EPRI ELECTRIC POWER RESEARCH INSTITUTE

Solar PV Market Update

December 2013 Volume 8: Q4 2013

Editor's Note

Welcome to the 4th and final edition of EPRI's quarterly Solar PV Market Update for 2013! As with prior publications, this Update explores front line economic, policy, and technology trends that are occurring throughout the PV segment.

It first highlights PV component, system, and PPA pricing developments during the second half of 2013, and describes an anticipated boom in the U.S. distributed PV market, aided by the emergence of innovative project financing models. Next, it relates perspectives gleaned from an in-depth Q&A with SolarCity, including the costs and benefits associated with the company's business model as well as potential "win-win" opportunities for SolarCity-utility collaboration. Finally, it examines the technical feasibility of utilizing cell metallization with copper plating to lessen material costs and improve cell efficiencies.

As always, please let us know how we can improve upon this issue. We welcome your comments and also your suggestions for future content coverage.

Sincerely,

The EPRI Solar Generation (P187), Integration of Distributed Renewables (P174), and Renewable Energy Economics and Technology Status (P84) Program Teams

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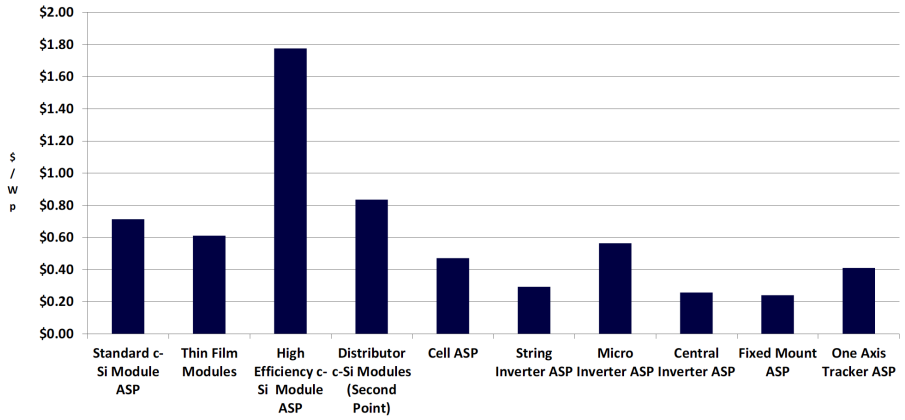
Cost Corner

Solar PV Pricing and Project Financing Snapshot: 2H2013

PV component and system prices are continuing to stabilize during the second half of 2013. The notable shift in market economics, first identified earlier this year, marks a departure from the several years of product oversupply and concomitant price drops during which the industry struggled to cope with unsustainable financial expectations. Today, module and other solar equipment shipments are up, improving margins for some manufacturers, while strong growth in the Asia and Americas market segments is fueling future optimism.

Figure 1 depicts global average selling prices (ASPs) for major PV hardware components. For standard c-Si modules in 2013, ASPs are slightly lower than they were in 2012, but pricing has been fairly steady over the first three quarters of the year, with slight increases occurring over the past six months—particularly in the U.S. market. Unilateral trade disputes and polysilicon price increases are largely responsible for the small rise in module prices (for additional details, see Vol. 7 PV Market Update, 3002001260). As a partial result, ASPs for the top 20 Tier 1 module suppliers were $0.63/W in Q3, and blended gross margins for these same suppliers increased from less than 1% at the end of 2012 to12.5% in Q3 2013.[1,2]

While most market analysts agree that the module market has not yet reached equilibrium (that is, prices are not based on the costs of raw materials and manufacturing), leading suppliers are pronouncing optimistic shipment and margin forecasts for 2014. Despite this outlook, however, there is currently strong market resistance to price increases, and industry margins throughout the value chain remain somewhat compromised as a consequence.



Note: ASPs are weighted global averages.
Source: SPV Market Research

Figure 1 – Global PV Hardware ASPs: Modules, Cells, Inverters, and Mounting Equipment

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[1] Many suppliers within the solar PV supply chain reported double-digit negative margins at the beginning of 2013.

[2] Mercom Solar Funding and M&A Q3 2013 Report.

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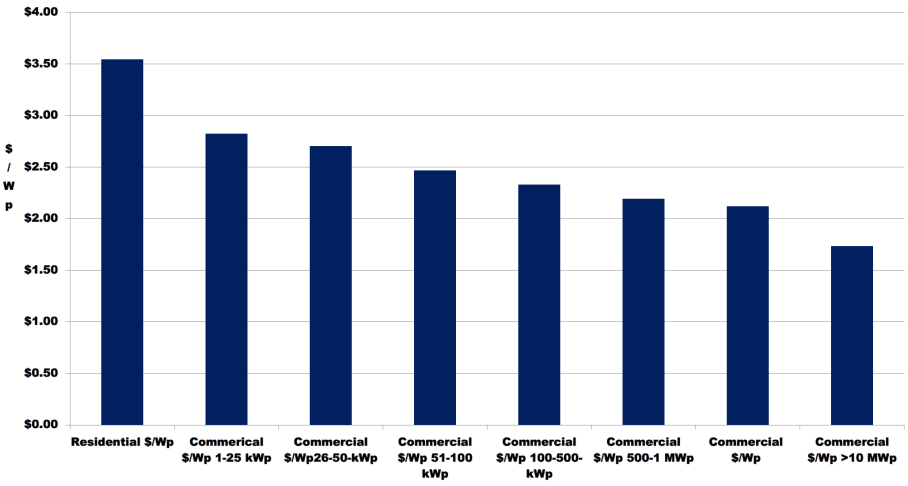
In the face of steadying PV hardware prices, install costs have actually fallen throughout the year. The most competitive, large-scale (20 MW+) utility projects with one-axis tracking in the North America market are pricing around $\$1.70/W_{dc}$.[3] Meanwhile, many projects in the 10-15 MW range are pricing predominately at $\$1.80\text{-}\$2.00/W_{dc}$, with some coming in slightly lower. Price reductions for these project sizes are, in part, attributable to fewer utility-scale project opportunities, which have led to fierce competition and lower developer margins. (However, the biggest factor driving install cost reductions continues to be the decline in system component costs, particularly for modules. Costs for inverters and other balance of system components have also been falling, and engineering, procurement, and construction (EPC) costs have been trimmed due to learning curve effects.)

As depicted in Figure 2, global average install prices in the residential segment are, as of Q4 2013, just above $3.50/W. Meanwhile, worldwide average prices for commercial systems (1 kW-1 MW) range between $2.20/W and $2.80/W. In North America, though, residential systems are closer to $5/W, while commercial systems start in the $3.40/W range due mostly to higher soft costs (e.g., project management-, compliance-, and other non-capital equipment-related activities, including permitting and interconnection; project design; conformity with safety, building, and electric codes; etc.).[4]

The Somewhat Regional Nature of PV Pricing

From 2007-2011, the European Union (EU) accounted for roughly 78% of the PV market, with Germany comprising over half of deployments. However, looking ahead, Japan, China, and the U.S. are anticipated to each accumulate growing market share over the near term. Amid this shifting market landscape, regional price differences are beginning to arise, caused by unique geopolitical factors, domestic power prices and incentives, as well as customer preferences. While global average prices continue to be the standard industry metric, the emergence of several major and distinct constituent markets raises the potential need to report out regional pricing to convey a more accurate appraisal of economic trends. Greentech Media, for example, recently reported that average delivered Chinese Tier 1 module prices vary by region, ranging from $0.62/W to $0.76/W (see Table 1).



