MAN Energy Solutions
Future in the making

CSP Reference Power Plant

ata insights

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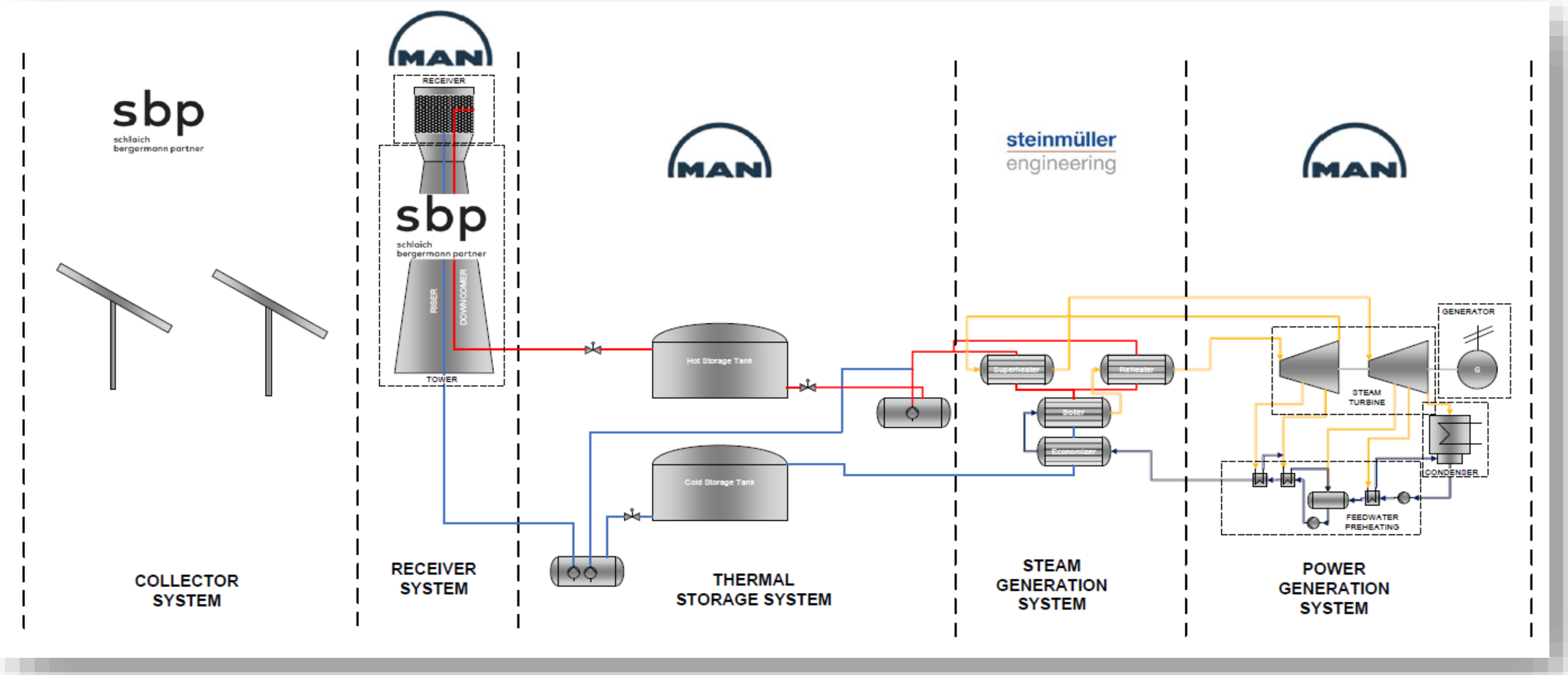
Agenda

