PHASING OUT FOSSIL GAS STEAM GENERATORS:
Demand-based generation of process steam from thermally stored renewable energy with the
Rotating Drum Heat Exchanger

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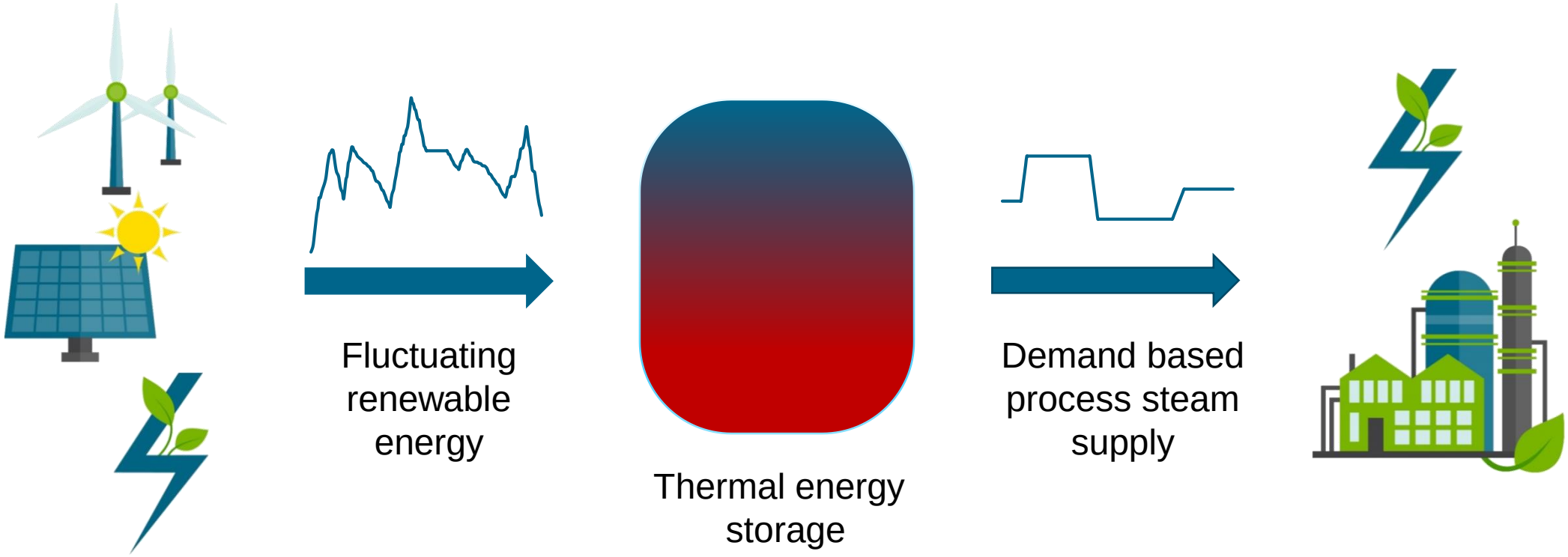
Demand based process steam supply



