R&D spending analysis of top PV module manufacturers in 2014

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ABSTRACT
R&D expenditure by major PV module manufacturers showed a remarkable turnaround in 2014. Previous reports had noted, especially in 2013, that R&D spending had not been immune to the PV industry's period of profitless prosperity and was deemed a discretionary spend by the majority of leading producers. A return to profitability for many in 2014 resulted in a year of new record spending. There was record spending from 11 of the 12 companies covered, with Hanwha Q CELLS' spending actually declining in 2014.

R&D spending patterns

The R&D expenditure in 2014 of 12 major Tier-1 PV module manufacturers that were historically tracked increased by almost US$100m from the previous year, to reach US$512.75m. Such is the rebound in spending that the total 2014 spend is at a new historical high, surpassing the previous historical high of US$510.4m set in 2011.

"The total 2014 spend is at a new historical high."

Dedicated crystalline silicon-related R&D spending (see Fig. 2) would have missed setting a new record by the slimmest of margins if there had not been a small contribution from First Solar's monocrystalline-based TetraSun. Without TetraSun's contribution, c-Si spending would have been US$368.85m, compared with US$369.9m in 2011; however, with TetraSun's contribution, the spending on crystalline R&D topped US$373.95m, another new record set in 2014.

The overall increase in spending in 2014 has also led to a breakout of several companies that have historically spent less than US$20m annually and had formed the largest cluster of companies in the analysis (by expenditure) since 2007. Notably, JA Solar and Trina Solar moved from the sub-US$20m annual spending cluster to the sub-US$40m cluster, which also includes SolarWorld.

On the basis of the trajectory of spending in 2014 (see Fig. 3), several companies (Jinko Solar and Wuxi Suntech) could also exit the lowest spending cluster in 2015, leaving (without drastic spending behaviour change) just Canadian Solar and Hanwha Q CELLS (formerly Hanwha SolarOne) in the sub-US$20m category.

Although the spending by REC Solar increased considerably in 2014, compared with the previous year, its acquisition by Chinese-owned Bluestar Elkem Investment in May 2015 has resulted in the company going private; it is therefore highly doubtful that it will be possible to continue tracking REC Solar's R&D spending behaviour. Several PV module manufacturers are currently being evaluated in order to backdate and start to include them in the 2015 analysis and beyond.

The increase in spending has also meant the sub-US$60m category holds only one company, ReneSola, in 2014, compared with three companies (ReneSola, SunPower, Yingli Green) in 2013. However, the sharp increase in spending by Yingli Green means it has elevated itself into the heights of the sub-US$100m category. Interestingly, only one other company, First Solar in 2010, has ever spent US$90m on R&D in any given year; indeed, the gap between First Solar and any rival covered remained relatively stable between 2010 and 2013. The increase in spending by Yingli Green and SunPower means that this is the first time since 2010 that the gap with First Solar has visually closed.

R&D staffing patterns

In line with the increase in spending, the number of employees designated to R&D activities has also gone up, as Fig. 4 shows. Having reached a headcount peak in 2011 of 3,575, R&D headcount numbers among the companies covered declined overall to 2,911 in 2013. Nine companies, however, increased R&D headcount in significantly varying degrees in 2014, while two companies (Hanwha Q Cells and SolarWorld) had very slight declines.

"In line with the increase in spending, the number of employees designated to R&D activities has also gone up."

Source: Hanwha Q CELLS.

Figure 1. R&D spending by some of the leading module producers bounced back in 2014 after two years of decline.

