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The potential for concentrating solar thermal energy in mining and minerals processing

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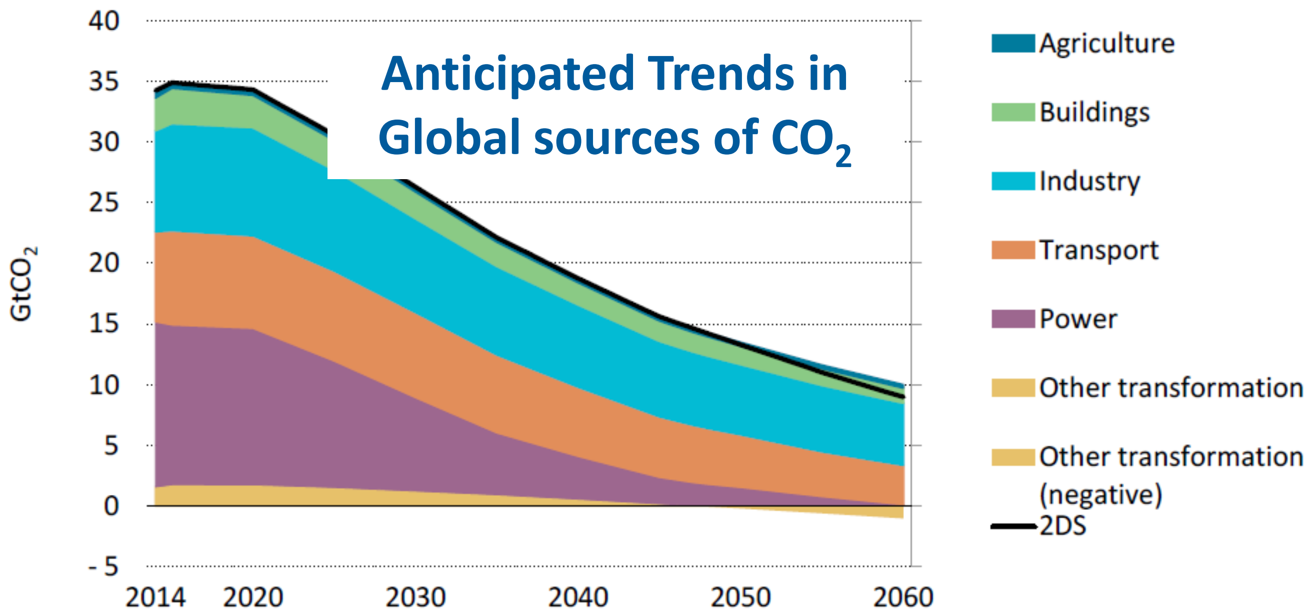
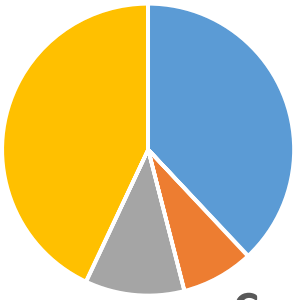
Industrial Heat: A Major Emerging CO_2 Challenge



Philibert, "Renewable Energy for Industry" IEA Report (2017)

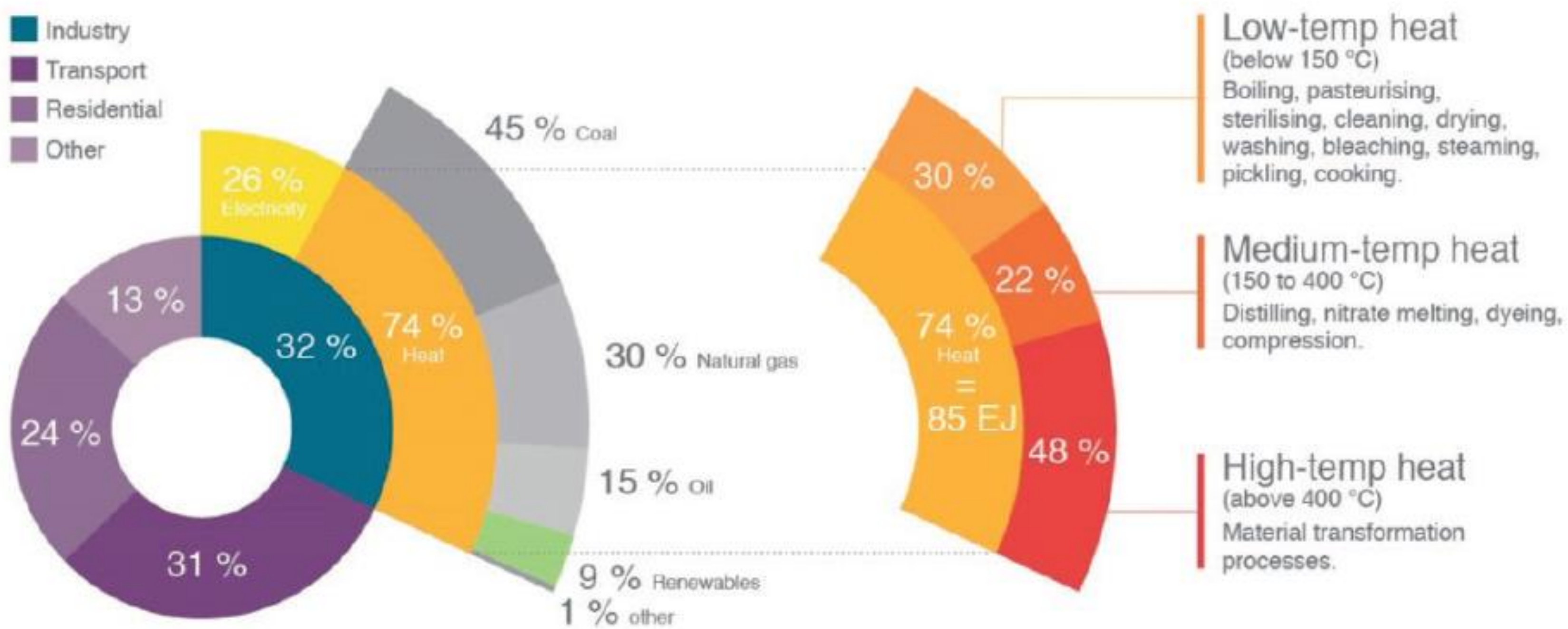
Australian End use Energy 2012 – 13



Sources:

1. Australian end use source data: Energy in Australia 2014, ABRE
2. Processing temperature data CSIRO Energy centre, Beath

