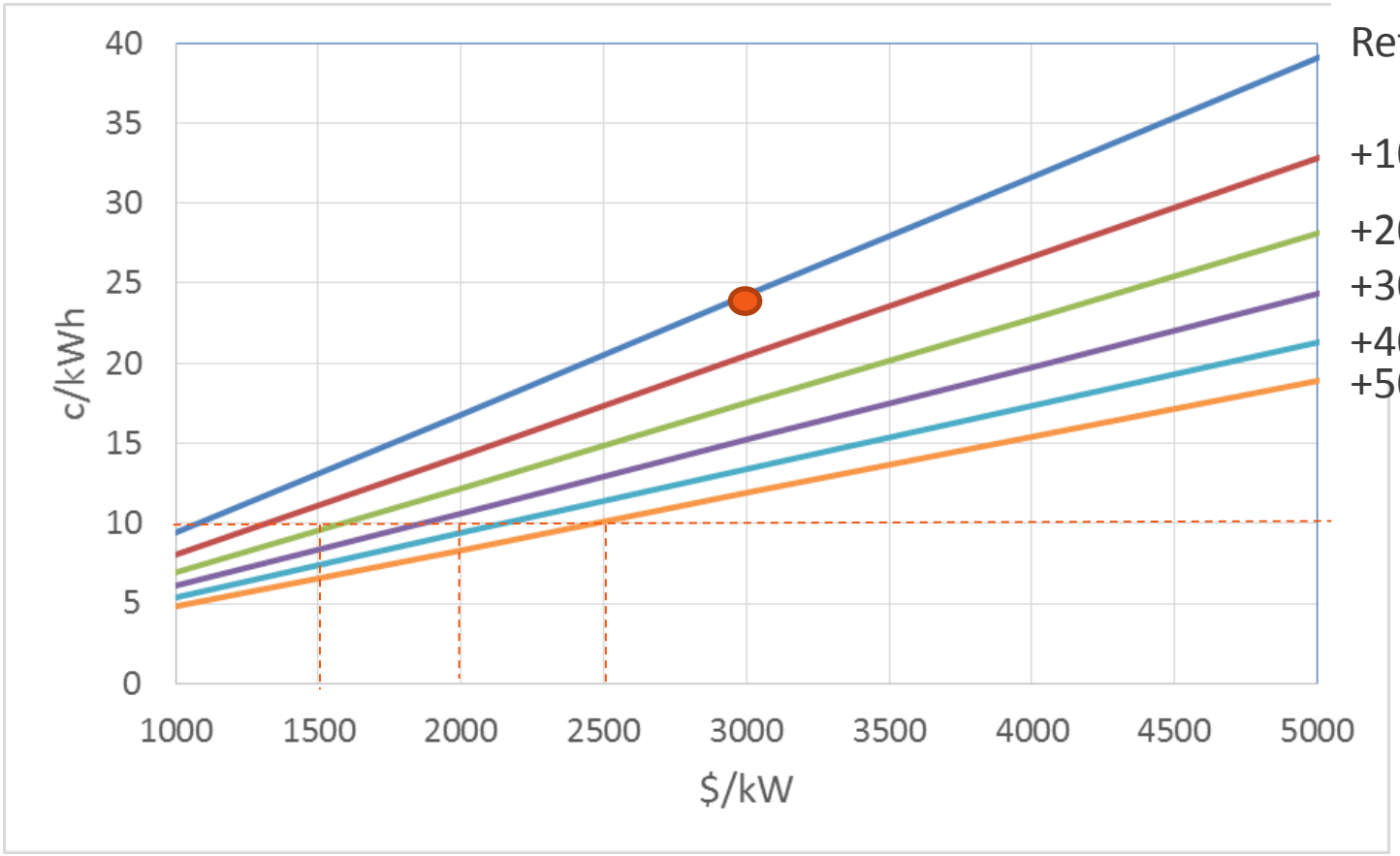
ASTRI
AUSTRALIAN SOLAR THERMAL RESEARCH INITIATIVE

CSP Research in Australia

ASTRI Annual Workshop, 2015

February 2015

The unavoidable relationship



1980 – 1990

ANU - White Cliffs 25kW dish/steam; NH3 cycle

$5M

1990 – 2000

Utilities, ANU, Uni Sydney, Govt.
- SG3 dish, CSP power station studies, evac. tubes, small troughs

Pacific Power, CSIRO
- Solar steam/dry reforming catalysts

CSIRO
- Steam reforming dish

$15M

2000 – 2010

CSIRO – first tower, small heliostats
ANU – SG4 (500m^2 dish)
SHP – linear fresnel

Formation of ASI
Approx $50M (ASI funds) on CSP applied R&D
Predominantly hi temp tower-based R&D

$120M

2010 – 2015

CSIRO – 2nd solar tower
Graphite Energy – graphite storage, tower
Solar Oasis – 30MW dish/steam (abandoned)
Kogan Creek Solar Boost – 44MW fresnel
Vast Solar – 5 x 235kWth tower
Solar Flagships programme and EIF
ASTRI commencement
Collinsville, Alinta Energy, Abengoa CSP proposals

