



CLIMATE ENERGY FINANCE

Solar pivot: A massive global solar boom is disrupting energy markets and speeding the transition

Global manufacturing capacity expands at record pace as prices plummet and installs escalate

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About Climate Energy Finance

[Climate Energy Finance](#) (CEF) is an Australian based, Australian funded think tank established in 2022 that works pro-bono in the public interest on mobilising capital at the scale needed to accelerate decarbonisation and the energy transition consistent with the climate science.

We conduct research and analyses on global financial issues related to the energy transition from fossil fuels to clean energy, as well as the implications for the Australian economy, with a key focus on the threats and opportunities for Australian investments, regional employment and value-added exports. Beyond Australia, CEF's geographic focus is the greater Asian region as the priority destination for Australian exports, particularly India and China. CEF also examines convergence of technology trends in power, transport, mining and industry in accelerating decarbonisation. CEF is independent, works with partners in the corporate and finance sector, NGOs, government and the climate movement, and is philanthropically funded.

About the Authors

Tim Buckley

Tim Buckley, CEF's founder, has 35 years of financial market experience covering the Australian, Asian and global equity markets from both a buy and sell side perspective. Before founding CEF as a public interest thinktank in 2022, Tim founded the Australia and Asian arms of the global Institute for Energy Economics and Financial Analysis in 2013 and was Australasian Director until 2022.

Prior to this, Tim was a top-rated equity research analyst over 2 decades, including as head of equity research in Singapore at Deutsche Bank; MD and head of equity research at Citigroup for 17 years; and head of institutional equities at Shaw & Partners. From 2010-2013, Tim was co-MD of Arkx Investment Management, a global listed clean energy investment start-up jointly owned with Westpac Bank. Tim is widely recognised as an expert on [Australian and international energy transition](#) and the accelerating shift of global capital to decarbonisation, and is a sought after [commentator and advisor](#).

Xuyang Dong

Xuyang Dong, CEF's China Energy Policy analyst completed her master's in International Relations at the University of Sydney, then joined Australia's top foreign policy think tank – the Lowy Institute – researching Australia's foreign policy, multiculturalism, development aid and Australia-China relations. Later, she joined London-based NGO think tank InfluenceMap as an analyst, where she assessed Australian oil and gas companies' lobbying activity and policy engagement, as well as tracking Australia's climate and energy policy. Xuyang's focus is to unpack China's decarbonisation trajectory and the interactions between China's energy policy and finance flows. Her research aims to accommodate energy cooperation between Australia and China, as well as Australia and the APAC region.

Key Findings

In CEF's view, the combined momentum of rapid ongoing solar price deflation, multifold increases in solar manufacturing capacity and successive record solar deployments, coupled with the surge in electric vehicles, battery supply chains and 'electrification of everything', create the conditions for a series of global cascading energy tipping points that have the potential to dramatically accelerate the decline of the incumbent fossil fuel industry, and the decarbonisation of the world economy. The economics of solar power are now compelling, and will only get stronger this decade.

1. **Solar investments globally are booming**, and this trend is accelerating in 2023.
2. Polysilicon prices are down two-thirds since December 2022 to just US\$11/kg in June 2023. As a result, solar module prices have dropped by a third from 2021, to US\$18c/watt in May 2023. And global freight costs have dropped more than 80% since the peak at the end of 2021. CEF expects **solar electricity costs to further drop 10% annually this decade, halving by 2030.**
3. Solar has seen **record annual installs every year this decade**, BNEF estimates a **global record of 268 GW** in 2022. CEF foresees the **world could hit 1,000 GW pa of solar installs by 2030.** This would have profound implications for electricity and energy markets globally.
4. BNEF estimates **solar module manufacturing capacity at 600 GW in 2022.** Announced solar manufacturing expansions will **double capacity by 2024-25** with most in China, and 3-5x expansions in the US, India and the EU (off low bases). In June 2023 the IEA estimates China alone will have 900 GW pa of integrated module capacity online by 2024, triple 2021 levels.
5. The **implications for the acceleration of the global energy market transition are profound**, raising the prospect of a chance to **address the climate crisis at the speed the science dictates.**
6. The **IEA has consistently underestimated** the rate of solar deployments, the massive deflation of solar generation costs, and accordingly the disruption of the global fossil fuel industry.
7. The **IEA World Energy Outlook 2022 estimates 462 GW of annual solar installs to 2030** under its Net Zero by 2050 scenario. There is likely to be manufacturing capacity for world **installs of double this.** Near term this will likely see some forced industry consolidation.
8. **Leading the world by a huge margin, China** is set to install 120-140 GW of solar in 2023, and ~260 GW pa by 2030; accounts for 40-60% of global annual RE installs including utility and distributed solar; and dominates solar manufacturing, with 11 of the 12 largest 1QCY2023 solar factory expansions at ~20-30 GW per facility (US and EU facility expansions are ~1-3 GW). And China's solar module exports in 4MCY2023 to-date are 69 GW +41% yoy.
9. Globally, solar manufacturing and installs are booming:

The **US Inflation Reduction Act** is driving a 5x expansion in solar manufacturing capacity by 2024 and a doubling of solar installs to 40-50 GW pa to 2030; a solar module import tariff and production credits enhance local manufacturing.

India plans to treble annual solar installs over 5 years, has a 40% solar module import duty, and has 110 GW of solar manufacturing commitments driven by an Incentive Scheme.

EU solar installs are set to quadruple to 80 GW pa by 2030. The **Net Zero Industry Act** is boosting supply chain security, with a 30 GW pa by 2025 solar module production target.

10. **Australia** had 30 GW of solar installs at the end of 2022, and is the 6th largest solar market globally; installs are set to continue at >4-6 GW pa (3 GW pa being rooftop). With appropriate policy settings and capital investment, abundant land, sun and wind and other competitive advantages enable Australia to position itself as a renewables superpower.

Executive Summary

Solar investments globally are booming, and this trend is accelerating in 2023. For an increasing number of markets globally, solar is the lowest cost source of new electricity generation, even absent a price on carbon emissions.

Climate Energy Finance forecasts solar costs will halve again before 2030, underpinning an accelerating disruption of world energy markets and driving energy transition momentum.

BNEF estimates the world installed a record 268 GW of solar in 2022, relative to installed world solar module manufacturing capacity at the end of 2022 of over 600 GW.

By comparison, as of the end of March 2023, Australia's total installed solar capacity [reached](#) 30.5 GW and the Australian National Electricity Market has 61 GW of total on-grid capacity.

If most current announcements of solar manufacturing capacity expansions proceed, this will see capacity double by 2024-2025, with the majority of this being developed by China, but with fivefold expansion in capacity planned for each of the US, India and the EU, admittedly off a very low base.

Solar has seen record rates of annual installs set every year for the decade. China has led this trend for the last decade, and is set to do so again in 2023, and beyond.

Solar module prices have dropped by a third from their end 2021 peak, with spot prices quoted as low as US\$18c/watt in May 2023.

With the massive build-out of integrated solar module manufacturing capacity well underway, CEF expects solar electricity costs to drop 10% annually for the rest of this decade, halving by 2030.

It is entirely foreseeable that the world will be recording 1,000 GW per annum (pa) of solar installs by 2030 at the latest, underpinned by continued deflation of solar costs.

The implications for global energy markets are profound, as they are for hope that we can address the climate challenge at the speed and scale the climate science dictates.

Solar cell and module technologies have been improving for the last few decades, and this trend is set to continue. This combines with continually improving economies of scale to underpin solar deflation.

2023 has seen a global technology and investment race in all decarbonisation sectors, with a dramatic elevation of focus on supply chain security and massive government subsidies to stimulate new factories and accelerated deployments of solar, wind, batteries, EVs and electrification of everything.

The US\$800bn Inflation Reduction Act (IRA), which has turbocharged clean energy investment, puts the US back in the race, but the Chinese have a decade's headstart.

The IEA World Energy Outlook is regularly cited as one of the key global reports on the status of energy markets as well as scenarios for energy trends out to 2050, relied upon by governments, industry and finance alike. For over a decade the IEA has consistently underestimated the rate of solar deployments and the ongoing deflation of solar generation costs by orders of magnitude. This in turn

results in an underestimation of the disruption of the incumbent global fossil fuel industry. This is good news given the climate crisis is also accelerating.

The IEA World Energy Outlook 2022 estimates 462 GW of annual solar installs in 2022-2030 under its net zero emissions by 2050 scenario (290 GW under Announced Pledges Scenario). The market is now increasingly talking of annual solar installs of double this by 2030, and the manufacturing capacity required to deliver on this is now in development. The rate of change is staggering.

China is leading the solar boom by a huge and increasing margin.

China is set to install 120-140 GW of solar in 2023, growth of 37-60% year on year (yoy), after 60% yoy growth in 2022 relative to 2021. By 2030, China's annual install rate will be ~260 GW, double the world record expected for 2023, according to BNEF.

China is 40-60% of the world's annual installs of utility solar, distributed solar and hydro, as well as both onshore and offshore wind in recent years, and this is set to continue.

China dominates the world solar manufacturing sector, and with 11 of the 12 largest solar cell and module factory expansions seen in the first quarter of calendar year 2023 (1QCY2023), this global dominance is set to increase. Whereas the US and European producers are announcing expansions 1-3 GW per facility, China is announcing expansions of 20-30 GW per facility.

May 2023 saw the world's largest to-date, with JinkoSolar planning a US\$7.9bn vertically integrated wafer-cell-module solar factory in Shanxi, northern China, with 56 GW of capacity in each component.

The US IRA is spurring a surge of clean energy investments, with a fivefold expansion in US solar module manufacturing capacity and with a likely doubling of annual solar installs to 40-50 GW annually through to the end of this decade.

India targets a trebling of annual solar installs over the coming five years, and has introduced 40% solar module import duties and a Solar Performance Linked Scheme (PLI) to incentivise solar manufacturing within India, leading to 110 GW of module manufacturing commitments.

European Union (EU) solar installs are forecast to quadruple to 80 GW annually by 2030, as energy security has become a key priority post Putin's invasion of Ukraine. The EU's Net Zero Industry Act (NZIA) has been introduced to incentivise an improved EU self-sufficiency in manufacturing supply chains, with a vertically integrated solar module production capacity target of 30 GW pa by 2025.

Australia, with 30 GW of solar installed at the end of 2022, is the sixth largest solar market globally, and annual installs are set to continue at >4-6 GW annually for the next few decades.

With its world-leading wind and solar resources, an enormous landmass with low population density, a global top 4 superannuation capital base and a track record as one of the world's largest and politically stable energy exporters, we expect Australia to become a renewable energy superpower.

Section 1: The Global Solar Disruption

Solar investments globally are booming, and this trend is accelerating in 2023. For an increasing number of markets globally, solar is the low cost source of new electricity generation, even absent a price on carbon emissions. Climate Energy Finance forecasts solar costs will halve again by 2030, underpinning an accelerating disruption of world energy markets to drive the energy transition.

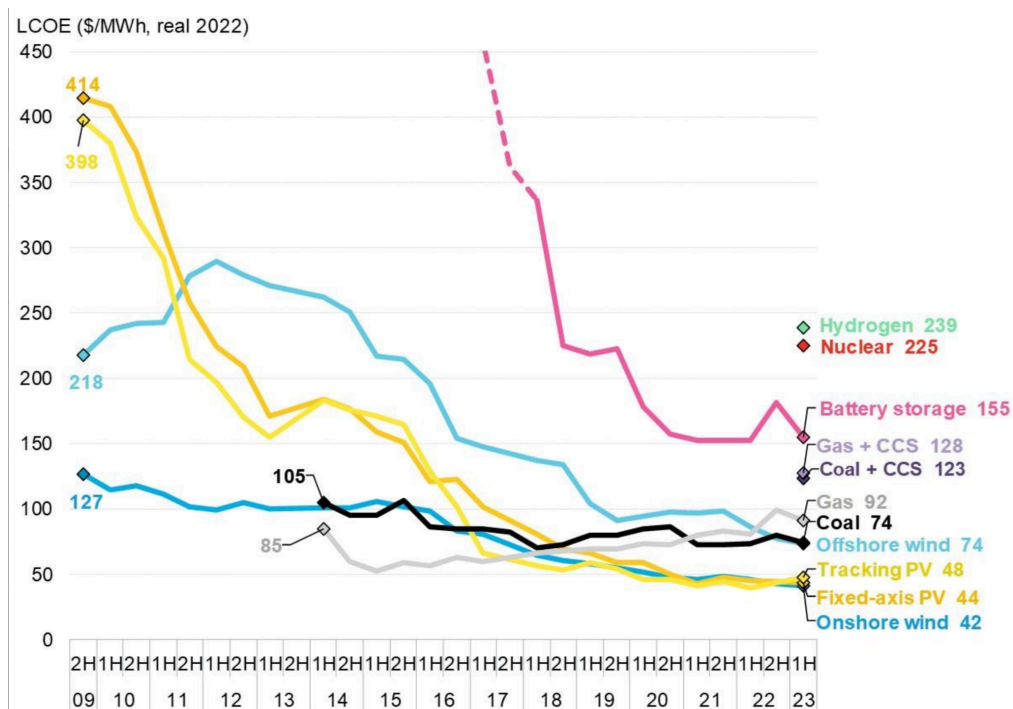
Putin's invasion of Ukraine has dramatically increased focus on energy security combined and brought into focus the growing need to accelerate decarbonisation.

The recent hyperinflation of fossil fuels has triggered a massive global economic shock, rising energy poverty and higher general inflation, which in turn has elevated global interest rates.

The near-term response has been a realignment to secure energy resources from outside of Russian fossil fuel, but we would argue that this hyperinflation of fossil fuel prices and the imperative to prioritise energy security has accelerated the world's pivot towards low cost, zero emissions renewable energy, particularly deflationary solar energy, and the electrification of everything.

Along with onshore wind, solar in 2023 is the lowest-cost source of new electricity generation in an increasing number of markets globally – Chart 1.1. We forecast that the world will see record solar installs in 2023, with growth of 30-50% yoy. With the dramatic expansion of solar module supply chains globally, and a return to solar cost deflation over the rest of this decade, it is now entirely possible that the world could be seeing 1,000 GW pa of solar installs by 2030.

Chart 1.1: Solar LCOE is now the low-cost source of new electricity generation



Source: Bloomberg NEF

1.1: Booming Solar Manufacturing Capacity

BNEF estimates the world installed a record 268 GW of solar in 2022, relative to installed world solar module manufacturing capacity at the end of 2022 of 600 GW. If most current announcements of solar manufacturing capacity expansions proceed, this will see capacity double by 2024-2025, with the majority of this in China, but with 3-5x expansion in capacity planned in the US, India and the EU.

In May 2023 BNEF reported its global solar installation forecast of 344 gigawatt direct current (GW_{DC}) for 2023 (with a range of 322-380 GW), representing +28% yoy, with the world reaching 675 GW pa by 2030.¹

But as BNEF Solar Lead Analyst Jenny Chase notes, the average consensus forecast at Shanghai's May 2023 New Energy Conference (with visitor registrations reportedly a staggering 500,000!) is for 400-450 GW_{DC} in 2023 (Huawei forecasts 500 GW in 2023²) and more than a terawatt pa by 2030.

Current polysilicon capacity is sufficient to support 600GW pa of solar installations, where polysilicon was the key constraint to solar sector growth over the last 18 months.

German engineering association VDMA estimates global module manufacturing capacity at the end of 2022 was 600 GW pa.³

SunPower Corporation is more optimistic and estimates that global solar module manufacturing capacity doubled over three years to reach almost 1TW pa by 2022. This is a tenfold expansion over the last decade. SunPower expects global capacity to more than double to 2.3TW pa by 2025.⁴

Global solar module manufacturing capacity is expanding at an unprecedented rate, with new factories being announced almost daily. The IEA reports that in 1QCY2023 alone, 294GW of new capacity was announced, counting only the largest 12 new facilities – Chart 1.2.

The IEA's May 2023 State of Clean Tech Manufacturing report notes that the expected capacity by 2030 for solar modules alone has increased by 60% since the end of 2022.⁵ This builds on the IEA's estimate that global solar module manufacturing capacity expanded 39% yoy in 2022. The IEA concludes:

"If all announced projects were to come to fruition, solar PV manufacturing capacity would comfortably exceed the deployment needs of the IEA's Net Zero Emissions by 2050 (NZE) Scenario in 2030. Even if only half of this new capacity were to be utilised – the global average utilisation rate of solar PV manufacturing capacity in 2022 was 40% – throughput would still be sufficient to reach demand levels in the NZE Scenario (around 650 GW per year in 2030)."

¹ Bloomberg, [EV Battery Leader CATL Joins BYD, Tesla to Tap Solar's Boom](#), 26 May 2023

² PV-Tech, [SNEC 2023: Huawei says global PV market could total 500GW in 2023](#), 9 June 2023

³ PV-Magazine, [PV manufacturing capacity hit 600 GW in 2022](#), 10 May 2023

⁴ SunPower, [Global Market Outlook for Solar Power 2022-2026](#)

⁵ The International Energy Agency, [The State of Clean Tech Manufacturing: An Energy Technology Perspectives Special Briefing](#), 19 May 2023

That is the motivation for this report. The IEA consistently under-estimates the learning curves, cost deflation and deployment rates of renewable energy, batteries and EVs, and has been doing so for at least the last decade. The climate science has been conservative, the climate crisis is unfolding in real time as we delay, but there is far more reason for hope given the ability of global capital to pivot unbelievably fast once the right policy frameworks emerge, leaving stranded fossil fuel assets and making a livable planet a real probability.

The IEA Renewable Energy Market Update of June 2023 forecasts China's integrated solar module manufacturing capacity will reach 900 GW pa by 2024, if all of these announcements proceed, nearly trebling China's capacity relative to 2021 levels. Chart 1.2 details the largest global capacity expansions announced recently.

Chart 1.2: Solar Modules Manufacturing - Major Project Announcements

Company	Location	Country	Production Capacity GW pa	Projected Completion year / year of reaching maximum throughput
Jinko Solar	Yuhuan	China	30	2024/2025
Solar Grids	Zhuhai	China	30	2024/2024
Tongwei	Yancheng	China	25	2023/2023
Tongwei	Nantong	China	25	2023/2024
Jinko Solar	Shangrao	China	24	2023/2025
LONGi	Taizhou	China	20	Operating / Already at max.
LONGi	Wuhu	China	20	2023/2025
Trina Solar	Yancheng Dafeng	China	20	Operating / 2024
Suntech	Chuzhou Fengyang	China	20	2023/2024
REC Group	Jamnagar	India	20	2023/2026
Solar Grids	Yiwu	China	20	2024/2024
Hoshine	Urumqi	China	20	2023/2026
Royal	Fuyang	China	20	2023/2025
Total			294	

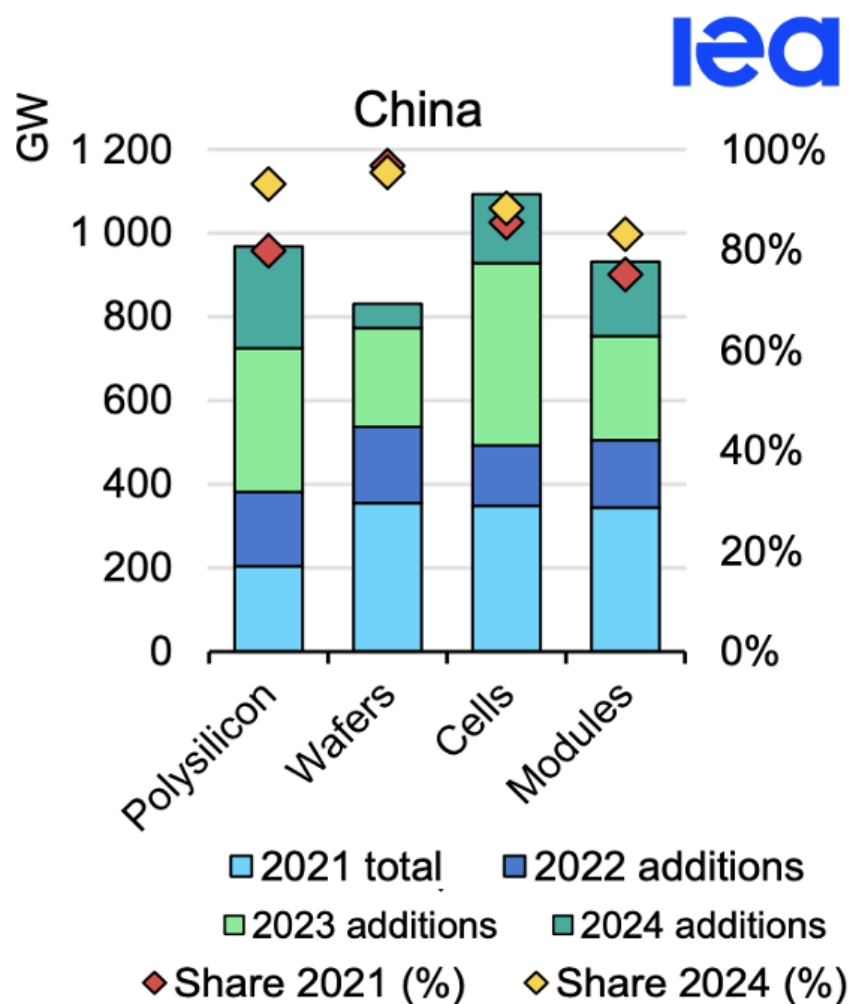
Source: Gerard Reid, IEA: *The State of Clean Technology Manufacturing*, May 2023

China's National Bureau of Statistics (NBS) reports the Chinese PV industry in the first four months of this year produced solar cells with a combined capacity of 144.4 GW, up 57% yoy, showing there is no let up in accelerating momentum from China, even as other nations respond with solar manufacturing capacity expansions of their own.⁶

⁶ PV-Magazine, [Trina Solar's new 6.5 GW Vietnam wafer plant to exclusively supply US market](#), 12 January 2023

The IEA estimates that should all announced projects proceed to completion, global solar module capacity will exceed 1,000 GW by end 2024, with China alone reaching almost 900 GW pa - with upstream polysilicon, wafer and cell capacity expansions of similar magnitudes - Chart 1.3. CEF notes that new factory announcements have continued beyond 1QCY2023, including a single Chinese integrated solar factory of 56 GW pa capacity announced in May 2023.

Chart 1.3: Solar Modules Manufacturing - Capacity Expansion Across the Supply Chain



Source: IEA, [Renewable Energy Market Update Outlook for 2023 and 2024](#), June 2023

1.2: Massive Solar Installation Buildout

Solar has seen record rates of annual installs every year for a decade. China has led this trend, and is set to do so again in 2023 and beyond, with installs in India also accelerating.

Solar is seeing ever-larger utility scale projects being announced. India and China lead this, with the development of massive scale solar industrial parks.

Phalodi, in the northern Indian state of Rajasthan, is reported to be the world's largest district for solar, with a total of 6.6 GW of capacity including the Bhadla Solar Park, currently #1 in the world at 2.245 GW.⁷ Rajasthan has huge solar aspirations, with a target to reach 30 GW by FY2025.⁸

Gonghe County in Qinghai's Hainan Prefecture, China, is the second largest district, with a reported 5.1GW of installed capacity across 18 plants. This includes the world's #2 plant Huanghe Hydropower Developments' 2.2 GW total⁹ and Longyangxia Solar-Hydro, #3 at 0.85 GW alongside the 1.28 GW Longyangxia Dam.

June 2023 saw Tongwei's TW Solar announcing a 3.4GW project across 52 fishponds in China this year, illustrating the increasing scope for solar to be deployed with reduced land conflicts over arable land.¹⁰

Australia has huge potential to be a renewable energy superpower, and this was evidenced in May 2023 with BP acquiring 23,000 hectares of land to advance development of the 10 GW wind and solar Geraldton Export Scale Renewable Energy Investment Project.¹¹ This sits along [BP's Australian Renewable Energy Hub](#), with aspirations for 26 GW of wind and solar capacity.

