

# Updates in Concentrated Solar Thermal

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APSRC 2020

Dietmar Tourbier, Energy Science Director, CSIRO  
December 2020

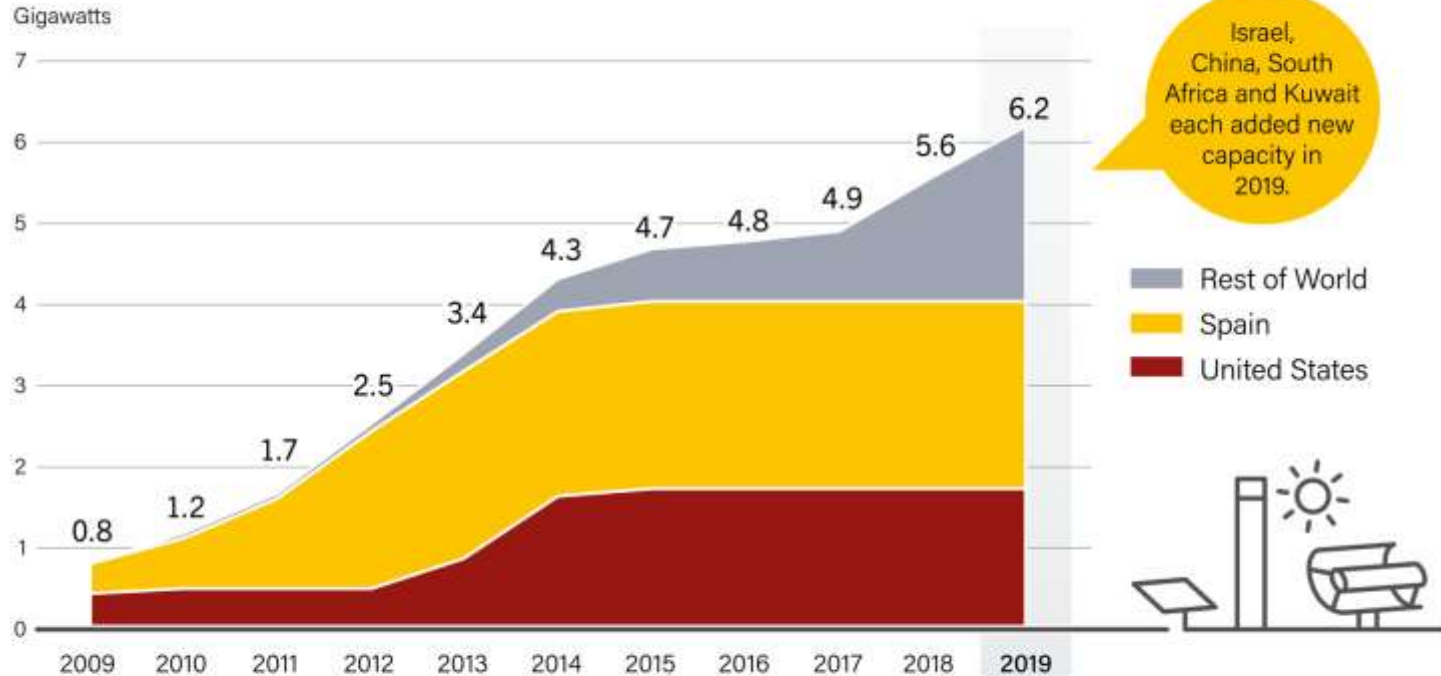


ASTRI

Australian Solar Thermal  
Research Institute

# CSP Global Growth

Concentrating Solar Thermal Power Global Capacity, by Country and Region, 2009-2019



# CSP Worldwide 2020



# CSP Morocco

**NOORo I  
CSP IPP**



**MOROCCO**  
Ouarzazate

**TECHNO-COMMERCIAL**

Offtaker	Moroccan Agency for Sustainable Energy (MASEN)
Offtake Contract	PPA 25 years
Power	160 MWe
Project Cost	USD 841 Mn
COD	Q4 2015
ACWA Power Effective Stake	73.13%

**NOORo II  
CSP IPP**



**MOROCCO**  
Ouarzazate

**TECHNO-COMMERCIAL**

Offtaker	Moroccan Agency for Sustainable Energy (MASEN)
Offtake Contract	PPA 25 years
Power	200 MWe
Project Cost	USD 1,300 Mn
COD	Q1 2018
ACWA Power Effective Stake	70%

**NOORo III  
CSP IPP**



**MOROCCO**  
Ouarzazate





**TECHNO-COMMERCIAL**

Offtaker	Moroccan Agency for Sustainable Energy (MASEN)
Offtake Contract	PPA 25 years
Power	150 MWe
Project Cost	USD 862 Mn
COD	Q4 2018
ACWA Power Effective Stake	75%



Source: ACWA Power – SolarPACES 2020

# CSP South-Africa and Middle East

BOKPOORT CSP IPP	Noor Energy 1																							
<p><b>SOUTH AFRICA</b> Northern Cape Province</p> 	<p><b>UNITED ARAB EMIRATES</b> Dubai</p> 																							
<p><b>TECHNO-COMMERCIAL</b></p> <table><tr><td>Offtaker</td><td>Eskom Holdings SOC Limited</td></tr><tr><td>Offtake Contract</td><td>PPA-BOO 20 years</td></tr><tr><td>Power</td><td>50 MWe (net) with 9.3 hours of thermal energy storage</td></tr><tr><td>Project Cost</td><td>USD 517 Mn</td></tr><tr><td>COD</td><td>Q1 2016</td></tr><tr><td>ACWA Power Effective Stake</td><td>40%</td></tr></table>	Offtaker		Eskom Holdings SOC Limited	Offtake Contract	PPA-BOO 20 years	Power	50 MWe (net) with 9.3 hours of thermal energy storage	Project Cost	USD 517 Mn	COD	Q1 2016	ACWA Power Effective Stake	40%	<p><b>TECHNO-COMMERCIAL</b></p> <table><tr><td>Offtaker</td><td>DEWA</td></tr><tr><td>Offtake Contract</td><td>PPA-BOO-35 YR</td></tr><tr><td>Power</td><td>150 MW</td></tr><tr><td>Project Cost</td><td>USD 4.3 Bn</td></tr><tr><td>ACWA Power Effective Stake</td><td>49%</td></tr></table>	Offtaker	DEWA	Offtake Contract	PPA-BOO-35 YR	Power	150 MW	Project Cost	USD 4.3 Bn	ACWA Power Effective Stake	49%
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Source: ACWA Power – SolarPACES 2020

