Silicon to Solar Study Overview Report

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About the Australian Photovoltaics Institute (APVI)

The APVI is a not-for-profit, member-based organisation providing data analysis, reliable and objective information, and collaborative research to support the development and uptake of PV and related technologies. The APVI and its predecessors have been operating since 1993. APVI members are organisations and individuals from industry and academia with an interest in solar energy research, technology, manufacturing, systems, policies, programs and projects. APVI undertakes deployment and information-focused projects and produces detailed technical and market publications, hosts seminars, workshops, conferences and member events, prepares submissions on key solar issues and promotes solar energy in the media.

Scope of Report

This document is the Overview Report of the of the full APVI Silicon to Solar Study (S2S Study). The Study is conducted by the Australian PV Institute (APVI) under the Australian Renewable Energy Agency's Advancing Renewables Program in collaboration with the Australian Centre for Advanced Photovoltaics, Bright Dimension, ITP Renewables and Deloitte.

The S2S Study analyses each step in the solar value chain from poly-Si to module production, evaluates if and where Australia can play a role and assesses requirements for the development of a domestic solar industry. The study will examine factors including the techno-economic analysis, business rationale and policy, develop a roadmap for establishing diversified PV supply chains, and provide recommendations to Government and industry stakeholders.

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1 Executive summary

Investing in Australia's clean energy future: Risk, Return, Reward

Investing in domestic solar PV manufacturing is an industry building exercise, but brings with it substantial benefits

Risk

The global PV supply chain is currently heavily concentrated, with over 90% of module supply in Australia coming from China. The COVID-19 pandemic and the Russian invasion of Ukraine have revealed the fragility of global supply chains, highlighting the risks of relying on foreign sources for energy supply and related critical components like solar modules. Potential future supply chain disruptions can have a significant impact on both the cost and availability of solar PV modules in Australia, jeopardising Australia's decarbonisation targets and ambitions of becoming a renewable energy superpower.

Development of 5GW* domestic solar PV manufacturing capability across the value chain is an opportunity to:

1 RISK MITIGATION

Benefit from mitigating risks

- **Secure access to sufficient solar PV modules** to meet domestic demand and underpin low carbon export ambitions
- **Build resilience to supply chain disruptions** Develop an insurance policy to increased costs and delays of potential future supply chain disruptions
- **Gain control over energy security** as Australia will be predominantly powered by solar energy in the future
- **Implement sustainable manufacturing standards** to ensure labour-transparent, decarbonised production with full product stewardship

2 RETURN

Generate immediate returns

- **Create 4,000 direct, skilled, well-paid jobs** e.g., for workers affected by the energy transition
- **Attract upfront investment of about 2.9bn AUD** in new state-of-the-art manufacturing facilities and stimulate ongoing operational expenditure over the production lifetime
- **Retain Australian IP and solar talent** Reverse the trend of world-class solar IP and talent leaving Australia
- **Grow ancillary industries** Catalyse opportunities for adjacent industries to grow, e.g., solar glass, module recycling, and low carbon aluminium

3 REWARD

Unlock long-term rewards

- **Unlock skill and knowledge spill-over into other industries** to better utilise the workforce and boost labour productivity
- **Create a manufacturing ecosystem** for innovative Australian technologies to scale up
- **Boost economic complexity and sophistication** through investment in high-tech, specialised manufacturing capability
- **Develop a new low-carbon export market** for poly-Si and ingot/wafers, and participate in a connected global clean energy supply chain with key strategic partnerships

**With 10GW/annum poly-Si capacity due to the minimum viable scale of facilities*

The Silicon to Solar Study (S2S)

The S2S Study assesses the feasibility of establishing economically viable, relevant and timely solar PV manufacturing capability in Australia. The study finds that establishing manufacturing capability of 10 GW of poly-Si and 5GW across the other steps of the value chain is credible and feasible, under provision of the right government policy support.

The solar PV Value Chain

Quartz — **Quartz mining***

MG-SI — **Metallurgical silicon (mg-Si)*** is formed by smelting quartz and has purity in the order of 99%.

POLY-SI — **Polysilicon purification (Poly-Si):** mg-Si is purified via a chemical gasification and vapour deposition process

INGOT & WAFERS — **Ingot/wafer:** Poly-Si is converted into ingots via a melting and crystal growth process, and subsequently cut into thin wafers.

SOLAR CELLS — **Cell conversion:** Wafers are converted to solar cells using semiconductor processing

SOLAR MODULES — **Module conversion:** Solar cells are assembled into solar modules.

Scope of this study

Techno-economic analysis to assess the technology and scale of industry needed to develop economically viable, relevant and timely solar PV manufacturing in Australia. This included a bottom-up cost model to compare cost of production in China and Australia, using a variety of industry and public data sources.

Business and policy assessment, to understand critical barriers faced by industry, evaluate successes and failures of policy case studies and model the effectiveness of policy levers to close the cost gap bewteen Australian manufactured products and products imported from China using a levelised cost of production (LCOP) assessment.

Stakeholder engagement with over 50 stakeholders, including Chinese and European manufacturers, the US Department of Energy and Australian industry and government representatives.

Next steps

Immediately

- Declare solar PV manufacturing a strategic priority industry
- Determine government alignment with the value chain development roadmap outlined in this report
- Set-up a Solar Manufacturing Taskforce to implement and deliver next steps and recommendations

Next 12 months

- Prioritise roll out of enabling support for people, permits and partners
- Develop implementation structure to allocate and deliver financial supply-side support (concessional finance and production subsidies)
- Design frameworks for demand-side support (government procurement, circular economy framework and local content incentives)
- Remove barriers for accelerated solar PV deployment
- Strive for broad political support
- Secure budget for the selected framework of subsidies

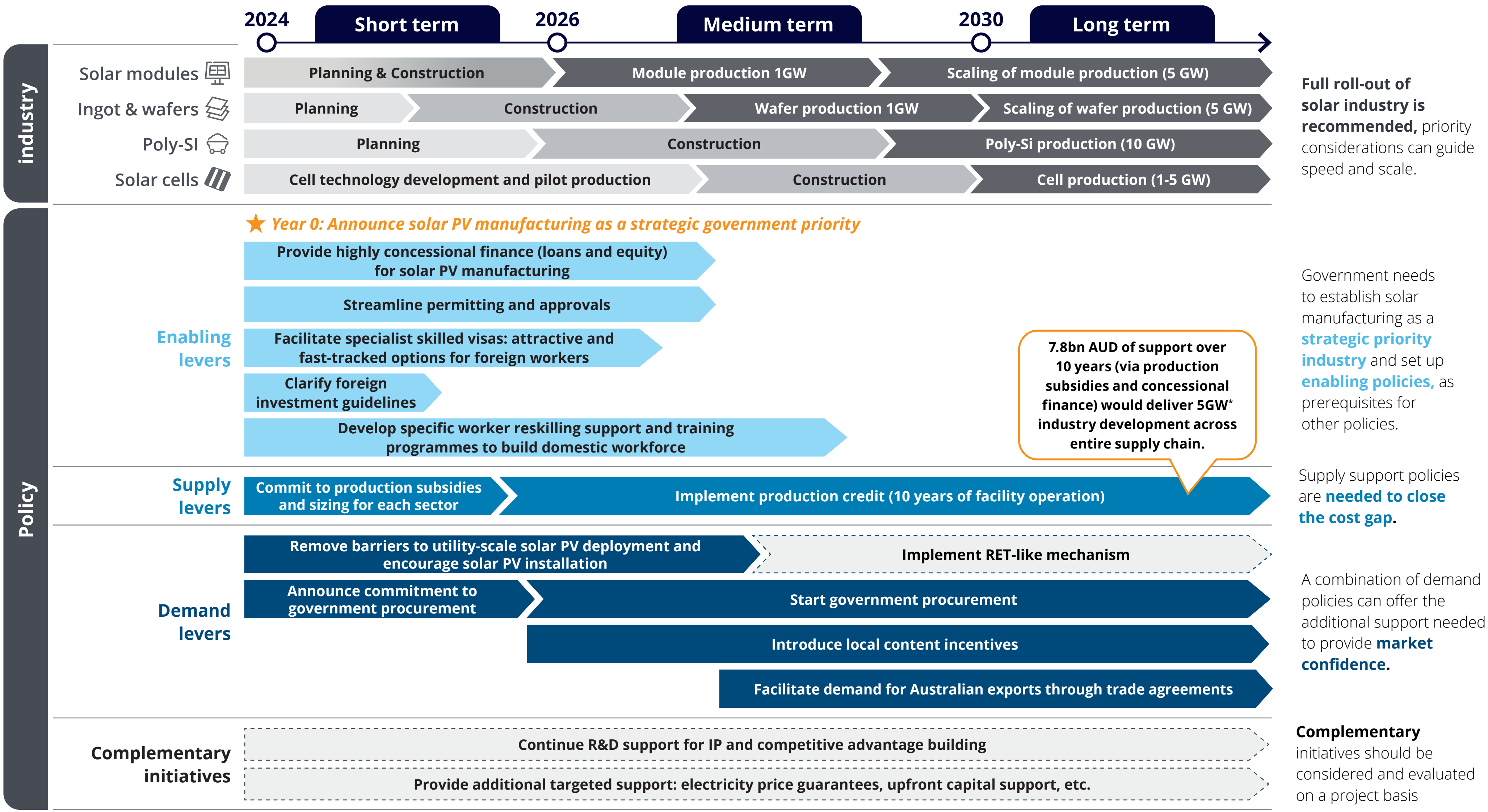
Years 1 - 5

- Implement policy support for 10 years of facility operation (see roadmap overleaf)

***Note:** Quartz mining and mg-Si smelting were excluded from the S2S study, as Australia's opportunities in this sector have been evaluated by CSIRO in the Australian Silicon Action Plan (2022), and supply does not suffer from diversification concerns.*

Roadmap for a credible future state of PV manufacturing in Australia

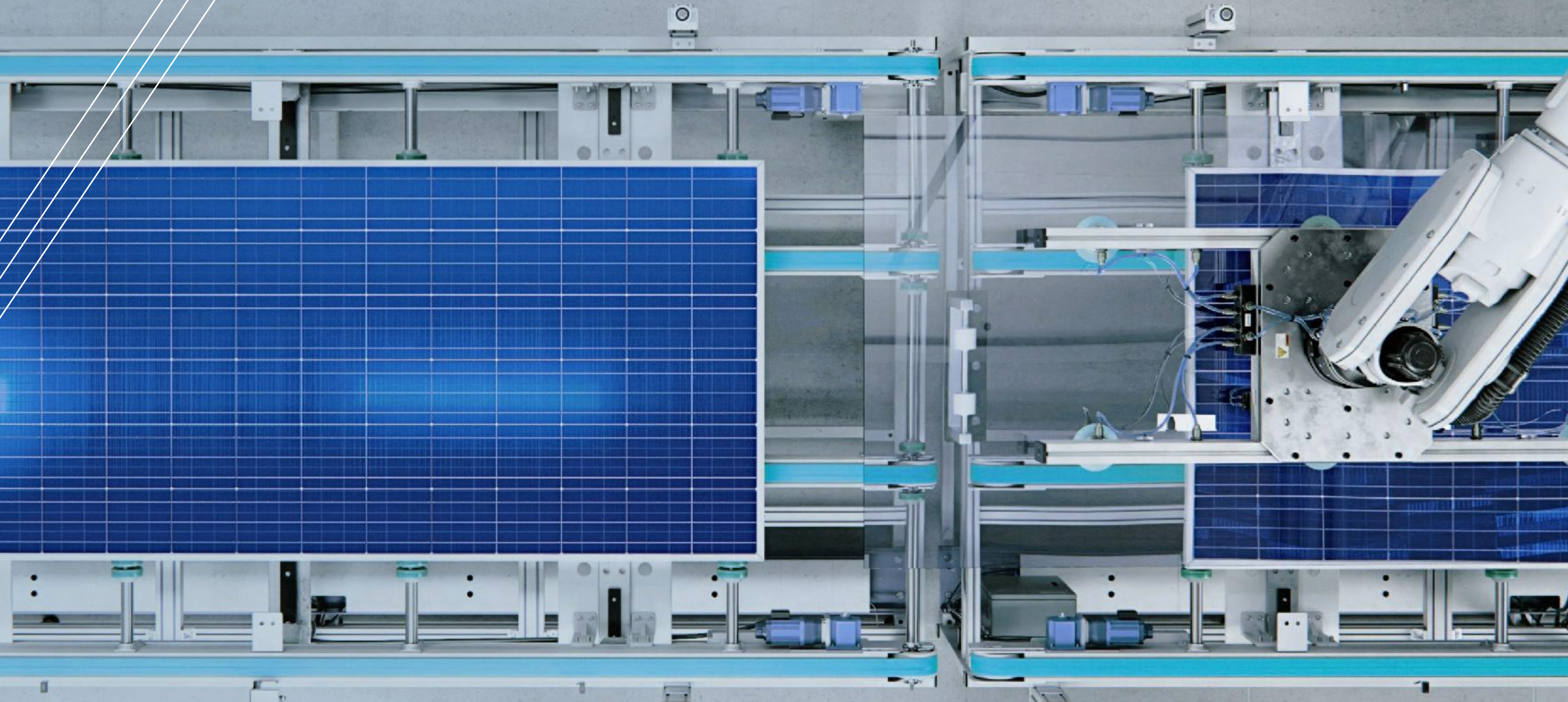
The roadmap and recommendations spelled out by the S2S Study and actioned by the government would lead to an Australian solar manufacturing industry that is viable, relevant and timely.