China leads the world with a cumulative 414.5 GW of solar installed by 2022 – Chart 1.4:

Chart 1.4: Top 10 Countries for Installations in 2022, and Total Installed Capacity in 2022

FOR ANNUAL INSTALLED CAPACITY				FOR CUMULATIVE CAPACITY			
1		China	106 GW	1		China	414,5 GW
(2)		European Union	38,7 GW	(2)		European Union	209,3 GW
2		USA	18,6 GW	2		USA	141,6 GW
3		India	18,1 GW	3		Japan	84,9 GW
4		Brazil	9,9 GW	4		India	79,1 GW
5		Spain	8,1 GW	5		Germany	67,2 GW
6		Germany	7,5 GW	6		Australia	30 GW
7		Japan	6,5 GW	7		Spain	26,6 GW
8		Poland	4,9 GW	8		Italy	25 GW
9		Australia	3,9 GW	9		Korea	24,8 GW
10		Netherlands	3,9 GW	10		Brazil	23,6 GW

Source: IEA Snapshot of Global PV Markets 2023

⁷ IEEFA, Solar is Driving a Global Shift in Electricity Markets, May 2018

⁸ Economic Times, [Rajasthan to meet 30,000 MW solar energy target by 2024-25: Gehlot](#), 27 November 2020

⁹ PV Magazine, [World's largest solar plant goes online in China](#), 1 October 2020

¹⁰ PV Magazine, [Chinese PV Industry Brief: TW Solar announces giant solar plant](#), 2 June 2023

¹¹ PV Magazine, [BP buys land to advance development of 10 GW wind-solar complex](#), 24 May 2023

1.3 China's Growing Global Solar Dominance

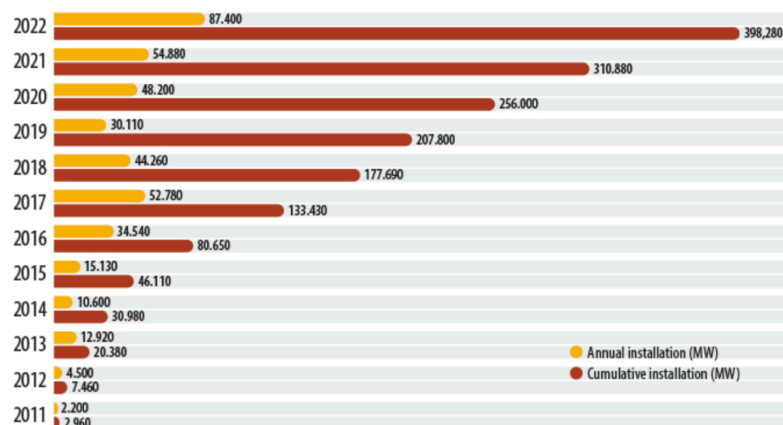
The industrialisation of Chinese PV began with “Sun King” Zhengrong Shi’s Suntech Power, founded in 2000 with backing from the Wuxi municipal government. The University of New South Wales (UNSW) graduate oversaw the opening of Suntech’s first 10 MW pa production capacity solar cell line in 2002, doubling China’s total cell capacity in a single move.¹²

Beijing’s February 2006 Renewable Energy Law supported the rise and rise of Suntech, as well as solar manufacturers LDK and Yingli, followed by Longi, Trina Solar, Canadian Solar and JinkoSolar. Vertical integration from polysilicon to wafers, cells and modules became a key part of the strategy, as was the less successful move downstream into solar project development.¹³

The value of China’s solar exports doubled from US\$15bn in 2018 to US\$32bn in 2021 (108 GW) before growing 64% yoy in 2022 to a record US\$52bn (154 GW). Woodmac estimates China’s cell export volume more than doubled from 11 GW in 2021 to 24 GW in 2022. Wafer export volume surged 44% yoy from 29 GW in 2021 to 41 GW in 2022.¹⁴ 4MCY2023 exports were 69 GW, +44% yoy.¹⁵

Whilst China’s solar module export focus has caused global concerns (refer Section 1.4), the continual rise of domestic solar installations has been equally impressive over the last decade. China overtook Germany to lead the globe in domestic solar installs back in 2013. Since then, annual installs have grown sixfold to 87.4 GW in 2022. And after a record 48.3 GW of solar were installed in the first four months,¹⁶ 2023 is set to eclipse that, with 120-140 GW estimated.¹⁷ The IEA estimates China’s solar module supply chain capacity is set to treble by 2023 to ~800GW pa relative to 2021 levels.

Chart 1.5: China’s Solar Installs (annual, and cumulative, MW)



Source: NEA, Vincent Shaw, PV Magazine

¹² PV Magazine, [China's solar century](#), 20 May 2023

¹³ PV Magazine, [Solar dawn](#), 23 May 2023

¹⁴ PV-Tech, [China's solar exports up 64% in 2022, will continue to dominate global PV manufacturing](#), 24 May 2023

¹⁵ Taiyangnews, [China Exported 69 GW PV Modules In 4M/2023, Says InfoLink Consulting](#), 7 June 2023

¹⁶ CEF, [China remains massively ahead in global cleantech investment during slow economic growth](#), 31 May 2023

¹⁷ SCMP, [Solar to jump into renewable energy driving seat at home and abroad, as China's capacity just keeps expanding, analysts say](#), 26 May 2023

1.4: Growing Concerns over Supply Chains

Putin's invasion of Ukraine at the start of 2022 focussed global attention on the key issue of energy security, and the need for diversity of supply. Along with this, there has been a growing realisation of China's global technology and investment leadership in key energy transition sectors, no more so than solar module manufacturing supply chains. China's solar manufacturing capability is largely vertically integrated, with the IEA estimating China has an over 80% global share of module manufacturing, and 90% of the world's solar wafers.

With growing trade tensions between the US and China, there has been a further focus on global supply chain diversity. The US IRA is underpinning a massive onshoring of energy transition manufacturing across the board, from solar modules to batteries to electric vehicles (EV). In response to the IRA, the EU's Net Zero Industry Act has likewise focussed on supply chain diversity. May 2023 saw the US-Australia Climate, Critical Minerals and Clean Energy Transformation Compact take this further, with Australia to be designated as equivalent to a domestic US supplier under the Defense Production Act.¹⁸

At the same time, major nations are looking to place restrictions on imports to protect domestic industry and capacity. This US has imposed import duties on solar modules (refer Section 5.2). June 2022 also saw the US introduce the Uyghur Forced Labor Prevention Act (UFLPA), which requires importers to show that forced labour was not used in the production of imports from China. As with the rising ESG focus more generally, this has become a focus for investors more globally.¹⁹

India has followed suit, with the Ministry of New and Renewable Energy introducing a basic customs duty of 40% on imports of solar modules and 25% on cells from April 2022.²⁰ The directive to implement basic customs duty (BCD) is part of the 'Atmanirbhar Bharat' initiative to support domestic manufacturing by making imports expensive through duties.

February 2023 saw China threaten to respond, with the Commerce and Science and Technology Ministries announcing a public consultation on potential changes to the Catalogue of Export Restricted Technologies, which could include a ban or restriction on exporting technology related to the production of solar wafers, black silicon, and ingots.²¹

Woodmac estimates China's local module manufacturing cost in 2022 was US\$0.24 per watt, significantly lower than the US (US\$0.56/w), Europe (US\$0.52/w), and India (US\$0.33/w). Southeast Asia's manufacturing cost was close to China at US\$0.26/w – Chart 1.6.²²

Climate Energy Finance notes that with the progressive decline of polysilicon prices in 2023 and beyond, ongoing technology improvements and the massive economies of scale underway, plus a looming oversupply crunching profit margins, this should see solar module prices decline ~10% annually through to 2030, consistent with the trend evident over 2010-2020. This will see the cost of

¹⁸ CEF, [Landmark AUS-US Climate, Critical Minerals and Clean Energy Transformation Compact](#), 21 May 2023

¹⁹ Clean Energy Council, [Addressing Modern Slavery in the Clean Energy Sector](#), 29 November 2022

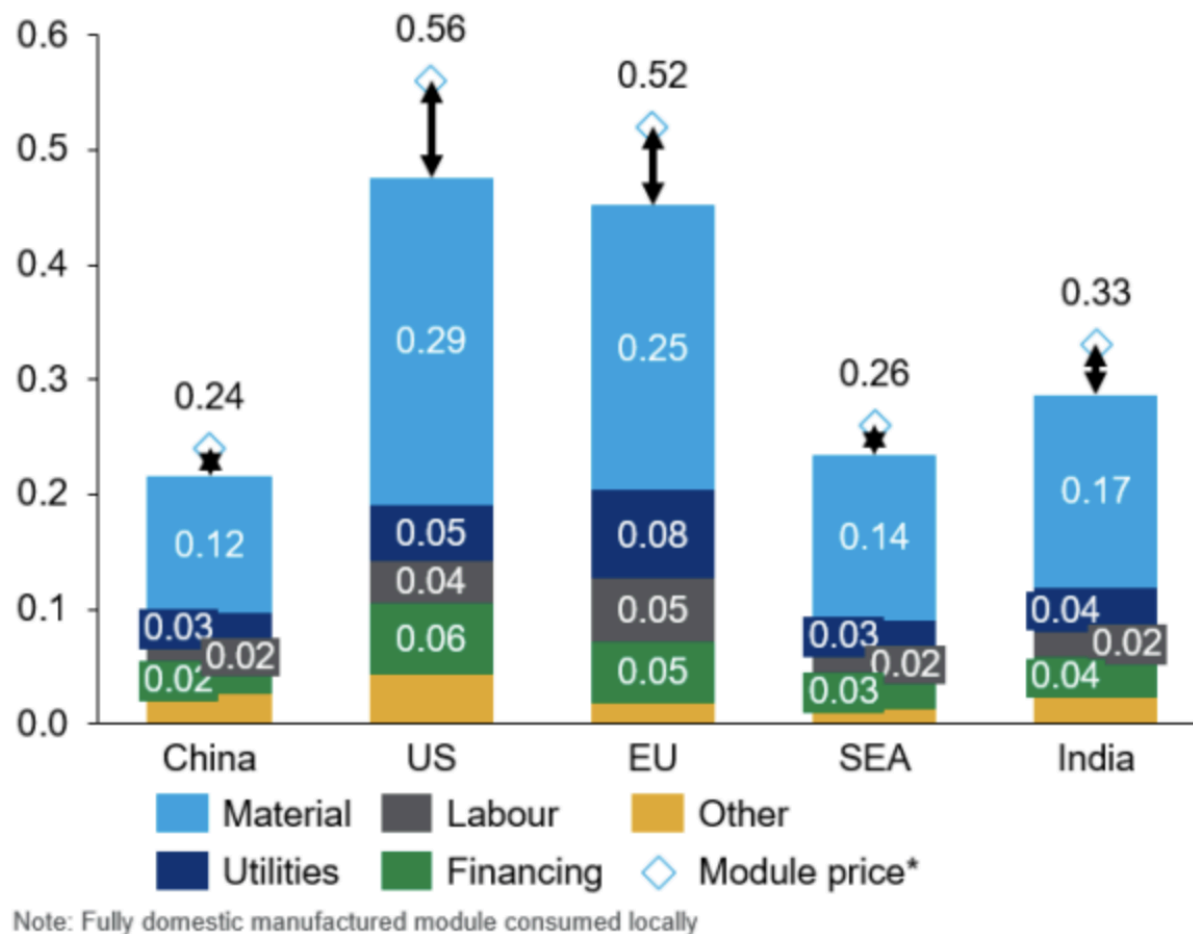
²⁰ Mercom India, [Basic Customs Duty of 25% on Solar Cells and 40% on Modules to Take Effect from April 2022](#), 9 March 2021

²¹ Mercom India, [China Contemplates Restricting Exports of Critical Solar Technology](#), 2 February 2023

²² PV Magazine, [Chinese solar exports rose by 64% in 2022, says Wood Mackenzie](#), 24 May 2023

solar modules halve by the end of the decade. Australian solar pioneer Professor Martin Green has long forecast a 2030 guesstimated module cost of just US10c/w.

Chart 1.6: Module Manufacturing Cost for Local Use, by Region, 2022



Source: Wood MacKenzie, PV Magazine

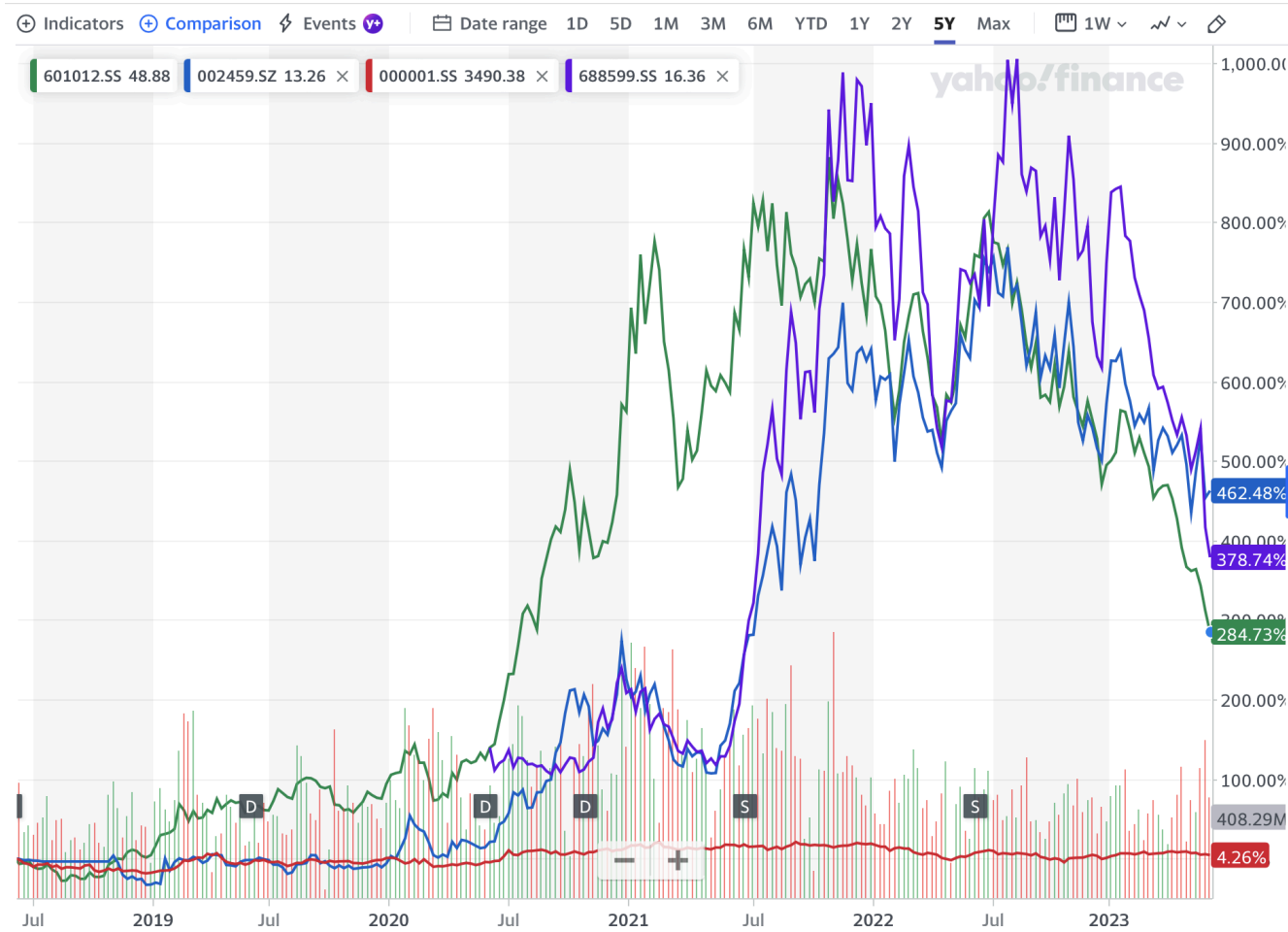
In May 2023, Li Zhenguo, president of Longi Green Energy Technology Co, warned that overcapacity and increased competition could prompt a wave of failures throughout the industry.²³ More than half of China's solar manufacturers could be forced out in the next two to three years because of excess capacity.²⁴ Li Zhenguo recommends strong financials and deploying the most modern technology as the best defence.

²³ Bloomberg, [EV Battery Leader CATL Joins BYD, Tesla to Tap Solar's Boom](#), 26 May 2023

²⁴ Bloomberg, [Top Solar Firm Warns Excess Capacity Risks Wave of Failures](#), 24 May 2023

But Chart 1.7 puts in perspective that Longi shares (green) have underperformed the Chinese market (red) overall by 55% on a one year view, and Trina (purple) and JA Solar (blue) have underperformed 44% and 24% respectively in the face of rapid solar price declines. But on a five year view all have massively outperformed, reflective of the spectacular long term volume growth potential of solar.

Chart 1.7: Chinese Solar Manufacturers Share Price (Rmb over 5 years)



Source: Yahoo Finance, Accessed 8 June 2023

1.5: Polysilicon Pricing Trends

Polysilicon is the key raw material in the polysilicon => wafer => cell => solar module manufacturing chain.

China accounts for 80% of current polysilicon capacity and virtually all of the projects under construction or planned.²⁵

The world's top four largest polysilicon producers in 2022 were Chinese companies, led by Tongwei with 345,000 metric tons (MT), followed by GCL Technology and Daqo. China's Xinte Energy overtook Germany's Wacker Chemie, the world's largest polysilicon producer as recently as 2019, for fourth place globally in 2022, relegating Wacker to fifth. The sixth-largest producer is China-based Asia Silicon, giving China a global solar-grade polysilicon share of 89%, up from a global share of 82% in 2021 and just 55% share as recently as 2017.²⁶

Since December 2022, the average domestic Chinese spot price for photovoltaic-grade polysilicon, the main ingredient for manufacturing solar cells, has almost halved, with increasing reports of a price war well underway,²⁷

Entering June 2023, US\$10.96/kg, the polysilicon price is down two-thirds from its peak – Chart 1.8.

Reports at the start of June 2023 show the polysilicon price decline is moving downstream, with wafer prices down 16-24% relative to May 2023.²⁸ Sustained lower polysilicon prices should return solar module pricing to its long term deflationary trend of the last decade.

Concurrently, global polysilicon production capacity has increased by almost half since 2020.²⁹ If all new projects announced or under construction materialise, it would expand by a further 164%, according to BloombergNEF in January 2023.

Bernreuter Research estimated in May 2023 that the six largest Chinese manufacturers alone have additional capacities of 1.5 million MT in the pipeline for 2023 and 2024, driving fears of massive overcapacity, even allowing for massive solar installation growth.

China's polysilicon imports are estimated to have fallen 23% yoy in 2022 to 88,094Mt, half their peak of 2017.³⁰ China is set to be entirely self-sufficient in polysilicon production in 2023.

²⁵ Bloomberg, [Silicon Crash Shows China's Relentless Domination of Solar](#), 6 January 2023

²⁶ PV-Magazine, [Tongwei led global polysilicon capacity in 2022, says Bernreuter Research](#), 16 May 2023

²⁷ PV-Magazine, [Polysilicon prices preserve downward trend, weighed down by supply factors](#), 12 May 2023

²⁸ PV Magazine, Chinese PV Industry Brief: TCL Zhonghuan reduces wafer prices, 2 June 2023

²⁹ PV Magazine, [Polysilicon prices plunge worldwide on bearish market sentiment](#), 2 June 2023

³⁰ PV-Magazine, [China's polysilicon imports fell by 23% in 2022, says Bernreuter Research](#), 24 February 2023

Chart 1.8: Polysilicon Price Index relative to the Bloomberg Global Commodities Index



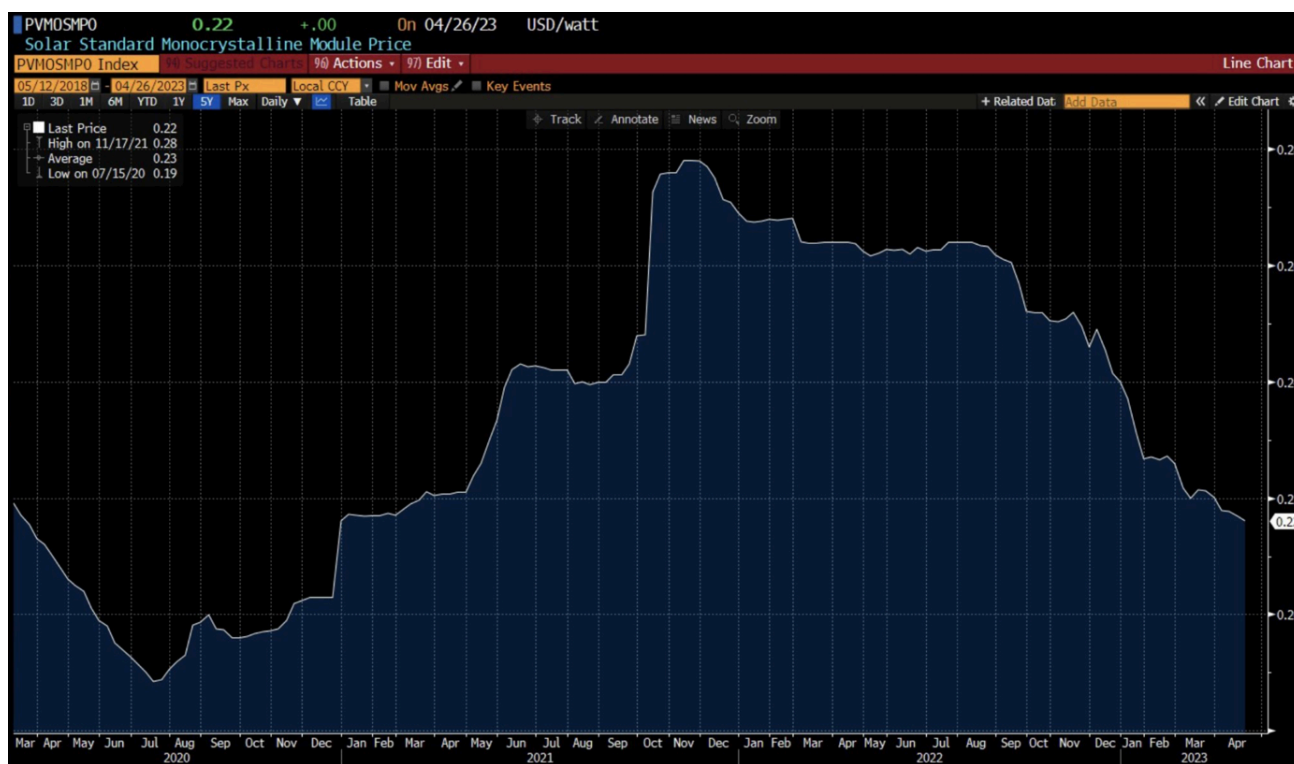
BCOM Index – Bloomberg Commodities Global Index
Source: Bloomberg Intelligence, 7 June 2023

1.6: Solar Module Pricing Trends

Solar module prices have dropped by a third from their end 2021 peak, with spot prices quoted as low as US\$18c/w in May 2023. With the massive build-out of integrated solar module manufacturing capacity well underway, Climate Energy Finance expects solar electricity costs to drop 10% annually for the rest of this decade, halving by 2030.

After three years of high and rising polysilicon prices, 2023 started with a significant drop in polysilicon prices, which in turn has fed through into progressively lower solar module prices. Chart 1.9.

Chart 1.9: Solar Module Price (US\$/W pa): US18c/w by end May 2023



Source: Bloomberg, 10 May 2023

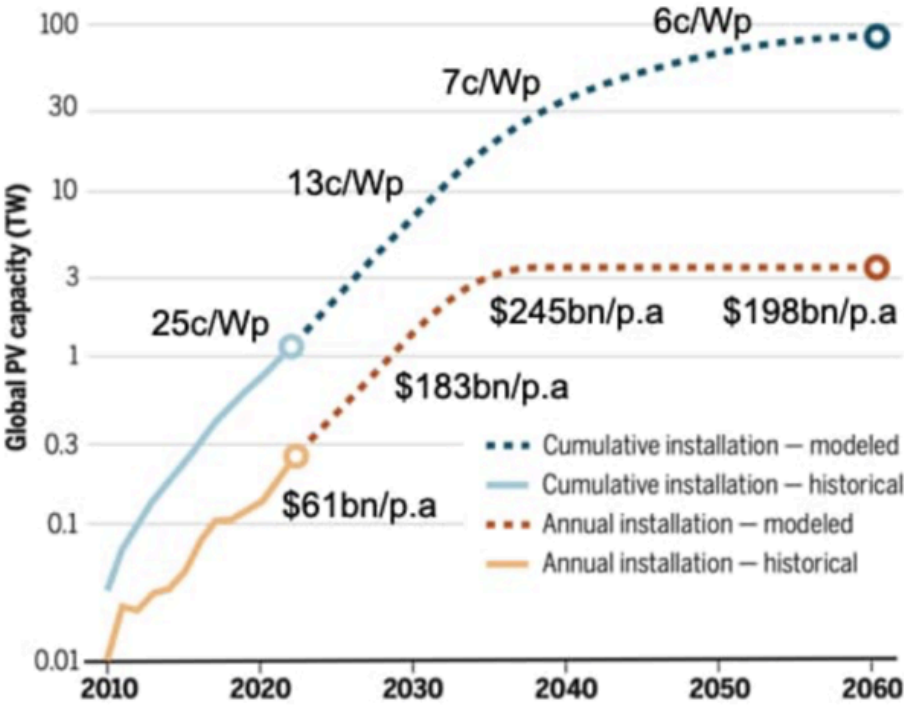
Australia's founding father of solar, University of NSW's Professor Martin Green is even more optimistic, forecasting solar module costs of US10c/w by 2030, based on his expectation of continued manufacturing scaling up combined with further technology enhancements.

A similar expectation is presented in Chart 1.10, presenting a rather bullish forecast of 3TW pa of solar installs before 2040.

Chart 1.10: Solar Installations Growth and Price Trajectory to 2060

PV installations and growth toward 75 TW by 2050

Modeled cumulative capacity going forward is based on sustaining 25% production rate growth over the next 7 years and then reducing slowly to steady state. Replacement needs are included by simple subtraction of installations 25 years before the modeled date.



