INTEGRATION OF CONCENTRATED SOLAR THERMAL ENERGY INTO FLASH CALCINATION PROCESS

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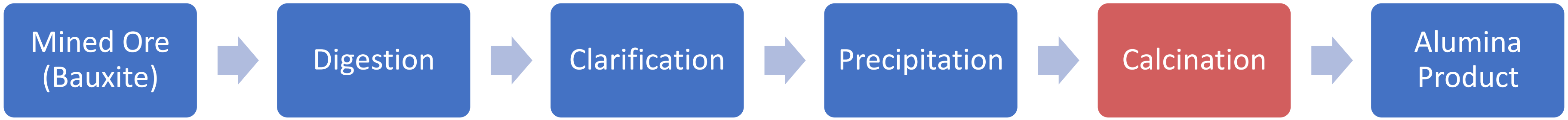
Introduction – The Bayer Process



- Calcination is the final step in the Bayer process, where gibbsite, precipitate from the precipitation process, is converted to smelter grade alumina.
- Australia is the number 1 exporter of alumina, with an annual production of over 20 million tonnes per year*.
- Alumina refineries are capital intensive, low margin and designed to be long life plants which operate continuously in order to be feasible.
- In the process, gibbsite particles are heated 950°C to remove the chemically bound water molecules, thus consuming 1/3 of the thermal energy input in the Bayer Process.
- The thermal energy for calcination process is through direct combustion of natural gas thus releasing 160kg CO_2/tonne of alumina produced.
- It is estimated 2% of total GHG emissions in Australia are from alumina refineries.
- Concentrated Solar Thermal (CST) energy hybridized with fuel could potentially be utilized in the flash calcination process in order to reduce GHG emissions.

* *Department of Industry, I. a. S. (2016, December). "Australia's Major Export Commodities- Aluminium, Alumina and Bauxite.*

