Updates in Concentrated Solar Thermal

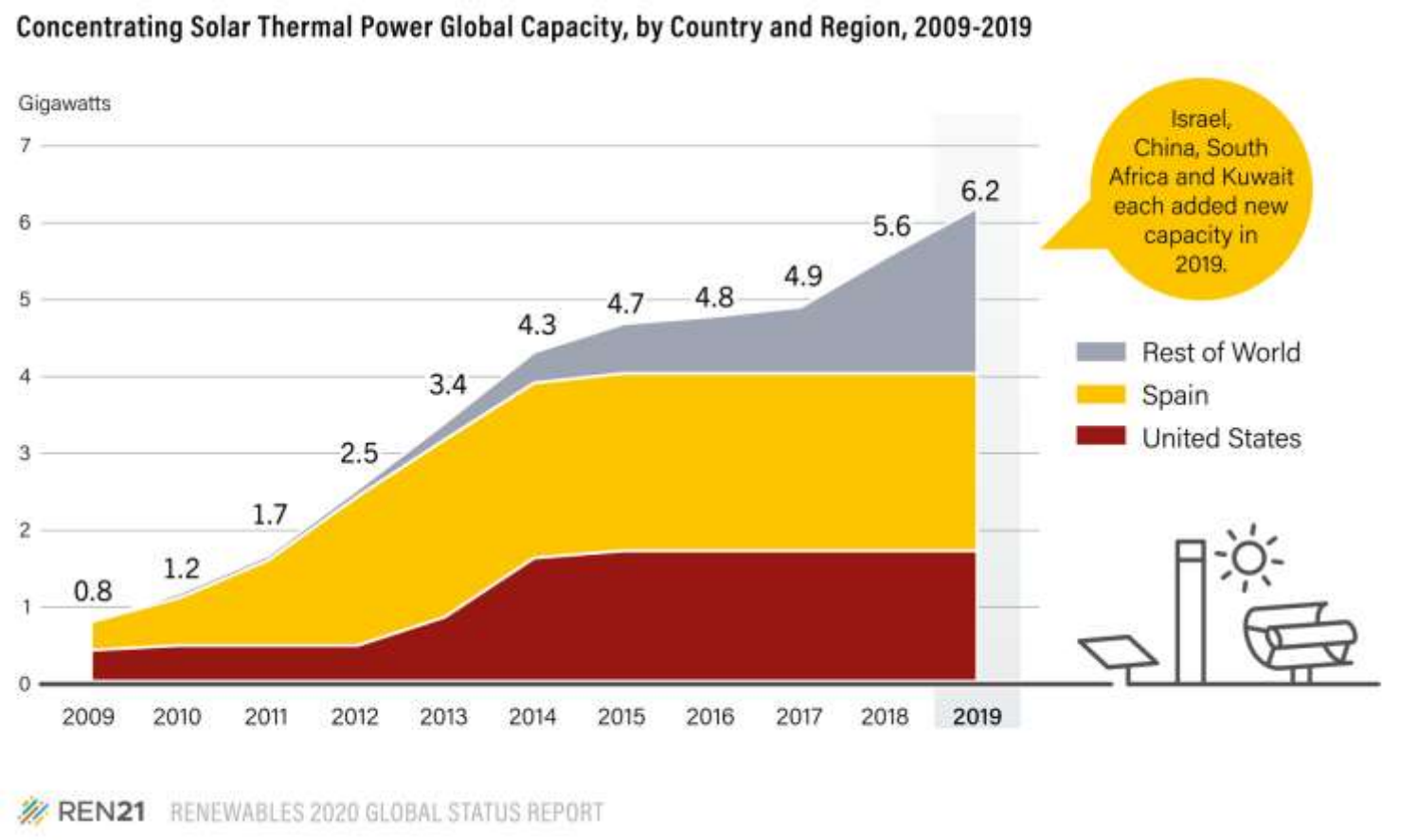
APSRC 2020

Dietmar Tourbier, Energy Science Director, CSIRO
December 2020

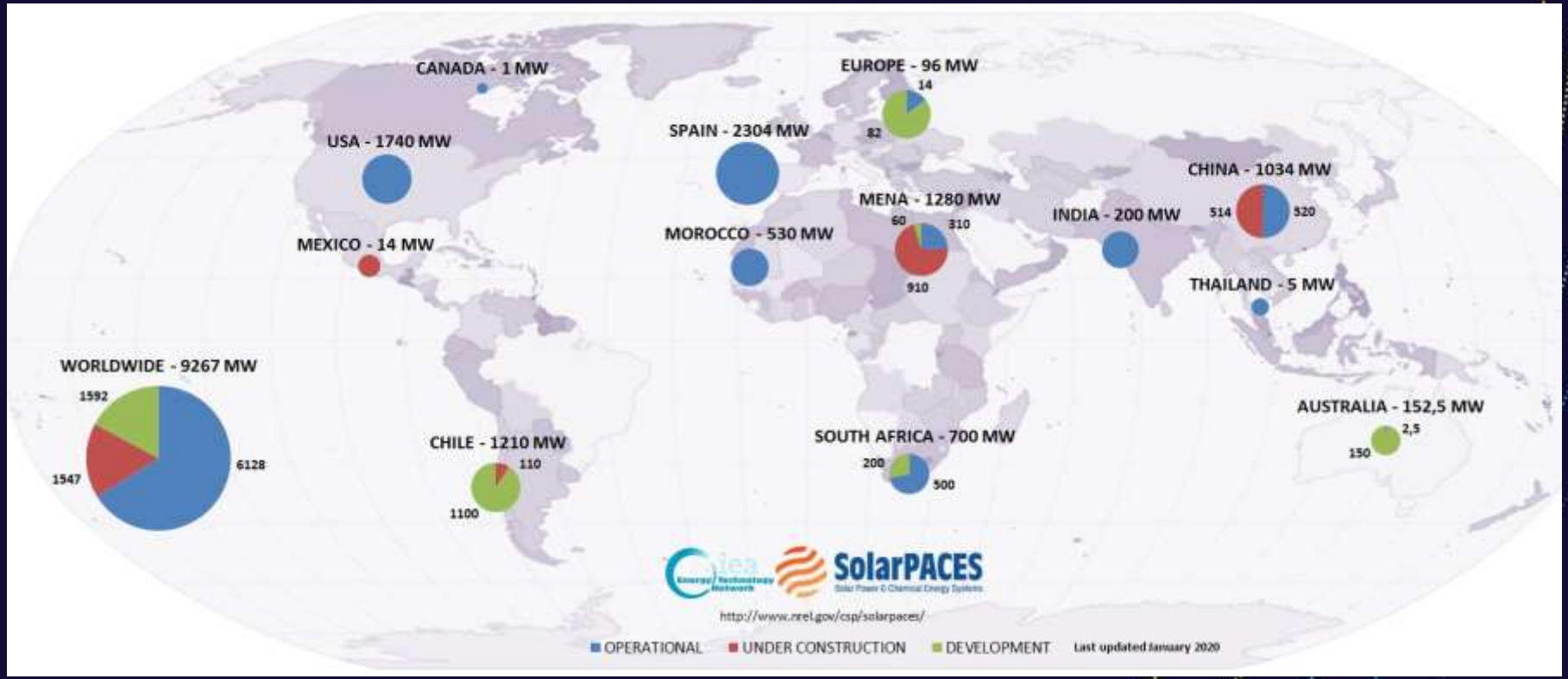
ASTRI

Australian Solar Thermal Research Institute

CSP Global Growth



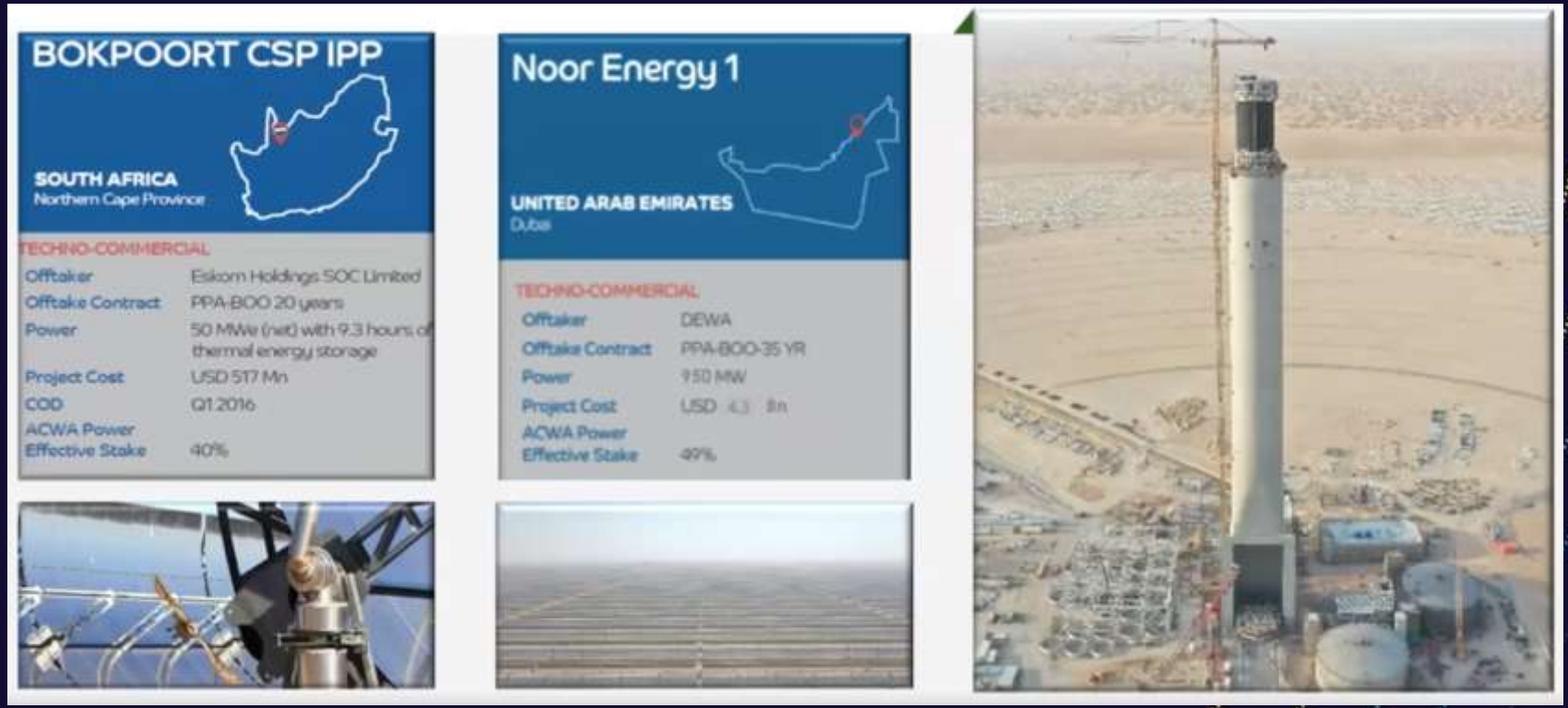