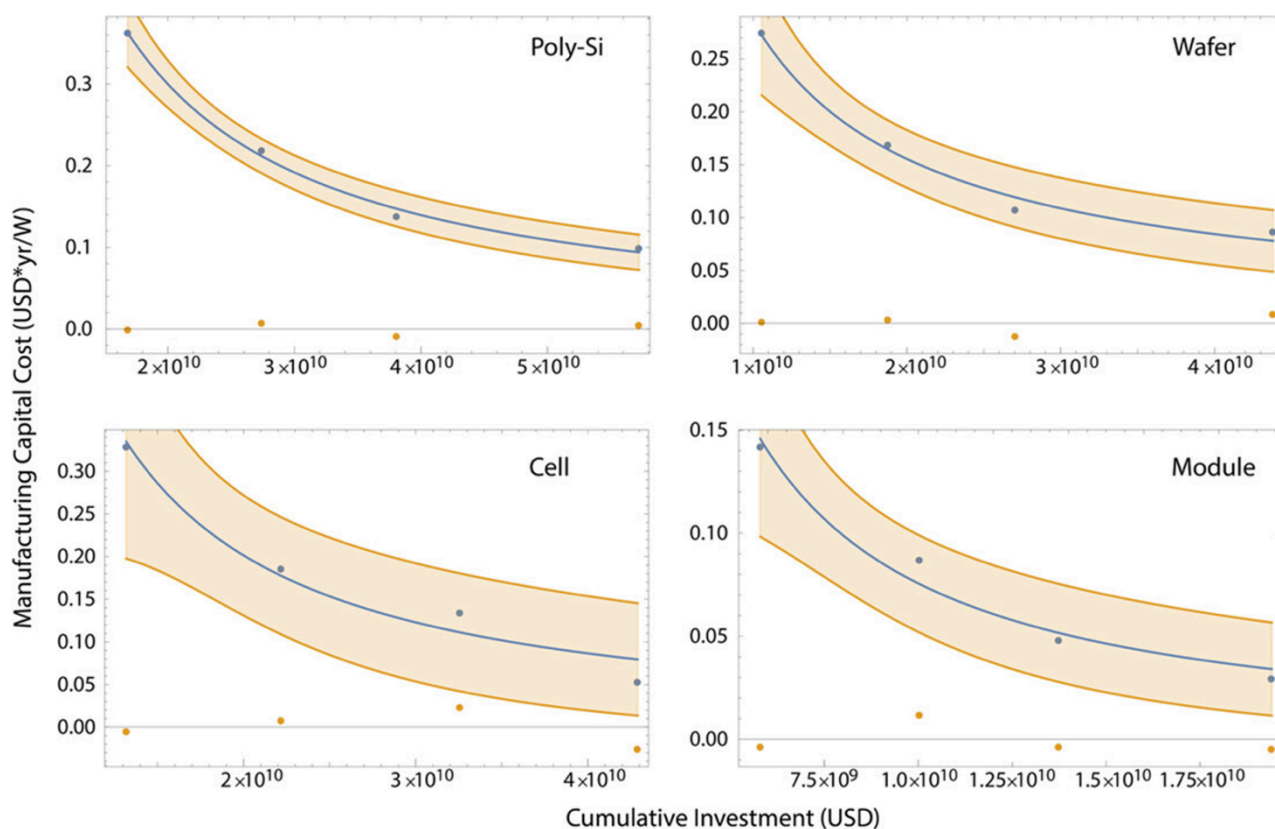
Source: UNSW, N Hagel et al, Photovoltaics at multi-terrawatt scale: Waiting is not an option, Science, 380,6640, page 39 2023

1.7: Massive Scaling Up Globally Still to Come

It is entirely foreseeable that the world will record 1,000 GW pa of solar installs by 2030 at the latest, and continued deflation of solar costs could see this growth continue well beyond this next decade. The implications for global energy markets are profound, as they are for hope we can address the climate challenge at the speed and scale the climate science dictates.

The US Department of Energy (DoE)'s National Renewable Energy Laboratory (NREL) in April 2023 estimated the world would need 2.9-3.7 Twa year of solar module manufacturing capacity requiring a capital expenditure (capex) investment of US\$600-660bn to reach 63TW of cumulative installed solar projects by 20250-2060, sufficient to reach global decarbonisation goals.³¹ This study assumes ongoing 'learning by doing' and research gains into new disruptive technologies (e.g. crystalline mineral perovskite-based PVs that enhance the efficiency of silicon based cells), and a likely extension of solar project useful lives out to up to 50 years, relative to the 20-25 year assumptions used today.

Chart 1.11: Photovoltaic Deployment Scenarios toward Global Decarbonization: Role of Disruptive Technologies manufacturing capital expense intensity (US\$/W pa)



Source: *Photovoltaic Deployment Scenarios toward Global Decarbonization: Role of Disruptive Technologies*, 7 April 2023

³¹ CleanTechnica, *Analysis Points to Massive Photovoltaic Deployment To Meet Decarbonization Target*, 7 May 2023

1.8: Massive Technology Acceleration

Solar has seen consistent technology improvements over the last few decades, and the rate of efficiency improvements of ~0.5% annually is expected to continue over the coming decade.

May 2023 saw perovskite-silicon tandem solar cell researchers Oxford PV of Germany claim a new world record for commercial solar cell efficiency converting 28.6% of sunlight into electricity, independently certified by Fraunhofer ISE, Europe's premier solar research institute. Oxford PV states: "the combined 'perovskite-on-silicon' tandem solar cell achieves a conversion efficiency that is substantially higher than that of mainstream silicon-only solar cells, which average 22–24%. ...Our latest efficiency achievement of 28.6% is more than 1.5% above our record set last year and exceeds our own roadmap plan of 1% annual increases."³²

May 2023 saw Korea's Hanwha Qcells announce plans to invest US\$100m into a perovskite-tandem cell pilot production line at its factory in Jincheon, South Korea, to be operational by 2024, with the aim of proving if this technology is stable enough for commercial deployment.³³

May 2023 saw American solar panel manufacturer First Solar pay \$38m to buy Swedish manufacturing startup Evolar AB, which claims its unique evaporation technology enables it to apply a thin-film layer of perovskite, known as "PV Power Booster" technology, to increase cell energy yield by 25% at a minimal cost.³⁴

In May 2023, the US DoE announced US\$150m of funding for the National Renewable Energy Laboratory (NREL) under the IRA, accelerating the research, development and demonstration (RD&D) of new energy technologies and grid integration.³⁵

As a clear illustration of China's global leadership in solar manufacturing R&D and technological innovation, Trina Solar invested a staggering CY2022 R&D of US\$687m, +73% yoy. It obtained 173 new patents in 2022 and now owns 1,159 patents.³⁶ Trina scored 100% in the BNEF Bankability Survey for the past seven years, was given the highest ranking, AAA, in the PV Tech Module Tech Bankability Ratings report, and entered 2023 with a solar cell efficiency of 25.3% in commercial production. In 2023, the company launched its new high efficiency and durability 440W Vertex S+ NEG9R.28 modules for both residential and commercial and industrial (C&I) rooftop applications with an efficiency of 22%.³⁷

China's JinkoSolar reported commercial production of high efficiency n-type TOPCon (tunnelling oxide passivated contact) cells of 25.1% at the end of 2022.³⁸ JinkoSolar targets a 27% TOPCon cell efficiency by 2025, stating: "After that, we'll go to TOPCon-perovskite tandem cells with efficiency of 32% and above. At least for JinkoSolar the roadmap is very clear. We will focus on that technology."³⁹

³² PV-Tech, [Oxford PV posts 28.6% efficiency on commercial perovskite-silicon tandem cell](#), 25 May 2023

³³ PV-Tech, [Qcells to invest US\\$100 million in perovskite-tandem pilot production line](#), 18 May 2023

³⁴ PV Magazine, [First Solar acquires Swedish perovskite specialist Evolar](#), 12 May 2023

³⁵ PV-Tech, [NREL receives US\\$150 million in IRA funding](#), 25 May 2023

³⁶ Trina Solar Press release, [Accumulative shipments of Trina Solar's modules totaled 140GW while 210mm module shipments exceeded 65GW by Q1 2023, ranking first globally](#), 27 April 2023

³⁷ OneStepOffTheGrid, [Powerful new Trina Solar rooftop module lands in Australia](#), 6 April 2023

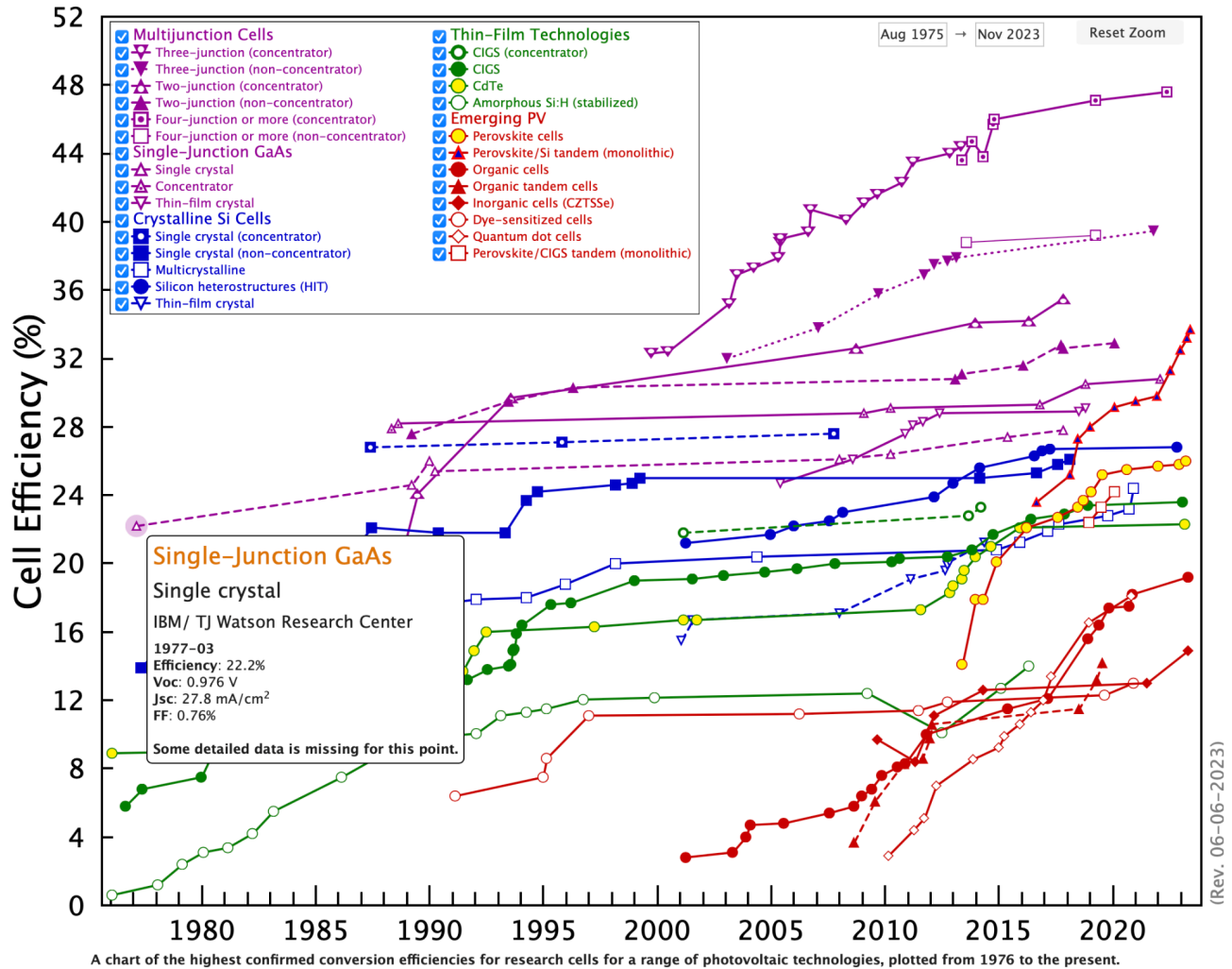
³⁸ PV-Tech, [JinkoSolar expects n-type modules to account for 60% of total shipments in 2023](#), 13 March 2023

³⁹ Taiyangnews, [SNEC Exclusive: JinkoSolar Executive Interview](#), 25 May 2023

May 2023 saw Tongwei announce its commercially produced cell efficiency has exceeded 25.5%. ⁴⁰

In June 2023, the US National Renewable Energy Laboratory (NREL) confirmed that solar panel manufacturer Moxeon US had achieved a 24.7% efficiency rating for its panels. ⁴¹

Chart 1.12: Best Research-Cell Efficiency (%)



Source: [NREL Photovoltaic Research](#)

⁴⁰ PV Magazine, [Tongwei Solar launches new breakthrough TNC and THC modules](#), 24 May 2023

⁴¹ PV Magazine, [Moxeon claims 24.7% efficiency for IBC solar panel](#), 2 June 2023

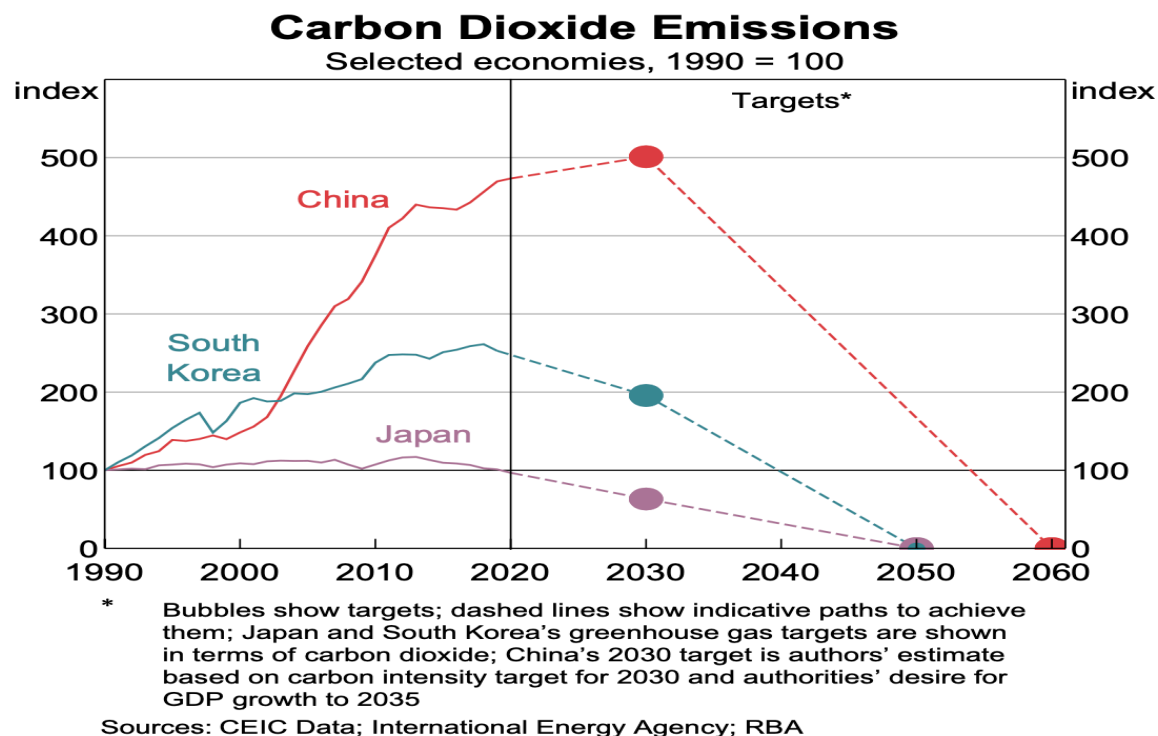
Section 2: The Rapidly Accelerating Momentum of Global Policy Action

2023 has seen a global technology and investment race in all decarbonisation sectors, with a dramatic elevation of focus on supply chain security and massive government subsidies to stimulate new factories and accelerated deployments of solar, wind, batteries, EVs and electrification of everything. The IRA puts the US back in the race, but the Chinese have a decade's headstart.

Extensive progress has been made in global policy developments relating to energy and CO₂ emissions over the last three years, starting with China pledging peak emissions before 2030 and NZE by 2060, quickly followed by Japan and Korea committing to net zero by 2050. These moves are aligned with the Paris Agreement acknowledgement that developed countries have a greater responsibility and capacity to act (Chart 2.1).

When President Biden was elected at the start of 2021, he committed to a 50-52% emissions reduction by 2030, transforming the global dialogue from vague pledges to do something in three decades time to immediate action this decade. Japan and South Korea again followed with strong pledges of a 46% and 40% emissions reduction this decade.

Chart 2.1: Carbon Dioxide Emissions Pledges by China, South Korea and Japan



Source: Reserve Bank of Australia October 2021

October 2021 saw South Korea build on its April 2021 pledge to cut national CO₂ emissions by 40% by 2030 with the presidential committee on carbon neutrality announcing an additional pledge to phase out thermal coal use in power generation entirely by 2050, using the country's existing national emissions trading scheme (ETS) as the mechanism to drive this.⁴²

In November 2021, Germany accelerated its already world-leading commitment to decarbonisation of its energy system. The government announced renewables would be 80% of its electricity mix by 2030 (up from the current law (EEG 2021) mandating 65% renewables by 2030), driven by 130 GW of onshore wind and 30 GW of offshore wind (until 2021 Germany led the world in offshore wind, and this target has just been doubled), and a near quadrupling of solar installations to 200 GW by 2030.⁴³

On 30 December 2021 China's State-owned Assets Supervision and Administration Commission (SASAC) announced more details of the country's decarbonisation strategy.⁴⁴ This document instructs the top five power utilities in China that they are required to have at least 50% renewable energy capacity by 2025. The SASAC policy means renewable energy investment will have to accelerate further in China, already the world's renewable energy superpower.

January 2022 saw President Xi Jinping⁴⁵ provide additional insights on the profound measures being undertaken by China as it "striv[es] to achieve the goal of carbon peaking and carbon neutrality". Amongst the six priority areas of focus on accelerating the energy system transition, the fourth is:

"Speed up the green and low-carbon technological revolution. It is necessary to pay close attention to tackling key green and low-carbon technologies, and accelerate the research and development, promotion and application of advanced and applicable technologies."

2022 saw the world increasingly targeting accelerated climate action and energy security.

This included the US Inflation Reduction Act (IRA);⁴⁶ the European Union (EU)'s REPowerEU,⁴⁷ the carbon border adjustment mechanism (CBAM) and the most recent Net-Zero Industry Act;⁴⁸ China's 14th Five Year Plan;⁴⁹ India's 450GW by 2030 renewables plan and the associated Production-Linked Incentives (PLI) scheme;⁵⁰ and the Japanese GX Roadmap with its Yen20 trillion investment stimulus to green energy and proposed phase-in of a national emissions trading scheme starting 2026.⁵¹

⁴² Argus Media, Seoul plans to phase out coal by 2050, 18 October 2021

⁴³ S&P Global Platts, German coalition plans for 480-540 TWh renewables by 2030 to exit coal, 25 November 2021

⁴⁴ State-owned Assets Supervision and Administration Commission (SASAC), "Guiding Opinions on Promoting the High-quality Development of Central Enterprises and Doing a Good Job in Carbon Neutralization", 30 December 2021

⁴⁵ Xinhua News Agency, Xi Jinping presided over the 36 collective study of the Political Bureau of the CPC, 25 January 2022

⁴⁶ The White House press release, [Biden-Harris Administration Releases Inflation Reduction Act Guidebook for Clean Energy and Climate Programs](#), 15 December 2022

⁴⁷ IEA, [Is the European Union on track to meet its REPowerEU goals?](#), December 2022

⁴⁸ The New York Times, [Talk of green trade war overshadows Davos optimism](#), 22 January 2023

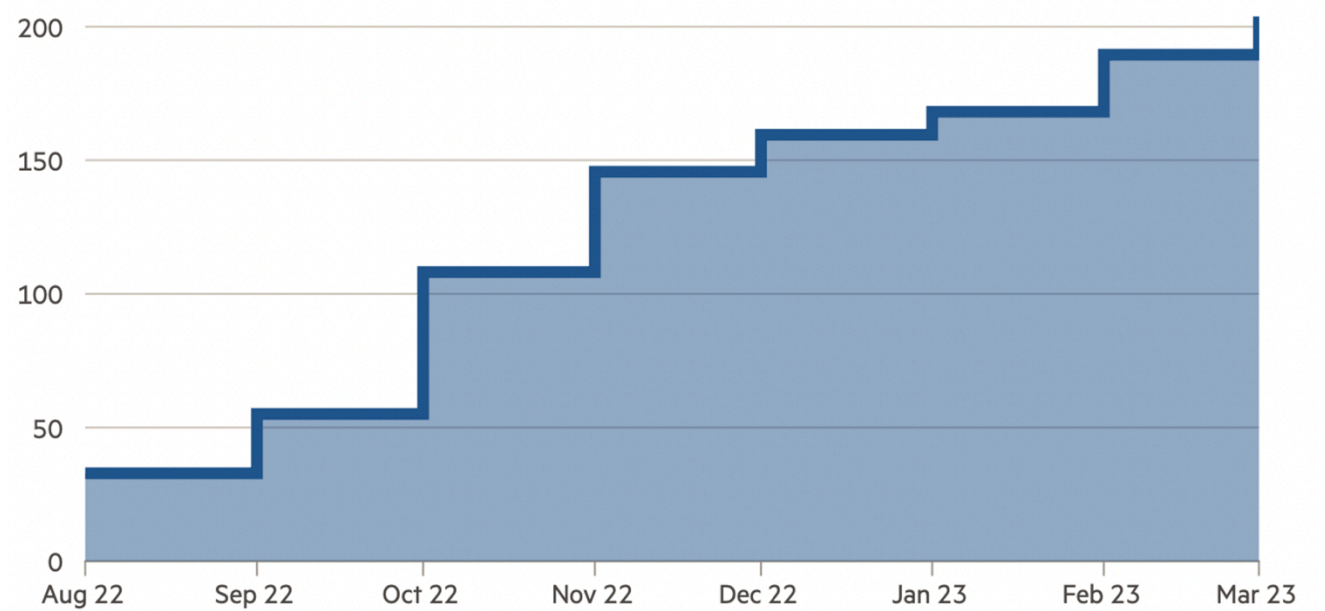
⁴⁹ IEA, [An energy sector roadmap to carbon neutrality in China](#), September 2021

⁵⁰ The New Indian, [Role of PLI scheme in India's quest for clean & affordable energy](#), 20 January 2023

⁵¹ Japan2Earth, GX: [Nuclear Power To Play a Key Role in New Green Transformation Roadmap](#), 10 January 2023

April 2023 saw reports that the US had galvanised over US\$200bn of new commitments for clean tech and semiconductor manufacturing across more than 75 sites since its Chips Act and IRA were introduced in August 2022.⁵² This includes the March 2023 announcement by LG Energy Solutions of South Korea’s proposed US\$5.5bn investment in a massive new EV battery factory in Arizona,⁵³ and Albemarle announced a US\$1.3bn lithium hydroxide plant in South Carolina.⁵⁴ May 2023 saw Tesla announce plans for a new lithium hydroxide plant in Texas,⁵⁵ while NEL Hydrogen of Norway announced plans to invest US\$400m to build the world’s largest to-date alkaline and PEM electrolyzer plant at 4GW pa in Michigan, US.⁵⁶

Chart 2.2: Cleantech and Semiconductor Investments in the US Since August 2022



Source: Financial Times, fDi Markets, Rystad Energy and Semiconductor Industry Association

⁵² Financial Times, [Transformational Change: Biden’s Industrial Policy Begins to Bear Fruit](#), 17 April 2023
⁵³ Just Auto, [LGES to supply EV batteries to Toyota](#), 30 March 2023
⁵⁴ Albemarle press release, [New U.S. Lithium Mega-Flex Processing Facility in South Carolina](#), 22 March 2023
⁵⁵ CNBC, [Elon Musk and Texas Gov. Greg Abbott break ground on Tesla lithium refinery](#), 8 May 2023
⁵⁶ Nel Hydrogen press release, [Nel plans gigafactory in Michigan](#), 3 May 2023

Section 3: Continued IEA Solar Underestimation

The IEA World Energy Outlook is regularly cited as one of the key global reports on the status of world energy markets as well as scenarios for energy trends out to 2050. Relied upon by governments, industry and finance alike, for over a decade the IEA has consistently underestimated the rate of solar deployments and the ongoing deflation of solar generation costs by orders of magnitude. This in turn results in an underestimation of the disruption of the incumbent global fossil fuel industry. This is good news given that the climate crisis is also accelerating.

The IEA World Energy Outlook 2022 estimates 462 GW of annual solar installs 2022-2030 under its net zero emissions by 2050 scenario (290 GW under Announced Pledges Scenario). The market is now increasingly talking of annual solar installs of double this by 2030, and the manufacturing capacity required to deliver on this is now in development. The rate of change is staggering.

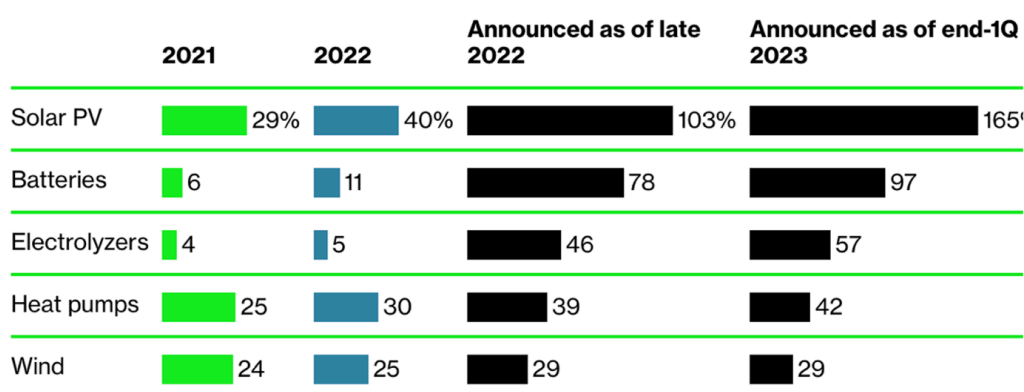
The IEA World Energy Investments 2023 Report notes that just 15 months ago, the installed and announced manufacturing capacity globally for solar was just 40% of that needed to deliver on the IEA's NZE scenario.

By the end of 2022 the world – with China leading by a significant margin – had announced solar manufacturing capacity expansions to deliver on the NZE scenario estimates of 462 GW pa of solar installs over 2022-2030, rising to 657 GW pa over 2031-2040.

By the end of 1QCY2023, there was 1,100 GW pa of global solar module manufacturing capacity announced – remarkably, sufficient to deliver 165% of the solar installs modelled in the NZE by 2050 scenario – Chart 3.1. And that was before the world's biggest integrated solar module manufacturing facility of 56 GW pa in Shanxi was announced by JinkoSolar. This presumes factories run at their historic utilisation rates, and no closures.