Source: SPV Market Research

Figure 2 – Average Selling Prices for Residential- and Commercial-Scale PV Systems

Table 1 – T1 Chinese Module Pricing by Region

Country	Avg. Delivered Tier 1 Chinese Module Price
Japan	$0.76/W
China	$0.63/W
EU	$0.72/W
U.S.	$0.70/W
India	$0.62/W
Latin America	$0.68/W
South Africa	$0.73/W

Note: Prices as of Q3 2013
Source: Greentech Media

Despite differences in module pricing, Bloomberg New Energy Finance (BNEF) argues that hardware prices naturally equilibrate over time and installed costs do not vary significantly by region, with the exception of Germany and Japan which reside on the low and high ends of the spectrum, respectively. Costs for EPC services may initially be higher in emerging markets, but are generally similar across different geographic areas. Notable price differences, in fact, appear to primarily be a function of regional subsidies. For example, Germany has reduced its feed-in tariff subsidies over time in such a way that the market has been incentivized to reduce costs while continuing to build projects. In Japan, where subsidies are currently among the highest in the world, players along the value chain have conversely been able to charge higher rates and thereby increase profits.

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[3] Bloomberg New Energy Finance estimates that tracking adds ~$0.25-0.30/W above the capital cost of projects with fixed-tilt arrays; very large projects may be able to obtain lower pricing for trackers, however. Performance improvements with trackers generally result in LCOE benefits, and those benefits are most pronounced in ideal solar resource locations. Consequently, projects with trackers are predominantly being deployed in desert locations today. All told, an estimated 30-50% of new utility-scale projects are being outfitted with trackers.

[4] Bloomberg New Energy Finance, "H2 2013 North American PV Market Outlook," Oct. 1, 2013.

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U.S. Market Outlook: Anticipated Scarcity of Utility-Scale Projects, Boom in Distributed Generation

In the U.S. market, a shift toward distributed PV appears to be looming as traditional utility solar power purchase agreements (PPAs) become increasingly scarce. According to industry consensus, opportunities for large PPAs are likely to become more limited as utilities begin to meet their renewable portfolio standard or goal obligations. As previously stated, rising competition among project developers is, in fact, already pushing down prices for large projects.

According to BNEF, recent PPA prices for large utility-scale projects (20MW+) in U.S. Western states have fallen from approximately $90-$135/MWh a year ago to $65-75/MWh today. This movement in PPA prices is mainly a reflection of competition for fewer contracts; cost reductions for PV equipment and learning curve effects are also having an impact.[5] Figure 3 illustrates the recent drop in PPA prices and also the dwindling number of contracts. (Note: only contracts 5 MW and above are shown.) Meantime, commercial PPAs (10kW-1MW) in the largest solar market in the country, California, are frequently coming in at $130/MWh or higher, roughly at the level of utility retail rates. In Massachusetts, a vibrant unbundled market that supports solar renewable energy credits (SRECs), commercial PPA prices are starting at ~$80/MWh.[6] In general, PPA prices for this project segment have held relatively steady in the past year with very slight declines.

The outlook for large centralized solar plant additions could, of course, change if utility requirements increase or if PV prices decrease sufficiently to incentivize utility-scale deployment in the absence of legal mandates. For now, though, fewer utility-scale projects are expected to be built in the post-2016 timeframe. Distributed residential and commercial PV installations are anticipated to fill their void, with GTM Research asserting that the third-party financed residential solar market could alone grow more than four-fold from $1.3B in 2012 to $5.7B in 2016.[7]

Favorable incentives and economics are the principal drivers of current and extected distributed PV growth. Notable is the proliferation of third-party ownership (TPO) and leasing models, which are lowering barriers to market entry for residential consumers as well as driving down prices through volume deployment. Prices in Figure 4 reflect those for systems that were financed and installed in California by a handful of leading 3rd-party operators over the last several years. (Prices have since fallen further in the last two quarters.)

Per BNEF, since the end of 2012, prices for customer-owned residential systems (<10kW) in California have dropped from $5.47/W to $5.01/W, and TPO offerings are now able to match those levels.[8] Reportedly, only $2.25 of the nominally $5/W TPO cost is for "hard costs," with the balance being "soft costs" and margins.[9] It is still more economical to own commercial PV systems (10kW-1MW) in California, with customer- and TPO-owned systems currently priced at $4.21/W and

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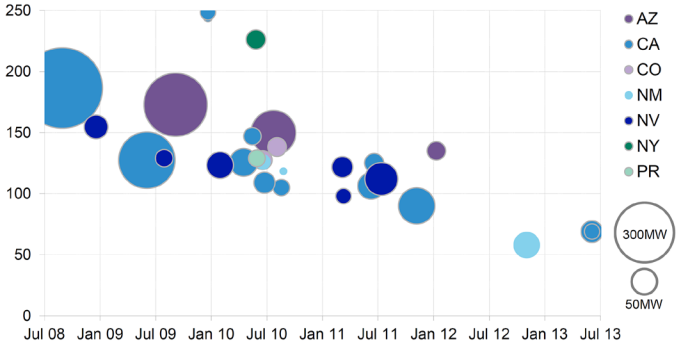
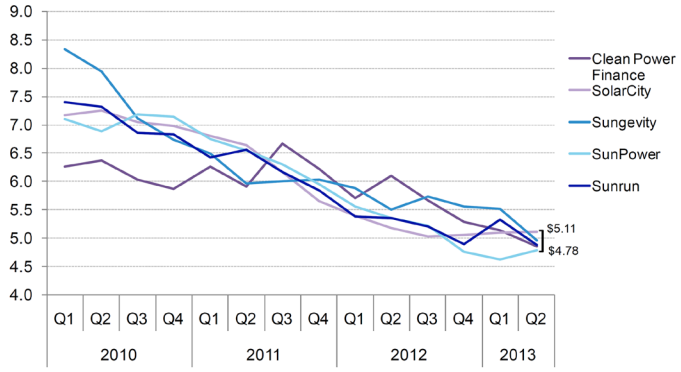


Source: Bloomberg New Energy Finance

Figure 3 – US Solar PPA Prices by Signing Date, H2 2008 – H1 2013 ($/MWh)



Source: Bloomberg New Energy Finance

Figure 4 – Average Selling Prices for Third-Party Financed PV Systems in California ($/W)

[5] Note: Lower PPA prices have been reported in CA. For example, the City of Palo Alto Utilities obtained a $69/MWh PPA for 80 MW (3 projects) and California IOUs that participated in the state's Renewable Auction Mechanism, a 1.3-GW program to procure renewable projects sized 3-20 MW, had a weighted average contract price of $89/MWh.

[6] In unbundled markets, primarily in the Northeast U.S., SRECs are sold separate from the electricity, which makes low PPA prices feasible; with SRECs in the $135/MWh range in Massachusetts, project developers can earn a decent return from the combined PPA/SREC revenue streams.

[7] E. Wesoff, "Financial Innovation Has Given Residential Solar Much to Be Thankful for This Year," Greentech Media, Nov. 25, 2013.

[8] Bloomberg New Energy Finance, "H2 2013 North American PV Market Outlook", Oct. 1, 2013.

[9] Hard costs include equipment costs, i.e., modules, racking, inverters, wiring, etc.; soft costs include labor, customer acquisition costs, overhead, permitting, developer profit, etc.