CSP Worldwide 2020



CSP Morocco

Source: ACWA Power – SolarPACES 2020

CSP South-Africa and Middle East



Source: ACWA Power – SolarPACES 2020

250 MW PV, 700 MW CSP

CSP Chile

110 MW

10,600 heliostats,140 m² each

243-meter high tower

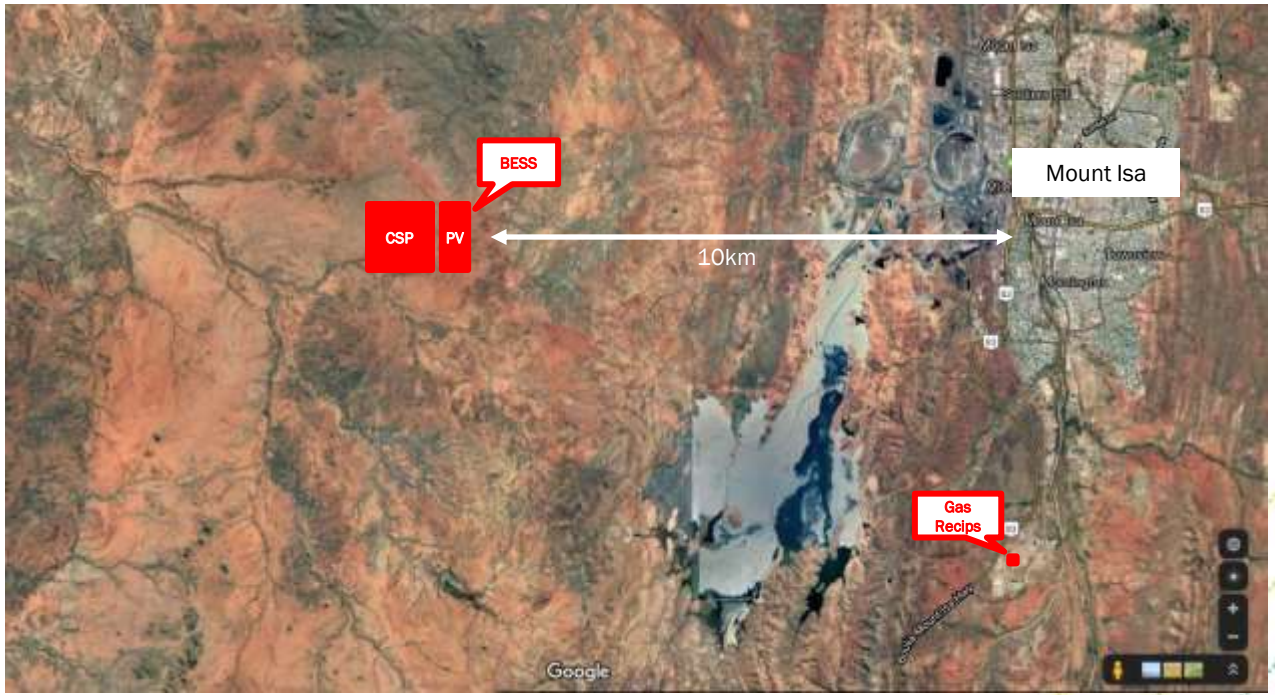
In Commissioning

