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Solar

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PV – Balance of Systems Innovation Reducing Installed Cost

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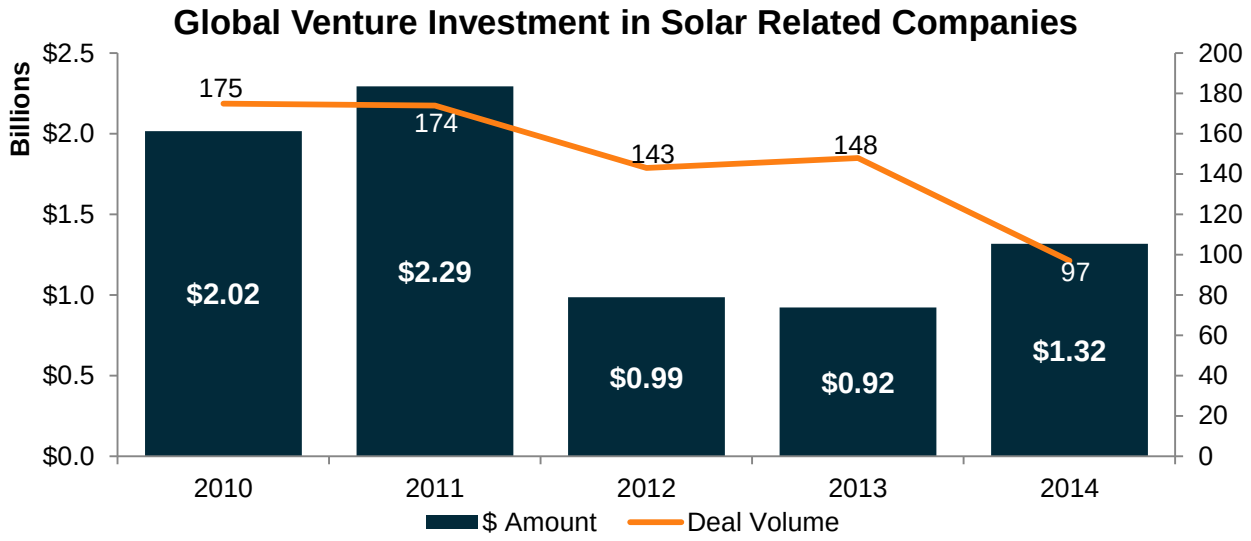
INTRO

The solar photovoltaics (PV) industry has seen a dramatic ramp in global installed capacity as the cost of solar panels has dropped precipitously. Now, as silicon panels approach barriers in both thrift and efficiency, further gains are coming from the remaining components – the so-called *balance of systems* – that go into commissioning a solar array. The i3 innovation network tracks deals in solar photovoltaic Balance of System technology areas including junction boxes, power optimizers, inverters, solar tracking systems and PV mounting & racking systems.



Balance of Systems technology areas are the main drivers of cost reduction in solar module installations in the residential, commercial, and utility-scale markets. Installed costs in U.S residential PV systems have come down, mainly thanks to innovative inverter and power optimization technologies as well as new generation racking systems that have reduced the typical rooftop installation time from forty-eight hours to four. Innovation in those segments will be addressed in this paper.

According to i3, 17%, or $770 million, of the $4 billion invested in PV innovation during the 2011-2015 period went to balance of systems technology. Relationships between corporations and startups have been flourishing: i3 counts 472 customer relationships and other partnerships formed since 2011. Notwithstanding a number of bankruptcies of European and American manufacturers, new emerging players with innovative offers are joining the market.

THE AGE OF MODULE-LEVEL POWER ELECTRONICS

One of the fastest growing segments in the PV industry today is module-level power electronics (MLPE) which includes products like microinverters and associated power optimizers. They solve several problems that have been encountered by PV module manufacturers, installers and users including module mismatch which is caused by a number of common factors including variances in module tolerance, partial shading, and soiling and/or uneven aging. Indeed, MLPE products, through maximum

power point tracking (MPPT) at the module level, mitigate mismatch effects and allow each module to operate at their maximum power levels. In addition, they can help designers to install more modules on the rooftop as they eliminate any electrical reason to decrease the size of a PV system. This increases installers' revenues and lowers the electricity bill of end-users through added system output. For all these reasons, MLPE have quickly moved from niche status to crucial components of residential and commercial installations.

