SOLAR COMES OF AGE

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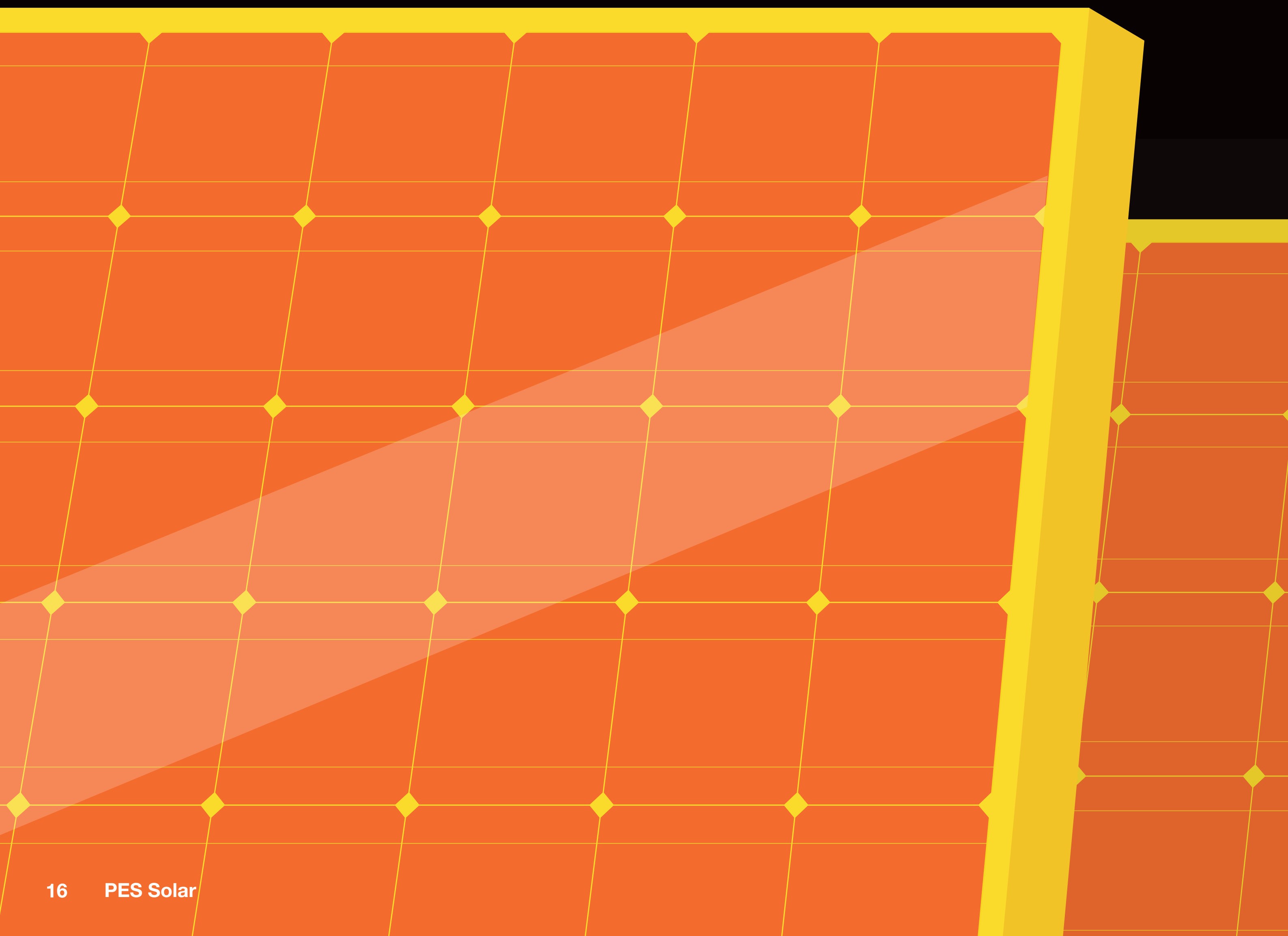