Source: CERRO Dominador – SolarPACES 2020

CSP in China 2020

Vast Solar CSP-PV Hybrid Plant – MT Isa

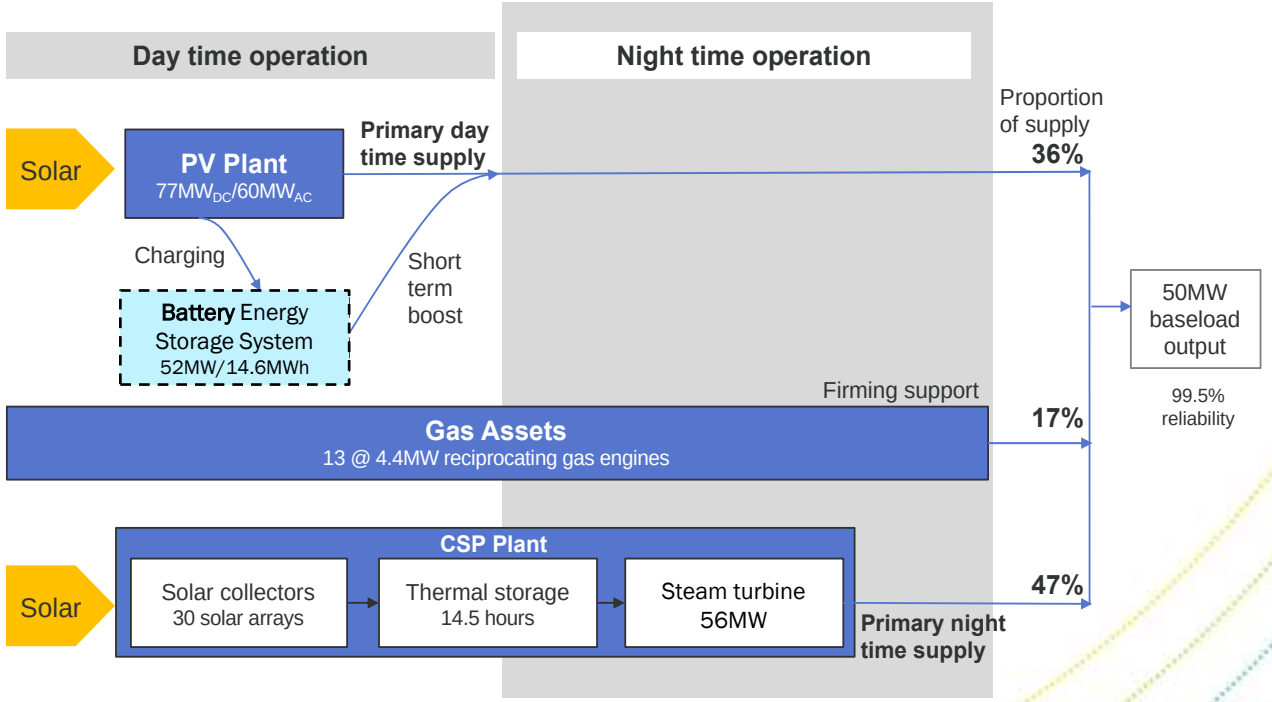
- ✓ Flat with good drainage
- ✓ Suitable geotech for piling / foundations
- ✓ Close to grid access
- ✓ Short drive to town
- ✓ No known heritage issues
- ✓ No known environmental issues