Development of revolutionary concepts with large cost reduction potential

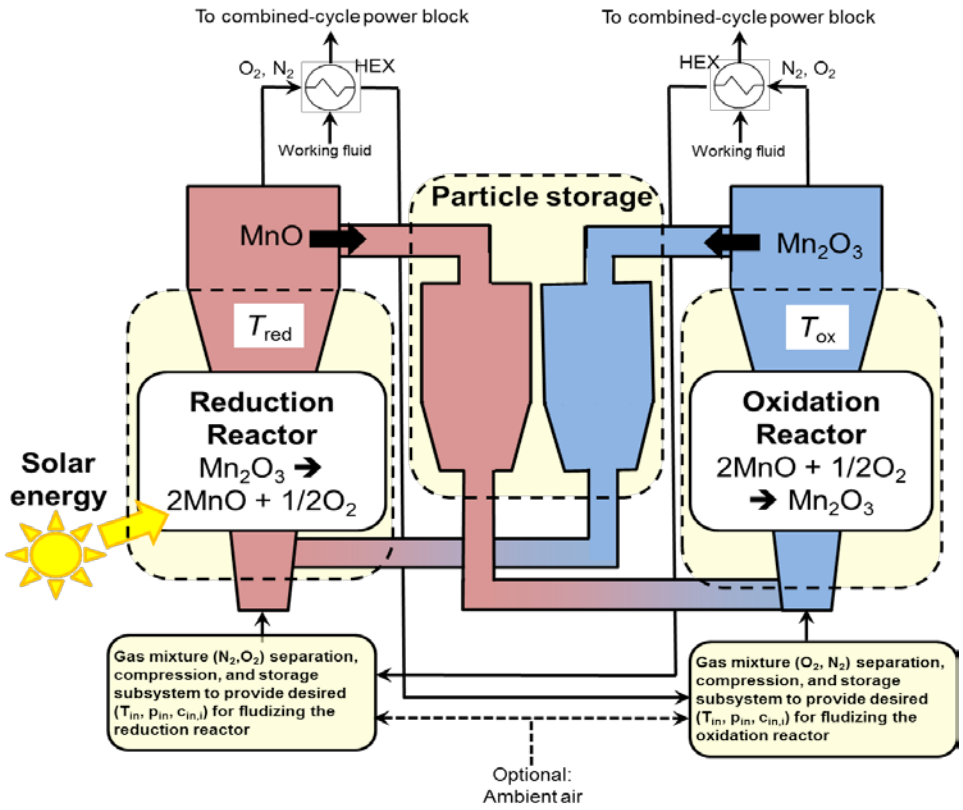
National (global?) consolidation of effort, particularly around large scale pilot (Solar Park)

$330M
(till 2015)

