Integrated Thermal Storage for Concentrating Solar Power

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Content

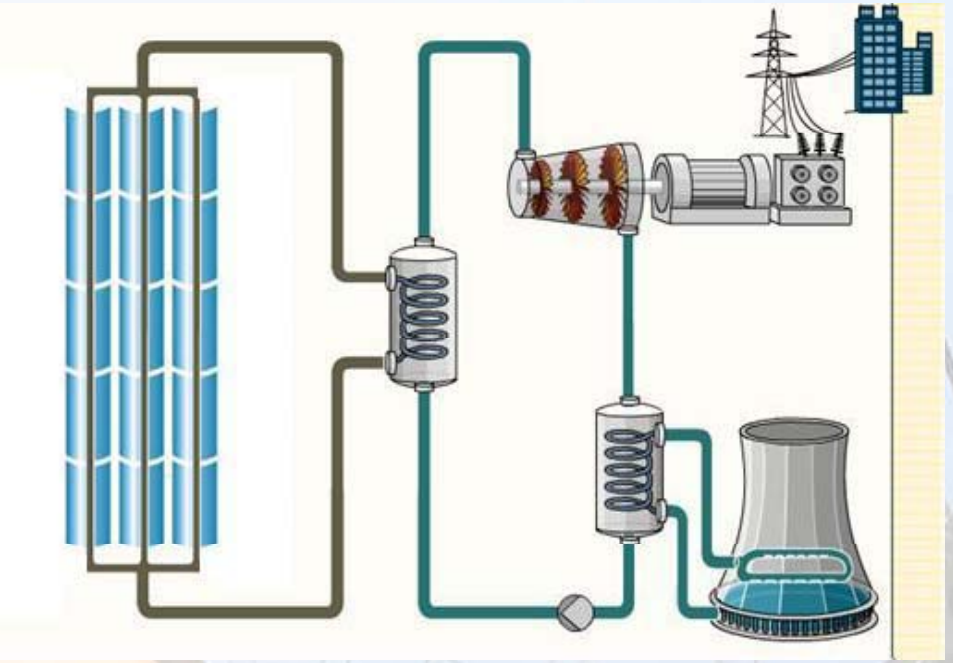
How does the storage work with solar power?

Molten Salt and Other Storage Media

What are the benefits?

Summary

Solar Power Plant without Storage



- Electricity Production is directly dependent on the available solar radiation
- Fluctuations in radiation will directly influence electrical output

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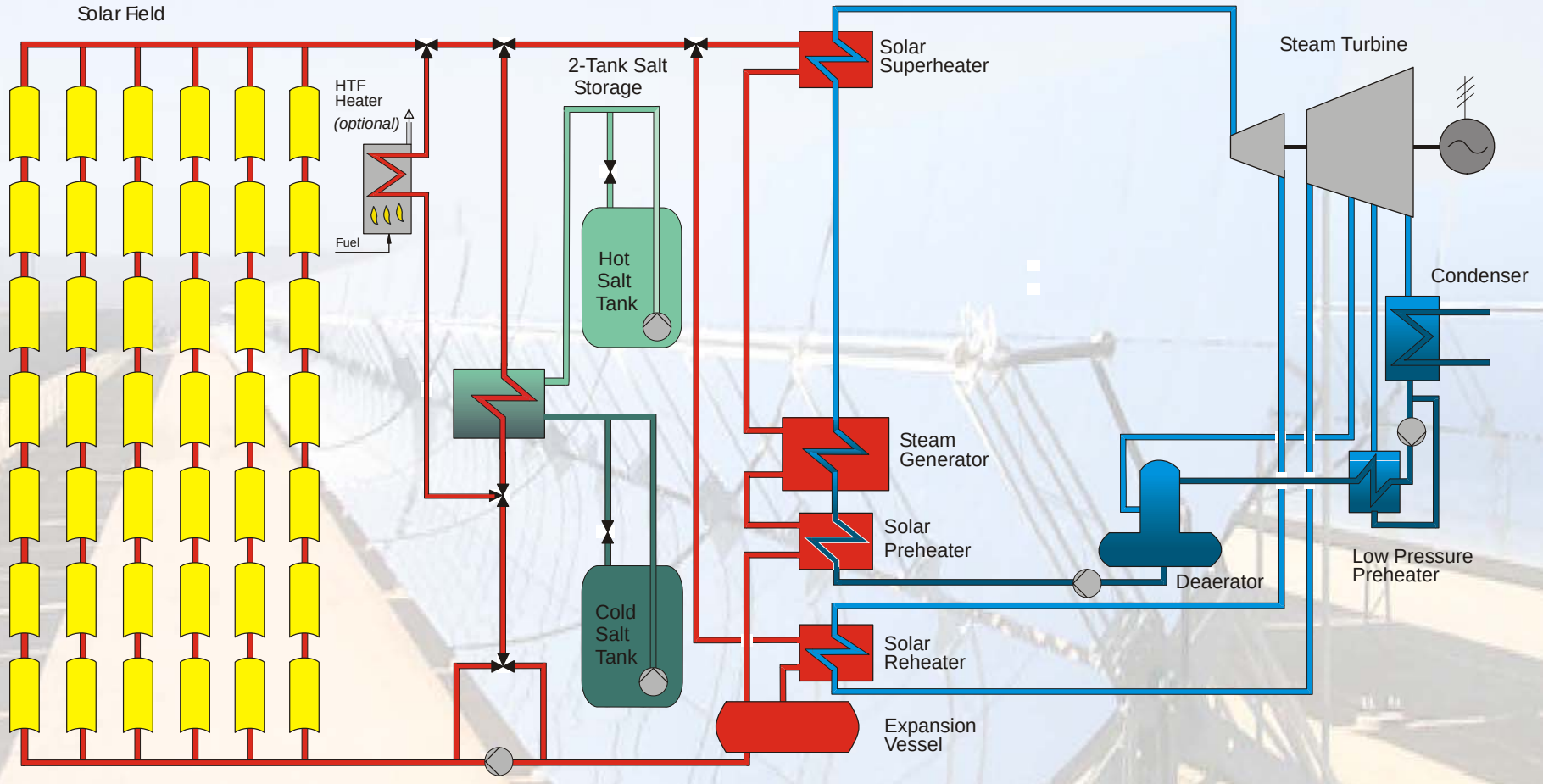