Courtesy of: VAST SOLAR

Vast Solar Hybrid Plant Configuration and Performance

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



Courtesy of: VAST SOLAR

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

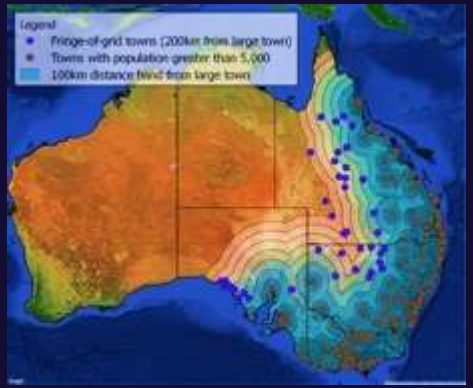
- Development and demonstration of next generation, higher temperature solar thermal technologies specifically designed to increase CSP system performance and market competitiveness through lower cost and improved efficiency
- Driving commercial readiness of next generation CSP technologies to facilitate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

Focus Area 2: Facilitate Domestic Commercial Uptake

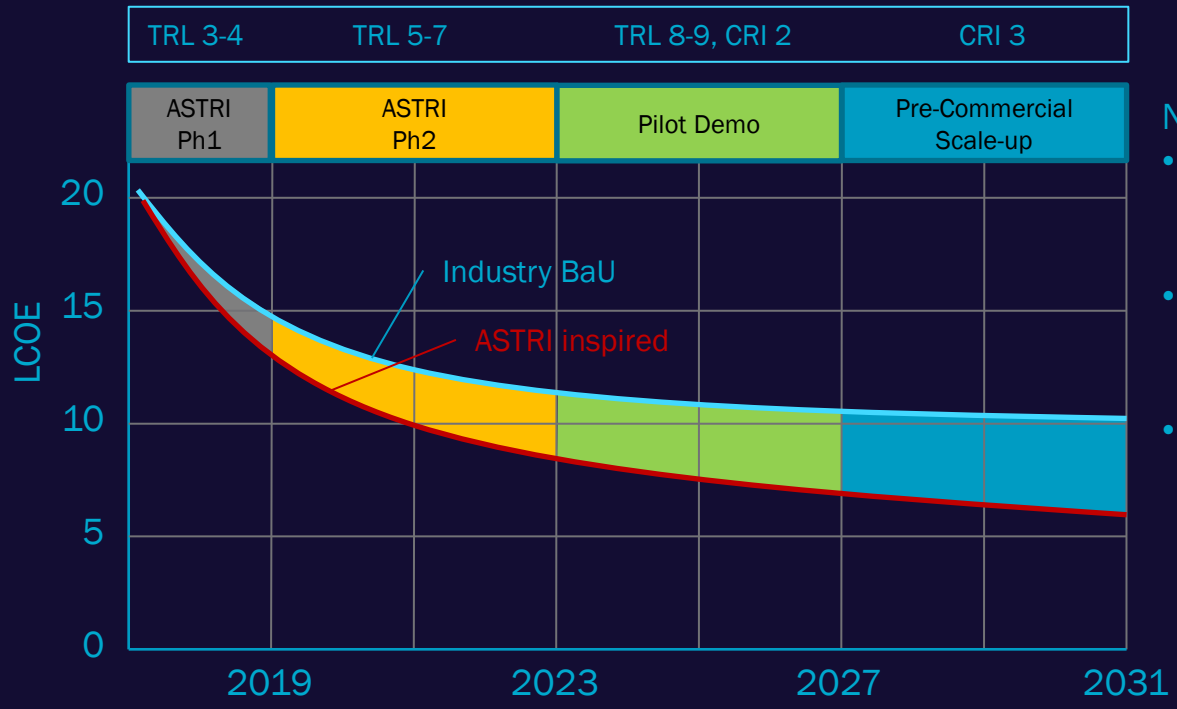
- Strong engagement with industry to help deploy CSP technology solutions in Australia
  - domestic and international companies
- Focus on current technologies, independent of ASTRI developed technologies
- Provide commercial and technical assistance

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.



