
STERG
SOLAR THERMAL ENERGY
RESEARCH GROUP

# Rock bed thermal storage: Concepts and costs

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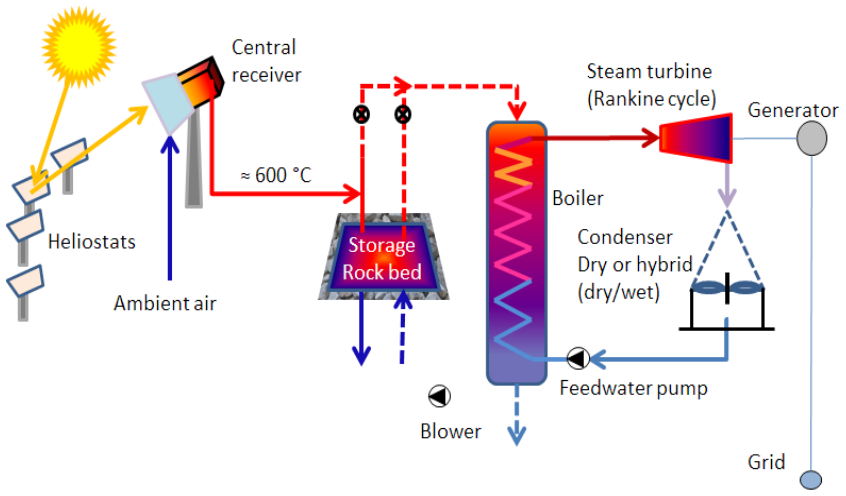
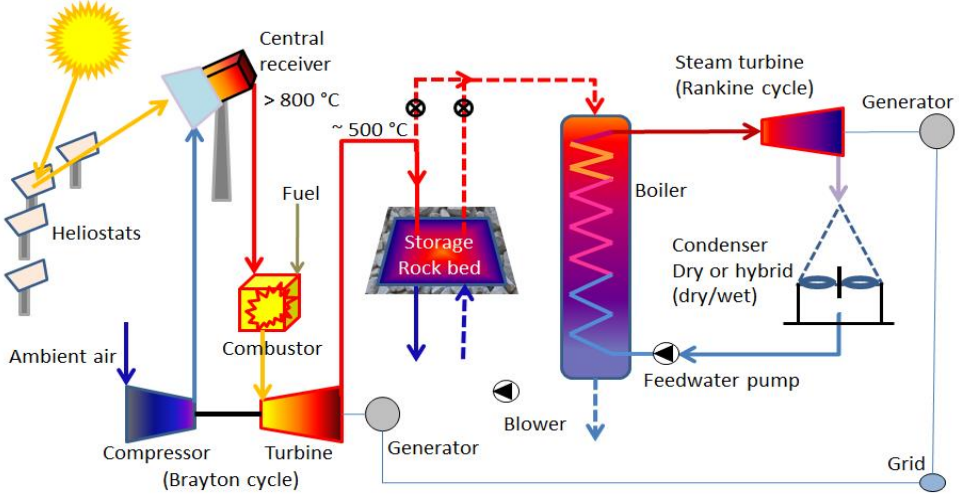
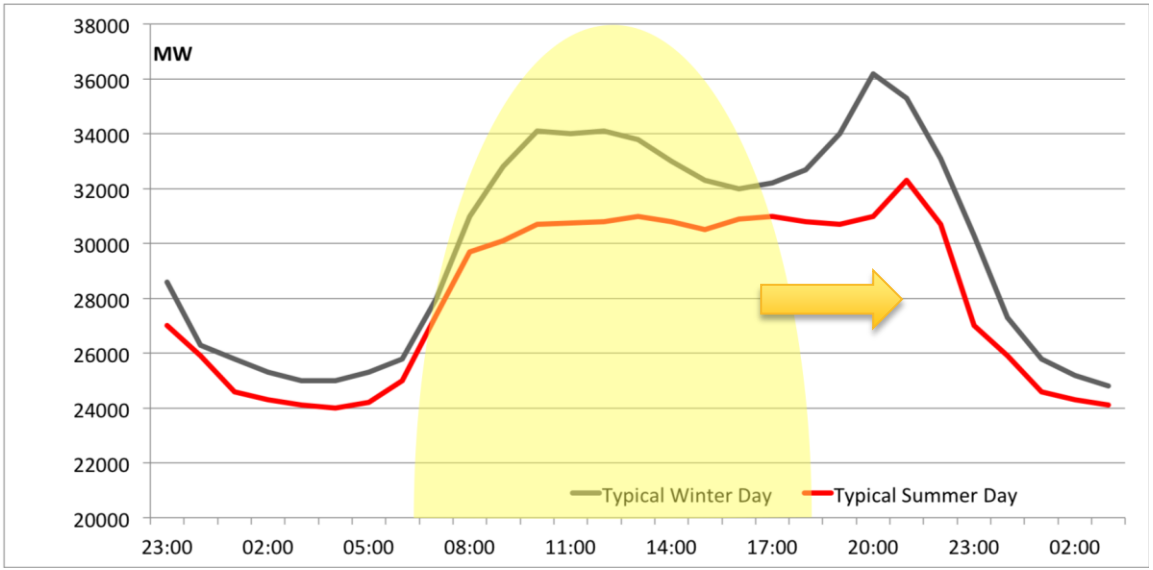