Industrial Process Heat



Philibert, "Renewable Energy for Industry" IEA Final Report (2017)

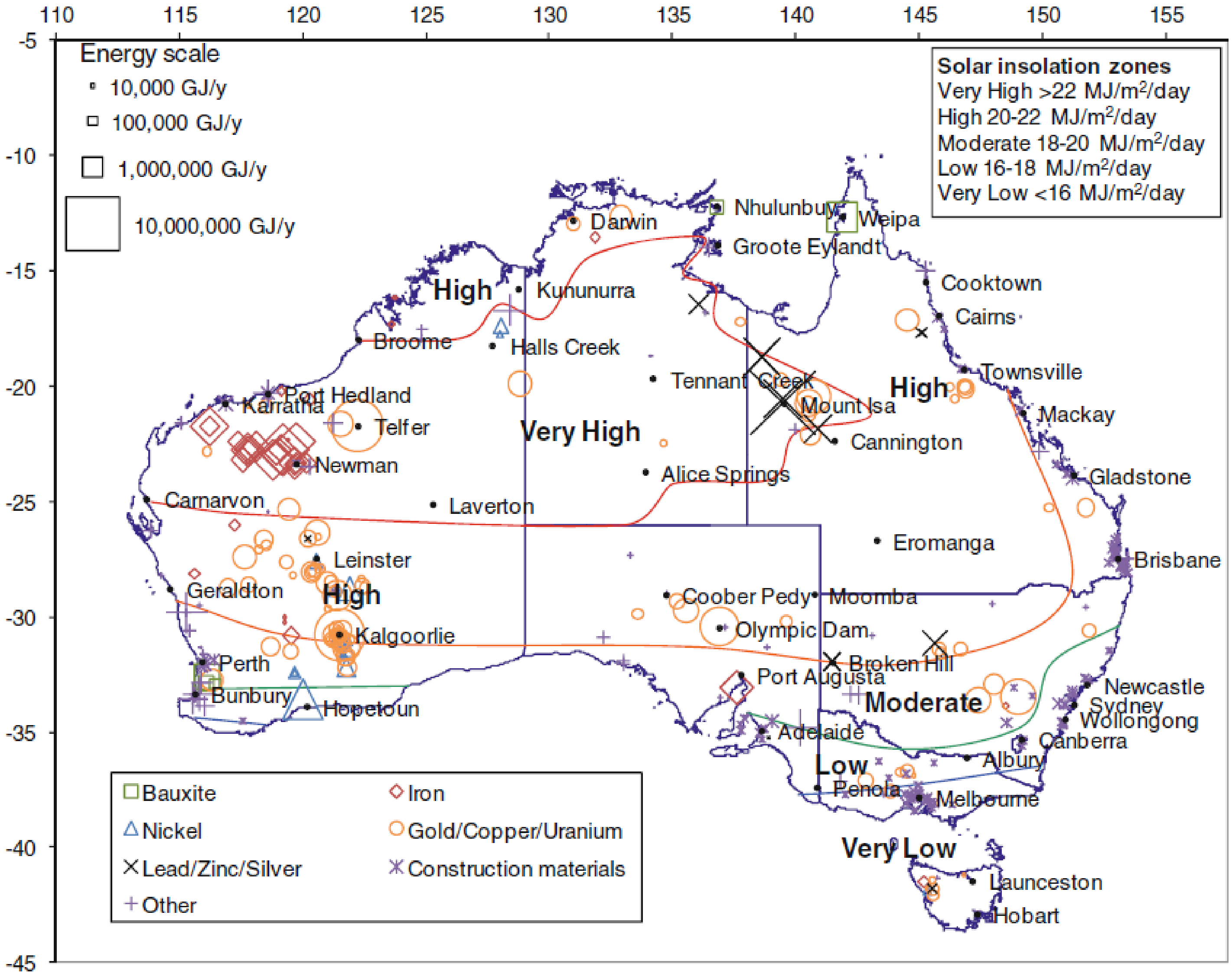
Low-Med (<400 °C) = 52%

- boiling & drying
- ore concentration & digestion
- Food industry

High temp (>400 °C) = 48%

- Reduction: Iron & steel, copper
- Calcination: cement and alumina
- Petrochemical