*With 10GW/annum poly-Si capacity due to the minimum viable scale of facilities

2 Introduction

The case for solar PV manufacturing in Australia



The case for domestic solar PV manufacturing in Australia

Large-scale growth and deployment of solar PV is critical to achieving Australia's decarbonisation goals and unlocking the opportunities associated with a low cost, clean energy export economy. This will require abundant access to solar PV panels.

The goal of achieving net zero emissions by 2050 has gained widespread acceptance in Australia and across the globe. To meet this target, a rapid transition to renewable energy is necessary and solar power is poised to emerge as the primary source of electricity generation.

Australia has the land and renewable energy potential to 'soak up' excess solar energy. This presents a significant competitive edge for the country and can serve as the foundation for exporting environmentally friendly, value-added products to replace our current high-carbon exports in the future. Access to a reliable source of solar PV modules will be vital in achieving these ambitions and unlocking other priority areas that the government has already announced support for. This includes the development of an export-focused green hydrogen industry and the establishment of a battery manufacturing capability.

Based on projected annual forecast demand, access to a reliable source of solar PV modules between 5 and 10 GW/annum will be needed to meet Australia's decarbonisation goals. However, several more ambitious scenarios have indicated annual demand for solar PV modules could increase to 15 – 70 GW/annum, depending on the scale of development of low-carbon alternatives in hard-to-abate sectors in Australia.

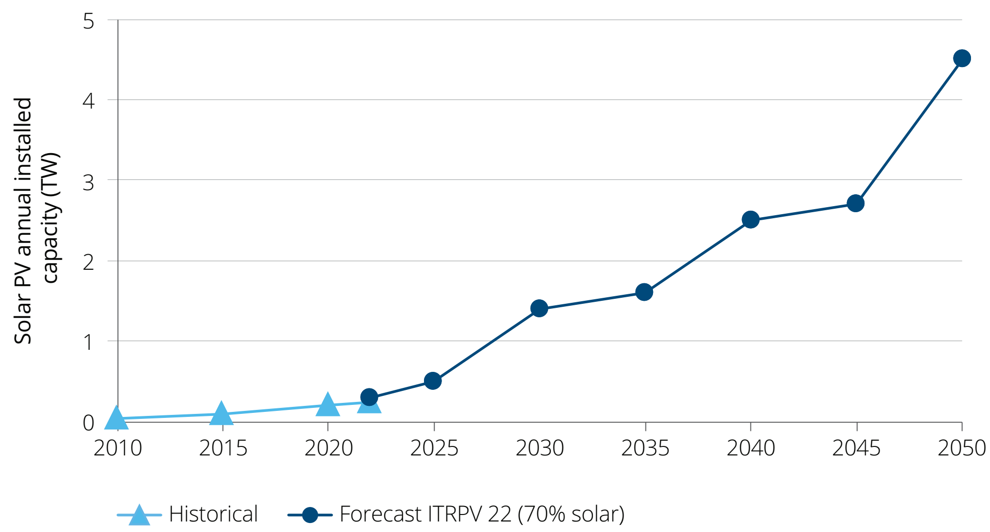
Existing government priorities and funding programs critically reliant on access to abundant solar power

- National Battery Strategy
- National Hydrogen Strategy and Hydrogen Headstart Program
- Future Fuels Strategy
- Alumina Decarbonisation Roadmap

Projected annual solar PV demand in Australia[1]

June 2023 installed capacity: (residential and utility)	AEMO ISP baseline forecasts: (Range: Step Change – Hydrogen Superpower)	Alternative ambitious forecasts: (Range: ARENA Ultra low-cost solar whitepaper – Net Zero Australia)
32 GW	**5 – 15 GW** *per annum*	**37 – 70 GW** *per annum*

Global Solar PV annual demand forecast – ITRPV scenario[2]



[1] Refer to Detailed Report for forecast demand projection analysis [2] VDMA, "International Technology Roadmap for Photovoltaic (ITRPV) – 2021 Results", March 2022

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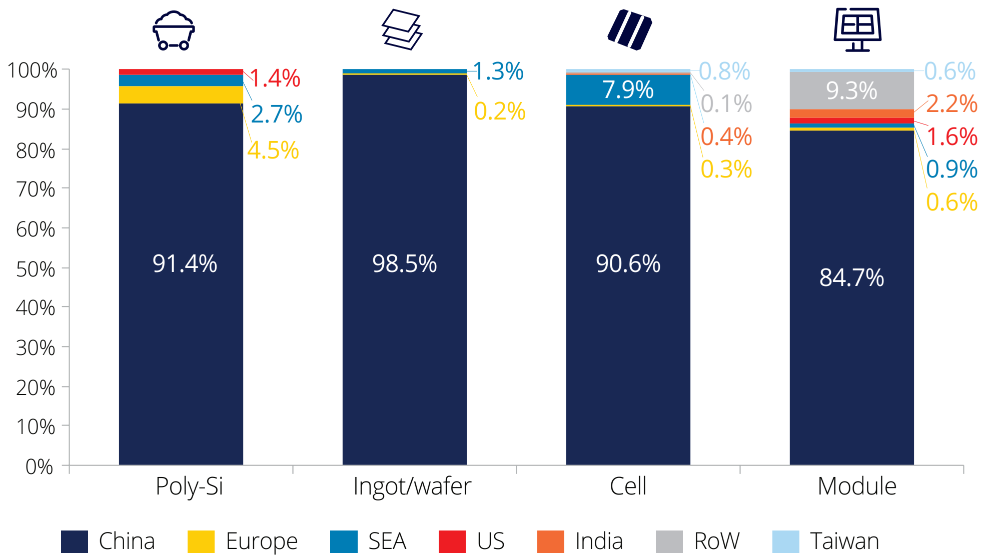
The need for domestic solar PV manufacturing in Australia: Risk

Global solar PV supply chains are heavily concentrated within China. Despite a shift in global industrial policy towards localised manufacturing in other economies, it is unlikely that future production will meet domestic demand in those new jurisdictions.[3]

China's long-term commitment to establishing a domestic solar industry has led to a strong leadership position in terms of industry size, manufacturing cost and technology. Over the past two decades, this has resulted in an astoundingly fast cost reduction of solar modules and substantial quality and performance increase, which has greatly benefited the deployment of solar energy worldwide.

However, the rise of natural disasters, the COVID-19 pandemic, and geopolitical tensions, have revealed the fragility of global supply chains and the risks of relying on foreign sources for energy supply and related critical components like solar modules. While major global economies such as the US, EU and India are beginning to expand their manufacturing capability, it is improbable that their production will meet their domestic demand and, even less probable, become available for export to Australia.

Market share in 2023 global PV manufacturing production[4]



United States – IRA[5,6]

The Inflation Reduction Act (IRA), with over 369 billion USD in support and funding, is the US' most ambitious climate legislation to date. The manufacturing credits included in the policy will support meeting the target of 50GW of annual domestic solar manufacturing capacity by 2030.

India – PLI[7]

The production-linked incentive scheme (PLI) has the objective of reducing India's reliance on solar imports. The support (~2.4 billion USD in the second round of funding) is expected to add 65GW of domestic solar PV manufacturing capacity.

European Union – NZIA[8]

The Net-Zero Industry Act (NZIA) is the EU's policy package to enhance supply chain resilience and boost domestic manufacturing capacity in net-zero technologies. At least 40% of annual deployment needs must be met by domestic manufacturing capacity by 2030.

Canada – IRA reaction[9]

In response to the US Inflation Reduction Act, Canada announced 80bn CAD in support for clean energy and sustainable infrastructure as part of its 2023 budget, with "Clean Technology Manufacturing Tax Credits" available to solar manufacturers.

A global shift in green industrial policy is occurring, with a strong focus on supply chain security and localised clean technology manufacturing. Major economies such as the US, EU, India and Canada are intervening in markets and have introduced unprecedented policy support to expand their own domestic manufacturing capability. However, these economies are developing domestic manufacturing capability for reasons other than market efficiency – reasons such as energy security, supply chain security, and the opportunity to become a first mover and capture value in future low carbon technologies that will be necessary in a globally decarbonised economy.

Australia needs to consider its role in this future global market. Australia should not necessarily match or compete with the scale and magnitude of funding support provided by other major economies with significantly larger spending power. Any Australian initiative needs to be assessed in the context of programmes by trading partners. Australia has a chance to develop a solar industry that becomes part of a globally diversified supply chain, complementing the efforts of our trading partners.

[3] Based on international policy domestic manufacturing targets and stakeholder insights [4] PV Cell Tech, "PV Manufacturing & Technology Quarterly Report", April 2023. [5] SEIA, https://www.seia.org/initiatives/domestic-solar-manufacturing, viewed 24th Oct. 2023. [6] Deloitte, https://www.deloitte.com/au/en/Industries/energy/blogs/inflation-reduction-act.html, viewed 24th Oct 2023. [7] PV-magazine, https://www.pv-magazine.com/2022/09/22/indian-government-approves-second-phase-of-solar-manufacturing-incentive-scheme/, viewed 24th Oct. 2023. [8] European Commission, https://single-market-economy.ec.europa.eu/industry/sustainability/net-zero-industry-act_en, viewed 24th Oct 2023. [9] Government of Canada, https://www.canada.ca/en/environment-climate-change/news/2023/04/minister-guilbeault-highlights-the-big-five-new-clean-investment-tax-credits-in-budget-2023-to-support-sustainable-made-in-canada-clean-economy.html, viewed 24th Oct. 2023

The need for domestic solar PV manufacturing in Australia: Risk Mitigation

Setting up viable, relevant and timely solar PV manufacturing in Australia can build resilience to future supply chain shocks, secure access to solar PV modules critical to meet Australia's decarbonisation targets, and ensure implementation of more sustainable manufacturing practices.

Risk mitigation benefits

1

Increased resilience to supply chain shocks

Australia's active participation in a globally diversified solar PV supply chain will create resilience to supply chain shocks (cost) and disruptions (availability). Proactive investment in this capability should ensure avoided costs of a supply chain disruption. This investment acts as an insurance policy against future sustained disruptions, which could significantly negatively impact module prices, as well as the timely delivery of solar projects.