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$4.84/W, respectively. Meanwhile, Massachusetts appears to have attractive economics for commercial-scale distributed PV deployment, with systems averaging $3.43/W. But residential system prices in Massachusetts slightly lag those in California at $5.86/W. For reference, Germany maintains the price to beat with average residential prices of $2.18/W.[10]

TPO and Other PV Financing Trends

The TPO model is taking off in the North American market (see Figure 5) and, without question, represents the predominant method for funding new, smaller scale distributed PV projects today. TPO financial models overcome the first cost barriers that have historically stunted end-user investment in solar PV. In essence, they entail commercial solar companies installing, owning, and operating customer-sited PV systems and either leasing PV equipment to end users or selling them PV electricity at prices typically lower than retail electricity rates. For solar customers, the approach lowers or eliminates up-front adoption costs, reduces technology risk, and enables almost immediate cost savings. Meanwhile, third party PV companies make money by securing guaranteed buyers for all of the electricity produced from their PV systems at agreed-upon prices. They also benefit from utility rebates, and other financial incentives in a way that allows them to attract cheap capital for financing future projects.

The distributed PV market sector has continued to flourish in 2013, with major players announcing increased installation estimates. For example, SolarCity, the largest of the TPOs, has set a goal to install 278 MW this year, which would amount to over 20% of the ~$6 billion U.S. distributed PV market. (See ***Q&A with SolarCity*** for more insights.) Others, such as Vivint, have successfully attracted $740M of investment capital in just three months. Barring major changes to its terms of use, it is likely that TPO contracting at-large will capture a considerably greater share of the expanding distributed solar market going forward.

The success of the TPO model has spawned a growing collection of companies in the PV ownership and leasing space. In turn, a greater amount of experimentation is producing a range of product offerings that employ a variety of structural wrinkles. Table 2, on the following page, distills the three major TPO approaches being utilized today, along with selected real-world examples of their use.

While the near-term expectation is that TPOs will continue to grow in existing markets and expand into others, as the costs of solar decline and conventional financing markets open up, customer-ownership may also accelerate due to increasingly attractive investment returns. Direct purchases through secure and non-secure debt financing are becoming more popular as the perceived risk associated with solar investment abates. Lease providers, banks, and module suppliers now all offer competitive loan financing. For example, SunPower recently reached agreement with Digital Federal Credit Union, which represents 36 credit unions, to offer $100M in debt loans for members of the credit union (up to $50,000 per member). Similarly, Canadian Solar works with Admirals Bank to finance projects up to $40,000.

Meanwhile, SolarCity has recently produced the first securitized portfolio of distributed solar assets. As with home mortgages and auto loans, solar securitization pools debt and

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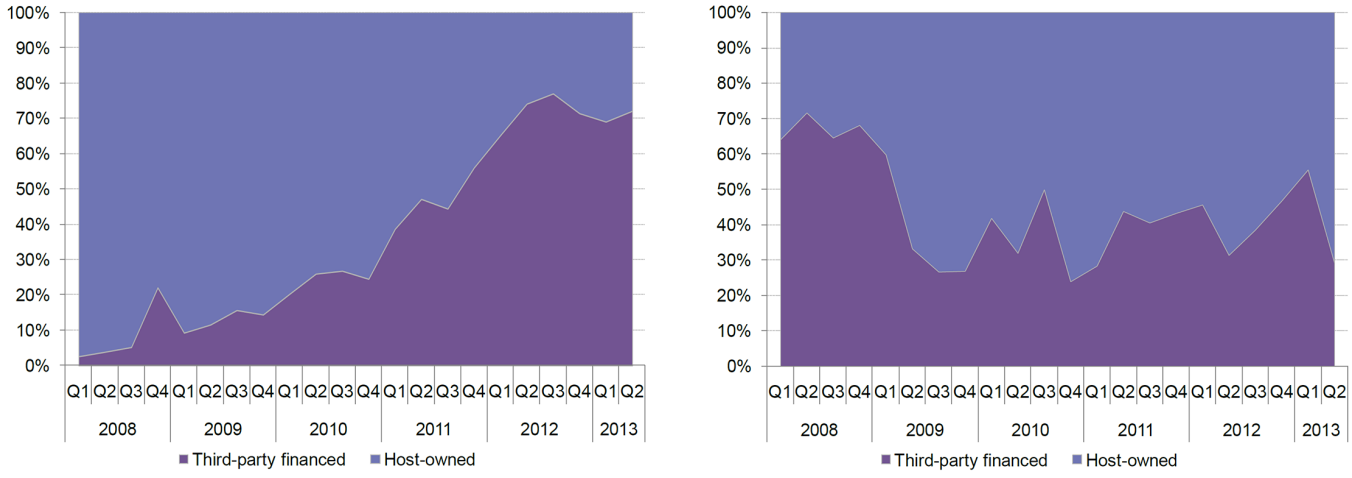

Source: Bloomberg New Energy Finance

Figure 5 – Residential (left, ≤10kW) and Commercial (right, 10kW-1MW) Installations per Quarter by Ownership (% Share)

[10] According to LBNL (J. Seel, G. Barbose, and R. Wiser, "Why are Residential PV Prices in Germany So Much Lower Than in the United States?", LBNL, Feb. 2013), the biggest likely cause of lower prices in Germany is the sheer market size; experience has driven out price over time. Reductions in feed-in tariffs have also pressured installers to continually reduce prices. Finally, soft costs are substantially higher in the U.S., including everything from marketing and advertising, customer acquisition costs, higher labor rates for installers and longer installation times, and higher sales tax.

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Table 2 – Mainstream TPO Approaches

Basic Approach	Description	Examples
The "In-House Model"	A singular company operates all segments of the solar leasing value chain—it creates the investment funds, sells the lease contracts, installs the systems, and provides O&M servicing.	SolarCity, the largest TPO, has pioneered this capital-intensive approach; others such as Vivint Solar Power have introduced similar products.
The "Dealer Network Model"	The solar lease company raises project funds and develops tools that allow smaller solar integration companies to generate proposals. The dealers originate lease contracts that the lease provider bankrolls and owns through its investment fund. In some instances, the dealers originating the sales do not install the system themselves, but have the lease provider subcontract out the installation. Most residential solar finance providers utilize the dealer network model. NRG SunLease offers its lease product to qualified dealer partners only. To expand its presence in the residential lease space, OneRoof Energy plans to open its dealer network to roofing contractors. SunPower provides a lease product to its authorized dealer base, allowing it to sell modules and provide its dealers with competitive offers. And SunRun selects preferred solar companies to source its deals and complete its installations.	Most residential solar finance providers utilize the dealer network model. NRG SunLease offers its lease product to qualified dealer partners only. To expand its presence in the residential lease space, OneRoof Energy plans to open its dealer network to roofing contractors. SunPower provides a lease product to its authorized dealer base, allowing it to sell modules and provide its dealers with competitive offers. And SunRun selects preferred solar companies to source its deals and complete its installations.
The "Open-Source Model"	The finance company handles only select elements of the value chain and leverages the core competencies of industry partners to fulfill remaining requirements. The Open-Source Model is likely to evolve as more companies provide specialized services (e.g., system design, installation, O&M. etc.).	Sungevity leverages its own fund to sell leases to residential customers using a virtual sales model; it employs a network of subcontractors to provide installation and O&M services. Clean Power Finance provides solar installers with tools to quote lease financing, secures funds to finance inked projects.