Coincidence of solar and mineral resources in Australia

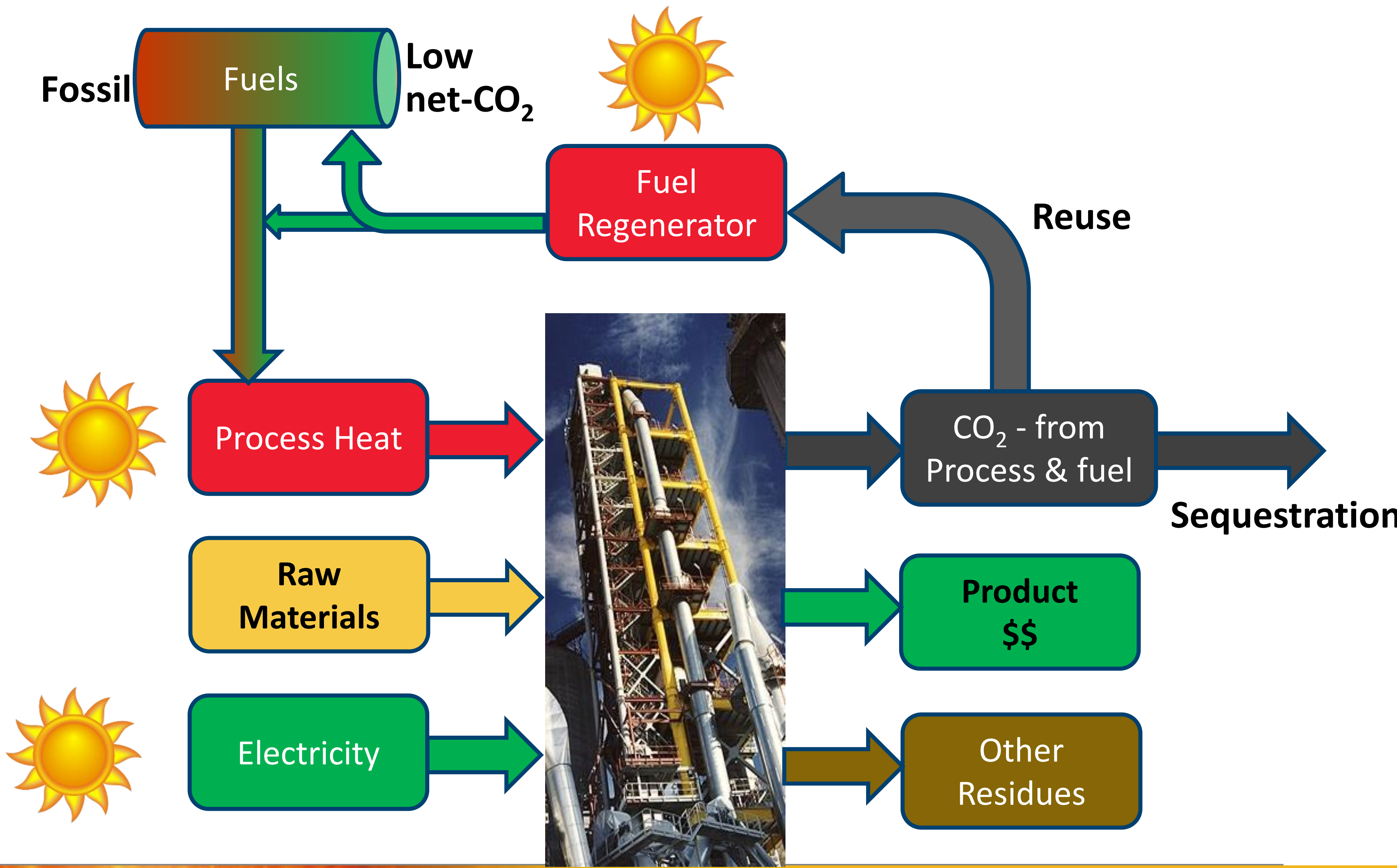


Egglinton, Hinkley, Beath & Dell'Amico, JOM, 65 (12): 2013.

Drivers and opportunities for CST in mining

- **Ore Concentration (Cu, Fe, etc) – typically at 180 - 300°C:**
  - Temperatures compatible with commercial trough / tower
  - Scales (tens of MW) smaller than most commercial CSP
- **Opportunities and challenges due to remote sites:**
  - High cost of commercial fuel - trucked LPG at > $US8 / GJ
  - Often have excellent solar resource;
  - High reliability and low O&M are needed
- **Potential opportunities for combined heat and power**
  - Electricity is also needed for crushing;
  - Steam turbine typically uneconomical at tens of MW
  - New power blocks are under development (e.g. SCO_2)

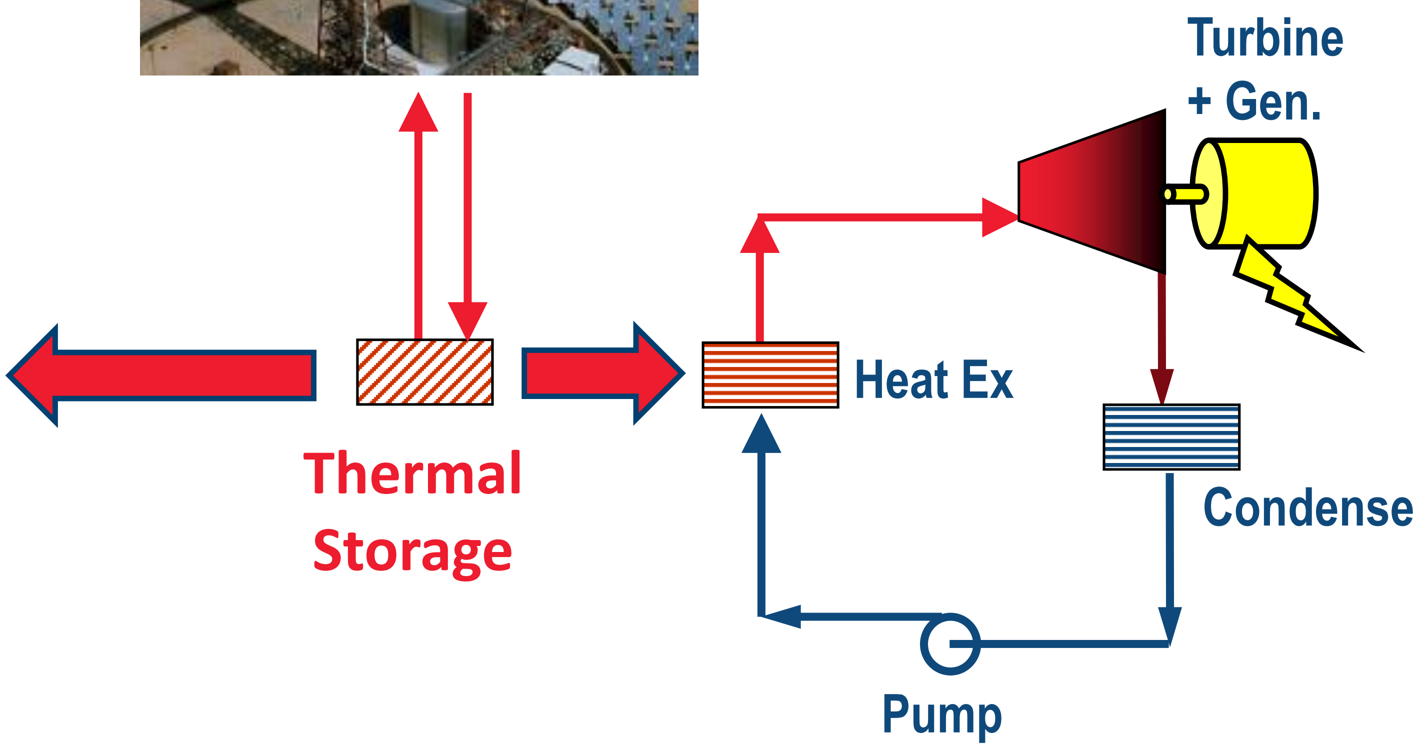
Options for producing valuable, green products