Chart 3.1: Global Cleantech Manufacturing Capacity Expansions (2021 to 1Q2023)

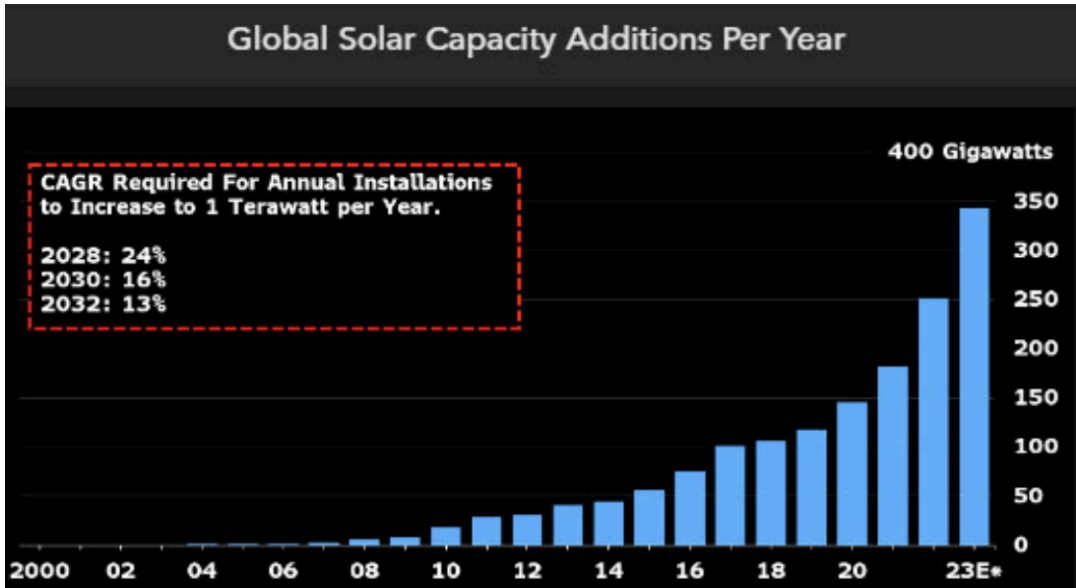
Installed and announced manufacturing capacity, relative to 2030 levels needed in IEA net zero scenario



Source: IEA World Energy Investments 2023, [Bloomberg](#)

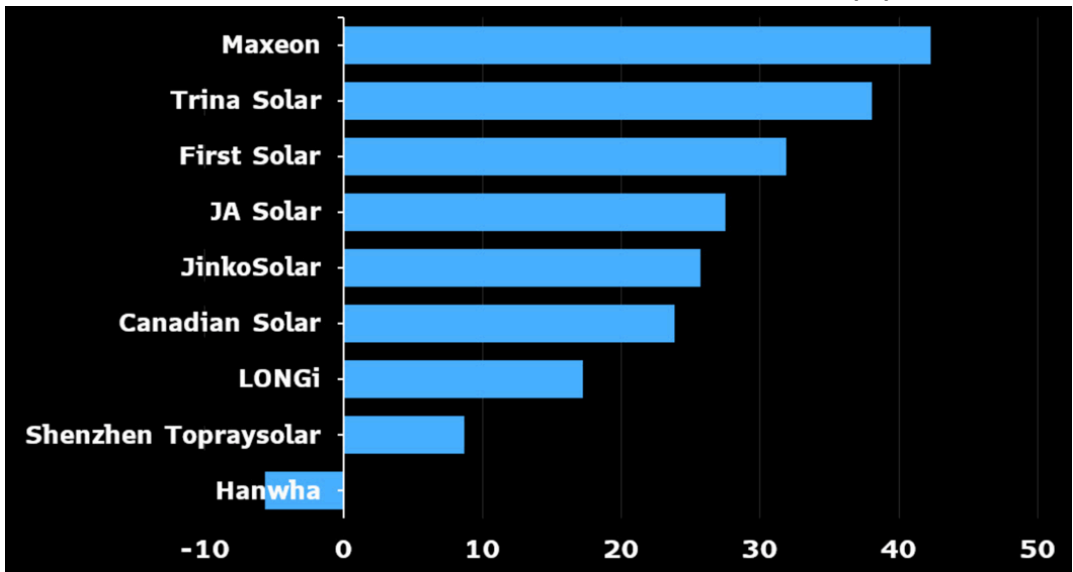
Bloomberg Intelligence’s Rob Barnett notes that the world can reach 1 TW pa of solar capacity additions as soon as 2028, assuming a compound annual growth rate (CAGR) of 24% (2030 at a CAGR of 16%, and 2032 at 13%). This CAGR to reach a 1TW pa of installs is significantly lower than the actual growth in 2022 of +38%, and the BNEF forecast of another 36% growth in 2023 to 344 GW of solar installs – Chart 3.2. Barnett also notes the median US listed solar firm has a 32% sales growth forecast in 2023 – Chart 3.3.

Chart 3.2: Global Solar Capacity Additions Per Annum (GW)



Based on BloombergNEF mid-case scenario as of 26 May 2023
Source: Bloomberg Intelligence, BloombergNEF

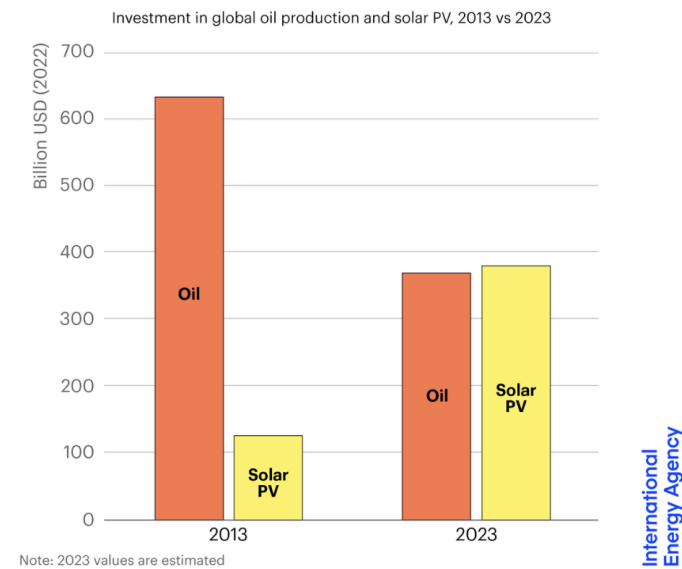
Chart 3.3: Listed US Solar Firms forecast 2023 Sales Growth rate (%)



Based on Bloomberg MODL consensus as of 24 May 2023
Source: Bloomberg Intelligence, Rob Barnett

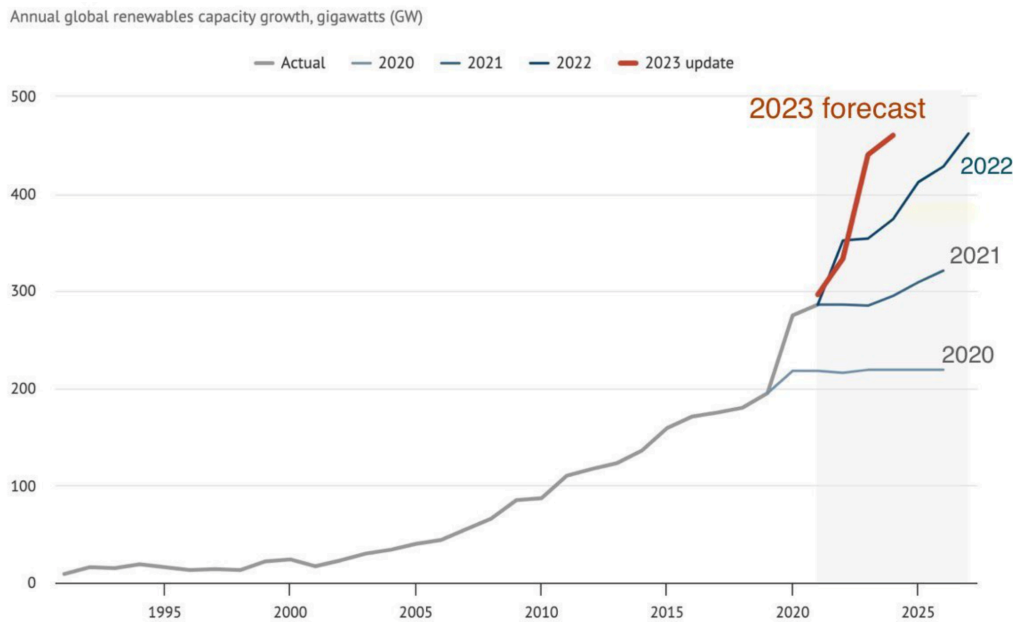
The IEA World Energy Investments 2023 report also noted that the world is on track to invest more in solar than in oil globally in 2023 – Chart 3.4.

Chart 3.4: Solar is set to attract more capital than oil production for the first time ever in 2023



Source: IEA World Energy Investment Outlook 2023

Chart 3.5: The IEA Projects 440 GW of Renewable Energy installs in 2023, Double its forecast in 2020



Source: IEA Renewable Energy Market Update 2023, Carbon Brief

Section 4: China

China is set to install 120-140 GW of solar in 2023, growth of 37-60% yoy, after 60% yoy growth in 2022 relative to 2021. And BNEF expects that by 2030, China's annual install rate will be ~260 GW, double the world record expected for 2023.

China accounts for 40-60% of the world's annual installs of each of utility solar, distributed solar and hydro, as well as both onshore and offshore wind in recent years, and this is set to continue.

In May 2023 China's Trina Solar chairman Gao Jifan predicted China's installed wind and solar will overtake thermal power capacity by as soon as 2025, and the cost of solar electricity will halve by then as well.⁵⁷ CEF agrees 100% with both forecasts.

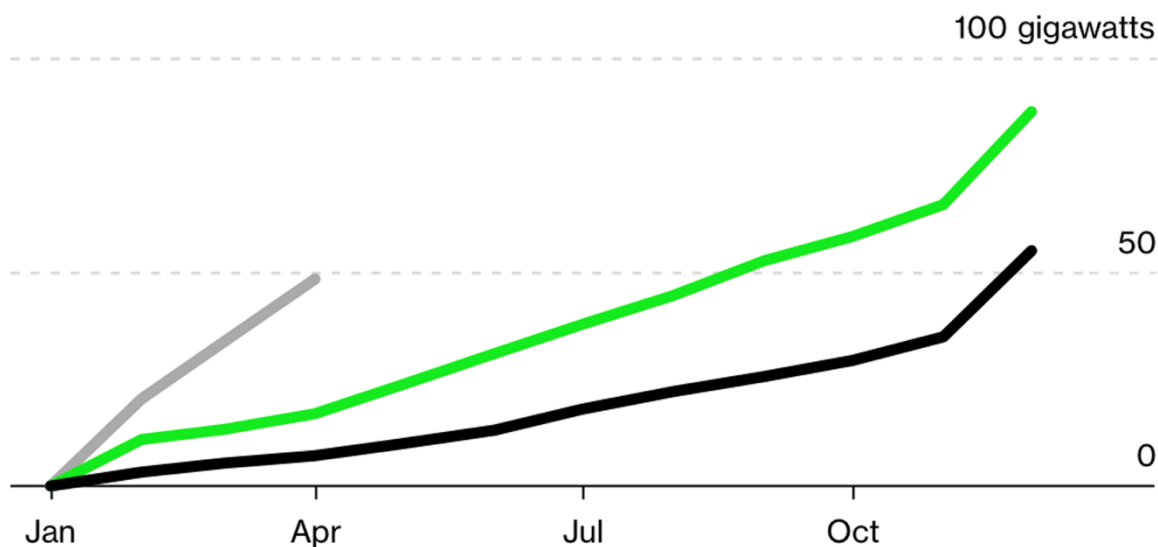
The China Photovoltaic Industry Association said in February 2023 that China would likely install 95-120 GW solar capacity this year — up from last year's record 87.4 GW. But the progress year-to-date has been well above expectations or previous years — Chart 4.1.

BNEF in May 2023 upgraded its 2023 forecast to 154GW, while JA Solar forecast 150GW, but with upside to potentially 180GW for 2023. Liu Hanyuan, Chairman of Tongwei Co, suggested in May that China's 2024 installations in China could surge to 200-300 GW.⁵⁸

Chart 4.1: China's Solar Installs are Booming YTD2023

New capacity installations in the first four months are higher than 2022

2021 2022 2023



Source: [Bloomberg News](#), China National Energy Administration

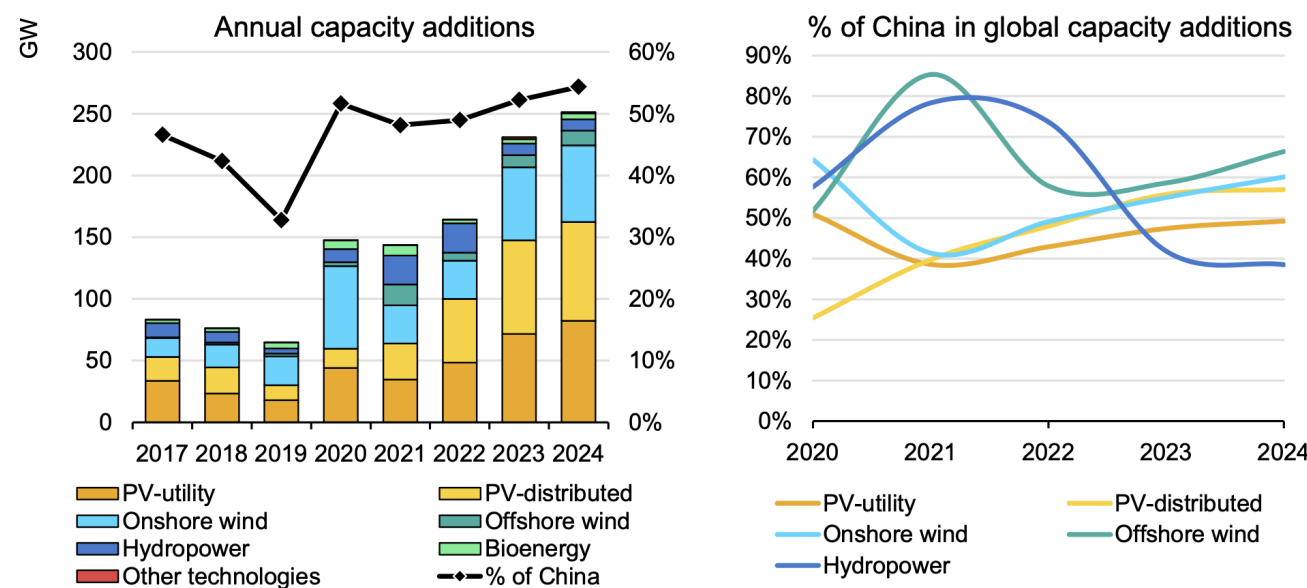
⁵⁷ Yicailglobal.com, [Solar, Wind Will Be China's Biggest Power Sources by 2025, Trina Chair Says](#), 11 May 2023

⁵⁸ Bloomberg, [China's Solar Boom Is Already Accelerating Past Last Year's Record Surge](#), 23 May 2023

In May 2023, BNEF upgraded its China annual solar installs forecasts for 2023-2030 by ~20% annually to over 260GW pa by 2030.

The IEA forecasts that China will install 235 GW of renewable energy in 2023, up from 160 GW in 2022, and that this will increase to 250 GW in 2024. China accounts for 40-60% of annual renewable energy installs of all main types globally – Chart 4.2.

Chart 4.2: China net renewable Energy Capacity adds and China’s share of global adds (GW)



Source: IEA Renewable Energy Market Update: Outlook for 2023 and 2024, June 2023

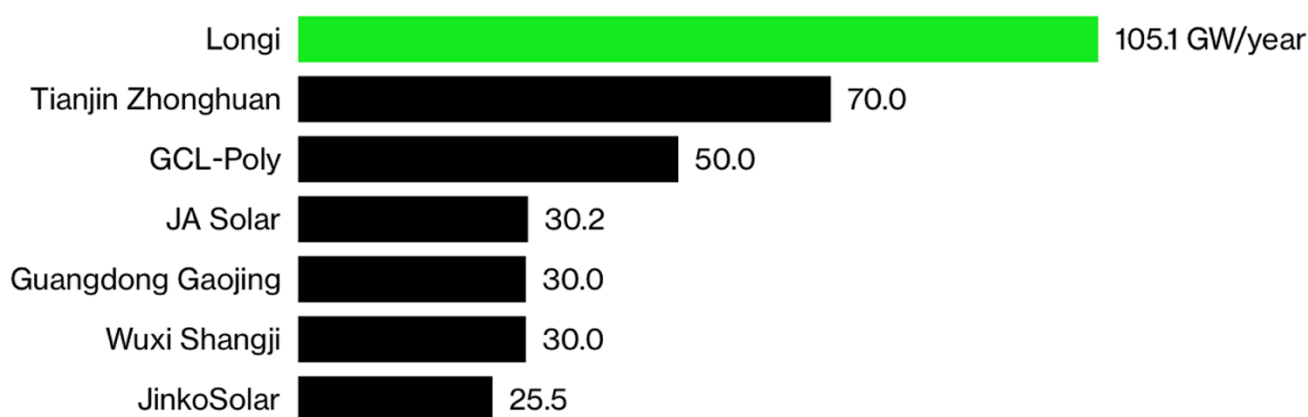
4.1 China Dominates Global Solar Manufacturing

China dominates the world solar manufacturing sector with 11 of the 12 largest solar cell and module factory expansions seen in 1QCY2023. Moreover, this global dominance is set to increase. China is announcing expansions of 20-30 GW per facility, whereas the US and European producers are announcing expansions 1-3 GW per facility.

And in May 2023, we saw the world's largest solar factory to-date, with JinkoSolar planning a US\$7.9bn vertically integrated wafer-cell-module solar factory in Shanxi with 56GW of capacity in each component.

It is no news that China dominates the world's solar manufacturing sector, with five of the top six polysilicon manufacturers, as well as the seven largest solar wafer manufacturers (Chart 4.3) and ten of the top 12 solar module manufacturers.

Chart 4.3: The World's largest Solar Wafer Manufacturers



Source: Bloomberg NEF

4.2 LONGi

LONGi exited 2022 with 133GW of wafer manufacturing capacity (Chart 4.4), as well as 50 GW of solar cell capacity, and produced 85GW of solar modules, generating collective revenues of Rmb129bn (US\$18.6bn), representing a 60% yoy growth.⁵⁹

LONGi projects a 43-120% expansion of its total manufacturing capacity over 2023 alone.

In March 2022, LONGi agreed with the government of Ordos City, Inner Mongolia, for the construction of a manufacturing facility will have a capacity of 20 GW for ingots and wafers, 30 GW for solar cells (of 25% conversion efficiency), and 5 GW for modules, and involve an investment of Rmb7.8bn (US\$1.1bn). March 2023 saw LONGi confirm this project was approved by the board to proceed.⁶⁰

⁵⁹ PV-Tech, LONGi produced 85GW of wafers last year amidst shipment and revenue growth, 5 May 2023

⁶⁰ Shanghai Stock Exchange, (601012), [Announcement on Investing in Construction of High Efficient Monocrystalline Cell Project with Annual Output of 30GW in Ordos](#), 14 March 2023

Chart 4.4: LONGi's Solar Manufacturing Capacity: 2023 vs 2022

GW	December 2022	December 2023	Change yoy
Wafers	133.0	190.0	43%
Cells	50.0	110.0	120%
Modules	85.0	130.0	53%

Source: PV-Tech, May 2023

May 2022 saw LONGi announce a 20 GW module factory in Wuhu, Anhui province.⁶¹

September 2022 saw LONGi announce the construction of the Phase II of its solar cell factory in Xixian New Area. This factory is expected to have 15 GW of manufacturing capacity when the constructions finish mid year 2023.⁶²

January 2023 saw LONGi announce plans to invest Rmb45bn (US\$6.7bn) to build the world's largest solar manufacturing base in China's Shaanxi province. This expansion project would allow LONGi to build new manufacturing capabilities to produce 100 GW of solar wafers and 50 GW of solar cells, doubling existing capacity by 3QCY2024.⁶³

March 2023 saw LONGi Solar announce an agreement with Invenergy - an U.S. solar project developer - to establish a new joint venture called Illuminate USA. Illuminate USA will build a solar panel factory of 5 GW solar module capacity per year in Pataskala, Ohio. The project is expected to include an investment of US\$600m and will create 850 jobs.⁶⁴

April 2023 saw LONGi announce a new Rmb2bn 10 GW pa module facility at Heshan, Jiangmen City, Guangdong.⁶⁵

June 2023 saw LONGi announce it will invest Rmb11bn (US\$1.6bn) in a new production facility to produce silicon ingots and mono cells, with an expected output of 20 GW and 24 GW respectively. The plan involves a first phase of 20GW monocrystalline silicon ingot project and the 12GW monocrystalline cell project, and the second phase is the 12GW annual monocrystalline cell project. The facility located in Xi'an, Shaanxi province of China. Full commissioning is due end 2024.⁶⁶

⁶¹ PV-Magazine, [Chinese PV Industry Brief: Longi to build 20 GW solar module plant](#), 17 May 2022

⁶² 环球网, [全球单体最大、产能最高的光伏电池生产基地在西咸新区正式投产](#), 28 September 2022

⁶³ Bloomberg, [Longi Plans World's Largest Solar Factory for \\$6.7 Billion](#), 18 January 2023

⁶⁴ AREADEVELOPMENT, [Illuminate USA Establishes Pataskala, Ohio, Solar Panel Plant](#), 16 March 2023

⁶⁵ Shanghai Stock Exchange, (601012), [Announcement on Investing in Construction of Heshan Monocrystalline Component Project with Annual Output of 10GW](#), 28 April 2023

⁶⁶ Shanghai Stock Exchange, (601012) ["Longi Green Energy Technology Co., Ltd." -- Announcement on Signing Investment Agreement on Monocrystalline Silicon Stick with Annual Output of 20GW and Monocrystalline Cell with Annual Output of 24GW and Supporting Projects](#), 7 June 2023

4.3 JinkoSolar

NYSE-listed JinkoSolar doubled its revenues to US\$12.1bn on a doubling of module shipments to 44.5 GW in CY2022. JinkoSolar lifted this to an annualised 52 GW in 1QCY2023 (+73% yoy), and a 17.3% 1Q2023 gross margin, up from 14-15% gross margins in CY2023.

JinkoSolar aims to exit 2023 with capacities of wafer, cell and module reaching 75 GW, 75 GW and 90 GW respectively. This will represent a 15%, 36% and 29% increase respectively on the back of capex of US\$1.5-2bn in CY2023 – Chart 4.5. JinkoSolar expects to upgrade 60% of its capacity for n-type TOPCon modules by the end 2023.⁶⁷ JinkoSolar is also exploring potential for the firm to expand domestic US module manufacturing capacity to work within US import tariffs and restrictions.

Of the total capacity detailed in Chart 4.5, JinkoSolar has 7GW of integrated solar module manufacturing capacity in South East Asia, and is looking to expand this to 12GW by the end CY2023. September 2021 saw JinkoSolar open a US\$500m, 7GW wafer manufacturing facility in Vietnam,⁶⁸ allowing export into the US for conversion into solar modules in JinkoSolar's Florida facility.

