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Trough Thermal Storage
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Trough Thermal Storage - Content

1. Storage incentive – Why storage

2. Trough thermal storage technology
   - how does it look for a commercial plant designer –

   a. 2 Tank Molten salt storage

   b. PCM (Phase Change Material) storage

   c. Cement storage

   d. Thermocline

3. Final judgment

Thermal Storage Incentive (1)

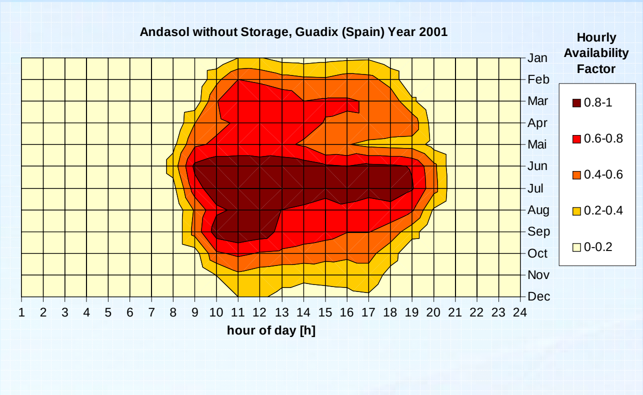
1. Solar at daylight, electricity demand also at dark night – Increasing the capacity factor of the plant

2. Shifting electricity production to peak demand

3. Fulfil firm capacity and dispatchability requirements

Thermal Storage Incentive (2)

On planet earth surface, solar energy is on daylight with changing intensity, but the demand has a different distribution over the time; hence an energy storage is required for shifting energy



- Electrical storage is not implementable due to cost reasons
- Thermal storages technologies are available which increase power plant utilization
- Economical justification:
  - For a flat rate energy payment tariff and no capacity limit there is no economical justification
  - Adding enough storage to a plant with maximum capacity will reduce the generation cost as long as the storage is cheaper than a second power island

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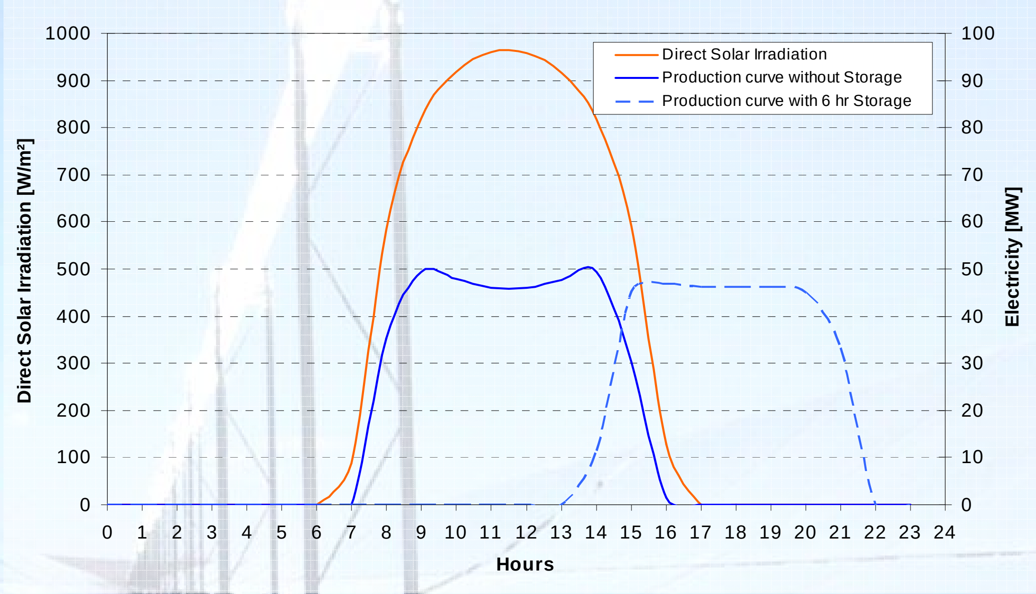
Thermal Storage Incentive (3)

Shifting energy to peak demand necessitate a mean of storage



- Electrical storage is not implementable due to cost reasons
- Thermal storages technologies are available which can shift the electricity production to the desired demand
- Economical justification:
  - The higher electricity rates for the practical shift of energy should compensate for the additional storage costs