Source: SolarPro

Table 3 – Emerging PV Financing Approaches

Method	Definition	Representative Company
Crowdsourcing	Individuals pool money to invest in solar projects	Solar Mosaic
Property-assessed clean energy (PACE) programs	Homeowners finance their PV systems through property taxes or other municipal taxes	Municipal financing districts, finance companies
Debt-leveraged loan programs	Debt-based loan products offered at competitive interest rates	OneRoof Energy, Sungevity, Admiral's Bank, EnerBank, Sungage, Canadian Solar, SunPower, Digital Federal Credit Union
3rd-party ownership (TPO)	TPOs install, own, operation customer-sited PV systems and lease equipment to end users	SolarCity, Vivint, SunRun, Sungevity, SunPower
Solar securitization	Pools contractual debt and sells it as pass-through securities to investors	SolarCity
Master Limited Partnerships (MLPs)	Investment option, publicly traded, limited liability and no corporate tax on profits	Not yet available
Real Estate Investment Trusts (REITs)	REITs own/operate income-producing real estate, without federal tax and distributing dividends (taxable income) to investors.	Not yet available

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sells it as a package to investors thereby improving liquidity (i.e., access to cash). The novel offering has enormous potential to spur greater demand for solar because it can lower project financing costs, and in turn make PV more affordable for homeowners. Furthermore, with access to deeper capital pools, developers can more rapidly scale, while stable, long-term solar assets can facilitate attractive investor returns. It's a potential win-win-win for developers, solar customers, and investors.

Still other project financing options are being explored that employ real estate investment trust (REIT) and master limited partnership (MLP) structures. These vehicles are currently being used to facilitate investments in other markets, and approaches are being investigated to adapt their use in the solar market sector. All told, per Table 3 (page 5), greater availability of capital is lowering the barriers to market entry for distributed solar on a national scale.

In tandem with the growth of TPO and new financing mechanisms, additional nuances will likely find their way into new and adapted ownership and leasing products as the segment evolves (i.e., storage capabilities through electric vehicles or onsite battery units). This anticipated future is certain to add complexity to regulated electric utility DG planning and management activities. Strategically considered, however, TPO and other financing models may offer benefits to utilities in a more DG-pronounced world.[11]

Industry Perspectives

Q&A with SolarCity

Introduction

With the unveiling of its first-of-a-kind solar leasing offering in 2007, San Mateo, Calif.-based SolarCity effectively unlocked the U.S. residential and commercial PV market segments. The success of the company's "disruptive" business model has accelerated new distributed PV capacity additions and spawned a host of imitators.[12] Moreover, it has prompted electric utilities to reexamine the business case for solar PV and debate strategies for addressing the resource's proliferation and potential mainstreaming.

In essence, SolarCity's third party ownership (TPO) financial model, and others like it, overcomes the first cost barriers that have historically stunted end-user investment in solar photovoltaics. The firm finances, permits, designs, installs, monitors, and maintains customer-sited PV systems and then typically either leases the PV equipment to end users or sells them PV electricity at prices lower than retail electricity rates over a 10- to 20-year period. For solar customers, the approach lessens or eliminates up-front adoption costs, locks in favorable long-term electricity rates, reduces technology risk, and enables almost immediate savings. Meanwhile, SolarCity is able to earn healthy returns by securing guaranteed buyers for all of the electricity produced from its PV systems at agreed-upon prices. It also benefits from economies of scale that, in turn, lower the company's financing, operational, and PV system costs.[13]

The impact of the TPO model has been conspicuous. In 2012, it helped fuel the highest level of annual PV growth in the U.S. residential segment (~415 MW), facilitating the deployment of over 50% of new residential PV capacity in Arizona, California, Colorado, and Massachusetts.[14] Thus far in 2013, the sector has continued to flower with major players announcing increasingly rosy installation estimates. SolarCity, the largest of the TPOs, expects to install 278 MW this year, which would amount to over 20% of the ~$6 billion U.S. distributed PV market.[15] Per Figure 6, the company has experienced a near

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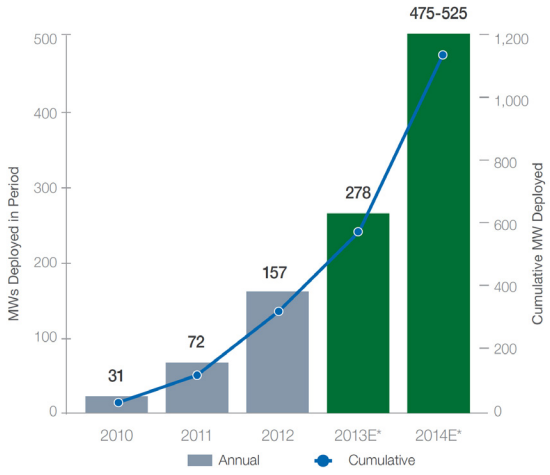

Source: SolarCity
*Note: * Represents SolarCity estimates.*

Figure 6 – SolarCity PV Capacity Deployments, 2010-2014E

[11] For instance, TPOs consolidate contact points, making it easier to oversee and possibly leverage thousands of customer systems more proactively in grid operation. TPOs are motivated to standardize PV design and the grid interface, which can enhance PV system uptime and availability in a manner that is closer to what utilities expect from their professionally managed generation fleets. And, owing to a basic structure that involves economy-of-scale PV system aggregation, TPOs can more readily respond to market pricing signals that specify deployment and operation guidelines.

[12] Today, there are roughly 8-10 relatively well established third party ownership companies that offer a variety of solar leases and PPAs, including SolarCity, Sungevity, Vivint, Clean Power Finance, SunRun, NRG SunLease, SunPower, and OneRoof Energy.

[13] In addition, TPOs can generally exploit tax credits and other financial incentives; they can typically also own the renewable energy certificates (RECs) generated by a PV system.

[14] Residential solar leases and PPAs are now available in 22 U.S. states, plus Washington, DC.

[15] As of 3Q13, SolarCity had ~$1.7B in 20-year contracts, up from $106M in 2009.

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year-over-year doubling in installations since 2010, and has set a goal to enroll 1,000,000 solar rooftop customers by July 4, 2018.

EPRI's Nadav Enbar recently sat down with SolarCity's Vice President of Government Relations, John Stanton, to discuss the company's innovative product offering and its overarching impact on both the solar and utility industries. Among the topics broached during the interview, a transcript of which follows: the costs and benefits associated with SolarCity's business model, potential "win-win" opportunities for SolarCity-utility collaboration, the commercial implications of battery storage, and solar leasing's future outlook. (Note: the interview transcript has been edited for clarity.)

Q&A Transcript

EPRI: How would you characterize SolarCity's business and approach to the solar market? What is the company's core business offering?

SolarCity: At the broadest level, SolarCity offers a variety of products designed to meet a customer's needs, whether it be with a cash sale, equipment lease, or power purchase agreement (PPA). We offer a range of financing options to enable solar PV deployment.

Electricity markets are bifurcated between regulated and deregulated. In the latter, SolarCity offers a PPA through which to sell electrons. In the former, where the incumbent power provider has an exclusive monopoly, the sale of electrons is not allowed. Accordingly, SolarCity offers a lease product. And, in both the deregulated and regulated markets, we offer a cash sale of equipment.

SolarCity serves both residential and commercial customers, and the share of the megawatts tends to fluctuate by period. However, the vast majority of our over 80,000 customers are residential homeowners who have entered into a third party ownership agreement. In this arrangement, SolarCity or a special purpose entity owns the solar property (i.e., the solar PV system) and the host customer receives the solar electricity by renting the property or entering into a PPA.

Editor's note: As of mid-November, 2013, SolarCity had inked energy contracts with over 82,000 customers, and had deployed ~464 MW of capacity (split approximately 60-40 between residential and commercial customers).