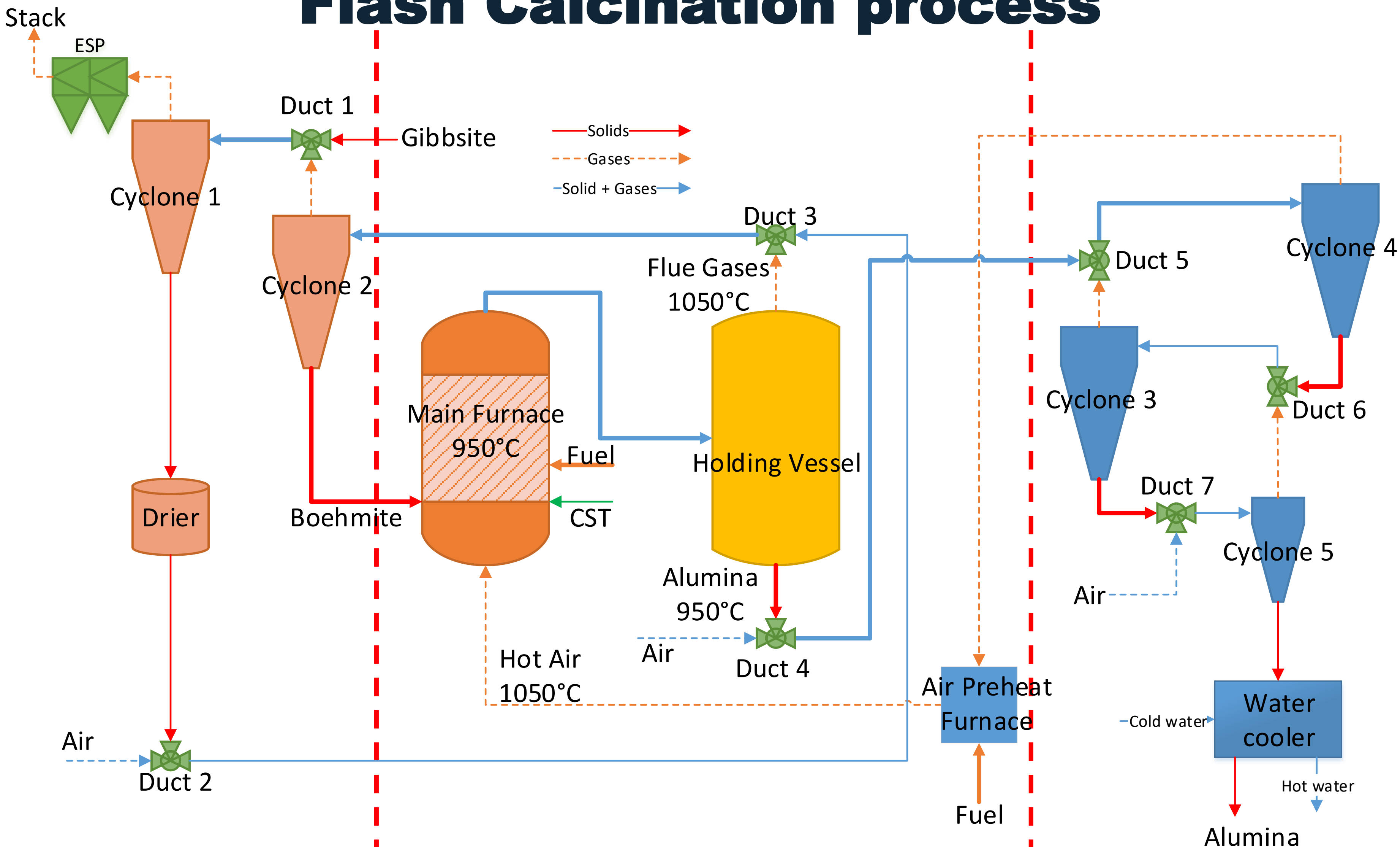
Aim

- To investigate integration of CST energy in to flash calcination process by directly irradiated hybrid particle receiver.

Objectives

- Develop a hybrid flash calcination process, where main furnace is replaced with a hybrid particle receiver.
- Assess performance of the hybrid flash calcination process.

