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ESTIMATE OF ECONOMIC BENEFITS TO AUSTRALIA OF PAST AUSTRALIAN PHOTOVOLTAIC RESEARCH

Summary

Past Australian photovoltaic (PV) research has disproportionately impacted the development of the global PV industry, with the flow-on benefits to Australia estimated as well over $8 billion.

The highest impact outcome of past Australian PV research likely arises from the training of Australian researchers and engineers responsible for the founding and explosive growth of the PV industry in China. Without this, the dramatic global reduction in PV prices seen over recent years would have being delayed by at least three years and possibly indefinitely. Flow-on benefits to Australia arise from both direct contributions to national wealth and also from the societal benefits of the earlier local deployment of substantial PV capacity than otherwise would have occurred.

One significant $1.4bn contribution to national wealth is estimated from the realization of the value of shareholdings and options, in what became billion dollar companies, held by the dozen or so Australians key to the founding and development of the Chinese PV manufacturing industry.

PV uptake in Australia during 2013-2015 was accelerated well beyond even 2012 estimates due to substantial PV module cost reductions arising from the explosive Chinese growth. At end-2015, Australia had approximately 5GW installed PV capacity. An estimated 2.4GW was installed pre-2013 under premium feed-in tariff schemes with a "bonus" 2.6GW subsequently installed largely unsubsidized (apart from certificate issues for imputed CO_2 emission credits). The net societal benefits arising from the value of the electricity generated by this bonus 2.6GW minus its cost, plus from the reduction of CO_2 emissions, from the health benefits due to avoided SO_2, NO_x and fine particulate material emissions and from reduced electricity distribution losses are estimated as in the range of $5.5 billion to $11.8 billion, depending on the value assigned to reduced CO_2 emissions. An additional $1.5bn impact is due to GST and tax payments, plus unemployment benefit savings.

A second major contribution of Australian research has been the development of the high efficiency PERC cell presently becoming the industry mainstream. Benefits in terms of Australian savings in "balance of system costs", such as the costs of installing these systems due to the smaller areas required, are estimated as $0.75bn over the 2018-2028 period.

1. Establishment of PV Manufacturing in China

Prior to the formation of the Chinese-Australian joint venture Suntech in 2001, prospects for PV in China were bleak [1-4]. China has been described as *"lacking all the factors representing necessary resources and opportunity"* [3], the PV ecosystem as *"rudimentary"* [3], and the technological level of existing state-owned enterprises (SOEs) that had been fabricating small quantities of PV during the 1990s as "*far below international standards*" [1,4]. Reflecting the bleakness of the PV outlook in China, the 2000 IEA World Energy Outlook predicted a total installed Chinese PV capacity of less than 0.1GW (sic!) by 2020 [5]. The Chinese government was also unaware of the potential until well past the critical stages of development, suggesting in September 2007 a slightly more upbeat target for 2020 of 1.8GW [6] (the present official target has been recently updated to 150GW).

Suntech provided the spark that completely changed this outlook (Fig. 1). By 2010, most of the world's PV manufacturing had shifted to China along with the associated supply chain. The financing of this turnaround was almost entirely through capital and debt finance raised on the US stock exchanges (over US $7 billion involved), a funding approach pioneered by Suntech with outstanding success.

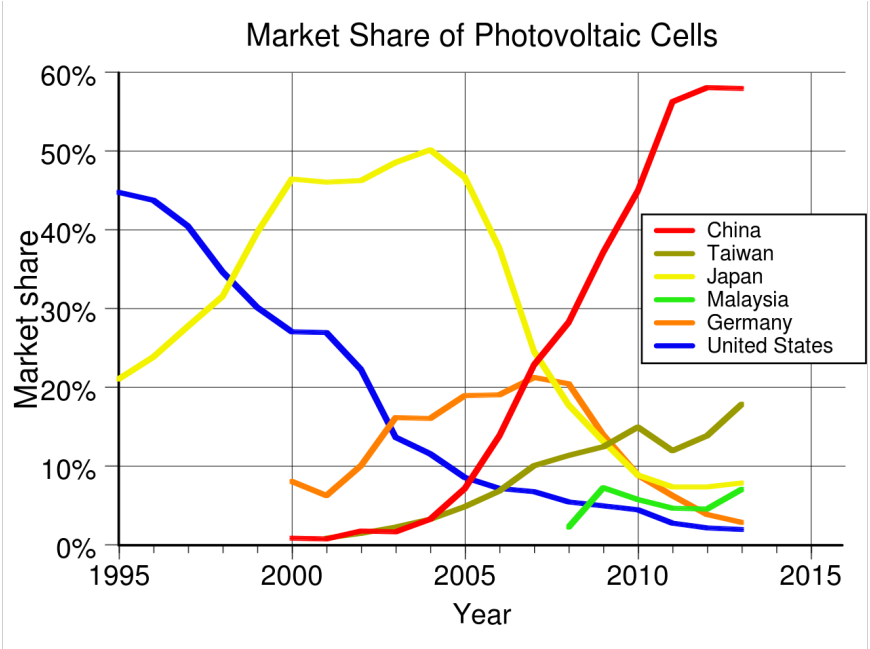

Figure 1: PV industry transformation from 2005-2010 [Wikipedia Commons].

Recent publications highlight and more fully document Suntech's seminal role [2,3,7]. Suntech is identified as the "root firm" in the development of the Chinese PV industry, providing the same critical spark as Fairchild provided in the development of Silicon Valley and the Olds Motor Works in the development of the Detroit motor industry [3].