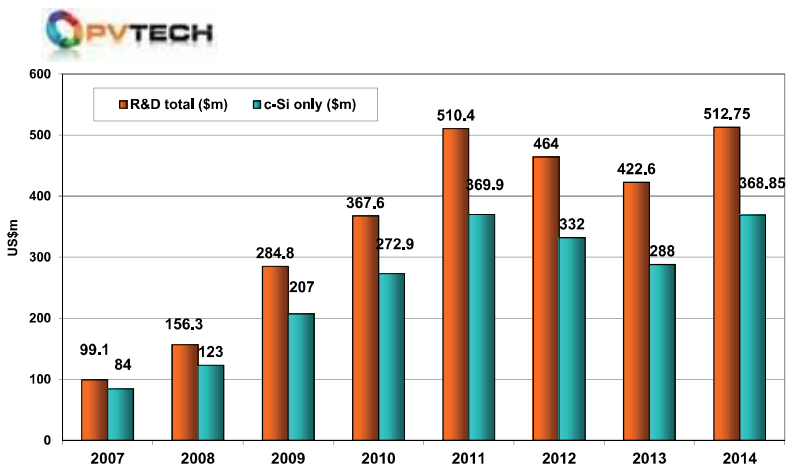

Figure 2. Key 12 PV module manufacturers' combined R&D spending (US$m).

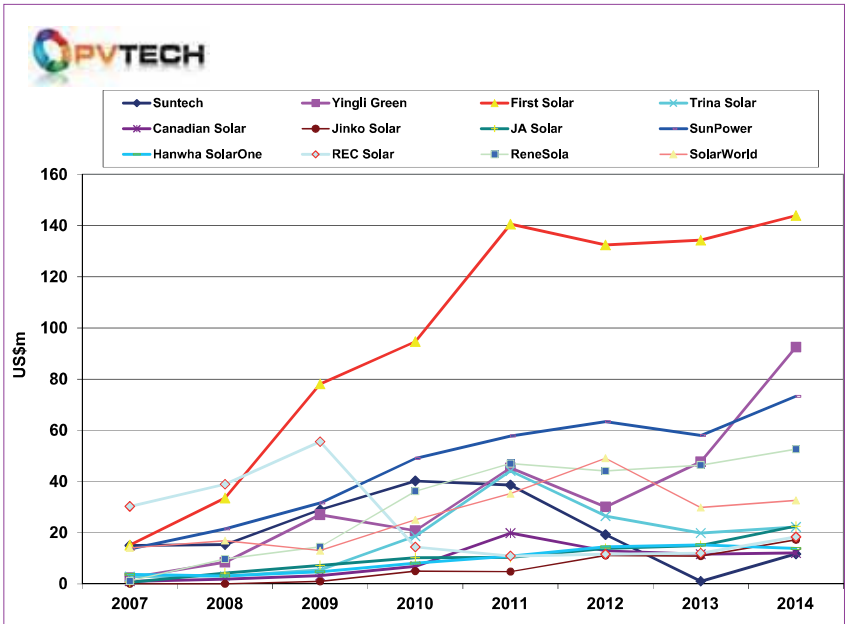

Figure 3. Key 12 PV module manufacturers' annual R&D spending (US$m).

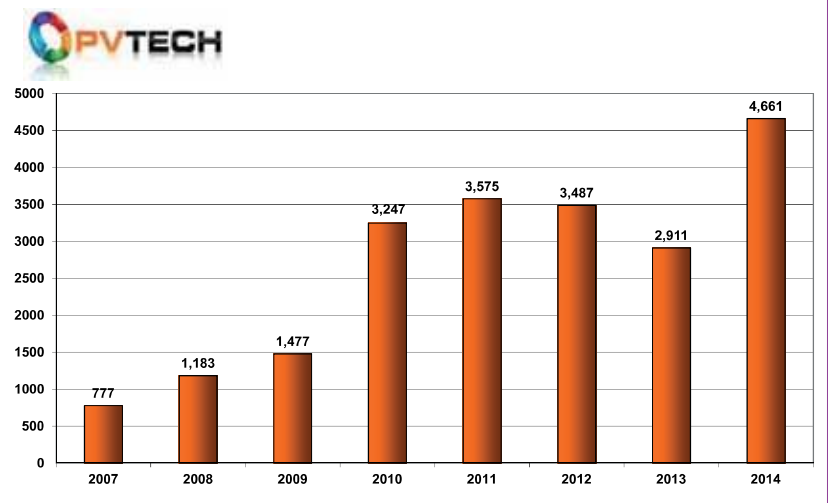

Figure 4. Key 12 R&D-spending PV module manufacturers' combined R&D headcount.