1 Overall Design of CSP RP

2 Operating States of Receiver

3 Design of Subsystems

- 3.1 Receiver
- 3.2 Storage System
- 3.3 Steam Generator
- 3.4 Power Block

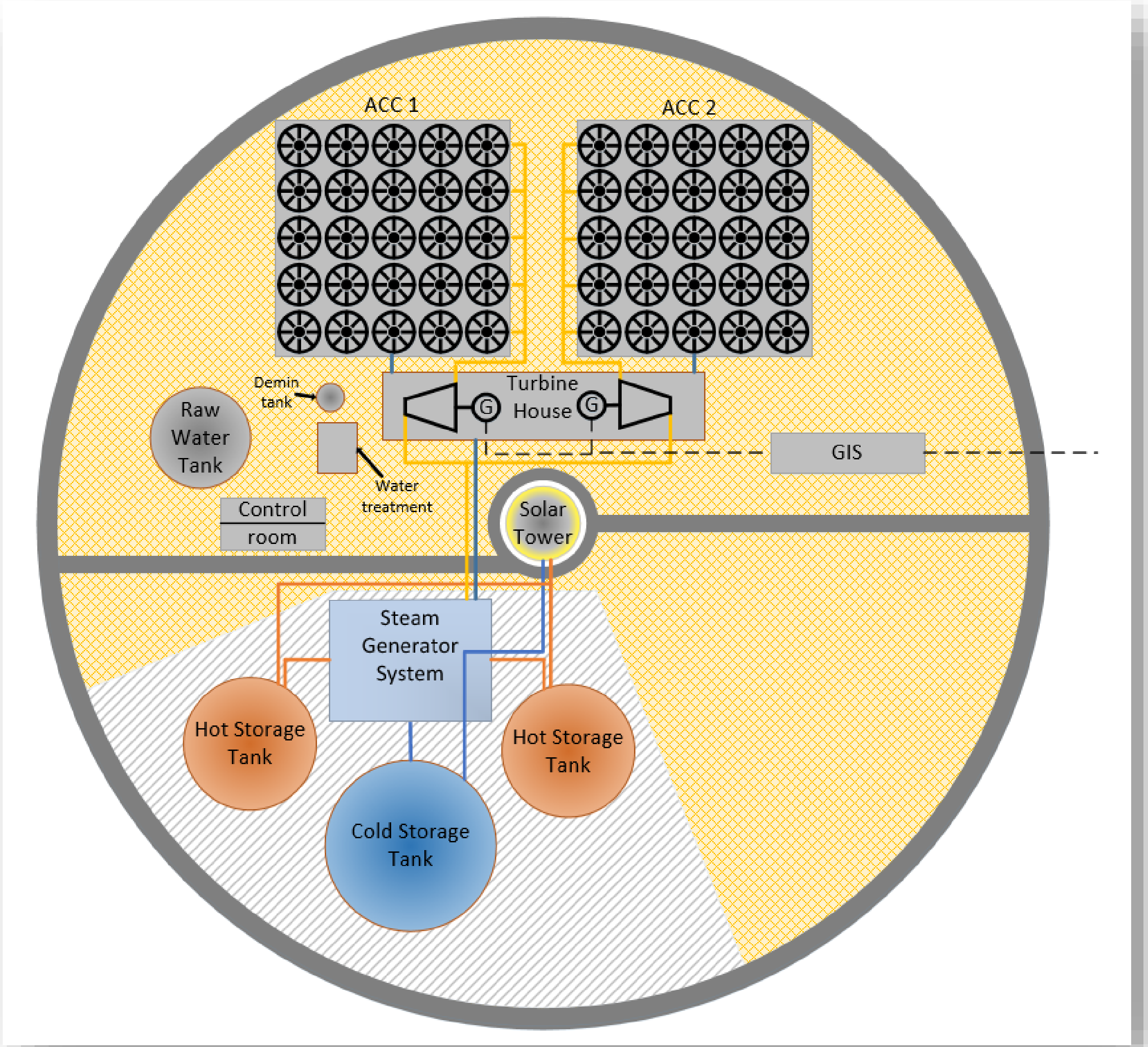


Overall Design

Layout

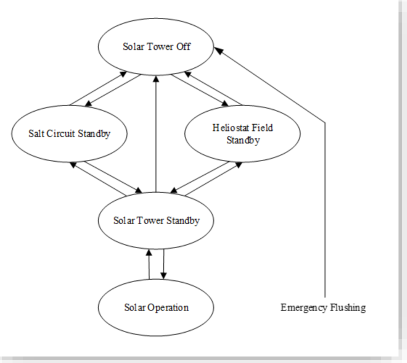
- **Minimized heat losses**
  - Compact arrangement of salt tanks and steam generator system
  - Turbines and ACCs are arranged close to each to minimize heat losses
- **Two steam generator units feed one turbine**
- **Lower placed drainage tank for draining exchanger units**