EPRI: Briefly, what are the costs and benefits of SolarCity's business for both SolarCity and its customers? What is the methodology SolarCity employs to determine equitable leasing price points?

SolarCity: For the consumer, the three main benefits associated with SolarCity's PV product are: 1) cleaner electricity, 2) vertical integration and ease of adoption, and 3) financial savings derived from lowered retail electricity costs.

In either the equipment lease or the PPA scenarios, the duration of the SolarCity contract is typically 20 years. What we've found is that it's difficult for customers to accept this 20-year arrangement unless they can achieve at least a 10% savings over their anticipated annual electricity costs. Of course, a lot of things come into play when calculating customer savings potential. It's tied to energy use, load profile, participation in a time-of-use or inclining block rate... We also allow customers to choose between either flat payments that start higher or lower payments that increase up to 2.9% annually. So, SolarCity's products can offer consumers both net present value savings as well as a hedge on future electricity inflation.

In the interest of transparency, our contracts are publicly available on the SolarCity website [http://go.solarcity.com]. We believe that the contract platform for our products is best-in-class and has been more thoroughly "due diligenced" than any other in the industry. We have yet to see any contract which has greater consumer protection than our own. That said, we think that it makes sense for every other solar provider in this vertical to use our contracts. We'd like to standardize that process.

Editor's note: Sample SolarCity residential solar PPA and lease contracts can be downloaded at: www.solarcity.com/downloads/SolarCity_Residential-Solar-PPA-Contract_sample.pdf and www.solarcity.com/downloads/SolarCity_Residential%20Solar-Lease%20Contract_sample.pdf. In addition, the company hosts a blog (http://blog.solarcity.com/?p=271) that, among other things, provides simplified contract tips to help educate would-be customers.

EPRI: Many consider SolarCity's business approach, and those like it, to be "disruptive" to the traditional electric utility business model. The prevailing utility attitude toward third party solar ownership and leasing companies has been one of growing vigilance, if not concern. Do you feel these attitudes are justified?

SolarCity: The provision of electricity today in America is not happening in a vacuum; it's happening in a context where consumers increasingly want choice. Medical choice. School choice. Cable provider choice. Telecommunication choice… Customers are looking at the provision of retail electricity in the same way that they're looking at their iPhone and cable box. They want optionality and to harness the latest and greatest technology in an integrated format. The changes that we're seeing with respect to the proliferation of distributed generation and the penetration of new technologies in the electricity sector are really just a reflection of consumer preferences. In this regard, what's happening in the electricity sector is unsurprising.

We believe that there's much greater promise than peril for electric utilities in providing customers with increased optionality and choice regarding electricity services. Utilities need to get out of the one-size-fits-all kWh sales model and provide innovative electricity products and services. That's where the consumer

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demand is. The overriding dictate that determines everything at SolarCity is customer satisfaction and preference. As a company, we're trying to go where customer sentiment is headed. My sense is that if SolarCity can be successful then far greater capitalized companies like electric utilities should be able to do likewise. Therein lies the opportunity.

EPRI: That being said, do you see potential "win-win" opportunities for SolarCity-utility collaboration? Are there particular utility power companies that are actively pursuing outside-the-box solar strategies?

SolarCity: There are a number of opportunities for the incumbent electricity provider to participate in the emerging DG economy. A prime example would be the investment made by Pacific Venture Capital, the investment arm of PG&E, into Solar City projects in 2010 (see sidebar). The recent (September 2013) partnership struck between SolarCity and Direct Energy—one of the largest competitive retail electricity suppliers in the U.S—is another good example of fruitful collaboration.[16] Together, we've created a dedicated investment fund to finance $124 million in commercial and industrial solar projects. For Direct Energy, the fund offers its C&I customers greater product choice and a means for reducing the utility rate for on-site solar generation. In this arrangement, eligible Direct Energy C&I customers can utilize solar power with little or no upfront cost, depending on their choice of plans. Customers can pre-pay for their solar electricity or make a monthly payment, with installation, insurance, repairs and monitoring service included.

Utilities like Arizona Public Service, through its Flagstaff Community Power Project initiative, are trying to figure out whether customer-side DG resources can be of benefit. The Flagstaff project is an example of APS exercising leadership to figure out whether it can successfully own and operate customer-sited generation assets and engaging in that vector.[17] We welcome that competition and think it's important for utilities to determine whether they can do it better and cheaper than SolarCity can... they certainly have the capital base and managerial expertise to excel.

NRG is another diversified electricity company that is actively participating in the DG marketplace, offering a solar value proposition on multiple levels. In addition to solar, the company also owns nukes, coal, wind, natural gas—by no means is it a non-traditional player in the market. And it provides a broad range of solar services and functions, such as EPC work, financing… it participates as an off-taker in larger solar PPAs, among other things.

EPRI: A major challenge facing both the solar and utility industries appears to be settling the controversy surrounding the value that solar provides to the grid and vice versa. How do you see this core issue evolving?

SolarCity: Today, utilities have a "defensive bunker mentality" with respect to solar deployment. They're looking at it myopically through the narrow lens of revenue erosion

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Utility Investment in Third Party PV Operators

Increasingly, unregulated utility holding companies are recognizing the business benefits of the third-party ownership and leasing model. Unhampered by the same restrictions placed upon their regulated cousins, a number of unregulated entities are promoting the development of distributed renewables by investing in third party solar installers and funds. In some cases unregulated utilities are launching their own solar leasing programs. The impetus behind these activities is predominantly economic. By investing in TPOs or programs based on TPO approaches, unregulated businesses are able to earn a steady rate of return on the associated distributed solar assets and diversify their investment portfolios. Among recent examples of unregulated utility involvement in the third party solar space:

- PG&E Corporation, through its subsidiary Pacific Venture Capital, LLC, has provided $161 million to two separate tax equity funds run by SolarCity and SunRun. The investments, funded by PG&E shareholders, have enabled the lease financing and development of an estimated 4,500 PV systems and are, in turn, providing PG&E with lease revenues along with tax equity benefits not available to regulated utilities.
- Duke Energy, Edison International, and two other undisclosed utilities have contributed to a $42 million equity round in Clean Power Finance, a residential solar financing outfit that manages roughly $500 million on behalf of TPOs.
- NextEra Energy and Edison International have respectively purchased third party solar finance and installation companies Smart Energy Capital and SoCore Energy to operate as subsidiaries. These acquisitions enable the utilities to more actively participate in the commercial and industrial distributed solar markets.
- Constellation Energy and Kansas City Power & Light have launched their own retail residential solar panel leasing programs in 2011 and 2013, respectively.

[16] Direct Energy is a subsidiary of Centrica plc, one of the world's leading integrated energy companies. It operates in 46 U.S. states, plus the District of Columbia and 10 Canadian provinces, and serves over 6 million customers.

[17] As part of its Community Power Project, APS has installed utility-owned solar arrays on ~200 homes, solar water heaters in ~50 homes, and small-scale wind turbines in a limited distribution area located in northeast Flagstaff. For more information: www.sgiclearinghouse.org/?q=node/1671&lb=1.