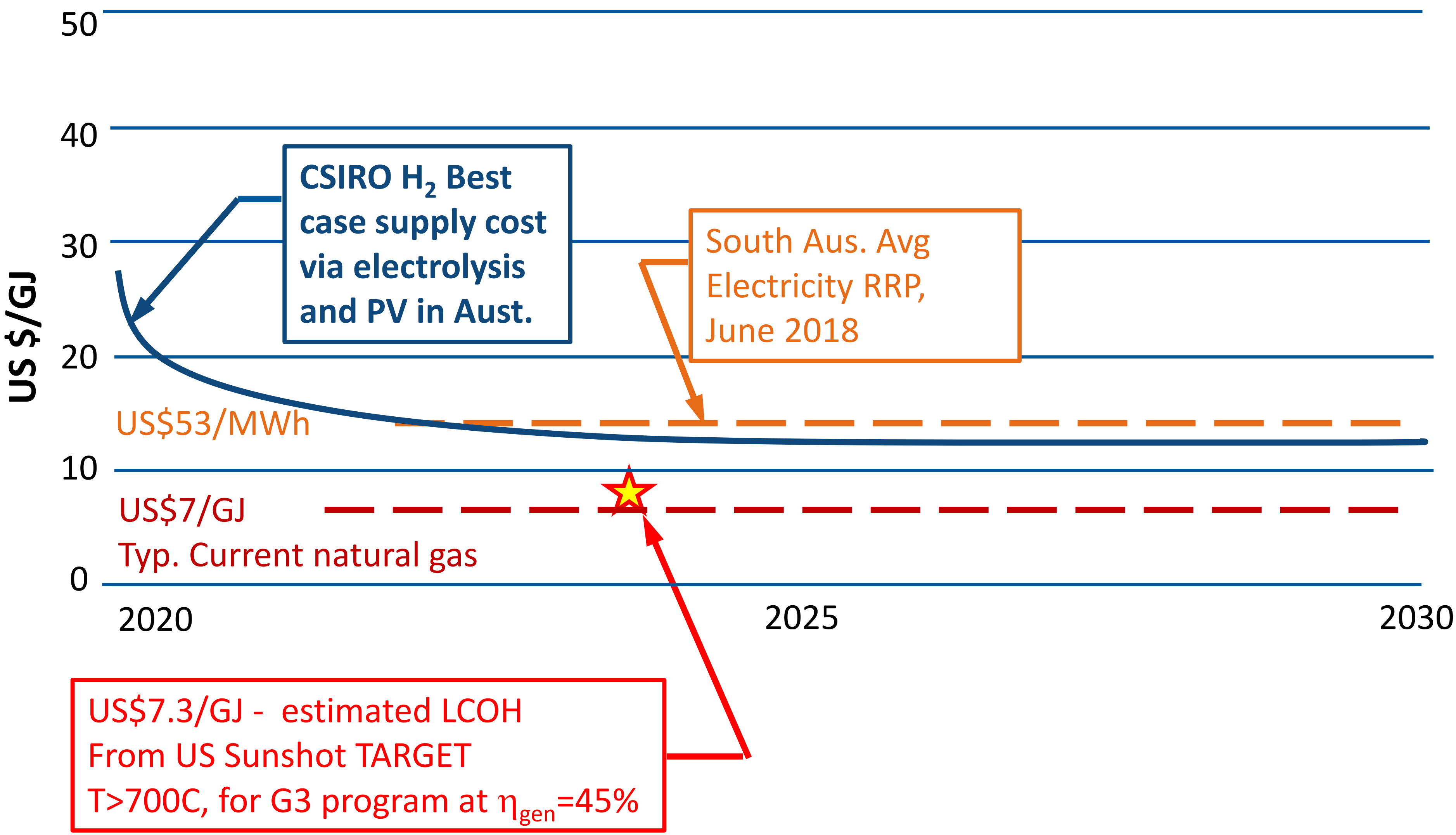
Direct use of solar heat avoids losses of power cycle