2

Secure access to sufficient solar PV modules

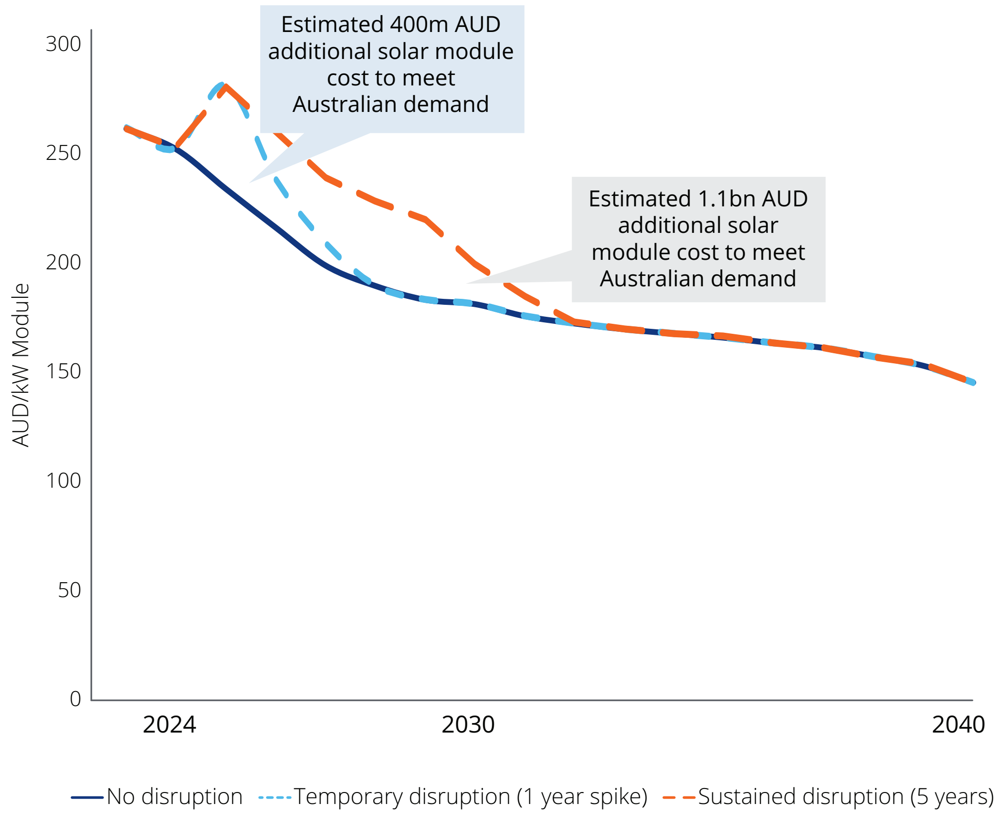
Developing a secure, local supply of 5+GW/annum of solar PV modules can support Australia's ambition to become a renewable energy superpower. Access to a reliable source of solar PV modules will be key to achieve the governments net zero commitments, decarbonisation targets and low-carbon export ambitions in green hydrogen, green steel, green ammonia and green aluminium. Securing domestic supply through domestic manufacturing capability may contribute to alleviating energy security and sovereign risk concerns.

3

More sustainable manufacturing practices

Developing domestic manufacturing capability can create more sustainable manufacturing practices and meeting broader environmental, social and governance (ESG) objectives. It provides a lever **to ensure increased supply chain transparency, decarbonise existing manufacturing processes and drive recycling and re-use of PV materials** through the eligibility requirements associated with funding or policy support.

Impact of supply chain disruptions on projected imported module costs[10]



[10] Deloitte analysis of a hypothetical supply chain disruption resulting in 20% module cost increase (as observed during COVID), using GenCost 22/23 solar capex cost projection data and S2S demand forecast data (15GW by 2050)

The need for domestic solar PV manufacturing in Australia: Return, Reward

Investment in a domestic solar manufacturing capability would bring short-term returns and long-term rewards to the Australian workforce and economy. There is a clear opportunity to capture value in adjacent low-carbon manufacturing sectors, increase economic complexity and drive labour productivity in the long term.

Return

1 Well-paying, skilled jobs for Australians

Solar PV manufacturing capability suggested in this report could result in over 4,000 direct, well-paying, highly skilled jobs, with many more indirect jobs created. New, highly skilled, manufacturing jobs provide an opportunity to better utilise the workforce and create opportunities for regional workers affected by the energy transition.

2 Private capital investment and returns on export revenue

Solar PV manufacturing capability suggested in this report would attract approximately 2.9bn AUD of upfront investment[11] in new state-of-the-art manufacturing capacity, with additional indirect beneficial impacts on the wider economy through ongoing operational expenditure over the production lifetime.

3 Retention of solar IP and talent within Australia

Domestic solar PV manufacturing presents an opportunity for Australia to reverse the ongoing trend of world-class solar IP and talent leaving Australia. Without an established industry, new solar technology and highly-skilled engineers from our leading solar research institutions will likely be forced to go overseas, as has happened many times within Australia's successful solar R&D history.

4 Growth opportunities for ancillary industries

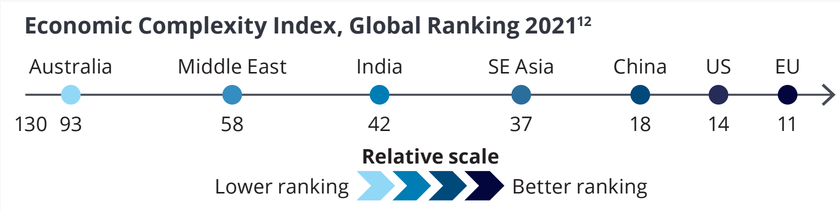
Solar PV manufacturing capabilility could catalyse opportunities for adjacent solar component industries to develop and grow e.g. solar glass, module recycling, and low-carbon aluminium

Reward

1 A manufacturing ecosystem that unlocks spill-over benefits in other industries

A viable and relevant solar manufacturing industry can contribute to the creation of an ecosystem for new technology developments to scale up in. An increased knowledge base and specialist skilled workforce can spill over to other manufacturing industries and elevate Australia's capability in advanced manufacturing and exporting complex products (e.g. energy storage products).

2 Boosted economic complexity and sophistication



Investment in high-tech manufacturing industries and net-zero technologies like solar PV manufacturing, would support Australia in adding value to the extraction of its raw resources, and modernise industry and regional economies, thereby boosting the (currently low) complexity in the Australian economy.

3 Australia as a key player in clean energy supply chains

Developing a new low-carbon export market for poly-Si and ingot/wafers presents an opportunity for Australia to contribute to a globally diversified supply chain at the most concentrated steps, and thus participate in a connected global clean energy supply chain.

[11] The estimated 2.9bn AUD of upfront investment is reflective of the development of 5GW domestic solar PV manufacturing capability across the value chain (with 10GW/annum poly-Si capacity due to the minimum viable scale of facilities).
[12] Harvard Kennedy School Growth Lab, https://atlas.cid.harvard.edu/rankings, viewed August 2023, refer to Appendix in Detailed Report for proxy assumptions.

3 Developing a solar PV manufacturing roadmap for Australia

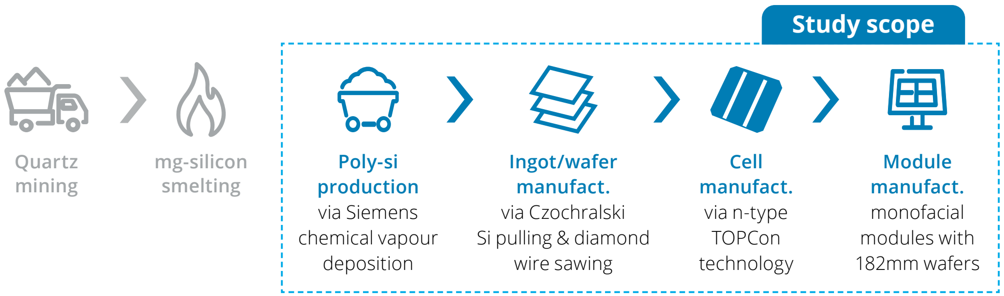
Value chain assessment: Study scope

Comprehensive techno-economic analyses (TEA), stakeholder engagement and policy analysis were conducted to evaluate viable, relevant and timely future manufacturing scenarios that can be achieved under appropriate government support.

The silicon to solar study outlines the results of a techno-economic assessment (TEA) and policy analysis to identify a credible future scenario of solar PV manufacturing in Australia. The study does not provide an exhaustive review of all possible onshore manufacturing scenarios, but instead focuses on one credible scenario using state of the art commercialised technology.

- **Viable:** The manufacturing step needs to be globally competitive and economically viable long term.
- **Relevant:** The manufacturing facility needs to have a scale that is appropriate and relevant for future Australian and global PV demand.
- **Timely:** The manufacturing capacity needs to be set up within a timeframe that is necessary to achieve net zero by 2050.

The scope and technology assumptions outlined below form the basis of the bottom-up manufacturing cost estimates and policy recommendations put forth in this study.



Case Study, alternative non-silicon technology

Currently, the only potentially viable, relevant and timely non-silicon alternative is cadmium telluride (CdTe). CdTe modules are manufactured by First Solar, a large-scale US manufacturer of thin-film solar modules. The purified cadmium and tellurium are directly deposited onto glass without the need for separate ingot, wafer and cell fabrication steps. Financial support required to support this manufacturing technology in Australia is likely to be comparable.

Despite a strong history in solar cell technology development at Australian universities, and historical manufacturing capability through to 2009, Australia's current presence in the solar PV manufacturing value chain is highly limited.

Current and historical solar PV manufacturing capability in Australia

	Quartz mining / Mg-silicon smelting	Poly-si production	Ingot/wafer manufact.	Cell manufact.	Module manufact.
Current presence in Australia	Simcoa (52,000t p.a)	None	None	None	Tindo (160MW p.a.)[13]
Historical presence in Australia	Simcoa (52,000t p.a)	None	None	BP Solar (50MW p.a.)	BP Solar (50MW p.a.)

Case Study: Simcoa[14]

Located in Kemerton, south-west WA, Simcoa is Australia's only silicon manufacturing facility. Established in 1987, it was acquired by Shin-Etsu Chemicals in 1996, and today employs over 175 people. It produces 52,000 tonnes of metallurgical silicon per annum and exports approximately 85% of its total production.

Case Study: Tideland Energy/ BP Solar[15]

Tideland Energy and Solarex were founded in the 70's in NSW, both designing and manufacturing PV products. Tideland and Solarex were acquired by BP Solar in 1985 and 1999, respectively. The new BP Solar factory in Olympic Park had a production capacity of approx. 50 MW but closed in 2009 due to competition from Japan and China.

[13] Maximum production capacity. [14] Simcoa, https://www.simcoa.com.au/history-silicon#:~:text=Our%20company%20was%20founded%20in,the%20Australian%20Industry%20Development%20Corporation, viewed August 2023.
[15] Energy Matters, https://www.energymatters.com.au/renewable-news/em217/, viewed August 2023.

Australia's competitive advantage on a global stage

Australia is competing on a global stage to attract investment in the solar PV industry and the required manufacturing capability. Industry has indicated that certain factors make Australia an attractive investment location. High costs and a lack of strong policy support are eroding this advantage.

Industry stakeholders have indicated that Australia is an attractive location for establishing a solar PV manufacturing industry, due to its strong trade relationships and existing status as a credible energy exporter; critical minerals availability; political stability; and existing bulk commodity export infrastructure.

In particular, Australia's high renewable energy potential makes it an appealing future manufacturing location for energy intensive goods. Large scale development of firmed renewable energy should drive down electricity costs over time and make Australia a competitive location for export of low-carbon modules and other products.

However, Australia's relatively higher costs of labour and construction, lack of manufacturing expertise, absence of supporting policies and financial support put Australia at a disadvantage compared to other regions. Australia can mitigate these disadvantages over time through provision of clear and direct policy support for clean energy manufacturing and facilitation of associated R&D and manufacturing expertise. Australia can leverage its strong relationships in solar with overseas partners to attract this know-how.

Relative disadvantage ›››› Relative advantage

Factors underpinning competitive advantage		Proxy Metric*	AU	CN	SEA	US	EU	IN	ME
Capex	**Construction costs**	*Construction cost index*							
Electricity	**Renewable energy potential**	*Solar potential (specific PV power output)*							
	Cost of grid electricity (current)	*USD/kWh*							
Demand	**Domestic offtake potential**	*Forecast annual solar capacity increase*							
Labour	**Cost of labour**	*Average manufacturing salary (USD/month)*						N/A	N/A
	Labour standards	*Existing labour practices/ standards*							
Materials	**High-quality quartz/ mg-Si supply**	*Presence of local industry (Y/Ann./N)*							
	Domestic solar glass/ Al industries	*Presence of local industry (Y/Ann./N)*							
IP	**Solar PV R&D capability**	*# dedicated research institutions*							
	Access to Chinese IP/ technology	*Trade relationship with China*		N/A					
General	**International investment certainty**	*Ease of doing business index*							
	Export infrastructure	*Logistics performance index*							
	Manufacturing expertise	*Economic complexity index*							
	Existing policy support	*Case studies/stakeholder engagement*			N/A				

* ***Note:*** *The table shows a high-level assessment of different factors underpinning competitive advantage. The chosen metric may not fully reflect the factor but is used as a proxy. Ratings for each metric are scored on a relative and not absolute basis. A country is scored with "N/A" (not assessed) when the source does not include information for the country or region. Refer to the S2S Detailed Report. AU – Australia; CN – China, SEA – South-east Asia; US – United States, EU – Europe; IN – India; ME – Middle East*

Government priorities: Where should Australia participate in a diversified supply chain

When considering the need for a diversified solar PV value chain, government should balance factors including vulnerability/criticality, industry interest, competitive advantage and economic benefits.