Layout for 2 x 200 MWel



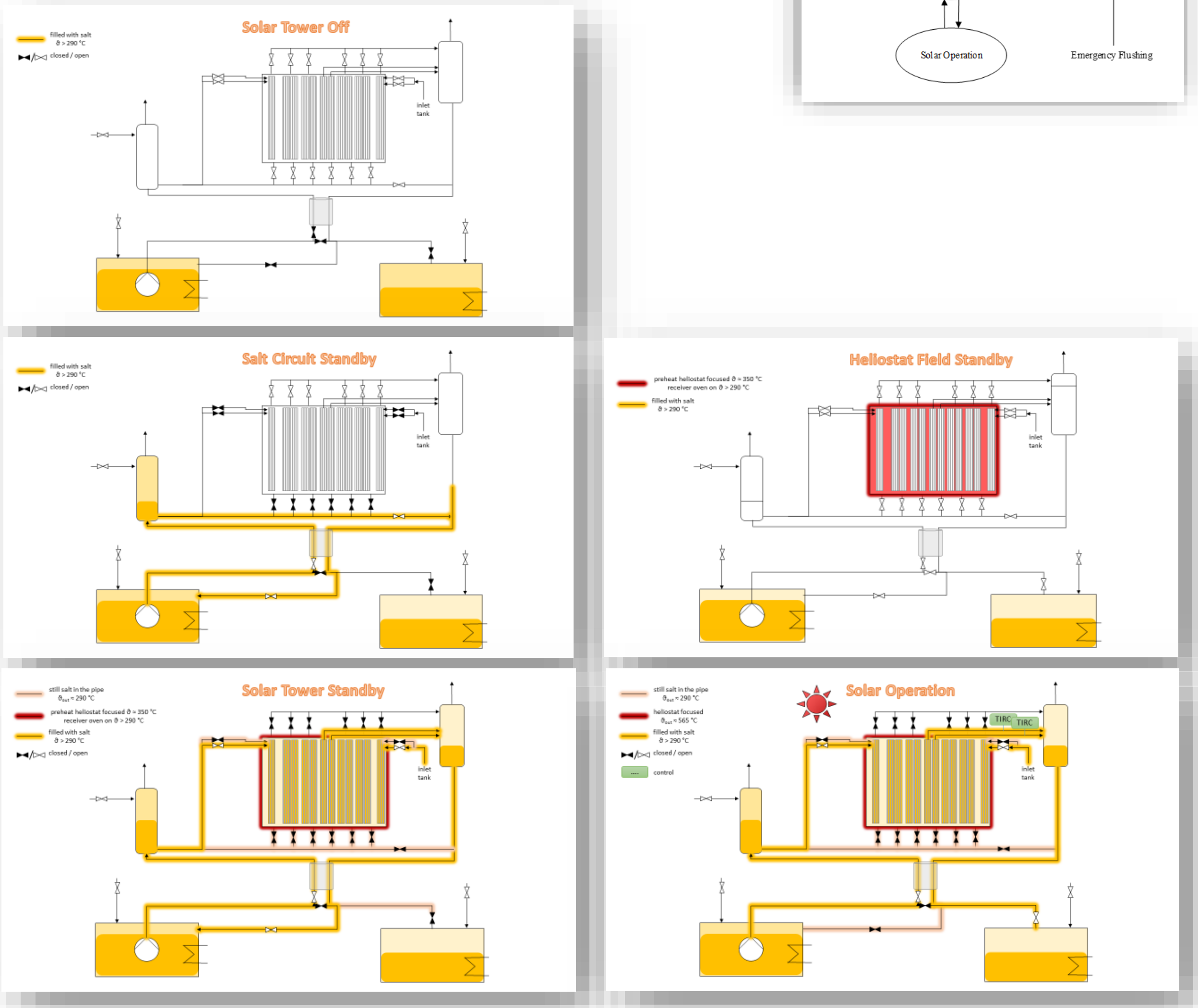
Operating States

Receiver



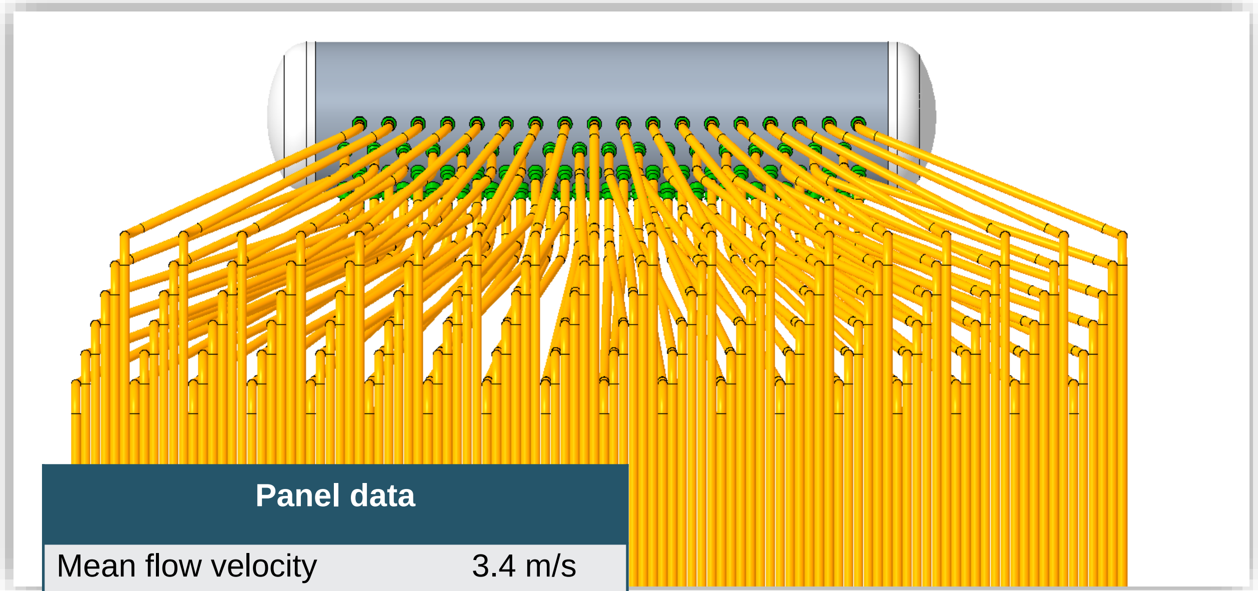
Five states for operation

- During a long-term shut down, **the solar tower including the heliostats is shut down**.
- To collect solar energy at first the salt circuit must be preheated and **filled** while some heliostats have to change position and **preheat the receiver**.
- **After both parts are in standby mode**, the receiver is prepared for starting. Salt flows through absorber tubes and **solar operation can start**.