250 MW PV, 700 MW CSP

# CSP Chile

110 MW

10,600  
heliostats, 140 m<sup>2</sup>  
each

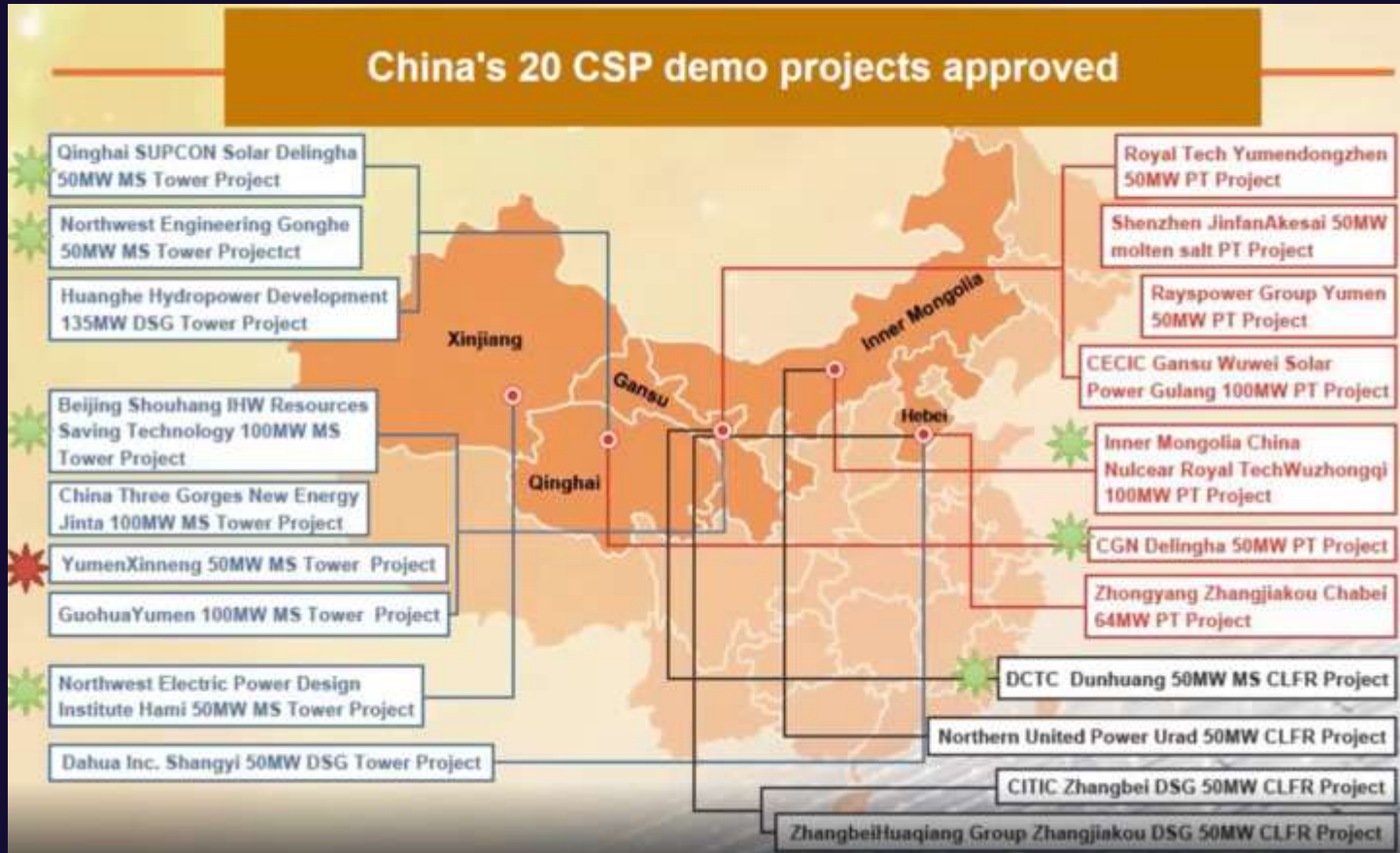
243-meter high  
tower

In Commissioning



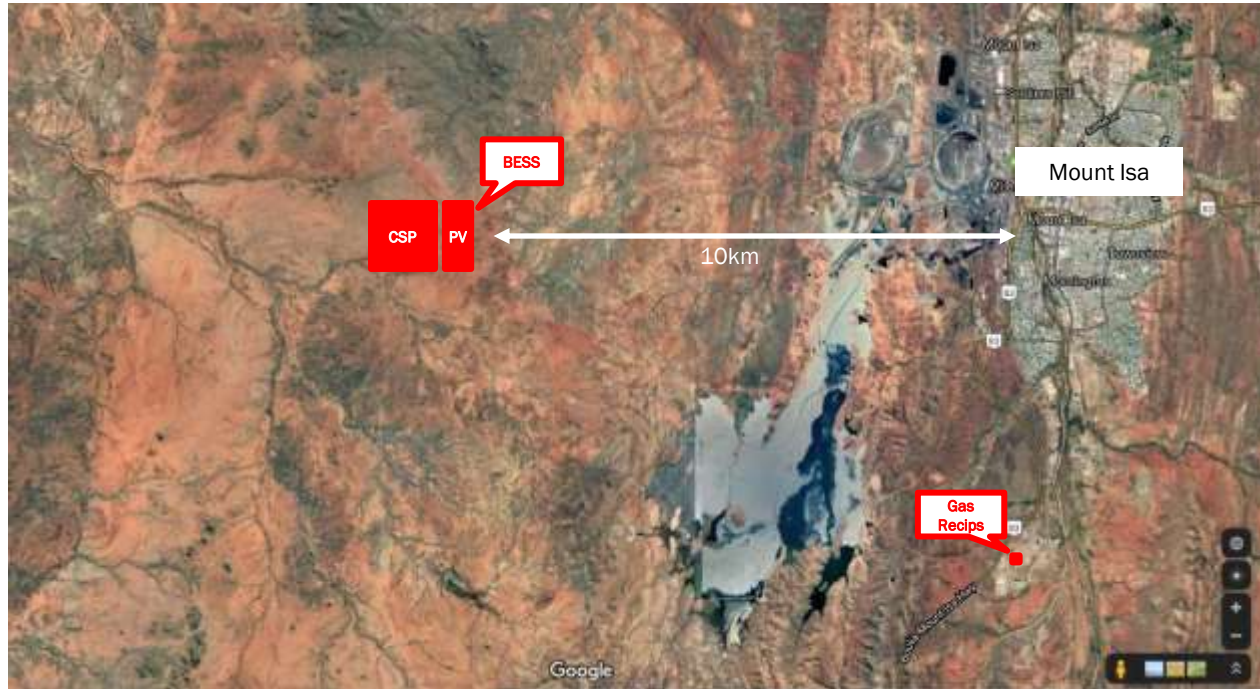
Source: CERRO Dominador – SolarPACES 2020

# CSP in China 2020



# Vast Solar CSP-PV Hybrid Plant – MT Isa

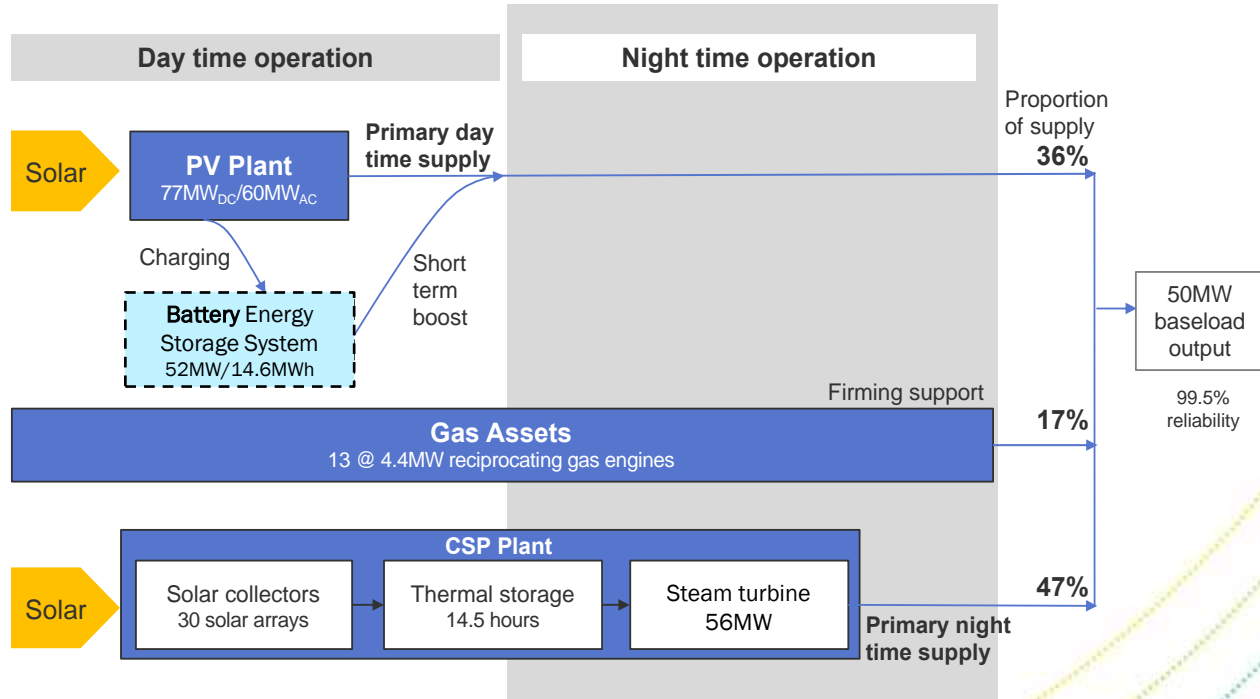
- ✓ Flat with good drainage
- ✓ Suitable geotech for piling / foundations
- ✓ Close to grid access
- ✓ Short drive to town
- ✓ No known heritage issues
- ✓ No known environmental issues





# Vast Solar Hybrid Plant Configuration and Performance

The optimised plant included an oversized PV array and BESS system to manage cloud transients



# ASTRI Background

- Consortium of leading research institutions and the CSIRO
- 11-year, \$100+ million program (\$50 million ARENA) established in late 2012.
- Established to advance technology development and facilitate the commercial uptake of CSP technologies and systems within Australia.
- Strong focus on international collaboration
  - to avoid duplication of effort
  - to ensure coordinated approach of international efforts to accelerate commercial uptake of CSP technologies