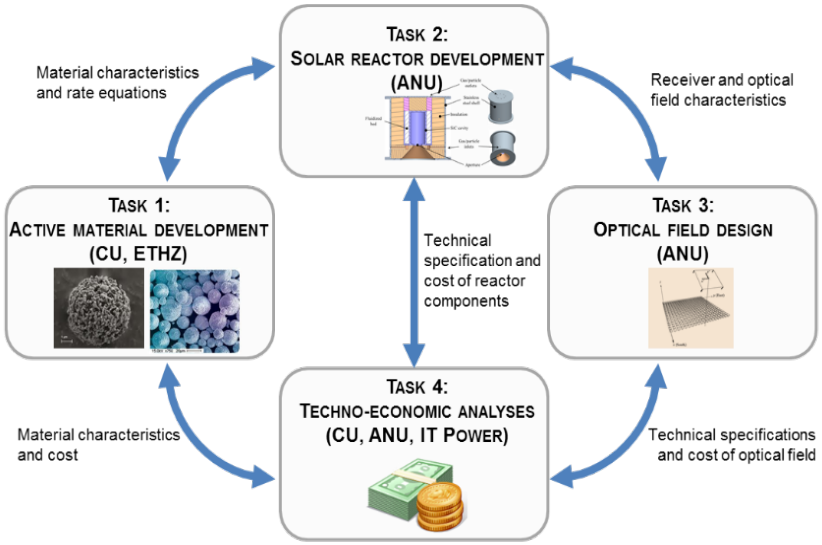
Project	ARENA funding	Total project cos	Status	Lead organisation
Feasibility study for Perenjori 20MW Dispatchable Solar Tower Project	$449,718	$899,436		Abengoa Solar
Port Augusta solar thermal feasibility study	$1,000,000	$2,300,000		Alinta Energy
Improving the accessibility of the System Advisor Model (SAM) for Australian concentra	$73,500		Complete	AUSTELA
Potential network benefits of Concentrating Solar Thermal Power (CSP) in the NEM	$179,965	$272,000	Complete	AUSTELA
High-temperature solar thermal energy storage via manganese-oxide based redox cycli	$1,193,534	$3,068,472		ANU
Improved high temperature receivers for dish concentrators	$1,436,210	$3,340,000		ANU
Improving solar-thermal receivers for reduced heat loss	$1,361,327	$3,527,985		ANU
Roof-mounted hybrid CST system for distributed generation of heating, cooling and ele	$3,235,710	$9,500,000		ANU
Development of a testing facility for storing heat from solar energy at high temperature	$689,500	$2,400,000		Barbara Hardy Inst.
Australian pilot of rooftop CST and CPV-T micro-concentrator solar energy systems	$3,461,680	$9,300,000	Closed	Chromasun
Kogan Creek Solar Boost Project	$34,900,000	$104,700,000		CS Energy
High efficiency solar thermal power using Allam cycle	$2,749,748	$7,046,100		CSIRO
Advanced solar thermal energy storage technologies	$3,538,846	$9,151,301	Complete	CSIRO
Advanced steam-generating receivers for high concentration solar collectors	$2,821,978	$5,980,000	Complete	CSIRO
ASTRI – Australian Solar Thermal Research Initiative	$35,000,000	$87,300,000		CSIRO
Development of combined cycle using solar reformed gas	$346,907	$702,906	Complete	CSIRO
Hybrid concentrating solar thermal systems for large scale applications	$520,011	$1,070,582		CSIRO
Hybridisation of concentrated solar thermal with carbon capture and storage	$667,500	$1,855,000		CSIRO
Optimisation of central receivers for advanced power cycles	$1,150,879	$3,200,000		CSIRO
Solar air turbine systems	$3,055,000	$15,600,000	Complete	CSIRO
Solar driven supercritical CO2 Brayton Cycle	$2,496,835	$6,240,000		CSIRO
Solar hybrid fuels	$1,585,853	$3,900,000		CSIRO
Solar Thermal Research Hub	$5,000,000		Complete	CSIRO
Thermoelectric generator for concentrated solar thermal systems	$2,200,912	$4,700,000		CSIRO
Novel concepts for low cost small heliostats in remote installations	$1,000,000	$2,158,071		CSIRO
Solar energy management system for utilities	$225,715	$570,430		CSIRO
Solar supercritical organic Rankine Cycle for power and industrial heat	$812,000	$1,700,000	Complete	Granite Power
Feasibility study into conversion of Collinsville Power Station from coal to hybrid solar t	$2,500,000	$5,600,000		RATCH-Australia
Micro Urban Solar Integrated Concentrators (MUSIC) Centre	$4,521,191	$13,200,000		RMIT
Fabrication of thermionic device using advanced ceramics	$515,359	$900,000	Complete	Uni Newcastle
Tools for design and scale-up of solar thermochemical reactors	$1,083,320	$5,300,000		UNSW
New photocathodes for solar hydrogen production	$500,000	$1,073,039		Uni SA
6MW Concentrating Solar Thermal (Central Receiver) Pilot Project with integrated ener	$4,966,960	$10,066,000		Vast Solar
Validation of CST solar array performance modelling	$437,243	$1,300,000		Vast Solar

High-temperature solar thermal energy storage via manganese-oxide based redox cycling

Proposed innovation

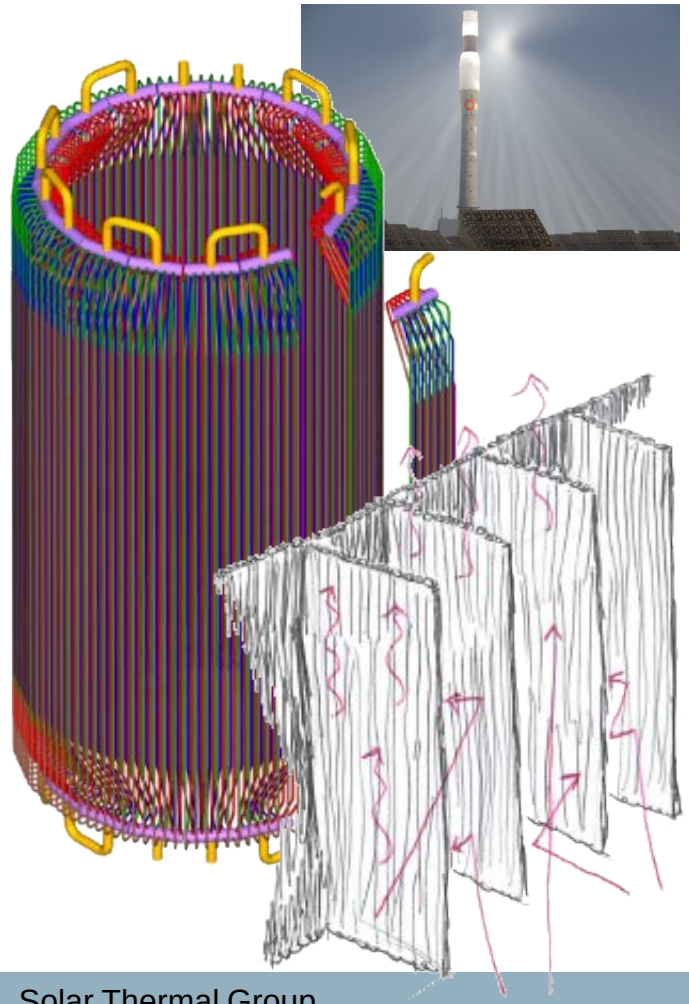


Approach



Organisation:	The Australian National University	**Start date:**	1 November 2014
Host unit:	Solar Thermal Group, RSEng	**Funding:**	1,193,533
Partners:	University of Colorado Boulder, ETH Zurich, IT Power Pty Ltd	**Total project value:**	3,068,471

