Solar PV manufacturing in 2017: factors driving technology change

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ABSTRACT

Having installed more than 75 gigawatts in 2016, the solar industry continues to create opportunities for cell and module manufacturers to expand capacities, while upgrading technologies and improving process flows. Supply remains dominated by p-type crystalline silicon modules, despite ongoing research into n-type variants and the addition of PERC on p-type mono cells. The efficiency increases from p-type mono are now driving p-type multi cell producers to accelerate changes to production lines from both black silicon and PERC. This is now setting new benchmarks for the supply of solar modules in 2017 to utility-scale solar installations.

There remains a high level of debate within the solar industry regarding the adoption of p-type mono as the preferred cell type. While not a new concept, the push in recent years has come from the expansions at the ingot and wafer stage by leading mono supplier LONGi Silicon Materials, coupled with the implementation of passivated emitter rear contact (PERC) on p-type mono production lines.

This article examines the factors that are impacting the balance of mono and multi cells produced by the industry, using the metrics from 2016 industry production. This is followed by a review of the issues that are likely to drive changes in cell and module technology during 2017.

End-market growth allowing companies to expand to multi-GW levels

The solar industry surprised all observers by the end of 2016, with overall demand for the year exceeding 75GW. At the start of 2016, almost everyone was forecasting demand levels to be in the 60-70GW band. The sharp uptick in demand appeared only to come to light in late December when figures were released from China, showing that the country's deployment in 2016 had over-performed by about 10GW.

In fact, China was the single reason the solar industry exceeded 75GW during 2016 and accounted for a staggering 35-40% of all solar installed globally in the year. During the past few years, China's dominance in terms of demand has had a strong impact on cell and module manufacturers and has directly affected the overall technology mix.

Indeed, Chinese companies continue to dominate cell and module supply to the industry, with many now having their own manufacturing facilities located in Southeast Asia or having access to cell and module supply through contract manufacturers in the region.

Leading cell suppliers in 2016

Cell manufacturing in 2016 was dominated by Chinese companies, as shown in Figure 1. Seven of the top-10 producers have headquarters in China, with all having manufacturing both inside China and other countries. First Solar is included here, using module production data as the reference point for analogous cell production rankings.

The two companies at the top of the table (Hanwha Q CELLS and JA Solar) are the two companies with the strongest background as cell producers with each moving into module production after having been established as industry leaders for cells.

Top-10 Solar Cell Producers in 2016

Ranking	Producer
1	Hanwha Q-CELLS
2	JA Solar
3	Trina Solar
4	First Solar
5	JinkoSolar
6	Motech
7	Tongwei Solar
8	Yingli Green
9	Canadian Solar
10	Shunfeng

Notes: Includes in-house cell production only. First Solar module production is scaled up for cell equivalent by blended c-Si CTM factor for ranking comparison. Shunfeng includes also cell production data from subsidiaries Wuxi Suntech & Suniva.

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Figure 1. The top-10 cell producers in 2016 were dominated by Chinese-headquartered companies, with increased cell production now done across Southeast Asia.

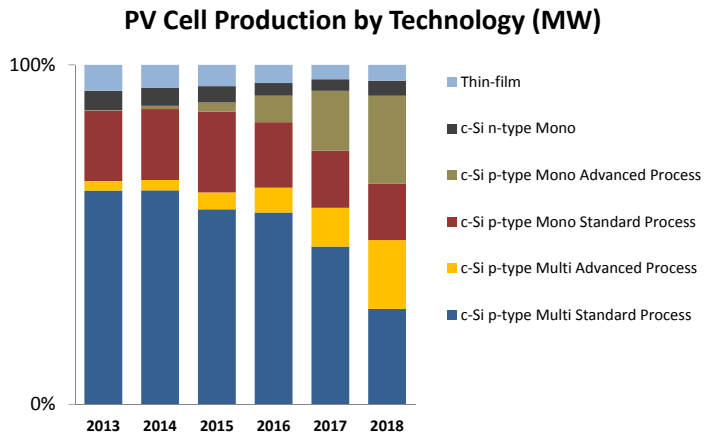

Figure 2. P-type multi c-Si technology remains dominant in the PV industry today, with many companies moving from standard cell process flows to advanced designs, especially PERC.