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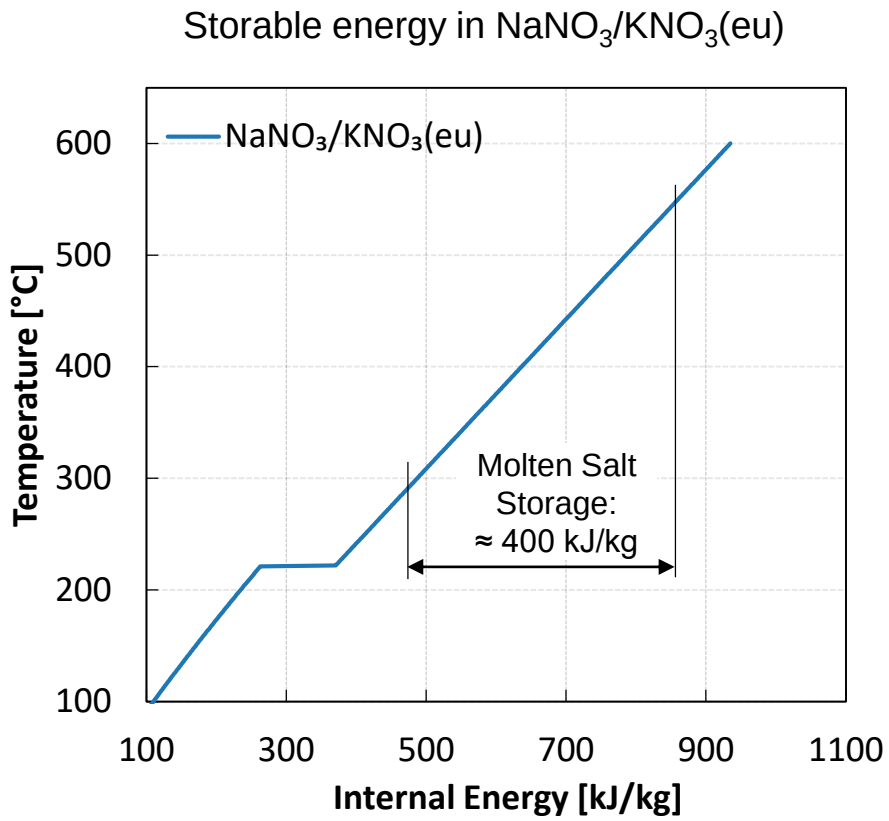
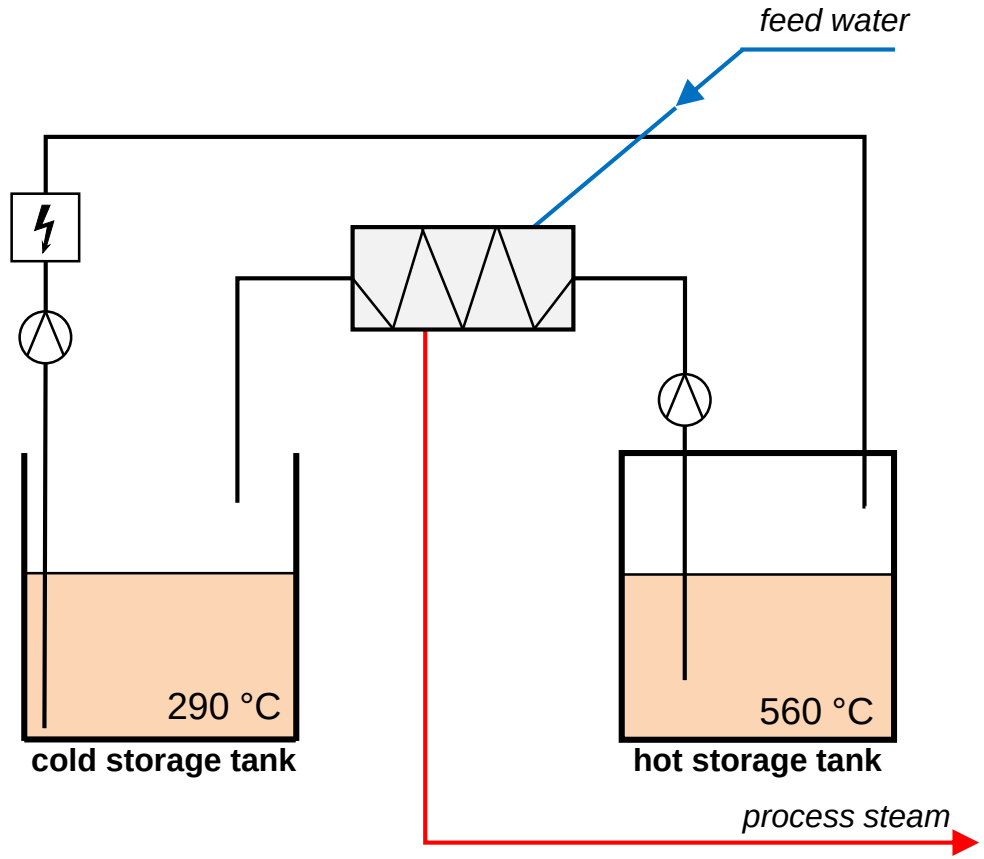
- Process steam amounts to 5 % of the final energy demand
- Today’s demand is mainly supplied by fossil gas steam boilers
- Renewable energy forms can be thermally stored for a demand based steam supply