MICROINVERTERS

Microinverter technologies replicate the inverter completely at the module level. They allow each panel to operate in isolation of the others in an array, enabling benefits such as enhanced safety, lower DC-boost multiples and lower balance of system costs. Not only size is critical to the success of an inverter, but so is the number of components, as fewer components leads to better reliability and reduced failure rates. In 2011, dual micro-inverters were introduced to the market. They essentially function similarly to regular microinverter, only on two solar panels instead of one, still lowering the costs but at the price of performance.

Traditional players like **Fronius** have dominated the microinverter space for years, thanks to continuous innovation. Fronius's FE inverter line is the company's solution for architectures using module-level power electronics in residential and commercial applications. It eliminates the need for specialty cabling or stand-alone boxes as the technology is already integrated into the FE Series inverter. This series, launched in 2014, is also suited for string inverters. There are a number of emerging companies also gaining traction with innovative inverter solutions. Some of the key ones we track in i3 are:

- **Enphase Energy**

Founded in 2006 in Petaluma, CA, Enphase Energy is considered as the company that first built a commercially successful microinverter. The company offers an energy management system that includes high-efficiency microinverters (96.5% efficient), communications and web-based monitoring analysis. In 2012, the company successfully IPO'd.

- **Sparq Systems**

Founded in 2009 in Kingston, Canada, Sparq Systems develops lower cost microinverters. In December 2014, the company received $11 million in funding from Canada-based Venture Capital firm ArcTern Ventures to help launch its new microinverter product, the uQuad microinverter. This "quad" microinverter allows a 1kW microinverter to work with four modules, which reduces the price per watt of microinverters and reduce the number of units in a PV system.

- **Empower Micro Systems**

Founded in 2011 in San Francisco, Empower Micro Systems has developed a micro-inverter technology based on the use of a proprietary solid state capacitor chip. The company's microinverter circuits have a claimed 5% efficiency advantage over current technology. The innovation relies on the semiconductor material and a differentiated technology for various power products. Empower Micro Systems' business

model is to sell the circuits to manufacturers for incorporation into micro-inverters and solar modules. The company is actively looking to partner with Chinese manufacturers.

POWER OPTIMIZERS

Power optimizer technologies are gaining traction for their ability to remove the electrical roadblocks of traditional system design and enable more modules to be installed per project. Indeed, by deploying only a minimal amount of electronics on the rooftop to handle the MPPT and DC to DC conversion, it leverages a centrally located inverter at the end of the string. This way, installers can reduce hardware on the rooftop, which improves reliability and cut costs. This corresponds to increased revenues for developers and installers, increased output and faster payback for system owners. Power optimizers can also be used in fixed-voltage mode, where the inverter determines current draw based on a predefined voltage target. The optimizers will all lock in on the same current value and deliver the remainder of the power as voltage. This advanced mode of operation means that string length is no longer determined by voltage but is now determined by power. The benefit is that string lengths are boosted by 60% in residential systems and by over 4-times in commercial systems. An added benefit is that inverter manufacturers can design inverters to accept voltages at the optimal level for DC to AC conversion reducing the need for DC boosters and other internal components. These reduced parts lead to lower cost products. Fixed voltage mode is the secret sauce for how SolarEdge's inverters and optimizers function.

- **SolarEdge**

The Israeli-based startup SolarEdge went public in March 2015, successfully raising $126m on the Nasdaq. SolarEdge provides distributed DC systems that maximize power generation of residential and large-scale photovoltaic solar sites, including power optimizers, inverters and web portals. The company's P-series power optimizer models, designed for the US market, boast a weighted efficiency of 98.8%.