Solar Plant with Molten Salt Storage

(indirect 2-tank)

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Solar Thermal Energy Storage Options

- Single Phase Liquid Storage
  - Two-Tank Indirect or Direct Storage
  - Thermocline Single Tank Storage
  - Molten Salt or Synthetic Oil Typical
- Phase Change Material Storage – Latent Heat
- Concrete (or similar) Mass Storage

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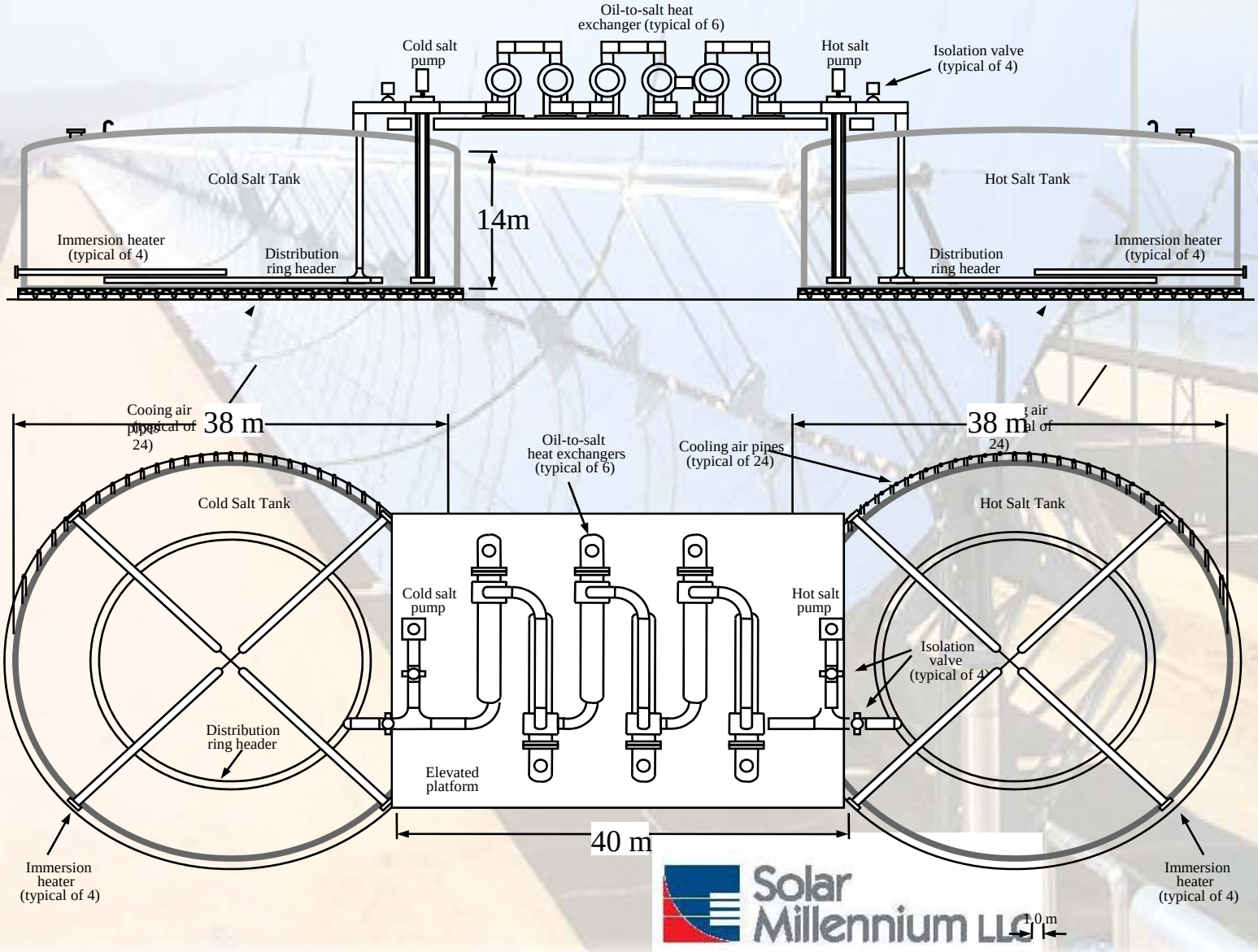
General Arrangement: Salt Storage System