Flash Calcination process

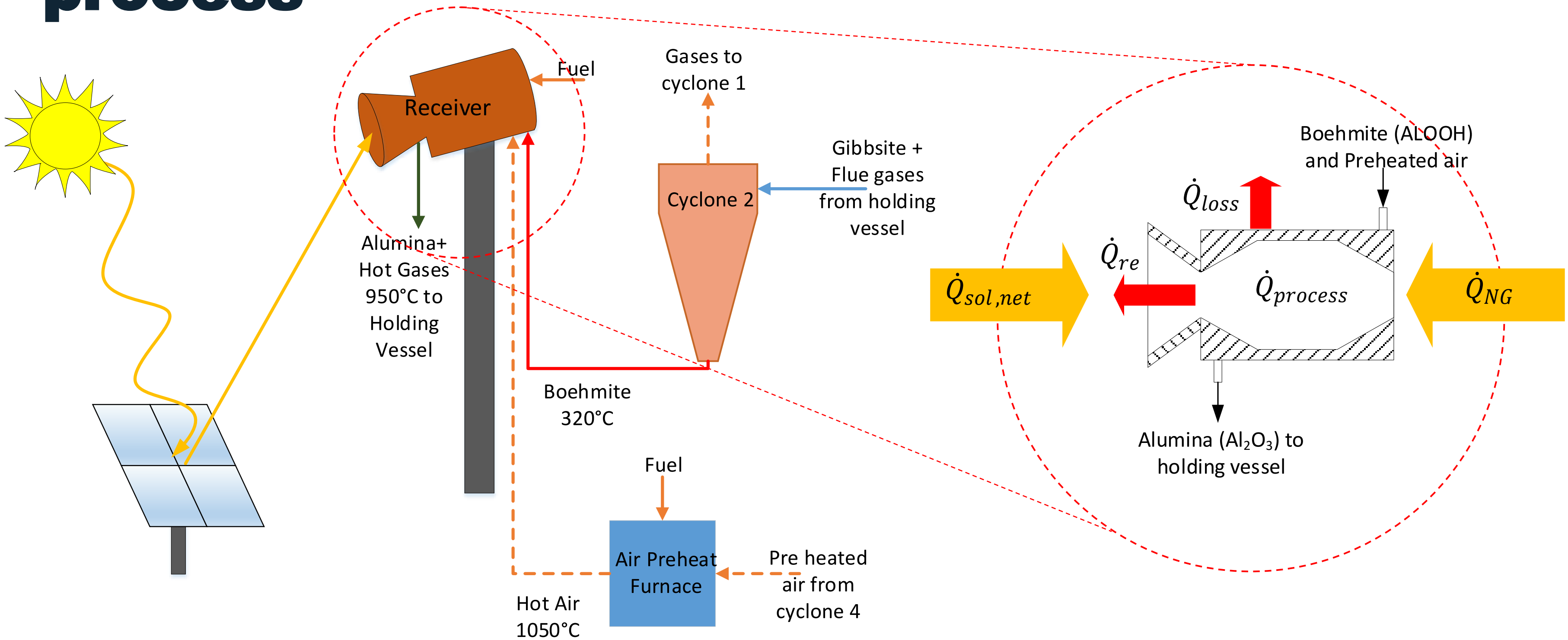


Pre-Calcination and preheating of incoming particles with Flue gases

Boehmite to Alumina calcination with direct natural gas combustion

Air preheating by exiting hot alumina particles

Incorporating CST energy to flash Calcination process



Total energy balance on hybrid flash calcination process

$$\dot{Q}_{Total} = (\dot{Q}_{NG,MF} + \dot{Q}_{NG,AP} + \dot{Q}_{sol,net}) - \dot{Q}_{process} - \dot{Q}_{re} - \dot{Q}_{loss}$$

Solar energy generated

$$\dot{Q}_{sol} = \eta_{opt} A_{coll} I$$

Optical efficiency

$$\eta_{opt} = \eta_{cos} \cdot \eta_{sb} \cdot \eta_{itc} \cdot \eta_{ref} \cdot \eta_{aa} \cdot \eta_{cpc}$$

Re-radiation loss

$$\dot{Q}_{re} = \frac{\sigma T_{rec}^4}{\tilde{C}}$$

Process Modelling

- Production rate 120 tonnes of alumina per hour.
- Hybrid particle receiver temperature is set at constant 950°C.
- Design DNI is set at 950 W/m² and minimum operation DNI set at 170 W/m².
- Hourly DNI data specific for the location for a year was used to calculate the amount of solar energy that would be available for the process.
- CST storage is not possible as in this configuration as solar irradiation cannot be stored.
- Re-radiation losses are assumed as constant as temperature of receiver is maintained constant

$$\text{Solar Multiple} = \frac{\dot{Q}_{\text{Sol},net}}{\dot{Q}_{sol,net\ process}}$$