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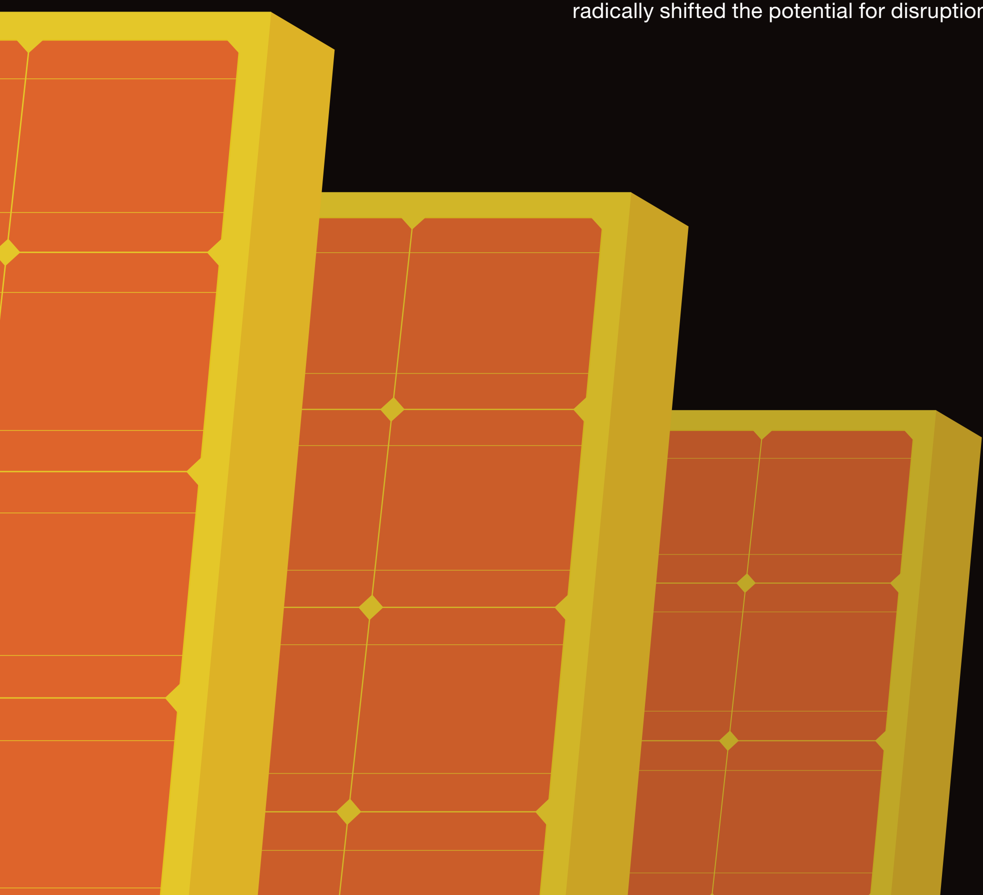
As photovoltaics emerge as the leading generation source of the future, with installations topping wind for the first time in 2016, the underlying production machine has reached maturity. Until relatively recently, in the early 2010's, uncertainty remained around the prospects of competing photovoltaic technologies. Thin-film companies championed CIGS and CdTe to sweep in an age of low-cost solar, while other options also seemed viable.

Hitting the supply chain from two ends

A brief stint of hype-driven venture capital poured into start-ups developing a range of organic photovoltaics, which they claimed would lead to multitudes of surfaces covered in photovoltaic material, for pennies. Others still envisioned a proliferation led by the combining optical systems with expensive, high efficiency, multi-junction cells in high concentration photovoltaic concepts. Despite strong commitments to research and development in these areas, the crash in polysilicon prices quashed these prospects and radically shifted the potential for disruption.



As a result, only a handful of companies still pursue high concentration photovoltaics, with Canadian-based Morgan Solar only now installing its first large-scale project in Ontario, after 10 years of operation. Meanwhile, the last few organic photovoltaic developers have pivoted away from lofty dreams of omnipresent installations as 3GSolar and G24 Innovations target integration with consumer electronics and wireless electronic networks.

Finally, thin-films have not become the dominant technology, but do retain a fair market share of roughly 8% championed by Solar Frontier and First Solar. In a market with a clear winner, seeing rapid levels of growth, opportunities for innovation are no longer those aiming to go head-to-head with crystalline silicon. However, technologies that target a narrower piece of the supply chain and are synergistic with silicon stand to reap extraordinary gains.

The existing crystalline silicon supply chain is built upon decades old technology, having seen only minor tweaks to reduce costs and increase efficiencies. Precursor polysilicon is still crystallized into ingots that need to be cut down into useable wafers. Cells are still metallized with silver busbars and strung together with aluminum tabs. Modules are still packaged using ethylene vinyl acetate encapsulation, glass, and polymer backsheets.

Recent trends in PERC cell architecture and glass-glass modules are incremental shifts. However, a more dramatic shake-up is taking shape as two start-ups – 1366 Technologies and Oxford Photovoltaics – aim to disrupt the established supply chain, targeting different ends.

From three to one: the simplicity of kerfless wafering

In Bedford, Massachusetts in the U.S., 1366 Technologies is far along its way in developing a novel process to reshape how multicrystalline wafers are produced. The company's approach – dubbed Direct Wafer Solidification (DWS) – yields a standard, drop-in 180 μm thick wafer, straight from a molten mass of silicon.

Polysilicon feedstock is melted down in a furnace from which it is then surface cooled with a high degree of precision – to create three-dimensional structures or even write one's name in the wafer. The benefits of DWS can be captured through counting the steps: polysilicon-to-wafer equals one vs. polysilicon-to-ingot-to-bricks-to-wafers equals three. DWS wins in simplicity.