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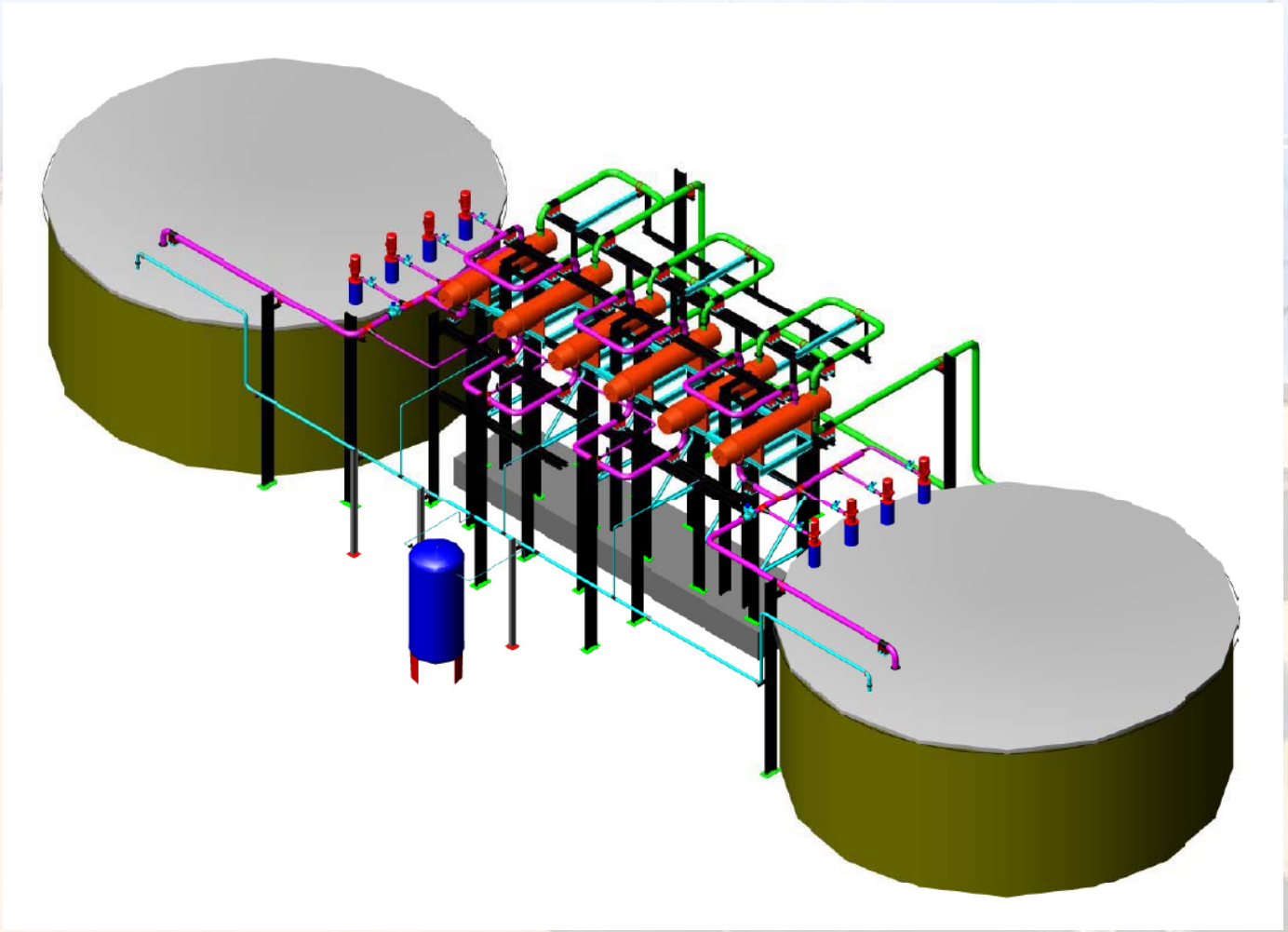

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Andasol-1 Construction

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Andasol 1 Storage Design Data

- Type: 2-Tank Molten Salt Storage
- Storage Fluid: Molten Salt (“Solar Salt”)
- Heat Exchanger Rating: ~130MW
- Storage Capacity: 1010 MWh
  (~7.5 hrs full load operation)
- Storage Tank Size: 14 m height
  38 m diameter
- Cold Tank Temperature: 292°C
- Hot Tank Temperature: 386°C
- Melting Point of Fluid: 223°C
- Salt Mass: 27 500 tons
- Flow Rate: 953 kg/s
- Annual Storage Efficiency: ~95%

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Molten Salt Storage – Current State-of-the-Art

- Any salt above it's melting point can be called "Molten Salt" (also "table salt" =NaCl)
- In industrial applications many different kinds of "molten salts" are used
- "Solar Salt" is used for the Thermal Storages (60%-w.$NaNO_3$+40%-w.KNO_3)

KNO_3 in its crystalline form at room temperature

Name	Melting Point
NaCl	**801°C**
$NaNO_3$	**307°C**
KNO_3	**334°C**
$NaNO_3$+KNO_3	**220°C**

*eutectic mixture

Why Molten Salt?

Molten Salts are used because of their properties like

- High specific heat relative to material costs
- Very low vapour pressure
- Low degradation rate – high chemical stability
- Non flammable
- Non explosive
- Environmentally Benign (also used as fertilizer)

But:

- They have a high crystallization temperature

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Typical Applications of Molten Salts

- Heat Treatment: Hardening baths, …
- Cleaning: removal of paint, rubber, polymers,…
- Heat transfer systems:
  - Remove heat (e.g. from exothermic reactions)
  - Supply heat (e.g. to endothermic reactions)

→ Reliable and safe operation since decades!