There is, however, an anomaly in these figures (see Fig. 5). Glaringly, Trina Solar has increased designated employees in R&D activities by around 1,398, bringing its total of R&D personnel to a massive 1,954. The company has confirmed the accuracy of this change, noting that a shift in its lab-to-fab approach had meant that those operating its pilot production line (called 'Golden Line' and housed in its State Key Laboratory Testing Center), as well as those carrying out traditional R&D activities, were categorized as R&D personnel. However, Trina Solar also confirmed that traditional R&D activities had retained staffing levels in line with 2013, which totalled 556.

A similar change took place at Yingli Green in 2010, with subsequent increases in R&D personnel through 2012. R&D personnel figures, however, have remained static for the last two years and reflect the company's lack of new capacity expansions. The company also has a State Key Laboratory of PV Technology, which has the same special status as the State Key Laboratory of Trina Solar.

Without the Trina Solar reclassification, the headcount figure would have been 3,263, still a decent increase from 2,911 in 2013. With Trina Solar and Yingli Green reclassifying a large number of manufacturing staff to R&D activities, not surprisingly both companies lead the pack in relation to R&D headcounts.

If R&D headcount figures from both these companies are excluded, however, JA Solar has shown the biggest increase in 2014, taking its R&D headcount to 290, up from 139 in 2013. JA Solar has also been one of the few companies covered that has incrementally added R&D staff since 2010, avoiding (unlike others) the temptation to trim staffing levels in 2012 and 2013.

ReneSola may not be adding new manufacturing capacity in 2015 but it has ramped up its R&D headcount in 2014. The company has both PV inverter and LED operations, which could partly explain the increase in headcount.

Also of note is SunPower, which is one of the few companies to have incrementally added R&D staff from 2007 onwards. In 2014 SunPower increased its R&D headcount from 300 to 337, ranking the company third behind Trina Solar and Yingli Green.

R&D spending rankings and analysis

Once again, First Solar led the pack in outright R&D spending in 2014 (Table 1). The CdTe thin-film firm has now

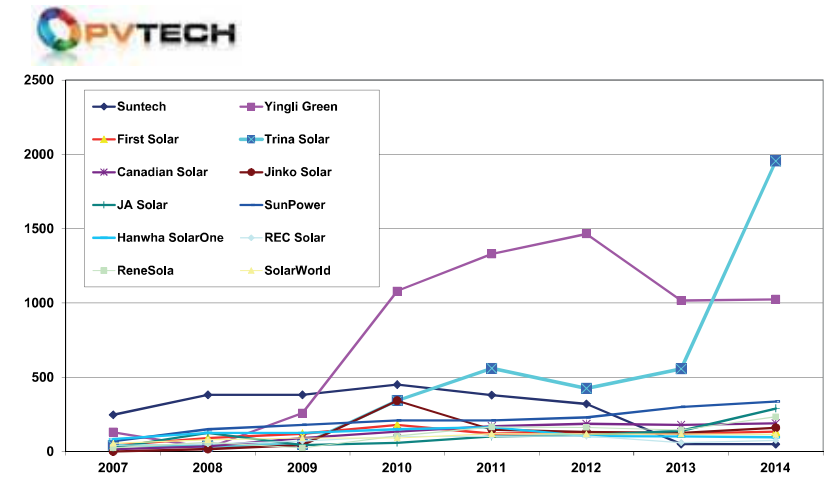

Figure 5. Key 12 PV module manufacturers' R&D headcount by company.

2011	2012	2013	2014	Ranking
First Solar	First Solar	First Solar	First Solar	1
SunPower	SolarWorld	SunPower	Yingli Green	2
REC	SunPower	SolarWorld	SunPower	3
ReneSola	ReneSola	Yingli Green	ReneSola	4
Yingli Green	REC	ReneSola	SolarWorld	5
Trina Solar	Yingli Green	Trina Solar	JA Solar	6
Suntech	Trina Solar	Hanwha Q CELLS	Trina Solar	7
SolarWorld	Suntech	JA Solar	REC Solar	8
Canadian Solar	Hanwha Q CELLS	Canadian Solar	Jinko Solar	9
Hanwha Q CELLS	JA Solar	REC Solar	Hanwha Q CELLS	10
JA Solar	Canadian Solar	Jinko Solar	Canadian Solar	11
Jinko Solar	Jinko Solar	Suntech	Suntech	12

Table 1. Top-ranked R&D spenders in 2014.

been ranked first for six consecutive years.