Each step in the PV value chain has different industry characteristics: from the complex, large-scale chemical industry at the poly-Si stage, semiconductor processing at cell level, through to reasonably low complexity module manufacturing. Whilst the S2S study recommends development of all steps of the value chain, a range of criteria can guide the Government with prioritisation of the timing of development. Stakeholder engagement found keen industry interest to build up manufacturing capability at each step, including through international partnerships and contracting arrangements.

Relatively Lower → Relatively Higher

Value chain step (minimum viable scale)	Poly-Si (10GW)	Ingot/Wafer (1GW)	Cell (1GW)	Module (1GW)
Vulnerability/criticality[16]	Moderate	Higher	Moderate	Lower
Competitive advantage[17]	Moderate	Moderate	Lower	Lower
Existing industry interest[18]	Higher	Moderate	Moderate	Higher
Initial capital investment	~1.3bn AUD	~119m AUD	~155m AUD	~56m AUD
Direct jobs[19]	520 FTE	190 FTE	240 FTE	260 FTE
LCOP Cost gap % (absolute)[20]	93% greater (3.3 AUDc/W)	72% greater (5.4 AUDc/W)	55% greater (7.0 AUDc/W)	19% greater (4.8 AUDc/W)
Offtake market focus	Domestic + Export	Domestic + Export	Domestic	Domestic

Case studies of existing industry interest:

Poly-Si: **Quinbrook** specialises in investing, developing, and operating large-scale renewable energy assets across the US, UK, and AU. They are sponsoring a poly-Si plant in Australia to meet their needs, with a strong commitment to green-power and high labour standards. Quinbrook is currently in the process of selecting a qualified technology operator.

Ingot/Wafer: **A new Australian company[21]** is planning to manufacture ingots and wafers in Australia leveraging excellent relationships with China for equipment and knowhow transfer. The company is also considering using their wafers for Australian modules via cell contract manufacturing overseas.

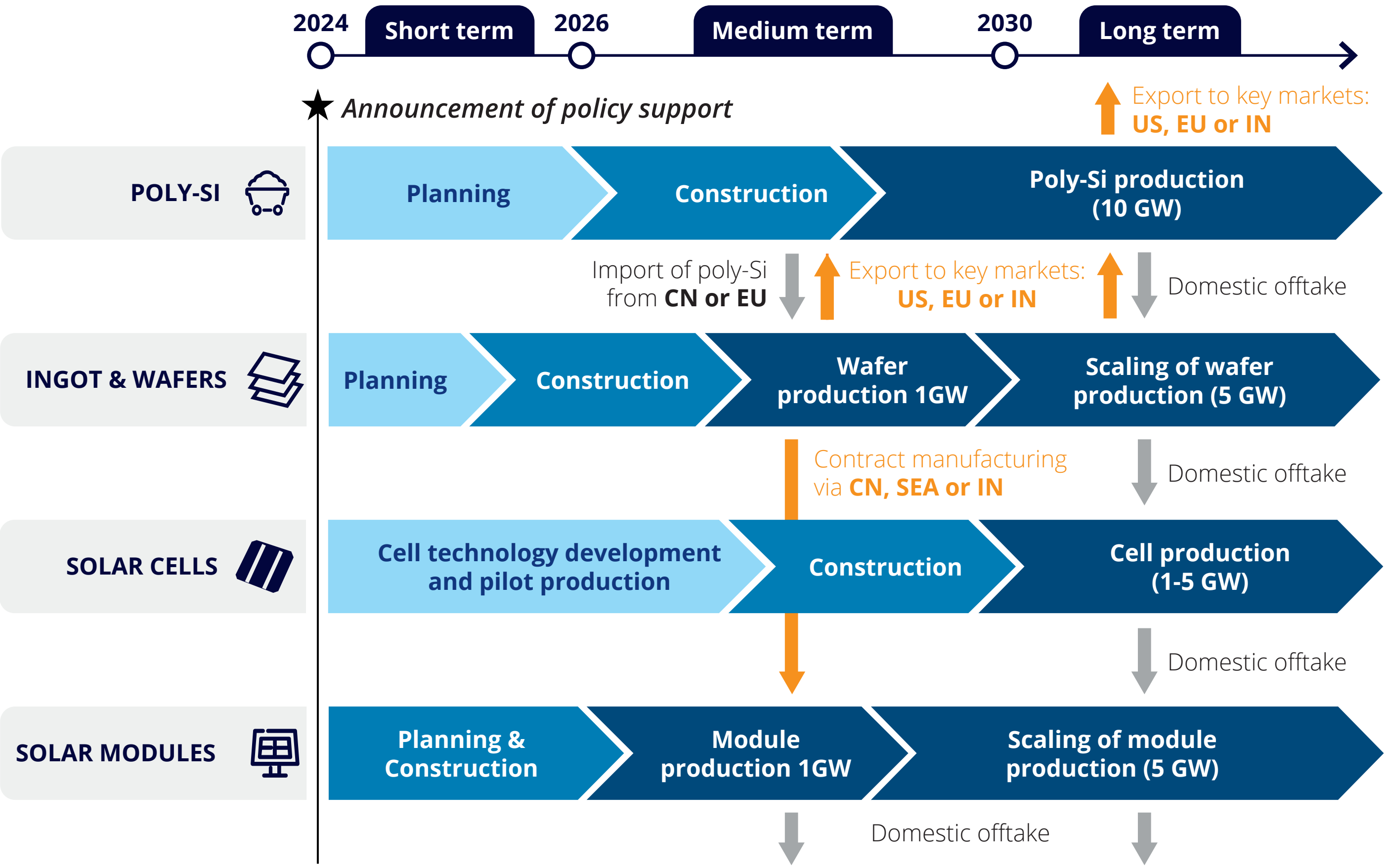
Cell: **SunDrive,** a solar commercialisation company based in Sydney, has developed cell technology that uses copper instead of silver for cell metallisation. Precursor cells are currently manufactured in China and metallised in Australia. A roadmap to 5 GW cell and module production has been presented.

Module: **Tindo Solar,** is located in Adelaide, SA, and is Australia's only PV module manufacturing facility. Founded in 2011, it is entirely Australian-owned, with a production capacity of 160 MW. Companies at previous steps of the value chain have also expressed interest in developing module assembly capability for vertical integration.

[16] % concentration in the supply chain, refer to page 10. [17] Competitive advantage rankings based on key metrics as presented in Detailed Report. [18] Existing industry interest rankings based on stakeholder engagement [19] Assuming that Australia will require 20% higher headcount than China [20] Based on quantitative analysis of the Levelised cost of production (LCOP) and estimated cost to import from China. Further information on analysis is provided in the Detailed Report. [21] Due to the stage of the development, the company can't be named yet. Note: *Exchange rate used for USD to AUD conversion: 0.7045 USD/AUD (average of 2023/4 to 2026/7, Deloitte Access Economics, https://www.deloitte.com/au/en/about/press-room/business-outlook.html, Sept. 2023)*

Credible future industry development pathway

To fully solve for supply chain security, capability at each step should be developed. With appropriate government support provided to all steps in parallel, a fully integrated domestic value chain can be developed to service domestic demand for modules and an export market at the poly-Si and ingot/wafer steps.



Priority considerations

At the poly-Si step, Australia can be part of a globally diversified supply chain exporting particularly to the rapidly growing US and EU markets. Australia would export energy-intensive value-added products and have direct control over poly-Si for the needs of the domestic solar market.

Ingot & wafer manufacturing addresses the most concentrated step in the solar value chain. Australian wafers can be exported to the US, EU and other regions. Contract manufacturing overseas could enable domestically produced wafers to be used in local solar systems in the medium term.

Rapid development of **cell technology** and large capacity scale up present a challenge to setting up viable cell production domestically. Australia's strong track record in cell research could lead to cutting-edge production, however, R&D, prototyping and pilot lines require additional time.

Module production represents a "low-hanging fruit" option due to the relatively small upfront investment and government support needed. However, building globally competitive module production is challenging and Australian modules would be for the domestic market only.

Note: *CN – China, SEA – South-east Asia, IN – India, EU – Europe, US – United States*

4 Value chain assessment

Manufacturing in Australia: Overarching barriers

A potential Australian solar manufacturing industry is faced with an economic gap at every step of the value chain compared to Chinese manufacturers. This is driven by fundamental cost disadvantages, two decades of industry experience and strategic support from the Chinese government. Development barriers in Australia also hinder industry growth.

Cost barriers

High electricity prices and future price uncertainty - Australia currently has relatively high electricity prices compared to several global peers, with recent wholesale price volatility and increased future price uncertainty.

High upfront capital cost and overheads – higher upfront capital costs compared to China can be attributed to higher construction costs, equipment import requirements, safety, technical and environmental standards, as well as longer project timelines. Overheads are assumed to be proportional to total production costs in the TEA and are therefore also higher in Australia.

Cost of labour – Skilled and un-skilled labour costs are high in Australia compared to China

Material and shipping costs – While the TEA assumes material sourcing from China (and hence only a marginal difference in material costs in addition to shipping), material intensive steps are exposed to global market prices.

Project development barriers

Permits: Permitting and approval uncertainty and timeline - investment uncertainty due to the lack of tailored guidance, additional complexities through interaction of federal and State approvals, as well as potentially lengthy and unknown processing timeframes.

Partners: Uncertainty on foreign equity position - A partnership or JV with an international technology provider is likely to be required to establish PV manufacturing in Australia, to secure IP and relevant skills. Prospective investors indicated a lack of certainty on foreign investment approvals for this type of model.

People: Access to skilled labour – Australian facilities will likely be dependent, in the early stages, on international skilled workers to set up, operate and train the domestic workforce. In addition, current domestic workforce labour shortages and skills shortages exist.

Access to capital – Financing risk related to nascency of industry and capital intensity

Importance of cost factor in final production cost/Criticality of enabling factor in attracting investment

Relatively Lower → Relatively Higher

Note – additional value-chain specific barriers are outlined in slides 20-23

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What would **poly-Si** manufacturing in Australia look like?

The establishment of one poly-Si facility would constitute an export focussed poly-Si industry in Australia, due to the minimum viable scale of production exceeding near-term domestic demand. A partnership with an international technology provider and access to sufficient additional firmed renewable energy supply would be required.

The opportunity

Due to the minimum viable scale of 25kt/10GW p.a., establishment of one facility would constitute an export focussed poly-Si industry. This presents an opportunity to complement the IRA, which is currently anticipated not to stimulate sufficient poly-Si capacity in the US. In addition, due to the current import tariffs on Chinese poly-Si, and historical human rights concerns for poly-Si production in the Xinjiang province in China, the US market would likely pay a price-premium for Australian-produced products.

Australia's competitive advantage

- **Renewable energy potential** – poly-Si purification is highly electricity intensive. Australia's abundance of sunshine and land present a potential competitive advantage to access low-cost, low-emissions electricity.
- **Existing bulk-commodity export infrastructure and energy trade credentials**
- **Existing high quality quartz deposits and mg-Si capability** – Australia has large deposits of high-quality quartz and mg-Si capability; process integration with mg-Si smelting has potential for substantial cost and energy efficiencies

Key factors & considerations for success

Development of a viable poly-Si facility will require:

- **Access to low-cost, low-carbon mg-Si supply,** either through increased domestic capacity building[22] or removal of import tariffs on Chinese mg-Si.
- **Access to dedicated low-cost, firmed decarbonised energy supply,** to ensure competitiveness in a future decarbonised world.
- **Access to existing high voltage grid infrastructure with sufficient capacity** to minimise need for costly grid infrastructure upgrades.
- **Partnering with an overseas technology provider;** Australia currently has neither the capabilities nor expertise to establish poly-Si capability.
- **Stringent health and safety controls,** for use and storage of highly flammable/combustible trichlorosilane (TCS) in the production process

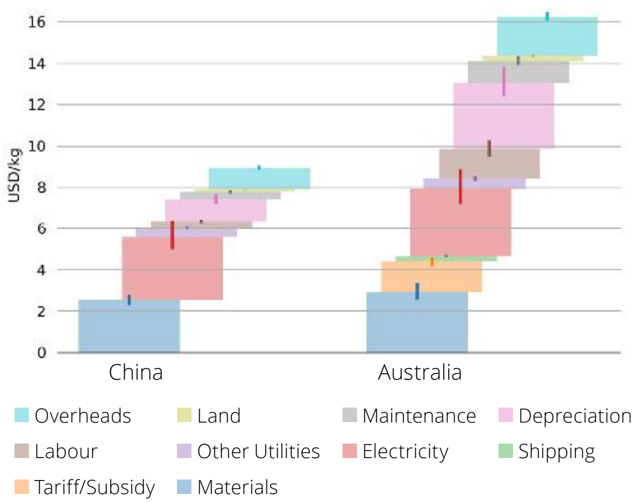
Facility properties

Minimum viable scale of production	10 GW (25kt) per annum
Facility life	20 years
Estimated upfront CAPEX	1.3bn AUD
Electricity requirements	1.3 – 1.5 TWh/10GW (170 MW average)
Labour requirements	520 FTE/10GW
Key material inputs	mg-Si (27.5kt/10GW)
Land requirements	300,000 m²/10GW
Estimated construction timeline AU	3 – 5 years

A poly-Si facility of this scale would likely be **export focussed** regardless of full value chain development in Australia

For comparison, the **Portland aluminium smelter** in Victoria requires 4.3 TWh (490MW average) electricity per annum for 300kt production

Poly-Si production cost



Key cost drivers compared to manufacturing in China:

- Electricity costs
- Capital costs (Depreciation)
- Overheads
- Cost of mg-Si (including presence of an anti-dumping tariff)

Note: *The TEA enables direct comparison of costs, without consideration of finance or time value of money.*

[22] *Note: Domestic mg-Si capacity building will require the identification of a sustainable charcoal source, as the WA government is implementing a ban on logging of local jarrah currently used as a charcoal source by Simcoa.*

What would **ingot/wafer** manufacturing in Australia look like?

