ABENGOA SOLAR

Solar Power for a Sustainable World

Realidad industrial y tendencias en almacenamiento a gran escala

Seville, Jun 15 2010

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Content

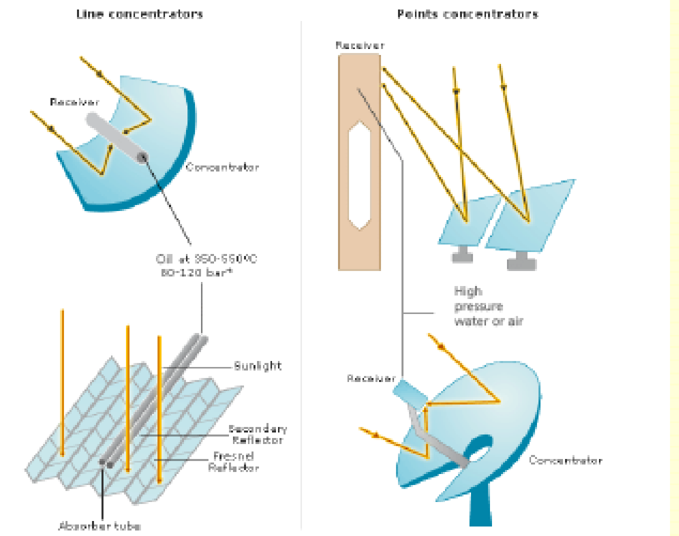
Abengoa Solar in Summary

Large international and integrated Solar Power Generation company offering proven technologies and developing new one, both CSP and PV

- A twenty year commitment to both CSP and PV technology development
- More than 400 professionals worldwide
- Two domestic markets (Spain and U.S.) and expansion to international markets (i.e. Algeria, Morocco)
- Proprietary solar technologies (trough, tower, thermal storage, other technologies)
- Assembly of a world class team of Solar experts, with unsurpassed collective experience and skills

… dealing with key technologies within the solar field…

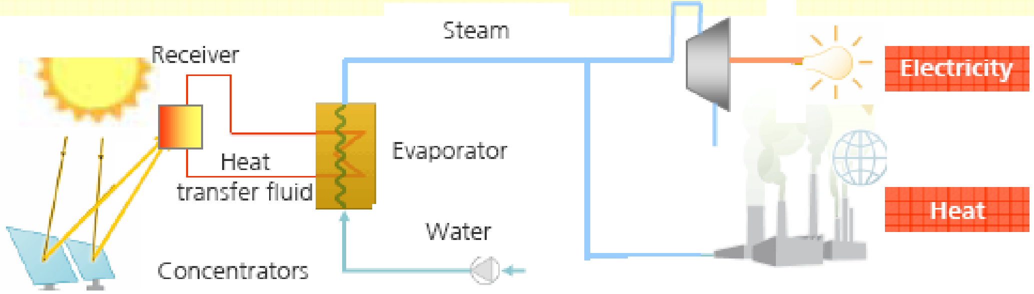
Concentrating Solar Power



Operating principle: generally speaking, CSP technology is based in solar radiation concentration to produce steam or hot air which could then be used in conventional electric plants. Solar energy capture, which has a relatively low density, is one of the main challenges in the development of solar plants. For concentration, most concentrating systems use mirrors with high reflectivity