First Solar

First Solar allocated US$143.9m to R&D activities in 2014, up from US$134.3m in the previous year. Although the company splits spending between manufacturing and downstream modular power plant developments, there has been more emphasis in the last two years on thin-film module efficiency gains and line throughput increases in addition to its initial ramp-up at TetraSun.

The perennial heavy spending on R&D can be partly explained by the proprietary nature of its CdTe production equipment and processes; however, the benefit of acquiring GE's CdTe technology IP and co-development work has really started to pay back in module efficiency gains.

First Solar said in June 2015 that it had surpassed multicrystalline module conversion efficiencies for the first time, with its CdTe module efficiency achieving a record 18.6% and corresponded to the company's eighth major update since 2011. At the beginning of 2015, First Solar reported a research cell with a conversion efficiency of 21.5%.

Yingli Green

One of the big movers in ranking in 2014 was Yingli Green. The company was ranked fourth in 2013, spending US$47.7m on R&D; in 2014, however, Yingli Green increased spending to US$92.5m, catapulting it ahead of SunPower and SolarWorld.

Yingli Green has both multicrystalline and monocrystalline technology roadmaps that are designed to meet production average efficiency targets in 2020 of 19% and 23% respectively. The company is aiming to narrow the gap between lab results and actual volume production, with only a 1% difference in multi and mono technologies by 2020.

By the end of 2014, Yingli Green said it had achieved an average cell conversion efficiency rate of 19.8% for its monocrystalline PANDA cell on its commercial production lines, and a record cell conversion efficiency rate of 21.2% on its PANDA trial line. The company is also adopting ion implantation for its PANDA cells in 2015.

SunPower

Although SunPower significantly increased its R&D spending in 2014 to US$73.3m, up from US$58m in the previous year, it dropped one ranking position to third, because of Yingli Green's spending splurge. SunPower has persistently been ranked either second or third since 2008, underlining that proprietary technology requires additional investment as compared to standard mono or multi cell technology.

Being a major downstream PV project developer, SunPower also splits R&D activities, but it has also been developing its low-concentration CPV technology in recent years. The main focus, however, remains on the next-generation Maxeon cell, which is being ramped up at its dedicated cell plant in the Philippines

The company attributed a US$10.3m increase in R&D spending to the additional headcount and salary-related expenses in 2014. It also noted that some of the extra labour costs were also associated with consulting services in relation to its next-generation cell technology.

SunPower expects to achieve production module efficiencies of 23% in 2015 using a simplified, and therefore lower-cost, manufacturing process, while the company reported that it had produced its first solar cells with over 25% cell efficiency in the lab in 2014.

ReneSola

Up one ranking position from fifth to fourth was ReneSola, spending US$52.6m in R&D in 2014, up from US$46.4m in 2013. A special focus for the company has been improving its wafer quality, production cost reductions and yield improvements across both multi and mono wafer production. ReneSola has achieved a conversion efficiency rate of 17.8% on its A+++ wafer-based multicrystalline solar cells, as well as reporting monocrystalline solar cell efficiencies of 19.2% at the end of 2014.

SolarWorld

Two companies dropped two ranking positions in 2014 – SolarWorld and Canadian Solar. SolarWorld was ranked third behind First Solar and SunPower in 2013, but the increased spending

by Yingli Green and ReneSola in 2014 negatively impacted SolarWorld's ranking position, as did the fact that the company only increased spending from US$29.8m in 2013 to US$32.6m in 2014.

Understandably, SolarWorld went through a major restructuring phase in 2014 and has not yet returned its R&D spending to the peak level of US$49.1m seen in 2012, when the company was ranked second. Interestingly, SolarWorld has had one of the most volatile R&D spending behaviours among the companies covered in this report, and since 2007 has occupied all positions from a lowest of eighth to a highest of second.

The company has focused on developing and migrating to PERC cell technology and migrating some of its production to five-busbar technology. With this technology, it has claimed to have achieved a cell efficiency of 21.51% on its crystalline p-type based wafer.

SolarWorld has also been involved with several EU-funded projects in recent years, to improve the cost competitiveness of monocrystalline wafer production.

