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Silicon Solar Cells: Australian Role in Present Low Costs and in Lower Future Costs

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Slide 1:
I'm Martin Green, Director of the Australian Centre for Advanced Photovoltaics, based at UNSW but involving four other Australian universities plus the CSIRO.
I'll be talking about Silicon Photovoltaics (PV), particularly how it relates to Australia.

Slide 2-4:
3 points – I'll back all these up:
1. Over the last 18 months, solar fields like this have become the cheapest way of generating electricity – and quickly becoming cheaper.
2. Australians have played a major role in this and in future cost reductions.
3. Solar will provide very cheap electricity while boosting Australian resource demand.

Slide 5:
This is a busy chart from IRENA, the International Renewable Energy Agency – showing $ bids in recent solar electricity auctions – timeline along this axis – for large PV systems in several countries.
This region to the left – only a few years back – may be familiar – solar promising but fairly expensive. Not so familiar may be the dramatic cost reductions over the last 18 months – now lower than any other technology in many countries.
On the left, I show the lowest recent auction prices. $59/MWh is the cheapest for coal, impossible to match in Australia. Unlike wind and solar, coal costs have 2 components – capital and fuel.
The really important development is not that solar is 2½ times cheaper than coal, but that solar is now becoming cheaper than coal fuel costs – with solar costs still decreasing.
Important since, in future, solar systems can be financed solely from fuel savings.

Slide 6:
Why will solar costs come down? – this "learning curve" explains all. This axis is price – specifically solar module price – plotted logarithmically. The other axis is also logarithmic – showing the accumulated PV production.
Learning curves can be plotted for any product, say TV sets. A straight-line gives a learning rate – 33% here means, for every doubling of amount produced, prices reduce by 33%.
This analysis shows 3 learning regions: "pre-production", "industry development" and the present "mass-production" phase with 40% learning rate – this high rate explains why solar electricity costs are dropping so rapidly.
Learning curves are useful in predicting future prices. This graph uses data up to 2012 but accurately predicts present PV module prices (US0.34 cents/Watt), 5 years down the track. More rapid uptake than forecast has just moved data points more quickly along the line – the 25c/W forecast for 2020 will now be reached during 2018.
1 terrawatt (TW) installed capacity will be reached in the early 2020's with prices below 20c/W. By the mid-2020s at present growth rates, 1 TW would be the annual installation rate, with prices around 10c/W.

Slide 7:
Bloomberg clarified the significance of rapidly reducing PV costs for future electricity supply about 2 years ago. This graph was important in highlighting that future electricity capacity growth will be dominated by renewables – particularly solar. This study – although ground-breaking – is proving conservative. In 2016, solar already became the largest

source of new generating capacity worldwide – instead of the 20% growth predicted, actual growth was 50%.

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Australia has played, and continues to play, a major role in this transformation, beginning in the lab – this shows a timeline of best silicon cell efficiency (fraction of sunlight energy converted to electricity). For 30 of the last 33 years, UNSW has held the record for silicon cell efficiency, increasing it by 50% (relative).

The end result was the PERC cell.

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The industry is now adopting our PERC technology *en masse* – here is market share of 4 different silicon cell technologies being marketed. Most new capacity is now UNSW PERC, with the present 20-25% market share growing to dominance within a few years, reducing costs.

Slide 10:

UNSW technology is having major impact, but our people have had even bigger impact. This is the UNSW team that made the first 20% efficient cell in the mid-1980s. Most companies are now manufacturing 20% cells and following us to 25%.

Slide 11-12:

This team has gone on to do great things, but our most impactful student has been Zhengrong Shi who joined three years later.

Slide 13:

Back to the "learning curve", Zhengrong, an Australian citizen, drove the industry through this "industry development" phase to "mass production". Helped by UNSW colleagues, Zhengrong headed an Australian-Chinese joint venture establishing the first commercial PV production line in China – this was its opening in 2002.