Dr Zhengrong Shi, who obtained his training and PhD in photovoltaics from UNSW and his subsequent management experience as Deputy Research Director of UNSW spin-off Pacific Solar, was the driving force behind Suntech. He played a seminal role in the critical steps of obtaining funding to initiate the company in 2001 and then much more substantial US funding in 2005 to finance its growth, in building up local infrastructure to support the on-going development of the Chinese industry from 2002, in opening up European markets in 2003 for Chinese PV products and in establishing the quality of Chinese product as equal to premium European products [3]. These initiatives, along with Suntech's often involuntary role as the source of the spin-offs that provided the critical mass for Chinese-based manufacturing to flourish completes the analogy with the other historically significant transitions earlier noted [3].

Suntech founders were Zhengrong, together with his colleagues from Pacific Solar, Ted Szpitalak (formerly PV group, UNSW) and Dr Fengming Zhang (PhD Newcastle), Huaijin Yang (Master of Economics from Macquarie), all Australian citizens, and Chengrong Xu, a friend of Zhengrong's from Yangzhong [3]. The non-technical members of the team (Huaijin and Chengrong) assisted with the introductions required for the successful initial capital raising of US$6 million. Zhengrong initially owned 20% of the company, with 8 companies from the local Wuxi area earning the remaining 80% by contributing to this US$6 million [2,3].

Apart from Zhengrong, two other Australians played key roles in the initial success of Suntech, Prof. Stuart Wenham and Ted Szpitalak. Ted had been responsible for equipment procurement and commissioning for the UNSW solar laboratories since the early 1980s and, since 1995, had been seconded to UNSW spin-off Pacific Solar as Acquisitions Manager.

Ted ordered and commissioned the equipment for Suntech's first production line, in the process training Suntech staff in its maintenance and operation. Professor Wenham, who had set up Australia's first PV production line with similar technology, then made several 1-2 week visits to China, fine-tuning the processing sequence and training Suntech engineers in this sequence and in quality control [8]. UNSW software, the "Virtual Production Line", developed by Prof. Wenham and his PhD student, Dr Anna Bruce, was a key part of this training, helping to overcome language barriers and giving Suntech engineers a thorough understanding of the subtle processing interdependencies involved in solar cell manufacturing [8]. As a result of this expert input, Suntech was able to offer cells that were at least the equal of those being produced internationally.

The first line of 10MW nominal capacity was a success despite the small available budget, producing its first saleable cells in August 2002 (Fig.2) and becoming profitable by December 2002, producing 1MW of saleable cells during 2002. Profits from this line were used to finance the installation of a second 15MW line, where even greater attention was paid to minimizing capital outlays, made possible by the technical competence and confidence of the key players.