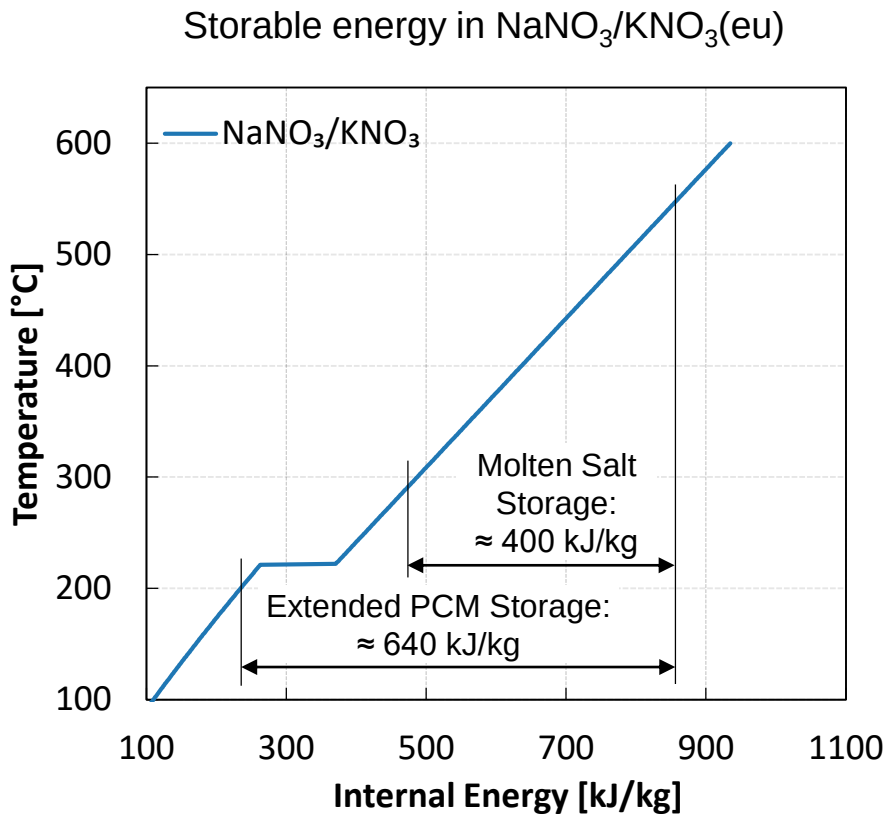
Increased Storage Density

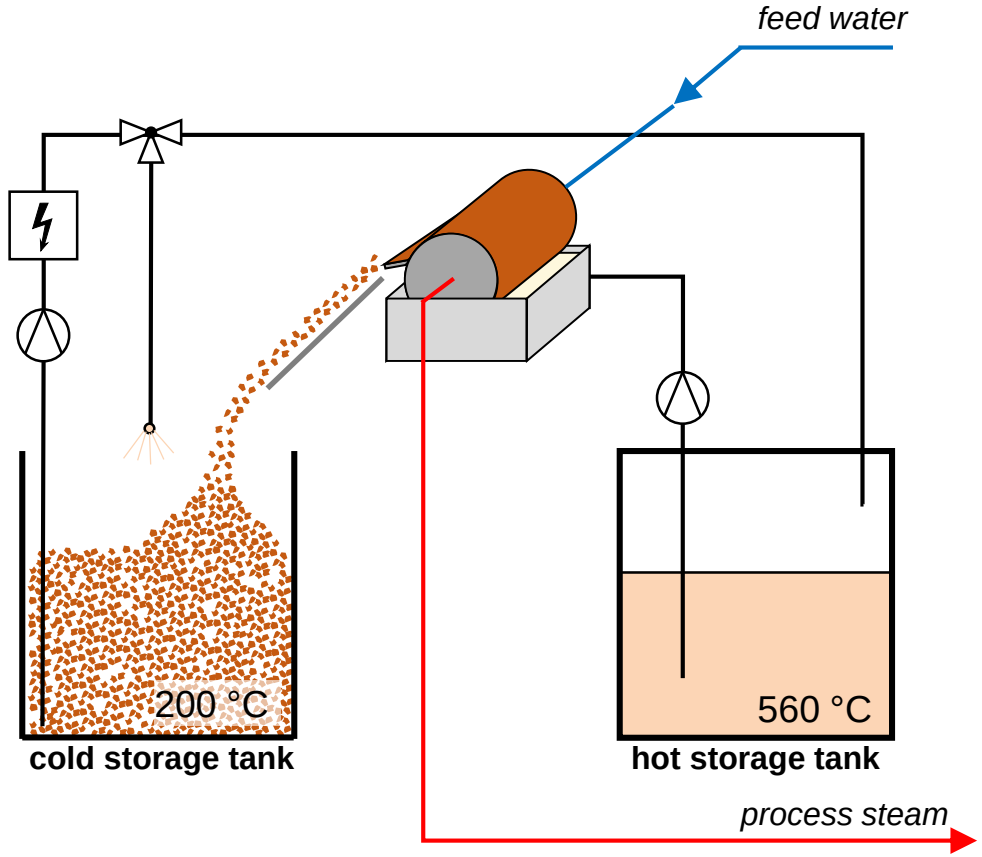




- State of the art 2-Tank molten salt storages: **400 kJ/kg | 195 kWh/m³**

Increased Storage Density





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- Extended PCM Storage with $NaNO_3/KNO_3$(eu): **640 kJ/kg | 310 kWh/m³**