Ingot/wafering is a highly specialised process, with state-of-the-art technology and IP owned by a few large companies in China. If set up in Australia, an ingot/wafer facility would likely require a partnership with an international technology partner and could be scaled up by one or a few companies to service both a domestic and export market over time.

The opportunity

Ingot/wafer manufacturing would address the most concentrated step in the value chain and could be scaled up in Australia to service both domestic capacity and an export market. This presents an opportunity to complement the IRA, which is currently anticipated not to stimulate sufficient ingot/wafer capacity in the US. In addition, due to the current import tariffs on Chinese wafers, the US market would likely pay a price-premium for Australian-produced products.

Australia's competitive advantage

- **History of close collaboration with China in the PV industry –** Australia's collaborative history in cell/module technology could cement advantages and opportunities when requiring Chinese expertise to establish local ingot/wafer production
- While the primary cost drivers underlying manufacturing of ingots/wafers do not naturally favour Australia (cost of labour and high upfront capex), Australia is also not largely disadvantaged in these categories compared to other OECD states such as the US and EU.

Key factors & considerations for success

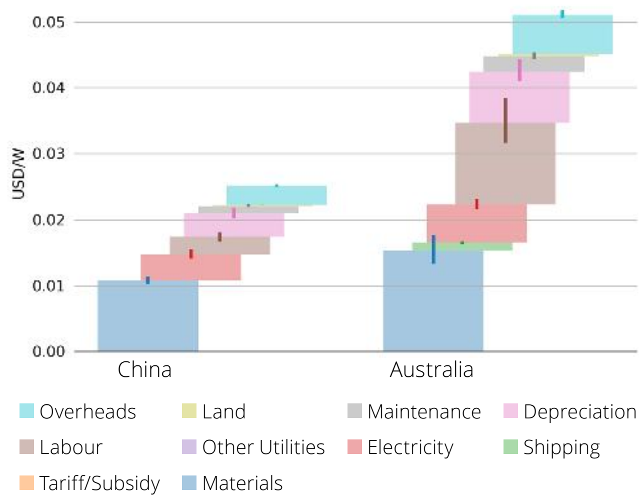
Development of a viable ingot/wafer facility will require:

- **Partnering with an overseas technology provider, to ensure access to state-of-the-art Chinese IP, equipment and skilled labour.** Australia currently has neither the capabilities nor expertise to establish ingot/wafer capability.
- **Access to highest levels of automation and manufacturing excellence,** as ingot/wafering has significant labour costs

Facility properties

Minimum viable scale of production	1 GW per annum
Facility life	20 years
Estimated upfront CAPEX	~119m AUD
Electricity requirements	60-70 GWh/GW (~5.7-8 MW)
Labour requirements	190 FTE/GW
Key material inputs	poly-Si (2.5kt/GW)
Land requirements	15,000 – 20,000 m²/GW
Estimated construction timeline AU	12 – 18 months

Ingot/wafer conversion costs (without poly-si)



Key cost drivers compared to manufacturing in China:

- Labour cost
- Capital cost (Depreciation)
- Overheads
- Electricity costs

Note: *The TEA enables direct comparison of costs, without consideration of finance or time value of money.*

What would **cell** manufacturing in Australia look like?

Australia has a strong history in cell technology development, with the potential for ongoing technology innovation to justify development of a commercialised new cell technology capability in the long-term. In the meantime, international partnerships with overseas cell manufacturers could facilitate contract manufacturing of Australian wafers into Australian modules.

The opportunity

Rapid development of cell technology and large production capacity in China, the US, the EU and India present a challenge to setting up a viable cell production domestically. Australia's strong track record in cell research could lead to a cutting-edge production in the longer-term, however, R&D, prototyping and pilot lines would require additional time to reach commercial scale. Investment would need the patience to move innovative cell technology to full commercialisation.

Australia's competitive advantage

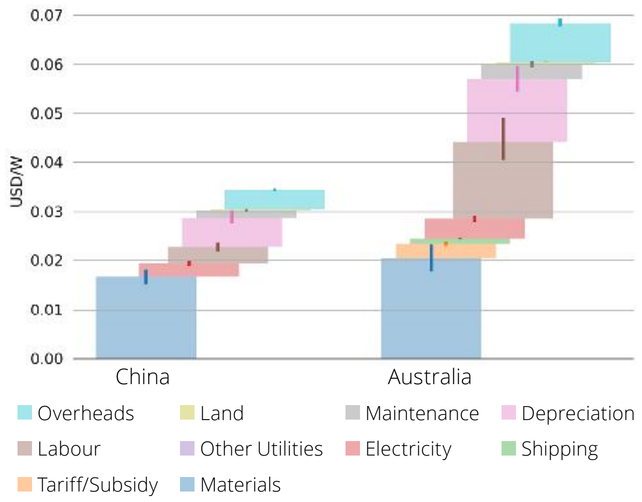
- **Australia's track record in developing cell technology.** Australia has a long history of expertise in cell technology development, responsible for the development of the PERC and TOPCon cell architectures, and process improvements to performance, reliability and cost
- **History of close collaboration with China in the PV industry.** Whilst Australia lacks manufacturing capabilities of semiconductor devices like solar cells compared to the US and EU, a new cell manufacturing industry can leverage the long-standing relationship in the solar industry to Chinese manufacturers and expertise.

Specific barriers & considerations

- **Supply chain concerns** - access to high-purity semiconductor-grade chemicals and silver pastes. Local suppliers lack the necessary scale and purity of chemicals, and silver pastes rely on IP-protected technologies, making its supply challenging
- **Sustainability considerations -** Stakeholders indicated increasing emphasis on safety and environmental considerations, such as a shift away from certain chemicals to ease management of chemical waste. This would require ongoing monitoring as technology develops.

Facility properties	
Minimum viable scale of production	1 GW per annum
Facility life	20 years
Estimated upfront CAPEX	~155m AUD
Electricity requirements	40 – 50 GWh/GW (5MW average)
Labour requirements	240 FTE/GW
Key material inputs	Silver paste (12 – 20t/GW), semiconductor grade chemicals, high-purity (4N-6N) gases
Land requirements	20,000 – 30,000 m²/GW
Estimated construction timeline AU	2 - 4 years

Cell conversion costs (without ingot/wafers)



Key cost drivers compared to manufacturing in China:

- Labour cost
- Capital cost (Depreciation)
- Overheads
- Silver paste cost (note, taricc/ subsidy cost represents a subsidy provided to Chinese manufacturers that is lost when exporting silver paste outside of China)

***Note:** The TEA enables direct comparison of costs, without consideration of finance or time value of money.*

What would **module** manufacturing in Australia look like?

Module manufacturing is less complex and technology dependent compared to the rest of the value chain, with shorter project lead times. As such, development of solar module capability in Australia could quickly be scaled from 1GW to match domestic demand. However, modules are unlikely to service a competitive export market.

The opportunity

Due to the relatively low upfront capital cost, short project development timeline, and relatively low complexity of the manufacturing process, barriers to entry for module manufacturing are considered to be relatively low. In addition, module manufacturing is the least concentrated step in the value chain. Due to the weight of key input materials such as aluminium and glass, and associated increases to shipping costs and emissions, domestic manufacturing may have a slight advantage over imported products. However, existing capacity announcements following the US IRA are almost three-fold the domestic demand in the US, therefore, Australian modules are unlikely to be competitive or find a market on an international scale.

Australia's competitive advantage

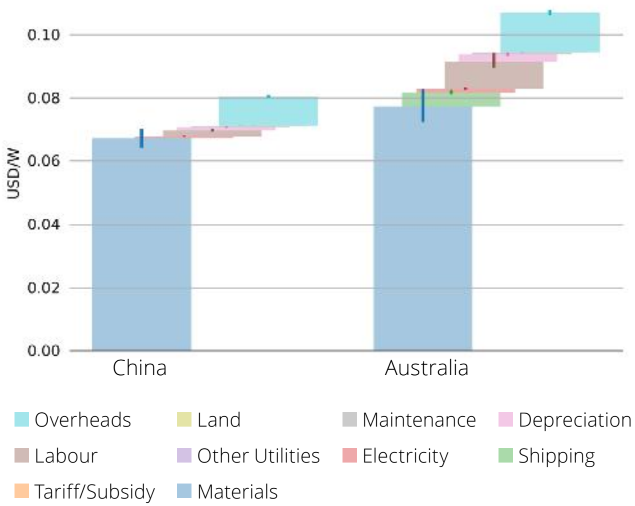
- **Large domestic PV demand potential** - TW-scale domestic solar demand potential (for installed module capacity), if Australia replaced its current carbon-intensive energy exports with green, solar powered exports
- **Local glass and aluminium production,** both energy- and emissions intensive processes, present an opportunity to support integrated low-carbon domestic manufacturing and reduce both emissions and costs from module production and shipping.

Specific barriers & considerations

- **High ongoing material cost and payment terms,** resulting in likely requirement for ongoing operational support such as working capital facilities and/or credit guarantees
- **Lacking module certification capability in Australia for rapid product development.** Recertification of modules following changes to the bill of material requires modules to be sent overseas, which is costly and time-consuming
- **Exposure to global market dynamics of key material inputs and reliance on overseas suppliers –**This results in a lack of flexibility to respond to short-term fluctuations in market pricing.

Facility properties	
Minimum viable scale of production	1 GW per annum
Facility life	20 years
Estimated upfront CAPEX	~56m AUD
Electricity requirements	10 - 15 GWh/GW (1.5 MW average)
Labour requirements	260 FTE/GW
Key material inputs	Aluminium (6 kt/GW), glass (40 kt/GW)
Land requirements	10,000 – 20,000 m²/GW
Estimated construction timeline AU	6 – 12 months

Module conversion costs (without cells)



Key cost drivers compared to manufacturing in China:

- Material and shipping costs
- Labour cost
- Overheads

Note: *The TEA enables direct comparison of costs, without consideration of finance or time value of money.*

5 Overcoming critical barriers:

Support needed to develop domestic solar PV capacity

Supportive policy ecosystem to unlock an Australian PV manufacturing industry

There is no silver bullet policy solution, rather, a supportive policy ecosystem comprising a combination of supply, demand and enabling policy levers will be required to address the diverse barriers identified by industry to establish solar manufacturing in Australia.