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Thermal Storage Incentive (4)

Dispatchability upgrades solar energy to the utility desired power supply, necessitate a source of thermal energy storage

- Thermal storages technologies are available which can delay and shift the electricity production in accordance with dispatcher instructions
- Economical justification:
  - Higher dispatchable electrical capacity value should compensate for the additional storage costs
  - In the extreme case of a fully dispatchable power plant, the plant utilization rate might be reduced, requiring higher compensation (for the energy waste due to “storage full” cases)
  - With a small amount of fossil backup full firm capacity can be achieved

Two Tank Molten salt storage

Molten salt storage proven at Solar Two

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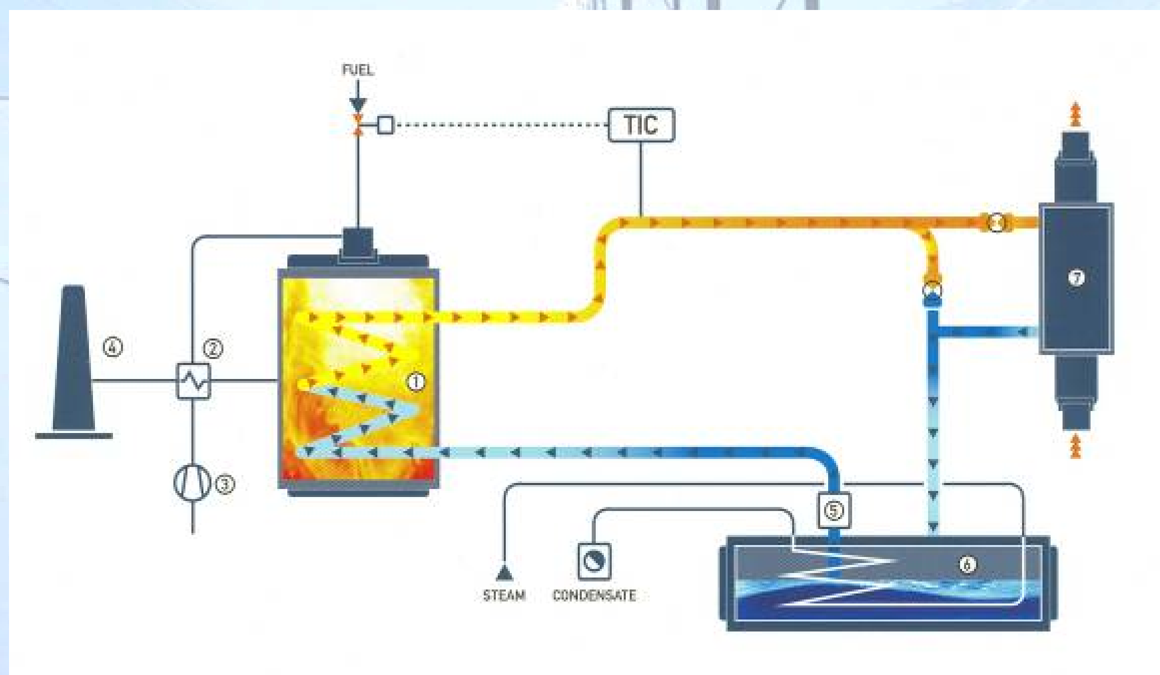
Widely used in Process Industry

a) Molten Salt system with an output of 14 MW at 430°C, England

b) Molten Salt system with an output of 88 MW at 400°C,Bauxite digestion plant in Germany

b) Molten Salt system with an output of 7.7 MW at 470°C,melamine plant in Germany

Heat Transfer plants. All photographs by Bertrams Heatec Ltd.