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which is preventing them from seeing the larger customer sentiment shift and opportunities associated with DG. But, for example, when Austin Energy went through the exercise of coming up with the cost-benefit ratio of solar [for its residential solar rate], it found that the benefits far outweigh the costs to its ratepayers.[18]

There is a very real under-appreciation of the benefit that distributed solar can provide to the system vis-à-vis voltage regulation, frequency regulation, resource capacity, demand-side management, and avoided or delayed infrastructure investment. An example of this lagging appreciation can be found in California. Despite the fact that the state hosts over 2 GW of distributed solar PV, the California-ISO (CAISO) does not interact with any of that generation, which is astonishing. There is no incentive for system owners like CAISO to provide ancillary services through distributed generation to the broader electricity market. If, in the context of ratemaking and tariff structures, a premium for services like load balancing, capacity, frequency regulation and voltage regulation was offered for DG, then I'd bet that the market would almost instantaneously respond to that and provide those services.

It's all about the price signal. And to date, there isn't an accurate price signal being sent to DG resources because of this notion that DG equates to revenue erosion to the incumbent electricity provider. The fear of revenue erosion is overwhelming any type of balanced view of whether or not this customer-dictated trend to adopt solar PV is good or bad for the utility.

EPRI: Battery storage, which SolarCity offers as part of its product line up, is a sort of wild-card technology that could significantly impact the future electricity landscape. What has been the commercial uptake of SolarCity's battery product and what is the company's outlook?

SolarCity: Customers have been enthusiastic about SolarCity's energy storage offering, but the difficulty has been the price point.[19] So far, very few of our customers have storage. But we think that, just as we've seen with PV, scale deployment will bring precipitous declines in the costs of storage technology. We are, for example, excited about the current California Public Utility Commission proceeding that proposes to mandate the installation of over 1.3 GW of energy storage in California between 2014 and 2020 by the state's three investor-owned utilities (Southern California Edison, San Diego Gas & Electric, and Pacific Gas & Electric).[20] We believe this mandate should include a minimum 200-MW set-aside for customer-side DG storage solutions.

In general, we believe that energy storage will play a definitive role in the future electricity arena, and we want to educate policymakers about the opportunities and impediments to battery deployment. Simultaneously, SolarCity is pursuing the technology in a variety of contexts. For example, we are involved in a CPUC R&D project with partners Tesla and UC Berkeley to research advanced grid-interactive distributed PV and storage.[21]

Editor's note: SolarCity is partnered with Tesla Motors to provide a bundled solar-storage product that pairs PV panels and a dispatch and monitoring platform with lithium-ion batteries. The company is currently deploying 10-kWh battery packs as part of a pilot program in California.

EPRI: What is SolarCity's near-term strategy for future expansion beyond the 14 U.S. states in which it currently operates? Are there opportunities being pursued in the international arena?

SolarCity: We're constantly looking for new opportunities to meet customer demand and expectation. Recently we announced that we have entered into a definitive agreement to acquire Zep Solar's frameless mounting solution. Once the acquisition is completed, we plan to aggressively deploy that product in the international marketplace. We're also engaged in a number of strategic alliances with Honda Motors, Viridian, Shea Homes and others that are similar to the collaboration described earlier with Direct Energy, in which investment funds have been created to enable solar adoption by partner customers.

Editor's note: In addition, to acquiring the balance-of-system company Zep Solar for $158 million in October, SolarCity also purchased direct marketing partner/lead originator Paramount for $120 million in September.

EPRI: Looking ahead, what is the future for solar leasing? Is the model threatened by continued capital cost reductions that make customer ownership pathways more attractive? Something else? What adaptive strategies do you see SolarCity potentially making to remain competitive in the dynamic PV market?

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[18] Austin Energy launched a value of solar tariff in 2012 that provides participating customers with 12.8¢/kWh, a level that is utility revenue-neutral. This rate—computed based on values derived from energy, capacity, T&D deferral, loss savings, fuel price surety, and environmental metrics—can be annually adjusted to account for calculated changes in value.

[19] For a comprehensive assessment of energy storage costs for a broad range of technologies, see EPRI report *Electricity Energy Storage Technology Options: 2012 System Cost Benchmarking*. EPRI. Palo Alto, CA: 1026462.

[20] The rulemaking is the result of a process started in 2010 with the passage of California Assembly Bill 2514 which calls for grid-scale energy storage. The amount of storage mandated, 1.325 GW, is similar to the total amount of installed non-pumped hydro storage across the world. EPRI believes that the deployment of storage systems in California is likely to strongly affect storage technology manufacturing and installation costs over the next decade, not just in California, but in all jurisdictions.

[21] The $1.7 million project was awarded in 2010 by the CPUC's California Solar Initiative Research Development, Deployment and Demonstration (CSI RD&D) Program.

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SolarCity: For a pure play equipment leasing company, the trend that you suggest could be a scary scenario. But for a company like SolarCity—which provides financing and also sells equipment outright—we're not as concerned by a potential shift to more cash sale asset purchases.

But I think the notion that the capital-intensive equipment purchase market is going to eclipse the far more capital light equipment lease approach is overstated. In fact, when we introduce a third party ownership product in new markets we see two trends: 1) rapid adoption of solar using financing, and 2) aggressive adoption by non-traditional demographic segments.

Note: In 2010, SolarCity installed a 187-kW PV array atop EPRI's HQ building in Palo Alto, CA. EPRI is financing the system through a PPA with SolarCity. The installation is aiding EPRI solar research by, among other things, providing real-time power quality data for distribution circuit analysis.

Figure 7 – SolarCity PV System Installation at EPRI HQ

The CPUC completed a study in 2012 that examined demographic trends with respect to PV adoption and found that the availability of third party ownership products resulted in much greater participation by younger and less affluent electricity consumers.[22] According to the study, since 2007, when SolarCity first began offering a lease product, solar adoption increased for lower income consumers with median incomes below $50k/year, by 364% (813 to 2,762), and for middle income customers, earning an average of $50-75k/year, by 445% (2,367 to 10,531). Solar leases and power purchase agreements are widely appreciated as an enabling tool for solar penetration.

EPRI: Finally, what are the primary barriers that you feel can be addressed in the near term to further accelerate solar growth among the residential and commercial customer segments?

SolarCity: The two greatest impediments to more robust DG resource deployment are cost of financing and soft costs (e.g., project management-, compliance-, and other non-capital equipment-related activities, including permitting and interconnection; project design; and conformity with safety, building, and electric codes). Historically financing costs for the solar economy have been far greater than the economy at-large. SolarCity is pursuing a range of options to lower the cost of capital. The company has closed multiple aggregation facilities to secure a lower cost of borrowing for its structured finance fund, recently completed a convertible debt securities offering, and earlier this month, announced its intention to pursue a securitization of its solar assets.

Meantime, more attention is starting to be paid to soft costs which have not markedly decreased over time despite scale deployment. For example, jurisdictions require that "wet" signatures be provided on rebate and permit applications, interconnection documents, and other contracts. In a society where facsimile and electronic submissions are allowed in our highest courts, the idea that you have to have a wet signature defies logic. Having to physically sign various applications and agreements with a pen and FedEx the paperwork back and forth among participating parties is just one of many examples whereby the transactional costs associated with deploying PV are unnecessarily high. SolarCity is working with permitting authorities and utilities to allow electronic submissions. Progress has been slow going, but the end game will pay major dividends.

EPRI Perspective

SolarCity's third party ownership contracting model, since emulated and adapted by a number of others, can be considered a game changer for the solar segment. (In fact, its core elements are now being applied in other distributed generation market sectors, such as in energy storage.)[23] The approach not only makes distributed PV more financially accessible to a wider range of consumers, but also simplifies the sales transaction—SolarCity's pitch primarily centers on the purchase of cheaper electricity, not the sale of the PV asset itself.