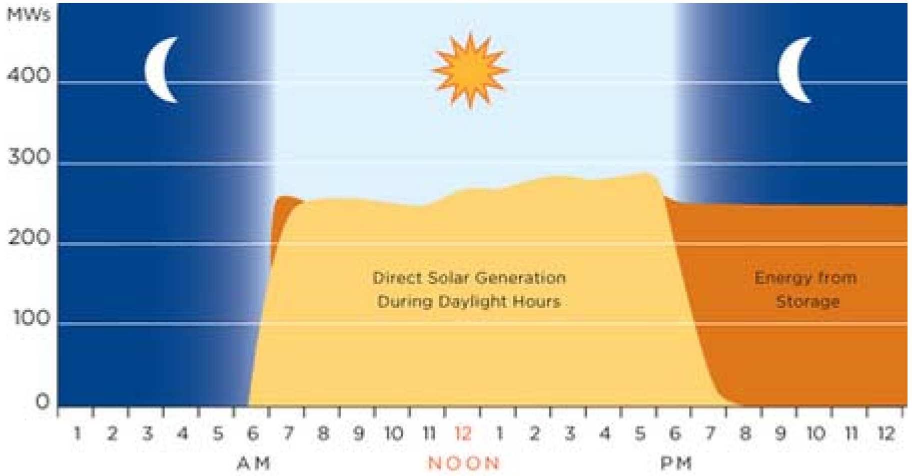
Main components

- **Concentrator:** different optical elements as mirrors, concentrate the solar rays on a point or a line where the receiver is located.
- **Receiver**: the receiver collects the concentrated solar rays and transfers the energy to a heat transfer fluid.
- **Evaporator**:In the evaporator the heat transfer fluid heats the water which becomes steam
- **Turbine**:the steam moves the turbine which produces electricity as in conventional methods .

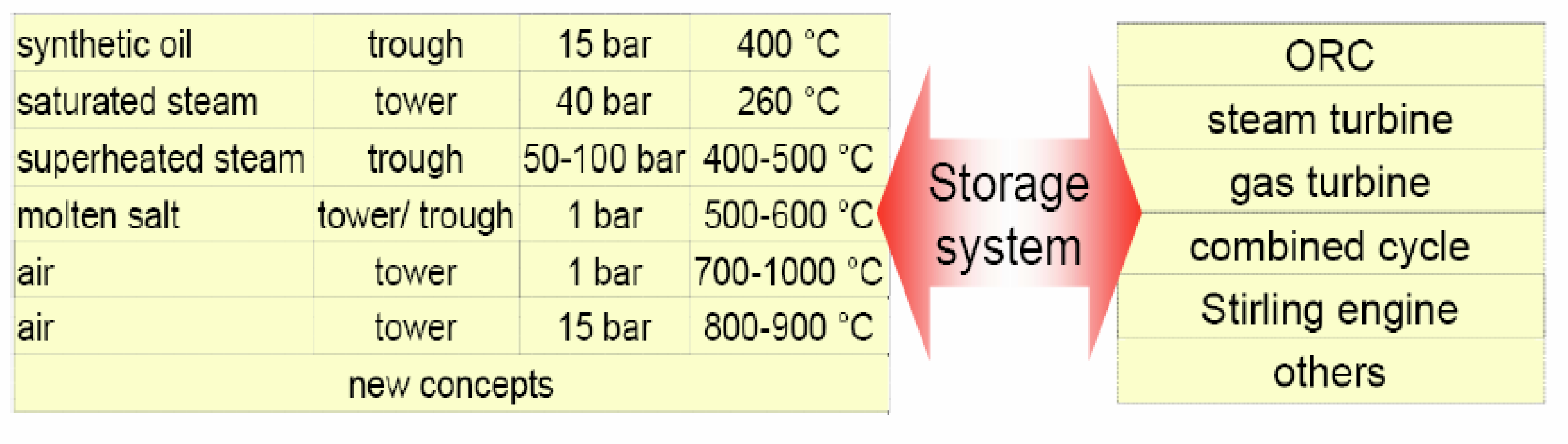


Thermal Storage

Using thermal storage allows energy provided by the sun to be distributed over a longer window of time. In the example above, the stored energy is used to provide heat for the electricity generation well into the night. The peak summer demand occurs in the early evening, often as late as 7 p.m., long after the sun has provided its most intense radiation. Thermal energy storage allows the solar trough to supply electricity when energy is most needed by customers.



Highly specific design specifications regarding:
Primary HTF – pressure – temperature – power level - capacity



synthetic oil	trough	15 bar	400 °C
saturated steam	tower	40 bar	260 °C
superheated steam	trough	50-100 bar	400-500 °C
molten salt	tower/ trough	1 bar	500-600 °C
air	tower	1 bar	700-1000 °C
air	tower	15 bar	800-900 °C
new concepts			

