Energy Storage Challenges

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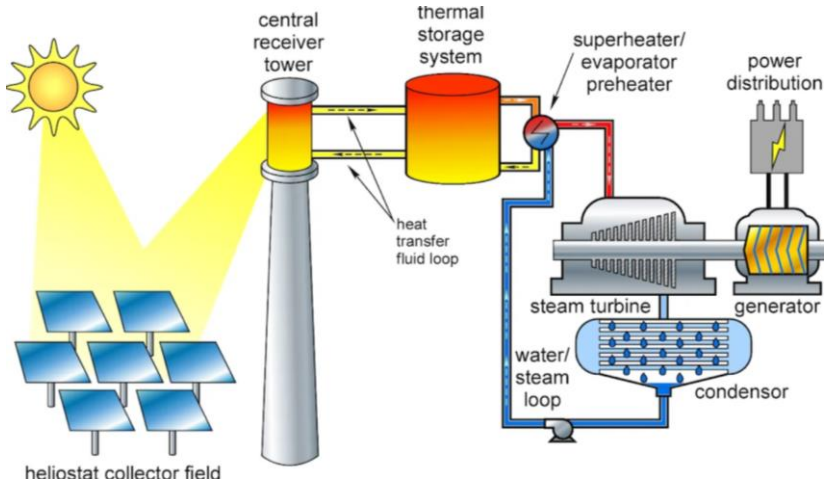
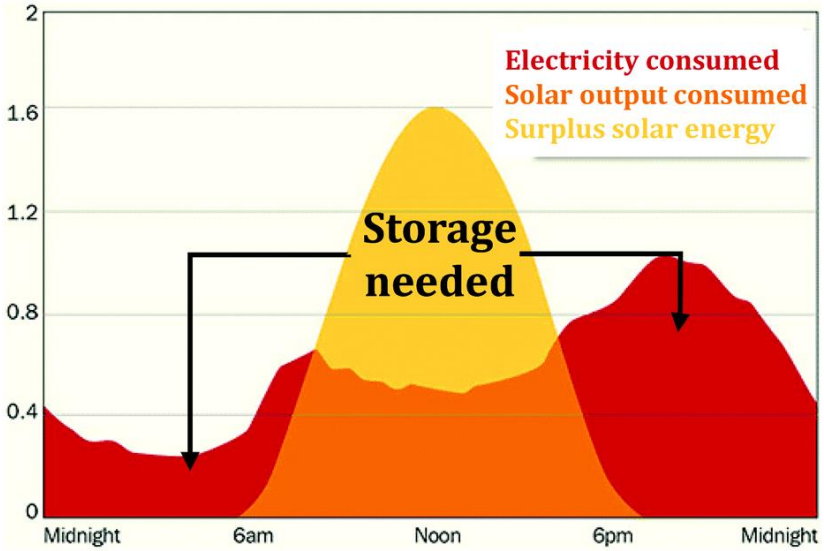
The importance of Energy Storage for RES penetration

- ❑ Most RES are intermittent while energy demand is 24/7
- ❑ Storage is the only solution to achieve 24/7 power production from RES
- ❑ **Concentrated Solar Power** → cost-effective in terms of storage integration





i) sensible
ii) latent
iii) thermochemical

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SET Plan Initiative for Global Leadership in CSP / 2017 - Priorities

Integrated Roadmap Action Advanced Research Programme	Potential contribution to strategic target 1	Potential contribution to strategic target 2
Action 1: More efficient components – HTF, receivers, reflecting surfaces	**5**	**4**
Action 2: Reliability of CSP plants	3	3
Action 3: Hybridization of CSP plants	**4**	**4**
Action 4: Storage systems	**5**	**5**
Action 5: Water consumption	1	1
Action 6: Weather forecasting	3	3

Integrated Roadmap Action Industrial Research and Demonstration Programme	Potential contribution to strategic target 1	Potential contribution to strategic target 2
Action 1: More efficient components – HTF, receivers, reflecting surfaces	**5**	**4**
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Action 3: Hybridization of CSP plants	**4**	**5**
Action 4: Storage systems	**5**	**5**
Action 5: Water consumption	1	1

- Storage → highest potential contribution among all actions related to CSP

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Possibilities of storage technologies in CSP

Commercial

Sensible heat storage

Solar salt
- ✓ *~0.7 GJ/m³*
- ✓ *~0.5 $/kg*
- ✓ *280-560ºC*

Ceramic materials
- ✓ *0.4-1 GJ/m³ (indicative)*
- ✓ *< 0.5 $/kg*
- ✓ *200-1000ºC*

R&D

Latent heat
- ✓ *> 1GJ/m³*
- ✓ *500-800ºC*

Thermochemical
- ✓ *Up to 10 GJ/m³*
- ✓ *500-1200ºC*

Challenging implementation
- ✓ *Phase changes, cyclic degradation, fragmentation of R&D activities*
- ✓ *Integration of a (chemical) plant into a CSP one*

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Examples of CSP plants with sensible heat storage

19.9 MW Gemasolar Plant, Seville, Spain

- ✓ Molten Salt storage @ **15 h**
- ✓ **24 h/day for 36 consecutive days**
- ✓ On since 2011 & has exceeded expectations

110 MW Cero Dominador, Atacama, Chile

- ✓ Molten Salt storage @ **17.5 h**
- ✓ Connected to the grid in April 2021

Storage provides high added value to solar thermal electricity

!!!It is not about the cost/LCOE but about the value of kWh!!!