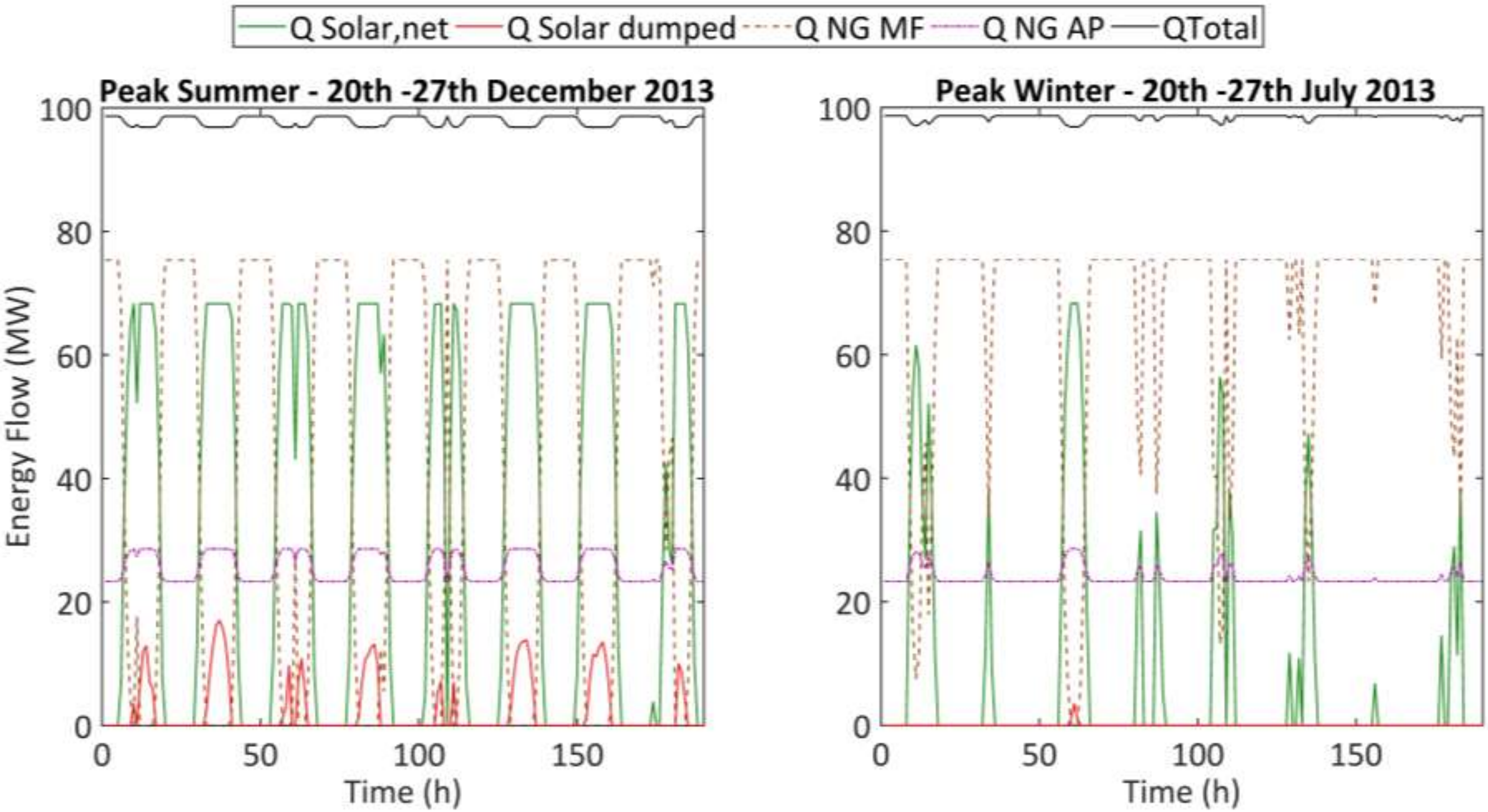
$$\text{Solar share(annual)} = \frac{Q_{sol,process}}{Q_{Total}}$$