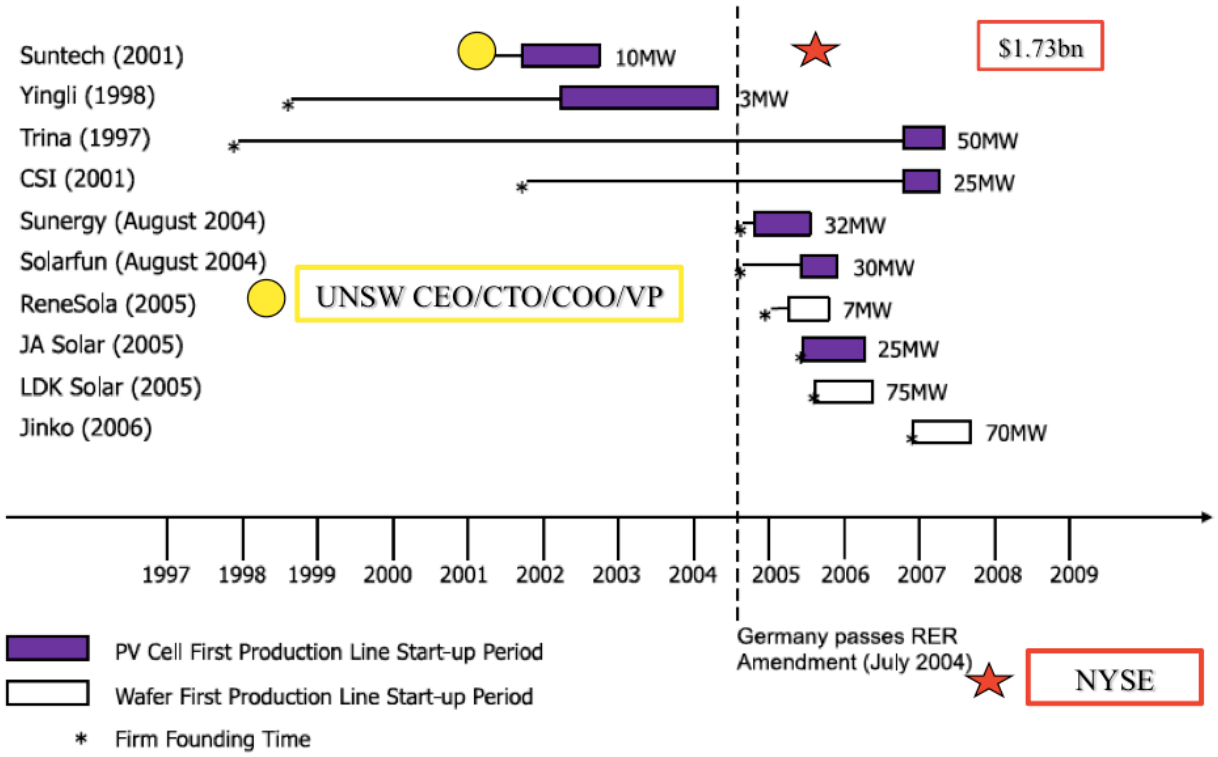

Figure 2: *Timeline for installation of production capabilities of China's top 10 manufacturers [2]. Additional information added is the commencement date for first involvement of a UNSW-trained scientist/engineer in a senior position (Founder, Chief Executive Officer (CEO), Chief Technical Officer (CTO), Chief Operating Officer (COO), Vice-President of Technology (VP)), in this case, at Suntech. The star represents the date of listing on a US exchange, in this case, the New York Stock Exchange (NYSE) on 14 December 2005. The dollar amount represents the total funds (US$) raised by the company through this exchange through share sales and senior convertible note issues.*

The next new line to come into operation in China after Suntech's was a small 3MW line at Yingli in March 2004 (Fig.2), planned as a demonstration line in 1998, but with construction *"stalled due to the uncertain domestic market and the weak policy prospects"* [2]. The line appears to have been based on the indigenous Chinese technology of the 1990s, with the engineer in charge being formerly with one of the SOEs. This gives an indication of how the Chinese industry might have struggled for international significance without the intervention of Suntech. Yingli commissioned its first competitive "turn-key" line in 2006, prior to the appointment of UNSW-trained Dr Guoxiao Yao as CTO in September 2006. Photon International [9] estimates Yingli cell production as 3MW in both 2004 and 2005, with Yingli reporting 37.02 MW cell production in 2006 from 60MW of capacity, 2 years after Suntech reached this production level (Table 1). This delay would undoubtedly have been longer without the Suntech example.

Table 1: Manufacturing capacity (actual production in brackets) in MW of Top-10 China-based manufacturers listed in Fig. 2 over the 2002-2007 period. Figures are taken from SEC filings [10] except where asterisked, when taken from Photon International [9] (figures in this case are often overestimates). Superscrript U indicates a company with UNSW-trained co-founders. Superscript S indicates a company founded by staff trained in UNSW co-founded companies. Superscript I indicates the year of company market listing (IPO).

Company	2002	2003	2004	2005	2006	2007
Suntech[U]	10 (0.9)	30 (6.4)	60 (29.5)	150 (67.7)[I]	270 (160.1)	540 (363.7)
Yingli	-	-	6 (3*)	6 (3*)	60 (37.0)	200 (145.5)[I]
Sunergy[U]	-	-	-	32 (4.4)	192 (46.4)[I]	192 (70.0)
Solarfun[S]	-	-	-	30 (1.0)	60 (26.2)	175 (132.9)[I]
JA Solar[U]	-	-	-	-	75 (26.3)[I]	240 (99.6)
CSI	-	-	-	-	-[I]	100 (40*)
Trina	-	-	-	-	-[I]	150 (28)

The next three companies after Suntech to set upon modern lines depended significantly on Australian expertise, with 2 of these commissioning internationally competitive lines prior to Yingli. In fact, the first of these, China Sunergy supplied over US$25m worth of cells to Yingli in 2006 while Yingli was awaiting the commissioning of a larger capacity line [10].

China Sunergy (CSUN) commenced in August 2004 as "Nanjing PV" with appreciable Australian equity (49% initially held by Australians) [10]. Ted Szpitalak, Dr Fengming Zhang and Huaijin Yang, Suntech founders, teamed up with another Australian-trained group consisting of Drs Jianhua Zhao and Aihua Wang, key players in the UNSW program producing the first 25% efficient silicon solar cells. Dr Zhao was to become Vice Chairman, President and Chief Scientist of China Sunergy, while Drs Wang and Zhang became Vice Presidents of Research and Development and of Manufacturing, respectively [10]. In a much better financed initiative than in the Suntech case, this team established the first 32MW line by December, 2005 with 5 more lines of this capacity following in 2006, giving the company a capacity of 192MW by end-2006, second in China only to Suntech (270MW), in terms of both capacity and production volume (Table 1) [10].

After establishing production at China Sunergy, Ted Szpitalak and Huaijin Yang formed another team with Dr Bruce Beilby and Dr Ximing Dai (both UNSW PhDs) to establish yet another production capability in China at JA Solar, established in May 2005 as a joint venture by the Jinglong Group, the Australia PV Science & Engineering Company (controlled by Dr Dai) and Australia Solar Energy Development Company (controlled by Ted), with the Australian groups holding 45% of the equity [10]. The first saleable output came from a 25MW line in April 2006,

with 2 more 25MW lines commissioned in October 2006, giving a total capacity of 75MW by year-end [10]. Huaijin Yang became CEO of JA Solar while Dr Dai became CTO, with both becoming Directors. Ted Szpitalak moved on to set up yet another cell production capability at Global Sunrise in Taiwan, a pioneer in successfully commercialising UNSW PERC cell technology.