Bladed receivers with active airflow control



- Novel configurations of tube-banks for central tower receivers.
- Potential identified for up to 50% reduction in thermal losses, 1–2 cAUD/kWh LCOE savings.
- Co-filed ANU/Sandia provisional patent application.
- Key activities:
  - Wind/water tunnel tests with PIV
  - CFD, ray tracing, integrated design optimisation
  - solar simulator radiative heat transfer tests
  - on-sun testing at CSIRO solar tower

Duration: 3 years from Dec 2014 **Funds:** $1.3M **Cost:** $3.5M
Participants: ANU, U Adelaide, Sandia, CSIRO
Researchers: 8 academics, 4 res officers, 2 PhD students

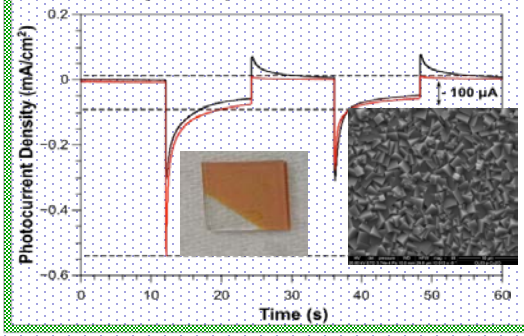
University of South Australia

The Wark

“Artificial Photosynthesis” (ARENA)

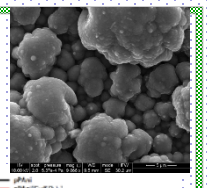
Metal Oxides

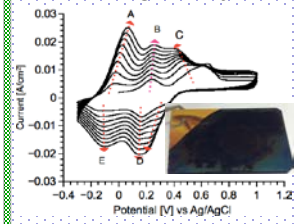
- Cheap and earth abundant
- Electrodeposition
- Inorganic synthesis

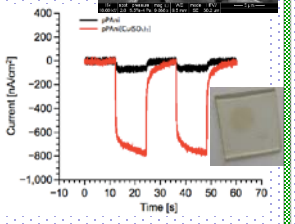


Conducting polymers

- Electropolymerisation
- Plasma technique
- Organic synthesis



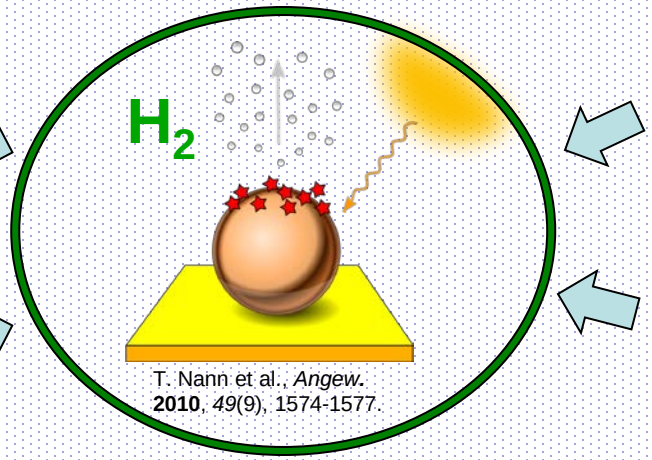




Australian Government

Australian Renewable Energy Agency

Australia

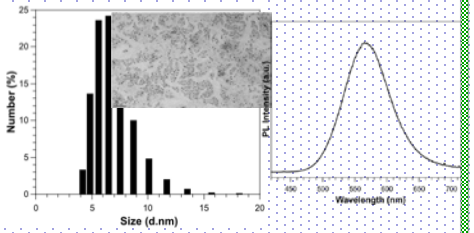


T. Nann et al., *Angew.* **2010**, *49*(9), 1574-1577.

Europe

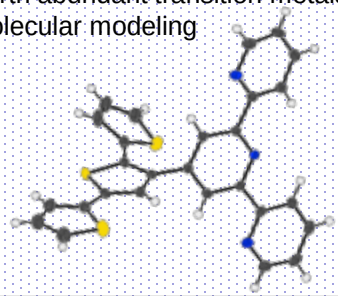
Quantum Dots

- Non-toxic
- Organic and inorganic synthesis
- Tunable optical spectrum
- Photocatalysts