# Why use CSP plants?

CSP is currently more expensive than wind or PV, so why use it?

- The availability of renewables does not necessarily meet the electricity demand
- Because CSP is based on thermal energy, thermal storage is “easy” to implement




Slide: F. Dinter

Gemasolar (Spain) - Wikipedia

# Current commercial thermal storage

## Molten nitrate salt


Solar Two - NREL


Solana

**22-30 $/kWh$_{th}$ (Kolb et al., 2011)**

# Thermal storage: keeping costs low

## Aims in CSP: higher efficiency

| Cost breakdown of LCOE (*All* costs) | | |
|---|---|---|
| **Heliostat cost** | 22.1 | % |
| **Indirect costs** | 20.8 | % |
| **Operations and maintenance** | 12.1 | % |
| **Power plant cost** | 12.1 | % |
| **Receiver cost** | 10.1 | % |
| **Tax** | 8.1 | % |
| **Storage cost** | 7.4 | % |
| **Balance of plant cost** | 4.0 | % |
| **Site cost** | 2.0 | % |
| **Tower cost** | 1.3 | % |

DOE: CSP ≈ 15 $ cents/kWh
REIPPP SA round 3: ≈ 1.6 R/kWh

40% of the costs are indirect costs and are site specific

Heliostats relate to 38% of the total hardware cost

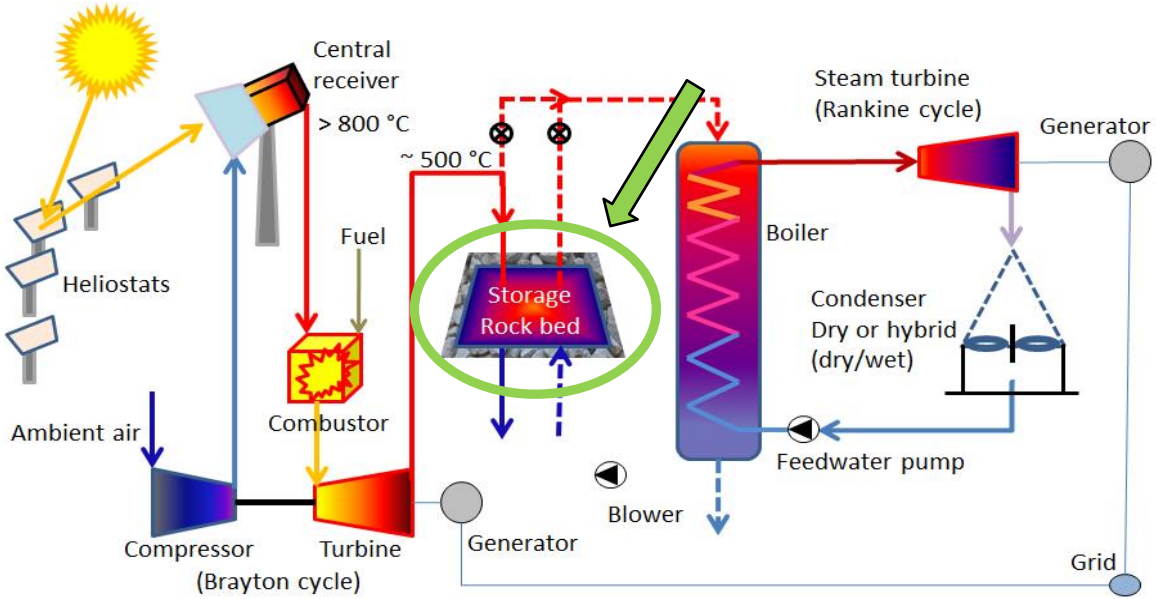
Higher temperatures – higher power block efficiency

Slide from J. Kotzé

# CSP & packed beds

## One example – a combined cycle

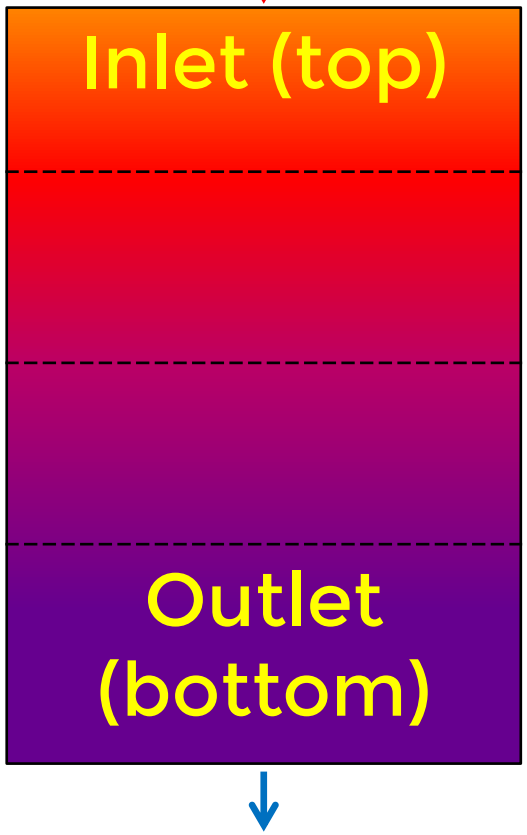
- Store thermal energy from gas turbine exhaust
- Storage temperature: ≈ 500 – 600 °C