Chart 4.5: JinkoSolar Manufacturing Capacity

GW	2022	2023 (est)	Change yoy	2024 (est)	2025 (est)	Change 22 vs 25
Wafers	65	75	15%	103	131	102%
Cells	55	75	36%	103	131	138%
Modules	70	90	29%	118	146	109%

Source: PV-Tech, March 2023 ⁶⁹ CEF calculations

March 2022 saw JinkoSolar announce a Rmb10bn 30 GW of wafer production capacity in Xining city of Qinghai province. In March 2022 the company announced a 24 GW of module production capacity in Shangrao city of Jiangxi province.⁷⁰ That month it also announced a Rmb10bn (US\$1.4bn) 10 GW cell and 30 GW module facility in Yuhuan City, Zhejiang Province.⁷¹

May 2023 saw JinkoSolar announce plans for a Rmb56bn / US\$7.9bn vertically integrated wafer-cell-module solar factory in Shanxi with 56GW of capacity in each component, with four phases. Phase I and II of 14GW each are forecast to be operational by 1QCY2024 and 2QCY2024

⁶⁷ PV-Tech, [JinkoSolar expects n-type modules to account for 60% of total shipments in 2023](#), 13 March 2023

⁶⁸ JinkoSolar, [JinkoSolar's New 7GW Ingot/Wafer Facility in Vietnam to Strengthen the Sustainability of its Global Supply Chain by 2022](#), 27 September 2021

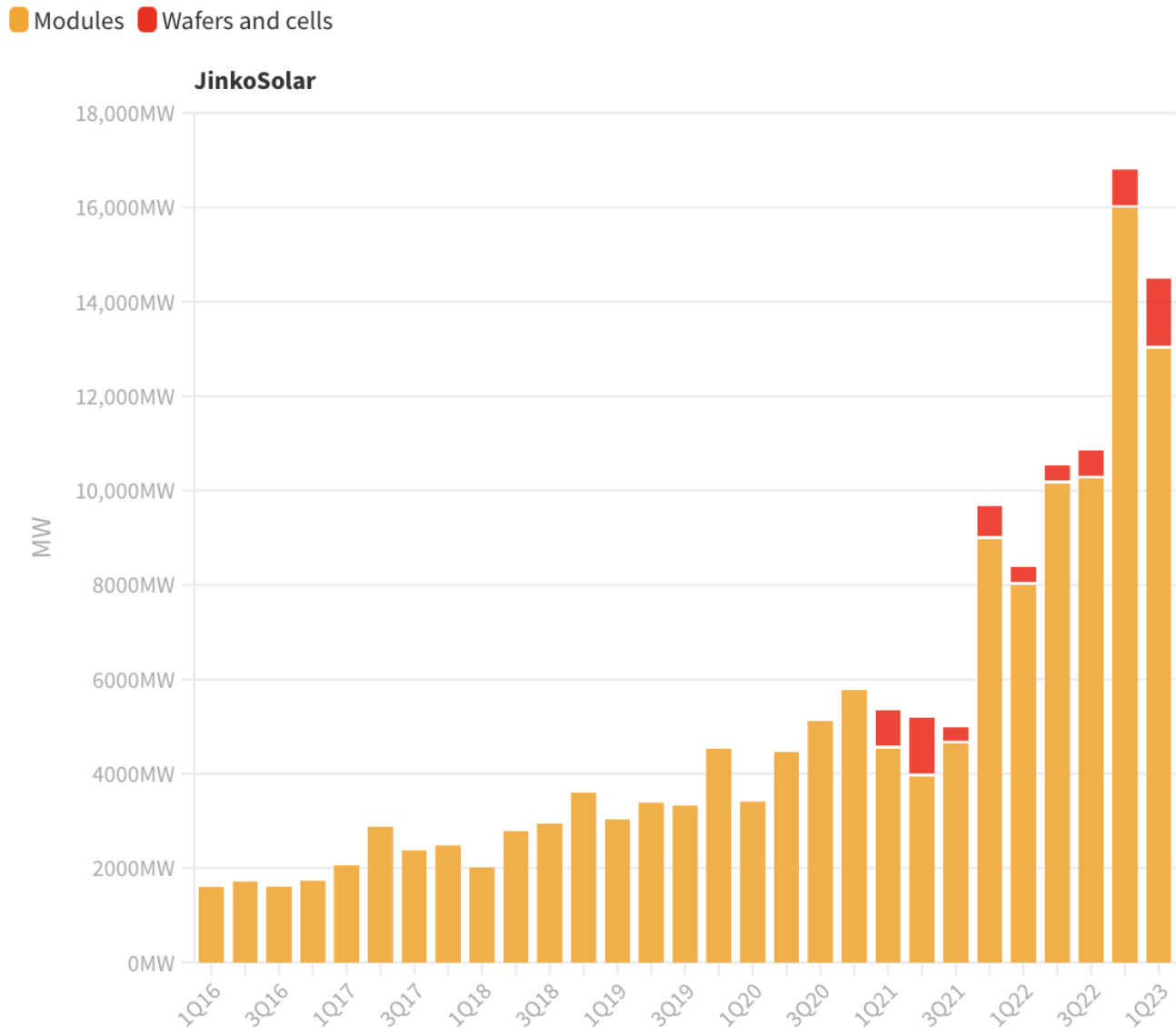
⁶⁹ Seeking Alpha, [JinkoSolar Holding Co., Ltd. \(JKS\) Q1 2023 Earnings Call Transcript](#), 28 April 2023

⁷⁰ Taiyangnews, [Jiangxi Jinko To Invest In 30 GW Ingots/Wafers, 24 GW Modules & 100,000 Ton Aluminum Frame Projects](#), 22 March 2022

⁷¹ PVTime, [10Bn Yuan! JinkoSolar Launches 10GW Solar Cell / 30GW Module Project in Yuhuan City of China](#), 29 March 2023

respectively, with the Phases III and IV due for commissioning in 2025.⁷² This would double JinkoSolar’s total global capacity over the next two years, taking the group to a cumulative 146GW pa of modules by 2025. An important reason JinkoSolar picked Shanxi as the site of this plant is accessibility to green electricity. As a RE100 member, JinkoSolar said it picked a site to satisfy this mass-scale production with a reliable green electricity supply.⁷³

Chart 4.6: JinkoSolar Quarterly Shipments (MW)



Source: JinkoSolar, PV-Tech, March 2023 ⁷⁴

⁷² Taiyangnews, [Massive PV Manufacturing Complex In China: JinkoSolar Plans RMB 56 Billion Vertically Integrated Solar PV Production Compound In Shanxi](#), 25 May 2023

⁷³ PV-Magazine, [JinkoSolar Announces Investment in Shanxi Vertical Integrated Factory. Propelling N-Type Technology Forward](#), 1 June 2023

⁷⁴ PV-Tech, [JinkoSolar expects n-type modules to account for 60% of total shipments in 2023](#), 13 March 2023

4.4 Trina Solar

Trina Solar aims to exit 2023 as the world's largest solar module manufacturer.

Trina Solar reported US\$9.38bn of module revenue in CY 2022, +76% yoy, representing the majority of Trina's total revenues in CY2022 of US\$12.5bn +83% yoy and net profit of US\$547m +96% yoy, a 16.2% return on equity.

Trina Solar's module shipments in 2022 totaled 43.1 GW (production 45.1 GW) on installed capacity of 51GW, and Trina Solar targets to nearly double production capacity 95 GW of module manufacturing capacity by end 2024. Trina is vertically integrated upstream into cell manufacturing, and is currently doubling its cell capacity from 35 GW to 70 GW by end 2024.⁷⁵

May 2023 saw Trina announce plans for a Rmb10.7bn (US\$1.55bn) 25 GW ingot factory in Shifang City, Sichuan province.⁷⁶

Besides China's domestic market, Trina Solar also leads global market share. January 2023 saw Trina Solar announce construction of a new 6.5GW wafer manufacturing facility in Vietnam, leveraging polysilicon supplied by US-based Hemlock Semiconductor to in turn exclusively supply the US. The move comes after the US Department of Commerce (DoC) determined in December 2022 that solar cell and module imports from Vietnam, Cambodia, Malaysia, and Thailand were circumventing antidumping and countervailing duty (AD/CVD) orders on cell and module imports from China.

Trina Solar's US subsidiary said it expects the wafers, cells, and modules imported from the new factory in Vietnam to "receive an exemption from circumvention."⁷⁷ This also addresses the US bans on solar imports from Xinjiang under the Uyghur Forced Labor Prevention Act (UFLPA). Production is expected to start as early as mid-2023.

Moreover, Trina Solar also announced in April 2023 that its latest rooftop solar module has landed in the Australian market, with a maximum power output of 440W and efficiency reaching 22%.⁷⁸

⁷⁵ Trina Solar Press Release, [Accumulative shipments of Trina Solar's modules totaled 140GW while 210mm module shipments exceeded 65GW by Q1 2023, ranking first globally](#), 27 April 2023

⁷⁶ PV-Magazine, [Trina Solar's new 6.5 GW Vietnam wafer plant to exclusively supply US market](#), 12 January 2023

⁷⁷ PV-Magazine, [Trina to build 25 GW ingot factory, Longi reduces wafer prices by 30%](#), 30 May 2023

⁷⁸ One Step off the Grid, [Powerful new Trina Solar rooftop module lands in Australia](#), 6 April 2023

4.5 JA Solar

China's JA Solar reported CY2022 sales reached Rmb72.9bn (US\$10.3bn) with employees totalling 32,500. JA Solar reported its 2021 module production capacity globally was 40 GW, with plans to reach 50 GW by the end of 2022, and then 80 GW by the end of 2023. Its wafer and solar cell capacity will continue to maintain about 90% of the module capacity.^{79 80}

February 2022 saw JA Solar announce a Rmb3.45bn (US\$486m) investment to add 14 GW of new capacity in China and Vietnam. This included a 10 GW of module capacity at Yiwu, China, 1.3 GW of cell capacity at Ningjin county in China's Shandong province, and 2.5 GW of new wafer capacity in Vietnam's Bac Giang province.

December 2022 saw JA Solar announce plans to invest Rmb11.5bn (US\$1.62bn) to add 10 GW of new wafer capacity and 10 GW of cell capacity at its factory in Shijiazhuang, in China's Hebei province. The company also said it will add 10 GW of PV cells and 10 GW of module capacity to its manufacturing facility in Dongtai, Jiangsu province in China.⁸¹

January 2023 saw JA Solar announce plans to invest Rmb40bn (US\$5.7bn) to build a vertically integrated 20 GW of wafer, 30 GW of cells and 10 GW of module capacity in Ordos, Inner Mongolia.⁸²

January 2023 also saw JA Solar announce plans to invest Rmb408m (US\$60.5m) in building a 2 GW PV panel factory in Arizona, U.S.⁸³ The factory is expected to create 600 new jobs.

4.6 Risen Energy

Risen Energy is a leading, global, Tier 1 manufacturer of high-performance solar products and provider of total business solutions for power generation, founded in 1986 and publicly listed in 2010. It had global sales in CY2022 of Rmb293.8bn (US\$41.5bn) and 10,000 employees.⁸⁴ Risen expects to exit 2023 with 45GW of solar module manufacturing capacity, up from 30 GW at the end of 2022. June 2021 saw Risen announce a 3 GW solar cell and module manufacturing facility in Malaysia, with the stated intent to invest US\$10bn in manufacturing and solar project developments across South East Asia and Australia.

⁷⁹ Solarbe Global, [JA Solar announces major production ramp-up plan](#), 13 December 2022

⁸⁰ Solarbe Global, [Major expansion plans: JA Solar invests \\$847m in new facility](#), 6 June 2023

⁸¹ PV-Magazine, [Tongwei, JA Solar reveals capacity expansion plans](#), 13 December 2022

⁸² PV-Tech, [JA Solar to build US\\$5.9 billion PV industry hub in China](#), 23 January 2023

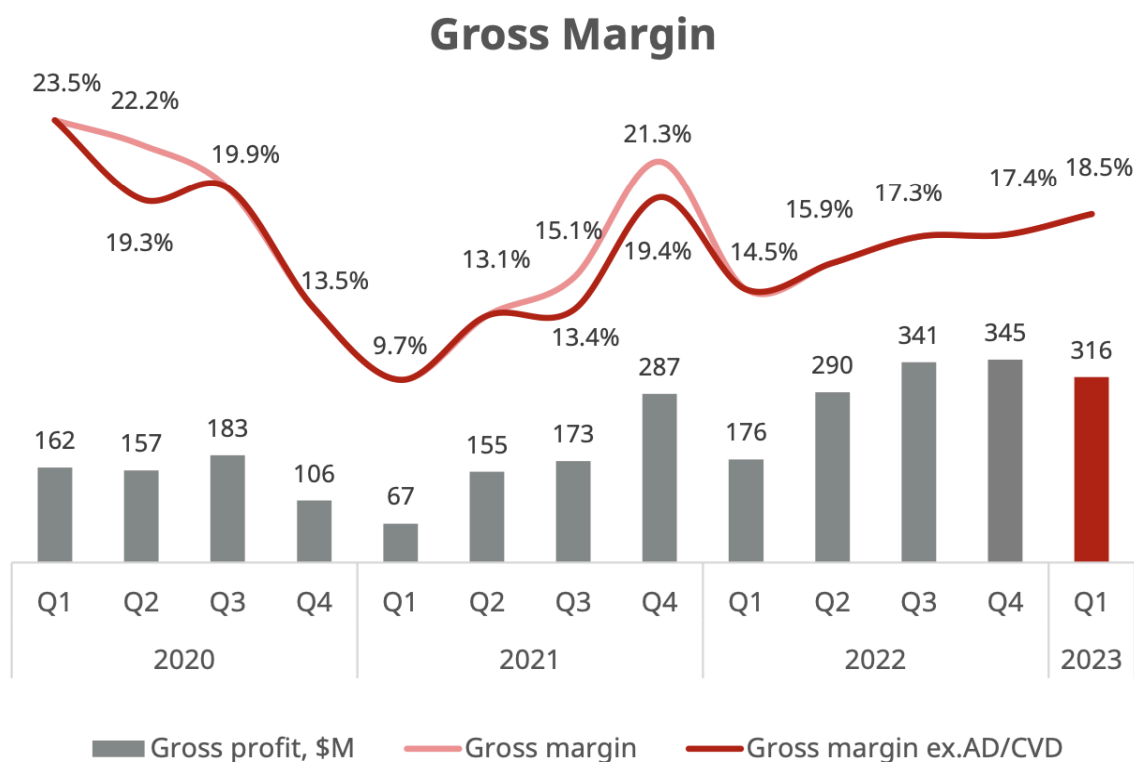
⁸³ PV-Magazine, [JA Solar plans to build 2 GW solar module factory in US](#), 11 January 2023

⁸⁴ Risen Energy

4.7 Canadian Solar

Canadian Solar is a US listed company with a Canadian head office but with majority Chinese management and operations. Canadian Solar delivered 6.1 GW of module shipments in 1Q2023, generating revenues of US\$1.7bn (+36% yoy) and a solid gross margin at 18.7% (Chart 4.7), reflective of high module prices and falling polysilicon prices.⁸⁵

Chart 4.7: Canadian Solar's Gross Profit & Margin Trends (2020-1Q2023, US\$m)



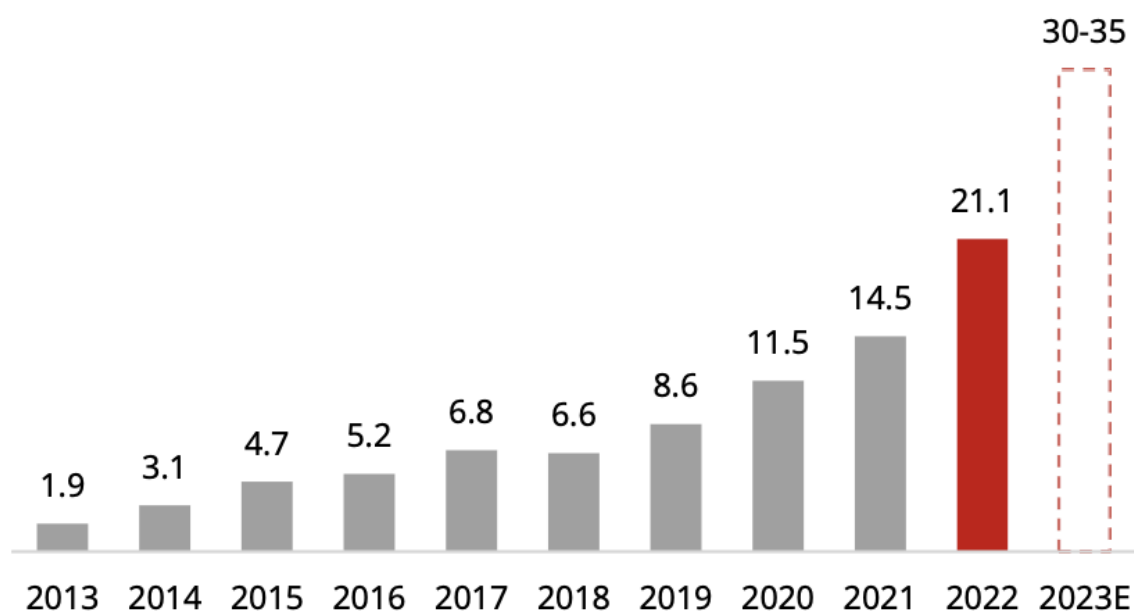
Source: Canadian Solar 1Q2023 Earnings Call, 18 May 2023 ⁸⁶

Canadian Solar forecasts module shipments for CY2023 will reach 30-35GW, a 42-66% yoy increase, as shown in Chart 4.8. Canadian Solar forecasts revenue of US\$9.0-9.5bn in CY2023, up 20-27% on the US\$7.5bn booked in CY2022, suggesting a ~20% decline in average selling price per unit.

⁸⁵ Seeking Alpha, [Canadian Solar Inc. \(CSIQ\) Q1 2023 Earnings Call Transcript](#), 18 May 2023

⁸⁶ Canadian Solar [1Q2023 Earnings Call](#), 18 May 2023

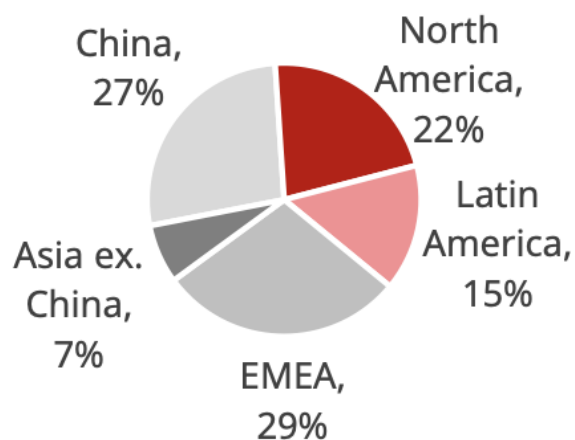
Chart 4.8: Canadian Solar Annual Module Shipments (GW)



Source: Canadian Solar 1Q2023 Earnings Call, 18 May 2023

Canadian Solar illustrates the global nature of China's solar module exports – Chart 4.9. With 29% of its revenue share in the Europe, Middle East and Africa (EMEA) region, 27% in China, and 22% in North America. 15% of Canadian Solar's revenue is in Latin America, and 7% from the Asia market outside China.

Chart 4.9: Canadian Solar's Geographic Revenue Breakdown (1QCY2023)



Source: Canadian Solar 1Q2023 Earnings Call, 18 May 2023

Canadian Solar, with a US\$1.5bn capex plan in CY2023, has announced a US\$1.2-1.3bn investment in a new 30GW solar wafer facility, with commissioning due by 2025.

Canadian Solar targets a 133% expansion in its global module manufacturing capacity over a 15 month time-period until March 2024, with a similarly aggressive 2-3 times expansion of upstream ingot, wafer and cell manufacturing capacity to ensure continued vertical integration for the majority of its output – Chart 4.10.

Chart 4.10: Canadian Solar’s Global Module Manufacturing Capacity (CY2022-CY2024)

GW	December 2022	December 2023	March 2024 (est)	Change 24 vs '22
Ingot	20.4	20.4	50.4	147%
Wafers	20.0	35.0	50.0	150%
Cells	19.8	50.0	60.0	203%
Modules	32.2	50.0	75.0	133%

Source: Canadian Solar 2022 Annual Report

In January 2023, Canadian Solar reached an investment agreement with the municipal government of Yangzhou City in Jiangsu Province. China plans to add vertically integrated high efficiency wafer, cell and module capacity, as well as battery system manufacturing capacity, in Yangzhou’s clean energy manufacturing industrial park. The implementation of the project includes three phases, with phase I adding 14 GW of annual wafer and cell capacity. Phase I is expected to commence production in 2HCY2023, while phases II and III are subject to market conditions. Canadian Solar expects to further increase the level of vertical integration and better control its costs, technology and product quality.

4.8 Tongwei Group

China-based Tongwei Group was the world’s largest polysilicon producer in 2022, with an effective 345,000 metric tonnes per annum (tpa) of capacity operational by the end 2022.⁸⁷ Tongwei is also China’s largest solar cell manufacturer.

March 2020 saw Tongwei plan a RMB20bn (US\$3.1bn), 30 GW cell manufacturing facility.⁸⁸

Tongwei targets a fivefold expansion in solar module production capacity to 80GW by the end of 2023, citing the booming China solar market fueled by the Dual Carbon policy of the central government to peak its carbon dioxide emissions before 2030 and be carbon neutral before 2060. The company is the world’s leading polysilicon and solar cell supplier with 70GW of solar cell capacity as at

⁸⁷ PV-Magazine, [Tongwei led global polysilicon capacity in 2022, says Bernreuter Research](#), 16 May 2023

⁸⁸ PV-Magazine, [Another massive polysilicon order, Tongwei starts operations at 30 GW cell factory](#), 1 June 2021

the end 2022, supporting its major downstream vertical integration, and the target to be the lowest cost supplier globally ⁸⁹

September 2022 saw Tongwei plan a Rmb4bn 25 GW module facility in Nantong, Jiangsu Province.⁹⁰

December 2022 saw Tongwei announce a second Rmb4bn (US\$0.6bn) 25 GW module facility in Yancheng City, Jiangsu Province.⁹¹

June 2023 saw Tongwei announce a Rmb10.5bn (US\$1.5bn) 25 GW solar cell and 20 GW module facility in Shuangliu District, Chengdu City, Sichuan province, for the construction of an integrated solar panel factory. Construction on the cell facility is expected to be completed within 2024, and the module facility as phase 2 for completion during 2025. ⁹²

4.9 GCL System Integration (GCL SI)

Chinese polysilicon through to module manufacturer GCL System Integration is a unit of Golden Concord Group Ltd (GCL). GCL is the world's second largest polysilicon producer behind Tongwei.

In March 2020 GCL SI filed a stock exchange announcement detailing plans to build the world's largest solar module manufacturing facility, with 60 GW pa capacity, in China's Anhui province for a total investment of US\$2.5bn, built over four phases of 15GW each with all four phases due for completion by the end of 2023. ⁹³ This represents a tenfold expansion on its existing capacity across six factories totalling 6GW, but three years on the expansion is well behind schedule.

October 2022 saw GCL SI announce a new 20GW TOPCon cell facility in Wuhu City, Anhui Province at a cost of Rmb8bn (US\$1.1bn).⁹⁴

March 2023 saw an announcement of plans to commence operations of a 12 GW solar factory in Funing county, Jiangsu province by October 2023, with a US\$290m investment to take total module capacity to 30 GW pa. GCL also announced plans to invest Rmb3.9bn (US\$500m) in a new TOPCon solar cell factory with a capacity of 10 GW in Wuhu, Anhui province.⁹⁵

⁸⁹ Taiyangnews, [SNEC Exclusive: Tongwei Chairman Interview](#), 25 May 2023

⁹⁰ PV-Magazine, [Tongwei, JA Solar reveals capacity expansion plans](#), 13 December 2022

⁹¹ PVTime, [4 Billion Yuan! Tongwei to Launch 25GW Solar Module Project in Yancheng City of China](#), 23 September 2022

⁹² Shanghai Stock Exchange, (600438), [Announcement on Investment in 25GW Solar Cell and 20GW Photovoltaic Module Project in Shuangliu District, Chengdu](#), 7 June 2023

⁹³ PV-Magazine, [GCL starts building 12 GW solar module factory](#), 30 March 2020

⁹⁴ GCL SI Press Release, [8 Billion Yuan! GCLSI to Launch 20GW TOPCon Solar Cell Project](#), 31 October 2022

⁹⁵ PV-Magazine, [GCL starts building 12 GW solar module factory](#), 30 March 2020

4.10 Daqo New Energy

Daqo New Energy is the world's third largest polysilicon producer behind Tongwei and GCL. Daqo sold 132,909 Mt of polysilicon in 2022, a 76% yoy increase from 75,356 Mt in 2021. 2022 revenues were US\$4.6bn, +174% yoy vs US\$1.7bn in 2021. Earnings before interest and tax (EBIT) was US\$3.04bn in 2022, +190% yoy vs US\$1.1bn in 2021, an EBIT margin of 66% in 2022 (63% in 2021).

Daqo had an average production cost of US\$769/kg in 4QCY2022, which indicates the magnitude of scope for the polysilicon price to even further (refer Section 1.5). Daqo's production is forecast to grow another 45% yoy to ~195,000Mt in CY2023.⁹⁶

Daqo increased total capacity to 35,000Mt in June 2019. Daqo completed its Phase 4A project to full production capacity in December 2019, doubling capacity to 70,000Mt. Daqo began its Phase 4B project in March 2021 and completed the construction of the 35,000Mt project in December 2021. This took Daqo's total annual production capacity to 105,000Mt, a trebling of capacity in just 2.5 years. Daqo then announced a Phase 5 plan to build polysilicon projects with a total annual capacity of 200,000Mt to take total annual capacity of 300,000Mt in Baotou, Inner Mongolia. The Phase 5A project for a 100,000Mt polysilicon project began in March 2022, and was completed in April 2023. Daqo began the construction of its 100,000Mt Phase 5B project in March 2023 and expect to complete it by the end of 2023.⁹⁷

Daqo's 1QCY2023 results state: "We believe a new era for Solar PV has just begun. The continuous cost reduction in solar products is expected to create substantial additional green energy demand likely exceeding most analysts' expectations. It is generally expected that solar PV will eventually become one of the most important energies to power the world. In addition, as solar PV technology keeps evolving, we believe that the increasing needs for polysilicon of very high purity will help differentiate us from our competitors thanks to our ability to produce the type of polysilicon required for the next generation of N-type technology. We will continue to maintain solid growth and make sure to have one of the best balance sheets in the industry in order to capture the long-term benefits of the global solar PV market."

We detail a some key financial metrics for Daqo over the last four years to illustrate the massive scaling up of the group, with revenues more than doubling each year since 2019. What Daqo also shows is that despite massive US\$2.1bn capex funded over 2019-2022, this has been funded entirely by retained earnings and minority equity. Given the extreme volatility of solar sector pricing, Daqo has been exceptionally prudent in terms of its lack of financial leverage, and has even been buying back shares as it has gone deep into net cash (US\$3.2bn as at December 2022). Customer advances and deferred capex payment terms feature, as does government subsidies to a lesser extent.

⁹⁶ PV-Magazine, [Daqo records average polysilicon price of \\$32.54/kg in 2022](#), 3 March 2023

⁹⁷ Daqo 20F-2022

While 2021 and 2022 was a landmark year in terms of capacity expansion, excessive returns were a key feature, with cash returns on assets (EBITDA/Total Assets) of 33.7% and 41.4% pa in 2021 and 2022 respectively, even as the firm massively scales up its capacity. EBIT margins were a record 66.0% in 2022, way up on the 13.6% delivered in 2019 when polysilicon prices were low. But this also highlights that China's now dominant polysilicon sector can absorb massive price cuts of up to two-thirds by profit margin compression. 2023 will see significant volume growth, but lower revenues on the back of collapsing unit prices and smashed profit margins as pricing deflation resumes its course after 3 years of above trend pricing – Chart 4.11.