# ASTRI Activity Focus Areas

## Focus Area 1: Technology Development

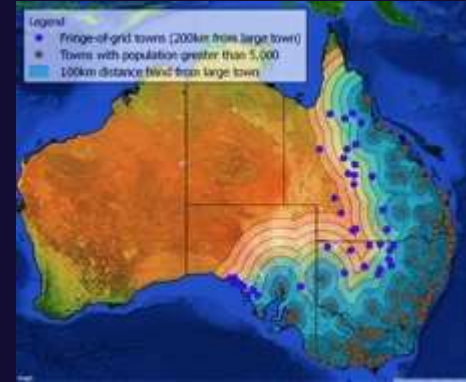
- Development and demonstration of next generation, higher temperature solar thermal technologies specifically designed to increase CSP system performance and market competitiveness through lower cost and improved efficiency
- Driving commercial readiness of next generation CSP technologies to facilitate market uptake within the next decade

## Focus Area 2: Facilitate Domestic Commercial Uptake

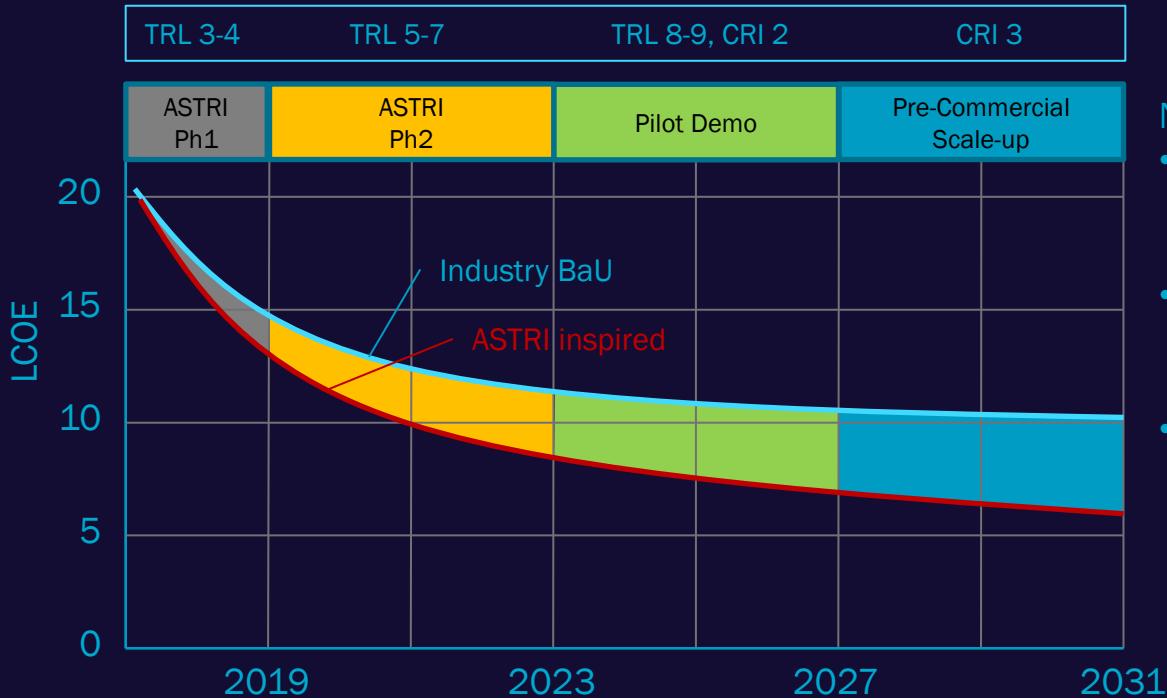
- Strong engagement with industry to help deploy CSP technology solutions in Australia
  - domestic and international companies
- Focus on current technologies, independent of ASTRI developed technologies
- Provide commercial and technical assistance

# Impact of CSP in Australia

- Australian electricity market is transitioning at a rapid pace
- AEMO Integrated Systems Plan identified the need for 21GW of utility scale flexible, dispatchable renewable energy by 2040:
  - to maintain reliability and firm the system given the rapid uptake of variable renewable energy.
- CSP provides a low-cost utility-scale dispatchable generation option
  - CSP Roadmap identifies uptake at \$120/MWh at fringe of grid (FoG) and at \$70/MWh for wholesale market
- A utility scale dispatchable renewable energy market likely to emerge in the next 5-10 years
  - investment now will allow next-generation high-temperature CSP systems to be competitive / commercially available option in this market.