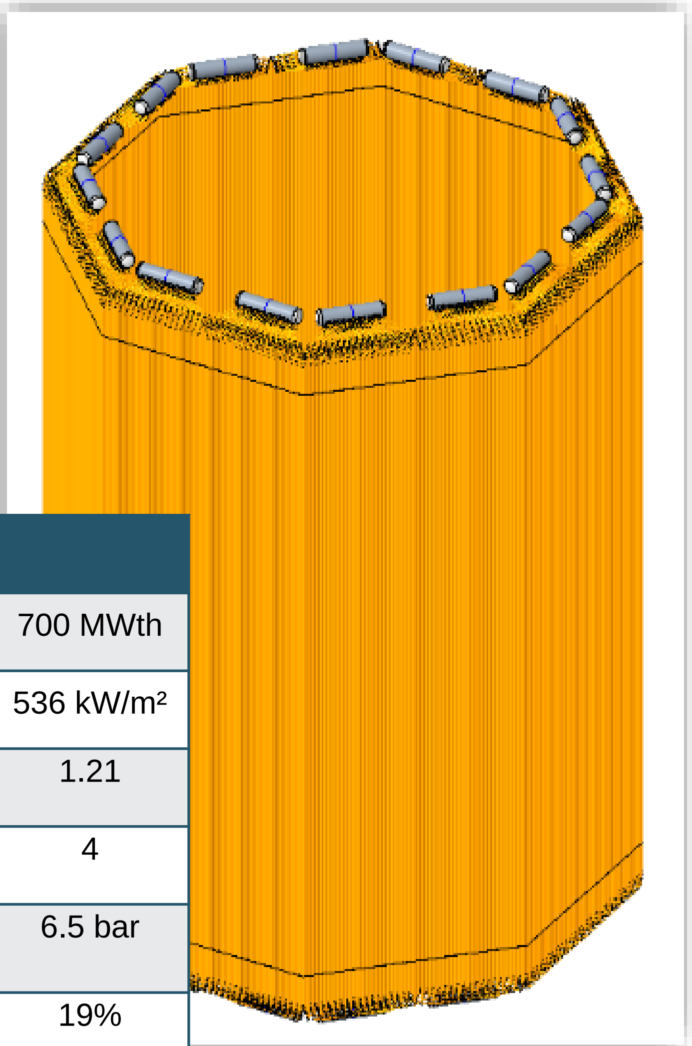


Receiver and Heat Transfer Cycle

Basic engineering – Design of main components



Panel data	
Mean flow velocity	3.4 m/s
Irradiated absorber length	23 m
Width of panel	7.2 m



Receiver data	
Heat Duty	700 MWth
Mean heat flux density	536 kW/m²
Height/Diameter ratio	1.21
Number of serial panels	4
Estimated pressure loss (only absorber tubes)	6.5 bar
Minimum part load	19%

Receiver

Rating after parameter study

Optimization of Receiver Design

Investigation of 11 variants

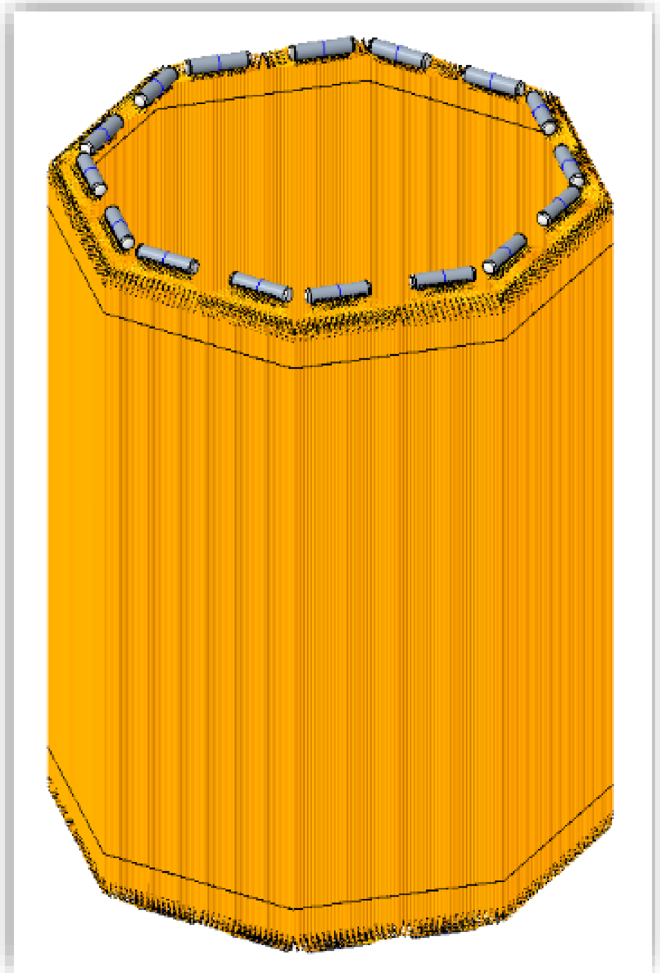
Reduction of LCOH due to:

Longer lifetime by lowering max. heat flux density (850 kW/m²)

Lower investment costs due to:

- Austenitic stainless steel
- Small receiver (less irradiated tubes)
- Less welding seams
- Very low pressure drop

→ Solar field and receiver are perfectly matched to minimize the LCOH



Storage system

Tank & Insulation

Storage tanks:

Reference plant includes 50.000 t salt (6032 MWh)

Cold tank: Ø 42,9 m x 20 m

Hot tank: 2 x Ø 31,9 m x 20 m

Insulation:

Specific costs: 1000 €/m³ (cold tank) and 1100 €/m³ (hot tank)

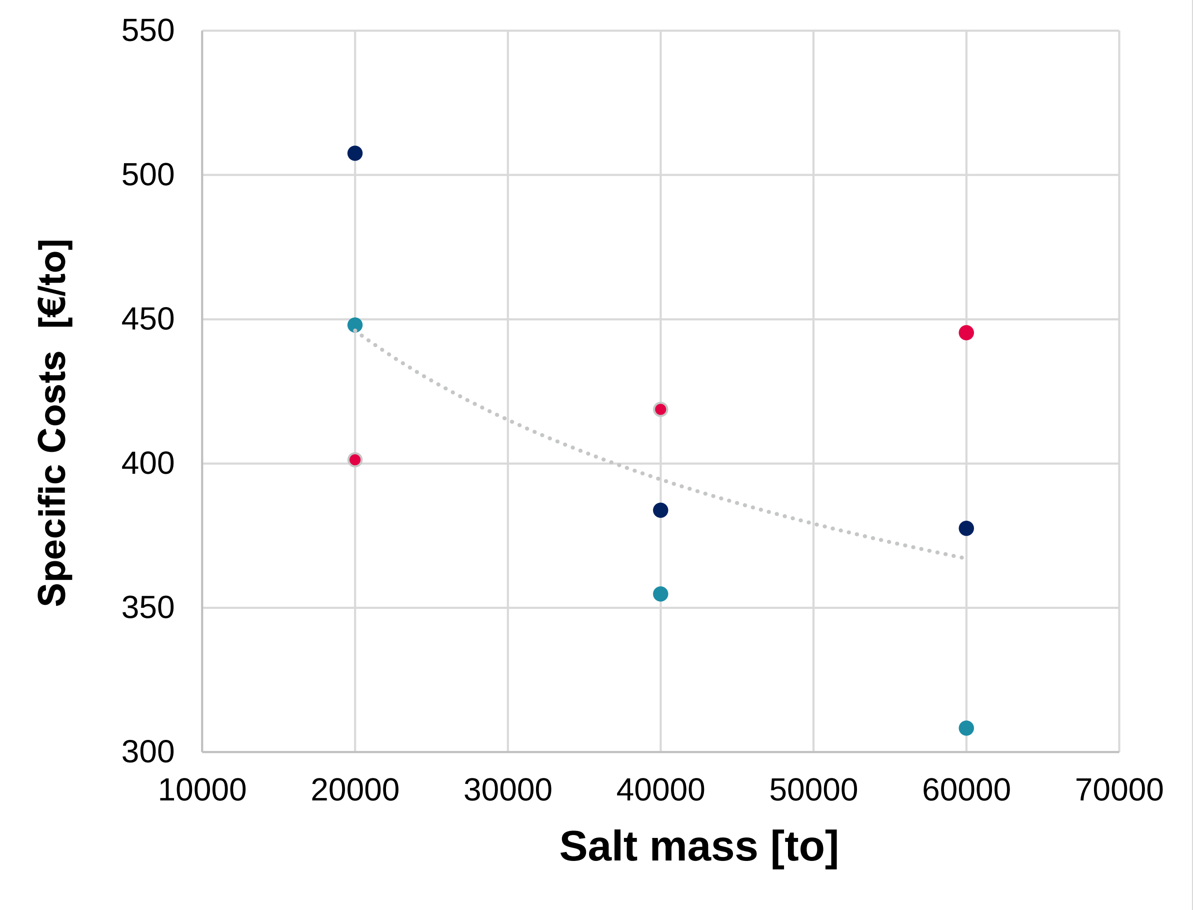
Insulation thickness: Cold tank 350 mm; Hot tank 500 mm

Solar salt:

Material costs: 850 €/to

Melting costs: 150 €/to

Price indication of three different suppliers



Overall costs incl. markup for storage system will be in a range between 20 and 22 €/kWh_th

Steam Generator

Natural Circulation

Heat exchangers:

Power of one SG unit: 240 MW_{th} → 100 MW_{el}

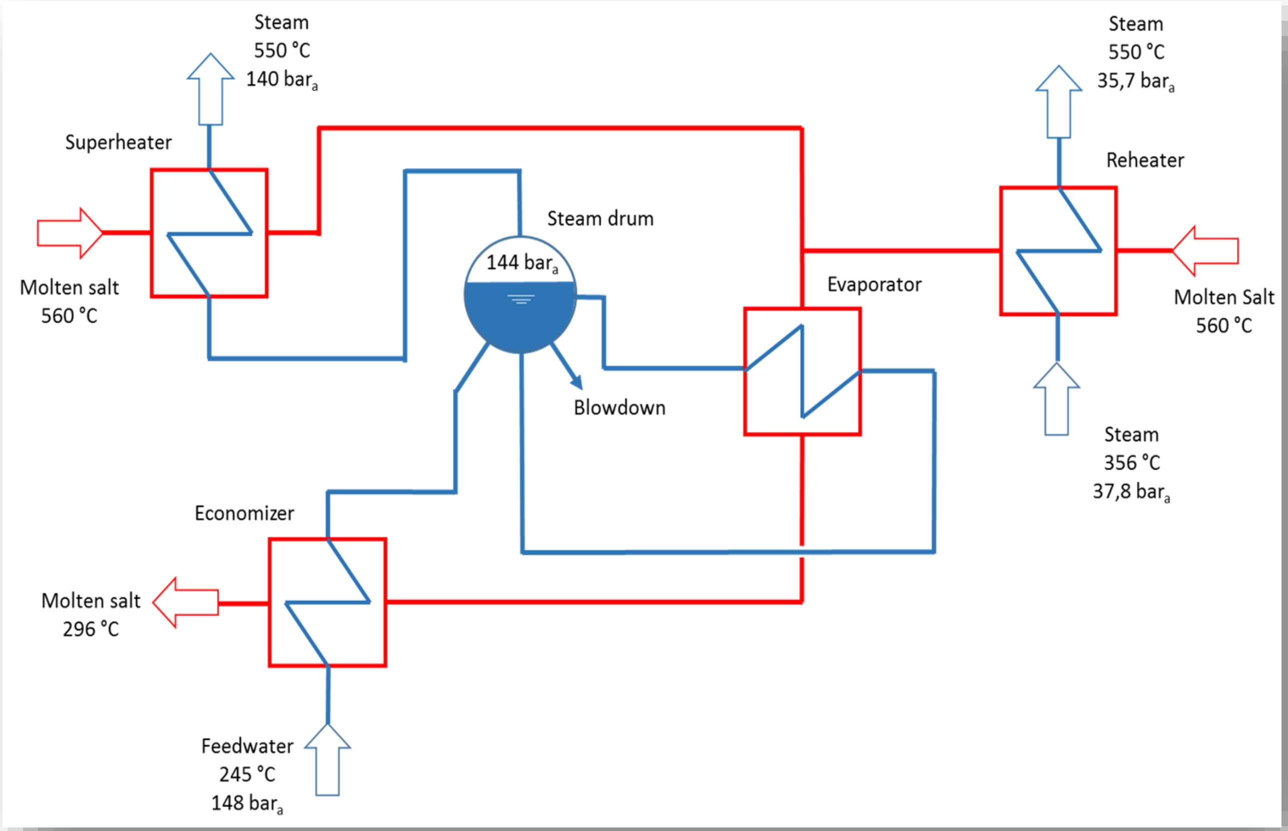
→ 2 trains necessary for 200 MW_{el}

Rating of chosen design

+ Low pressure losses
(Evaporator: 6 bar, Reheater: 3 bar)

+ Low costs

- Lower load changes transients than once-through SG



Power Block

Boundary conditions and assumptions

Nominal power: 200 MWel (2 x 200 MWel)

Live steam parameters: 140 bar a / 550 °C

Air cooled condenser (ACC)

Design exhaust pressure: 135 mbar

Minimal pressure: 100 mbar

Air inlet temperature: 30°C; air humidity: 60 % (night operation)

Nominal power consumption 6200 kW

Steam Turbine

Net efficiency 41,6% at 200 MW nominal load

Low efficiency drop (41,6% → 39,2%) at partial load down to 50%

→ Reduced power consumption of ACC by speed control

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Thank you very much!

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