The advantages of a reduction in steps can be further quantified: 1366 believes it will be able to achieve a cost of $0.35 per-wafer, less than half the cost of wafers produced with the incumbent process. This is a direct result of reduced energy consumption through process simplification and an increase in silicon utilization by reducing kerf losses associated with sawing.

Any excess silicon is thrown back into the molten silicon and reused in the next solidification. With a low-cost drop-in wafer option, 1366 has an immediate route to market adoption, as cell manufacturers will be able to source DWS wafers without any modifications to their production lines.

Despite the potential, 1366 is presenting to the industry, a radical and encompassing shift in upstream production, which is far from realization and the company has a long path ahead of it before dominating wafer production.

The company is currently constructing a 250 MW facility in New York, U.S. with projected completion by the end of 2017. Amounting to only 0.3% of global wafer production, DWS is certainly not a disruptively, worrying shockwave. Plans to reach gigawatt scale production are highly dependent. Nonetheless, the company is establishing strong connections, within the industry, to prove the performance of its wafers and refine its processes.

Over the next five years, 700 MW of its production is locked-up with Hanwha Q Cells, its historical technology development partner, with whom it has successively surpassed conversion efficiency records over the past two years.

The cell and module manufacturer known for pioneering the PERC (passivated emitter rear contact) architecture is clearly satisfied with increasing efficiency of cell's using a DWS wafer from 17.7% in March 2015 to 19.9% in March 2017. Given that PERC adoption has proliferated in the industry, adoption of 1366's wafers is a much needed differentiator for Hanwha Q Cells. Successful market adoption through Hanwha Q Cells could lead to a significantly larger supply agreement in the future, accelerating 1366's scale-up.

Meanwhile, German-based Wacker – one of the largest polysilicon producers in 2016 – made a $15 million equity investment in 1366 in mid-2016, promising to supply polysilicon and apply its technical expertise to further develop the DWS process. These two relationships bolster 1366 Technologies momentum, pushing it closer to a confrontation with incumbent multi-crystalline wafer producers and reducing final module costs by 12%.

Reining in a promising new material

Across from 1366 at nearly the other end of the production line stands Oxford PV. But instead of proposing to simplify the production process, Oxford is offering to add complexity. The company is developing a novel tandem cell architecture that couples conventional crystalline silicon cell architecture with a perovskite layer.

Perovskites have re-inspired the imagination of the photovoltaic industry, having been the subject of countless conversion efficiency breakthroughs in academic labs around the world. While it is possible to produce a stand-alone perovskite module similar to incumbent thin-films, Oxford PV is pursuing an approach that would directly compete with crystalline silicon modules and also complement them.

The fundamental concept is that the upper perovskite layer can be tuned such as to absorb the blue portion of solar spectrum more efficiently than the crystalline silicon layer. Meanwhile, green and red light will pass through the perovskite layer and be absorbed by the silicon cell. Oxford PV, along with other developers and academics, believe this can result in a cell with an efficiency above 30% – surpassing the physical limit of silicon efficiency of 28%.

The company's goal is to develop a monolithic, tandem cell in which a perovskite layer would be applied as part of the cell production process, on-top of the silicon architecture. Oxford PV believes this approach is the only economical solution for a perovskite-silicon tandem cell, in contrast to a mechanically connected tandem, in which two parallel cell production lines would be required: one for a perovskite cell and one for the silicon cell. Only at the end of the line would the completed perovskite cell be placed on-top of the silicon cell.

Unlike 1366 Technologies, Oxford PV is far from seeing any market adoption of its process, as it is still in early stages of development. The company has just begun construction of a demonstration plant in the old Bosch plant in Germany where it will produce tandem cells to supply as proof of concepts to potential customers.

Oxford PV has already demonstrated a 23% efficient tandem cell and hopes to reach above 25% by the end of 2018. While questions remain around the durability and stability of perovskite, Oxford presents a compelling option to upgrade existing cell lines to produce a cell breaking the silicon efficiency barrier.

Re-envisioning photovoltaics

1366 Technologies and Oxford PV both are proposing a reshape of the silicon module. Both are produced in two concurrent visions of disruption. While they are both targeting opposite ends of a production line, it is not clear whether the two technologies will ever come together.

1366's process is only applicable for multi-crystalline silicon production while Oxford's will likely best be suited for mono-crystalline to yield the highest efficiency. As such, each will exist in two different worlds, falling well in-line to perpetuate the trends we see today.

Multi-crystalline silicon costs are sinking lower and lower, leading to continual record breaking low cost solar tariffs while mono-crystalline silicon offers high performance options for distributed installations. While these two companies aim to redefine production, their potential for success is because they fall within these established trends in the mature industry of photovoltaics.

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