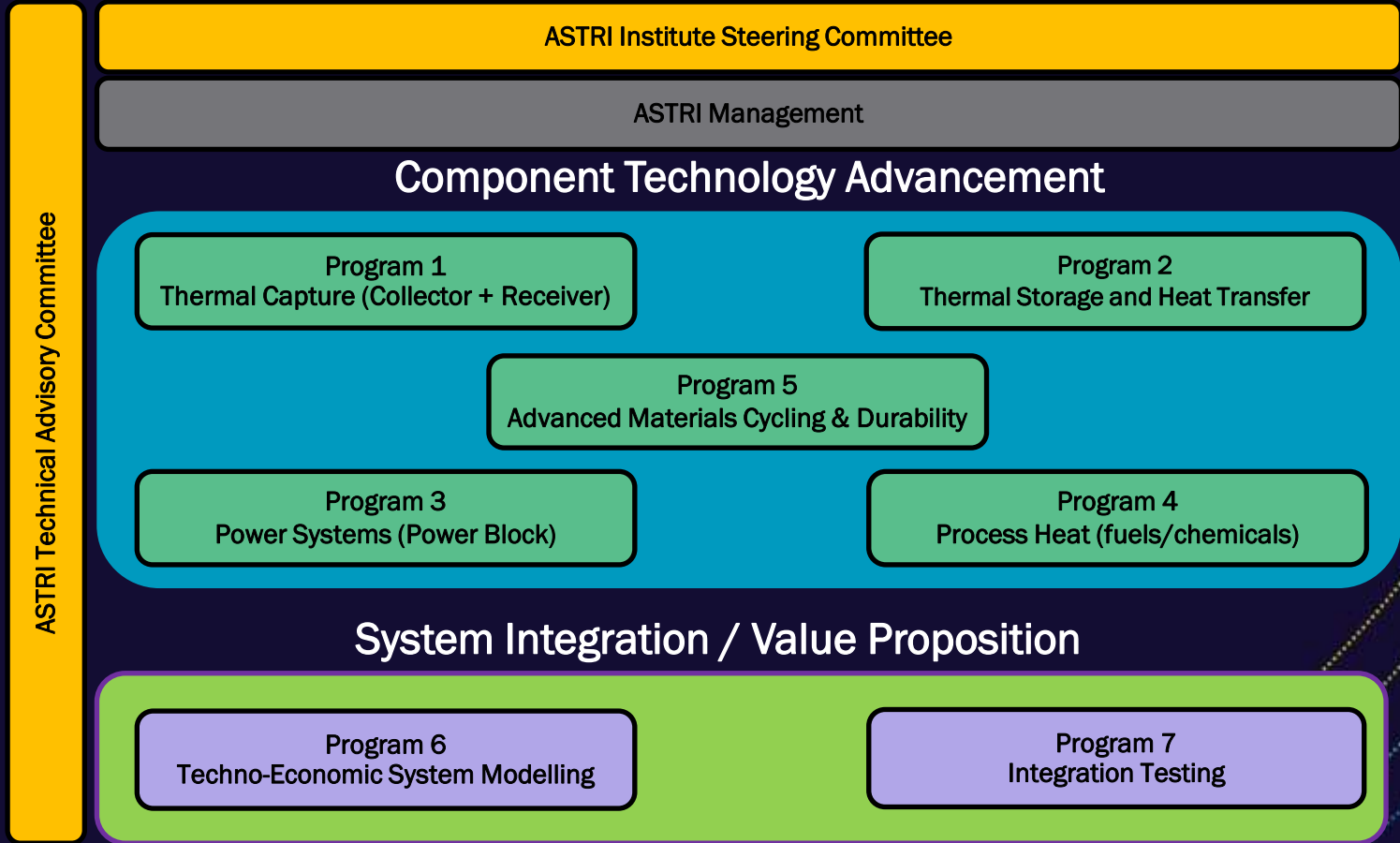
# ASTRI's CSP Path to Market



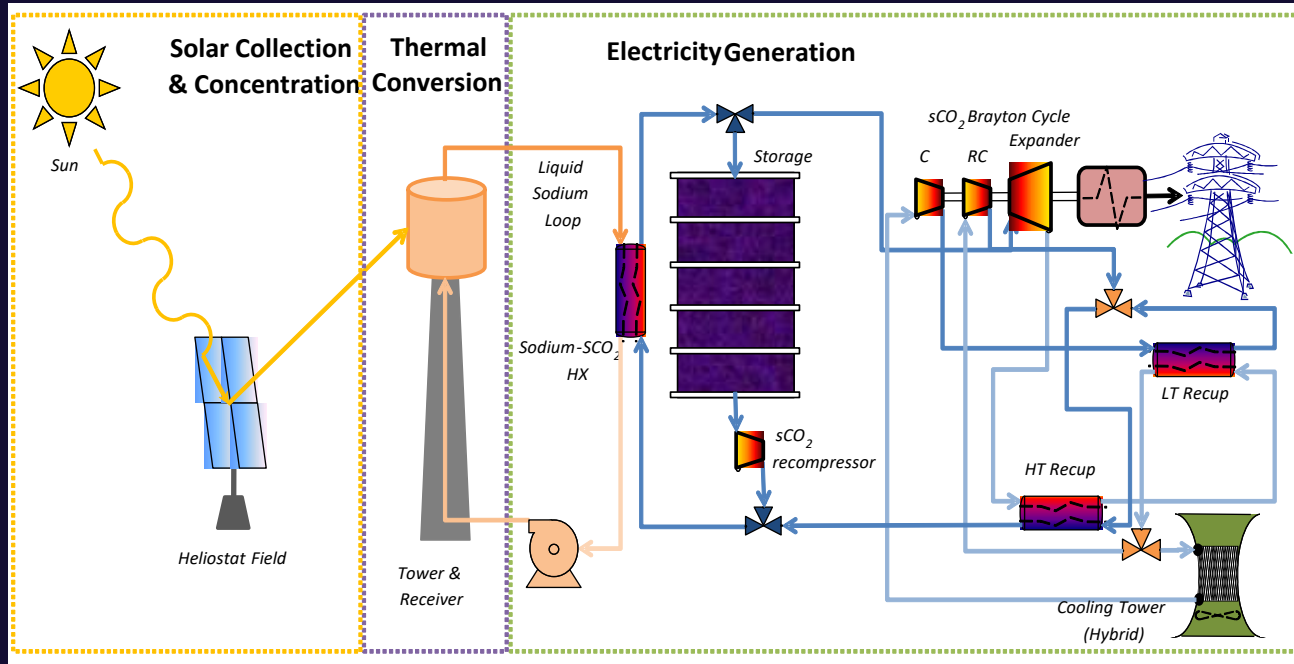
## Notes:

- Typical industry learning rate yields cost reductions without disruptive technology advances
- ASTRI's disruptive technology advances "add to" the industry learning rate
- The margin between the curves widens as ASTRI technology is "de-risked" and probability of technical success improves