$$\text{Heliostat field utilization (annual)} = \frac{Q_{sol,net}}{Q_{sol}}$$

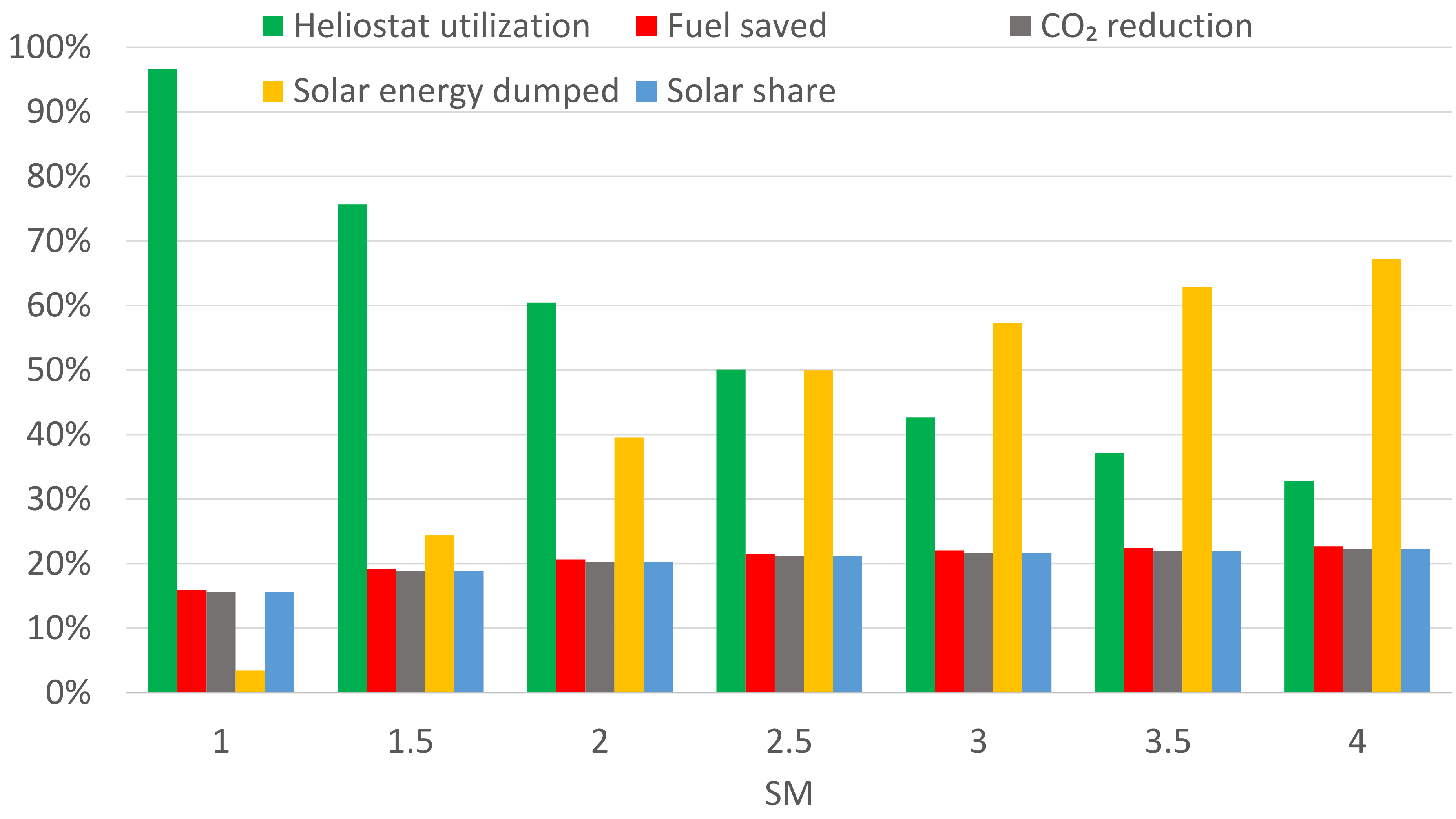
Results – Process Modelling Hybrid Calcination Process

	Conventional Flash Calcination Process	100% Solar with no extra air	100% Solar with extra air
Cyclone 2 Temperature (°C)	327	275	325
Enthalpy of Flue gases from holding vessel (MW)	69	62	69
Q Main furnace (MW) Natural Gas	75	0	0
Q Main furnace (MW) Solar,net	0	71	68
Q Air Preheater (MW) Natural Gas	23	23	29
Total (MW)	99	94	97
Energy per tonne Alumina (GJ/Tonne)	2.9	2.8	2.9