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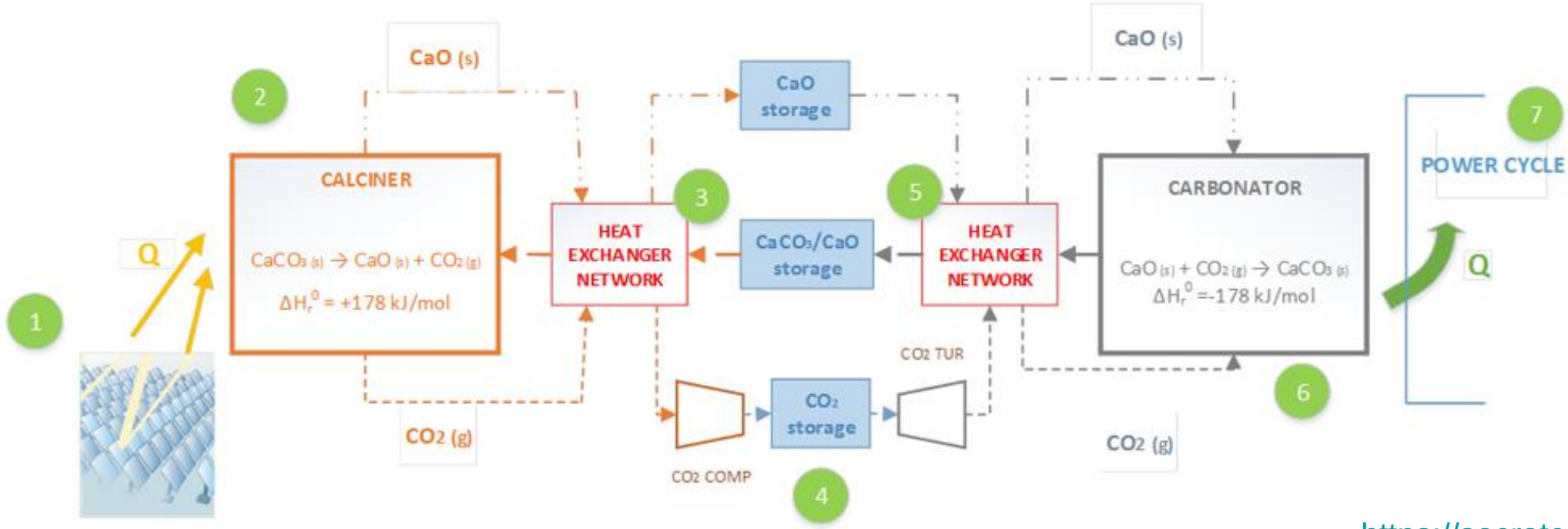
Examples of thermochemical energy storage - SOCRATCES



https://socratces.eu

$$CaO_{(s)} + CO_{2(g)} \leftrightarrow CaCO_{3(s)}; \quad \Delta H^{o}_{r} = \pm 178\ kJ/mol$$

- ✓ *~2 GJ/m³*
- ✓ *Storage cost < 12 €/kWh (project's target)*

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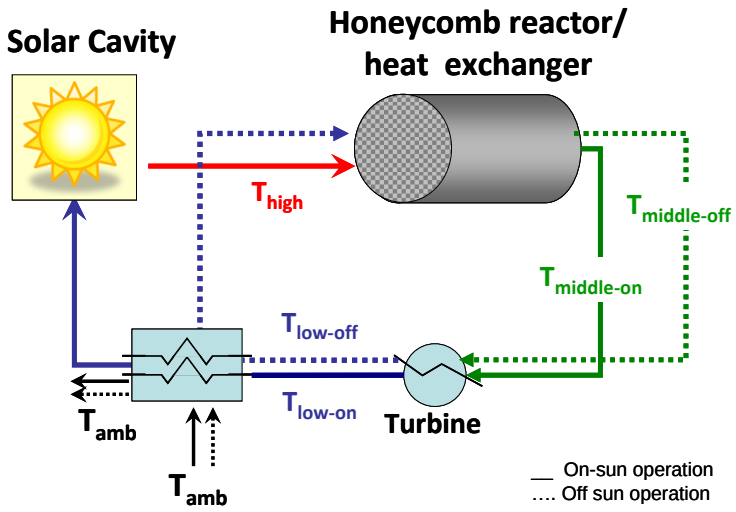
Examples of thermochemical energy storage - REDOX

$$MO_{x(s)} \leftrightarrow MO_{x-1(s)} + 0.5 \cdot O_2$$

- ✓ *Co_3O_4/CoO, $Mn_{2-x}Fe_xO_3/Mn_{3-x}Fe_xO_4$, $CaMnO_3/CaMnO_{3-\delta}$*
- ✓ *Up to ~1.5 GJ/m³*



