Direct Solar Steam Generation
Direct Solar Steam Generation
Thermo-hydraulics
Direct Solar Steam Generation
Control

Compact-Steam Separators

Top View: coarse stage fine stage

Side View: 1.24 m
Linear Fresnel Systems

The Linear Fresnel Design

- More simple design offers potentially lower investment cost
- Lower optical efficiency compared to parabolic troughs
- Therefore, high optical accuracy required
- Several pilot installations presently under investigation
Comparison of Fresenel and parabolic trough collector

The steam producing principle is based on flat mirrors, concentrating the parallel solar radiation on a receiver tube. Inside the tube water is vaporised and directed to steam turbine.
Central Receiver Systems

Higher temperature than troughs → thermodynamic advantages

- **Steam Receiver**
  - Solar One (US)
  - PS10/20 Seville

- **Molten Salt Receiver**
  - Solar Two (US)
  - Solar Tres (Spain)

- **Open Air Receiver**
  - Phoebus/Solair concept
  - metallic or ceramic volumetric receiver
Tubular receiver

Volumetric receiver

Heliostats up to 120 m²
Central Receiver Systems - Examples

- Solar-Two
- PSA
- PS10
- PS20
The Solar Gas Turbine Approach

CC
\( \eta = 25\% \) (annual)

Rankine
\( \eta = 16\% \) (annual)
Combined Cycle Process with Gas Turbine, inlet temperature up to 1100°C
REFOS Receiver for Combined Cycle Process

- pre-concentrator
- quartz glass window
- absorber
- vessel
- insulation

Inlet
Outlet

Concentrated solar radiation

Pre-concentrator
State of the Art

- 400 kW receiver module has been tested for more than 500 h up to 15 bar and 850°C
- 1 MW receiver group with 250 kW gas turbine has been installed and operated
- 4.5 MW demonstration plant under construction
Thermal Storage

> Thermal Storage = More operating hours = Cost reduction

![Graph showing relative electricity costs vs. storage capacity. The graph indicates that as storage capacity increases, relative electricity costs decrease. A key point is marked with no storage, electricity costs = 100%. There is a note specifying that the graph assumes specific investment costs for the storage of 10 Euro/kWh.]
Liquid Phase High Temperature Heat Storage

Solar field

Heat transfer fluid (HTF) loop

Cold liquid

Hot liquid

Solar steam loop

Steam generator

Superheater

Natural gas

Turbine

Generator

Condenser

Cooling water loop

Cooling tower

Oil tank (Barstow)

Liquid salt tank, (Kramer Junction)
Solid Material Heat Storage  Latent Heat Storage

Pilot-scale concrete heat store  Salt phase change heat store