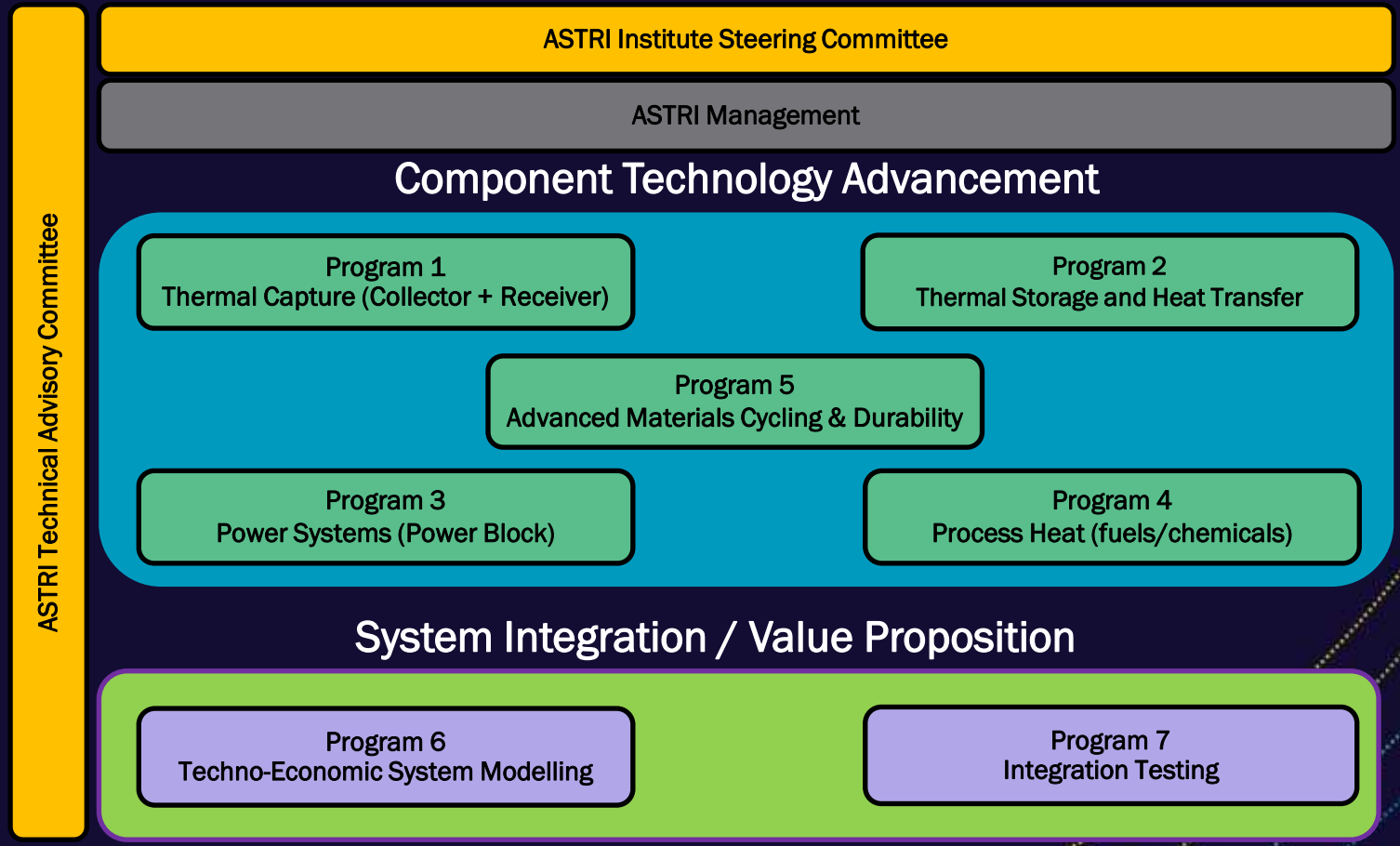
ASTRI's CSP Path to Market



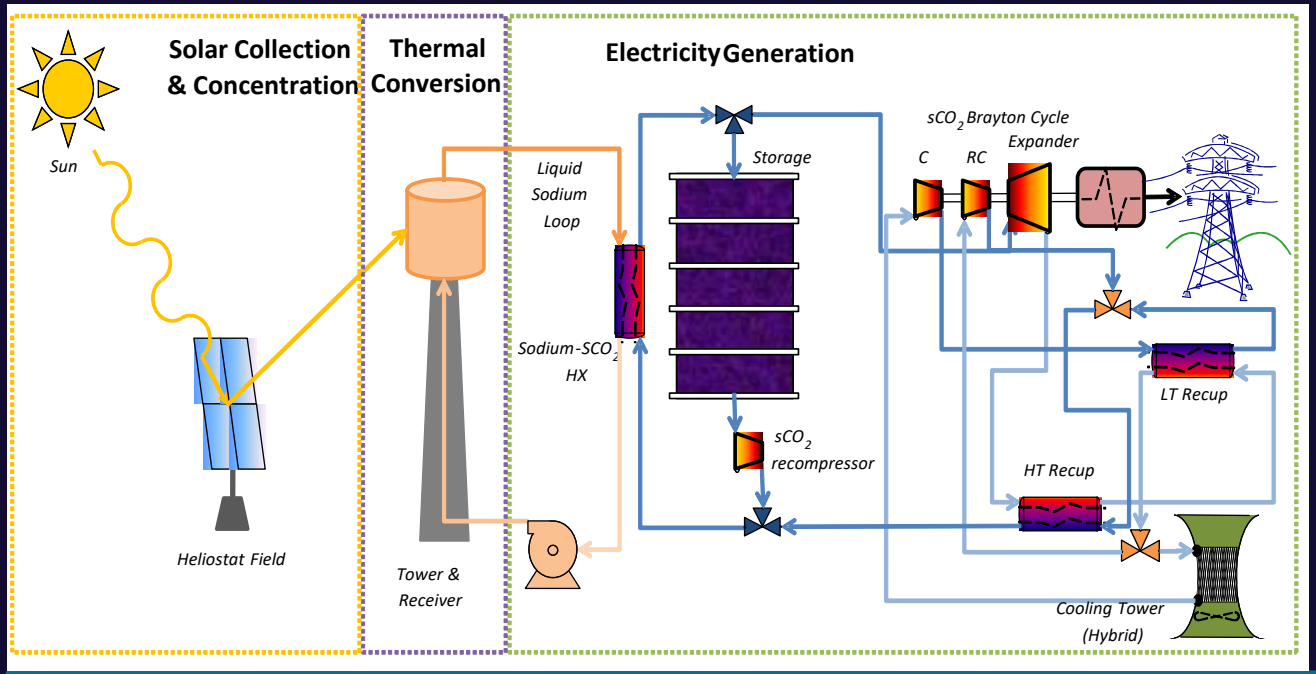
Notes:

- 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

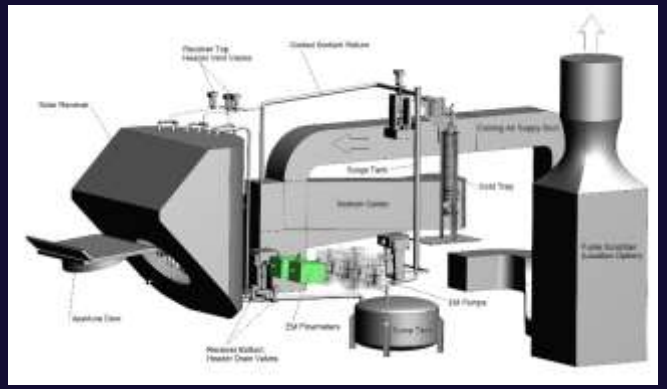


Today	$120/m2	$200/$kW_{th}$	<560C	$50/$kWh_{th}$	35% eff	$1,000/kWe	Steam	**14 c/kWh**
ASTRI Target	$ 80/m2	$150/$kW_{th}$	>720C	$20/$kWh_{th}$	50% eff	$1,000/kWe	sCO2	**7 c/kWh**

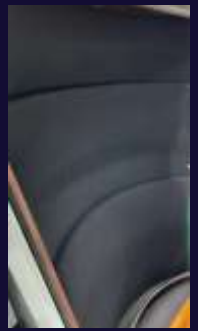
ASTRI Highlights 2020

