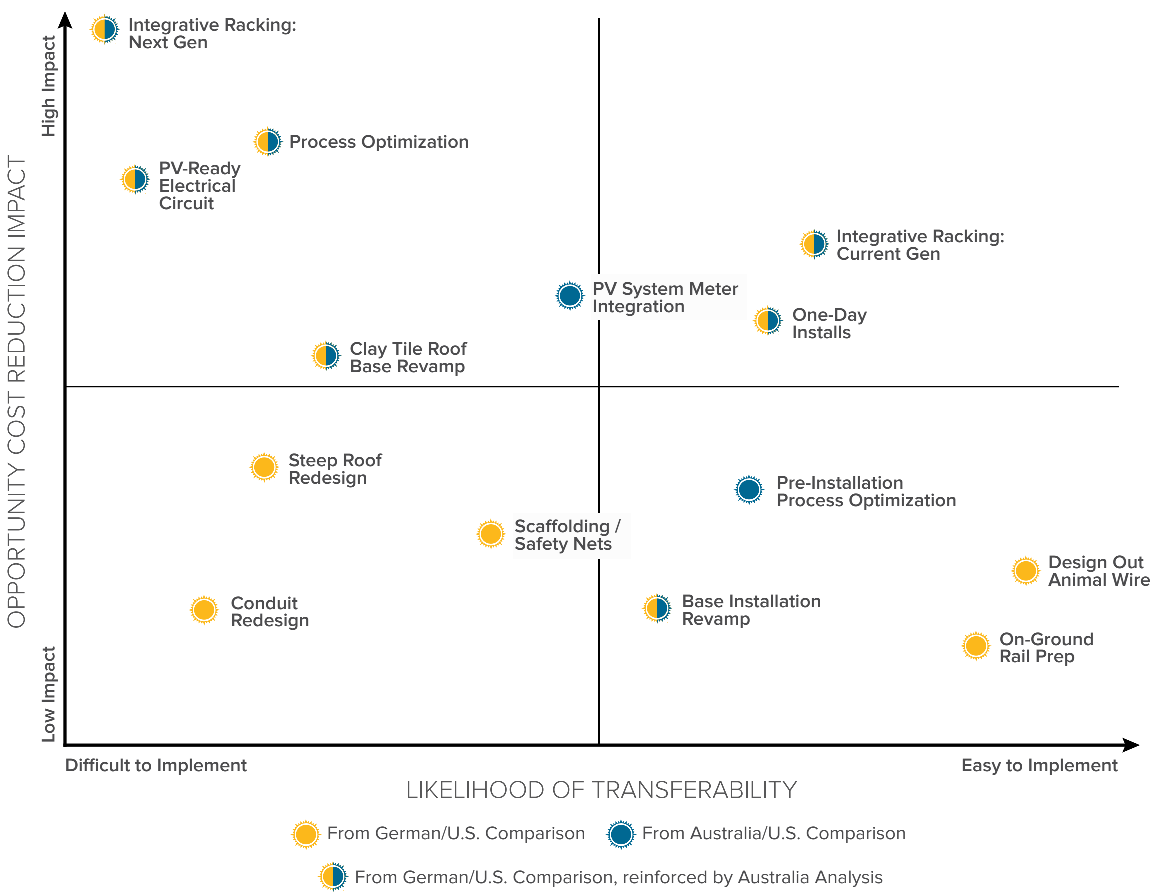
FIGURE 3: NEAR-TERM U.S. INSTALLATION COST REDUCTION OPPORTUNITIES



We highlight the one-day installation as a target given the additional overhead / non-production activity time and cost reductions realized by eliminating each additional day on site from the total installation process. Note the large apparent difference in time spent on non-production activities between the U.S. and Australia (see figures 2 and 3), largely the result of multi-day installations in the U.S. vs. one-day installations as the norm in Australia, where some retailers even achieve multiple installations per day.

Longer-term cost reduction opportunities have also been identified, specifically innovative technologies currently in development, such as next-generation integrative racking and a PV-ready electrical circuit. These opportunities are in development, but are currently not commercially available. The development of next-generation integrative racking, and/or a PV-ready electrical circuit could significantly reduce the total cost of installation on a residential rooftop PV system in both the U.S. and internationally.