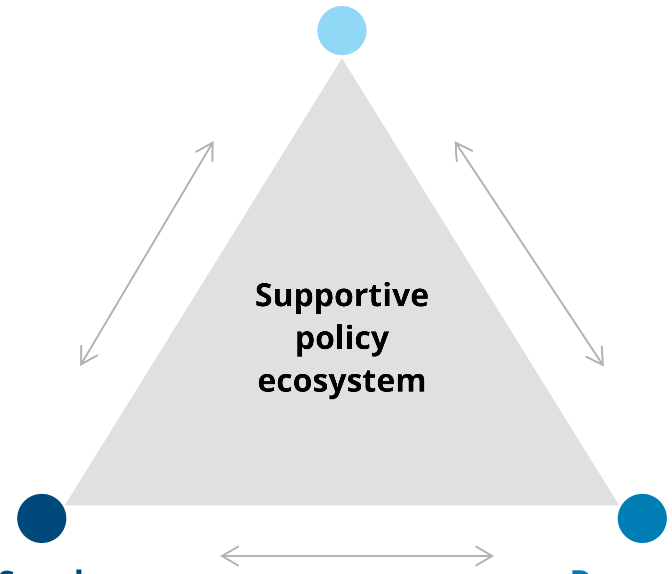
Supply: direct or indirect financial support to bridge the cost gap to comparable imported products over a set period will be key to ensure that Australian facilities can remain cost competitive with other economies, many of which are providing substantial financial incentives for domestic manufacturing.

- **Upfront capital support** incentivises construction, and is often preferred by industry, especially upstream in the PV supply chain, due to the higher upfront time value of money.
- **Ongoing operational support** – incentivises production, as companies must be operational and producing outputs to receive financial support. The longer-term nature of the support provides cost certainty for producers, while linking government spend to direct production results.

A combination of upfront capital and ongoing operational support can balance industry and government priorities.

Enabling

Development of frameworks and support to improve ease of doing business



Supply

Direct or indirect financial support to help bridge the cost gap

Demand

Stimulation of demand certainty through supportive policies

Enabling support to target a range of non-financial barriers which may otherwise inhibit industry development. Extensive stakeholder engagement has identified that key barriers at the project development stage need to be addressed for successful industry establishment, and for projects to reach final investment decision. Without this, direct or indirect financial support will unlikely be effective at attracting private investment to Australia.

Offtake or demand certainty is critical to provide longer-term investment certainty for new or developing industries, which may be disadvantaged by economies of scale and market tactics of established international players to import cheaper, international products. The suitability of various demand levers may change over time and maturity of the industry.

- **Demand incentives ('carrots')** are critical in early to medium-stage industry development to encourage offtake of domestic products without penalizing consumers or increasing the cost of products.
- **Supply restrictions ('sticks')** such as import tariffs or import standards may have a role to play following the successful establishment of a domestic industry or to limit certain practices, however, they have a high risk of decreased economic efficiencies, retaliatory action and trade disputes.

Enabling support required to overcome critical barriers: Priorities, Permits, Partners

Regardless of the value chain step, key barriers at the project development stage need to be addressed for successful industry establishment. Without this, direct or indirect financial support will unlikely be effective at attracting private investment to Australia.

	Priorities: Uncertainty on solar PV manufacturing as a strategic government priority	**Permits:** Uncertainty on solar PV manufacturing as a strategic government priority	**Partners:** Uncertainty on foreign investment process and outcomes
Barriers to industry development	Australia is competing on a global stage to attract international solar PV manufacturing capability and private investment to Australia. Industry stakeholders have repeatedly identified the need for certainty in the governments' intention to support the solar PV manufacturing sector as a strategic priority in the long-term.	Stakeholder engagement identified that they continue to face significant investment certainty relating to permitting and approval timing and outcomes. Stakeholders emphasised the need for clear guidance and streamlined processes in order to enhance certainty on timelines and outcomes, particularly for the large-scale energy and chemical-intensive facilities required at the poly-Si, ingot/wafer and cell manufacturing steps.	Australia does not currently possess the expertise necessary to establish manufacturing, in particular for poly-Si and ingot/wafer manufacturing. International operating partners will likely be required to provide technology IP, equipment, setup and initial training of domestic workforce. However, stakeholders (both international players as well as Australian industry seeking partners) have indicated high uncertainty around foreign investment approvals, with regards to both timing and outcome.
Recommendations	**Announcement/recognition of solar PV manufacturing as a strategic government priority** • Explicit inclusion of solar PV manufacturing as an eligible sector for existing and recommended support mechanisms • Consider definition of a national target for solar PV manufacturing (e.g. 20% of annual demand by 2030)	**Provide clear upfront guidance and streamlined process for permitting and approvals:** • Provision of targeted pre-approval engagement service for solar PV manufacturing facilities • Commitment to accelerated processing timeframes through increased staffing, or maximum application processing timeframes • Publication of sector-specific approvals and permitting guidance • Increased coordination between government agencies to ensure timely delivery and outcomes of approvals • Government facilitation of place-based environmental planning for strategic industrial hubs	**Provide clear and early direction on joint ventures or partnerships with foreign investors:** • Clear guidance on acceptable foreign investment and joint venture/partnership requirements for the solar PV manufacturing sector • **Note:** additional support recommended in this study should be prioritised for Australian companies through competitive selection processes and eligibility criteria.

Enabling support required to overcome critical barriers: People and Concessional Finance

Support to ensure access to skilled foreign workers will be key to create an attractive investment environment in Australia and enable rapid speed to market for proponents. In addition, access to capital at concessional terms will be key to mitigate financing risk and unlock national and international finance.

Barriers to industry development

People: Access to skilled labour

Domestic labour shortage: Australia currently has a large shortage of skills in the clean energy industry. Solar PV manufacturing would be competing with other high wage-paying industries in Australia, such as mining.

Lack of training of domestic workforce: Specialized manufacturing skills are currently not taught at Australian universities or vocational training institutions.

Lack of workers with direct solar manufacturing experience: Australia currently lacks workers with direct solar manufacturing experience, which can only be obtained overseas. Foreign skilled workers will need to come to Australia in the first stages of industry development to set-up, operate and train the domestic workforce.

Lack of sufficiently attractive visa options for highly skilled foreign workers: stakeholders noted lack of sufficiently attractive (permanent resident) visas and delays in processing timelines as key barriers.

Concessional Finance: Access to capital at concessional terms

Industry emphasized that access to capital at concessional terms is essential to unlock solar PV manufacturing in Australia. Many commercial lenders are not willing to give sufficient concessional terms due to the nascency of the industry and high-capital intensity. Government will need to step in to overcome the current funding gap for emerging industries.

Note: As part of this study and quantitative assessment of policy support, concessional finance was evaluated as a low interest, long-term loan. However, several forms of concessional finance, including equity investment and guarantees may be appropriate, and could be evaluated on a case-by-case basis.

Recommendations

Ensure streamlined visa pathways exist for solar PV manufacturing workers in the short term, while developing specific worker reskilling support and training programs for solar PV manufacturing:*

- Add trades with specialist solar PV manufacturing skill shortages to the priority migration skilled occupation list.
- Commit to a set number of streamlined skilled worker permits or visas to support solar PV manufacturing facilities. These could be linked to domestic workforce training requirements for international partner companies.
- Promote collaboration between industry and academic institutions to set-up relevant PV manufacturing training courses and apprenticeships, and provide subsidised training programmes for workers in solar PV manufacturing.
- Provide additional industrial workforce incentives, e.g. by linking industrial clusters with affordable housing, affordable quality childcare and schools, public transport and other amenities.

Provide clear and early direction on joint ventures or partnerships with foreign investors:

- Clear guidance on acceptable foreign investment and joint venture/partnership requirements for the solar PV manufacturing sector
- **Note:** additional support recommended in this study should be prioritised for Australian companies through competitive selection processes and eligibility criteria.

***Note:** *Stakeholder engagement suggests every specialist skilled migrant in the solar value chain will create up to 9 new local jobs.*

Demand-side policy support required to overcome investment uncertainty

Domestic demand-side support for industry will be key to provide offtake and revenue certainty for investment decisions. The type of support required will likely evolve over time, in line with the scale and maturity of industry development in Australia.

Barriers to industry development

Demand uncertainty for locally-produced PV products

Although local and international stakeholders have indicated that there is an appetite for Australian-made, supply-chain transparent and low carbon solar PV products, voluntary willingness to pay a premium is unlikely in the absence of mandates or financial incentives. Incentives to boost demand for locally produced products will be key to provide confidence to industry and mitigate the risk of market tactics by international players to undercut a domestic industry.

Demand uncertainty for Australian exports

Demand for Australian-produced products (upstream of the value chain) will largely be dependent on target export markets and trade dynamics. Poly-Si and ingot/wafer prices in the EU and US are higher than in China, making these attractive markets for Australian products. Ensuring market access will help create demand certainty for Australian manufacturers.

Domestic solar PV deployment uncertainty

While there is a large pipeline for renewable projects in Australia, developers currently face numerous barriers and difficulties, including challenges in the grid connection process, delays and difficulties in the permitting and environmental approvals, as well as opposition from local communities to large-scale transmission and solar farm infrastructure. The costs of these processes, as well as costs of delays are leading to a lack of projects reaching final development and increased uncertainty on Australian demand for PV products.

Recommendations

Government procurement:

- Commitment from federal and State governments to procure minimum % of annual PV demand from local producers (where available).

Implement a form of local content incentive/bonus:

- Local content incentives or requirements in renewable energy industrial precinct (REIP) and renewable energy priority regions selection process
- Local content bonus for solar PV developers, e.g. through the renewable energy target (RET) or an alternative system. The scope could be broadened to include locally produced batteries, wind components and other green energy products, thereby supporting the efforts made in other clean energy supply chains.

Facilitate preferential trade arrangements with key economies for solar PV components, such as through the Australia – US Compact and Joint India – Australia Solar Taskforce

Remove barriers for low-carbon manufacturing to ensure success of Australian exports in target EU and US markets and minimise the impact of future carbon tariffs:

- Government support to accelerate additional large-scale renewable energy deployment will be critical to ensure sufficient access to additional renewable energy supply for energy-intensive poly-Si and ingot/wafer facilities.

Remove barriers to utility-scale solar PV deployment:

- Link grid transmission infrastructure to new production centres
- Facilitate and coordinate planning of network investments and grid connection process
- Streamline approvals, without undermining social and environmental concerns
- Address installation skill shortages, such as electricians and solar installers
- Encourage solar PV installation with subsidies in the short term, moving towards mandates in the longer term. Continuing a similar incentive to the RET mechanism would provide incentives to utility-scale PV developers as well as individuals and businesses to install solar PV.

Supply-side policy support required to overcome investment uncertainty

A production credit combined with a form of concessional finance are the most effective policy levers to close the cost gap for Australian manufacturers. A production credit could be modelled on the existing Hydrogen Headstart program.

Barriers to industry development

Cost gap between cost of manufacturing in Australia and imported products from China

If sized to close the cost gap between the cost of production and assumed competitive sales price for a fixed number of years, a production credit can provide substantial upfront investment certainty to industry and financial institutions. The 'payment on results' basis means that cost to government is only incurred if the production eventuates. In combination with concessional finance, this can effectively overcome both upfront capital and ongoing operational cost barriers.

Recommendations

Implement a production credit in combination with concessional finance (refer to page 27) to close the cost gap to imported products.

Production subsidies are an effective financial support lever to overcome the cost gap to international products, and can be applied as a uniform lever across all steps of the value chain, irrespective of underlying cost drivers (e.g. electricity, labour, materials). This would simplify administration across multiple sectors and could be sized in accordance with government priorities and industry needs. Support could be designed to leverage the existing Hydrogen Headstart model, to minimise administrative complexities and send a clear signal to industry.