Tescari *et al*, 2017, Applied Energy, 189, 66-75

Pilot system tested successfully @ Solar Tower Juelich

~ 0.75 GJ/m³

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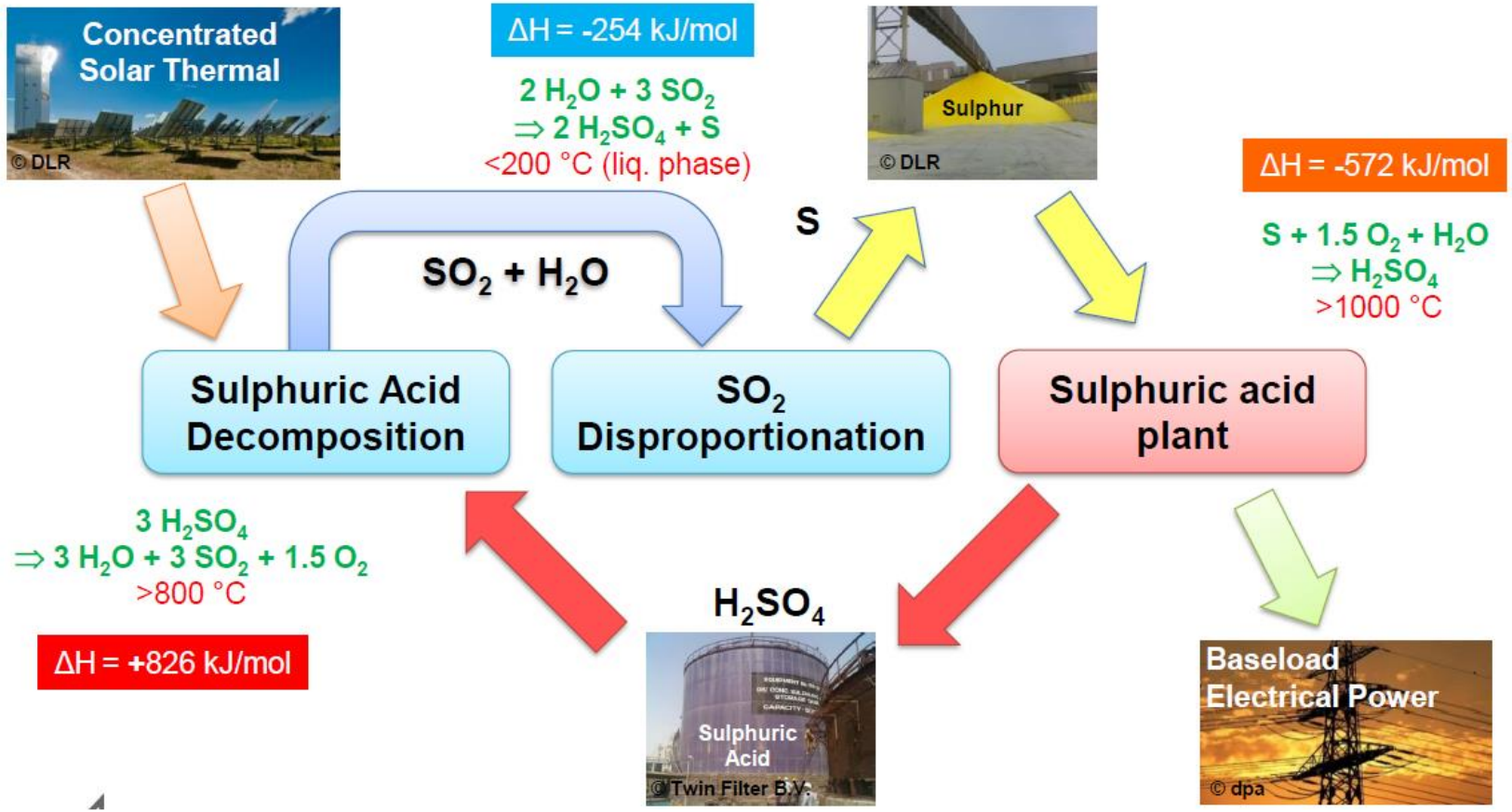
Example of thermochemical energy storage - SULFUR



- Up to ~10 GJ/m^3
- Potential for **synergies with the sulfuric acid industry**
- Sulfur: An emerging solar energy carrier

EU-funded project PEGASUS
https://www.pegasus-project.eu/

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Thoughts for discussion

- Advancement of thermal storage is vital to CSP/CST → the value of kWh
- Limitations imposed by solar salt (T < 600ºC) hold back next generation high temperature CSP plants
- New emerging concepts:
  - Particle receivers → 1000ºC or higher
  - Coupling with combined cycles: Air-Brayton or sCO_2 cycles → higher efficiency
  - Thermochemistry as the next generation of storage
  - …
- A clear roadmap for storage technologies in CSP/CST is needed

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Thank you for your attention !!!

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