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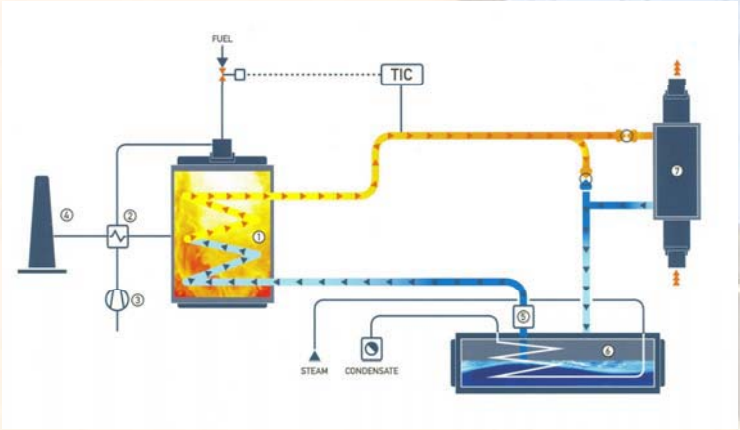
Molten Salts in Process Industry

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

c) 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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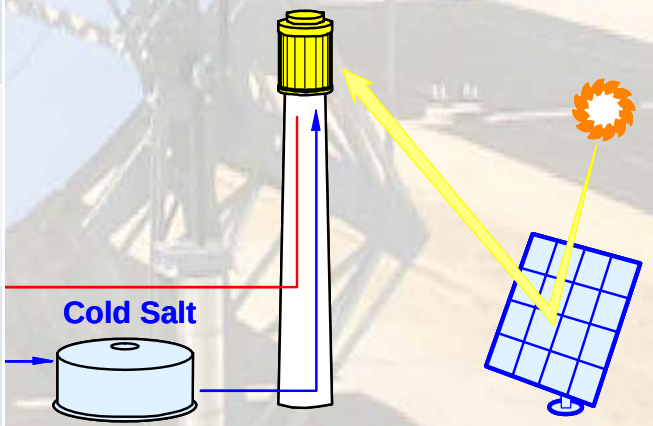
Molten Salts in Solar Thermal Applications

Projects	Year
SUNSHINE (Japan)	**1981**
THEMIS (France)	**1983**
Solar Two (USA)	1996-1999
ENEA (Italy)	**Since 2004**



Thermal Storage – US Applications

- 2 x 2-Tank Molten Salt Storage
- Storage Fluid - Solar Salt – $NaNO_3/KNO_3$
- Power Rating - 268 MWe
- Storage Cap. 2,400 MWh
- Storage Tank Size:
  - 15 m height
  - 40 m diameter
- Hot Tank Temp. - 732 ^oF
- Cold Tank Temp. - 558 ^oF
- Freeze Temp. - 433 ^oF
- Salt Mass - 65,000 tons
- Turn-around Efficiency - 95%

SM Andasol 1 Project

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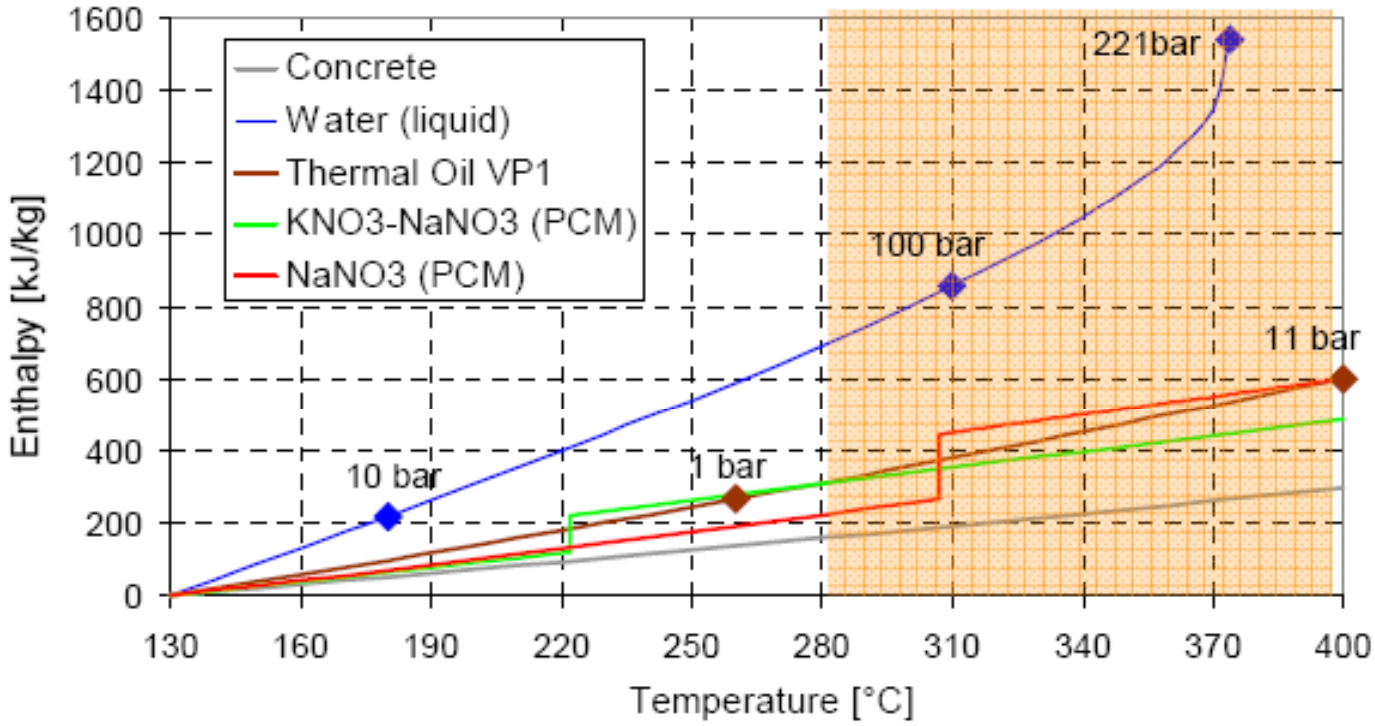
Thermal Energy Storage
Motivation