Design considerations

Support should be provided as a direct subsidy payment rather than a tax credit, such as in the US IRA, to maximise ability of facilities to access support, even if they are loss-making, and minimise administrative complexities associated with trading of credits on a second-hand market. To minimise risks to government, key design features should include:

- Allocation and sizing of support based on a reverse auction tender process, with applicants nominating volumes to be produced and subsidy size required
- A support cap to provide government cost certainty
- Upside sharing or funding reduction features linked to increased market sales prices
- Eligibility requirements linked to key social and environmental objectives (refer to page 34 and Section 7.4.4 in the Detailed Report)
- A payback provision if the agreed term of production and subsidy support is not completed
- Clear communication of duration and gradual phase-out, to mitigate risks of overreliance on support
- Allocation of support in alignment with priority sectors for development, and in consideration of competitiveness with other jurisdictions
- Allocation of support in consideration of corporate and technology diversity to the extent possible

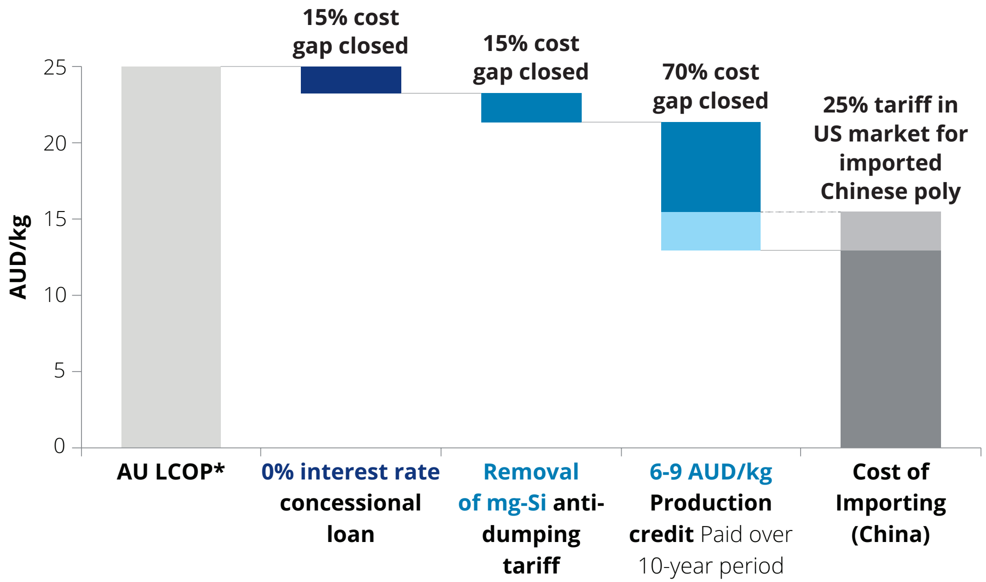
Alternative supply side support may be considered by government, e.g. through the provision of capital grants or electricity price guarantees. This may be particularly appropriate for a poly-Si facility, given the capital and energy intensity of the facilities, the large minimum scale of production, and the potential to access price-premium offtake markets (and hence require less support). However, this support in isolation would not be sufficient to close the cost gap to imported products from China.

Note: *additional analysis on the sizing of support to fully close the cost gap at each step of the value chain is presented on the following pages. This presents a sensitivity of maximum support required to be competitive with China, however,* ***less support may be needed depending on project-specific considerations****.*

Developing **poly-Si**: supply-side policy options to close the cost gap to China

Quantitative assessment of a theoretical 10GW poly-Si facility in Australia indicates a combination of concessional loan and production credit of 9 AUD/kg poly-Si would be effective at bridging the cost gap to China over a 10-year production period. This could reduce to 6 AUD/kg or less if targeting a likely price premium market such as the US.

PolyiSi: Combined policy impact to close the cost gap



The modelled scenario shows estimated sizing of support to be competitive with import costs from China, as a maximum sensitivity. This would counteract cost increases for Australian consumers if ingot/wafering and subsequent value chain steps develop in Australia.

- *Production credit:* Allocation of support via a competitive reverse auction tender process would capture potential reductions in support required based on company and project-specific conditions. In addition, export to price-premium markets such as the US may significantly alter project financials.
- *Concessional finance:* modelled as an interest free loan, however, similar or higher impact could be achieved through government equity
- *Removal of Mg-Si anti-dumping tariff (55%):* imposed on Chinese importers to Australia until 2025. Impact on the domestic mg-Si smelting industry and ability to supply a domestic silicon PV value chain would need to be further evaluated.

To support **10 GW/annum** domestic manufacturing capacity and fully close the cost gap:

2.1bn AUD
Total support required
(discounted)

288m AUD
Annual support for 10 years of production
(undiscounted)

Comparison with IRA

4.5 – 6.5 USD/kg
AU Production credit

3 USD/kg
US IRA Production tax credit

Project announcements in the US to date and stakeholder feedback have indicated the IRA is unlikely to be sufficient to stimulate significant investment in poly-Si, as support is comparatively lower than other steps of the value chain, and sunsetting of support from 2030 leaves insufficient time for a new poly-Si facility to access a large portion of support. This presents an opportunity for Australia to complement the IRA through development of an export-focussed industry.

Alternatively, a combination of levers and sizing of support may be appropriate to overcome specific cost barriers for a poly-Si facility:

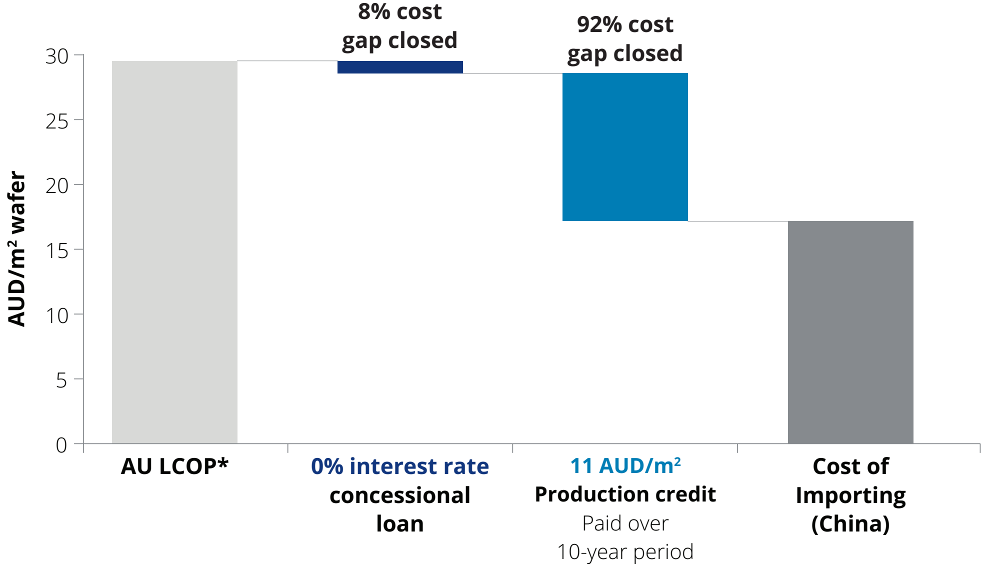
- *Electricity price guarantee:* An electricity price guarantee of 43 AUD/MWh (30 USD/MWh) was identified as a desirable/achievable price to be competitive internationally. This would close the cost gap by ~18%.
- *Capital support:* An upfront capital grant or capital support in the form of concessional land and ancillary infrastructure could overcome capital intensity barriers. A grant equivalent to 100% of upfront capex would close the cost gap by ~70%.

***Note:** The levelised cost of production (LCOP) represents the average unit cost of production over a 10-year period in present value terms. This considers the cost of finance and time value of money in addition to the TEA cost of conversion. Modelling assumptions are outlined in the detailed Report. Total support required includes the cost of production subsidies, as well as 'lost revenue' from removal of the anti-dumping tariff and provision of a 0% interest rate loan. Exchange rate for USD to AUD conversion: 0.7045 USD/AUD (average of 2023/4 to 2026/7, Deloitte Access Economics, https://www.deloitte.com/au/en/about/press-room/business-outlook.html, Sept.). Minor discrepancies may exist due to rounding.*

Developing **ingot/wafering**: supply-side policy options to close the cost gap to China

Quantitative assessment of a theoretical 1GW ingot/wafering facility in Australia indicates a combination of concessional loan and production credit of 11 AUD/m² wafer could bridge the cost gap to China over a 10-year production period.

Ingot/wafer: Combined policy impact to close the cost gap



The modelled scenario shows estimated sizing of support to be competitive with import costs from China, as a maximum sensitivity. This would counteract cost increases for Australian consumers if cell and module manufacturing capability develop in Australia.

- *Production credit:* Allocation of support via a competitive reverse auction tender process would capture potential reductions in support required based on company and project-specific conditions
- *Concessional finance:* modelled as an interest free loan. However, similar or higher impact could be achieved through government equity

To support **1 GW/annum** domestic manufacturing capacity and fully close the cost gap:

350m AUD
Total support required
(discounted)

52m AUD
Annual support for 10 years of production
(undiscounted)

Alternative combination of levers and sizing of support may be appropriate to overcome specific cost barriers for an ingot/wafer facility:

- *Capital support:* An upfront capital grant or capital support in the form of concessional land and ancillary infrastructure could overcome capital intensity barriers. A grant equivalent to 100% of upfront capex would close the cost gap by ~40%.
- *Electricity price guarantee:* An electricity price guarantee of 43 AUD/MWh (30 USD/MWh) was identified as a desirable/achievable price to be competitive internationally. This would close the cost gap by ~10%.

Comparison with IRA

8 USD/m² wafer
AU Production credit

12 USD/m² wafer
US IRA Production tax credit

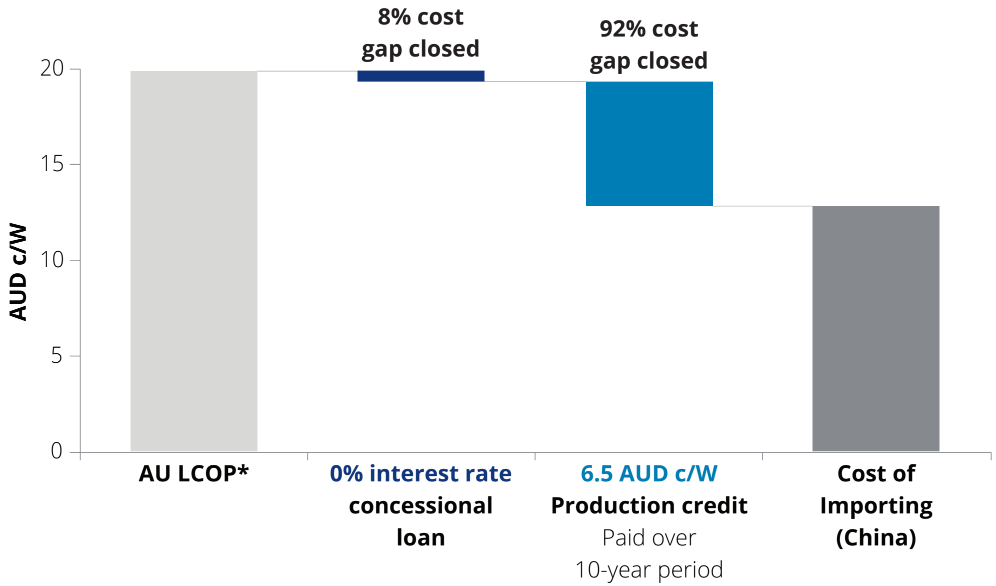
The estimated subsidy is approximately two thirds that of the IRA at 12 USD/m2 wafer. Project announcements to date and stakeholder feedback have indicated that, despite the size of the production credit, the IRA is unlikely to stimulate significant investment in ingots/wafers due to limitations in accessing state-of-the-art Chinese IP and technology. This presents an opportunity for Australia to complement the IRA by developing an export-focused industry.

***Note:** The LCOP represents the average unit cost of production over a 10-year period in present value terms. This considers the cost of finance and time value of money in addition to the TEA bottom-up cost of conversion. Modelling assumptions are outlined in the full report. Total support required includes the cost of production subsidies, as well as 'lost revenue' from provision of a 0% interest rate loan. Exchange rate for USD to AUD conversion: 0.7045 USD/AUD (average of 2023/4 to 2026/7, Deloitte Access Economics, https://www.deloitte.com/au/en/about/press-room/business-outlook.html, Sept. 2023). Minor discrepancies may exist due to rounding.*

Developing **cells**: supply-side policy options to close the cost gap to China

Quantitative assessment of a theoretical 1GW cell facility in Australia indicates a combination of concessional loan and production credit of 6.5 AUD c/W would be required to bridge the cost gap over a 10-year production period.

Cells: Combined policy impact to close the cost gap



Comparison with IRA

4.6 USD c/W
AU Production credit

4.0 USD c/W
US IRA Production tax credit

This estimated subsidy is approximately equivalent to, albeit slightly higher, than the IRA at 4.0 USDc/W. Project announcements to date in the US indicate that the IRA-sized support will be highly successful at developing a cell manufacturing industry in the US, indicating the sizing of the US production credit is sufficient, and Australia would be unlikely to export to the US.

The modelled scenario shows estimated sizing of support to be competitive with import costs from China, as a maximum sensitivity. This would counteract cost increases for Australian consumers if module manufacturing capability develops in Australia.