Direct use
$\eta \sim 90\%$

Power cycle
$\eta \sim 35\%$



Projected H2 cf CST targets and current fuels / electricity



Project target: a viable path to 50% CST in Bayer Process

Based on displacing natural gas at AUD$10/GJ

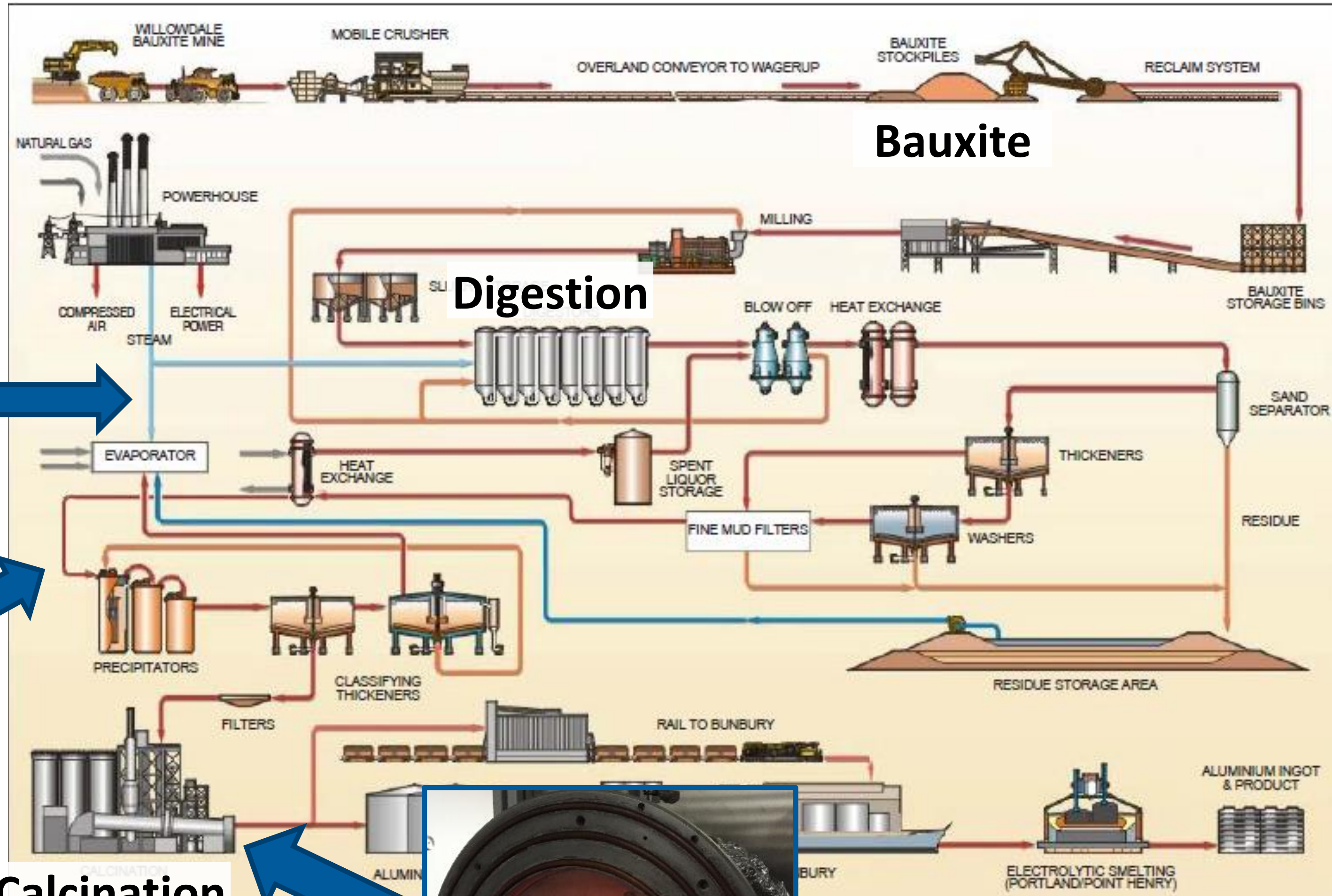
Solar Digestion

Steam at 180°C

(alone or as CHP)