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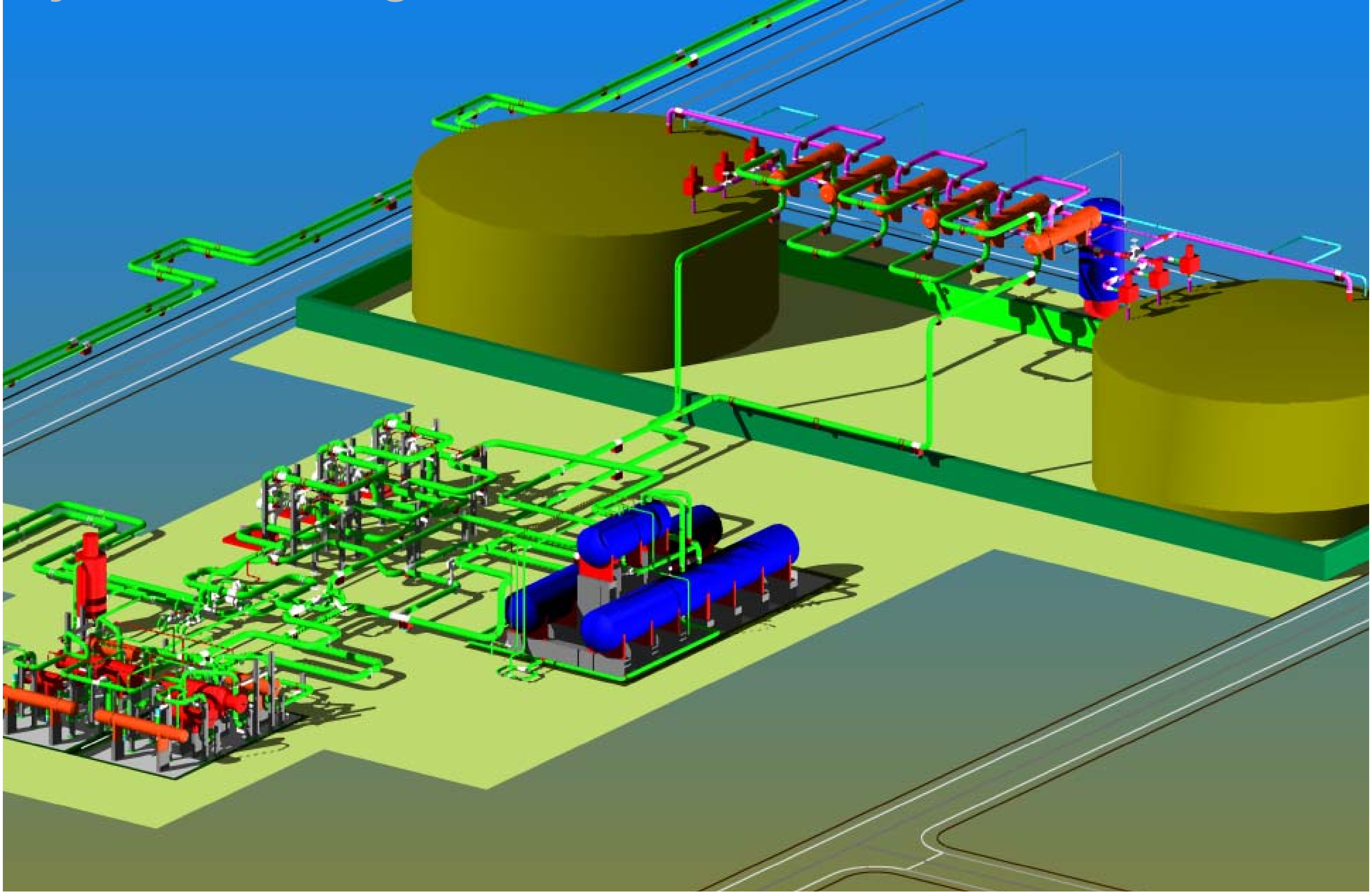