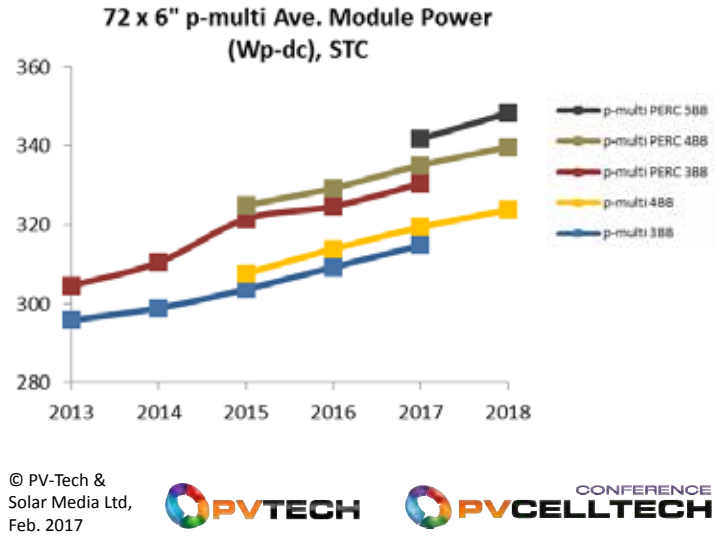

Figure 3. 72-cell p-type multi modules remain a preferred choice for many utility-scale markets, with the top performing modules expected to reach average powers of 350W by the end of 2018.

All the c-Si producers are heavily focussed on p-type production, with most of the production lines currently running on p-type multi. Most have p-type mono PERC, with Hanwha Q CELLS the clear leader using PERC on p-type multi.

The list is likely to be similar by the end of 2017. However, there are still over 100 companies outside the top 10 making solar cells today, with most in China. Many of these companies are only providing cells being used in modules that get shipped within China to its domestic market.

The dominance of p-type multi

Figure 2 shows the split of cell technologies produced in 2016, and reveals how resilient p-type multi has been in the past few years. The major changes have occurred by moving both p-type mono and p-type multi to advanced cell designs, reducing the percentage produced from the standard cell designs (full aluminium back surface field). This has been driving efficiencies higher, and is discussed below in the article in more detail.

In addition to the China end-market and domestic-production issues already mentioned, the other reason p-type multi has remained dominant is the utility segment of end markets globally. Utility-scale solar is the big driver for most of the leading end markets, and this segment has traditionally chosen p-type multi as the preferred module technology. In recent years, p-type multi has retained dominance with an increased move from 60 to 72-cell module configurations.

The main question from Figure 2 relates to the forecasting for 2017 and 2018 that shows p-type mono gaining market share. This is something that may change, however, if the leading multi wafer suppliers can continue to drive costs down, in particular through moving to diamond wire saw cutting. Coupled with creating black silicon texturing on the front surface of multi cells and adding PERC, this would certainly keep p-type multi as highly competitive in the market, potentially with a greater market share than shown in the forecast period.

Module power ratings from 60 and 72-cell designs

The easiest way to view the improvements from cell production is to look at the average power ratings from modules at standard test conditions (STC). This is shown in Figure 3 for p-type multi and Figure 4 for p-type mono.

The figures show the two key changes for cell technology in the past three to four years: the increase from three-busbar designs to four or five today; and the addition of PERC. Adding busbars to increase the efficiency has been the most common route for all cell manufacturers, with some often combining the busbar upgrades at the same time as moving lines for PERC.

Figure 3 shows the module power increases for 72-cell p-type multi. In 2013, the typical average module power was approximately 300W. By 2018, the five-busbar PERC versions are likely to be at the 350W level.

For mono, the graphic shown in Figure 4 is for the 60-cell design that remains popular in many rooftop installations, both residential and commercial. In addition to adding PERC and busbars, mono has also benefitted from the increased supply of larger wafer sizes from 156.0mm (M0) to 156.75mm (M2). In fact, M2-size wafers are also now coming through for multi. The efficiency gap between standard mono cells with three busbars on M0 wafers, and the top-performing mono PERC cells with five busbars on M2 wafers is significant and translates to premium module pricing in the market today.