- **Tigo Energy**

A competitor to SolarEdge and Enphase Energy, Tigo Energy is the first U.S. player to commercialize full optimizer integration at the module level: the optimizer is integrated inside the module's junction box. The company's flagship product is the add-on dual maximizer-ES (MM-2ES) and focuses on establishing partnerships with module manufacturers to develop and list DC-optimized smart modules that feature integrated DC optimization. The Tigo Energy system includes modules by manufacturers such as Jinko Solar, Trina Solar and Upsolar, plus the Smart Junction Box, the Tigo Energy Gateway, the Maximizer Management Unit (MMU) and web-based monitoring software. For example, its Tigo Energy–optimized Trinasmart modules, launched in 2012, have predictable and controlled output voltage that can increase string length by 30% in many systems.

- **Optistring**

Founded in Stockholm in 2011, Optistring's technology works in the opposite way when compared to traditional power optimizers. Instead of smart modules in which power optimizers are connected independently to string inverters, the company has developed a technology that encompasses the whole system. Electronics are placed onto the panel and are connected to a central unit, thus achieving a claimed 99% conversion efficiency. Because the electronics are distributed between the panels and the central unit, the performance is higher. The other advantage of this approach is that it reduces the cost of electronics by half compared to a traditional power optimizer system. This comes from the use of less hardware, and less expensive materials; a one conversion stage (instead of 3 for some technologies), and a better algorithm that increases the intelligence of the system and better control. Optistring sells its technology to large OEMs and system integrators and large installers. It is currently doing advanced testing of smart modules using its technology with existing customers and work on the industrialization of the electronics to be able to soon produce high volumes.

- **Ampt**

Founded in Fort Collins, Colorado, in 2007, Ampt offers a range of power optimization and monitoring solutions developed to increase system output and decrease O&M costs via module- and string-level power optimization and monitoring, as well as to reduce BOS costs by increasing PV source-circuit length. The company's products include three models in the Ampt-x line DC to DC external power optimizers that incorporate module-level MPPT, output voltage and current limits, plus optional two-way wireless communication compatible with third-party monitoring solutions. Ampt also offers four models in the Ampt-i line of integrated optimizers, which it developed for full factory integration at the module level. In July 2014, Ampt announced its new String Optimizer. This product can double the allowable string length when used with third-party inverters equipped with a smart module mode setting, referred to as Ampt Mode, which optimizes the inverter for use in systems with a distributed power architecture.

SMART MODULES

As panel manufacturers look for new ways to differentiate their products, more are partnering with MLPE providers to offer a more integrated smart module. Smart modules also allow installers to reduce the part count at a project rather than add MLPEs to the panels on-site themselves. Since power optimizers are smaller and more compact, they can be embedded by module manufacturers during the manufacturing process as a replacement for the traditional junction box. The resulting smart modules further reduce parts count and streamline installation at a project site.

- **Jinko Solar**

Founded in Shanghai in 2006, Jinko Solar is a Chinese giant who went public in 2010. It offers solar modules, cells, mono and multi crystalline silicon ingots and silicon wafers, as well as solar system integration and project development services. The company recently launched a new smart-module line, the M Series, featuring integrated circuitry that performs MPPT on the cell-string level of an individual

module. The M Series modules corrects mismatch issues towards cells and module strings by using embedded cell optimizer ICs that provide sub-panel level MPPT functions. This allows any underperforming cell or module strings to continue contributing power to the string while not restricting the flow of the others. The smart modules also significantly minimize the risk of hot spots which are the primary cause of module failure.