Developing on a similar timeline to China Sunergy was Solarfun Power Holdings, also established in August 2004. This was what might be termed a "second-generation" beneficiary of UNSW expertise, highlighting the role of Suntech as the "root firm" in the growth of the Chinese PV industry [3]: *"In line with what may be described as an inherent part of the definition of a root firm, Suntech was a major source of spin-off entrepreneurs and experienced personnel, to the extent that it earned the nickname of the "West Point" of China's solar PV industry. Many of these first- and second-generation spin-offs would emerge as key players in the global solar PV industry. The first to leave were part of Suntech's founding team, who left just after Suntech launched its first production line and later started Sunergy ……. Wang Hanfei, the first professional manager hired by Suntech, moved to Solarfun and used his experience to help that firm launch its competing PV cell production line in seven months and list on NASDAQ just a year after Suntech. These spin-off entrepreneurs and their firms further benefited from the large pool of mid-level engineers and managers who gained training, experience and technical know-how at Suntech."*

Haifei Wang worked at Suntech from 2001-2004 and was Zhengrong's "2IC" in his role as Manufacturing Manager and Deputy Production General Manager. He had no prior training in PV, but developed his own expertise through exposure to the UNSW know-how involved in getting Suntech established. The offer to move to join Solarfun (established in August 2004) was too good to refuse. Haifeng was offered 12.5m shares in the new company (5.23% of post-IPO share ownership), valued at over US$31m at the initial offering price of $2.50/share [10]. Along with Yingli, Sunergy and JA Solar, Solarfun began producing reasonable quantities of cells in 2006, about 2 years behind Suntech, with UNSW-trained Fei Yun appointed as Director of Technology in September 2006, 3 months prior to the company's NASDAQ listing [10]. UNSW PhD graduate Dr Guangfu Zheng had been appointed sometime earlier as a Senior Researcher, with the two listed as key company resources on the Solarfun prospectus [10].

The other companies earning their position on the list of Fig. 2 through cell manufacturing, CSI and Trina, did not begin this cell manufacturing until 2007, subsequent to their listing in November and December of 2006, respectively [10]. Prior to listing, Trina appointed UNSW-trained Dr Mohan Narayanan as CTO. CSI made its first senior UNSW-trained appointment 6 years after listing, with the appointment of Guangchun Zhang as Chief Operating Officer in 2012. Prior to listing, both companies had been involved primarily in the technically less challenging, and much less capital intensive, PV module assembly [10].

2. Building Up Local Supply Chains

A key strategy followed by Suntech was the development of the local Chinese PV supply chain, realizing that the low costs available through this strategy would give the company a competitive edge internationally. The company's role in encouraging the manufacture of local furnaces, poly-silicon, silicon ingots and wafers and Al and Ag supply is described in great detail elsewhere [3].

3. Penetrating the German Market

From the start, Zhengrong was keen to establish an internationally competitive product, obtaining ISO 9001:2000 certification of Suntech's production in June 2002, followed by IEC61215 certification of its modules in June 2003 [2,3]. All 2002 module sales were in China [2,3,10]. Zhengrong began participating in trade shows in Germany from November 2002, securing the first sales of Chinese modules into Germany in 2003. A major development from such activities was the announcement in the SolarWorld 2004 Annual Report that SolarWorld had *"concluded a license agreement with Chinese solar manufacturer Suntech Power Inc. for the production of SolarWorld modules in China in the first quarter of 2005"*. A *"volume of around €100 m over the next two years"* was also mentioned [10]. Suntech's 2006 Annual Report Notes that 32.1% and 21.4% of total net income in 2005 and 2006 were attributable to its largest customer, elsewhere mentioned as SolarWorld [10]. On this basis, it can be concluded that over US$200 million worth of sales were made to SolarWorld over this period.

This endorsement of Suntech's product as equivalent to its own by one of the better-known German manufacturers undoubtedly contributed to Suntech's subsequent success in the German market and in its US listing and lent credibility to other Chinese product offerings. This opening up the German market for Chinese product by Suntech was crucial to the subsequent success of the PV manufacturing industry in China. Part of the success of penetrating the market can be attributed to Zhengrong's personal marketing and communication skills, with one of the largest German deals in 2004 concluded directly with the principal of the German firm involved, reportedly by a handshake over a glass of wine in a castle on the Rhine, a scenario hard to imagine with the CEOs of the other major Chinese manufacturers, largely not comfortable with communication in English.

4. US Stock Market Listing

From an interview reported elsewhere [7]:

CEO of Suntech: "*The company needed money. We had eight local shareholders. They didn't really want to put in more money at the time. We needed access to the capital market. There were*

some American banks and investors that had followed us for more than a year, which I didn't realize".

Interviewer: *"Who approached you with the idea of an IPO?"*

CEO of Suntech: *"Some financial experts. Goldman Sachs, Morgan Stanley."*

This overseas interest triggered what might be described as a management buy-out. A new set of international investors led by Goldman Sachs provided the funds to buy-out the original Wuxi investors at a handsome profit, with this buy-out assisted by the Wuxi government [3]. The US$6 million original investment was bought for US$80 million. Zhengrong emerged with a majority shareholding in the new company structure, described below [10]:

"To enable us to raise equity capital from investors outside of China, we established a holding company structure by incorporating Power Solar System Co., Ltd., or Suntech BVI, in the British Virgin Islands on January 11, 2005. Suntech BVI acquired all of the equity interests in Suntech China through a series of transactions that have been accounted for as a recapitalization. In anticipation of our initial public offering, we incorporated Suntech Power Holdings Co., Ltd., or Suntech, in the Cayman Islands as a listing vehicle on August 8, 2005. Suntech became our ultimate holding company when it issued shares to the existing shareholders of Suntech BVI on August 29, 2005 in exchange for all of the shares that these shareholders held in Suntech BVI. We conduct a significant portion of our operations through Suntech China."