# ASTRI Structure



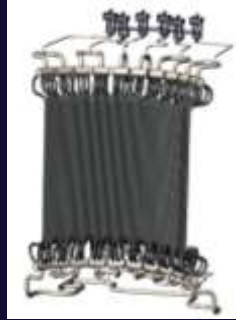
# ASTRI: Performance Targets



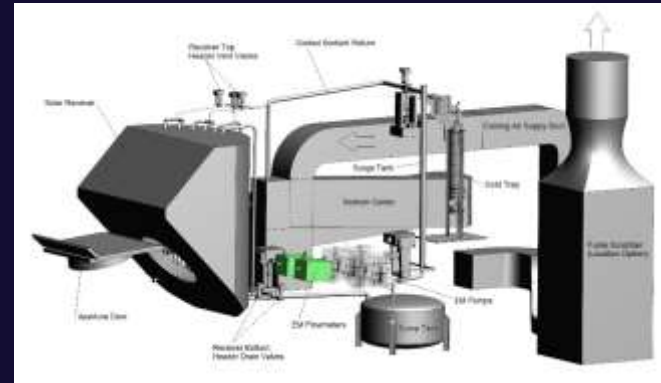
Today	\$120/m <sup>2</sup>	\$200/kW <sub>th</sub>	<560C	\$50/kWh <sub>th</sub>	35% eff	\$1,000/kWe	Steam	14 c/kWh
ASTRI Target	\$ 80/m <sup>2</sup>	\$150/kW <sub>th</sub>	>720C	\$20/kWh <sub>th</sub>	50% eff	\$1,000/kWe	sCO <sub>2</sub>	7 c/kWh

# ASTRI Highlights 2020

- Heliostats
- Sodium Receiver
- Particle Receiver



ASTRI Mark 1 Sodium Receiver



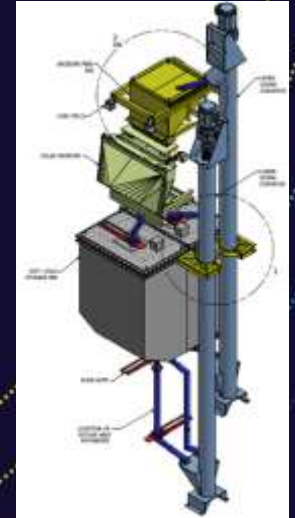
Sodium Receiver Test Setup



ASTRI Particle Receiver



CSIRO Solar Test Field



Particle Receiver Test Setup

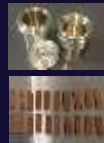


# ASTRI Highlights 2020 (cont'd)

- Thermal Energy Storage



Packed-bed storage concept (suitable materials)