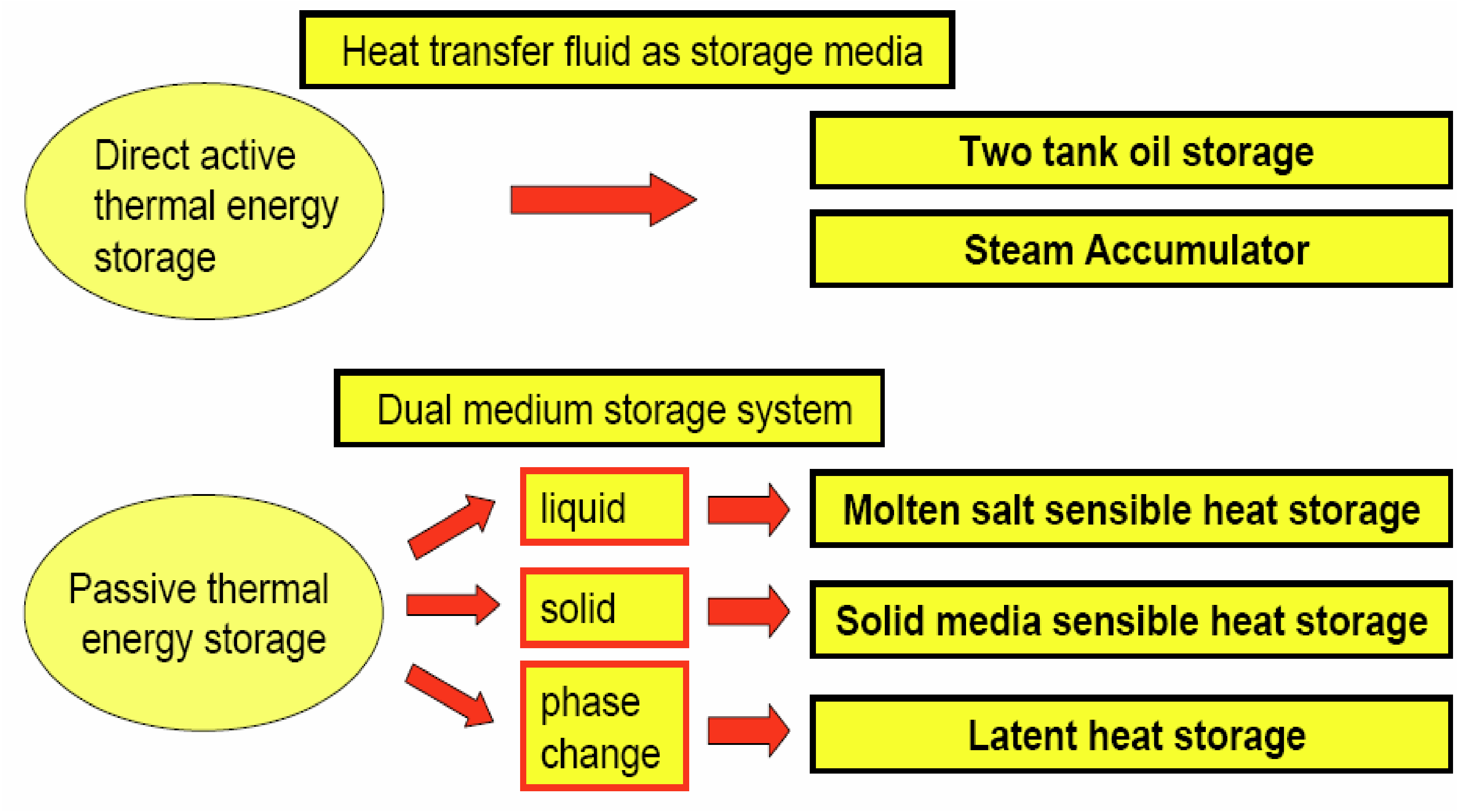
Storage system

ORC
steam turbine
gas turbine
combined cycle
Stirling engine
others

One single storage technology will not meet the unique requirements of different solar power plants

Storage concepts for parabolic trough power plants

Classification



Heat transfer fluid as storage media

Direct active thermal energy storage

Two tank oil storage

Steam Accumulator

Dual medium storage system

Passive thermal energy storage

liquid

solid

phase change

Molten salt sensible heat storage

Solid media sensible heat storage

Latent heat storage

Thermal Energy Storage for CSP Plants
Status und Development

Commercially available storage systems

- Steam Accumulator
- 2-Tank sensible molten salt storage based on nitrate salts

Alternative materials and concepts tested in lab and pilot scale

- Solid medium sensible heat storage – concrete storage
- Latent heat – PCM storage
- Combined storage system (concrete/PCM) for water/steam fluid
- Improved molten salt storage concepts
- Solid media storage for Solar Tower with Air Receiver (e.g. natural rocks, checker bricks, sand)