Changes in manufacturing locations

During the past few years, cell and module manufacturing has increased across Southeast Asia, and in particular in Vietnam and Thailand. Alongside Malaysia, these are the three preferred countries today for many of the cells and modules that end up in the European and US markets. This has arisen largely due to the import tariffs introduced in these two regions in the past few years, and will likely remain a key factor in further expansions by leading cell producers in the next two to three years.

Figure 5 shows the geographic breakdown of capex by the PV industry. This covers the entire value chain from polysilicon to modules, but is most heavily influenced by the cell and module stages currently.

Capex remains one of the leading indicators in the industry today, both at the company level and for consolidated manufacturing trends. Tracking and forecasting capex allows visibility into changes 12-18 months out, including technology.

China still dominates overall PV capex, with maintenance spending and line upgrades alone more than most other country's total PV capex figures. In the past few years, there has also been a huge amount of new cell and module capacity added, often by companies only supplying to the China end market and using only Chinese-produced production equipment.

The graph shows the emergence of India, Thailand and Vietnam as new locations for PV manufacturing, with Thailand and Vietnam key regions for OEM supply. Spending on PV manufacturing in the US and Europe remains low, with the occasional module assembly plant being announced these days. The industry is awaiting the outcome of SolarCity's Silevo plans for a gigawatt-level cell and module facility, which would obviously be the most significant development for US PV manufacturing for many years.

Contract manufacturing returns

The PV industry has always seen strong outsourcing, where cells and modules are routinely made by third-party companies, either through spot-market buying or pre-arranged contracts. On the module side, there have been a few global contract manufacturers that had created solar factories to move into this area. These were located in Europe, North America and Southeast Asia.

In recent years, driven mainly by the restrictions on Chinese and Taiwanese cells to Europe and the US, there has been

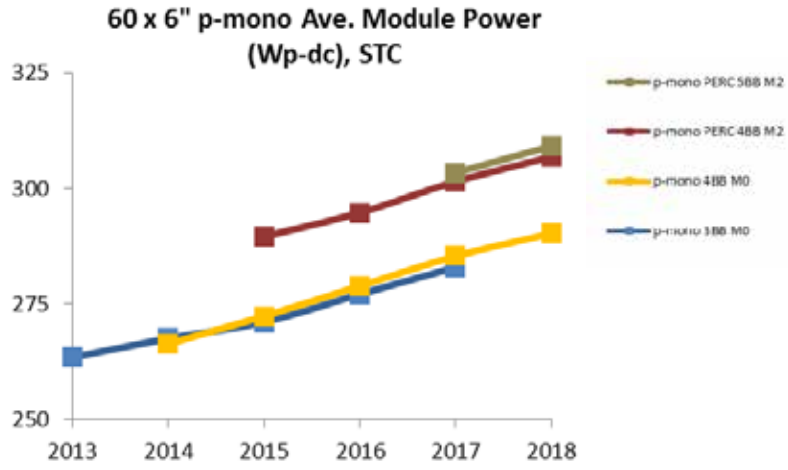

Figure 4. 60-cell arrangements remain common for p-type mono modules, especially for rooftop or space-constrained applications.