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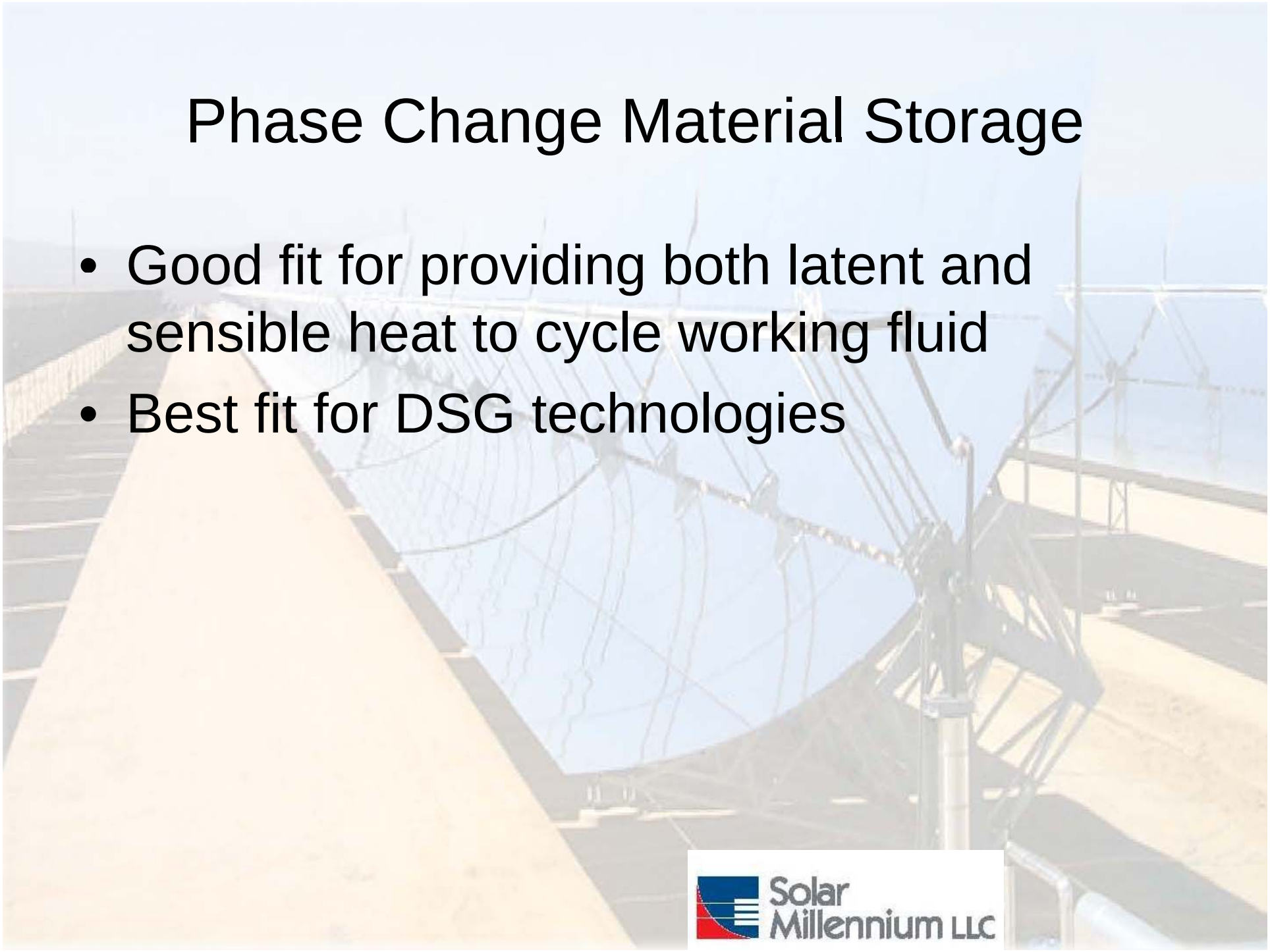
Phase Change Material Storage

- Good fit for providing both latent and sensible heat to cycle working fluid
- Best fit for DSG technologies



Cement Storage

- Potential for very low cost
- Can be built in modules
- Best use for sensible heat transfer
- Can be used with DSG technologies
- Under Development