SUNSPOT combined cycle schematic

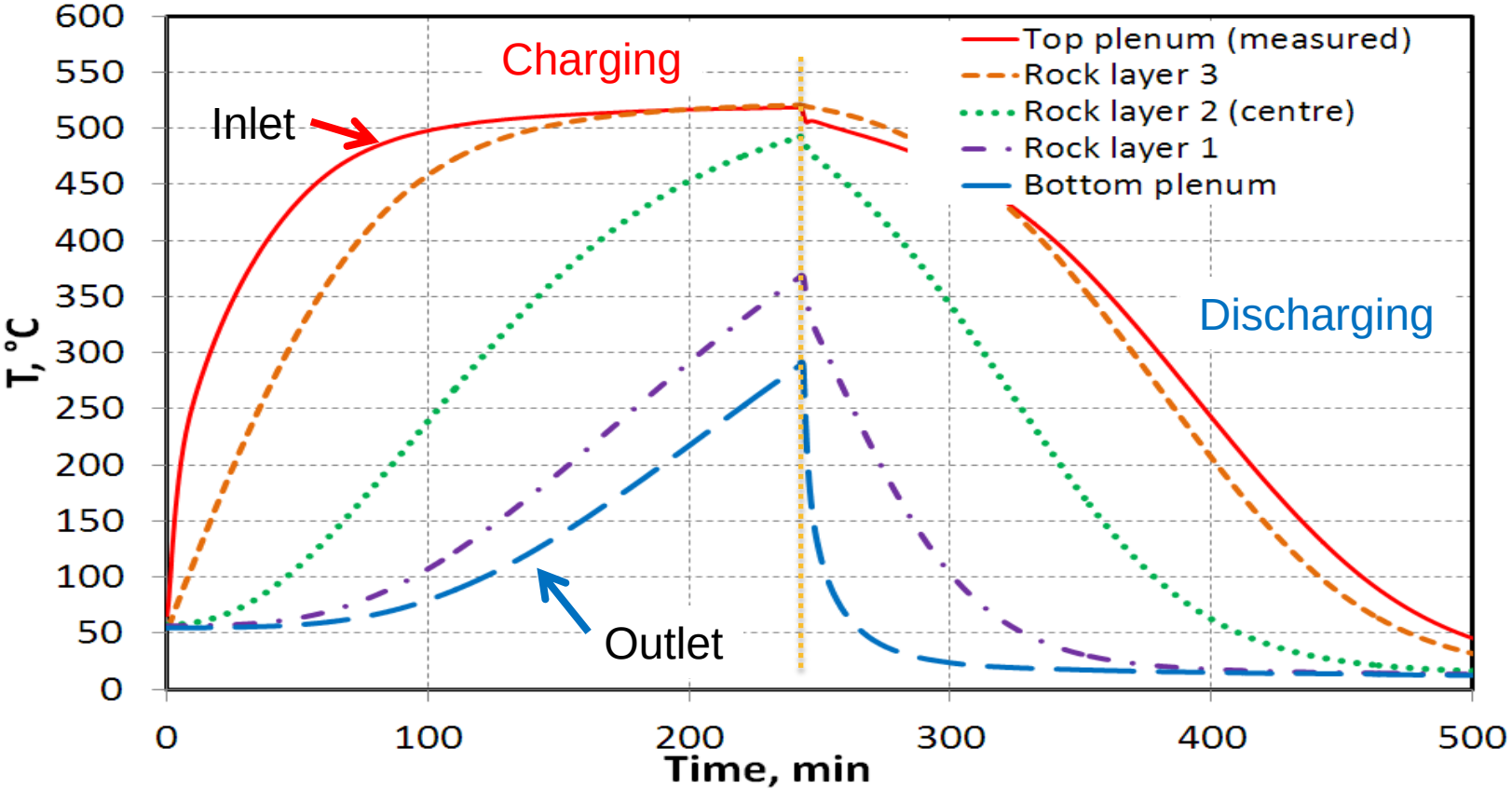
# Packed beds

## Our experimental system



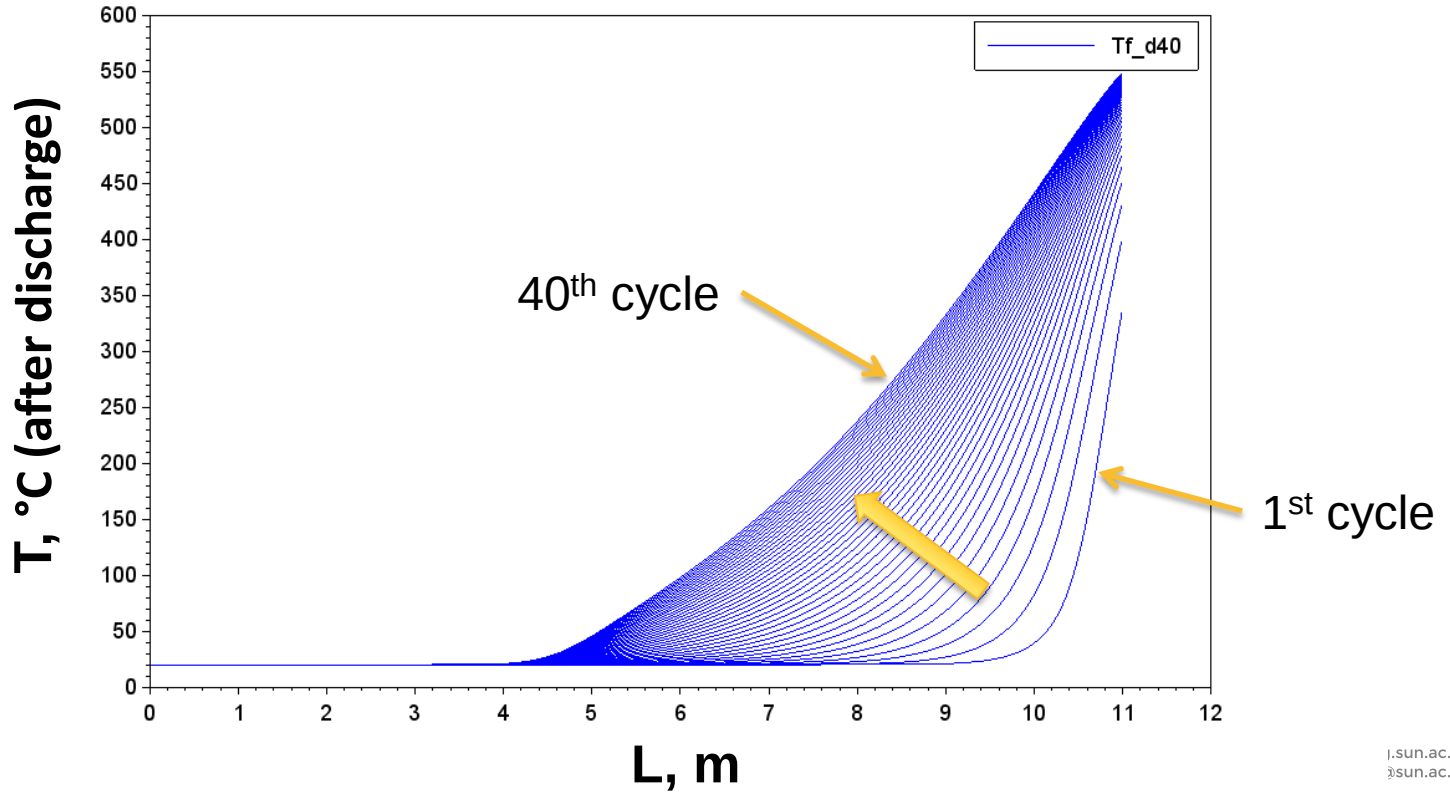

# Packed beds

## Sample temperature profile – charge-discharge