FIGURE 4: OVERALL U.S. INSTALLATION COST REDUCTION OPPORTUNITIES



Pre-Installation Preparation Process Optimization

U.S. installers spend a considerable amount of time on the pre-installation process, including time at the warehouse preparing and loading the truck, traveling to the site, and setting up once on site. Benchmarked U.S. installers spend 1.63 labor hours per kW on pre-installation activities. In comparison, benchmarked German and Australian installers spend 0.41 and 1.49 labor hours per kW, respectively. A majority of the allocated pre-installation time in Australia comes from travel to and from the site. However, once on site, benchmarked Australian installers demonstrated high levels of task specialization and efficiency that allowed system installation to begin within approximately 20 minutes of arrival. This highlights an opportunity to encourage increased efficiency in the U.S. PV market through warehouse organization and task identification, and better coordination throughout the pre-installation process.

Base Installation Optimization (Standard / Clay Tile Roof Base Revamp)

Clay tile roofs were the most commonly observed roof type in the Australian time-and-motion research survey. Benchmarked Australian base systems were installed in half the median time—and for half the cost ($0.026/W)—of benchmarked U.S. installers ($0.05/W). In contrast, asphalt roofs were most common in the U.S. dataset, with clay tile roofs taking two to four times longer (and proportionally higher cost) than the benchmarked U.S. median value for base system installation. Given the preponderance of clay tile roofs in a number of key U.S. solar markets (including both Arizona and California), there is a significant opportunity for U.S. installers to draw lessons from Australian and German clay tile installation practices.

Opportunities to reduce base installation time and cost include:

- Simplified base designs that require little if any assembling
- Pre-assembling bases prior to roof conveyance
- Racking bases that self-seal or otherwise obviate the need for additional flashing
- Racking systems that require fewer base attachments / penetrations

Integrative Racking - Current Generation

Though not common in Australia, the U.S., or Germany, modern rail-less racking systems have shown promise in reducing installation times by removing an entire hardware component. Limited time-and-motion data indicate faster total installation times associated with integrated racking systems currently available. These systems still require base installation and can come at a higher cost, but should be explored by installers in all three markets. Further research is needed to provide a full cost-benefit analysis of these systems and the potential trade-offs between higher system costs and potential installation time savings.

PV System Meter Integration

Benchmarked Australian installers are able to complete off-roof electrical installation activities in approximately 30% less time than benchmarked U.S. installers. Observations of off-roof electrical installation activities indicate the process in Australia is similar to the one followed in the U.S. A key difference and cost driver comes from the number of meters installed on U.S. PV systems. It was not uncommon to see at least two meters installed on a single PV system in the U.S., compared to zero in Australia, with each monitor tracking system output for a different entity (e.g., the utility, third-party finance groups). The set of activities required to connect each meter includes: attaching each meter; measuring, cutting, bending, and attaching conduit; and installing electrical wiring between the meter and the next electrical component. Integrating and reducing the number of PV system meters can significantly reduce the total time required to complete off-roof electrical installation activities, helping the U.S. approach international levels of efficiency.

ONE-DAY INSTALLS

The one-day installation is stated as a target due to the additional cost reduction opportunities associated with eliminating "overhead" or non-production activities, such as travel, breaks, meals, cleanup, and delays. While these activities are a necessary component of the installation process, when required on a multi-day installation they can add significantly to the total time and cost of installation.

As installers lean installation practices and move towards one-day installation levels of efficiency, time spent on non-production activities will decline as fewer meal breaks, rest breaks, and cleanup periods are needed during each day. In our previous comparison of U.S. and German practices, by moving to a one-day installation, installers on average would see a $0.10/W reduction in total install cost.

While these are beginning to occur more often in the U.S., they are still uncommon among all installers. In Australia, it is common for a two- to three-person team to install an average of 4.5 kW per day. This is accomplished through task specialization, well-coordinated roles, racking system designs, and architectural elements (including roof design and construction) that allow for installation efficiency.