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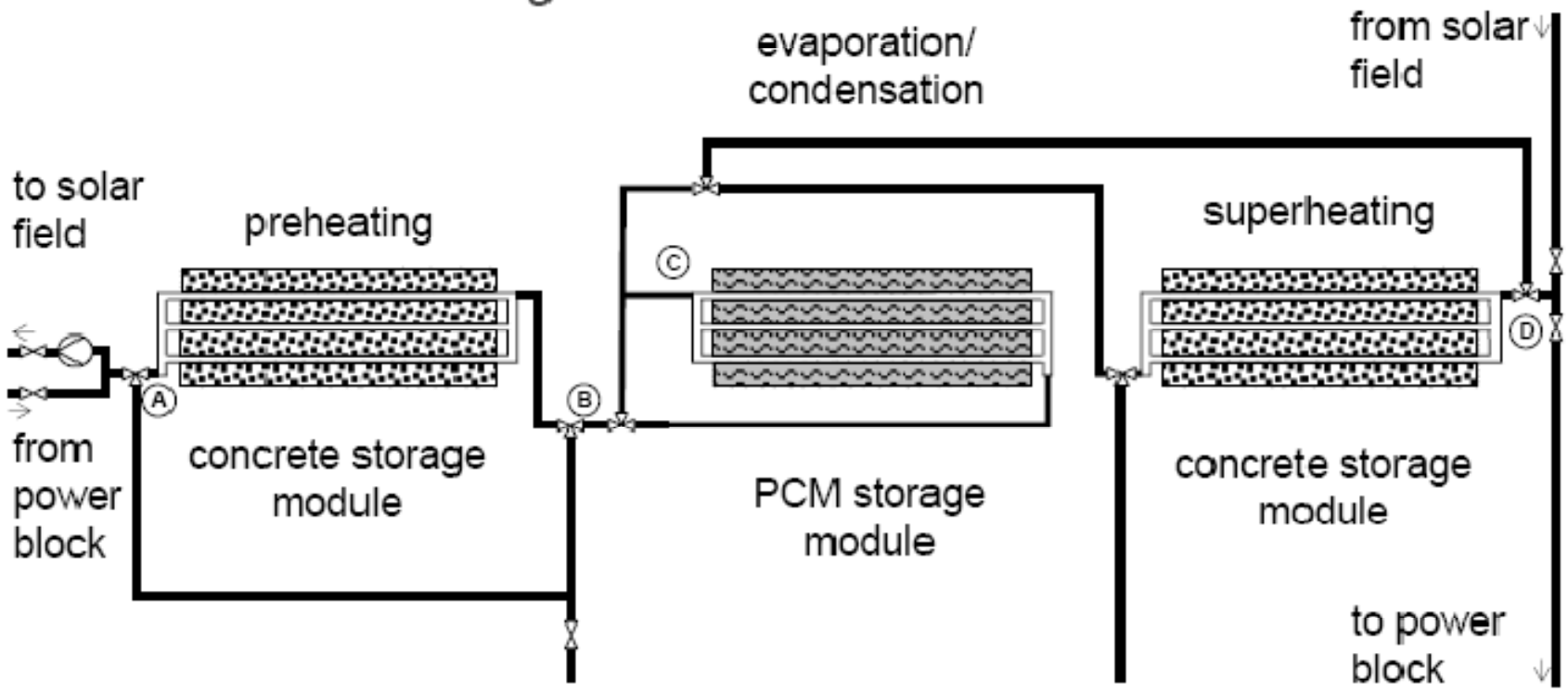
Concrete Storage for Direct Steam Generation



A feed water inlet / outlet
B liquid water
C saturated steam
D live steam inlet / outlet

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Plants with integrated storage can provide greater value to the utility grid

- Increase of annual capacity factor of solar power plants
- Electricity production during system peak demand periods
- Buffering during transient weather conditions
- More even distribution of electricity production
- Provide reliable peaking capacity