- Heliostats
- Sodium Receiver
- Particle Receiver

ASTRI Mark 1 Sodium Receiver

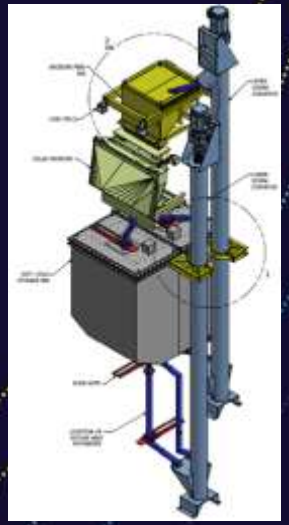


Sodium Receiver Test Setup



ASTRI Particle Receiver

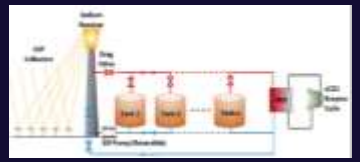
CSIRO Solar Test Field

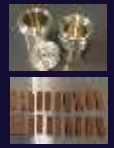


Particle Receiver Test Setup

ASTRI Highlights 2020 (cont'd)

- Thermal Energy Storage





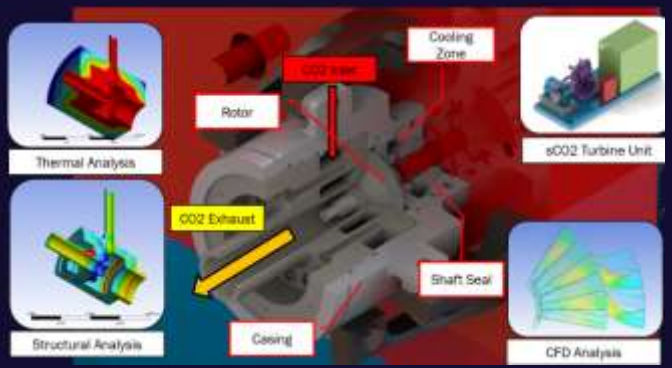
Packed-bed storage concept (suitable materials)