TECHNOLOGY UNDER DEVELOPMENT

Integrative Racking - Next Generation

The RMI/GTRI team has worked to design novel racking systems employing minimal base preparation, roof penetration, integrated string/grounding management, and no conventional rails. These designs could help the U.S. reduce the amount of time spent on racking system installations to a fraction of current U.S. benchmarks and even surpass benchmarked international levels of efficiency.

PV-Ready Electrical Circuit

Time spent on off-roof electrical activities to connect the solar array to the home electrical panel is consistently the highest (or tied for highest) cost area of any of the bucketed activities, whether in the U.S., Germany, or Australia. The high cost of off-roof electrical activities indicates a significant opportunity for both product and process innovation. PV-ready electrical circuits could accept a single connection from the PV system to drastically reduce the required time. Though this hardware has yet to reach a wide marketplace, it is being investigated by the U.S. Department of Energy's "Plug and Play" initiative[xvi] and should gain widespread use by installers when it enters the marketplace, both in the U.S. and internationally.

CONCLUSION AND NEXT STEPS

As hardware costs stabilize, soft costs continue to represent a primary opportunity for solar system cost reductions. Retailers and installers frequently have little control over hardware costs, but have greater control over soft cost reductions. Australia provides a unique perspective on the ability of retailers and installers to reduce soft costs when market competition drives leaning of processes.

Without using advanced technologies or processes, Australian installers are able to achieve solar installations in less than two-thirds the labor hours per kW of U.S. installers. This has often been driven by the market structure and associated incentives—installers in Australia make more money by installing systems in less time. The U.S. installation market may not adopt the flat-rate system common in Australia, but motivation systems to establish the credibility and effectiveness of the one-day installation as standard are necessary. Though equipment changes and system design may aid this, Australia shows that it is primarily through market competition and market incentives that installers can lean processes in order to reduce installation time. As market demand increases, this may occur naturally as U.S. installers can shift to one or more installations per day, rather than being constrained by limited demand.

Retailers in Australia have benefited from regulatory structures that reduce PII costs and customer acquisition costs through government regulation to encourage industry growth. Retailers have also significantly decreased their margins and overhead costs when compared to U.S. retailers in order to attract the customer base. A large volume of customers has allowed the residential solar market to remain profitable despite these reductions.

While PII and customer acquisition costs remain high in the U.S., we believe there are tangible and accessible near-term opportunities to significantly reduce inefficiency and costs from the residential PV installation process.

Building on similar analysis of the U.S. and German PV markets, RMI and GTRI have focused on several key takeaways from Australia to reduce installation labor costs:

- Optimizing the pre-installation process
- Reducing time spent on base installations, especially for clay tile roofs
- Pursuing rail designs that minimize installation labor
- Reducing the number of meters installed in each electrical system to monitor PV output
- Viewing the one-day installation goal as an opportunity to reduce time spent on non-production activities such as meals, travel, breaks, setup, and cleanup

The primary goal of these process optimizations and incentive systems is to push the U.S. PV installation market towards the one-day installation as a standard. Certain groups are already achieving this, but it is sometimes accomplished through a higher number of workers. Two to three workers installing a 4–5 kW system in one day is standard in Germany and Australia, and can be achieved in the U.S. German installers are averaging 4.3 labor hours per kW for solar systems, and Australian installers are averaging 6.1 labor hours per kW. The 9.4 labor hour per kW in the U.S. can be decreased to 7.1 if our key changes are undertaken to improve process efficiency and work towards a one-day installation goal.

The development of Australia's solar market, and the drastic cost reductions it saw over a short period of time, emphasize that high market demand and transparency in costs is a key towards reducing soft costs. When the market is large enough, solar installers and retailers can rely more upon volume for profitability and can create reductions in soft costs in order to compete in the marketplace.

WHAT IS SIMPLE BoS?

The SIMPLE Balance of System (BoS) project is a partnership between Rocky Mountain Institute (RMI) and Georgia Tech Research Institute (GTRI) to better understand the cost drivers of rooftop PV and identify opportunities for cost reduction. The project was made possible through a three-year, $5.8 million research program funded by the Department of Energy's SunShot Initiative.