PCM Test Unit

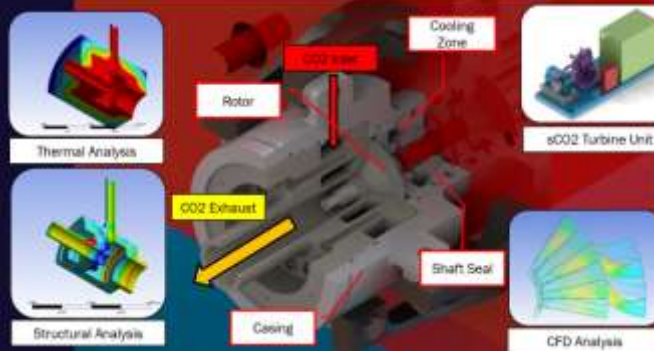


ANU Sodium Test Loop



Photos source: MGA Thermal

- Power Block



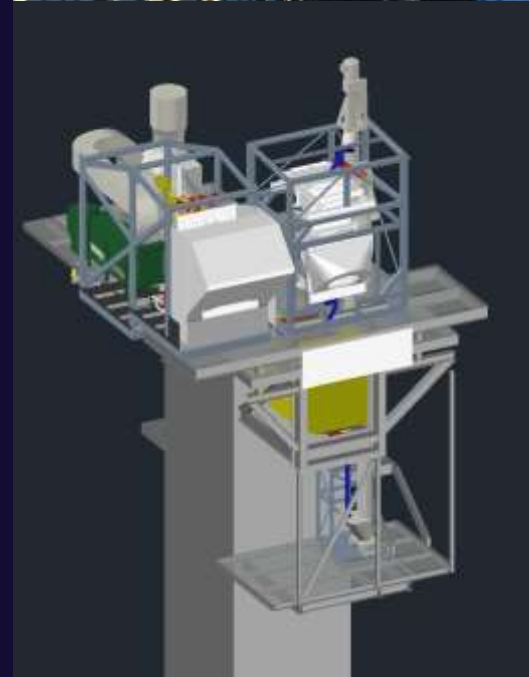
ASTRI sCO<sub>2</sub> Turbine Design

- Materials

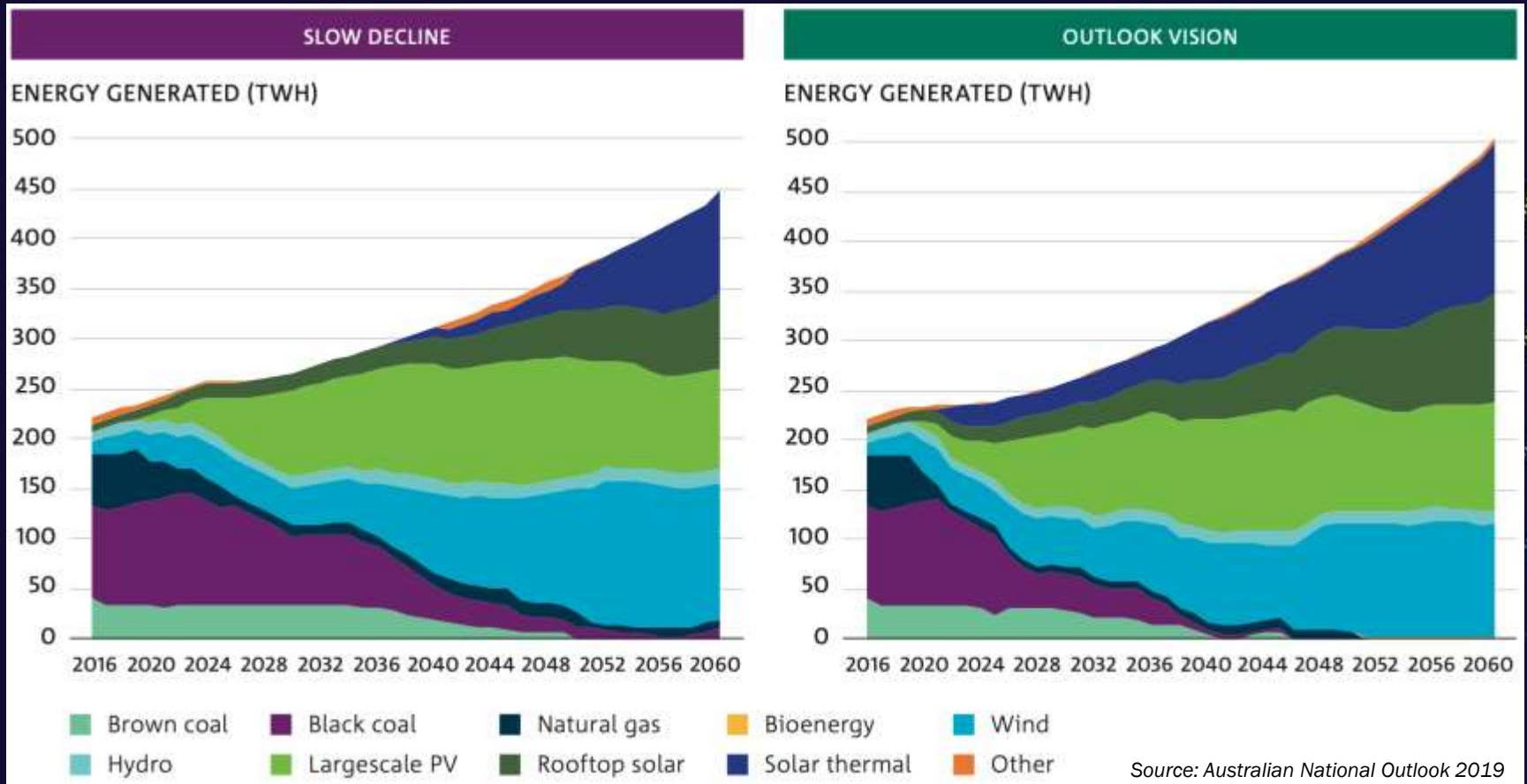
  - High-T metals testing with Sodium, Salts, sCO<sub>2</sub>

# ASTRI Outlook 2021

- Particle receiver demonstration
- Sodium receiver demonstration
- Energy storage demonstration
- Commercial engagement with several potential applications of CSP
- Increase focus on industrial heat application for solar thermal



