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PV Innovation in North America: the gateway to solar gigawatts

by Nathan Furr und Travis Bradford
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The \$50 billion global PV industry is fast approaching a critical juncture in its history. Buoyed by climate change, national security concerns and slowing productivity in traditional, fossil fuel-based power generation, PV has emerged over the last 20 years as an economically and environmentally sustainable source of energy. However, the global recession, tightening credit markets and slow integration into the global power sector presage at least two years of difficulty for the majority of players in the PV industry. Despite these pressures, one constant force remains a primary driver of growth in this important and dynamic market - technological innovation.

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PV power plant "ElDorado" with panels by First Solar (left). PV panels with cylindrical modules by Solyndra. Courtesy:: First Solar Inc.; Solyndra Inc.

Among the things that are critical for making sound investments and planning decisions in this difficult financial environment include: understanding how incumbent PV technologies will affect cost curves, learning what hot new technologies are emerging to disrupt established players, and considering how end users are incorporating new and up-and-coming PV technologies into their power-generation portfolios and daily lives. Greentech Media (GTM) and the Prometheus Institute for

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Sustainable Development's latest industry-leading report, PV Innovation in North America, analyzes these critical technology issues within the context of the dynamic North American PV market. Most importantly, this report highlights the ways in which North American-based technological innovation will contribute to make this the world's leading PV market. With kind permission of GTM the solar report on solarserver.com sketches developments and potentials of PV companies as well as technology in North America as a key factor for a gigawatt solar industry and market.

Dominant US firms started with unparalleled technologies in terms of cost and performance

Small, entrepreneur-driven PV companies are the dominant force in the North American PV market. There are more PV technology developers in North America than in Europe and Asia combined, and these companies are rapidly developing the newest generation of innovative PV technologies. North America's two dominant firms, First Solar and SunPower, began as small, entrepreneur-driven companies whose technologies are unparalleled worldwide in terms of cost and performance. These two companies are the yardstick by which success among North American PV companies is measured.

New Government support and traditional sources of private capital to engender industry growth

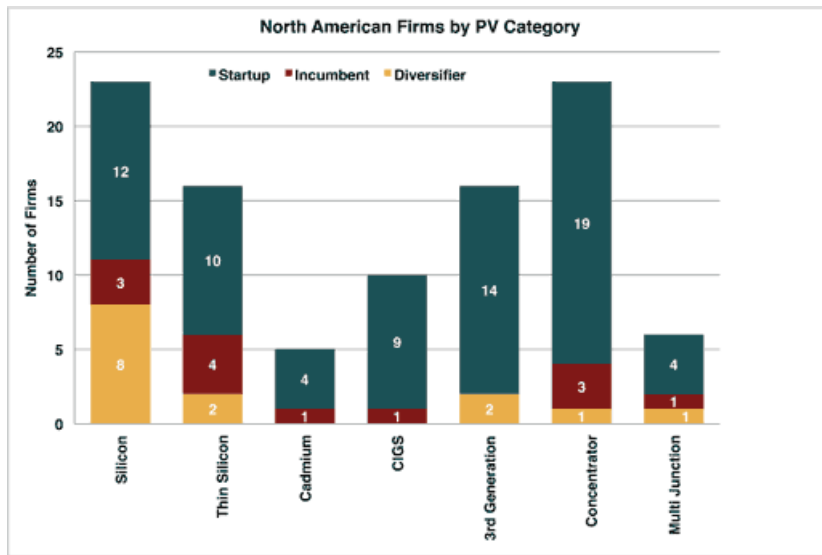
Unlike the majority of European and Japanese PV companies, North American PV companies emerged largely independent of government support. As a political climate favorable toward renewable energy takes hold in the United States, government support combined with traditional sources of private capital will engender industry growth unseen in other leading global PV markets. Tightening credit markets and higher costs of capital will slow demand for PV installations in established markets. Recessions, however, historically are potent times for research, development and innovation, which require little in the way of project finance. North America's small, entrepreneur-driven PV companies stand to emerge well-positioned globally following the resetting of credit markets in 18 to 24 months.



CPV-System by GreenVolts (left). OPV production line in a Konarka facility. Courtesy: GreenVolts, Inc.; Konarka Inc.

The North American PV industry as a whole represents a strongly diversified technology portfolio, with firms developing x-Si, thin-film, concentrating photovoltaic (CPV) and third-generation organic and nano-scale PV technologies. No other global market has as much technological diversity and, as such, North American firms will likely emerge as the commercial leaders in each of these important technology verticals. Though the expected shakeout in the PV industry, combined with the global recession, will result in the failure of many PV companies, those that exhibit significant technological differentiation in terms of cost, performance or application are likely to succeed. The majority of technologically differentiated firms are located in North America.