Future focus for CSP

- Higher plant efficiency   Increase process temperature
- New fluids: steam, molten salt, gas/air

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State of art

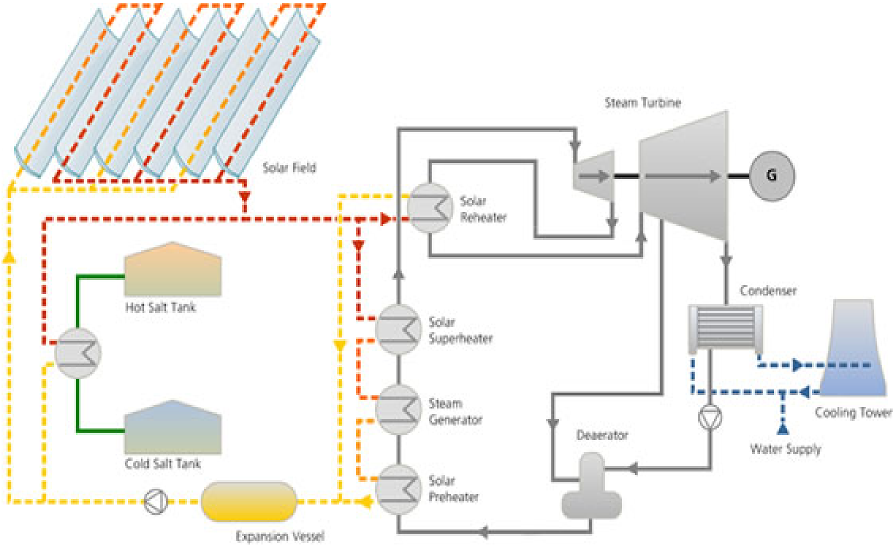
Commercial plants

Sensible heat

Latent heat

2-Tank Molten Salt

- 2-Tank Indirect Molten Salt



- Storage Fluid: Nitrate salt mixture (60% $NaNO_3$ and 40% KNO_3)
- Melting Point of Fluid: 221°C
- Cold Tank Temperature: 292°C
- Hot Tank Temperature: 384°C
- Heat transfer fluid: Hot oil
- Heat exchanger: oil/salt

2-Tank Molten Salt

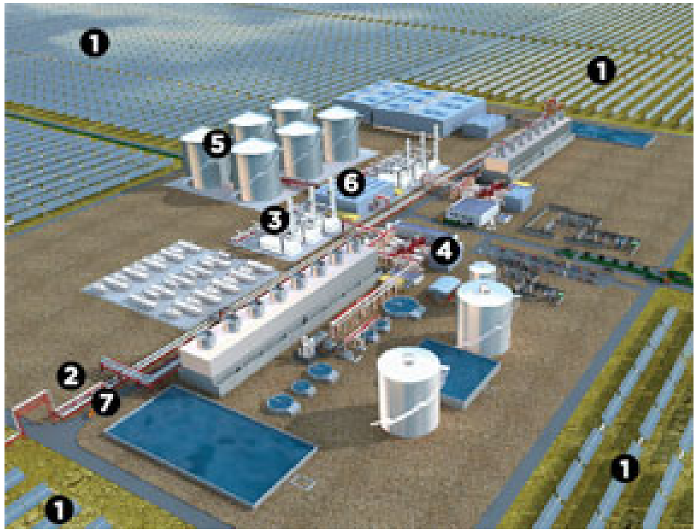
- 2-Tank Indirect Molten Salt

MoltenSalt Storage– TES PS10: Demo plant in operation from January 2009

2-Tank Molten Salt

- Solana: The world’s largest solar plant

Solana features thermal storage-equipped parabolic trough technology with 280 MW of power output capacity. Once operational, it will have the capability of supplying 70,000 homes and will prevent the emission of 400,000 t of CO2.