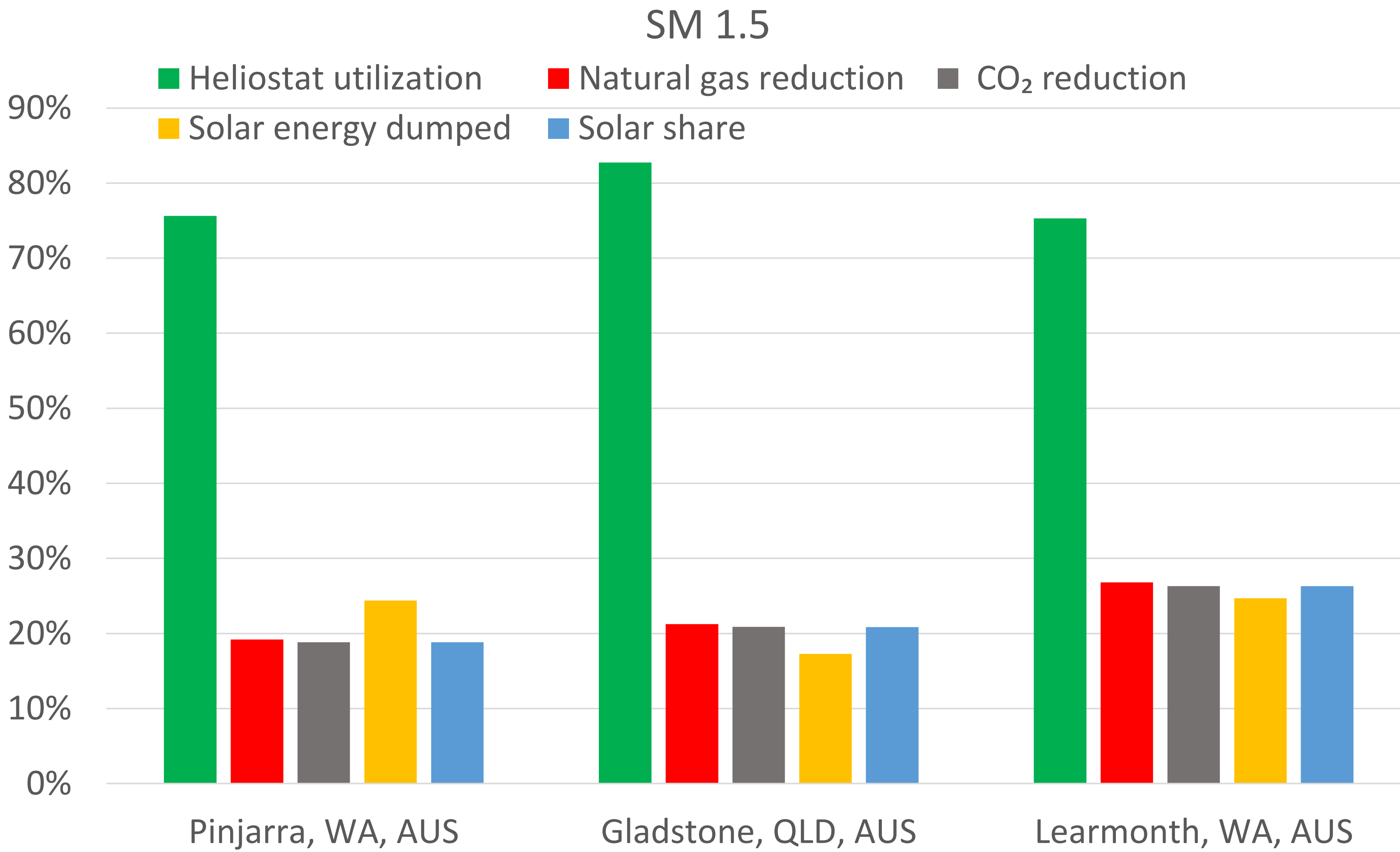
Results – Simulations of energy flows in to hybrid calcination process with CST energy during peak winter and summer with SM 1 at Pinjarra



Results – Annual Performance of Hybrid Calcination process at Pinjarra



Results – Performance comparison of hybrid calcination process at different locations



Conclusion

- The proposed solar hybrid calcination process can potentially reduce annual CO_2 emissions from 160kg CO_2/ t of to 130kg CO_2/ t of alumina produced.
- The annual natural gas consumption can potentially reduce by at least 20% with a solar multiple of 1.5 at the 3 Australian sites.
- Replacing natural gas with CST in main furnace results in a reduction in flue gases being generated, which could potentially affect the pre-calcination and preheating of particles before entering the main furnace.

Future work

- Experimental work is being carried out, to better understand the reaction kinetics and alumina product quality with lower temperature conditions to develop a lower temperature calcination process.

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