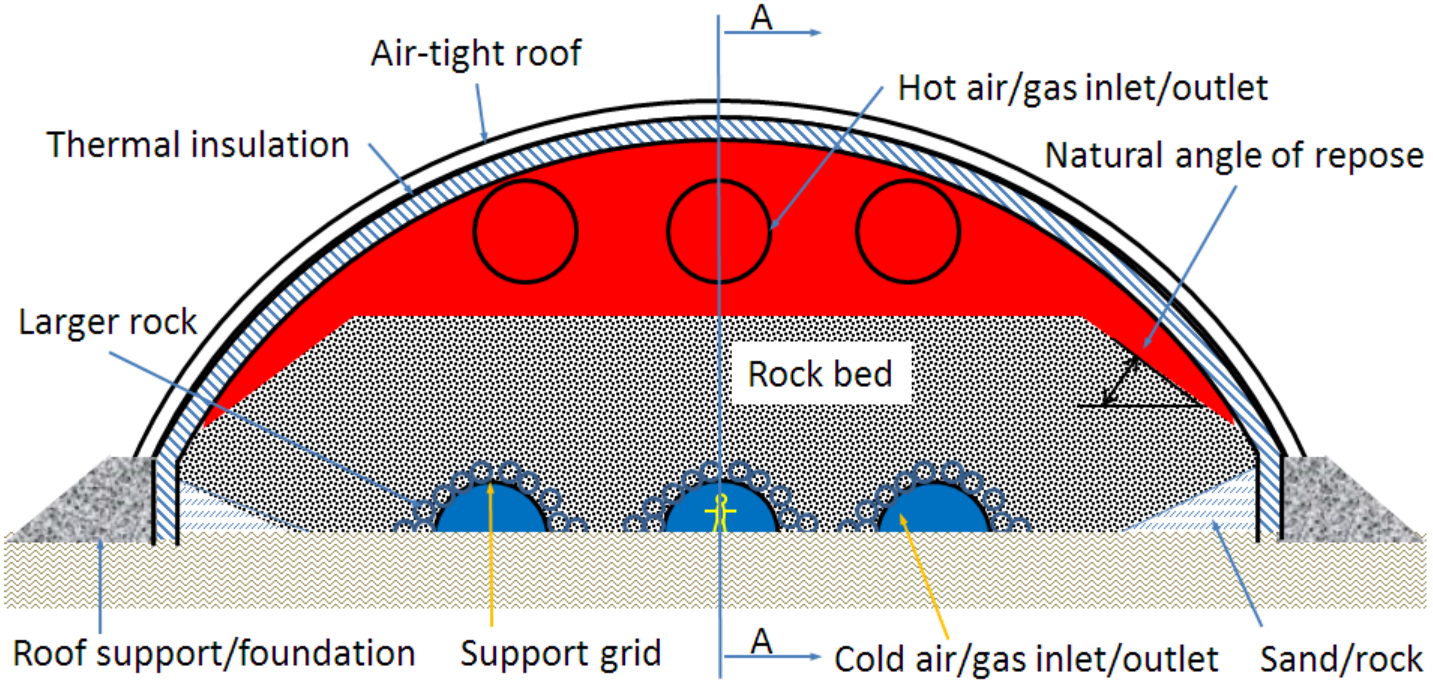
# Packed bed temperature profile

## The steady cyclic state



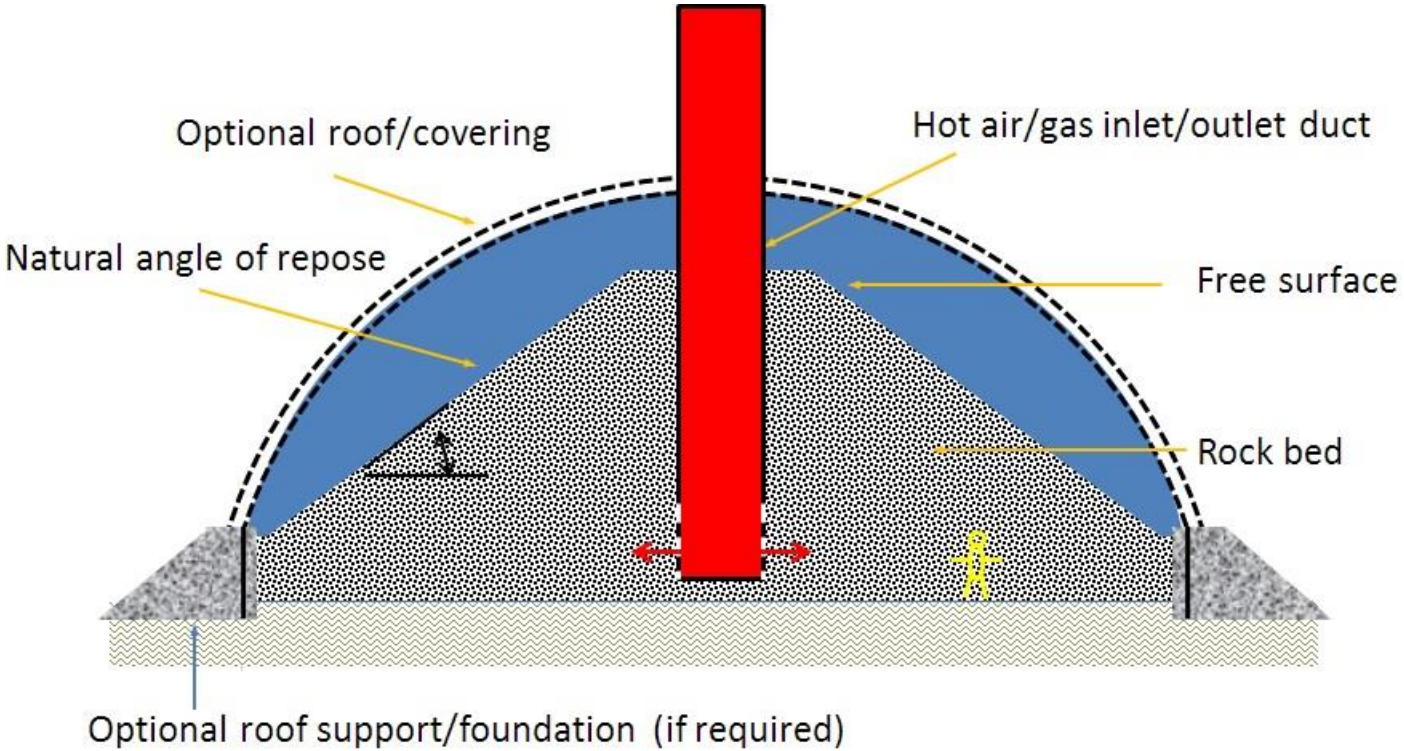
# Packed bed concept I

## Patent of Kröger (2013)



# Packed bed concept II

## Patent of Gauché (2014)



# Design variables – 16 hr storage

## Parameters of a 10 $MW_{th}$, 160 $MWh_{th}$ rock bed (16 hrs storage)

| Parameter | Value | Parameter | Value |
|---|---|---|---|
| $c_p$ (55 °C) | 815 J/kgK | $T_c$ | 600 °C |
| $D_v$ | 0.025 m | $T_d$ | 20 °C |
| $G_c$ | 0.2 kg/m$^2$s | $t_c$ | 8 hrs |
| $G_d$ | 0.1 kg/m$^2$s | $t_d$ | 16 hrs |
| $L$ | 11 m | $\varepsilon$ | 0.45 |
| $m_r$ | 14 000 tonnes | $\rho_p$ | 2700 kg/m$^3$ |