Chart 4.11: Daqo - Key Financial Metrics (US\$m)

Year ended 31 December	2019	2020	2021	2022
US\$m				
Total Assets	1,201	1,239	3,344	7,594
Net Debt (Cash)	369	170	(652)	(3,257)
Paid in Equity	366	437	1,083	1,908
Retained Earnings	201	330	1,079	2,899
Minority Equity	1	32	502	1,797
Revenue	350	676	1,679	4,608
EBITDA	95	257	1,128	3,147
EBIT	48	188	1,051	3,040
Net Profit after tax (pre-MI)	30	134	865	2,480
Capex	286	118	509	1,250
Revenue Growth (%)	16.0%	93.0%	148.5%	174.5%
EBITDA Margin (%)	27.1%	38.0%	67.2%	68.3%
EBIT Margin (%)	13.6%	27.8%	62.6%	66.0%
Cash Return on Assets (%)	7.9%	20.7%	33.7%	41.4%
EBIT Return on Assets (%)	4.0%	15.2%	31.4%	40.0%

Source: Daqo New Energy Corporation 20F 2022 Annual Report

4.11 Other Chinese Solar Corporate Leaders

The solar manufacturing sector in China is transforming and growing at an unprecedented speed, and it is beyond the scope of this paper to detail all major players. Reports suggest that there are 67 Chinese enterprises investing in the latest new solar module technologies, including 22 new companies. 12 solar manufacturing enterprises are planning on exceeding module production capacity of 30 GW pa, including Jietai Solar (44 GW) and Runergy (36 GW). We detail some of the second-tier solar manufacturers in China in this section, most of which are at least as large as any of the major solar firms from the developed world that are featured in this report.⁹⁸

Xinte Energy

TBEA-owned Xinte Energy is the world's fourth largest polysilicon producer behind Tongwei, GCL and Daqo, having overtaken Germany's Wacker Chemie in 2022. March 2022 saw Xinte announce plans to invest Rmb17.6bn (US\$2.8bn) to build another 200,000 metric tpa polysilicon facility in the Xinjiang Uygur autonomous region, with a scheduled completion in just 24 months.⁹⁹ TBEA is also a major solar inverter manufacturer.

BYD

The world's largest EV manufacturer, China's BYD, entered the solar module manufacturing sector in 2008. BYD makes wafers, cells and modules of a total capacity of 5GW pa.¹⁰⁰ BYD states its heterojunction panels promise great potential as they offer the chance to harness perovskite technology and potentially lift module efficiency to new highs.

Contemporary Amperex Technology Co. Ltd (CATL)

The world's largest EV battery manufacturer, China's CATL, revealed in May 2023 that it is exploring options to enter the solar manufacturing sector, leveraging the potential R&D breakthrough of perovskite cells, among the most promising methods to drive new improvements in solar panel performance. CATL also announced an agreement with JA Solar to cooperate on scientific innovations, marketing and storage.¹⁰¹

Shanghai Tianchen Co.

In May 2023 Shanghai Tianchen announced it would build a Rmb11.6bn (US\$1.7bn) investment in a phase I 5GW solar cell factory in agreement with the government of Wuhu City, in China's Anhui Province. Tianchen said the new factory is planned to have an annual solar cell capacity of 20 GW and a battery capacity of 20 GW.¹⁰²

⁹⁸ Solarbe Global, [TOPCon cells capacity may reach 518GW in 2023, 117GW for heterojunction](#), 14 April 2023

⁹⁹ PV-Magazine, [Chinese PV Industry Brief: Xinte wants to add another 200,000 tons of polysilicon capacity](#), 15 March 2022

¹⁰⁰ Bloomberg, [EV Battery Leader CATL Joins BYD, Tesla to Tap Solar's Boom](#), 26 May 2023

¹⁰¹ Bloomberg, [EV Battery Leader CATL Joins BYD, Tesla to Tap Solar's Boom](#), 26 May 2023

¹⁰² PV-Magazine, [Shanghai Tianchen enters solar cell production with 20 GW factory](#), 5 May 2023

In February 2022, Shanghai Tianchen signed an agreement with Chinese module maker Huasun Solar to set up a joint venue for the development of heterojunction solar modules. February 2023 saw Huasun start manufacturing panels in Anhui at its HJT solar cell factory in Xuancheng with a capacity of 2.4 GW pa and a reported cell efficiency of 25.26%. Huasun announced in September 2022 plans for 7.2GW pa capacity at its HJT solar cell production facility in Anhui province using Maxwell Technology equipment, due online by end 2023.¹⁰³

TCL Zhonghuan Semiconductor Co

TCL Zhonghuan reached revenues of US\$6.1bn and 40 GW of solar wafer manufacturing capacity in 2021.

January 2022 saw TCL Zhonghuan plans to increase the production capacity of wafers to 30 GW pa.¹⁰⁴

TCL Zhonghuan Semiconductor Co is a 24.2% owner of Maxeon Solar US.

Aiko Solar Energy Co.

Shanghai listed Aiko Solar reports cell capacity of 42.5GW (up from 22 GW in 2020) and 9,100 employees with sales of Rmb35bn (US\$5bn) in CY2022. April 2023 saw Aiko Solar announce a Rmb36bn (US\$5bn) 30 GW integrated solar cell and module factory in Jinan in Shandong province in three 10 GW phases over the coming 5 years.¹⁰⁵ Aiko targets cell capacity of 50 GW pa at its Zhejiang facility and another 26 GW of capacity at its Zhuhai facility, taking total capacity up 80% on its 2022 base.¹⁰⁶

FuturaSun of Italy

FuturaSun is an Italian based, globally focussed integrated solar firm with 1GW pa of solar module manufacturing capacity in Taizhou, East China.¹⁰⁷ FuturaSun is currently developing a second 1GW factory in Suzhou, Jiangsu province. May 2023 saw FuturaSun announce a vertical integration strategy with the launch of a €150m 10 GW solar cell factory in Huai'an, in the province of Jiangsu. It aims to start production in spring 2024.¹⁰⁸

Huonen Solar

Huonen Solar is a Chinese module maker company with its headquarters based in Zhejiang Province, China. March 2023 saw Huonen Solar announce a plan to invest US\$33m via Huonen's subsidiary in the U.S. to acquire a factory in Orangeburg, South Carolina, U.S.¹⁰⁹ According to Huonen Solar, the new factory will create 200 job opportunities. Huonen Solar is the third Chinese solar manufacturer to

¹⁰³ PV-Magazine, [Chinese PV Industry Brief: Maxwell secures 7.2 GW order for HJT solar lines](#), 6 September 2022

¹⁰⁴ Solarbe Global, [Zhonghuan Semiconductor subsidiary to increase G12 capacity to 30 GW](#), 13 January 2022

¹⁰⁵ Solarbe Global, [Aiko Solar to invest 36 billion for 60GW cell module production](#), 24 April 2023

¹⁰⁶ [Aiko Solar](#), 2022 ESG Report, accessed 2 June 2023

¹⁰⁷ [FuturaSun](#), accessed 2 June 2023

¹⁰⁸ PV-Magazine, [FuturaSun to start PV cell production with 10 GW solar factory in China](#), 12 May 2023

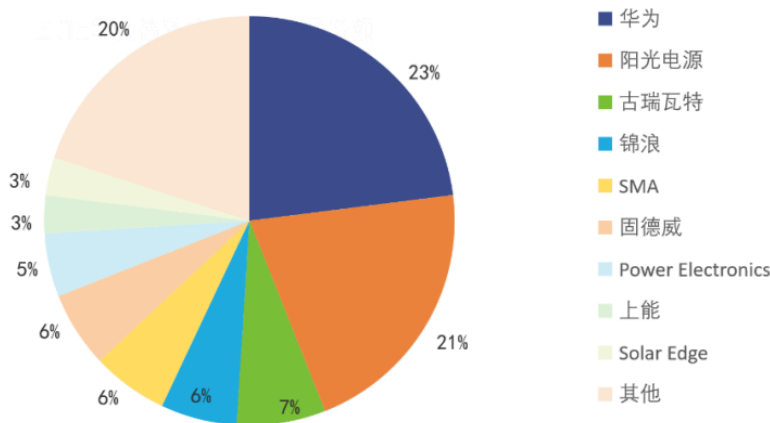
¹⁰⁹ PV-Magazine, [昊能光电将在美国建造1 GW太阳能组件工厂](#), March 2023

announce plans to build a factory for solar manufacturing in the soil of the U.S. since the launching of the IRA.

Huawei

As the leading global provider of information and communications technology (ICT), Huawei also entered the field of PV inverters in 2011.¹¹⁰ In 2021, Huawei has already dominated the global inverter market with a total of 23% of the market share as shown in the chart below.

2021年光伏逆变器市场格局



来源: Wood Mackenzie, 西部证券研发中心

Source: Wood Mackenzie¹¹¹

March 2022 saw Huawei Digital Energy Technology Co., Ltd sign an agreement with Jiahua Mineneg Technology Co., Ltd - a leading PV developer in West Africa - to build a 1 GW ground-mounted PV power station and a 500 MWh energy storage project developed by Huami Energy in Ghana.¹¹²

Royal Group

August 2022 saw the Royal Group, a leading Chinese dairy firm, announce plans for a 20 GW solar cell factory in Fuyang city, Anhui province.¹¹³

¹¹⁰ OFweek, [华为又一个鲜为人知的隐秘帝国](#), 18 May 2023

¹¹¹ <https://solar.ofweek.com/2023-05/ART-260002-8460-30597031.html>

¹¹² Solar Huawei, [1 GW + 500 MWh! 佳华美能与华为携手助力加纳绿色发展](#), 7 March 2022

¹¹³ Solarbe Global, [Dairy company to build 20 GW TOPCon solar cell fab](#), 17 September 2022

Suntech

February 2022 saw the commencement of construction for a new 10 GW PV module production facility (Phase 1) at Fengyang County, Chuzhou City. Phase 2 will take this up to 20 GW pa of module capacity,¹¹⁴ trebling total installed capacity relative to the 10 GW of 2020.

Znshine Solar

June 2023 saw Znshine Solar announce plans to invest Rmb5bn (US\$0.7bn) in 10 GW solar cell facility in Ganyu.¹¹⁵

Lingda Group

June 2023 saw Lingda Group announce it will invest Rmb9.15bn (US\$1.3bn) in a 20 GW PV cell facility in partnership with Tongling Shizishan High-tech Zone Management in Shizishan High-tech Zone.¹¹⁶

¹¹⁴ Suntech Power, [Cornerstone Laying Ceremony of Fengyang Suntech 10GW PV Module Production](#), 15 February 2022

¹¹⁵ Solarbe Global, [LONGi To Invest In Silicon Ingot And Cell Facilities & More From Tongwei, JA Solar, Autowell, Znshine, YC Solar](#), 7 June 2023

¹¹⁶ Solarbe Global, [DAS Solar Announces Latest N-Type Product Prices & More From TaiyangNews, Goodwe, TCL Zhonghuan, Lingda, Fusion, Boamax](#), 1 June 2023

Section 5: America

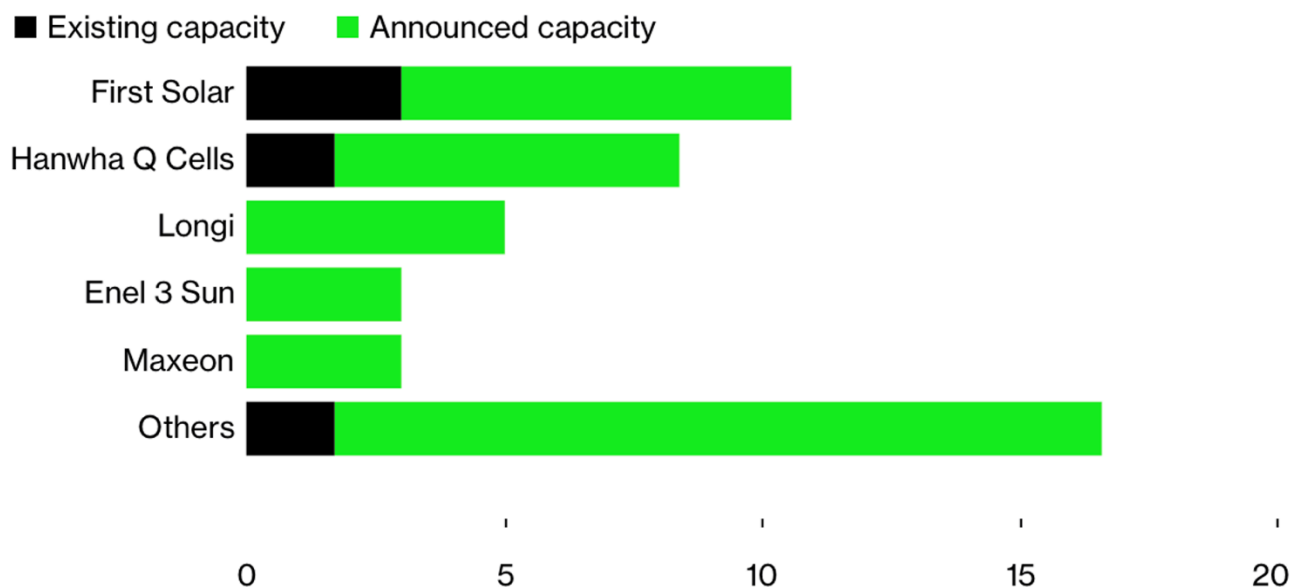
The US Inflation Reduction Act is spurring a surge of clean energy investments, with a sixfold expansion in US solar module manufacturing capacity by 2024 and a likely doubling of annual solar installs to 40-50 GW annually through to the end of this decade.

BNEF calculates that the US has seen solar module manufacturing capacity announcements sufficient to take total capacity to over 40 GW by the end of 2024, a six-fold expansion vs current rates – Chart 5.1.¹¹⁷ Further, the US could see solar installs rise fourfold with the addition of 360 GW of solar by the end of this decade, 40-50 GW annually.¹¹⁸

Leading Chinese manufacturers Longi, JinkoSolar and Canadian Solar are each considering US domestic cell and module manufacturing as well as sourcing domestic glass and aluminium to circumvent US import duties and restrictions and comply with US IRA requirements of domestic manufacturing content.

April 2023 saw JinkoSolar receive US\$2m DoE funding for a 1GW pa module factory expansion at Jacksonville, Florida.¹¹⁹ In May 2023, the U.S. Department of The Treasury issued a clarification stating that developers of US solar projects can apply for the new 30% IRA tax credit, as well as an additional 10% project cost subsidy for locally manufactured projects even if the US assembled modules use Chinese sourced cells, so long as 40% of the total components are US sourced.¹²⁰

Chart 5.1: Producers Plans to Expand Solar Module Manufacturing Capacity by end 2024 (GW)



Source: Bloomberg NEF

¹¹⁷ Bloomberg, [Biden's Landmark Climate Bill Lures China's Clean Energy Giants](#), 2 April 2023

¹¹⁸ Bloomberg, [Solar Panel Orders Point to Clean Energy Boom From US Climate Law](#), 4 May 2023

¹¹⁹ Solarbe Global, [Jinko Solar gets approval to expand US plant](#), 26 April 2023

¹²⁰ Solarbe Global, [Solar projects using cells from China can apply for IRA subsidies](#), 16 May 2023

5.1 Inflation Reduction Act

The IRA introduced an Advanced Manufacturing Production Credit in August 2022 for solar modules and solar module components manufactured in the US and sold to third parties. The credit, which may be refundable or transferable to a third party, is available through 2032, subject to phase down beginning in 2030.

As cleantech consultancy Apricum reports, IRA financial incentives subject projects to stringent local content requirements. In order to qualify for an additional 10% tax credit, local content must constitute 40% of the project if starting construction pre-2025, rising by 5% p.a., to 55% for projects starting construction in 2028.¹²¹

This builds on the existing Federal Investment Tax Credit (ITC) for business and residential solar systems, reinstated by Congress at 30% through to 2032 as part of the IRA. The credit is currently scheduled to step down to 26% for projects that commence construction in 2033, 22% for projects that commence construction in 2034, and will expire thereafter. The positive impact of the ITC depends on the availability of tax equity for project financing or the ability to transfer the ITC to other taxpayers.

5.2 US Solar Import Tariffs

The US currently imposes different types of tariffs on certain imported crystalline silicon PV cells and modules from various countries.

In February 2022, the President proclaimed a four-year extension of a global safeguard measure under the 1974 Trade Act that provides for tariffs on imported crystalline silicon solar modules of 14.4%, excluding imports of bifacial modules. The extension measure also provides an annual tariff-rate quota, whereby tariffs apply to imported crystalline silicon solar cells above the first 5.0 GW_{DC} of imports.

The US currently imposes antidumping and countervailing duties on certain imported crystalline silicon cells and modules from China and Taiwan. The duties change over time, subject to annual reviews conducted by the U.S. Department of Commerce (USDOC). In March 2022, the USDOC initiated inquiries into alleged circumvention of these duties on Chinese imports by cells and module imports assembled in Cambodia, Malaysia, Thailand, and Vietnam. In December 2022, the USDOC determined there was “country-wide” circumvention of the duties in those four countries, but it also found that certain firms were not circumventing the antidumping duties. The USDOC was scheduled to issue its final circumvention determinations in May 2023, with this date subject to extension.

¹²¹ Apricum, [US utility scale solar opportunities and risks in a post IRA environment](#), 7 February 2023

5.3 First Solar

First Solar is the US's leading solar module manufacturer, with current installed capacity of 9.8GW for the production of polycrystalline thin film Cadmium Telluride (CdTe) modules. CY2022 production was 9.1 GW, with plans to expand to 16GW by the end of 2023 and 21.4GW by 2026.

First has a current installed US capacity of ~3GW, and plans to expand to 10.7GW by 2026.

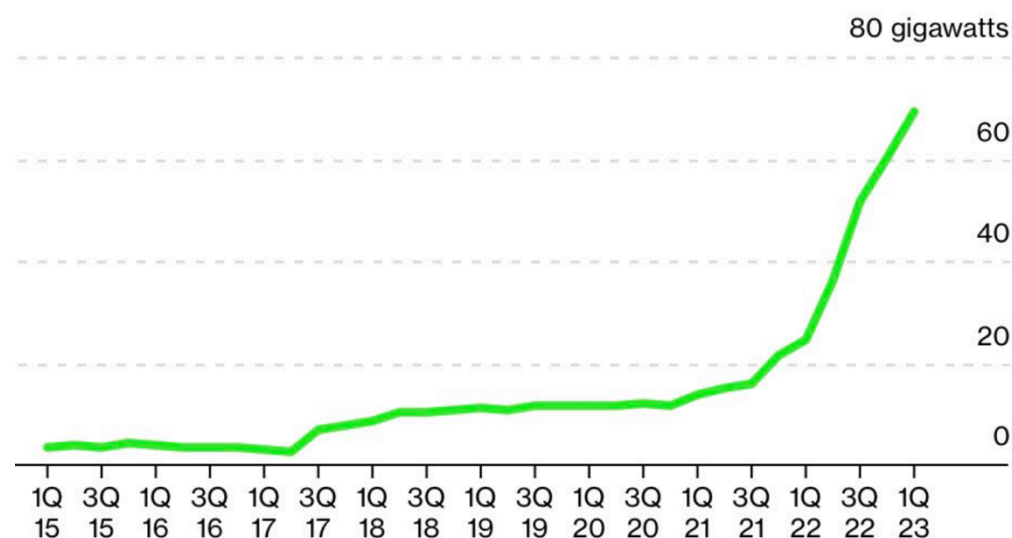
In August 2022, First Solar announced it would build its fourth US module factory with an investment of US\$1bn in a new, 3.5 GW_{DC} manufacturing facility in Alabama and an expectation it would commence operation in 2025.

At that time, First Solar also announced a US\$185m investment to upgrade and expand its manufacturing footprint across two factories in Ohio by 0.6 GW_{DC} to 3.6 GW_{DC} pa of module capacity. It commissioned its third Ohio factory in the first half of 2023, adding 3.5 GW_{DC} new capacity. These two expansions will increase First Solar's total Ohio manufacturing facilities to a cumulative annual production capacity of 7 GW_{DC} by 2025.¹²²

First Solar also operates factories in Vietnam and Malaysia, and is building its first new manufacturing facility in India of 3.4 GW pa capacity, scheduled to begin operations in the second half of 2023. On completion of its expansion plans in the US and India, the company expects to have over 20 GW_{DC} of annual global manufacturing capacity in 2025.

Bloomberg charts the direct impact of the IRA on First Solar's orderbook, which has increased 400% in the last 18 months – Chart 5.2:

Chart 5.2: First Solar Quarterly Order Book(GW)



Source: Bloomberg Intelligence, *BloombergNEF's Nat Bullard*, 4 May 2023

¹²² First Solar US Press Release, [First Solar to Invest up to \\$1.2 Billion in Scaling Production of American-Made Responsible Solar by 4.4 GW](#), 30 August 2022

First Solar invested US\$270m in R&D in CY2022, and reports a module efficiency of 19.7% (on a cell efficiency of 22.3%). It reports a module energy payback time of just four months, which represents a 90-fold energy return on investment over a theoretical 30-year system lifetime, with 0.3% annual degradation.

The IRA is spurring a boom in renewable energy investments in the US. Protected by domestic content rules and the module import duties, US solar firms are seeing a surge in earnings before interest, tax, depreciation and amortisation (EBIDA) margins in 2023. CEF would expect the dramatic reduction in polysilicon prices in 1H CY2023 to see solar module prices decline materially into 3CY2023 and beyond, spurring on solar energy installations.

Chart 5.3: US Listed Solar Majors: EBITDA Margin Trends (2019-2023 est.)

	Ebitda Margin				
	2019	2020	2021	2022	2023E*
Array Technologies		18%	5%	8%	14%
Canadian Solar	9%	10%	7%	8%	11%
Enphase	23%	27%	27%	32%	32%
First Solar	12%	14%	29%	9%	32%
Maxeon Solar		-5%	-16%	-10%	8%
Sunnova	37%	37%	36%	21%	27%
Sunrun	-3%	-24%	-17%	-9%	-8%
SolarEdge	15%	12%	13%	16%	21%
Shoals		35%	29%	28%	31%
SunPower	5%	4%	4%	5%	6%
Median	12%	13%	10%	9%	17%

Note: *Based on MODL Consensus as of June 6, 2023

Bloomberg Intelligence BI

Source: Bloomberg Intelligence, Rob Barnett, 9 June 2023

Hanwha Q Cells of South Korea

January 2023 saw Hanwha Q Cells of South Korea announce plans to invest US\$2.5bn to treble its integrated Georgia solar manufacturing capacity from 1.7GW pa as of 2022 to 8.4GW by 2024.¹²³ This involves a new facility in Bartow County, where it will manufacture 3.3 GW of solar ingots, wafers, cells and modules. Its existing facility in Dalton will expand from 1.7 GW to 5.1 GW. Q Cells is also the largest shareholder in REC Silicon, which is building a new polysilicon facility in Washington state due for commissioning in the second half of 2023.

¹²³ Reuters, [S.Korea's Hanwha Q Cells to invest \\$2.5 bln total in U.S. solar manufacturing](#), 11 January 2023

Maxeon Solar Technologies

Maxeon Solar Technologies (a 2020 spinoff from SunPower Corporation US), NYSE listed and 24.7% owned by TotalEnergies of France and 24.2% by China's Tianjin Zhonghuan Semiconductor Co, is in the due diligence phase for a DoE LPO loan guarantee. Maxeon is planning to expand beyond its current ~2.5GW pa of solar module manufacturing bases in Malaysia, Mexico and Philippines with the addition of a 1.8GW of US bifacial module manufacturing capacity.¹²⁴ This capex is being funded by a May 2023 equity raising of US\$199m, supported by TotalEnergies and Tianjin Zhonghuan.¹²⁵

Maxeon also owns a 16% equity stake in its Huansheng Solar joint venture (JV), which currently has a capacity to supply 12 GW pa of solar panels, with plans for expansion of capacity in 2023 to 20 GW.

ENEL Green Power of Italy

November 2022 saw Enel of Italy announced plans for its US subsidiary 3Sun USA LLC to commence building a 3 GW bifacial HJT solar cell and module facility in the US with a commissioning date slated for end 2024.¹²⁶ Enel has suggested scope to double this capacity to 6GW pa. This follows Enel's move to build the 3Sun Gigafactory in Catania, Italy where Enel plans a 3 GW pa facility supported by EU funding.

SEG Solar

March 2023 saw SEG announce plans to invest US\$60m in a 2 GW module plant in Houston, Texas.¹²⁷

Meyer Burger of Germany

May 2023 saw Meyer Burger announce a 2 GW solar cell manufacturing facility in Goodyear, Arizona to vertically integrate with its existing solar module manufacturing facility there.¹²⁸

¹²⁴ [Maxeon 20-F](#)

¹²⁵ PV Magazine, [Maxeon raises \\$199.4m for IBC module manufacturing expansion](#), 22 May 2023

¹²⁶ Taiyangnews, [IRA Brings Enel To US; Italian Group To Build 3GW Cell & Module & Scale Up To 6 GW](#), 18 November 2022

¹²⁷ PV-Tech, [SEG Solar completes funding of 2GW Texas TOPCon module factory](#), 20 March 2023

¹²⁸ PV Magazine, [Meyer Burger considering US solar cell production](#), 31 May 2023

Section 6: India

India targets a trebling of annual solar installs over the coming five years, and has introduced a 40% solar module import duty and a Solar Performance Linked Scheme (PLI) to incentivise solar manufacturing, leading to 110 GW of module manufacturing commitments.