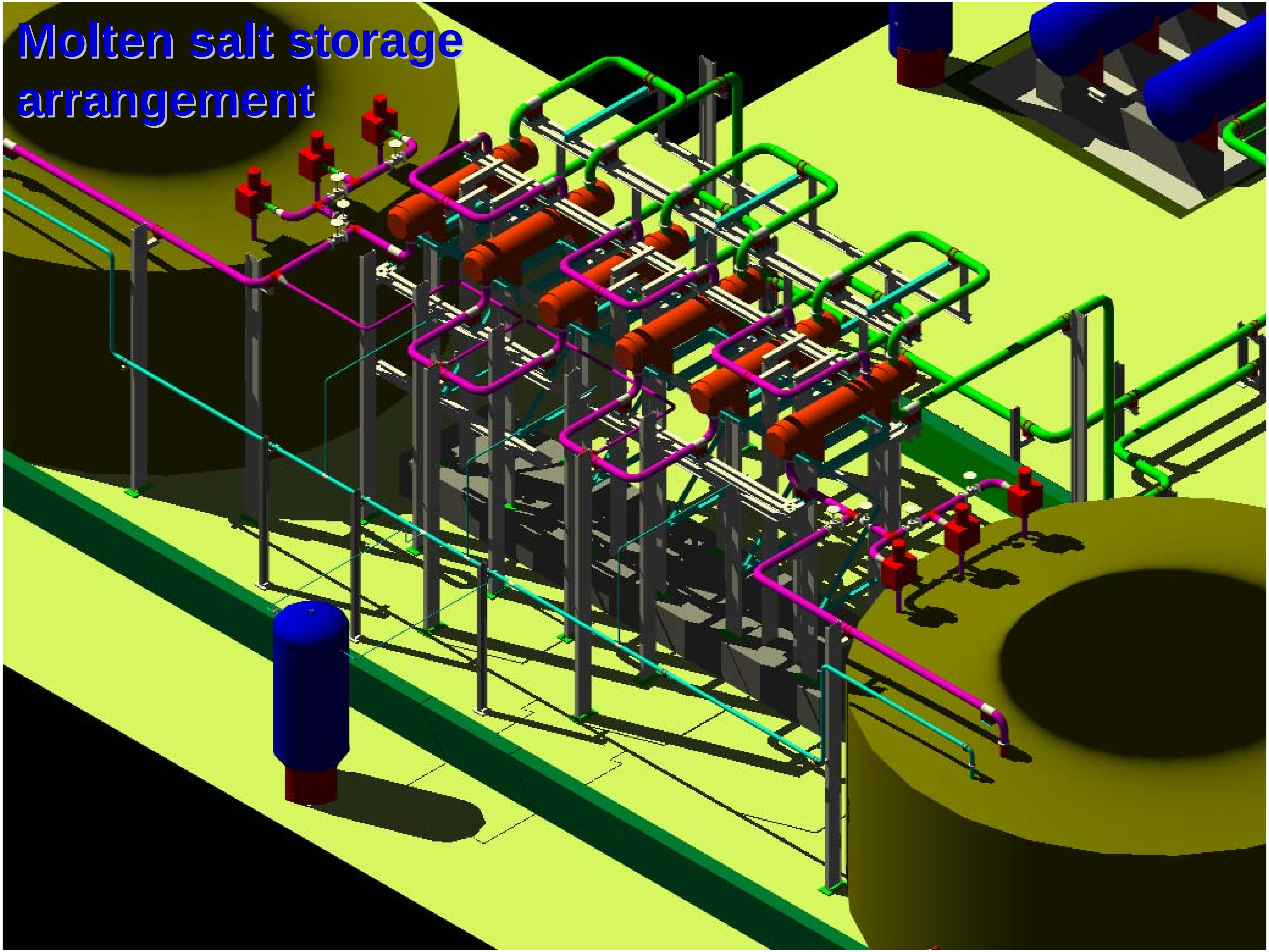
Andasol HTF and molten salt storage systems arrangement