JA Solar

JA Solar achieved its highest ranking position in 2014, having increased R&D expenditure from US$15m in 2013 to US$22.5m in 2014. It was ranked sixth, climbing two ranking positions from the previous year.

The company reported late in 2014 that it had achieved multicrystalline module efficiencies of 17.2%, generating 280W in a standard 60-cell format. Its p-type monocrystalline solar cells (PERCIUM) had also surpassed a conversion efficiency of 20.5% in late 2014. The company's high-performance multicrystalline RIECIUM series cell was reported to yield a conversion efficiency of over 18.8%.

JA Solar is continuing to develop cells using metal wrap-through (MWT) technology and n-type cell technology.

Trina Solar

The leading global PV manufacturer (by module shipments) in 2014 was Trina Solar, having surpassed Yingli Green. However, in terms of R&D spending, Trina Solar lost ground on that company, with a spending of US$22.2m, compared with US$19.9m in 2013. As a result of relatively low R&D spending and only a small incremental increase in 2014, Trina Solar was ranked seventh, down one position as JA Solar ramped up spending at a higher rate.

Despite the level of R&D spending, Trina Solar demonstrated some significant developments in 2014. The company announced that its Honey Plus modules were using multicrystalline PERC cell technology, with cell efficiencies said to be 18.7% on initial volume-production levels. It also said that its Honey M Plus monocrystalline module would have average power outputs of 285W and average cell efficiencies of 20.4%. The company also noted that its PERC cell technology for the Honey modules would also use an advanced five-busbar front-side contact for lower overall series resistance. At year-end Trina Solar announced that its Honey Plus p-type PERC cell had achieved an efficiency of 20.76%, independently confirmed by Fraunhofer ISE CalLab in Germany.

Trina Solar claimed to have set four new world records in 2014 for p-type PERC cells and modules. These include new records for large-area (156mm × 156mm) p-type silicon substrates, of 21.40% for monocrystalline and 20.76% for multicrystalline silicon solar cells, as well as new peak power output records for commercial PV modules, of 335.2Wp for monocrystalline and 324.5Wp for multicrystalline silicon solar cells.

REC Solar

A strong mover in 2014 was REC Solar, as its R&D spending increased from US$12m in 2013 to US$18.4m in 2014, propelling the company to eighth place, up two ranking positions from the

previous year. This is also the first time since 2008 that REC Solar's ranking has not declined. When it was leading the field, the company was spending on fluidized bed reactor (FBR) technology for polysilicon production. The company split its polysilicon business and became a pure-play integrated PV module manufacturer in 2013, which explains its current ranking and R&D spending behaviour.

REC Solar focused on technology developments in ingot/wafering in 2014, with the aim of reducing wafer cost and significantly increasing cell efficiencies. The company had also been working on migrating lines to PERC, with several lines coming on stream in the first quarter of 2015.

The company has also developed and qualified a four-busbar cell technology and half-cut cell technology. Future-technology research work has been centred on low-cost and high-efficiency processes using monocrystalline wafers. Solar cell efficiencies in excess of 20% have been achieved, according to the company.

Jinko Solar

One of the big surprises in 2014 was the fact that Jinko Solar significantly increased R&D spending, attaining a new annual expenditure record that coincided with average solar cell efficiencies also reaching new heights. The company had been a laggard among its major rivals in R&D expenditure since the company started production and was only beaten to the bottom-ranked position within the 2013 analysis by Suntech because of the latter's bankruptcy. In 2014, R&D spending topped US$17.2m, up 62.8% from US$10.8m in the previous year.

Part of the significant increase in R&D expenditure was the increase in the number of employees dedicated to R&D activities: personnel had been cut to 125 in 2013 but expanded to 160 in 2014. Jinko Solar's peak R&D headcount occurred in 2010, when R&D staffing levels topped 342.

The company reported that the average conversion efficiency rate of its monocrystalline cells had increased to 19.6% by the end of 2014, up significantly by 100 basis points from 18.6% at the end of 2013. This is significant for the company, as its average monocrystalline cell efficiencies had been stagnant since 2012.