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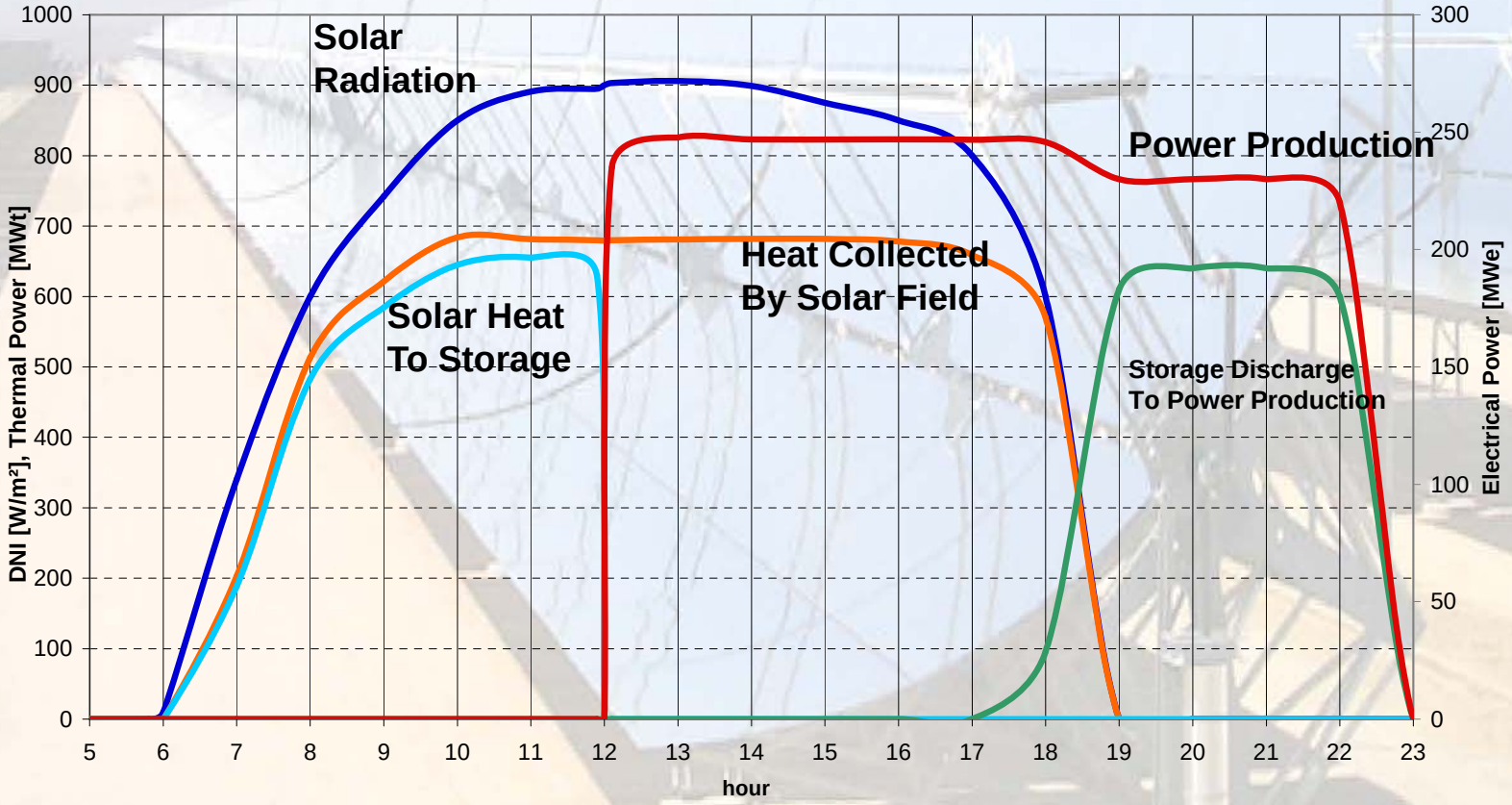
Shift Output from Morning Off-Peak to Evening On-Peak
Charge Storage fully before noon
Discharge in early evening to maintain plant output beyond sunset



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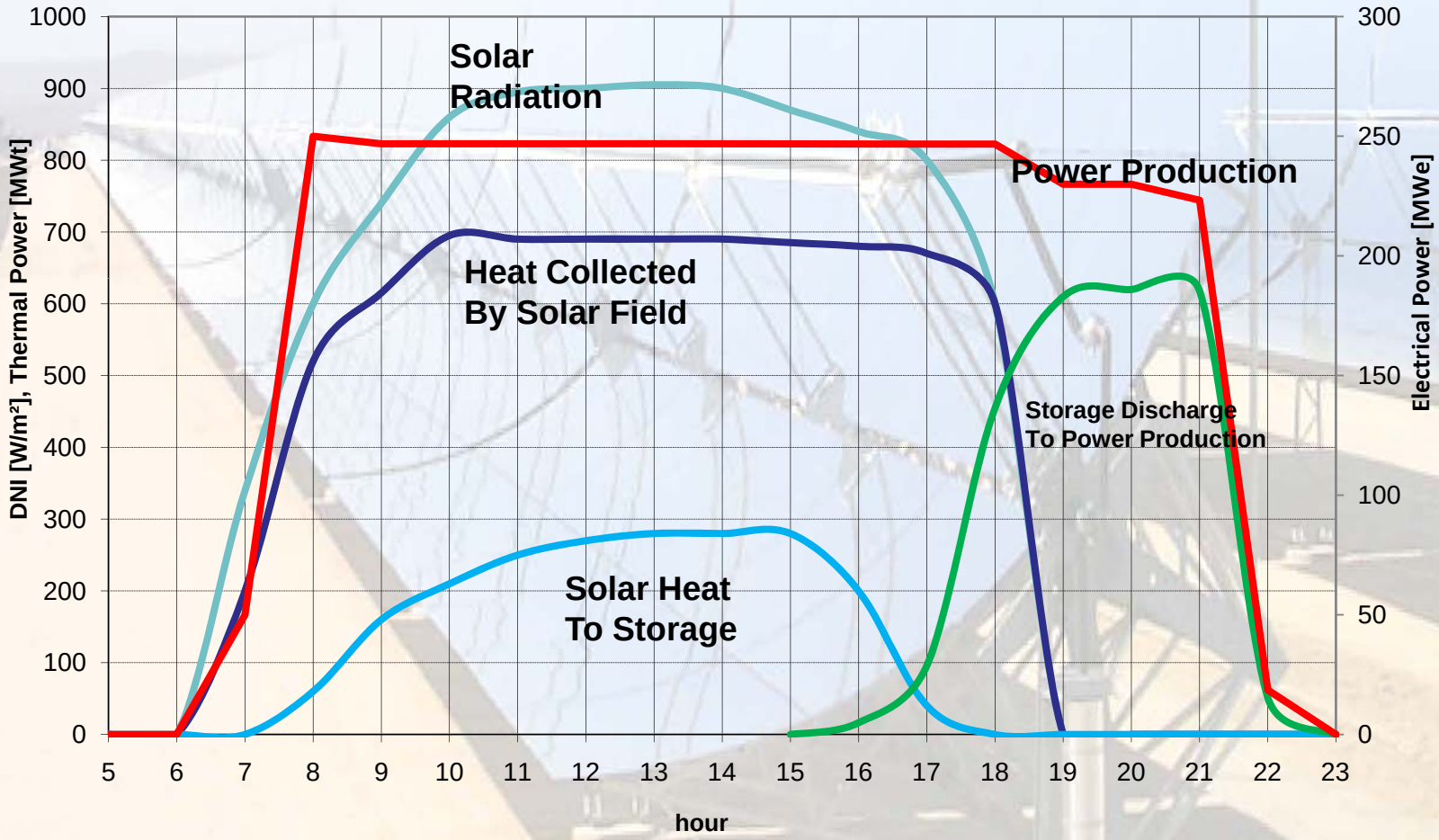
Extend operation from Sunrise to Late Evening
Power Generation at Sunrise; Gradual Storage Fill All Day
Discharge Storage in early evening to maintain plant output beyond sunset