- *Production credit:* Allocation of support via a competitive reverse auction tender process would capture potential reductions in support required based on company and project-specific conditions (e.g. through innovative technologies)
- *Concessional finance:* modelled as an interest free loan, however, similar or higher impact could be achieved through government equity

To support **1 GW/annum** domestic manufacturing capacity and fully close the cost gap:

459m AUD	**69m AUD**
Total support required (discounted)	**Annual support for 10 years of production** (undiscounted)

An alternative combination of levers and sizing of support may be appropriate to overcome specific cost barriers for a cell facility:

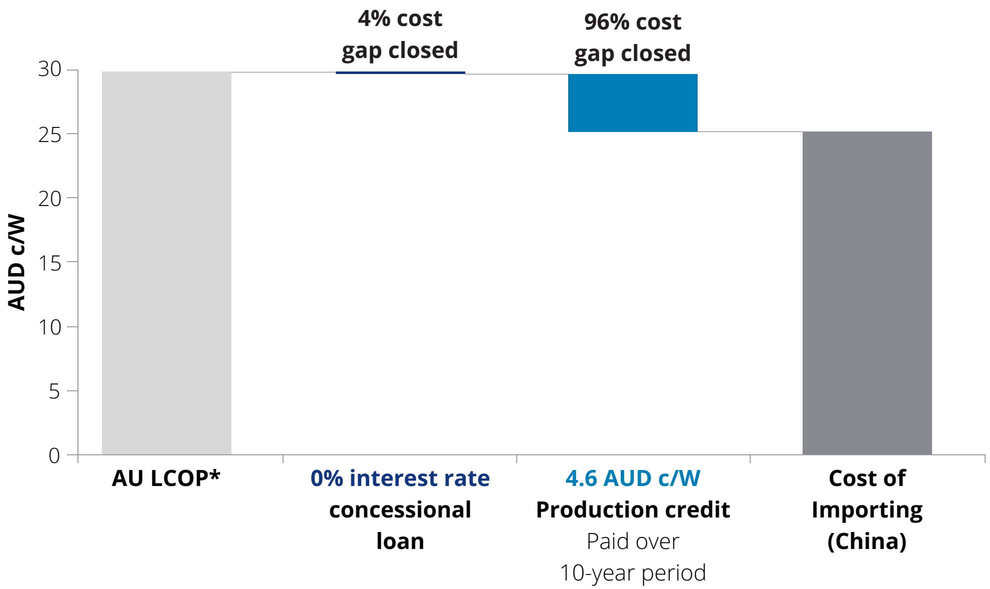
- *R&D support:* upfront R&D support could support innovative technologies with significant cost advantages to existing technologies, therefore minimising operational support required for ongoing production.
- *Capital support:* An upfront capital grant or capital support in the form of concessional land and ancillary infrastructure could overcome capital intensity barriers. A grant equivalent to 100% of upfront capex would close the cost gap by ~39%.

***Note:** The LCOP represents the average unit cost of production over a 10-year period in present value terms. This considers the cost of finance and time value of money in addition to the TEA bottom-up cost of conversion. Modelling assumptions are outlined in the full report. Total support required includes the cost of production subsidies, as well as 'lost revenue' from provision of a 0% interest rate loan. Exchange rate for USD to AUD conversion: 0.7045 USD/AUD (average of 2023/4 to 2026/7, Deloitte Access Economics, https://www.deloitte.com/au/en/about/press-room/business-outlook.html, Sept. 2023). Minor discrepancies may exist due to rounding.*

Developing **modules**: supply-side policy options to close the cost gap to China

Quantitative assessment of a theoretical 1GW module facility in Australia indicates a combination of concessional loan and production credit of 4.6 AUD c/W would be required to bridge the cost gap over a 10-year production period.

Modules: Combined policy impact to close the cost gap



The modelled scenario shows estimated sizing of support to be competitive with import costs from China. This would counteract cost increases for Australian consumers and offtakers.

- *Production credit:* Allocation of support via a competitive reverse auction tender process would capture potential reductions in support required based on company and project-specific conditions.
- *Concessional finance:* modelled as an interest free loan, however, similar or higher impact could be achieved through government equity

To support **1 GW/annum** domestic manufacturing capacity and fully close the cost gap:

317m AUD
Total support required
(discounted)

48m AUD
Annual support for 10 years of production
(undiscounted)

Alternative levers and sizing of support may be appropriate to overcome specific cost barriers for a module facility:

- *Demand side support:* implementation of demand-side support for locally produced content would have a similar effect to a local manufacturer of scale. Instead of off-setting the production costs to make the local producer competitive, the higher sales would compensate for the higher production costs.

Comparison with IRA

3.3 USD c/W
AU Production credit

7.0 USD c/W
US IRA Production tax credit

This estimated subsidy is less than half that of the IRA at 7.0 USDc/W. Project announcements to date in the US indicate that module capacity will exceed forecast domestic demand by a factor of three in response to the IRA. While it is unlikely that all of these projects will become operational, this indicates the sizing of the IRA may be too generous. Australia's increasing domestic market demand may therefore be an attractive incentive for industry, despite the lower subsidy.

Note: *The LCOP represents the average unit cost of production over a 10-year period in present value terms. This considers the cost of finance and time value of money in addition to the TEA bottom-up cost of conversion. Modelling assumptions are outlined in the full report. Total support required includes the cost of production subsidies, as well as 'lost revenue' from provision of a 0% interest rate loan. Exchange rate for USD to AUD conversion: 0.7045 USD/AUD (average of 2023/4 to 2026/7, Deloitte Access Economics, https://www.deloitte.com/au/en/about/press-room/business-outlook.html, Sept. 2023). Minor discrepancies may exist due to rounding.*

Supply side support: Key policy design recommendations

Direct financial support must be clearly linked to well-defined assessment and/or eligibility criteria, to ensure use of public funds ensures benefit sharing with the Australian public, as well as meeting broader sustainability and social license objectives.

Design of a production credit and other support levers must consider appropriate use of public funds and alignment with broader government objectives, such as delivering emissions reductions, ensuring shared benefits of the energy transition (particularly for most affected local communities), and embedding circularity principles in policy. Both India's PLI scheme and the US IRA include social and environmental factors in the policy design. These can be implemented through assessment criteria, eligibility requirements or additional incentives.

Decarbonised electricity supply – 'additionality'

Subsidisation of energy-intensive industries should be clearly linked to decarbonised electricity requirements and adoption of more energy-efficient practices. Renewable electricity for a facility should be **additional and dedicated** to the extent possible, to not detract from existing electrification and decarbonisation efforts.

Worker reskilling and training

Financial support for new facilities should be linked to worker reskilling and training requirements where possible, such as through partnerships with universities and TAFE, **commitment to knowledge sharing**, etc. In the case where companies are structured as international partnerships/JVs, this may include requirements on foreign skilled worker visas linked to domestic training requirements.

Repayment clause and consumer price protection

Provision of support may be **linked to a repayment clause** should a minimum operational period or production period not be met. In addition, financial support can be linked to a domestic provision requirement, to ensure prioritised sale of end-products to Australian consumers at reasonable prices. This can prevent domestic supply shortfalls should international market dynamics become more favourable for an Australian export market.

PV recycling and circular economy requirements

Financial support given to solar PV manufacturers can be coupled with eligibility requirements to develop capabilities for PV recycling. This could be implemented through development of a **product stewardship scheme** to mandate recycling at the federal level and put the onus on manufacturers to ensure all panels produced will be collected and recycled at the end of the product life.

Locating in areas transitioning away from a fossil-fuel based economy

Financial support should include eligibility criteria or incentives to encourage **locating in areas affected by the energy transition**, such as existing industrial hubs or regions with retiring coal mines and power plants.

India PLI – Case Study

The successful recipients of solar PV manufacturing support in India's PLI are required to source at least 20% of the manufacturing plant's electricity consumption from renewable energy sources.

India PLI – Case Study

The successful recipients of solar PV support in India's PLI are required to set up facilities for recovery and recycling of solar waste and encouraged to adopt circular economy principles in their production processes and supply chains.

US IRA – Case Study

The investment tax credit for PV developers in the IRA can be raised by 10% when the project is located in a low-income community (defined by the New Markets Tax credit) or on native land. The renewable electricity production tax credit for PV developers can be raised by 10% when a project is located in an "energy community".

Estimated support needed to establish fully integrated domestic manufacturing in Australia

Total support needed to develop a fully integrated domestic manufacturing capability of minimum viable scale across the value chain is estimated at 3.2bn AUD over a 10-year production period. However, this is dominated by the poly-Si facility, and scale up of other steps from 1GW will come at an incrementally lower cost.

	Total support needed (discounted) **one minimum viable scale facility***	Total support needed (discounted) **10GW/5GW domestic manufacturing capacity**
POLY-SI	**2.1bn AUD** to support a **10GW/annum** poly-Si facility over a 10-year production period	**2.1bn AUD** to support a **10GW/annum** poly-Si facility over a 10-year production period
INGOT & WAFERS	**350m AUD** to support a **1GW/annum** ingot/wafer facility over a 10-year production period	**~1.8bn AUD** to support **5GW/annum** ingot/wafer capability over a 10-year production period
SOLAR CELLS	**459m AUD** to support a **1GW/annum** cell facility over a 10-year production period	**~2.3bn AUD** to support **5GW/annum** cell capability over a 10-year production period
SOLAR MODULES	**317m AUD** to support a **1GW/annum** module facility over a 10-year production period	**~1.6bn AUD** to support **5GW/annum** module capability over a 10-year production period
FULL VALUE CHAIN	**3.2bn AUD** Over 10 years	**7.8bn AUD** Over 10 years

Development of an integrated solar supply chain for Australia at scale:

The development of a solar industry of 10 GW of poly-Si and 1 GW of ingot/wafer, cell and module capacity is credible at the minimum viable scale, it is, however, recommended to clearly set the target for 5GW or above to meet a sizeable share of Australia's future domestic demand and grow the industry to a scale that is internationally relevant as a whole. The scaling of the industry should be considered in any of the policies.

***Note:** *Total support required includes the cost of production subsidies, as well as 'lost revenue' from provision of a 0% interest rate loan. Exchange rate used for USD to AUD conversion: 0.7045 USD/AUD (average of 2023/4 to 2026/7, Deloitte Access Economics, https://www.deloitte.com/au/en/about/press-room/business-outlook.html, Sept. 2023). Minor discrepancies may exist due to rounding of the numbers.*

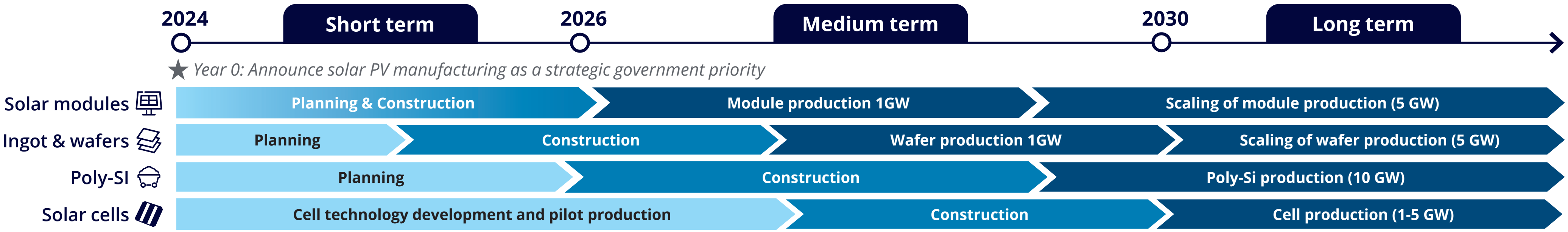
6 Conclusion:

A roadmap for PV manufacturing in Australia

Building a credible future state of economically viable, relevant and timely PV manufacturing in Australia

A roadmap of actions to achieve the credible future state of solar PV manufacturing in Australia outlined in this report is presented below. Immediate action by government will be needed to ensure viable, relevant and timely industry development.

Credible future industry development pathway



Recommended actions and next steps

Immediately

- Declare solar PV manufacturing a strategic priority industry
- Determine government alignment with the value chain development roadmap outlined in this report
- Set-up a Solar Manufacturing Taskforce to implement and deliver next steps and recommendations

Next 12 months

- Prioritise roll out of enabling support for people, permits and partners
- Develop implementation structure to allocate and deliver financial supply-side support (concessional finance and production subsidies)
- Design frameworks for demand-side support (government procurement, circular economy framework and local content incentives)
- Remove barriers for accelerated solar PV deployment
- Strive for broad political support
- Secure budget for the selected framework of subsidies

Years 1 - 5

- Implement concessional finance and production credit support for 10 years of facility operation
- Start government procurement
- Introduce local content incentives
- Continue R&D support
- Consider the provision of targeted support on electricity price guarantee
- Consider the provision of additional up-front capital support
- Implement a RET-like mechanism of mandated solar PV installations

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