In contrast, Jinko Solar had only achieved minor incremental efficiency gains with its multicrystalline solar cells, taking average cell efficiencies from 17.6% in 2012 to 18.2% by the end of 2014. The company may be able to boost multicrystalline cell efficiencies at a faster pace in 2015, as a result of plans to add 450MW of high-efficiency PERC capacity at its new production plant in Malaysia.

The company has also recently announced a strategic collaboration agreement with DuPont for the implementation of next-generation metallization pastes, using DuPont's PERC-specific Solamet PV19x series pastes.

> "First Solar led the pack in outright R&D spending in 2014."

Hanwha Q CELLS

The only company to reduce R&D spending in 2014 was Hanwha Q CELLS, formerly Hanwha SolarOne before officially merging with sister company, Hanwha Q CELLS, in the first quarter of 2015. Hanwha SolarOne had spent US$15.2m in 2013, but its R&D spending fell to US$13.8m in 2014, causing the company to drop three ranking positions to tenth place; this was also the biggest drop among the companies covered in this analysis.

It is unclear why the company cut R&D spending in 2014, although the planned Hanwha Q CELLS merger may have been a factor because of Q CELLS' well-known R&D activities in Germany, which have in recent years been supporting Hanwha SolarOne's cell and module efficiency improvements. Q CELLS had not been public since its acquisition by Hanwha in 2012 and therefore R&D spending figures are not publicly available.

With the merger undertaken there is a strong probability, especially with plans to migrate to PERC technology, that R&D spending from the combined entities will increase significantly in 2015. Q CELLS' former R&D facility and personnel are also being retained after the merger and are included in a total of 350 personnel being retained at Hanwha Q CELLS in Germany.

At the end of 2014, Hanwha SolarOne's multicrystalline cells had achieved a conversion efficiency rate of 17.7%; however, Q CELLS' mono PERC cells had conversion efficiencies of 19.5%, and traditional BSF multi cells had conversion efficiencies of 18.8%.

Canadian Solar

Although the spotlight has been on Jinko Solar as a laggard in R&D spending, major PV manufacturer Canadian Solar has historically tracked along the bottom with Jinko Solar. Canadian Solar allocated only US$12.05m to R&D activities in 2014, up slightly from US$11.6m the previous year. With both REC Solar and Jinko Solar reporting a greater increase in R&D spending in 2014 than Canadian Solar, the latter fell two ranking places to eleventh.

Canadian Solar has historically focused on in-house cell technology advances, which could explain its persistent laggard status, yet the company has still achieved an increase in cell efficiency of 0.5% abs. per year over the past five years. However, it has also developed PERC cell technology in this time frame, which is associated with many other companies raising R&D spending in recent years.

Putting its R&D expenditure levels in perspective, Canadian Solar had full-year 2014 revenue of almost US$3bn and was the third-largest PV manufacturer (by module shipments) last year. The company also has ongoing initiatives in relation to n-type bifacial cells, with efficiency targeted at exceeding 22% by 2017; this is in addition to work on heterojunction cells and IBC cells, but R&D spending certainly seems at the moment to be spread thinly across many projects.

At the end of 2014, Canadian Solar's multicrystalline cells had achieved conversion efficiencies of 18%. The company is also planning to enter production with its ONYX (black silicon) cells with initial efficiencies of 18.31% in the first quarter of 2015. Later in the year, Canadian Solar is proposing to enter production with its ONYX II PERC cell, which is claimed to yield efficiencies of around 19%.

Wuxi Suntech

The good news for bottom-ranked Wuxi Suntech, since its acquisition by Shunfeng, has been the relaunch of R&D activities after its former bankruptcy. Suntech spent US$11.7m on R&D expenditure in 2014, up from US$2.2m in 2013.

Wuxi Suntech is expected to spend around US$16m in 2015. The migration to PERC cell technology is ongoing and the company recently launched its multicrystalline p-type SuperPoly module, said to also integrate an in-depth reflection technology and passivation process, yielding module efficiency rates of up to 16.7%.

Conclusion

R&D spending reached a new record high in 2014, fuelled by cell technology developments, primarily centred around PERC. This was supported by a record number of R&D personnel employed and a shake-up in the rankings, though First Solar remained ahead of the pack.