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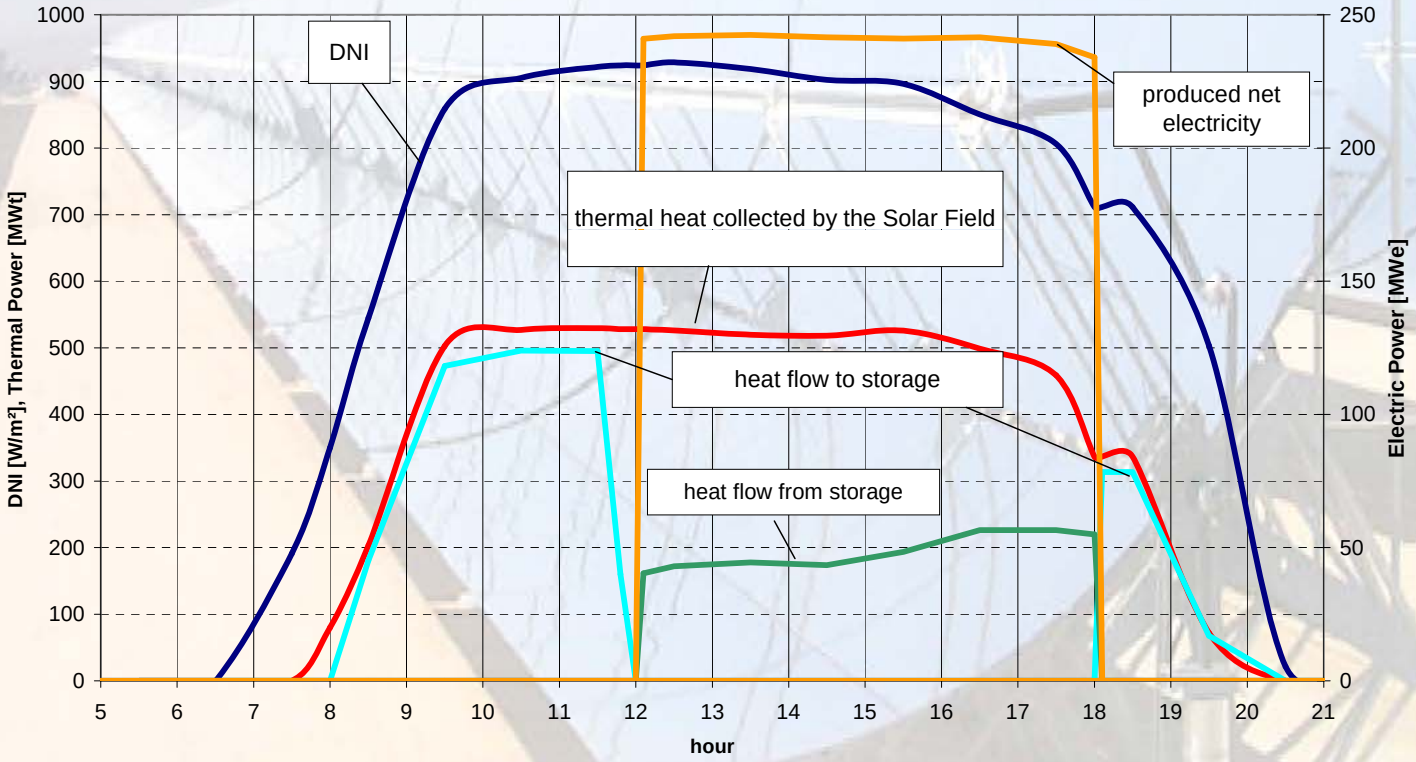
SOLAR BOOSTER : Shift the solar power from the morning/evening hours to the afternoon hours!

- Now: Solar multiple < 1



- Charge of storage until noon (without any electricity production)
- Electricity production from noon to 6 PM using heat of solar field AND storage
- Charge the storage again in the evening

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Summary

- Storage can improve economics of solar thermal power plants
- Storage helps to increase availability and plant capacity factor and improves system flexibility
- Molten salt technology is a proven technology in the process industry
- Risks are manageable
- Clear market pull from many utilities

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