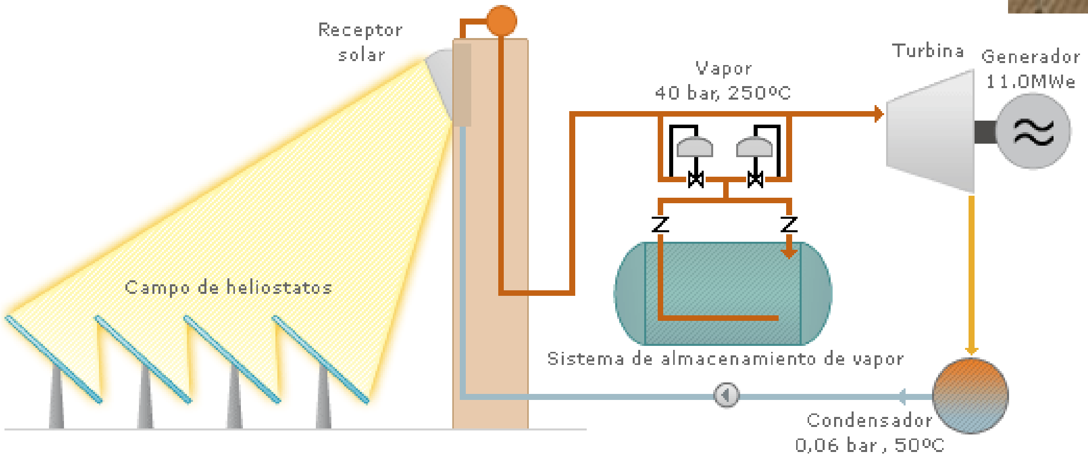


1. Parabolic mirrors heat the heat transfer fluid.
2. Hot fluid returns from the solar field.
3. The hot fluid transfers its heat energy to water, creating steam.
4. Steam is used to drive a turbine, creating electricity.
5. The hot fluid also heats molten salt.
6. If the sun is not shining, the fluid can be heated by the molten salt.
7. The fluid is sent back to the solar field.

Steam Accumulator

- PS 10: Steam Accumulator

Steam Storage– PS10 and PS20: 4 Accumulators per plant



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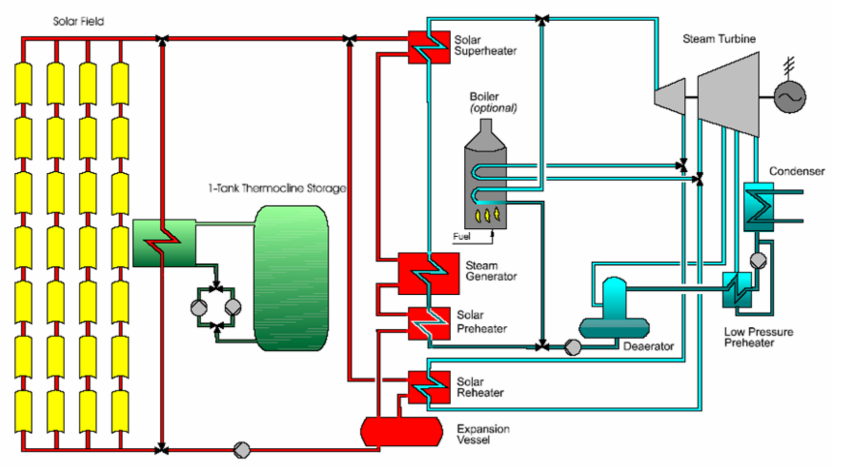
- State of art
- Commercial plants
- Sensible heat
- Latent heat

Sensible Heat (Thermocline)

Benefits:

- Replaces much of salt with less expensive rock
- Higher utilization of tank volume allowing for potentially fewer tanks



Potential Issues:

- Additional tank wall stresses
- Freeze protection
- Maintaining acceptable thermocline level
- Charge and discharge control strategy (especially partial events)
- Possibility of thermal ratcheting in tank