- **SineWatts**

Founded in 2011 in Charlotte (Add State), startup SineWatts is a manufacturer of fully silicon PV modules. The company received $1m from the U.S. Department of Energy in a second round of funding in December 2014 to help commercialize its patent-pending inverter "Molecule", designed to significantly reduce the cost and increase the efficiency of solar power projects. The product is an integrated circuit that is made as part of the solar panel. It replaces external inverters that convert the direct current electricity generated by the panels into alternating current for distribution on the grid. It is expected to lower solar installation costs by up to 70 percent. The Inverter Molecule is also designed to improve panel output efficiency and provide utilities with more detailed information about a solar project's operations to make it easier for a utility to integrate solar power in its distribution system. With this round of funding, the startup will grow to seven employees. The company is focusing on technology development to reduce manufacturing costs, improve the analytical information available to utilities and integrate the inverter with silicon solar panels.

MOUNTING & RACKING SYSTEMS

Solar mounting and racking systems segment account for 7-10% of the total cost of the installed solar system, which gives it a similar market size as the $6bn inverter market. This is thus the second major area where innovation is key. Players focus on reducing soft costs, including labor and supply chain costs as well as installation cost.

Although several major players have addressed installation costs by eliminating the clamping together of the module and rack during installation, some new comers are directly competing with established companies.

- **SOLON**

SOLON CORP's SOLquick is an integrated laminate and racking system. Instead of the traditional model having a module and a rack, and then clamping them together, a frameless module is assembled with a wood composite rack at the manufacturing facility and shipped, as a pre-assembled rooftop system. The frameless laminate looks like a traditional module, without the aluminum frame which is adhered to a non-metallic substructure made from Fibrex, a wood polymer with a PVC coating. The system is suited for commercial rooftops, from 100 kW to as big as it gets.

- **SunLink**

Founded in San Rafael, CA in 2004, SunLink is a developer of mounting systems, combiner boxes and wire management tools for solar applications. The company's PV rooftop mounting systems are designed to reduce installation time, thanks to a few innovations including: wind deflectors that are

installed on the outside of rear spars, which speeds up installation time; shorter tilt brackets for north and south rows that create more room between the system and the roof edge – this allows for more rows and enhancing design flexibility; a universal clamp block which is compatible with all module types and allows for more play between panels, which also eases installation.

- **PanelClaw**

PanelClaw is a developer of solar flat roof and ground mounted solutions. Its Ballasted Rooftop Systems are industry-first offerings of ballasted, parts-integrated, ready-to-install racks, racks with advanced materials roof protection and advanced-fasteners ground-mounted products. They are lighter than and as safe as traditional racking system. They are less expensive as well, since there is less labor involved. PanelClaw even guarantees its customers that if the system doesn't result in savings, the company will pay them to make them even. The company will also now cover the freight costs for its rooftop products within the contiguous 48 states and provide "wind and seismic stamps" for its flat-roof products.

- **Sollega**

Founded in 2008 in San Francisco in 2008, Sollega is a manufacturer of a simple ballasted solar racking system for PV panels. In June 2014, it released its new FastRack510 solar racking system. This product is a light-weight ballasted hybrid roof-mount solution, made in partnership with BASF, and manufactured with the advanced plastic Ultramid, which is engineered to weather extreme rooftop conditions and weighs only 4.5 pounds. The FR510's lightweight materials and streamlined design reduces overall project costs by simplifying the installation process: the universal one-piece stackable design arrives at the project site fully assembled and accommodates any type of module at 5 to 10 degree tilt angles. It also simplifies project logistics by keeping part counts low and enabling 500 kW of racking materials to fit in a standard 40-foot-long shipping container.

REMOTE OPERATION & MAINTENANCE

The development of module-level power electronics brought innovation in balance of system components maintenance as well. Microinverters and power optimizers are connected to software platforms that allow for remote operation and maintenance. As the MLPE systems are equipped with module-level monitoring to provide operators greater transparency into the performance of a system, any issues can be pinpointed from a remote location, enabling more efficient maintenance and higher system uptime. Moreover, these systems feature enhanced safety measures that reduce system voltages during instances of extremely high temperatures and/or grid disconnection. Companies such as Tigo Energy, Enphase Energy, Enecsys, SolarEdge, Advanced Energy, Solarbridge Technologies or Petra Solar all provide monitoring software with their microinverter and power optimization technologies.

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