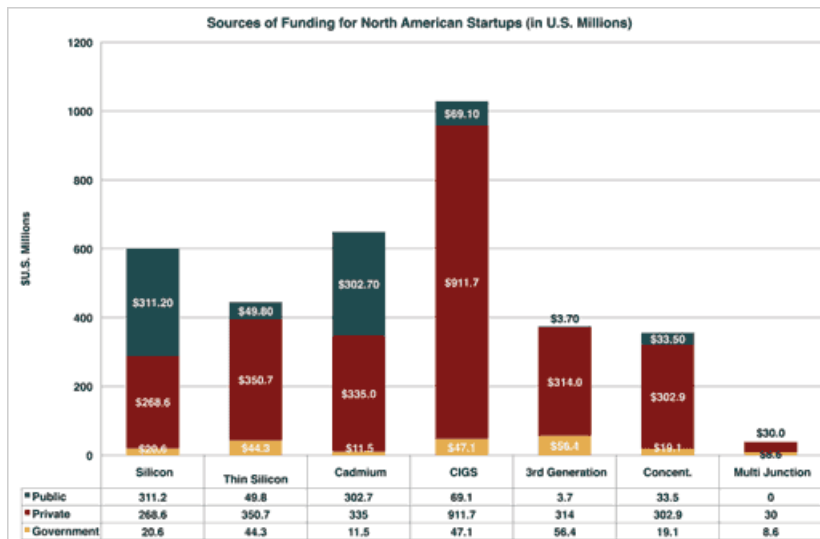
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Courtesy: Greentech Media

Success depending on cost and performance

The global recession, however, will not be kind to all PV companies or all PV technologies. Lack of access to capital and the failure to prove PV technologies at scale and at cost means many companies will not survive the coming shakeout. Larger firms will acquire some companies in the anticipated wave of consolidation, while some companies will merely fall by the wayside. This report argues the companies that will fail to succeed are those that fail to market technologies differentiated by lower cost or performance. It is the goal of this report to analyze the companies and technologies that will succeed and the grounds upon which that success will be built.



Courtesy: Greentech Media.

Core PV Technologies

Currently, the global PV market can be characterized by dramatic expansion in three-plus generations of PV technology: first generation (silicon), second generation (thin film), third generation and concentrating PV (CPV).

First-generation technologies, based on silicon wafers, have experienced the most dramatic increase in production volume, as manufacturers, particularly in Germany, Japan and China, have scaled up well-defined manufacturing technologies. These producers have the capacity to

produce in the gigawatts but have been constrained by a severe shortage in raw silicon, which has increased costs and decreased volumes. As the constraints on silicon supply ease up, these manufacturers will provide a massive quantity of solar PV to the market. This dramatic increase in volume will drive down costs through economies of scale and price competition. The downside will be that, like in all developing industries, as competition among large producers increases, inefficient producers will likely be forced out of business, leaving behind a cadre of highly efficient manufacturers. That being said, even given massive scale advantages, silicon is still an inherently expensive material with a long supply chain and therefore will face significant competition from up-and-coming PV technologies.



Left: Silicon Genesis produces 50 micron (μm) solar-cell substrates. Right: Konarka develops and commercializes "Power Plastic" a PV material that converts light to energy. Sources: Silicon Genesis; Konarka

Second-generation PV technology, or thin film, has just begun to broadly reach commercial scale. Multiple manufacturers in each thin-film category have reached the commercial stage with others coming online every quarter with large manufacturing capacities. In terms of global distribution, a number of manufacturers in this category have sprung up in Europe and North America with some of the most innovative coming from North America.

Third-generation PV technologies are diverse and generally promise higher efficiencies or lower cost manufacturing than either first- or second-generation technologies. This PV category includes technologies like: dye-sensitized solar cells, quantum dots, nano-antennas, nano-modified materials and organic cells. Generally these technologies, while promising, are further from the market, although organic cells appear to be on the cusp of being produced at commercial scale. This remains a technology category to be watched. In terms of geographic dispersion, again North America is a center for much innovation in third-generation technologies.

Finally, although not a "generation" of technology, concentrating PV has become a major global category. Concentrating PV employs mirrors or lenses to focus light on a small area of actual PV material, the argument being that lenses and mirrors are less costly than PV, thereby lowering costs. This category can be divided into low concentration modules (often two to 10 times) that do not normally require tracking and high concentration modules (often 100 times or greater) that require tracking (an element that increases installation requirements and costs). Furthermore, many high concentration units employ multi-junction PV cells—solar cells capable of capturing multiple spectrums of light and thereby capturing more power from the light falling on the cell. Geographically, North America has seen an explosion of concentrating PV technologies.

Innovation in PV Technologie

Technology developers and suppliers in each of the leading global PV markets are distinct in their approach. Chinese manufacturers, for example, have focused on high-volume, low-cost production, while their Japanese counterparts have introduced manufacturing techniques from semiconductor and plasma display fabrication. European manufacturers,

by and large, produce high-cost, high-performance PV components directed primarily at their domestic markets. The lack of certain, clear policy support in North America combined with a market focused on early-stage research and development has spawned a large number of small, entrepreneur-driven PV companies, some which will be well-positioned as industry leaders in the coming years.