Molecular Catalysts

- Metalorganic synthesis
- Earth abundant transition metals
- Molecular modeling



VU UNIVERSITY AMSTERDAM

GSI

Cookson Electronics Enthone

High temperature latent heat storage materials

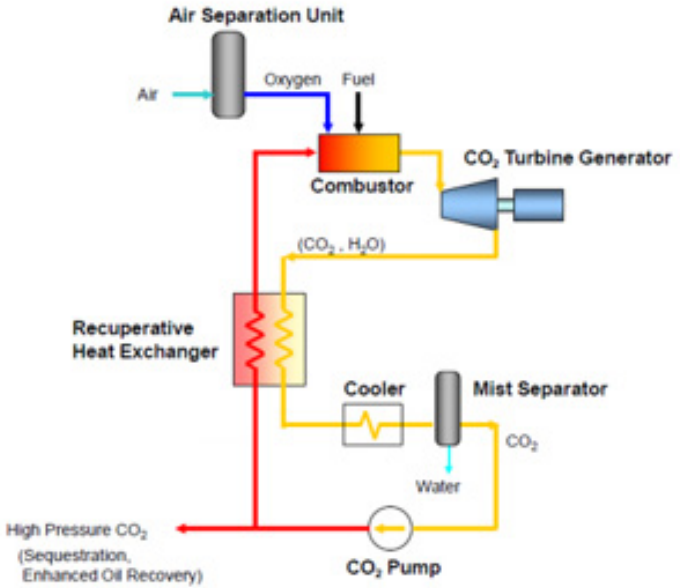
Compound	Melting temperature	Heat of fusion	Density (kg/m^3)		Specific heat (kJ/kg·K)		Thermal conductivity (W/m·K)	
	(°C)	(kJ/kg)	Solid	Liquid	Solid	Liquid	Solid	Liquid
$NaNO_3$	306	172	2261		1.10		0.5	
KNO_3	335	95	2109		0.953		0.5	0.425
$MgCl_2$/KCl (39/61 wt%)	435	351	2110		0.80	0.96		0.81
$MgCl_2$/NaCl (52/48 wt%)	450	430	2230		0.92	1.00		0.95
$BaCl_2$/KCl/NaCl (53/28/19 wt%)	542	221	3020		0.63	0.80		0.86
Pb	328	23						
Al	660	397						
Al-Mg-Zn (60/34/6 wt%)	450.3	329.1						
Mg-Al (34.65/65.35 wt%)	497	285	2155					
Al-Si (12/86 wt%)	576	560	2700		1.038	1.741	160	
Al-Si (20/80 wt%)	585	460						

- Inorganic salts and salt composites
- Metals and metal alloys
- Ongoing work aims to extend range to 900ºC

Liu, M., Saman, W. and Bruno, F., (2012) Review on storage materials and thermal performance enhancement techniques for high temperature phase change thermal storage systems, Renewable and Sustainable Energy Reviews, Vol 16, Issue 4, pp 2118– 2132

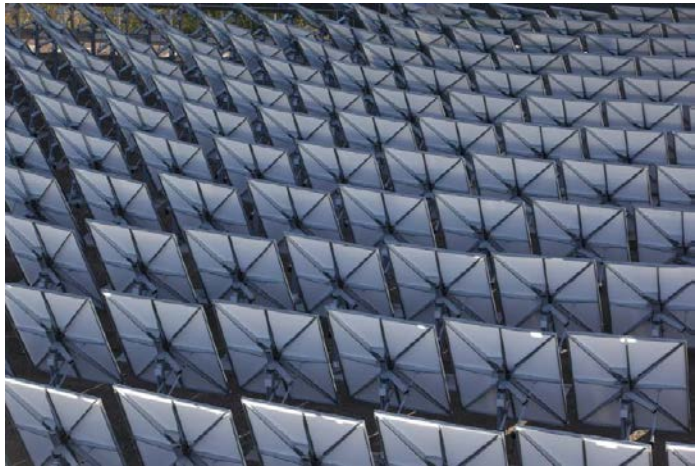
Solar Allam Cycle

- This project will solarise the Allam cycle, a particular version of the supercritical CO2 turbine technology that is one of the highest efficiency power cycles under development for the fossil power industry today.
- A liquid metal (most likely sodium) will be used as the heat transfer fluid in the receiver to ensure very high levels of heat transfer at temperatures of 720 degrees Celsius.
- Partners: CSIRO, Toshiba International Corporation, Abengoa Solar, 8 Rivers, NREL, CAS