An exciting report emerged in 1QCY2023 that India's draft new National Electricity Policy (NEP) has proposed that India stop building of new coal-fired power plants beyond those already under construction.¹²⁹ This proposal complements the report that India is looking to tender out 250GW of new RE projects by FY2028.¹³⁰ At 50 GW annually, this is more than triple the run-rate of the last three years. With 4.5 GW of new tenders building on the 4.95 GW of RE tenders auctioned and allotted in April 2023 alone, the Government of India is off to a good start.¹³¹

It remains to be seen if this mooted amendment is approved by the national cabinet chaired by PM Narendra Modi, and then implemented. Without getting too excited preemptively, this strategic shift is potentially a critical, globally significant milestone in decarbonisation, highlighting the accelerating global investment and technology race to build out the zero emissions industries of the future, put into overdrive by the US IRA.

The Union Minister for Power and New and Renewable Energy RK Singh has made energy security and decarbonisation key objectives for India, as energy demand escalates, stating in May 2023: "We have pledged that 50% of our capacity will come from non-fossil fuels by 2030. This trajectory will be adhered to. Our electricity demand is growing rapidly. By 2030, energy consumption is expected to double. We will need to add capacity so that our country can grow. Net Zero is important, but what is more important is that we ensure enough electricity for our growth." Whilst solar and wind are key priorities, so is hydro for firming, particularly until batteries are more commercially viable. Additionally, India considers nuclear another source of zero emissions domestic electricity supply.¹³²

May 2023 saw India's Central Electricity Authority report on the most cost-effective and optimal generation capacity mix for India in FY2030. It found that a generation capacity of 777 GW, with renewables accounting for 62.4% (485 GW), supported by 42 GW/208 gigawatt hours (GWh) of battery energy storage systems, is the operationally feasible solution to meet the country's electricity demand.¹³³

¹²⁹ Independent, [India pauses plans to add new coal plants for five years, bets on renewables](#), batteries, 2 June 2023

¹³⁰ ET EnergyWorld, [Govt unveils plans to add 250GW renewable energy capacity in next five years](#), 5 April 2023

¹³¹ JMK Research, [Monthly RE update – April 2023](#)

¹³² ET, [Net Zero is important, but we must provide enough electricity for growth: Power Minister RK Singh](#), 26 May 2023

¹³³ PV Magazine, [India's optimal electricity generation mix for 2029-30](#), 16 May 2023

6.1 Solar in India

India targets 450 GW of renewable energy by 2030, or 500 GW including hydro-electricity. This compares to the 125 GW of renewable energy installed as at April 2023, representing 30% of total installed capacity in India (172 GW including hydro, 41% share of capacity).¹³⁴

Installed solar capacity stands at 67 GW as at April 2023, representing 53% of the renewable total, and India has been installing 12-14GW pa of solar. The government target is to install 50 GW renewables annually over the next five years, i.e. 40 GW of solar and 10 GW of wind, triple current run rates.

The Ministry of New and Renewable Energy ([MNRE](#)) in May 2023 announced reforms in its [Approved List of Models and Manufacturers \(ALMM\)](#) mechanism for solar modules, lowering the application and inspection fees by 70-80% with a commitment to speed up approvals to ease business. MNRE has introduced an end-use minimum module efficiency threshold for enlistment in ALMM. This stands at 20% for grid-scale power plants, 19.5% for rooftop and solar pumps, and 19% for solar lighting.¹³⁵

For a dramatic lift in variable renewable energy share in India, the concurrent expansion of hydro, pumped hydro storage and batteries is a key priority for the Government of India. Important to see this new June 2023 development of 5.7 GW of proposed new investments in pumped hydro storage by Torrent Power.¹³⁶

¹³⁴ Central Electricity Authority, [All India Installed Capacity Report](#), April 2023

¹³⁵ ET EnergyWorld, [MNRE announces ALMM reforms to ramp up domestic solar module manufacturing](#), 15 May 2023

¹³⁶ PV Magazine, [Pumped hydro storage development surging in India](#), 7 June 2023

6.2 Solar Manufacturing in India

The MNRE's May 2023 ALMM consists of 91 module manufacturing facilities with aggregate solar PV module manufacturing capacity of a nameplate (or maximum) 22.4 GW per year.

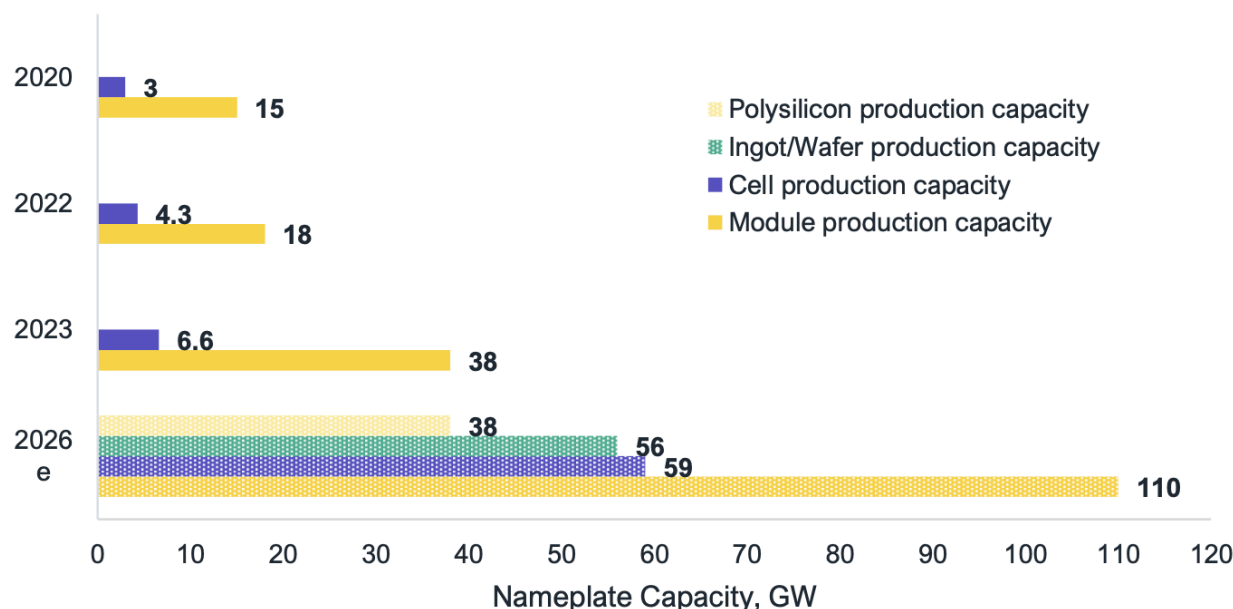
Tata Power, India's largest integrated power company, estimated effective capacity in 2022 at 8.8GW for modules and just 2.5GW for cell manufacturing. Climate Energy Finance considers this a more realistic assessment of the effective capacity available and producing, given many plants have high nameplate capacities but low operating rates, and do not have the scale and modern technology access to remain viable.

India's Prime Minister Narendra Modi has made solar supply chain security a key government priority, both to reduce over-reliance on Chinese supply chain dominance, and to drive domestic investment and employment opportunities as India pursues its decarbonisation objectives.

India has long toyed with the import duties and tiered solar tariff tenders that prioritise domestic production. It introduced a BCD on solar imports of 40% on panels and 25% on cells from April 2022. This adds to the 20% duty on inverters that came into effect in February 2021. This prioritisation of domestic solar manufacturing was enhanced in 2022 with the solar Performance Linked Scheme (PLI) – refer Section 6.3.

Having doubled capacity in FY2022/23, Indian corporates have collectively announced a massive module capacity expansion to a nameplate of up to 110GW by 2026, with vertical integration up to polysilicon – Chart 6.1.

Chart 6.1: Indian Solar Manufacturing Capacity Expansion Plans (GW)



Source: JMK Research ¹³⁷

¹³⁷ JMK Research & IEEFA, [India's Photovoltaic Manufacturing Capacity Set to Surge](#), April 2023

6.3 Performance Linked Scheme

India's Finance Minister Nirmala Sitharaman committed Rs 19,500 crore (US\$2.4bn) of incentives for new domestic solar manufacturing capacity under the PLI scheme – up from Rs 4,500 crore (US\$0.5bn) previously – in the Union Budget in February 2022. This is part of the wider Rs 2 trillion (US\$24bn) PLI scheme covering 14 industry sectors to encourage Indian self-sufficiency.

December 2022 saw a total integrated capacity of 8.7GW allocated under Tranche-I of the PLI Scheme managed by Indian Renewable Energy Development Agency (Ireda). The government selected Reliance New Energy Solar, Shirdi Sai Electricals and Jindal India Solar Energy as the beneficiaries.

In March 2023 the Government's Solar Energy Corporation of India (SECI) allocated another 39.6GW of domestic solar module manufacturing capacity under its Solar Performance Linked Scheme (PLI) Tranche-II. This involves 11 companies – Chart 6.1. Of this, 7.4GW of manufacturing capacity is expected to become operational by October 2024, 16.8 GW by April 2025 and the balance of 15.4GW by April 2026.^{138 139}

Chart 6.2: India's Solar PLI Expansion Plans (GW)

MW pa capacity	Polysilicon	Wafer	Cells	Modules
Shirdi Sai Electricals's Indosol	6,000	6,000	6,000	6,000
Reliance Industries	6,000	6,000	6,000	6,000
First Solar	3,400	3,400	3,400	3,400
Waaree		6,000	6,000	6,000
Avaada		3,000	3,000	3,000
Renew Energy		4,800	4,800	4,800
JSW		1,000	1,000	1,000
Grew		2,000	2,000	2,000
Vikram Solar			2,400	2,400
AMPIN			1,000	1,000
Tata Power Solar			4,000	4,000
Total PLI-II	15,400	32,200	39,600	39,600
Reliance Industries		4,000	4,000	4,000
Shirdi Sai Electricals's Indosol		4,000	4,000	4,000
Adani Infrastructure		737	737	737
Total Solar PLI Tranche-I		8,737	8,737	8,737
Total PLI - I & II	15,400	40,937	48,337	48,337

Source: Indian Ministry of Power, March 2023

¹³⁸ ET EnergyWorld, [Govt allocates 39,600 MW domestic solar module manufacturing capacity under PLI tranche-II](#), 28 March 2023

¹³⁹ Ministry of Power, [Government allocates 39600 MW of domestic Solar PV module manufacturing capacity under PLI \(Tranche-II\)](#), 28 March 2023

This involves three Indian firms winning awards to vertically integrate back to polysilicon manufacturing, something India has never previously done.

The new PLI allotments are notable for skipping public sector firms altogether. Coal India Limited's corporate strategy involves diversifying away from being the world's largest coal mining firm to pivot into clean energy installation (targeting 3 GW of solar) and solar module manufacturing, as well as other forms of mining and aluminium refining. It bid 4 GW pa of wafer-cell-module manufacturing capacity into the PLI.

6.4 Reliance Industries: First Amongst Equals

NSX-listed Reliance Industries is India's leading conglomerate with a May 2023 market capitalisation of Rs17 trillion (US\$205bn), run by Chair Mukesh Ambani is Asia's richest man. In 2022 Reliance Industries announced its latest business development – New Energy – to leverage world technology breakthroughs, noting this sector is expected to see new investments over time growing up to US\$5 trillion annually. Reliance has set a net zero carbon by 2035 target.

2021 saw Reliance announce the setting up of the Dhirubhai Ambani Green Energy Giga Complex in Jamnagar in the western Indian state of Gujarat, with the aim to establish and enable at least 100GW of solar energy by 2030. It is establishing five Giga Factories across photovoltaic panels; energy storage; green hydrogen; power electronics; and fuel cell systems, with bio-energy as an additional focus. Reliance has committed Rs75,000 crore (US\$9bn) to its world-leading integrated New Energy manufacturing ecosystem in Jamnagar.¹⁴⁰

Reliance won 4GW of integrated polysilicon-wafer-cell-module capacity support from the PLI Tranche-I and then a further 6GW under PLI Tranche-II for its Jamnagar facility, sufficient to double this capacity to 10GW pa of cells and modules in a phased manner by 2026.

Reliance states this will be the first of its kind 'quartz-to-module' facility globally – integrating production from quartz, to metallurgical silicon, to polysilicon, to ingots / wafers through to cells and modules. Further, Reliance aims to then invest in glass and POE film manufacturing (in which a thin polymer film is applied to modules to increase efficiency and durability), exploiting natural synergies with its chemical and materials business. The stated strategy is that this will provide supply security, cost advantage, and the ability to capture chain margins with maximum recycling. Reliance states it will continue to strive for manufacturing excellence and innovation through technological collaborations and partnerships with leading start-ups globally.

October 2021 saw Reliance invest US\$29m in [Germany's NexWafe](#) to commercialise its high efficiency monocrystalline "green solar wafers" in its new solar manufacturing plant in India, with the promise of using 70% less energy in wafer production, dramatically reduced silicon wastage, and a 26% cell efficiency.¹⁴¹ In May 2023, NexWafe secured €30m funding for a new wafer factory in Bitterfeld,

¹⁴⁰ Reliance Industries, [Chairman Statement](#), 29 August 2022

¹⁴¹ NexWafe, [A path to record-beating efficiency](#), accessed 28 May 2023

Saxony-Anhalt, Germany, and a second facility in Saudi Arabia in conjunction with Aramco, Saudi Arabia's public oil and gas company.¹⁴²

This builds on Reliance's October 2021 acquisition of REC Solar of Norway,¹⁴³ attracted by its global leadership in providing highest efficiency HJT solar panels with 23% module efficiency currently, and a target to lift this to 26% by 2026 and further improve it to 28% through innovations like perovskite-tandem cell technology. Reliance also aims to extend the life of PV modules from 25 to 50 years. April 2022 saw Reliance Industries order 4.8 GW of HJT solar cell production lines from China's Suzhou Maxwell Technologies, working with REC Solar.¹⁴⁴

2022 saw Reliance announce an expansion of its REC solar module manufacturing plant in Singapore from 1.2GW to 1.8GW pa of capacity.

Reliance has also committed to establishing 20 GW of solar energy generation capacity by 2025, which it intends to be entirely consumed by its captive needs of round-the-clock (RTC) power and intermittent energy for green hydrogen. Once proven at scale, Reliance states it is prepared to double the investment to scale up its manufacturing ecosystem, no idle promise given Reliance in the space of 18 months hired 2,500 scientists, engineers and professionals into its New Energy group. This complements its stated intent to expand the group tenfold in the next few years so India can become a net exporter of green energy, and to build out the domestic R&D base to make India a reservoir of intellectual property, as well as a global leader in new energy manufacturing.

Ambani's ambition is to establish India as a "a credible alternative to China", noting "the world's transition from fossil fuels to renewables will provide Reliance with an opportunity for continuous hyper-growth over many decades."

This sounds all very grand, but with an FY2022/23 EBITDA of US\$18.8bn, +23% yoy,¹⁴⁵ strong cashflows, low financial leverage (net debt just 0.7x EBITDA), capex of US\$17bn and a captive market of 1.5 billion people in the fastest growing large economy in the world, this is no idle boast!

6.5 Other Indian Solar Module Manufacturers

India has over 20 solar module manufacturing firms, but only four have annual nameplate capacity of over 2GW, and so existing players lack the scale and capacity to use world leading technologies, a key constraint for India given the speed of research and developments occurring in solar globally. However, the PLI scheme creates a step-change in ambition and scale, as well as vertical integration.

Below we highlight some of the key solar manufacturers in India.

¹⁴² PV Magazine, [NexWafe secures funding to build wafer factory in Germany, announces new factory in Saudi Arabia](#), 16 May 2023

¹⁴³ REC Solar Press Release, [Norwegian solar energy company REC Group becomes part of Reliance Industries Ltd. and accelerates its expansion](#), 10 October 2021

¹⁴⁴ Yicai.com, [China's Maxwell Soars After India's Reliance Orders PV Equipment](#), 18 April 2022

¹⁴⁵ Reliance Industries, [FY2022/23 Results Presentation](#), 21 April 2023

Waaree Energies

In addition to being a solar engineering, procurement and construction (EPC) firm, Waaree is India's largest solar module manufacturer with 9GW of capacity at its plants in Surat and Umbergaon in Gujarat, with another 3GW of wafer-cell-module capacity proposed under the PLI Tranche-II. It was reported Waaree ordered a 10 GW module automation production line from Jinchen during SNEC PV Power Expo 2023 in Shanghai.¹⁴⁶ Waaree solar panels are rated tier 1 by BNEF and in 2022 it was awarded IECCE CB certifications for its bifacial solar modules.

Vikram Solar

Vikram Solar has 3.5GW of solar module manufacturing capacity installed across two factories in West Bengal and Tamil Nadu, and won an additional 2.4 GW of wafer-cell-module in PLI-Tranche II (PLI-II). Vikram Solar is a 'Top Performer' in PV Evolution Lab's (PVEL) PV module reliability scorecard and has been included in the Tier 1 solar PV modules manufacturer list of BloombergNEF.¹⁴⁷

Goldi Solar

Based in Surat, Gujarat, Goldi Solar's nameplate solar module manufacturing capacity installed fivefold over 2022/23 to 2.5GW with a new factory at Navsari,¹⁴⁸ and it won an additional 2.4GW of wafer-cell-module in PLI-II. Goldi plans to vertically integrate into solar cell manufacturing in FY2023/24 and expand module capacity to 6 GW and cell manufacturing to 5 GW by 2025.

Adani Enterprises

The largest private coal mine owner and developer in the world, NSX-listed Adani Enterprises has also expanded to currently be one of the largest solar cell and module manufacturers in India, commissioning a second 2.0 GW of cell and module capacity in March 2023 whilst also expanding its existing facility from 1.5 GW to 2.0GW of capacity, to give 4.0 GW in total.¹⁴⁹

Beyond Coal India, Adani Group was a notable absence from the PLI-II allocation. Adani unsuccessfully bid for 4GW of integrated polysilicon-wafer-cell-module manufacturing capacity, but is currently mired in the Hindenburg Research allegations that the Group has perpetrated the largest corporate fraud in world history.¹⁵⁰

FY2022/23 module production was 1.27 GW (+15% yoy), a capacity utilisation rate of 85%.

Tata Power

As a leading Indian renewable energy focussed power conglomerate, Tata Power has delivered a significant outperformance over the last 5-years. Tata Power stock has increased by 149% vis-à-vis a ~74% increase in the Indian benchmark SENSEX.

¹⁴⁶ PV Magazine, [Waaree signs 10 GW solar module line deal with Jinchen](#), 5 June 2023

¹⁴⁷ Vikram Solar press release, [Vikram Wins PVEL'S Top Performer Position 6 Times In Last 7 Years](#), 23 May 2023

¹⁴⁸ [Goldi Solar](#)

¹⁴⁹ Adani Enterprises, [FY2023 Investor Presentation](#), 4 May 2023

¹⁵⁰ Saurenergy.com, [Solar PLI Tranche 2 Allocations Released, 48 GW Of Domestic Manufacturing Capacity By 2025-26](#), 28 March 2023

One of the first Indian leaders to commit to building no new coal power and pivot into renewables development, Tata has 8.8 GW of installed thermal power capacity and 5.25GW of renewables in operation, with another 2.7 GW in its development pipeline.

Tata Power has expanded across the green energy value chain with presence in solar EPC, rooftop solar, solar powered agricultural pumps and solar cell and module manufacturing. In April 2022, a BlackRock-Mubadala Investments consortium agreed to invest ₹4,000 crore (US\$525m) in Tata Power's Renewable Energy Platform for an 11% stake.

TP Solar Ltd is building an integrated 4GW solar cell and module manufacturing plant at Tirunelveli, Tamil Nadu, supported by the PLI.¹⁵¹ This is TP Solar's second plant, an expansion from its existing 0.55 GW solar cell and module manufacturing plant in Bengaluru, Karnataka.¹⁵²

Shirdi Sai Electricals's Indosol

Shirdi Sai Electricals (SSE) is a leading transformer manufacturer and EPC contractor in India with revenues of US\$170m pa and 1,000 employees. SSE's subsidiary Indosol Solar won a 4GW polysilicon-wafer-cell-module award under PLI-I to be built at Nellore, Andhra Pradesh, along with a glass factory of 5 GW pa capacity, all scheduled for commissioning 2024, with a phase 2 expansion to 10 GW post the PLI-II award of a second 6 GW allocation.¹⁵³ SSE is working with PV engineering and technology firm Viridis.iQ GmbH of Germany.

First Solar US

December 2021 saw First Solar secure a US IFC US\$500m debt financing program for its 3.4 GWdc module assembly facility in Tamil Nadu due for commissioning in the second half of this year (2HCY2023), with PLI Tranche-II support.

Avaada Ventures

April 2023 saw reports Brookfield Global Transition Fund of Canada will invest US\$1bn in Avaada Ventures of India,¹⁵⁴ a renewables firm founded by Vineet Mittal. This follows the acquisition in July 2021 by PTT of Thailand of a [42% stake](#) in Avaada Energy for US\$454m. Funds from this capital raising will be deployed in building a proposed solar cell and module manufacturing capacity of up to 5GW pa, with phase 2 plans to expand to 10 GW pa, as well as backward-integrate into polysilicon and solar wafers, as well as to fund a proposed Rs 40,000 crore investment in green ammonia manufacturing in Rajasthan.¹⁵⁵ Avaada won a 3 GW wafer-cell-module manufacturing award under PLI-II.

Grew Energy

March 2023 saw Grew Energy of Gujarat announce plans to invest Rs 5,400 crore (US\$650m) to set up a 4GW solar module factory, with backward integration of 3 GW of solar cells and 2 GW of ingot wafers phased in over the next 3-4 years. The first phase is a 1GW cell-module facility under

¹⁵¹ ET EnergyWorld, Jobs: [TP Solar organises virtual walk-in interview drive for recruitment](#), 10 May 2023

¹⁵² PVTech, ['Huge potential' for solar manufacturing in India, says Tata Power Renewables president](#), 5 January 2022

¹⁵³ Mercom, [Shirdi Sai Electricals to Bid for PLI-II, Expand Manufacturing Capacity to 10 GW](#), 7 February 2023

¹⁵⁴ Economic Times, [Canadian investor Brookfield investing \\$1 billion in Avaada Ventures](#), 10 April 2023

¹⁵⁵ Avaada Energy press release, [Avaada Group signs MoU for Rs 40,000 crore Green Ammonia plant with Rajasthan government](#), 22 August 2022

construction near Jaipur, Rajasthan, expanding to 2 GW in phase 2 consistent with its PLI-II award.¹⁵⁶ Grew is a subsidiary of the Chiripal group, a Gujarat-based textile manufacturer.

Navitas Green Solutions

Indian solar module manufacturing company Navitas Green Solutions announced in April 2023 plans to expand manufacturing capacity by another 1.2 GW pa from the current 500 MW pa.¹⁵⁷ Vineet Mittal of Avaada Ventures is a co-founder of Navitas.

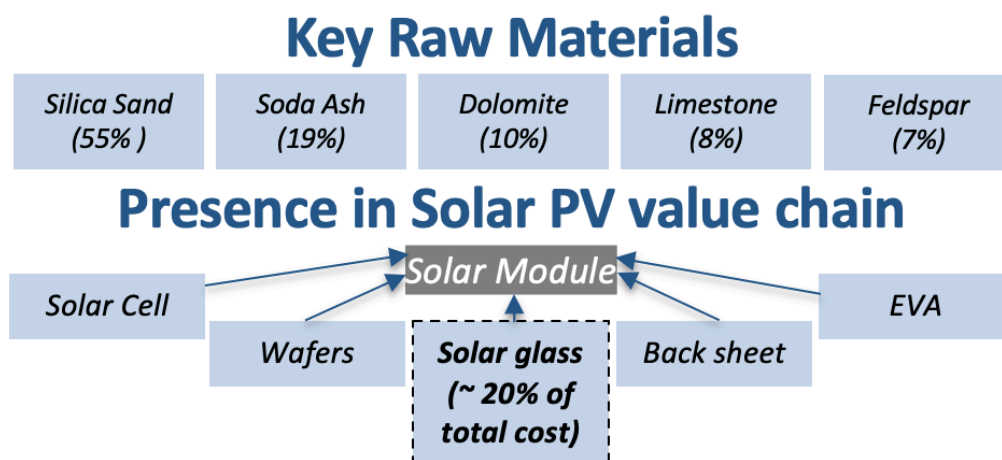
Borosil Renewables

NSX-listed Borosil Renewables is a manufacturing success story, being India's largest flat-glass producer with 3.75 GW pa of flat glass capacity for solar modules at its Bharuch, Gujarat plant, having expanded capacity by 1.5 GW since 2021, and with plans underway to add another 2.75 GW pa of glass capacity. Borosil exports some 20% of its product, a sign of international competitiveness.

The company's fortunes are illustrative of the need for stable domestic government policies.

In FY2020/21 Borosil posted an all time high EBITDA led by higher glass prices, driven by the imposition of Countervailing Duty (CVD) on solar glass imports from Malaysia (which China used as a proxy market) along with a BCD on import of solar cells and modules, which started from April 2022. However, Borosil was then hit with an announcement by the Indian Finance Ministry in August 2022 that no Anti Dumping Duty (ADD) would be applicable on imports of solar glass from China (reversing the imposition of ADD on China imports in 2017). This adverse outcome combined with a trebling of fuel costs for the year, resulting in a 41% decline in FY2022/23 EBITDA.