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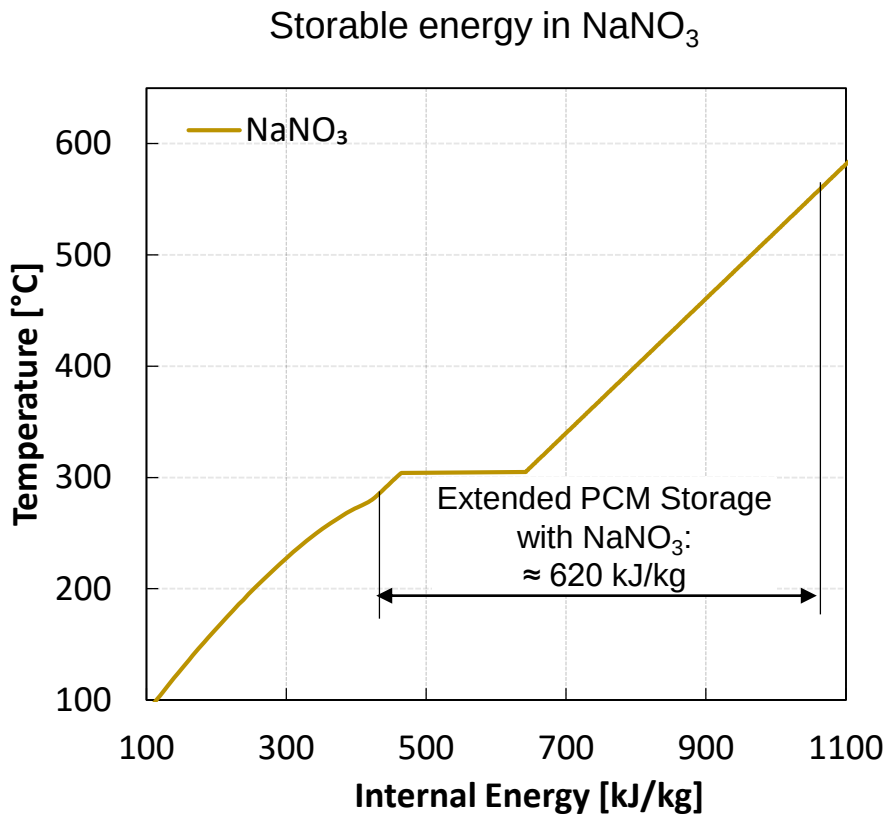