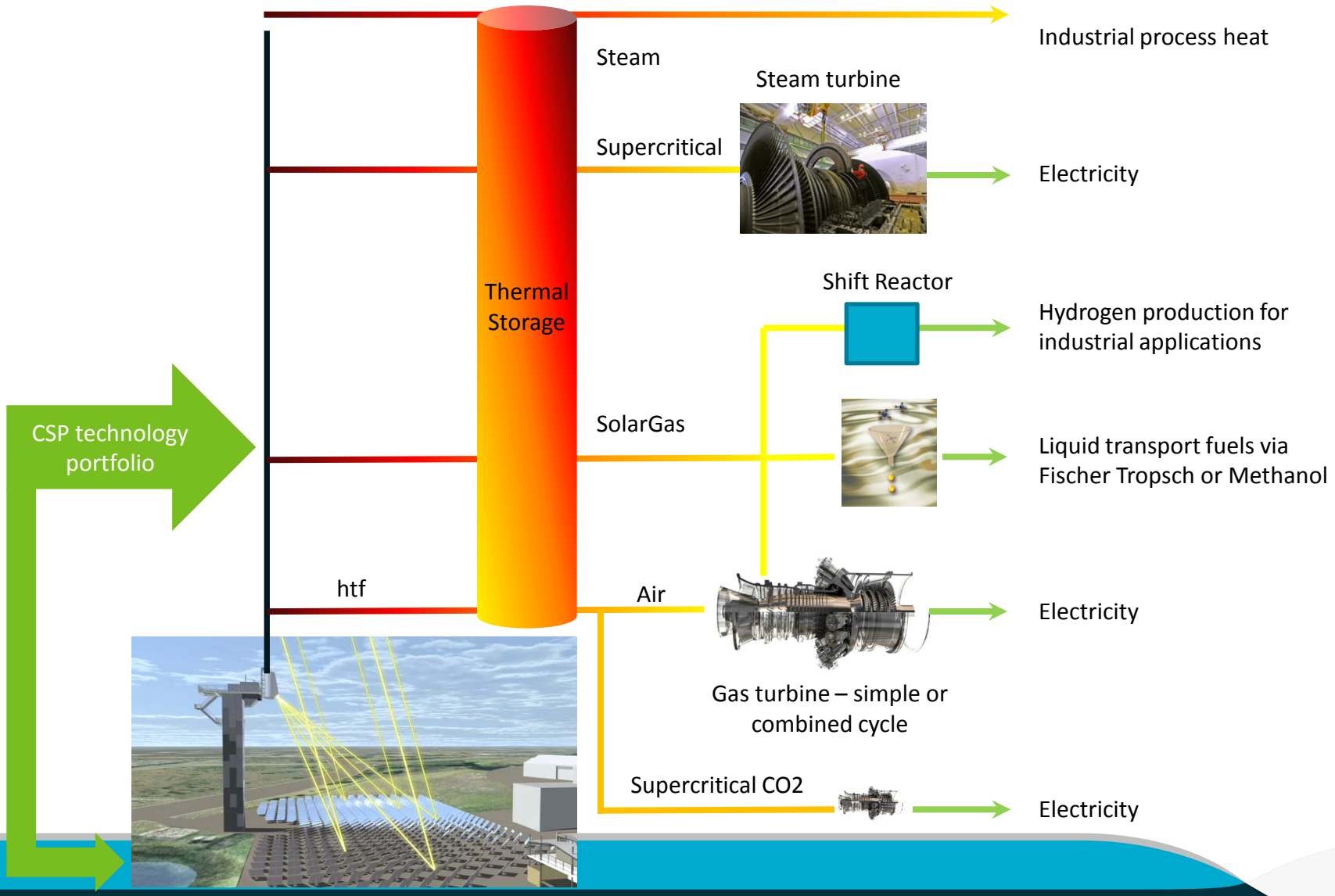
Low cost heliostats for remote regions

- Regional and remote areas of Australia are particularly attractive for deployment of central receiver solar energy systems. Many remote locations have high quality solar resource, demand growth and are supplied by expensive generators.
- High labour rates, distance from major supply centres and extreme site conditions present unique challenges.