In late 2011—with a project goal to reduce balance of system racking and labor costs by 50% of industry best practice in residential, commercial, and utility-scale photovoltaic applications—multi-disciplinary teams of students and faculty from the Georgia Institute of Technology produced 132 design concepts to meet this aggressive goal. To inform and validate this design work, time-and-motion studies conducted by RMI and GTRI provided baseline data to evaluate the performance of current technologies, emerging designs, and state-of-the-art installation methodologies.

In addition, RMI has built on work conducted by Lawrence Berkeley National Laboratory to focus on the large apparent difference in installation labor costs internationally, and to identify and transfer potential cost reduction opportunities to the U.S. residential PV market. RMI and GTRI have utilized the time and motion methodology to collect and analyze data on installation processes in the U.S., Germany, and Australia between February 2013 and April 2014.

In December 2013, RMI and GTRI published *Reducing Solar PV Soft Costs: A Focus on Installation Labor*, which utilized time-and-motion data to highlight differences in the installation process between the U.S. and Germany, and opportunities for cost reduction in the U.S. residential solar PV market. This analysis builds on the December 2013 report, highlighting how Australian soft costs compare to the U.S. and Germany, and further identifying cost reduction opportunities.

ENDNOTES

[i] Lovins, Amory B., and Rocky Mountain Institute. *Reinventing Fire: Bold Business Solutions for the New Energy Era.* Chelsea Green Publishing. White River Junction, Vermont. 2011. <http://www.rmi.org/reinventingfire>

[ii] U.S. DOE SunShot <http://energy.gov/eere/sunshot/sunshot-initiative>

[iii] Wiser et al. *Tracking the Sun VI.* Lawrence Berkeley National Laboratory. July 2013. Pages 13–15. <http://emp.lbl.gov/sites/all/files/lbnl-6350e.pdf>

[iv] *Bloomberg Sustainable Energy in America 2014.* <http://www.bcse.org/sustainableenergyfactbook.html>

[v] Johnston, Warwick. "Australia Out-installs Germany in Sub-10 kW System Size…Again!" *Renewable Energy World.* June 11, 2014. <http://www.renewableenergyworld.com/rea/blog/post/2012/05/australia-out-installs-germany-again>

[vi] Trabish, Herman. "Why Germany's Solar is Distributed." *Greentech Media.* May 29, 2013. <http://www.greentechmedia.com/articles/read/why-germanys-solar-is-distributed>

[vii] SolarChoice. <http://www.solarchoice.net.au/>

[viii] Parkinson, Giles. "Australia's gold medal in soaring electricity prices." *Renew Economy.* April 11, 2014. <http://reneweconomy.com.au/2014/australias-gold-medal-in-soaring-electricity-prices-62967>

[ix] Australian PV institute. <http://pv-map.apvi.org.au/analyses>

[x] Australian PV Institute. <http://pv-map.apvi.org.au/analyses>

[xi] *H1 2014 Australia Energy Market Outlook*. Bloomberg New Energy Finance. February 20, 2014.

[xii] *Small-scale technology certificates data modeling for 2013 to 2015*. Green Energy Markets. February 2013.

[xiii] *H1 2014 Australia Energy Market Outlook*. Bloomberg New Energy Finance. February 20, 2014.

[xiv] Parkinson, Giles. "Graph of the Day: Super-sizing rooftop solar systems." *Renew Economy.* May 28, 2013. <http://reneweconomy.com.au/2013/graph-of-the-day-super-sizing-rooftop-solar-systems-66771>

[xv] "Solar Market Insight 2013 Q3." Solar Energy Industries Association. <http://www.seia.org/research-resources/solar-market-insight-2013-q3>

[xvi] "Energy Department Announces Funding to Develop 'Plug-and-Play' Solar Energy Systems for Homeowners." U.S. Department of Energy. April 24, 2012. <http://energy.gov/articles/energy-department-announces-funding-develop-plug-and-play-solar-energy-systems-homeowners>