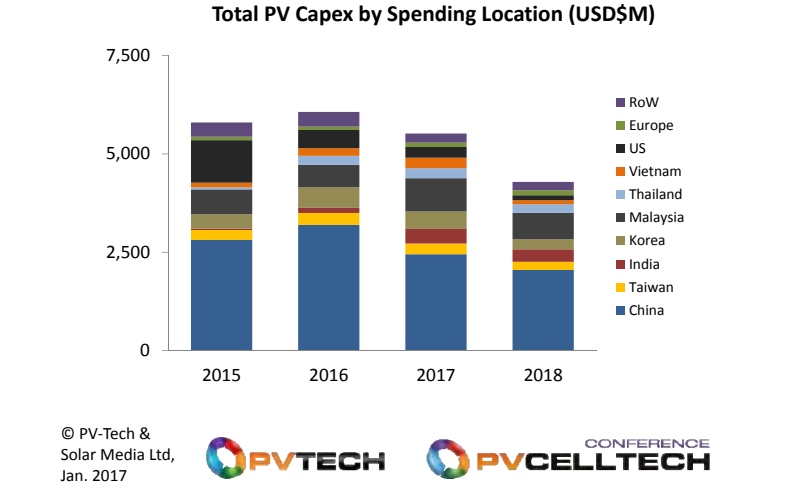

Figure 5. PV capex is now seeing stronger contributions from India, Thailand and Vietnam, with new capacity for both cells and modules still coming online in 2017.

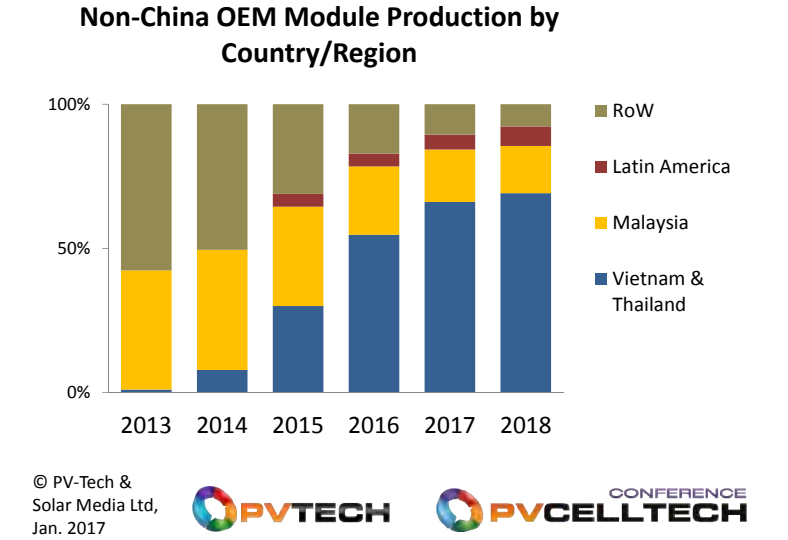

Figure 6. Vietnam and Thailand have now become the leading countries, outside China, for outsourced OEM or contract manufacturing of cells and modules.

a strong uptick in OEM manufacturing from PV-specific companies in Southeast Asia, especially Thailand and Vietnam. Some of these companies would appear to be financed and operated from mainland China, and end up doing cell and module production for branded modules being shipped to Europe and the US.

Figure 6 shows the changes in OEM contract manufacturing in the industry over the past few years, with mainland China companies excluded from the analysis. In the graphic, Vietnam and Thailand are grouped together, to emphasize the market changes expected to continue to the end of 2018 also.

Summary

Many of the issues that will impact PV technology in 2017 would appear to be the same ones as 2016, with the question of supply and demand to the Chinese end market being the most important. Cell efficiencies will continue to increase, with wafer size, busbars and PERC being the drivers to having the most competitive modules. The debate will likely focus on how much multi capacity is converted to black silicon variants, and what production equipment is finally chosen as the industry standard.

India is likely also to become a stronger contributor to cell manufacturing, with most of attention being on Adani when the full cell capacity is ramped up. Vietnam and Thailand may well slow down however, due to the volume of cell and module capacity located in Southeast Asia.

Finally, from a technology perspective, n-type is likely to be in a stronger position by the end of 2018, due to SunPower's upgrades to its higher efficiency platform, and new capacity from other companies in China such as Jolywood. There continues to be strong investments into n-type manufacturing, and this is probably the one factor that remains the largest threat to the p-type industry as a whole today.

About the Author

Finlay Colville is Head of Market Research at Solar Media Ltd, also the publisher of *PV Tech* and *Photovoltaics International*. Prior to this, Dr. Colville was Head of Solar at NPD Solarbuzz between 2010 and 2014. As the leading market analyst tracking PV manufacturing, technology and equipment spending trends, Dr. Colville has been active in the solar industry for more than a decade. Prior to NPD Solarbuzz, he held various senior sales and marketing positions at leading capital equipment supplier, Coherent Inc.