Cayman Island registration is a common approach for allowing foreign companies to operate on US exchanges [11]. Zhengrong chose the New York Stock Exchange (NYSE) for listing, the first private Chinese company to be listed on this exchange. The listing was a huge success, reported as the largest technology float of 2005, raising $396.5m. The US financial companies supporting the listing made large profits. For example, Goldman Sachs held 10.8 million shares at listing purchased at US$2.31 per share [10], worth US$20.26/share after the first day of trading, corresponding to a minimum US$200 million profit. Zhengrong's shareholding had a value over US$1 billion, stimulating numerous press articles on the "first solar billionaire".

The success of the float had two consequences:

1. It encouraged other solar companies in China to follow the same path;
2. It encouraged US venture capitalists to aggressively seek out and groom Chinese companies to repeat Suntech's success. For candidate companies that did not already have a senior UNSW staff member involved, this grooming included encouraging the company to capture such involvement, helping to explain the large number of companies appointing UNSW CTOs in the period between the Suntech float and the candidate company's listing (e.g. Trina, Solarfun, Yingli and Jinko).

Not all these companies had anything like the technical or financial strength of Suntech at the time of listing but still did well. Both CSI and Trina raised circa US$100 million on listing a year after Suntech at the end of 2006, despite only having relatively limited sales and the technological capability only to make modules (not cells and modules) at the time of listing [10]. By lowering the barriers to entry through its success, Suntech opened the floodgates for massive US investments in the growth of the Chinese PV industry.

Table 2: Financing of "Top-10" China-based manufacturers on US Markets (2005-2010). All values in US dollars. Most of the financial data is from Ref. 12.

Company	Exchange	Date Senior UNSW Appointment	Date IPO	IPO Value (US$)	Date Follow-On Issue	Follow-On Value	Date Debt Issue	Completed Debt Amount	Total Funds Raised
Suntech	NYSE	Founders	14/12/2005	$396.5m	29/5/2009	$277m	12/2/2007	$500m	$1,748m
							17/3/2008	$575m	
CSI	NASDAQ	12/2012 (post IPO)	9/11/2006	$116m	7/11/2009	$103m	17/6/2008	$75m	$294m
Trina	NYSE	10/10/2006	19/12/2006	$98m	21/7/2008	$120m	21/7/2008	$138m	$680m
					17/8/2009	$149m			
					24/3/2010	$176m			
Solarfun	NASDAQ	9/2006	20/12/2006	$150m	29/1/2008	$135m	29/1/2008	$173m	$720m
					16/7/2008	$97m			
					12/11/2010	$166m			
JA Solar	NASDAQ	Founders	6/2/2007	$225m	11/10/2007	$266m	15/5/2008	$400m	$891m
Sunergy	NASDAQ	Founders	17/5/2007	$94m			1/7/2008	$54.5m	$148m
LDK	NYSE	10/2010 (post IPO)	31/5/2007	$469m	23/9/2008	$200m	14/4/2009	$400m	$1,424m
					1/2/2011	$164m	2/2/2011	$191m	
Yingli	NASDAQ	9/2006	8/6/2007	$319m	12/12/2007	$24m	12/12/2007	$150m	$720m
					23/6/2009	$227m			
Renesola	NYSE	-	29/1/2008	$130m	23/6/2008	$187m			$388m
					5/10/2009	$71m			
Jinko	NYSE	1/2010	13/5/2010	$64m	5/11/2010	$126m			$190m
TOTAL			IPO	$2,061m	Follow-On	$2,488m	Debt	$2,656m	$7,203m

The extent of this investment is over US$7 billion as documented above in Table 2 [12]. If the shares and options granted to company employees and subsequently sold on US markets are regarded as reimbursement for activities contributing to development of the Chinese industry, this could be regarded as further boosting this investment to circa US$10 billion. Figure 3 below is an updated version of Fig.2 summarising the additional information on UNSW involvement, listing dates and capital raisings.