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[22] The study is embedded in the California Solar Initiative 2012 Annual Program Assessment, which can be downloaded at: www.cpuc.ca.gov/PUC/energy/Solar/2012CASolarLegReport.htm. Another analysis finds that third-party business models have attracted less affluent, younger, and less educated populations in southern California: www.academia.edu/1299862/The_transformation_of_southern_Californias_residential_photovoltaics_market_through_third-party_ownership.

[23] In October, Stem, an energy storage system manufacturer, secured a $5 million fund backed by Clean Feet Investors (CFI) to facilitate the deployment of up to 15 MW of its product by C&I customers at no upfront cost.

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Meanwhile, the company appears to be pursuing a variety of strategies to pave the way for future growth. Like some of its competitors, it is moving toward greater vertical integration to improve business efficiencies and streamline costs. For example, recent acquisitions of frameless mounting system manufacturer Zep Solar and direct marketing/lead originator Paramount aim to lower installation labor requirements and customer acquisition costs, respectively. And alliances with the likes of Honda Motors, Shea Homes, Kohl Construction, Viridian, Direct Energy, and Home Depot, attempt to broaden sales channels.

But it is the company's recently announced intention to introduce another industry first—a securitized portfolio of distributed solar assets—that offers the greatest prospective payoff.[24] As with home mortgages and auto loans, solar securitization pools debt and sells it as a package to investors thereby improving liquidity (i.e., access to cash). Consequently, this novel offering has enormous potential to spur greater demand for solar because it can lower project financing costs, and in turn make PV even more affordable for homeowners. Furthermore, with access to deeper capital pools, SolarCity can more rapidly scale, while stable, long-term solar assets can facilitate attractive investor returns. It's a theoretical win-win-win for SolarCity, its customers, and investors.

Looking ahead, the near-term consensus expectation is that SolarCity and others of its ilk are likely to capture a considerably greater share of the expanding distributed solar market. The pace and extent of PV growth via third party contracting models will, however, be impacted by a number of open and unresolved issues. Chief among them: the determination of "fair market value" for leased PV assets and possible changes to existing state net energy metering policies (which underpin the majority of PV leasing models). Other wildcards include the long-term reliability of deployed TPO assets, the upshot of the federal ITC's scheduled reduction (from 30% to 10% in 2017), and the shape and scope of future electric utility solar initiatives (in the form of programs, structural changes to rates, etc.).

Regardless, the anticipated future of distributed solar deployments, driven in part by SolarCity and other TPO vehicles, is certain to add complexity to utility planning and grid management activities. For power companies, considering opportunities to collaborate with third party operators to, for instance, optimize the location of PV system deployments and boost their operational value, may be a worthwhile strategic pursuit. Likewise, coordinated, perhaps outside-the-box strategies that leverage smart grid infrastructure or that re-imagine conventional PV operating protocols (e.g., utility ownership of the inverter at the customer premise) may prove beneficial. Alternatively, competitive tactics that co-opt TPO business schemes might help meet bottom line business objectives.

Technology Spotlight

Innovations in Crystalline Silicon Photovoltaics: Cell Metallization using Plated Copper

The commoditization of crystalline silicon (c-Si) PV panels, particularly over the last decade, has sharply reduced module prices to the extent that most manufacturers now face tight, perhaps unsustainable margins. In effect, because many of the costs have already been mined out of the module production process, prices are now near or below the costs of production. As a partial result, industry participants are increasingly exploring innovations that can boost panel conversion efficiencies and enable further levelized cost of electricity (LCOE) reductions, but also improve bottom-line company financials. By producing more power per panel, manufacturers aver that their products can command higher dollar-per-Watt ($/W) price points and, in turn, generate greater revenues and profits.[25] One such method being explored to both lessen material costs and improve cell efficiencies is through cell metallization using copper plating.[26]

Background

Metallization is a key process step in the fabrication of c-Si solar cells that, to a large extent, determines a solar cell's design and efficiency. It entails adding pathways to a prepared semiconductor wafer in order to enable the flow of electrons (i.e., current)—effectively laying down metal electrodes to collect the electricity generated by sunlight.

The typical metallization approach incorporates an aluminum plate on the back of each PV cell, and a series of metal fingers and bus bars (collectively referred to as "traces") on the front of each cell (see Figure 8). The fingers collect free electrons (which create an electric charge) from the semiconductor wafer, and feed them into the bus bars. The bus bars then ultimately transport the elec-

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[24] In early November, SolarCity announced in an SEC document that it plans to offer a private placement of $54.4 million of an "aggregate principal amount of Solar Asset Backed Notes, Series 2013-1 with a scheduled maturity date of December 2026."

[25] Higher efficiency panels, in the range of 22-24%, have higher average selling prices (~$0.94/W) than those for lower efficiency modules, in the range of 13-16% (~$0.70/W and lower).

[26] Other methods being pursued to further PV panel price reductions include those that increase solar plant energy delivery (e.g., via gallium-arsenide nanowires), reduce module and balance of system costs, and lower module degradation rates.

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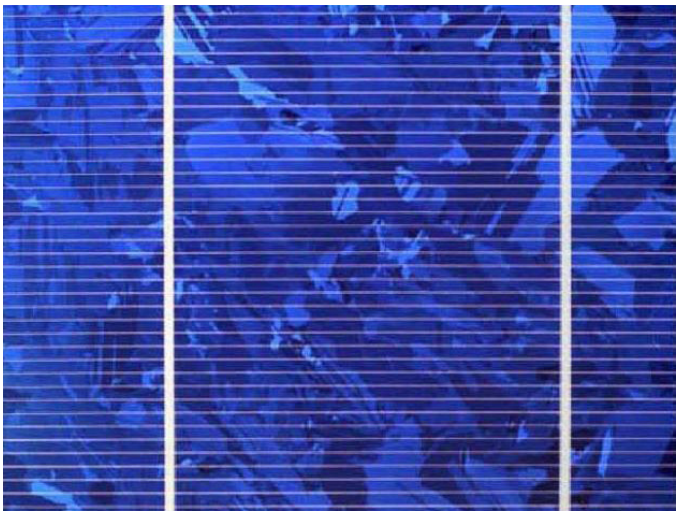
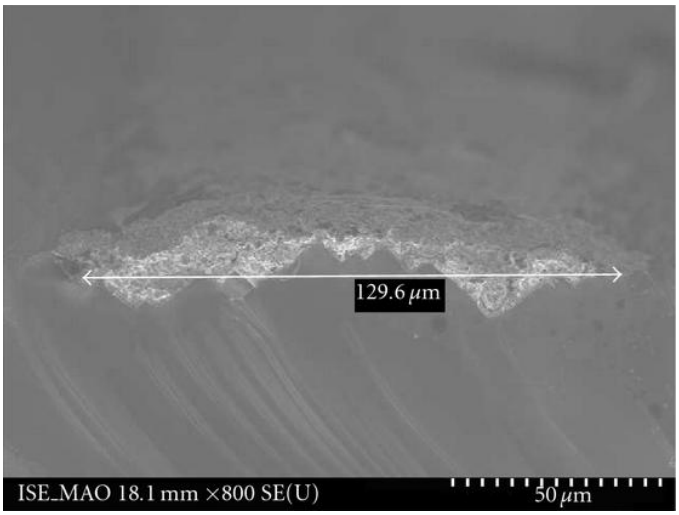


Note: The fingers, the narrow horizontal traces, are connected to the wider vertical busbars. The current carried by each finger is small, thus they are thin. Individual fingers feed into larger busbars which carry larger currents.