Solar Reforming

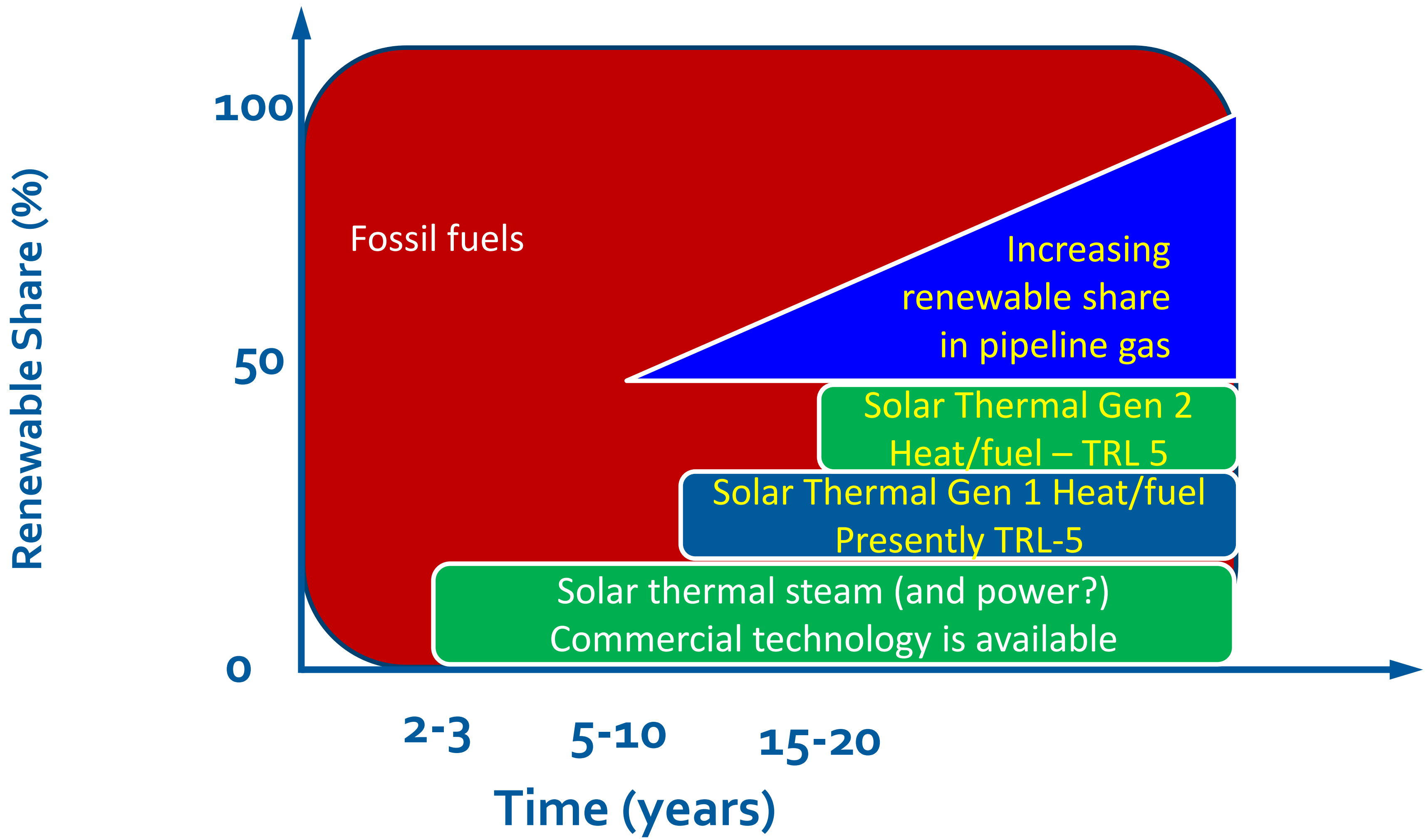
Nat Gas to syngas



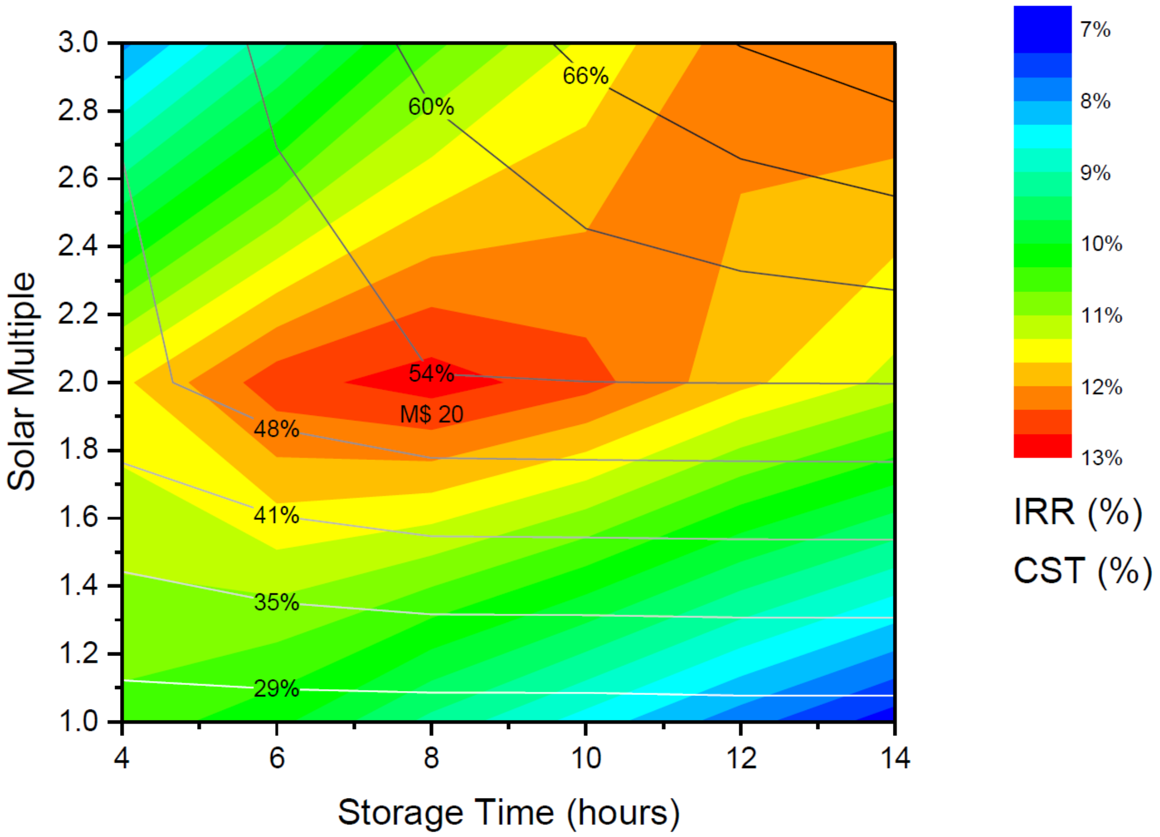
Solar Calcination

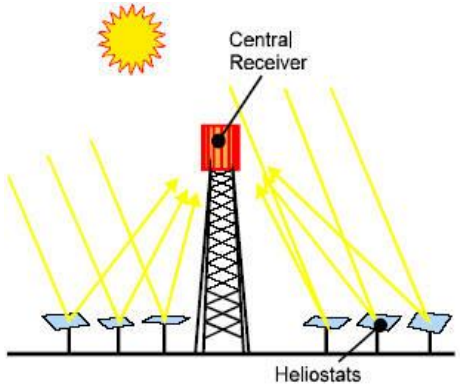
at ~1000°C

Plausible pathway to transform heat in Bayer process



Solar Share and NPV for tower-based CHP
Calculated using costs from suppliers





Results in preparation for publication obtained from data from suppliers
Lovegrove, Bader, Bayon and Beath

(Image sources: top right: Torresol Energy; bottom right: http://www.solarpaces.org)

Challenge of Integration for Calcination Process

Land is available for heliostat field:

- Industrial "Buffer zone" around the plant

Incorporating CST into high temperature process is challenging

- Calciners are integrated into plant, >200m from potential field

Lowering cost requires minimising risk, and hence changes

Integration options considered

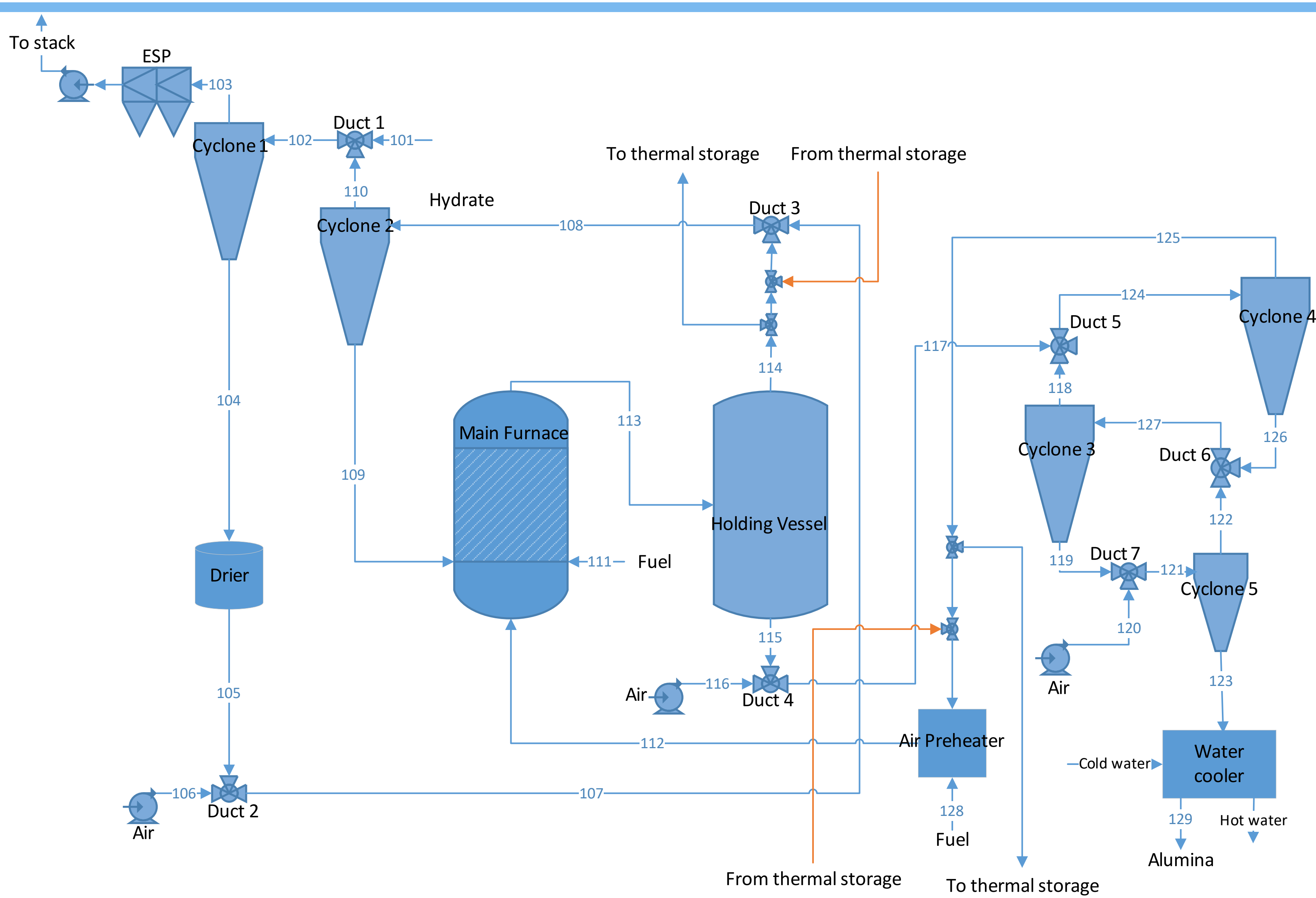
Considered two options:

- Transporting suspended alumina to and from tower
- Transporting hot air to and from tower

Transporting air: lower technical risk and higher solar share

- Requires no significant change to the process

Process modelling of configuration to integrate stored, hot solar air into Bayer alumina process



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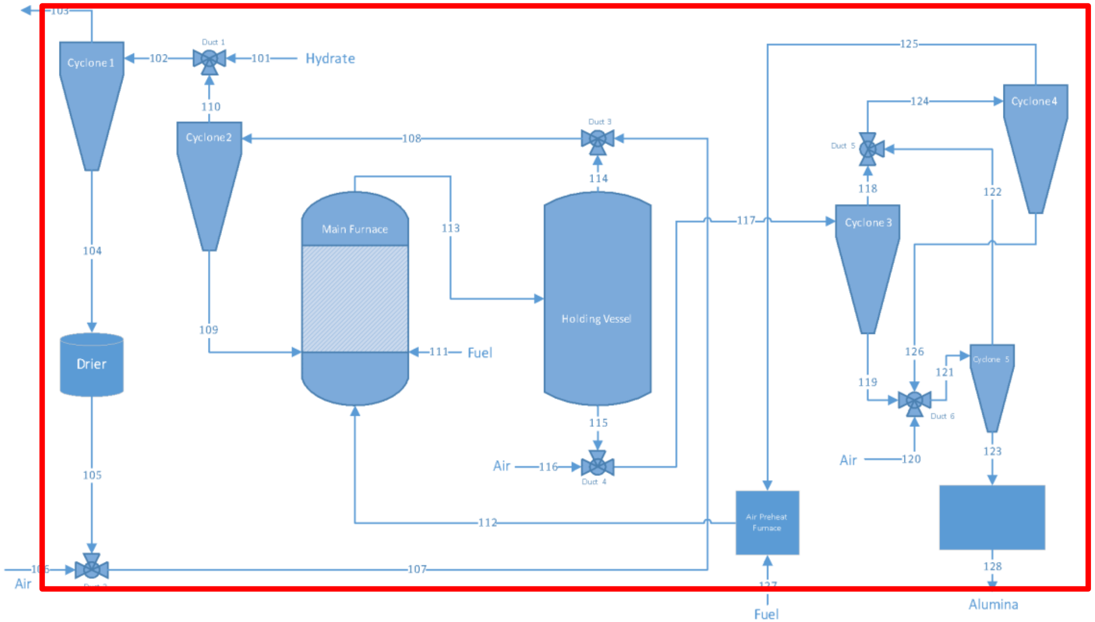
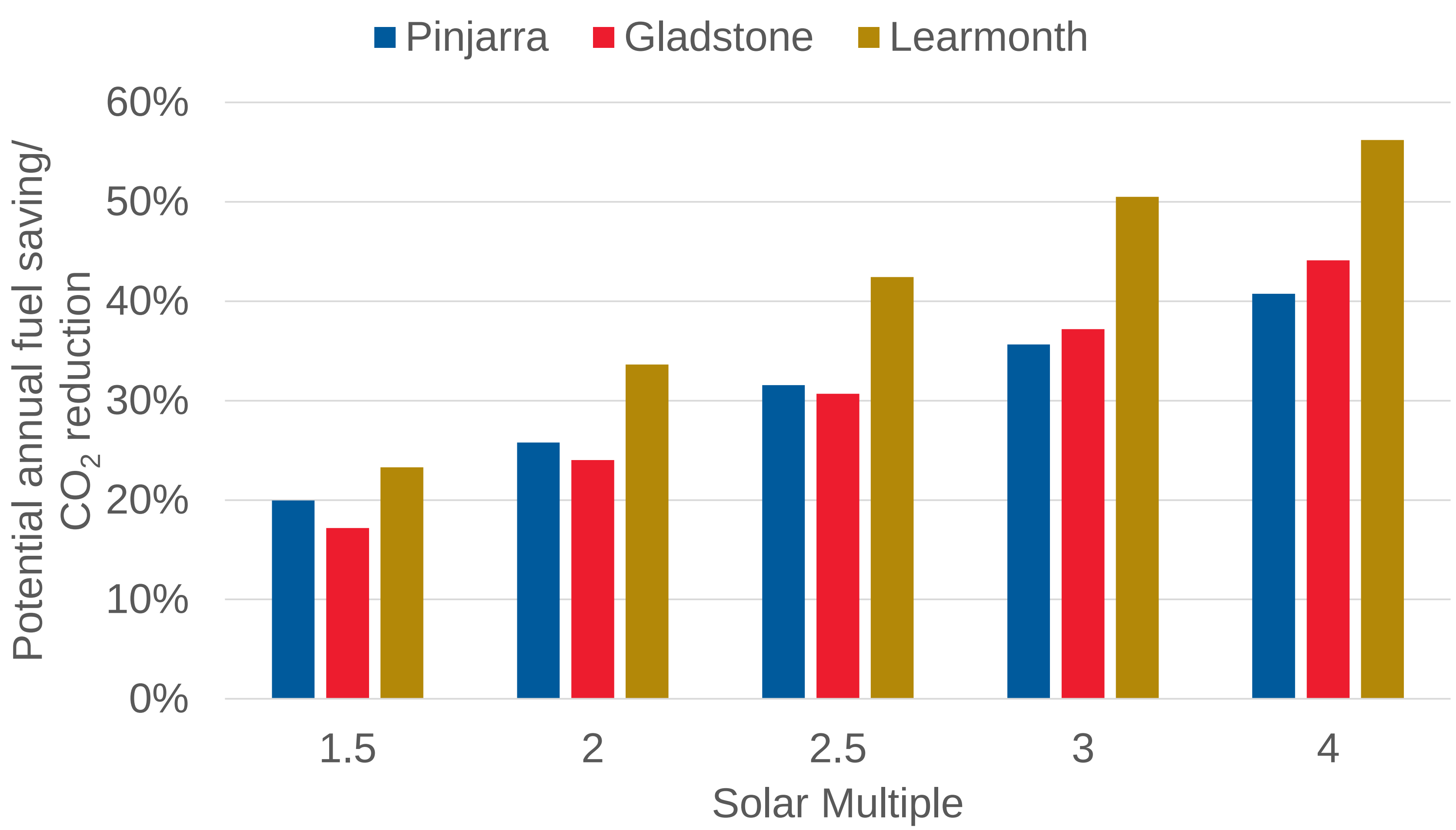