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Over the next 2 years, Zhengrong consolidated by combining good technology with low costs. In 2005, he listed on the New York Stock Exchange – a very Australian affair with Suntech then 55% Australian-owned – of the 12 on the podium, 5 are Australians, 3 American and 4 Chinese nationals.

A huge success – the largest technology float of 2005. Further share and convertible net issues injected US$2 billion in total, financing the transition to "mass-production". Zhengrong became the first "solar billionaire", with the US venture capitalists involved also doing well.

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This stimulated interest in listing other Chinese-based firms – technical credentials were boosted by recruiting key staff from UNSW. Suntech founders, excluding Zhengrong, were involved with 3 more joint ventures with strong Australian ownership. Nine Chinese-based PV companies managed to list prior to the 2008 financial crisis, with the US$10 billion raised converting small operations to the manufacturing powerhouses delivering recent cost reductions.

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UNSW consequently has strong links with this industry, importantly now working with it perfecting 25% PERC cells in production.

We also aim for a further 50% boost by stacking a second cell onto silicon, sustaining ongoing cost reductions.

Slide 17:

To finish, I'll examine the impact of strong PV uptake on our resources industry – it's all good news.

This graph is from the Global Carbon Project showing global CO_2 emissions until 2014, then a projected trajectory to keep temperature rise below $2^{o}C$ – things look pretty hopeless!

Even allowing for the efforts of our 4 biggest emitters, we quickly run into a problem – the rest of us can't emit anything!

Here PV could prove critical. As mentioned, we are approaching 1 TW installed PV and, at present growth rates, installing 1 TW/year by the mid-2020s is feasible. The arrow shows the annual reduction in CO_2 emissions from 1 TW of PV. If we install 1 TW/year by the mid-2020s, CO_2 emissions can reduce close to the 2^oC trajectory rate.

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But won't that be bad for Australia? Installing 1 TW/year PV will reduce thermal coal demand by about 600 Mt/year, 10% of the present market. While great for the rest of the world, Australia is No. 2 thermal coal exporter and our coal exports, worth $15 billion in 2015-2016, will suffer.

Economics is an inexact science, so I aim for consistency not exactitude by estimating this loss by what I call a "Share the Gain/Share the Pain" approach. If the world market drops by 10%, I assume Australian exports drop the same 10%, or $1.5 billion. Bad news!

Slide 19:

But maybe not! According to IRENA, 1TW of PV requires 56 million tonnes (56 Mt) of steel for mounting structures and the like, or about 60 Mt of coking coal, 6% of the present market. Australia is the largest exporter of coking coal, with increased demand increasing earnings by $1.2 billion, estimated as before. This nearly offsets thermal coal losses.

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But we also need iron ore to make the steel, about 110 Mt more, 3.3% of the world market – another $1.6 billion for our exports – we are now well ahead.

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But that's not all! IRENA estimate another 19 Mt aluminium is needed for module frames and supports, or about 38 Mt of alumina. Australia is again the biggest exporter – another $3.3 billion gain.

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Also another 5 Mt of copper where Australia is 4th biggest ore exporter – another $2.1 billion.

Slide 23:

Any loss in thermal coal sales due to strong solar PV uptake will be offset likely 5 times over by increased demand for more valuable resources – coking coal, iron ore, alumina and copper.

This neglects other resources where demand will increase – silver, lithium, cobalt, nickel, for example.

This also neglects Australia's No. 1 position in solar resources. With future very low cost solar electricity, lower than almost anywhere in the world, Australia could add value to its resources by increasing the amount of local processing.

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To recap on my 3 points, electricity from large solar PV is already cheaper than from any other source and it's going to get a lot cheaper – maybe 2-3 times cheaper than at present.

Australia has played a major role in getting to this stage through its research leadership – this role should be encouraged and even accelerated due to my third point.

Accelerated worldwide solar PV deployment benefits the Australian resources industry enormously and may give Australia the world's cheapest electricity further down the track.

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