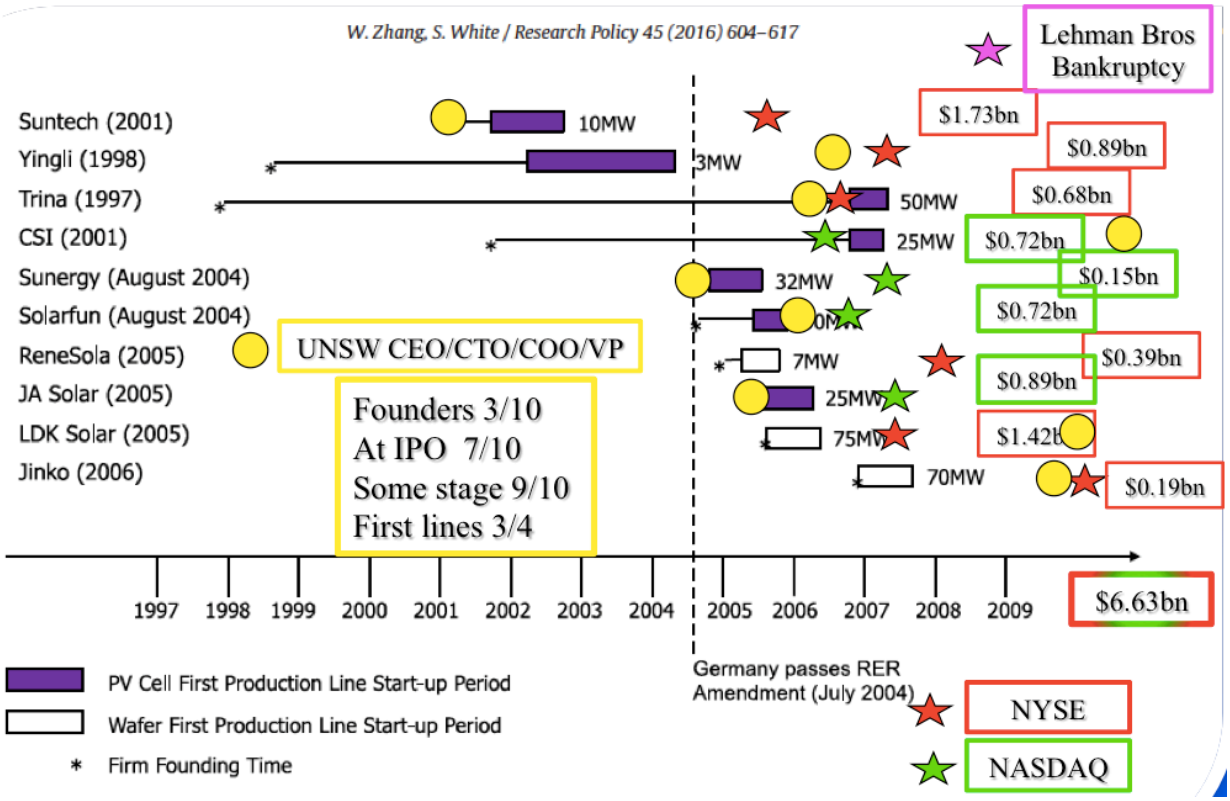

Figure 3: *Updated timeline for installation of production capabilities of China's top 10 manufacturers [2]. Additional information added is the commencement date for first involvement of a UNSW-trained scientist/engineer in a senior position. The star represents the date of listing on a US exchange. The dollar amount represents the total funds (US$) raised by the company through this exchange through share sales and senior convertible note issues.*

5. Acceleration of Development of Chinese and Global Industry

It is clear that Suntech and the training resulting from past Australian research activities played the seminal role in establishing the Chinese industry. This role was reinforced by strong UNSW-trained personnel involvement in largely involuntary spin-off companies from Suntech [2,3]. To estimate the benefits to Australia from this acceleration directly attributable to past Australian research, a conservative estimate of the resulting number of year's acceleration of the development of the global industry will be made.

A lower bound can be placed by historical realities. The next cell production lines were 2 years behind Suntech in reaching significant capacity levels (Table 1). However, these lines would not have appeared on this timescale without the Suntech precedent.

In the absence of Suntech, Yingli, Trina and CSI remain as the most likely sources of the spark needed to ignite the Chinese industry. As we have seen, the latter two were not initially interested in cell technology, establishing cell lines only in 2007, 5 years after Suntech. Without Suntech's success in opening-up US markets as an option for capital raising, any such lines would have been delayed ever further. This leaves Yingli, who had delayed construction of its first small, non-

competitive 3MW line by 5 years due to the unfavourable environment. Possibly it was Suntech and the publicity attracted by the opening of its first line [3] that provided the more favourable environment that saw this line finally completed. However, Yingli lacked all the attributes required for forming a "root firm" for the industry [3], being dependent on indigenous expertise at this stage and targetting local applications.

Acceleration can therefore be estimated as *"somewhat more than 2 years"*. Note that a delay of this length may well have decreased prospects for capital raising on the US markets due to the global financial crisis, that can be dated from the Lehman Brothers bankruptcy in September 2008. It was only the US market capital raising and the consequently strong manufacturing foothold gained by the Chinese industry that generated the Chinese Government's subsequent interest in strongly supporting this industry, with strong support commencing only after 2009 [2].

A not unlikely scenario is that, without Suntech, China would have remained a PV backwater and manufacturing would have remained dominated by Europe, USA and Japan. It is likely that thin-film PV technology would have played the more dominant role originally expected, with the industry by now having had a crisis in both tellurium and indium supply [13]. Prices may have been pinned to those possible with low volume manufacturing of silicon cells, several time the present value, as indeed was the pre-Suntech expectation for the industry. China may have entered the industry through its control of much of the world's supply of tellurium and indium [13].

On the basis of such consideration, 3 years acceleration of the global industry by Suntech's seeding is taken as a conservative value in the subsequent discussion.

5. **Contribution to the National Wealth of Australia**

National wealth is defined as the total value of assets including tangible assets and net foreign assets possessed by all citizens of a nation at a set point in time [14]. According to the Grattan Institute, the drivers of future Australian prosperity include the generation of net wealth, as the store of resources that can be spent in future, with older generations ultimately passing on much of their accumulated wealth to younger generations [15].

In their role as founders, Australian citizens controlled 54.5% (46.8%) of shares in Suntech immediately before (after) listing, as well as 21.7% (14.3%) of shares in JA Solar and 16.8% (13.1%) of shares in China Sunergy [10]. During 2007, the combined market value of these firms exceeded US$17 billion with the "book value" of Australian ownership peaking at over US$7 billion. In addition to these original share holdings, literally millions of share options were granted at exercise prices much less than subsequent market prices.

Dr Shi made the BRW list of the "Top 200 Wealthiest Australians" from 2006 to 2011, beginning at position number 4 in 2006, the "wealthiest ever debutant" [16]. Had they been better known, two other Australians involved in these companies could also have made this list based on

the peak values of their assets. For those with minor share-holdings, realizing as much as possible of this peak value would have been of key interest, while other considerations may have constrained major shareholders from quickly parting with their shares.