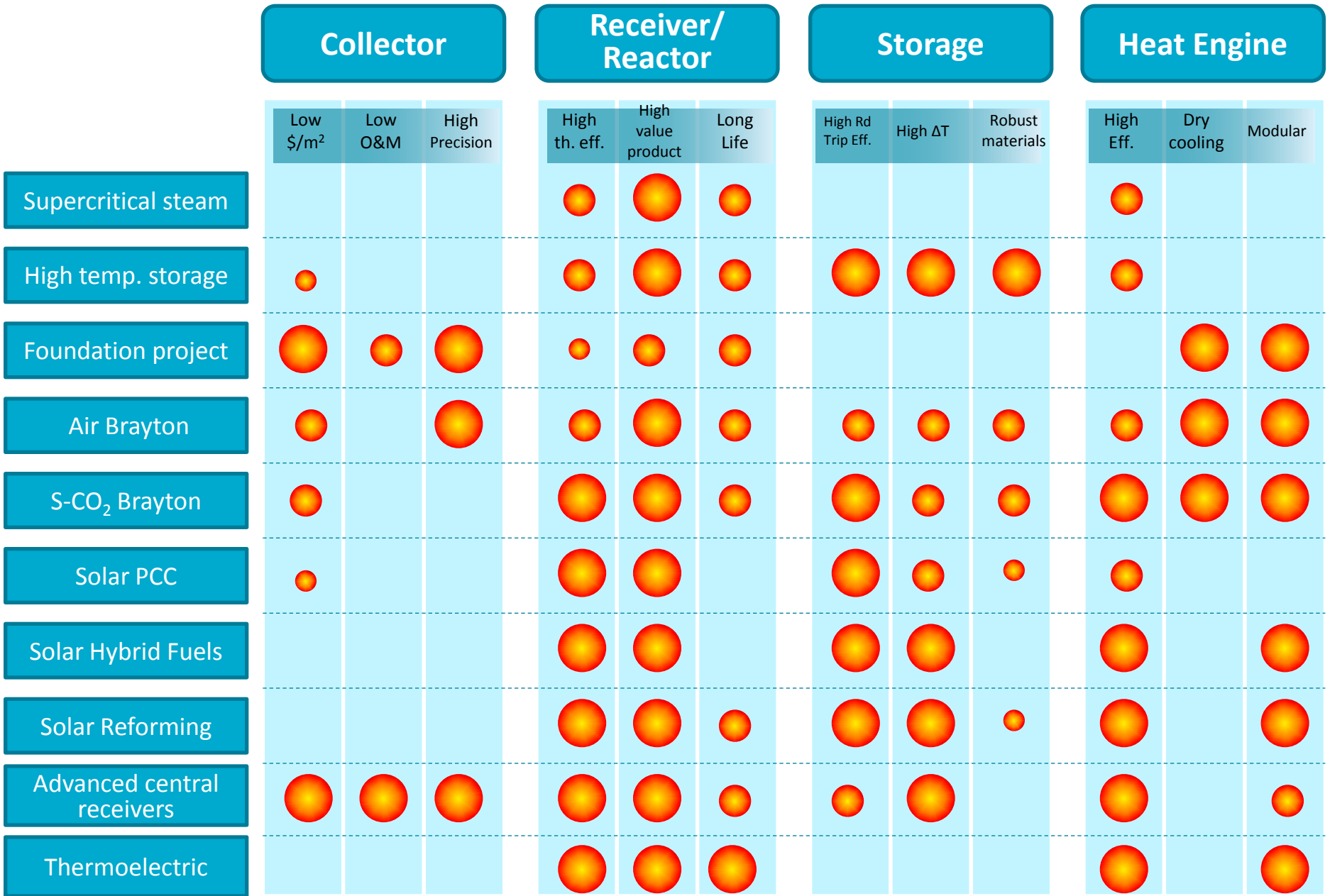


- The high cost of labour in remote areas will be avoided through manufacturing offsite using automotive style mass manufacturing methods, optimised for freighting from existing manufacturing capacity.
- A novel direct drive electric actuator and motor will be used for the heliostat movement system to extend maintenance intervals.
- An advanced control system will be developed to allow the heliostats to reflect sunlight accurately with minimal set-up and to eliminate initial and ongoing calibration. This will make the site ground conditions less important, speeding up project deployments.

Targeted portfolio of CSP Research Activities



Aim: Solar energy technology which is competitive with conventional sources



Graphite Energy:
G1 Pathway to Commercialisation

delivering superheat and
storage from solar energy

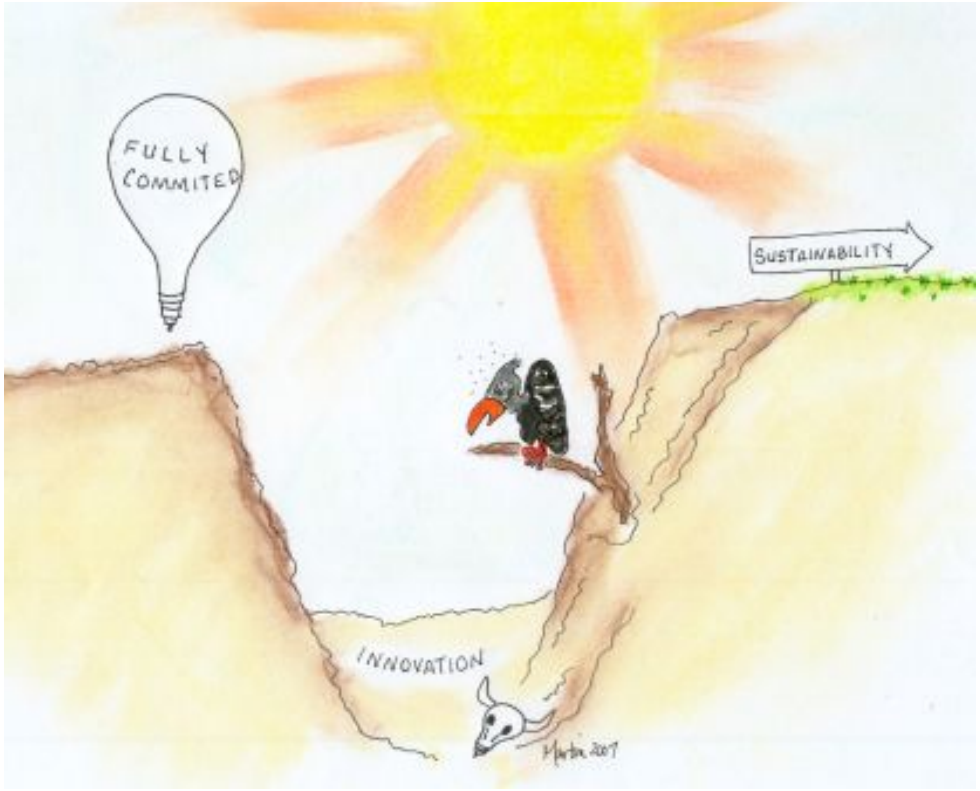
Graphite Energy

- Australian private company (2008)
- Commercialise graphite-based solar thermal receiver technology
- Built Australia's first fully integrated 3MW$_e$ solar thermal power station at Lake Cargelligo, NSW
- World Class engineering partners – Bechtel and Parsons Brinckerhoff