Innovation alone, however, does not make a market. As such, not all of the more than 120 North American PV companies will make a significant impact in the global PV industry. Those poised for success are ones that have addressed three significant technology development criteria. First, they have developed or are developing PV technologies that serve an addressable market. Low concentration CPV technologies, for example, may never gain widespread deployment in the residential solar space because the efficiency advantages are overshadowed by complex designs and high manufacturing costs relative to the small scale these technologies are meant to address. Conversely, flexible BIPV technologies may prove disruptive because they address balance of system cost inefficiencies in ways no other PV technology can.



Left: CIGS panels by Ascent Solar. Right: High efficiency panels on trackers by SunPower. Courtesy: Ascent Solar Technologies, Inc. SunPower Corp.

Second, the underlying manufacturing processes drive cost reductions at the plant level and minimize manufacturing complexity. No fewer than nine Copper Indium Gallium Selenide (CIGS) manufacturers lay claim to the title of "Next Big Thing". However, all of these companies are pursuing a separate manufacturing process to fabricate their CIGS cells and modules. Where companies are producing roughly identical products, it is likely that a convergence across manufacturing technologies will occur, with some of these companies disappearing in the ensuing shakeout. In the current credit environment, project finance will look kindly on those companies with low cost, easily reproducible manufacturing technologies that support, rather than inhibit, the commercial production of the downstream PV technology.

Third, downstream PV technology must provide tangible value to the end user. A popular argument, and one advanced first by Greentech Media and the Prometheus Institute for Sustainable Development, is that the PV industry will be dominated by two types of firms: those manufacturing low cost technologies that generate high internal rates of return and those manufacturing high performance technologies that generate high gross returns. First Solar is an example of the first, while SunPower is an example of the second. Regardless of the level of innovative skill that a PV company embodies, failure to fall into one of these categories will meet with little success at commercial scale.

PV on the way to become one of the world's major industries

The international PV market has experienced robust growth in established technologies as well as a diverse flowering of innovation. The international market looks set to continue a long run of growth and expansion that will benefit the national economies that foster innovation, support manufacturing and sustain installation.

Summary of State of PV Innovation

Innovation in PV has reached unprecedented levels across all generations of PV technology. In first generation silicon-based technologies, entrepreneurs are innovating along the entire value chain, from the production of raw silicon, to ingots, wafers, cells and modules. In particular, innovation has focused on creating thinner wafers, cell architecture with higher efficiency and modules that capture power more effectively.

Second-generation thin-film technologies, which have been on the backburner for decades, are finally reaching commercial scale. Again, entrepreneurs are pushing the bounds of innovation, particularly in manufacturing technologies that can produce modules at breakneck speeds, promising to dramatically lower costs and increase production capacity.

Third-generation technologies are not far behind, with firms innovating with both high-efficiency cells as well as high-speed manufacturing. Although not commercially viable for the most part, the innovations in this space promise yet another wave of disruptive innovation in the near future.

Concentrating PV has exploded with an array of both high- and low-concentrating modules. Innovators are exploring a host of potential combinations of materials and formats, including flat-module formats that can integrate into existing installation infrastructures. Furthermore, many concentrating PV producers are designing products with total system cost in mind with the goal of reaching grid parity.

Tackling costs along the value chain

Finally, both PV producers and other entrepreneurs are beginning to take into account other areas of the value chain, such as installation, and tackling costs. Solyndra, for example, has designed a module that can capture light when installed horizontal- a simpler installation format that could shave \$1 per/watt of installation. Similarly, firms like Optisolar are integrating all the way through power sales in order to capture savings from mass installation of large format modules. Alternatively, other entrants such as Solar City or SunEdison are focused purely on the integration and installation of solar.



Left: CPV system by SolFocus. Right: PV plant by SunEdison (1,3 MWp) in Veracruz. Courtesy. SolFocus Inc.; SunEdison Deutschland GmbH

PV to become one of the major industries of the century

The PV industry continues to be poised for significant growth. Large manufacturers are driving down costs in established technologies and a diverse flowering of new entrants suggests that several waves of innovation will likely yield fruit and drive PV costs further down, which will in turn stimulate demand. Furthermore, this innovation is being led by startups founded by experienced entrepreneurs often with the backing of professional investors, all of whom expect a return on their investment. Although some might be suspicious of economic motives, they in fact yield the most benefits, leading innovators to drive down costs while increasing volume. Indeed, the PV industry and clean technology, like

industries such as semiconductors, biotech and information technology, will likely be the major growth industry for the next several decades. Entrepreneurs, investors, companies and countries who foster innovation, manufacturing and installation will reap the benefits for years to come. Entrants and investors should always exercise financial wisdom and avoid pushing PV into a market bubble but the products produced in the PV industry are inherently linked to the healthy future of all economies. Therefore, as the industry naturally evolves, it will become one of the major industries of the century and into the future.

The GTM reports provides essential analysis of the companies and technologies that meet these criteria, as well those that are not. As such, it is essential reading for any investor, entrepreneur, project developer, or end-user actively searching for innovative PV companies that will emerge successful in the rapidly evolving global PV market and the rapidly changing global economy.

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