# The Future Role of CSP in Australia



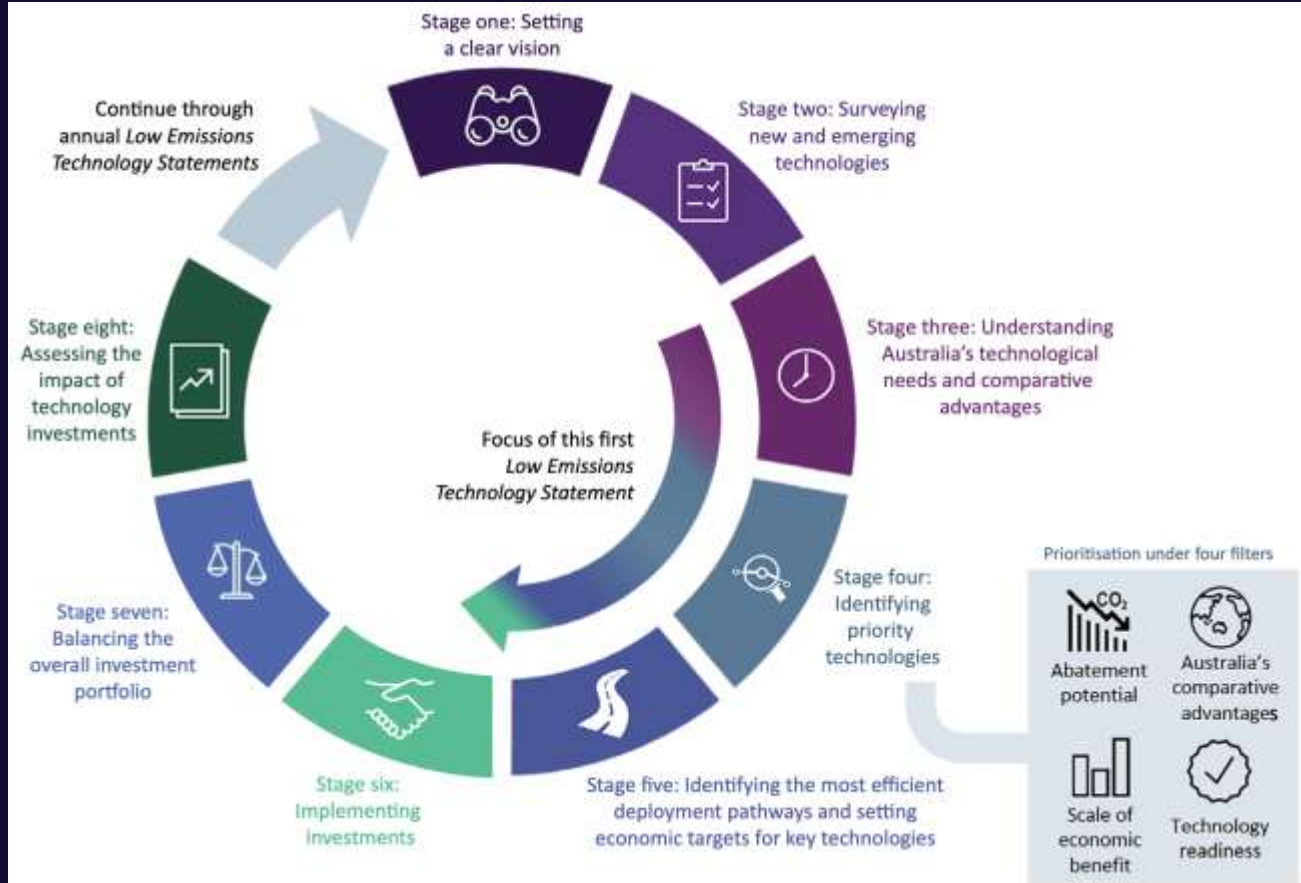
# Barriers for CSP in Australia

- CSP plants need to be big to be cost competitive (just like coal)
  - primarily due to power block efficiency
  - this is changing with new advanced sCO<sub>2</sub> power cycles
- Perceived technology maturity
  - as a relatively unknown technology in Australia, people are waiting to see how CSP performs and for the wrinkles to be ironed out
- Australia market economics
  - markets have not fully valued the firm capacity and night time generation profile provide by daily, multi-hour dispatchable renewable energy, because Australia doesn't yet need it
  - Australia currently has sufficient capacity to meet demand – on most days of the year
  - however, the industry is starting to realise that if you don't start planning now you may pay a lot more in the future
- Perceived operational risk
  - operators and energy end users want proven technologies with minimal operational risk – first movers beware

# Barriers for CSP in Australia (cont'd)

- Process integration risk
  - many generators, and industrial / mining sector users want a hybrid solution that can be integrated within existing thermal management / heat processes
  - this creates process integration risk, which can be difficult to mitigate without cost/commitment from industry.
- Lack of supporting policies
  - support renewable energy uptake, independent of time of use
  - support firm capacity, independent of generation type
  - dispatchable renewable energy uptake has primarily targeted the FCAS market
  - once FCAS market is serviced, other policy mechanisms may be needed to meet future capacity requirements
- Lack of awareness / understanding
  - many stakeholders do not understand the value, economics and operational benefits of CSP systems
- Low investment appetite
  - as a result of all of the above, the investment appetite for CSP is low – but this is now changing

# Australia's Technology Investment Roadmap



# Australia's Low Emission Tech Statement



## PRIORITY TECHNOLOGY STRETCH GOALS

**CLEAN HYDROGEN**  
under \$2 per kilogram

**ENERGY STORAGE**  
electricity from storage for firming under \$100 per MWh\*

**LOW CARBON MATERIALS**  
low emissions steel production under \$900 per tonne and low emissions aluminium under \$2,700 per tonne

**CCS – CO<sub>2</sub> COMPRESSION, HUB TRANSPORT AND STORAGE**  
under \$20 per tonne of CO<sub>2</sub>

**SOIL CARBON**  
measurement under \$3 per hectare per year

\* This would enable firming wind and solar at pricing at or below today's average wholesale electricity price



## ANTICIPATED IMPACTS FROM THE PRIORITIES

**OVERACHIEVE**  
on our Paris Agreement commitments, with a pathway to deeper emissions reductions beyond 2030

**SUPPORT OVER 130,000 JOBS BY 2030**  
with more than half in regional communities

**PRESERVE AND EXPAND EMPLOYMENT**  
in our energy-intensive manufacturing sectors

**AVOID IN THE ORDER OF 250 MILLION TONNES OF EMISSIONS PER YEAR BY 2040**  
through deployment of priority technologies at home and Australia's low emissions exports

**SIGNIFICANTLY REDUCE GLOBAL EMISSIONS**  
from energy, transport, industry and agriculture if priority technologies achieve widespread deployment. These sectors account for around 90% of emissions and emit approximately 45 billion tonnes of CO<sub>2</sub> each year.



## PUBLIC-PRIVATE PARTNERSHIP

**AIM TO CATALYSE \$3-\$5 OF NEW INVESTMENT FOR EACH DOLLAR OF COMMONWEALTH FUNDING**  
to achieve \$50 to \$100 billion in new investment domestically over the decade to 2030

**A TECHNOLOGY INVESTMENT FRAMEWORK**  
to improve coordination of delivery agencies – ARENA, the CEFC and CER – towards national technology priorities and expected Government investment of \$18 billion in low emissions technologies over the decade to 2030

**RETAIN ARENA ON THE FRONTLINE OF DIRECT GOVERNMENT INVESTMENT**  
in low emissions technologies, playing a central role in delivering Roadmap priorities. New funding for the CEFC to support grid reliability

**ARENA WORKING WITH THE CEFC AND OTHER AGENCIES**  
to develop a goal-oriented program for priority low emissions technologies like low emissions steel, low emissions aluminium, and energy storage

**ESTABLISH AUSTRALIA'S FIRST REGIONAL HYDROGEN HUB**  
co-locating domestic hydrogen users with an export focus to create global hydrogen supply chain linkages

**SCALE CCS**  
to support emissions reduction from power generation, oil and gas extraction, natural gas processing, industry or hydrogen production

# Australia's Low Emission Tech Statement

## Opportunities for Solar Thermal

**PRIORITY TECHNOLOGY STRETCH GOALS**

- CLEAN HYDROGEN**  
under \$2 per kilogram
- ENERGY STORAGE**  
electricity from storage for firming under \$100 per MWh\*
- LOW CARBON MATERIALS**  
low emissions steel production under \$900 per tonne and low emissions aluminium under \$2,700 per tonne
- CCS – CO<sub>2</sub> COMPRESSION, HUB TRANSPORT AND STORAGE**  
under \$20 per tonne of CO<sub>2</sub>
- SOIL CARBON**  
measurement under \$3 per hectare per year

\* This would enable firming wind and solar at pricing at or below today's average wholesale electricity price

- Solar Thermal for high-temperature H<sub>2</sub> production
- CSP with thermal energy storage
- Solar Thermal for industrial heat



# Acknowledgment



*The Australian Solar Thermal Research Institute (ASTRI) Program is supported by the Australian Government through the Australian Renewable Energy Agency (ARENA)*



# Thank you