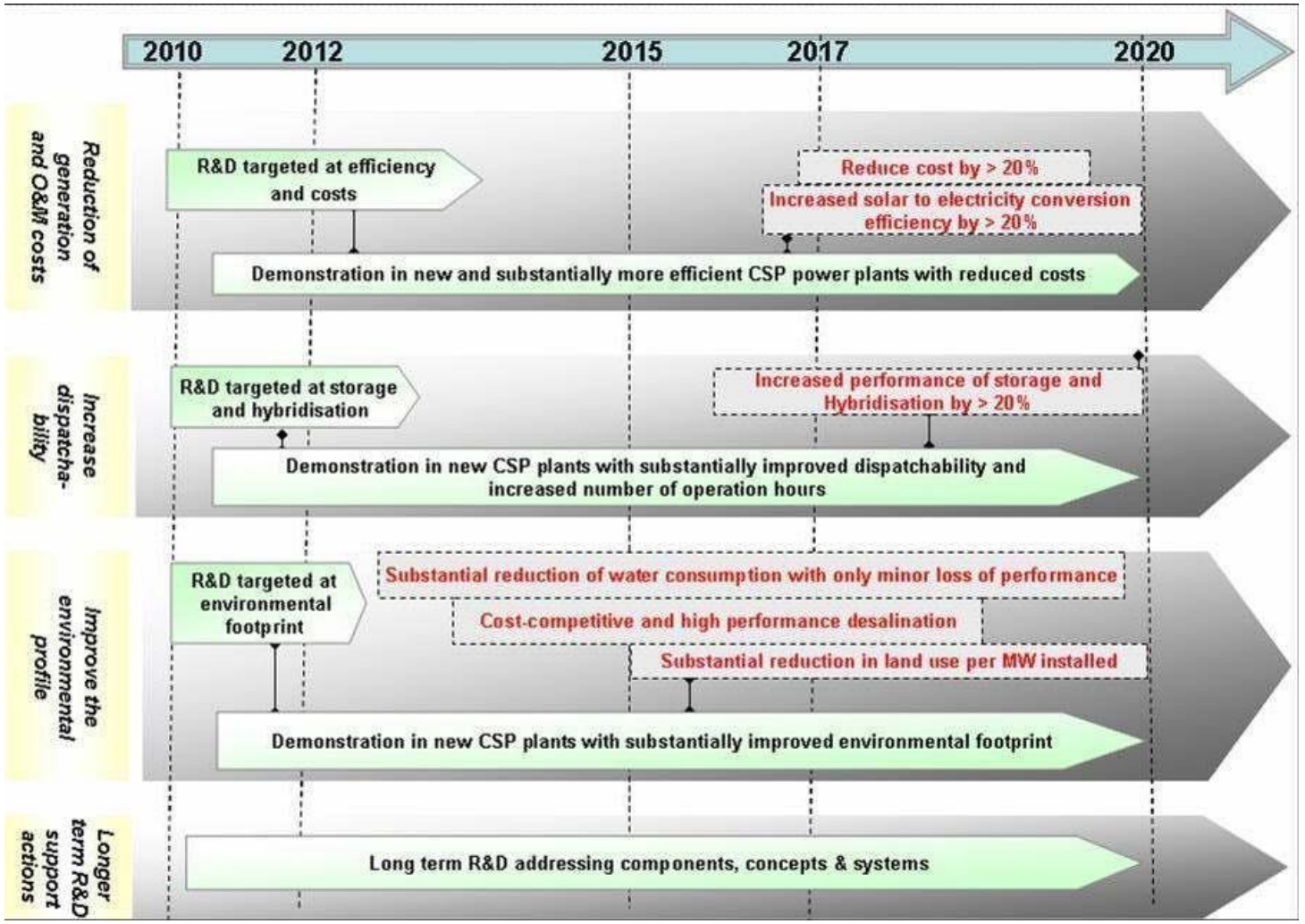
Product development journey

- Solar thermal is expensive way to boil water
- Maximum value of solar thermal energy:
  - Increase steam temperature - superheat
  - Achieves >50% thermal-to-electrical efficiency
- Development of the G1-HRSG Solution

Where are we at in the CSP investment cycle in Australia?



European Industrial Initiative on Solar Power



Acknowledgements

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Australian National University

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

THE UNIVERSITY of ADELAIDE

University of South Australia

Flinders UNIVERSITY

Thank you

Wes Stein

Group Leader/ Solar Technology

CSIRO