Flow diagram of flash calcination process

Tonnes/hr	In						Out	
	101	106	111	116	120	127	103	128
Temperature (°C)	25.00	25.00	25.00	25.00	25.00	25.00	546.32	464.27
Gibbsite - Al(OH)3	145	0.00	0.00	0.00	0.00	0.00	7.26	0.00
Boehmite - AlOOH	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00
Water removed from alumina - H2O (AL)	0.00	0.00	0.00	0.00	0.00	0.00	47.73	0.00
Water from combustion - H2O (CH4)	0.00	0.00	0.00	0.00	0.00	0.00	13.67	0.00
Natural gas - CH4	0.00	0.00	6.08	0.00	0.00	0.00	0.00	0.00
Carbondioxide - CO2	0.00	0.00	0.00	0.00	0.00	0.00	16.71	0.00
Oxygen - O2	0.00	2.01	0.00	12.76	12.76	0.00	3.22	0.00
Nitrogen - N2	0.00	7.55	0.00	42.00	42.00	0.00	91.54	0.00
Alumina -Al2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	90.00
Total	145	9.55	6.08	54.76	54.76	0.00	180.42	90.00
	270.42						270.42	

Mass balance around the overall process

Estimated fuel savings and CO_2 mitigation using process model
Case with CST used to heat air & commercial storage



Hot air at 1000°C

Potential to integrate CST into Bayer Process

- **Displacing 20-50% fuel with solar heat seems realistic**
  - Requires no significant changes to the process
  - Pathway from commercial steam (~17% share) to pre-commercial fuels and process heat (~17% share each);
  - Exact share will depend on solar resource
- **Air chosen as the HT fluid for direct use of heat because:**
  - Integration of solar heat appears straight forward
  - Preliminary estimates suggest AUD$10/GJ is achievable
- **Direct irradiation of suspended particles targeted for receiver**
  - Good potential for efficient performance and scale-up
  - Project will better evaluate potential and de-risk upscaling
  - Comparison with other technologies is planned

Thankyou!

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Considerations in developing new technology for HiTeMP processes

Capital intensive plant with long life & low margins:

- Any new plant needs to have no risk
- Production:

Image: alamy.com

New technologies should be retrofittable with a "no-regrets option" allowing reverting to current operation:

- Offers low risk to loss of production

Continuous, steady-state operation is vital to viability:

- Solar thermal heat is best hybridised with fuels

High temperature (>800°C) calcination processes

Calcination – removes gas from material with heat

- Cement: removes CO_2 limestone to lime at ~850°C
- Alumina: removes H_2O from hydrate at ~1000°C

Mostly performed in "flash" reactors

- Particles of ~100μm carried in suspension
- Efficient heat recovery through a series of cyclones

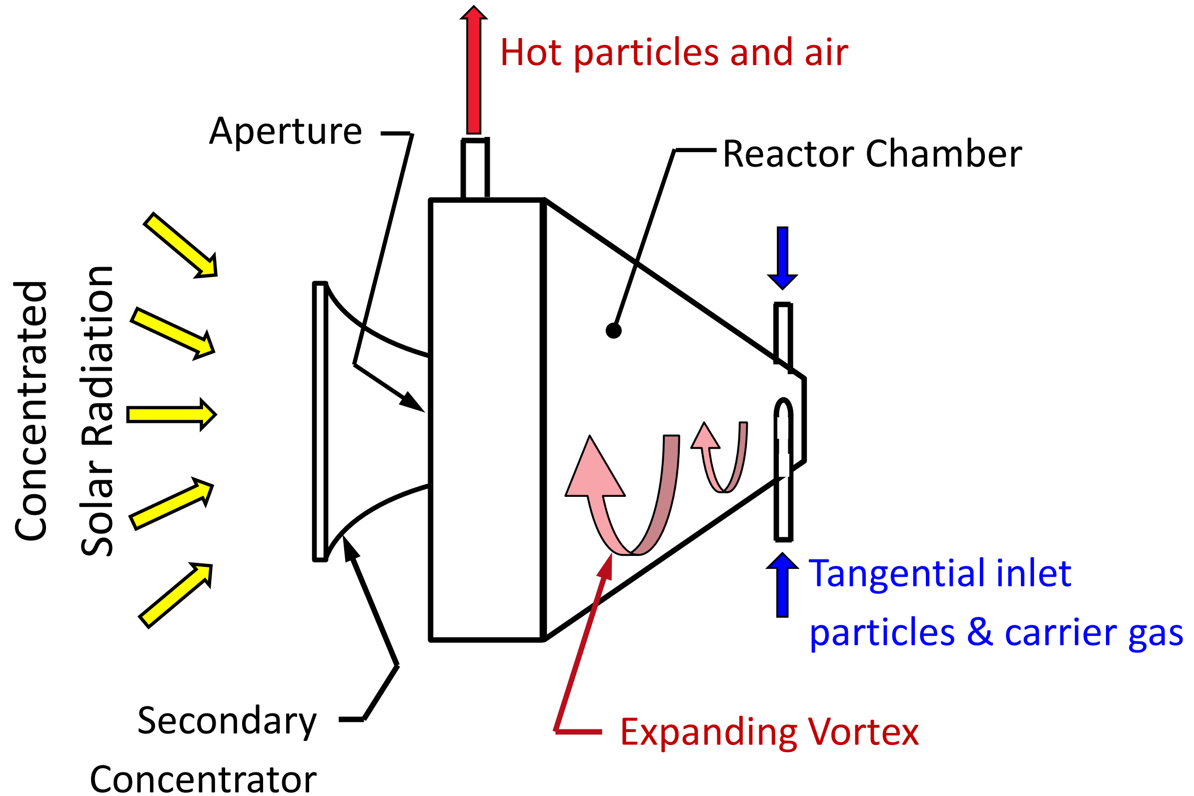
Calcination is a good target for direct use of solar heat:

- Can be performed in air (unlike reduction)
- Temperatures have been demonstrated

Alumina was targeted for Conc. Solar Thermal because

- Alumina is a major export commodity for Australia
- Waste fuels are more challenging than in cement

Windowless solar expanding vortex receiver



Key Features

- **Low rate of particle convection through aperture**
- **Large particles preferentially recirculated**

Chinnici, et al., (2017) Solar Energy, **141**, 25-37