PCM Test Unit

ANU Sodium Test Loop

Photos source: MGA Thermal

- Power Block

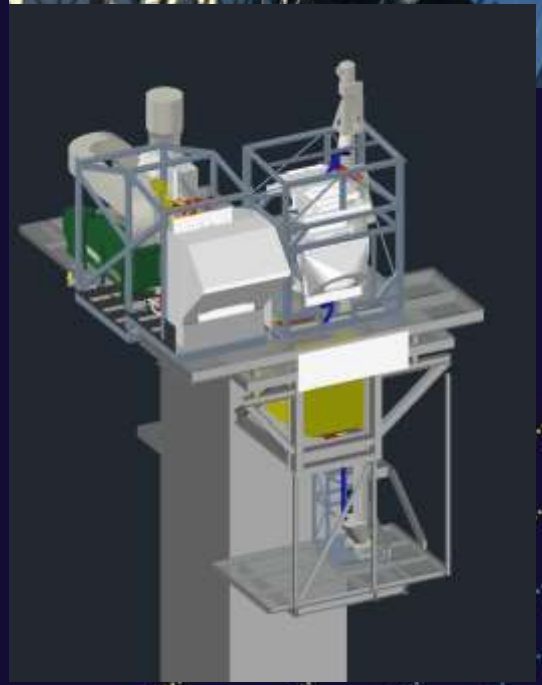


ASTRI sCO_2 Turbine Design

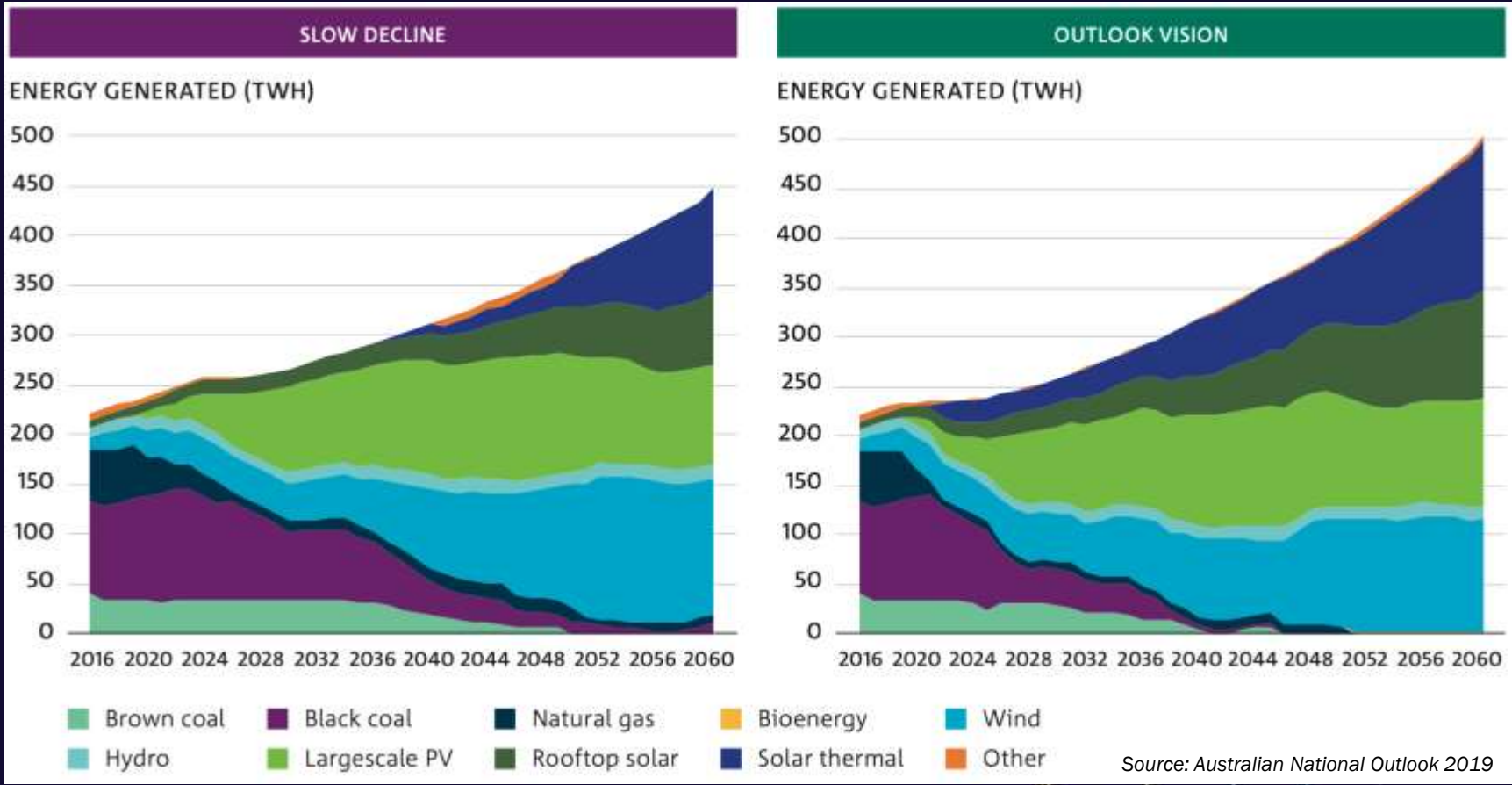
- Materials
  - High-T metals testing with Sodium, Salts, sCO_2