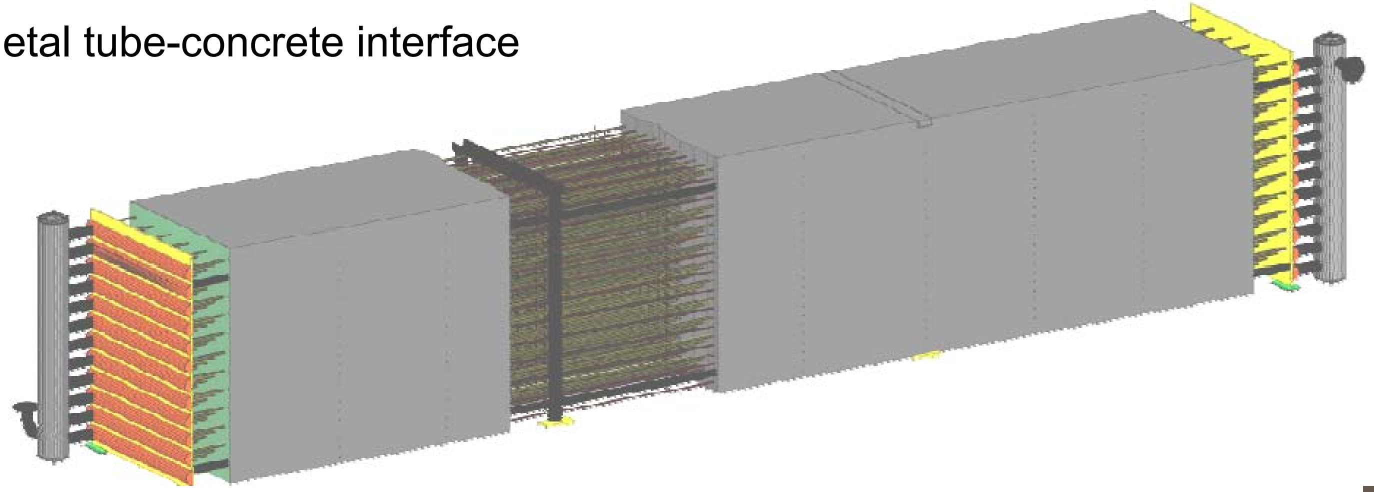
Sensible Heat (Concrete)

Benefits:

- Low cost and abundant material
- Modular and scalable

Obstacles:

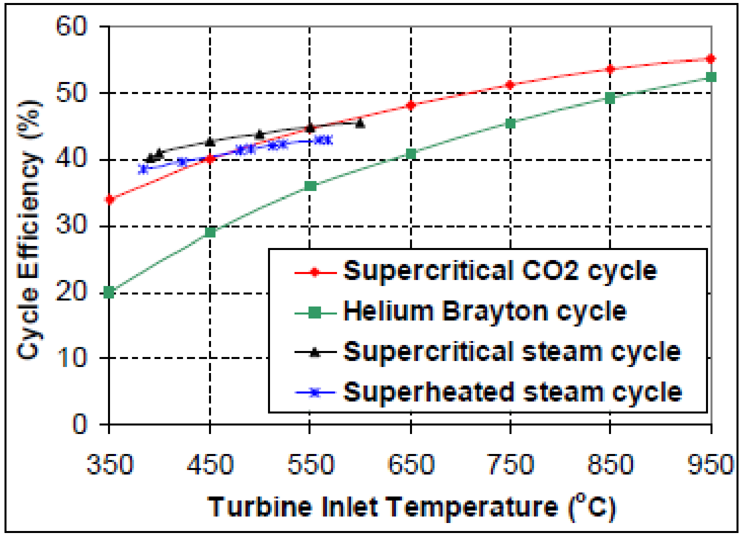
- Requirement of metal tubes doubles cost
- Poor utilization factor and changing oil outlet temperature
- Degradation of metal tube-concrete interface
- Low conductivity



Sensible Heat (Supercritical-CO_2)

Benefits:

- Low cost and abundant material
- No freeze or upper temperature limits
- Allows possibility for high efficiency CO_2 Brayton Cycle and direct storage



Power cycle efficiency as a function of inlet temperature.

Obstacles:

- Only critical (~73 bar) or supercritical pressures allow for acceptable fluid properties
- Pressure vessels for TES are prohibitively expensive
- Storage must be accomplished with secondary material
  - Packed-bed Thermocline

Content

State of art

Commercial plants

Sensible heat

Latent heat

Latent Heat
(Phase Change Material – PCM)

Phase Change Material (PCM)

Benefits:

- Heat of fusion is high compared to sensible heat capacity
- Significantly reduces volume of storage material and, hence, cost

Obstacles:

- Constant temperature of each PCM requires cascading configuration
- Heat transfer rate degrades during course of discharge due to solids formation
- Can results in poor utilization factor
- Corrosion issues with various PCM options
- Degradation of PCM over 30 years
- Structure fatigue cycle issues over 30 years