Molten salt storage arrangement



Andasol storage - Technical parameter

- Type: 2-Tank Molten Salt Storage
- Storage Fluid: Nitrate salt mixture (60% $NaNO_3$ and 40% KNO_3)
- Melting Point of Fluid: 223°C
- Storage Capacity: 1,010 MWh (~7.5 hrs full load operation)
- Storage Tank Size: 14 m height, 37 m diameter
- Salt Mass: 27,500 tons
- Flow Rate: 953 kg/s
- Cold Tank Temperature: 292°C
- Hot Tank Temperature: 386°C

Andasol storage - construction

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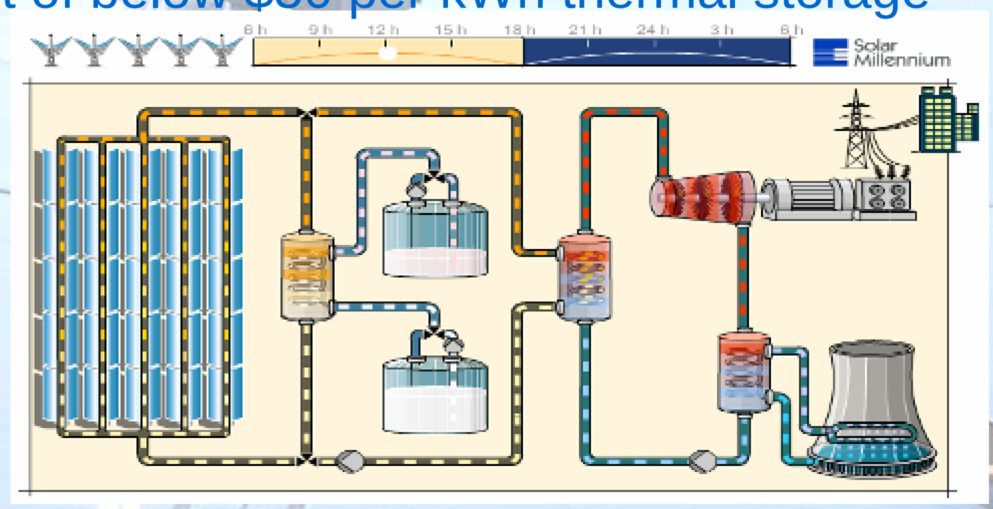
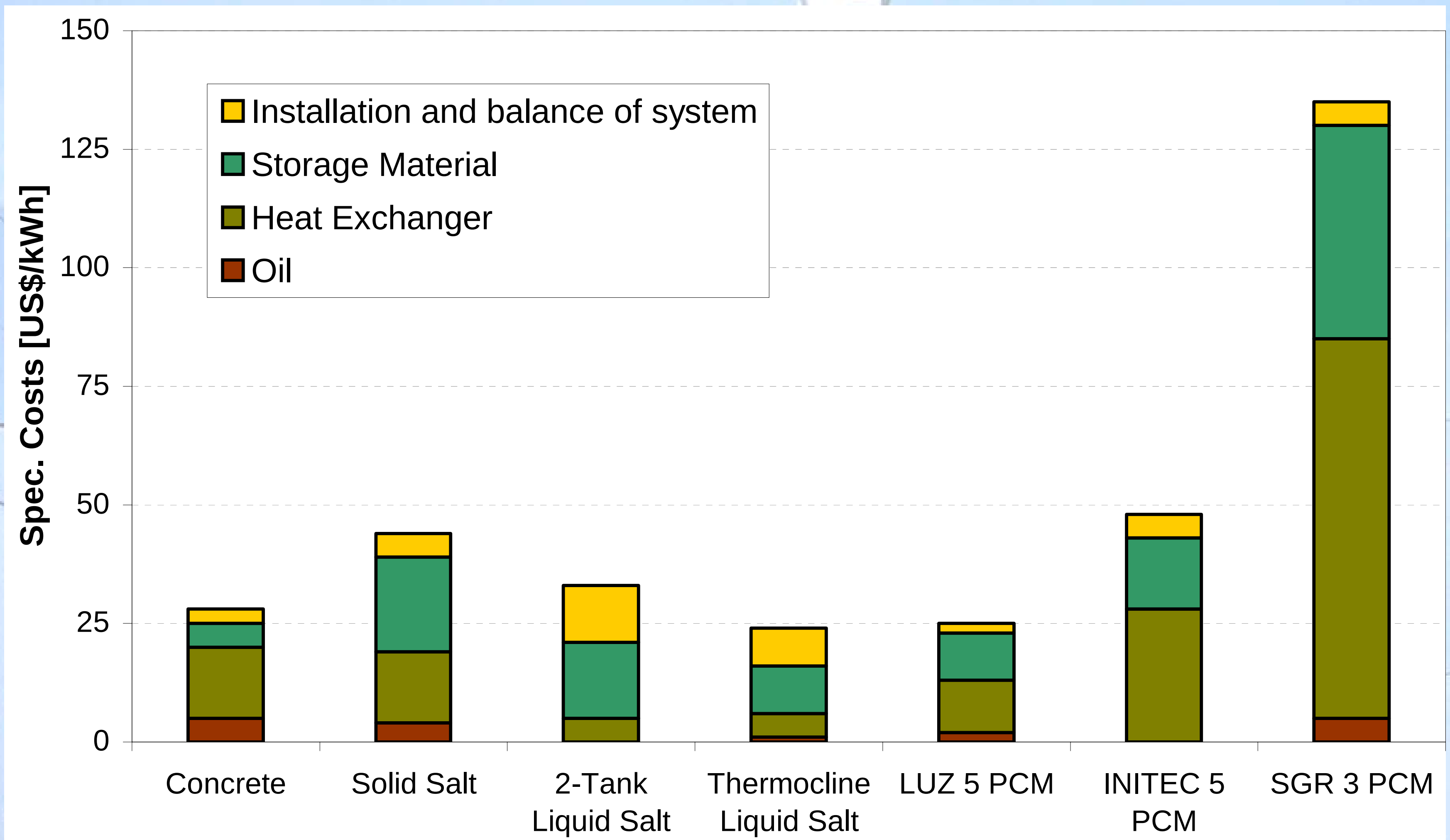
Andasol storage - Economical justification