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



Source: Australian National Outlook 2019

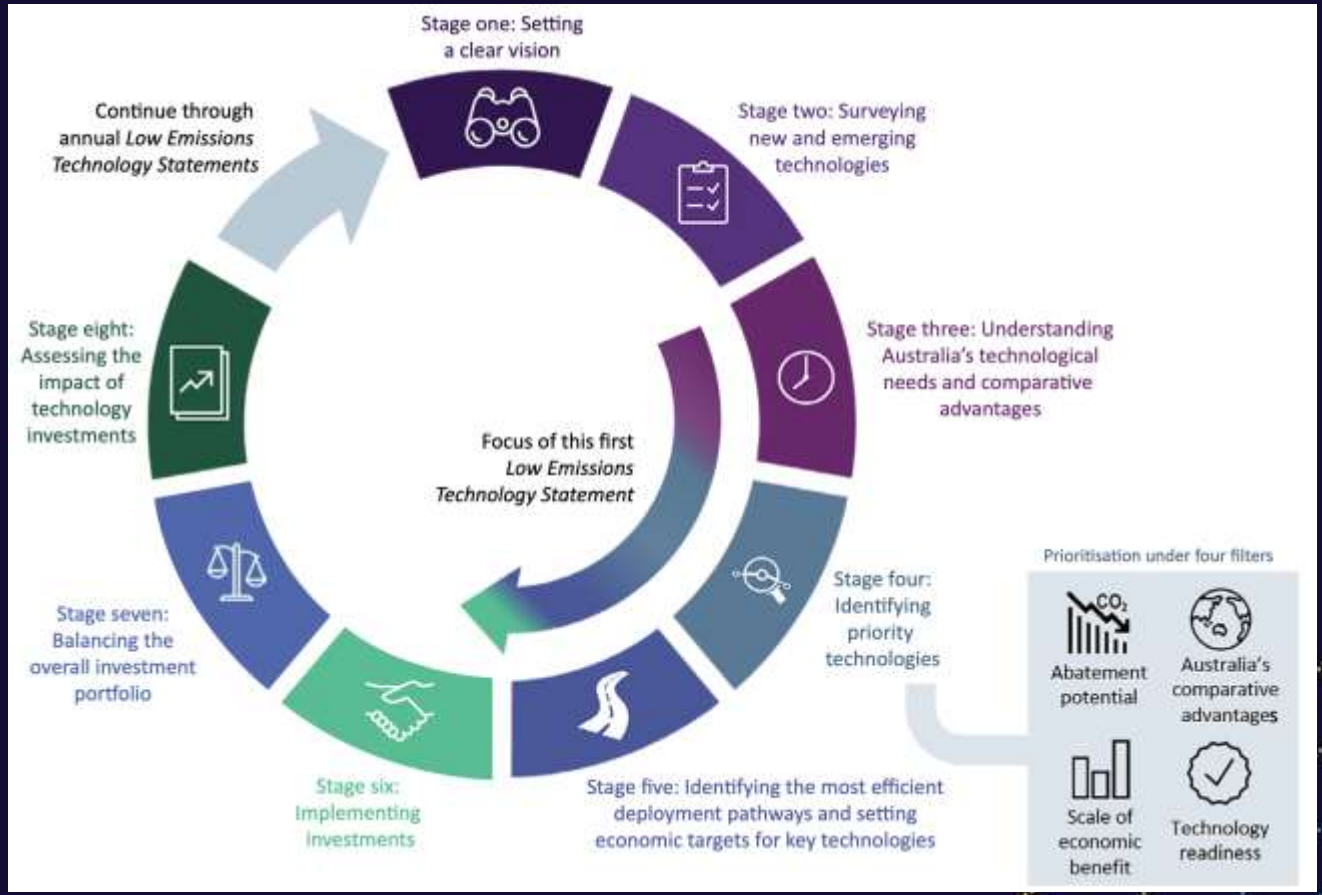
Barriers for CSP in Australia

- 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 sCO2 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)

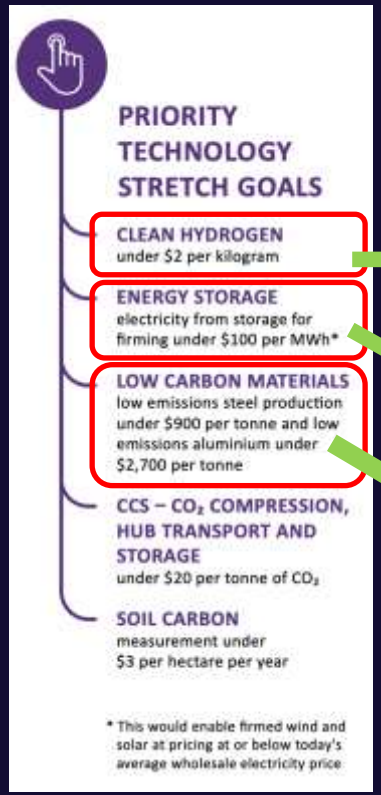
- Process integration risk
  - many generators, and industrial / mining sector users want a hybrid solution that can be integrated within existing thermal management / heat processes
  - this creates process integration risk, which can be difficult to mitigate without cost/commitment from industry.
- 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

Australia's Low Emission Tech Statement



Opportunities for Solar Thermal

- Solar Thermal for high-temperature H_2 production
- CSP with thermal energy storage
- Solar Thermal for industrial heat

Acknowledgment

ARENA
Australian Government
Australian Renewable Energy Agency

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

CSIRO
Australian National University
Flinders University
QUT
The University of Adelaide
University of South Australia
The University Of Queensland

Thank you