Chart 6.2: Borosil Renewables Flat Glass Cost Structure for Solar Modules



Source: Borosil Renewables Corporate Accounts, prepared by Shantanu Srivastava, IEEFA India

¹⁵⁶ Economic Times, [Grew Energy to invest Rs 5,400 cr in solar manufacturing over next 3 years](#), 31 March 2023

¹⁵⁷ ET EnergyWorld, [Navitas Solar to expand manufacturing capacity](#), 28 April 2023

Section 7: European Union

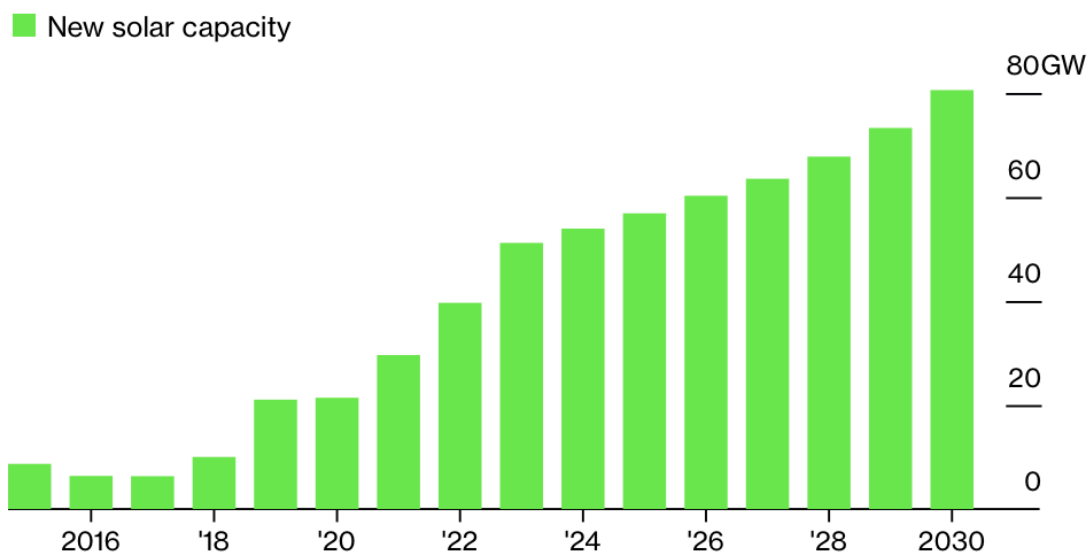
Energy security has become a key priority post Putin's invasion of Ukraine, and European Union (EU) solar installs are forecast to quadruple to 80 GW annually by 2030. The Net Zero Industry Act (NZIA) has been introduced to incentivise and improve EU self-sufficiency in manufacturing supply chains, with a vertically integrated solar module production capacity target of 30 GW pa by 2025.

The EU is determined to diversify its supply chain lines away from the over-dependence on China, a priority endorsed by the International Renewable Energy Agency, even as the EU targets a doubling of renewable energy share of generation by 2030 to both diversify away from reliance on Russian fossil fuels and to become carbon neutral.¹⁵⁸ The EU is also introducing the first phase of its Carbon Border Adjustment Mechanism (CBAM) from 1 October 2023 on seven carbon-intensive industries including steel, cement, fertilisers, aluminium and hydrocarbon products. From January 2026, selected imports will be hit with a 20-35% import tax.¹⁵⁹

In May 2022, the European Commission set forth its REPowerEU plan, which aims to reduce dependence on Russian fossil fuels by 2027. The plan supports a rapid deployment of renewable energy sources as a means to establish greater energy independence. It includes targets for all EU member states, and an EU energy mix with a 45% share of energy from renewable sources by 2030. Solar targets for the same period include 300 gigawatt alternating current (GW_{AC}) installed by 2025 and 600 GW_{AC} by 2030.

BloombergNEF forecasting annual installs to rise fourfold to 80GW pa by 2030 – Chart 7.2.¹⁶⁰

Chart 7.2: Europe Will Install a Record Amount of Solar Every Year to 2030 (GW)



Source: BloombergNEF

¹⁵⁸ ET EnergyWorld, [Europe must reduce China renewable dependence: Agency](#), 10 May 2023

¹⁵⁹ ET EnergyWorld, [India seeks exemptions for MSMEs from EU's carbon tax](#), 10 May 2023

¹⁶⁰ Bloomberg, [Solar Beats Coal in Europe for First Time - But There's a Glitch](#), 3 June 2023

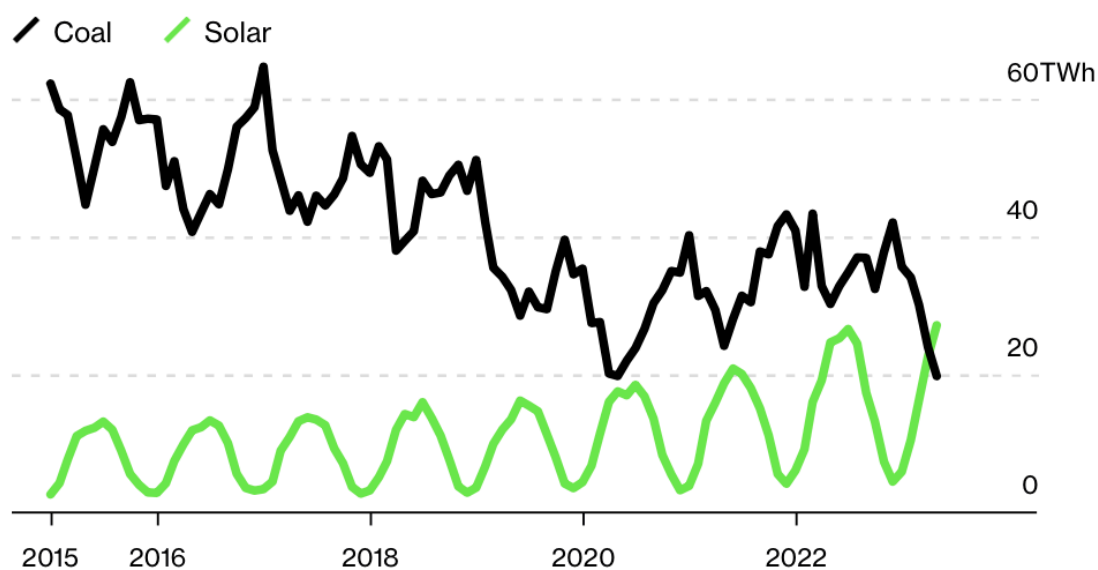
The REPowerEU plan also aims to facilitate solar deployment through easier access to land and a framework to expedite permitting at national and local levels.

The EU has a recently upgraded target of achieving a vertically integrated solar module production capacity of 30 GW by 2025 (previously 25 GW),¹⁶¹ and leading energy research firm Rystad reports this is supported by proposals totalling 35 GW in consideration,¹⁶² although the hyperinflation of electricity prices across the EU in 2022 put this at serious risk. While Germany's Wacker Chemie has some 16GW of EU polysilicon manufacturing capacity, the existing EU wafer manufacturing capacity is estimated at just 2 GW.

May 2023 also saw the EU argue for the need for global collaboration, and the serious energy transition risks of geopolitics, particularly rising US-China trade tensions and on-shoring of manufacturing spurred by the US IRA, which is a key positive in stimulating a global technology and investment race but also undermining international cooperation. As the Dutch Trade Minister Liesje Schreinemacher notes, "[China is] doing a lot on [R&D] and it would really be a shame if we decoupled fully from China." The minister said the Netherlands had a "strong trade relationship with China", that "we need each other when it comes to making our economies more sustainable and the green transition," and that "decreasing our strategic dependencies does not mean we should stop trade fully as long as we are diversifying our value chains".¹⁶³

May 2023 was an EU milestone, with solar generation exceeding coal fired power generation for the first time – Chart 7.1:

Chart 7.1: EU Solar Farms Now Produce More Power Than Coal Plants



Source: Ember, Bloomberg

¹⁶¹ Taiyangnews, [EU's 30 GW/Annum Vertically Integrated Solar PV Manufacturing Target For 2025 Gets Institutional Push With Official Launch Of Industry Alliance](#), 9 December 2022

¹⁶² Taiyangnews.info, [High Power Prices Dent Europe's Renewable Energy Supply Chain: 35 GW Of European PV Manufacturing Capacity May Be Stalled If Power Prices Continue To Rise](#): Rystad, 10 October 2022

¹⁶³ Financial Times, [Europe's green transition impossible without China](#), 28 May 2023

June 2023 saw Germany announce it had reached 3 million solar installations, and was targeting 4 million solar installs by 2024. Germany has a total installed solar capacity of 70 GW, having added over 7 GW in 2022, and is targeting over 9 GW of additions in 2023 to build energy independence. The federal government aims to achieve an installed solar capacity of 215 GW by 2030, with half utility scale and half rooftop installs.¹⁶⁴

7.1 Enel Green Power of Italy

Enel is expanding its 200MW bifacial HJT solar modules pilot plant in Catania, Italy, into its 3 GW pa 3Sun Gigafactory HJT cell and module manufacturing plant, supported in November 2021 by €118m from the EU's Innovation Fund.¹⁶⁵

Enel has also announced a 3GW solar module manufacturing facility in the US to access the IRA.

7.2 Other EU Solar Manufacturing Proposals

Iberdrola of Spain

April 2023 saw Iberdrola announce plans for a 1.6 GW solar module factory in Extremadura in Spain's west; and has applied For European Commission funding within the NZIA.¹⁶⁶ Under its 2025 Strategic Plan, Iberdrola will invest €17bn to increase its installed renewable energy capacity from 12.1 GW now to 52 GW, comprising 6.3 GW PV, 3.1 GW onshore wind, 1.8 GW offshore wind and 700 MW batteries.

Carbon

French PV startup Carbon has flagged a €1.5bn investment plan to build a 5GW cell and 3.5GW module manufacturing facility for commissioning by end 2025 in Marseille in response to the EU NZIA, aiming to diversify the EU overreliance on Chinese solar supply chains. Carbon suggests a phase 2 expansion to production of 30 GW of wafers, 20 GW of cells and 15 GW of modules by 2030.¹⁶⁷

REC Group

In December 2022, Reliance Industries of India's solar module producer REC Group decided to put its plans to realise a HJT solar panel factory with 4 GW annual capacity in France 'on hold due to various changes in market conditions',¹⁶⁸ despite the proposal being one of the winners of the European Commission's second Innovation Fund round in July 2022.¹⁶⁹

¹⁶⁴ PV Magazine, [Germany surpasses 3 million PV systems as demand soars](#), 2 June 2023

¹⁶⁵ Taiyangnews, [3 GW Bifacial HJT Modules Fab In Europe: Enel Green Power Wins EU Funding To Expand HJT Module Capacity](#), 19 November 2021

¹⁶⁶ Taiyangnews.info, [Iberdrola Announces 1.6 GW Solar Factory In Extremadura; Applies For EU Funding](#), 5 April 2023

¹⁶⁷ PV-Tech, ['We need strong industrial ambition and plans': PV newcomer Carbon sets sights on 20GW of European cell production by 2030](#), 15 March 2023

¹⁶⁸ Taiyangnews, [Another Setback For European Solar Manufacturing; After Maxeon Shuttered French Module Fab, Norway's REC Group Puts Its 4 GW HJT Factory Plans In France On Hold](#), 6 December 2022

¹⁶⁹ Taiyangnews, [EU Picks REC Group's 2 GW HJT Module Plant Under 2nd Innovation Fund Round](#), 12 July 2022

Maxeon Solar Technologies

In June 2021 Maxeon received support from the first round of the EU Innovation Fund to expand an existing 44 MW pilot plant to 1.4 GW of solar manufacturing facility in France but in October 2022 cancelled this proposal, citing the challenging pricing environment and energy cost increases.¹⁷⁰

FuturaSun of Italy

March 2023 saw FuturaSun announce plans for a €25m 2 GW pa solar module manufacturing facility in Padua, Italy, to rebuild European supply chains. FuturaSun currently manufactures solar modules in its Chinese facility.¹⁷¹

¹⁷⁰ Taiyangnews, [Maxeon Solar's French Production Line Discontinued](#), 10 Oct2022

¹⁷¹ PV Magazine, [FuturaSun announces new 2 GW solar module factory in Italy](#), 9 March 2023

Section 8: Australia

With 30 GW of solar installed at the end of 2022, Australia is the sixth largest solar market globally, and annual installs including 3 GW pa of rooftop solar are set to continue at >4-6 GW annually for the next few decades.

Australia's world leading renewables resource, an enormous landmass with low population density, a world leading superannuation capital base – which can be mobilised to support nation-building domestic renewable energy investment – and a track record as one of the world's largest and politically stable energy exporters, position Australia to become a renewable energy superpower.

However, Australia must respond in a timely way and at scale to the international developments and the pace of change outlined in this report, with appropriate policy and funding settings to leverage Australia's solar opportunities.

8.1 Australia's Expanding Focus on Energy Transition

The race is on. As Climate Energy Finance detailed in its recent report, A Critical Minerals Value-adding Superpower, Australia needs to acknowledge and embrace this global trend, decouple its economy from its historic dependence on fossil fuels, and play to its competitive advantages in critical minerals and metals, energy transition materials, and firmed renewables to position itself as a cleantech superpower in the new world economy.¹⁷²

The investment opportunities for Australia in embracing an accelerated decarbonisation strategy are huge, but so too are the threats to its leading global trade position should it not do so with the urgency that the global transition dictates. Global supply chain diversity is a critical focus, and Australia needs to both protect its own energy security, but also provide an alternative source of green energy supply for its key trade partners.

Landmark policy and funding initiatives such as the US IRA and the EU's NZIA, the rise of CBAMs and carbon ETs across Europe, China and now Japan's GZ Roadmap,¹⁷³ shows that global energy transition momentum is building rapidly.

Pressure is mounting on fossil fuel multinationals operating in Australia to implement decarbonisation strategies in line with international policy developments, the climate science and the flight of capital to cleantech. In April 2023, for example, gas giant Woodside, which operates some of the world's largest methane production and processing facilities in Australia, faced increasing shareholder pressure to commit to a credible scope 1-3 net zero emissions pledge, and associated roadmap, a call which was prominent from the floor of the company's 28 April AGM, as investors the world over seek increased decarbonisation momentum.^{174 175}

¹⁷² Climate Energy Finance, [A Critical Minerals Value-adding Superpower: Mapping Australia's 'once in a century' opportunity to lead the world in new economy minerals mining and renewables-powered onshore refining pre-export](#), March 2023

¹⁷³ Prime Minister's Office of Japan, [Video Message by PM KISHIDA Fumio at the Hydrogen Council Global CEO Meeting](#), 2 June 2023

¹⁷⁴ AFR, [Why investors want more control over companies' climate plans](#), 27 April 2023

¹⁷⁵ Financial Times, [Investors defy Goldman, Wells Fargo and BofA in vote for climate plans](#), 27 April 2023

May 2023 saw Australia's Federal Budget expand the new government's energy transition programs to A\$40bn, including establishing the national Net Zero Authority with an \$83m funding commitment to ensure the national interest is central to our energy and climate policy framework. This development appropriately mandated support for First Nations participation, and will be vital to position Australia's workforce and communities to pivot from the fossil fuel focused industries of the past to the clean energy, critical minerals and value-adding opportunities of the future.

The budget included measures to plan for the accelerating energy transition, and to establish domestic supply chains and areas of priority focus, including value-adding our critical minerals pre-export, leveraging our world leading renewable energy resources to refine, process and manufacture so we can export "embodied decarbonisation".

The government provided further detail on the previously announced \$1.9 billion Powering the Regions Fund. This includes the \$400m Industrial Transformation Stream, the \$600m Safeguard Transformation Stream for trade-exposed facilities in the Safeguard Mechanism, and a \$400m Critical Inputs to Clean Energy Industries Stream to support decarbonisation of sovereign manufacturing capability of critical inputs to the energy transformation, such as steel, cement, lime and aluminium.

The 2023/24 budget was a modest advance in the context of the October 2022 budget review, which had established significant public financing support for the energy transition, including the \$20bn [Rewiring the Nation Fund](#) managed by the Clean Energy Finance Corporation (CEFC); the \$3bn renewables, green metals and low emissions technologies funding included in the wider [\\$15bn National Reconstruction Fund](#) (NRF); the \$525m Hydrogen Hubs; \$146m Driving the Nation Fund; \$83m First Nations Community Microgrids; and \$188m community batteries fund each managed by the Australian Renewable Energy Agency (ARENA).

Climate Energy Finance had hoped for more substantive public finance support in the budget for economy-wide decarbonisation, such as a \$20bn national strategic interest funding allocation to the Future Fund, Australia's sovereign wealth fund, to take strategic equity stakes in emerging corporate leaders in domestic value-added renewables-powered critical minerals and green metals mining, and to help retain majority Australian ownership.

There was a significant focus in the May budget on home and business electrification, responding to the crushing cost of living crisis exacerbated by hyperinflation of fossil fuel energy prices off the back of the Russian war on Ukraine. There was \$1bn in low-cost loans for solar panels, double glazing and other energy improvements, as well as \$300m funding to improve social housing and \$310m in tax deductions for businesses that invest in renewable energy and energy efficiency. The package begins to address the challenge and opportunity identified in Sauln Griffiths' *Rewriting Australia's plan to "electrify everything"*,¹⁷⁶ a call reflected in the Climate Capital Forum's January 2023 roadmap to decarbonisation.¹⁷⁷

¹⁷⁶ [Rewiring Australia](#).

¹⁷⁷ [Climate Capital forum discussion paper](#), January 2023.

8.1 Solar price deflation driving investment

The geopolitical energy shift driven by the solar price deflation we have mapped in this report has underpinned the emergence of world-leading clean energy investment proposals in Australia, including solar and wind.

Andrew Forrest's FFI / Squadron has 1.1 GW of renewables currently in operation with a 20 GW renewables push that includes the recently announced \$3 billion renewable energy precinct in Central Queensland, with Squadron acquiring Stage One and Two of the Clarke Creek wind, solar and battery farm to create the largest renewable energy precinct in the southern hemisphere. The project will generate enough wind, solar and battery energy to power equivalent to 40% of Queensland households, and export lower cost electricity directly into the National Electricity Market.^{178 179}

BP's Australian Renewable Energy Hub¹⁸⁰ in the Pilbara region of Western Australia will develop in multiple phases 26 GW of wind and solar, producing 90 TW of electricity pa, which represents one third of Australia's total electricity generation in 2020. The Hub will reportedly support the production of 1.6Mt of hydrogen or 9Mtpa of green ammonia, and will replace the equivalent 17Mt of carbon in domestic and export markets pa.

Mike Cannon-Brookes' globally ambitious US\$22.6bn SunCable solar and battery project – the world's largest – comprises a 20-GW 15,000 hectare solar farm and 42GWh battery complex in the Northern Territory. The venture plans to link the hub to Singapore via a 4200-kilometre subsea cable, to supply 15% of Singapore's electricity needs.¹⁸¹

The scale of these projects is a good indicator of the opportunities the solar boom presents for Australia.

8.2 Spotlight on SunDrive

A key example of Australian innovation in solar manufacturing is SunDrive, an Australian solar technology firm spun out of UNSW and supported by the CSIRO and CEFC. It is developing a process that replaces the silver required for solar cells with far cheaper copper, whilst also delivering the world's record highest solar cell efficiency to-date. Suntech founder Zhengrong Shi was SunDrive's first investor in 2015.¹⁸²

The consumption of silver is a key issue for the PV industry. Demand for silver from the industry increased by 28% from 110.0 million ounces (Moz) in 2021 to 140.3 Moz last year, according to the World Silver Survey 2023, with further growth to 161.1Moz in 2023 forecast, taking share to 14% of total silver demand.¹⁸³ Countervailing this, research by the VDMA, Germany's engineering industry association, found that efforts to reduce silver consumption in solar cell production have proceeded

¹⁷⁸ [Andrew Forrest announces \\$3bn Qld renewable energy precinct](#), 27 February, 2023.

¹⁷⁹ About Squadron Energy, [Unlocking Australia's energy future](#)

¹⁸⁰ [Australian Renewable Energy Hub](#)

¹⁸¹ Australian Financial Review, [The billionaires are still battling over how exactly Sun Cable sold](#), 28 May 2023

¹⁸² The Australian, [Canva, Atlassian billionaires join Turnbull in solar hopeful](#), 13 October 2022

¹⁸³ PV Magazine, [Average silver price expected to drop 2% to \\$21.30 per ounce this year](#), 4 May 2023

faster than predicted in the 2022 International Technology Roadmap for Photovoltaics (ITRPV), and have now reached an average of 10mg/W, with forecasts that this should fall to 6.5mg over the next decade.¹⁸⁴

SunDrive has the potential to capitalise on and accelerate this trend. It is building a 20MW pilot plant in Sydney, and is seeking government support for a multi-gigawatt module manufacturing facility in Australia, developed over three phases – an example of Australia’s opportunity to establish itself as a player in global energy supply chain while bolstering its energy independence and its stake in the zero-emissions future.

8.3 Australia’s solar opportunity

Australia has the potential to be a global renewable energy superpower, with brilliant wind and solar resources, massive landmass and low population density, strong capital markets and the ability to build world scale energy projects.

CEF sees unprecedented trade and investment opportunities, in the order of hundreds of billions of dollars, for Australia to “ship sunshine”, embodying decarbonisation in its exported by using its abundant solar and wind energy to process its world-leading critical minerals reserves onshore, and to power manufacturing of energy transition materials pre-export at scale.

Australia’s abundance of the critical minerals and green metals used to produce cleantech components – some of the largest reserves in the world – also help secure its position in the solar module production supply chain.

Further, there are opportunities to build Australia’s solar manufacturing capability to create some domestic supply chain security, assuming the right level of domestic policy support can be put in place, for example an underwriting of such an investment via a production tax credit, time limited to, say, a decade.

And Australia’s massive headstart as a global leader in uptake of distributed rooftop solar enables it to build on this lead and accelerate the rollout of household and business electrification, bringing enormous benefits both in terms of decarbonisation and permanently lower electricity prices, alleviating cost of living pressures.¹⁸⁵

The Albanese federal government, elected in May 2022, swept the climate-science denying luddite Morrison government out of office after a lost decade of LNP climate and energy policy inaction and chaos. The new government has made significant strides in setting the policy and funding architecture to leverage Australia’s once in a century opportunity to establish itself as a zero-emissions leader.

However, supportive policy and public finance must now be deployed at speed and on a scale that matches the staggering pace of change detailed in this report, de-risks and attracts significant private

¹⁸⁴ PV-Magazine, [PV manufacturing capacity hit 600 GW in 2022](#), 10 May 2023.

¹⁸⁵ Clean Energy Council, [Australian rooftop solar breaks new ground in 2022](#), 18 April 2022.

investment, and responds to the domestic incentives our trade partners and competitors are putting in place. With decarbonisation efforts increasing across the globe, including in solar, it is CEF's view that a step-change is needed in Australian public capital investment and policy ambition.

CEF recommends:

1. A focused, sizable and urgent Australian response to the US IRA, in the form of a \$100bn commitment by the federal government of strategic national interest capital to crowd-in \$200-300bn of private investment and seize Australia's renewables investment, employment and export opportunities, including solar, funded by the government's nation-building and energy transition finance instrumentalities including the CEFC, the Future Fund, ARENA, Export Finance Australia (EFA) and the Northern Australia Infrastructure Facility (NAIF).
2. Mobilisation of Australia's world leading pool of superannuation capital into zero-emissions investments. As CEF has argued, the federal government should adjust the investment benchmarks applying to superannuation to prioritise low-carbon investments. Changing the benchmark to include low-carbon indices would help to unlock Australia's \$3.4 trillion in Australian superannuation assets for climate-responsible investments.¹⁸⁶ The change by the Treasurer to require the superannuation industry regulator, the Australian Prudential Regulation Authority (APRA), to consider climate risk is a step in the right direction.¹⁸⁷
3. A clear and ambitious value-added critical minerals strategy to secure Australia's position in the global supply chain of minerals and metals that underpin the global cleantech industries. CEF awaits with interest the federal government's critical minerals strategy, due for release in July 2023. CEF's key recommendations for the strategy are embodied in our submission on the government's discussion paper, and centre on the policy and funding asks outlined above.¹⁸⁸
4. Time limited production tax incentives for domestic cleantech manufacturing, including solar and offshore wind supply chains. In CEF's view, Treasurer Jim Chalmers should use the mid-year economic update to introduce a solar module production tax credit – time limited for a single decade – so Australia can secure its position in the solar production supply chain by deploying the world's best solar cell technology, developed by UNSW (see SunDrive, above). This could see a 1GW per year module manufacturing facility bring 1,000 high value jobs back onshore, and cut our reliance on solar imports from >99% currently to 'just' 80% by 2025, and down to 60% by 2026 with a second facility, bringing another 1,000 regional jobs with it.
5. Aligning an Australian CBAM with the EU, to protect Australian trade-exposed industries as they respond to regulatory and market pressures to decarbonise and reorient strategic investment to cleantech, eg., into renewables-powered operations.
6. Acting on our Global Methane Pledge and evaluating methane emissions from coal and gas facilities on a global warming potential over 20 years (GWP20) basis rather than the current

¹⁸⁶ Tim Buckley/Janaline Oh, [Five reforms to boost Australia's climate finance in a rapidly decarbonising world](#), 7 July 2023.

¹⁸⁷ Treasurer Jim Chalmers, [APRA Statement of Expectations](#), 7 June 2023.

¹⁸⁸ [CEF submission to federal consultation on a national critical minerals strategy](#), 3 February 2023.

100 year (GWP100) standard that fails to reflect methane's near-term climate impacts. This must include quality monitoring, public reporting and verification (MVR) for all safeguard mechanism facilities. Appropriately rigorous regulation of methane under the mechanism will help pivot industry capital investment to cleantech.

7. A further boost to funding to accelerate solar uptake and the electrification of everything, particularly across the housing sector (with specific targeted support and regulatory modernisation for renters/ low-income/apartments/public housing/first nations), whilst rolling out a NatHERS (nationwide house energy ratings) scheme, including compulsory building energy and appliance efficiency reports on all residential property sales so as to drive valuation clarity on building energy efficiency ratings.

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