Simplified indication of thermal storage required costs

- Andasol, Spain power plants design incorporate about 1,000,000 kWh thermal storage for the 50MW power block
- Conventional steam turbine power island costs are at about $1000 per kW
- The alternative to the thermal storage introduction would be about equivalent to the double of the power block
- Requiring an equivalent of below $50 per kWh thermal storage



Specific Cost of Storage Concepts



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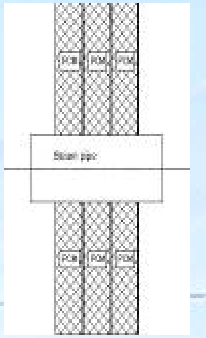
Phase Change Material storage

- **Originally attractive due to PCM high latent heat capacity**
- **Coat a tail wind from DSG (Direct Steam Generation) as DSG needs latent heat storage for evaporation**
- **$20/kWht target price**

- Re. cascading PCM´s for sensible heat HTF; better wait for one PCM results, current molten salt storage almost reached cascaded PCM potential price

PCM storage design; approach

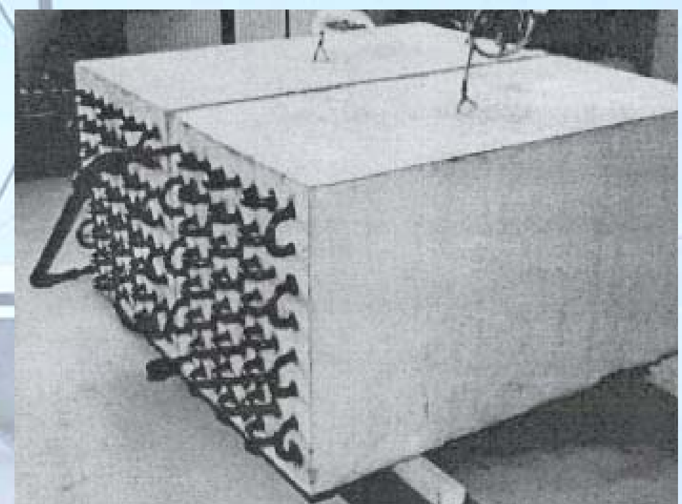
- **Composite (tested in laboratory)**
- **Encapsulation (tested in laboratory)**
- **Sandwich (Test in 2007)**
- **Inter-media (under investigation by Weizmann Institut Research)**



- The composite and encapsulated feasibility have been both proven in laboratory, the Sandwich test will assess its lower costs potential

Cement Storage

- **Attractive due to its low costs potential**
- **Could serve both for oil as well as for DSG sensible heat portions (pre and super heating's)**
- **~$25/kWht target price**
- **Tube register design found to be the best**
- **Heat transfer enhancement is important:**
  - **Material: concrete with quartz aggregates**
  - **Fins and other structure not cost effective**



- **Modular storage, SH and PH sections for example, enhance utilization and reduces size (costs)**
- **Full scale storage test ITES 2007-8 (1MW for a 5MWe plant)**

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Thermocline storage

- **Saving potential with storage filler**
- **~$20/kWht price potential**

- **Filler is essential**
- **No saving without filler (1 tank saving < +~1/4 nitrate salt dominant costs)**
- **Test filler material selection: quartzite and silica sand**
- **2.3 MWh successful proof of concept test**

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Final judgment

- Storage converts „as available energy" to much more valuable „dispatchable energy"
  ➔ *Storage will be required in the future*
- Molten Salt: most promising, O&M will assess its costs and potential reduction
- Cement: Simple and therefore straight-forward to evaluate but not proven up to now
- Thermocline: Clear potential with filler, needs full scale test
- PCM: potentially available for DSG (costs unclear), doubtful for sensible HTF