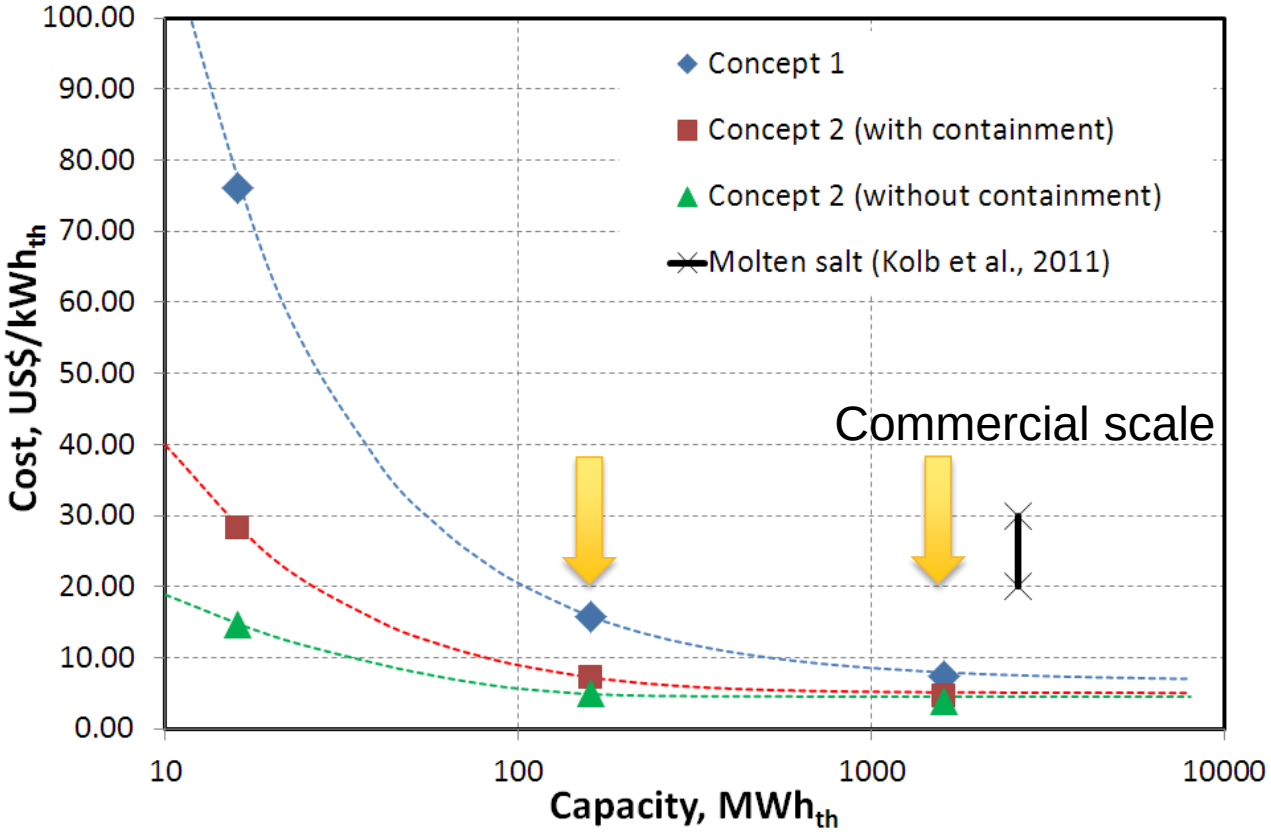
Estimated footprint: ≈ 1400 m$^2$

# Cost estimates for Concepts 1 & 2

## Costs for a 10 $MW_{th}$, 160 $MWh_{th}$ rock bed

| Component | Concept 1, $/kWh$_{th}$ | Concept 2 incl. containment $/kWh$_{th}$ | Concept 2 excl. containment $/kWh$_{th}$ |
|---|---|---|---|
| Containment | 1.7 | 1.7 | 0 |
| Insulation | **9.9** | 0 | 0 |
| Rock | 1.6 | 1.6 | 1.6 |
| Ducting | 1.1 | 1.1 | 1.1 |
| Blower & instrumentation | 1.4 | 1.4 | 1.4 |
| **Total cost (incl. labour)** | **15.9** | **7.3** | **4.9** |

# Cost variation with scaling



# Conclusion

- Thermal storage for peak and baseload
- Packed beds: a low-cost alternative to molten salt
  - ➢ About 5-15 $/kWh$_{th}$
- Next step:
  - ➢ 16 MWh$_{th}$, 1 MW$_{th}$
  - ➢ Funding ≈ R 15 million

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# In closing …


## ACKNOWLEDGEMENTS:

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CRSES


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