Figure 8 – Front-side Metallization of a Polycrystalline Wafer



Note: The dark material with pyramid shapes is the top surface of the semiconductor.
Credit: R. Woehl, et.al.[29]

Figure 9 – Cross-sectional View: Screen Printed Silver Finger with 129.6 μm Geometric Width

trons produced by multiple cells to external module wire connections. (Once individual cells are fabricated, they are connected together and packaged to form a module. Electrically the cells are connected in series with the front-side bus bars attached to the back plate of the adjacent cell through stringing.)

Optimal metallization approaches facilitate higher cell efficiencies and enable maximum power production. The trick is to integrate metallization pathways with sufficient cross-sectional area that permit the safe and efficient transmission of current without blocking too much sunlight from striking the cell surface, thus reducing cell output. It's a delicate balance because as current increases within the c-Si cells, the cross-sectional area of the traces must also increase to transmit the current. (Since the bus bars carry more current than the fingers, they must have larger cross sectional areas, and therefore be much wider than fingers.) There is an inherent tradeoff between the uninhibited flow of current and cell shading losses.

The standard metallization process for crystalline silicon PV cells involves screen printing fingers and bus bars using a thick silver paste.[27] The printed cell is then put in a furnace to anneal the silver and create positive contact with the front-side semiconductor in the cell (see Figure 9). The resulting traces have a low aspect ratio, meaning the height perpendicular to the cell surface is very short relative to the width of the traces. To carry current with less resistance, traces can be widened. However, the effect of widening the traces is that they now create greater shading losses on the cell. There is an effective optical width which is different, and typically smaller, than the geometric width of a trace.[28]

Innovations in Metallization: Copper Plating

Copper plating is among the innovations afoot that aim to reduce the material costs associated with the manufacture and application of traces, and also minimize their shading effect to maintain or boost cell efficiency.[30] In contrast to screen printing, the plating technique combines a seed layer created by aerosol printing with a light induced plating (LIP) process to deposit traces on the surface of a wafer.[31] It utilizes the photovoltaic effect to create a negative potential on the top surface of a wafer which, in turn, attracts metal ions to build the traces. The resulting traces have higher aspect ratios and are roughly semicircular in shape, as shown in Figure 10 on the following page. Thus, they can carry the same amount of current as traditional traces but create less shading because of their narrower geometric and effective optical widths.

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[27] An average module contains ~2/3 Troy ounces of silver.

[28] Traces actually shade less of the cell than would be expected from their actual (geometric) width.

[29] R. Woehl, M. Horteis, and S.W. Glunz, "Analysis of the Optical Properties of Screen-Printed and Aerosol-Printed and Plated Fingers of Silicon Solar Cells," Advances in OptoElectronics, vol. 2008, Article ID 759340, 7 pages, 2008. doi:10.1155/2008/759340

[30] Other innovative approaches for reducing metallization costs include nickel phosphide and non-contact printing techniques.

[31] Plating methods can incorporate either silver or copper as a raw material input.

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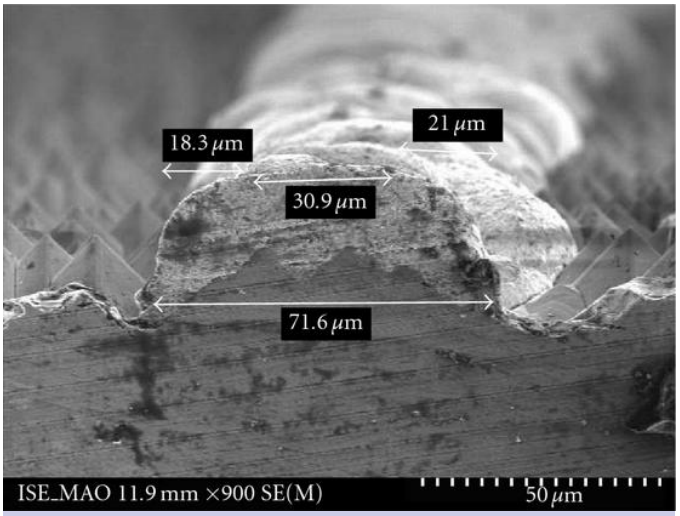

Figure 10 – Finger Created with Aerosol Seed Layer and LIP using Silver

While the LIP process increases cell efficiency, the use of copper instead of silver as the raw material input to the plating process helps further reduce overall solar module production costs. Over the past decade, silver prices have risen four-fold to ~$22/oz, motivating R&D efforts to explore the use of alternative materials. Consequently, companies and research organizations have increasingly been turning to copper to exploit the raw material's abundance, established use and reputation in the semiconductor electronics industry, and cheaper prices—roughly $0.21/oz, or 1% the price of silver.[32] These price points in mind, a 72-cell, 300W c-Si module would contain $14.41 of silver ($0.048/W), almost 7% of the average selling price of a module (~$0.70/W). Replacing the silver with copper would result in the module containing $0.04/W of copper or less than 1% of a conventional $0.70/W module.

Unfortunately, copper pastes used in plating approaches are not yet ready for commercial prime time primarily because they lag in cell performance and long-term durability. Per Table 4, there are multiple barriers associated with copper as a metallization solution, and thus far, little progress has been made at the commercial level.

Table 4 – Barriers to the Adoption of Copper Plating as a Replacement for Front Silver Metallization

Challenge	Comments
More processing steps	Although a screen printing and dry step is eliminated, the steps of dielectric opening, plating at least 3 layers, and annealing are typically added. Maintaining high yields can be challenging.
Higher CAPEX	Plating equipment adds significant cost.
Low adhesion strength	Typically the most challenging technical problem, particularly when soldering wires to the busbar. Module reliability risk.
Plating solution costs	While copper is much cheaper than silver, it can be challenging to use a dissolvable copper bar anode. If a significant amount of the plated copper comes from consuming the plating solution, the costs can increase.
Copper diffusion into the silicon	Diffusion of copper can create shunting and other problems that lower cell performance.
Steadily improving screen print technology	Narrower screen printed fingers with better contact resistivity and a wide variety of other ways to reduce silver mass per cell reduce the incentive to adopt the more complicated and risky copper-based technology.

Sources: GTM Research, EPRI

However, a number of R&D efforts are underway to develop copper pastes for practical c-Si and CIGS PV metallization techniques with the hope of supplanting silver screening methods. For example, First Solar, the world's leading thin-film PV manufacturer, acquired PV technology startup TetraSun in early 2013 to help commercialize TetraSun's 21%-efficient solar cell (it integrates a copper metallization solution). Volume production is planned by mid-2014. In addition, imec, a micro- and nano-electronics research center based in Belgium, and Japan's Kaneka Corporation have been jointly pursuing R&D around copper metallization. In mid-2012, the two parties achieved an efficiency of 22.68% on a six-inch semi-square heterojunction silicon solar cell using an electroplated copper contact grid. Also, Japan's National Institute of Advanced Industrial Science and Technology (AIST) has produced wiring and electrodes for c-Si solar cells by applying a low-damage print manufacturing technology that uses copper paste fabricated by Napra Co.

It remains to be seen whether metallization based on plated copper will take commercial hold. But the technique has clearly been identified by the PV segment as one of a number of innovative concepts that has potential to drive future cost reductions in crystalline silicon PV.

For more information on this Technology Spotlight item, contact EPRI's Travis Coleman (505.715.1561, tcoleman@epri.com).

[32] As of this writing, silver was selling at $21.62/ounce, and was as high as $45/ounce within the last 3 years, while copper was selling for $3.29/lb, or ~$0.21/ounce.

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