Full information is publicly and readily available for insider transactions for listed US-registered companies [17], but information appears less accessible for US-listed, foreign-registered companies. Annual Form 20-F filings track total shares held by officers who are major shareholders, but information on sales price and how annual variations in shares held are divided between sales and exercising share options is missing. Restricted information of this type is available for 7 of the 12 Australians known to have held shares or options through their involvement as founders or in a technical role [10], allowing reasonable estimates of selling patterns and likely sale prices. Where shares are still held, these are valued at current market price. For the remainder, it was assumed the same share disposal pattern was followed as for similar senior officers of First Solar, a US company listing within the same period, where it was possible to estimate their average selling price of 4 officers studied in detail to within 20% accuracy by combining 74% of July 2007 share price with 26% of the December 2007 price [17].

Table 3: Known Australian shares and options assigned to key personnel at time of initial listing of the companies indicated together with the estimated value from the sale of these shares and exercised options, net of "strike price" for options [10].

Company	Date of Listing	Ordinary Shares per ADS*	Total Ordinary Shares at Listing	Total Share Options at Listing	Estimated Proceeds
Suntech	14/12/2005	1	68,233,334	2,500,000	US$840m
JA Solar	6/2/2007	3,5	18,800,000	720,000	US$240m
Sunergy	17/5/2007	6,18	30,024,000	-	US$30m
Solarfun	20/12/2006	5,50	-	800,000	US$3m
Jinko	14/5/2010	4	-	650,000	US$2m
TOTAL					**$1.115 billion**

* Multiple values indicate changes with time in number of ordinary shares per ADS (American Depository Share)

The US$1.1bn estimate is thought accurate to about 20%. At an average conversion rate over this period of AUD$1 = US$0.8, this converts to an AUD$1.4bn contribution to national wealth.

5. Acceleration of Australian PV Uptake

PV uptake in Australia during 2013-2015 was accelerated well beyond even 2012 estimates due to substantial PV module cost reductions arising from the explosive Chinese growth. Figure 3 summarises various estimates made between March 2011 and May 2012 for the capacity of residential PV installed in Australia over coming decades [18]. The median estimate for 2020 is 5.1GW, a figure actually reached at the end of 2015.

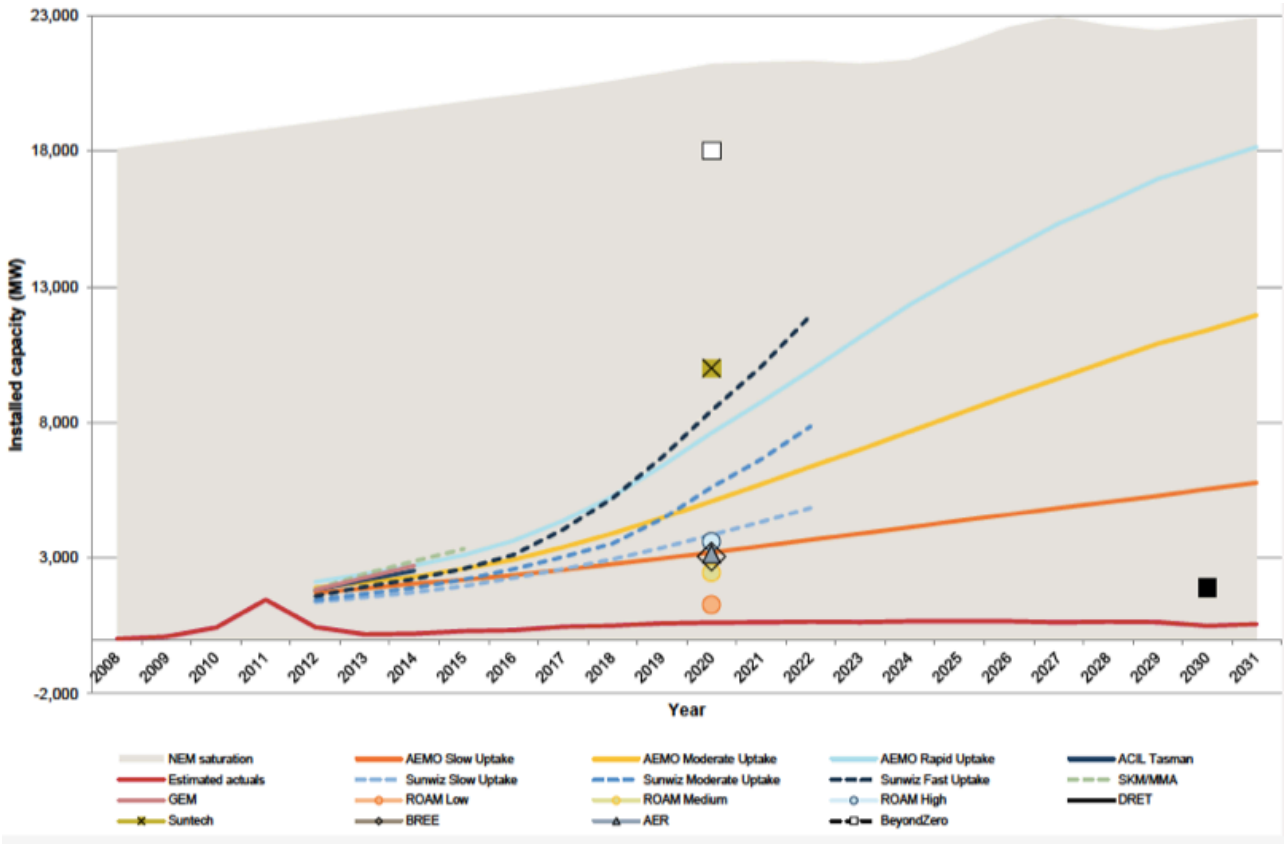

Figure 4: Collection of forecasts for the Australian residential PV capacity made over the March 2011 to May 2012 period (most estimates made in December 2011)[18]. The median estimate for the 2020 capacity is 5.1GW (AEMO "Moderate Uptake"). This capacity was actually reached at the end of 2015, with the acceleration due to lower than expected PV module prices. Full details of these forecasts are given elsewhere [18].

The rationale behind these low estimates was that the withdrawal of the various generous feed-in tariffs by State Governments during 2011 and 2012. This was though likely to bring installations to a virtual halt until economic payback times became more attractive. Meanwhile, the Chinese industry had exploded due to the Suntech seeding and PV prices were already compatible with "socket parity" by 2013.

The economic benefits to Australia of this acceleration can be estimated by the simple approach of describing all installations pre-2013 totaling 2.4GW as *"feed-in tariff assisted"*, not influenced by the developments in China (this is an approximation, albeit a reasonably accurate one, since although feed-in tariff schemes in the major states did cease in 2011 and 2012, there were schemes still operating in the first half of 2013 in the ACT, NT and SA with installations also carried over into 2013 in Queensland). Installations over the three years of 2013, 2014 and 2015 of 0.80GW, 0.82GW and 1.01GW (totaling 2.6GW) are treated as unanticipated in projections such as in Fig.3, and are attributed to the explosive growth of the Chinese industry, providing cost reductions 3 years ahead of the anticipated global schedule. The market beyond 2015 is then treated as evolving as

originally anticipated except for the addition of 2.6 GW of capacity from the 3 bonus years ("bonus" capacity). This approach has the advantage of not only being very transparent but also allowing benefits to be calculated solely in terms of this bonus 2.6GW capacity.

The benefits to Australia of this bonus 2.6 GW are estimated in terms of its societal value minus the costs of obtaining this value. The most recent, thorough, internationally peer-reviewed study of the societal value of installing PV in Australia is that of Sebastian Olivia [19,20]. The present value of the societal impact of photovoltaics installed in Australia is estimated as $4,900/kW for one internationally accepted model of societal benefits of savings in CO2 emission (LES model [21]) and $7,300/kW for a second model (A1B model [21]). The present value of costs incurred including subsidies was estimated as $3,100/kW based on 2013 costs [19,20]. Based on published subsequent system price reductions, this estimate is decreased to $2,740/kW in 2014 and $2,550/kW in 2015. Depending on the model chosen for the value of CO_2 emission savings, the net societal benefit to Australia of this bonus 2.6GW is between $5.5 billion and $11.8 billion.

Neglected in these estimates are employment and other benefits from the large associated capital injection into the Australian economy and likely improvement in PV system output since the 2009/2010 study on which these figures are based. These improvements include efficiency improvements in inverters, the tightening of the standards for specifying module output, improved installation practices including better models for projecting and avoiding the impact of shading. The economic benefits from the deferral of network acquisition expenses was also excluded due to their large impact on installation location, estimated as an additional $48/kW to $220/kW.

An additional contribution is made to National Wealth by the retained coal and gas resources not burnt as a result of the "bonus" capacity.

6. Capital Expenditure Benefits

The additional 2.6GW bonus installs reflects the sum of the annual installs over the years 2013 to 2015. At an average $2.10/W this has injected $5.4 billion into the economy over this time period. While the hardware is largely imported, there is a significant local content in sales, installation and service, being 40% of the total cost, or 2.2 billion, spent in Australia and employing over 10,000 Australians each year (figures from PV in Australia report, APVI, 2013 and 2014).

Many of the 10,000 FTE jobs each year occurs in SMEs and, reflecting the deployment of solar, is distributed around the country, providing significant regional opportunities.

The present value of the total GST to be paid on these systems is estimated as $0.7bn. The labour component plus margin on these systems would have attracted company, payroll and personal taxes estimated as $0.4bn. Additionally, each qualified installer generally works with a team of largely

unskilled labour for each installation, provided relief from unemployment benefits during this period of growing unemployment, with estimated savings of $0.4bn.

The expertise in Australia and the increased affordability of solar continue to create new opportunities in specialist manufacturing (BTimaging), in deployment (5B) in integration (Solar Analytics) and in engineering consulting (GSES, IT Power, Cat Projects etc).

7. Impact Of PERC Cell

The PERC cell was invented and developed at UNSW [22-24] and is now becoming the commercial standard, allowing manufacturers to cost-effectively increase cell efficiency. Industry forecasts are that this will become the dominant commercial technology some time between 2018 and 2020. The advantage of the higher efficiency is that transport and installation costs are reduced, in an environment where these are becoming increasingly important components of costs, as module costs themselves decline.

An example calculation provided by Prof. Blakers of the benefits of improved solar energy systems in Australia [25], based upon PERC solar cell technology, is as follows: a 5% relative efficiency improvement on 50% of Australian photovoltaic systems over the ten-year period 2018-2028, with average annual installation rate of 2 Gigawatts per year and average area-related costs of $1500 per kilowatt, translates to savings of $750 million. Worldwide, the savings are about 50 times larger.

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