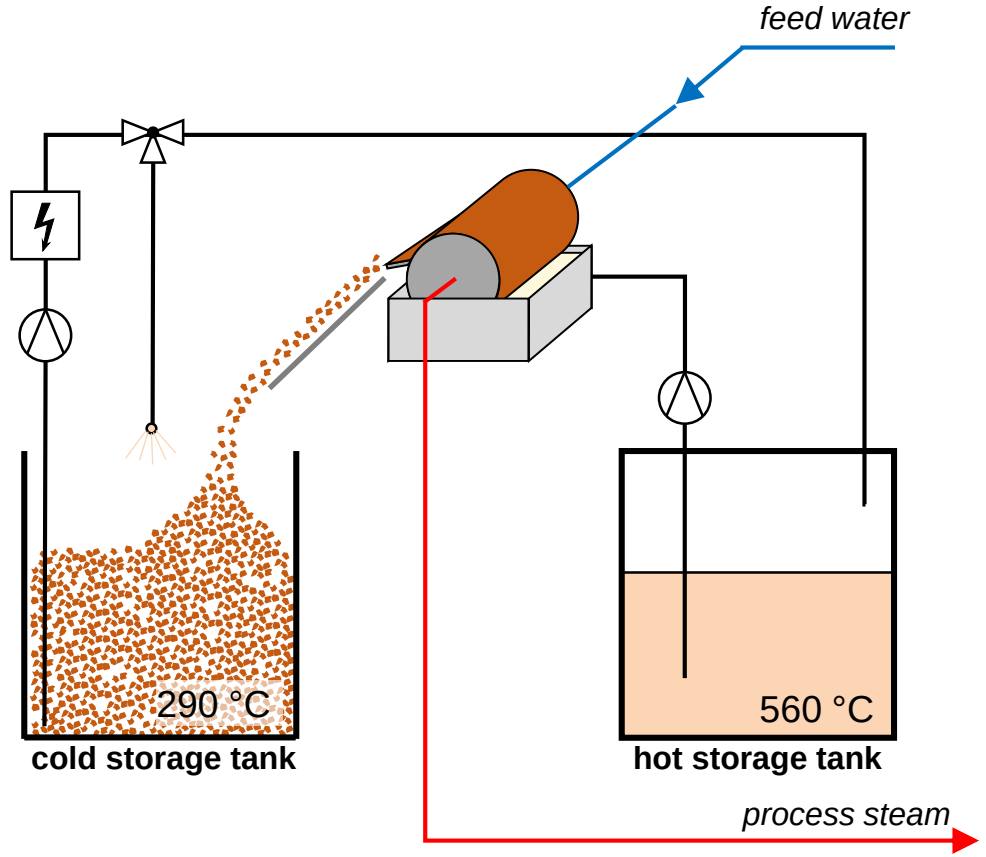

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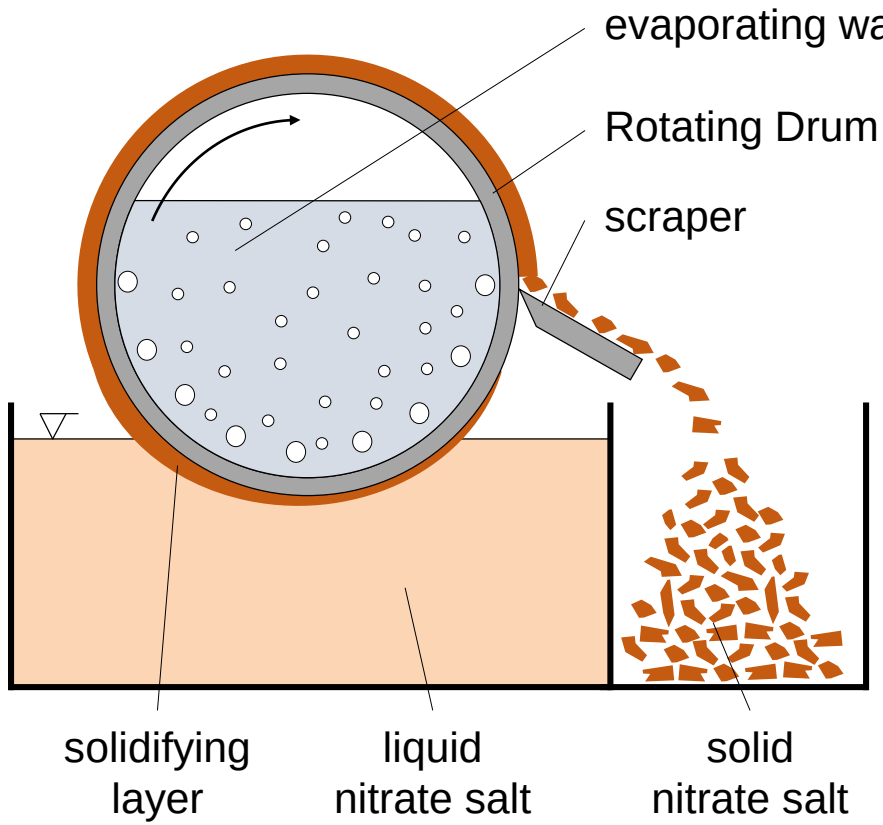
- Extended PCM Storage with $NaNO_3$/KNO_3(eu): **640 kJ/kg | 310 kWh/m³**
- Extended PCM Storage with $NaNO_3$: **620 kJ/kg | 305 kWh/m³**
- **Reduced Tank Size (-38%) and less/cheaper storage material reduces investment costs**

The Rotating Drum Heat Exchanger

- Hollow drum partially immersed in liquid Phase Change Material (PCM)
- Solidification at the outer side
- Evaporation inside the drum
- Stationary scraper removes solid PCM
- Separation of solid and liquid PCM

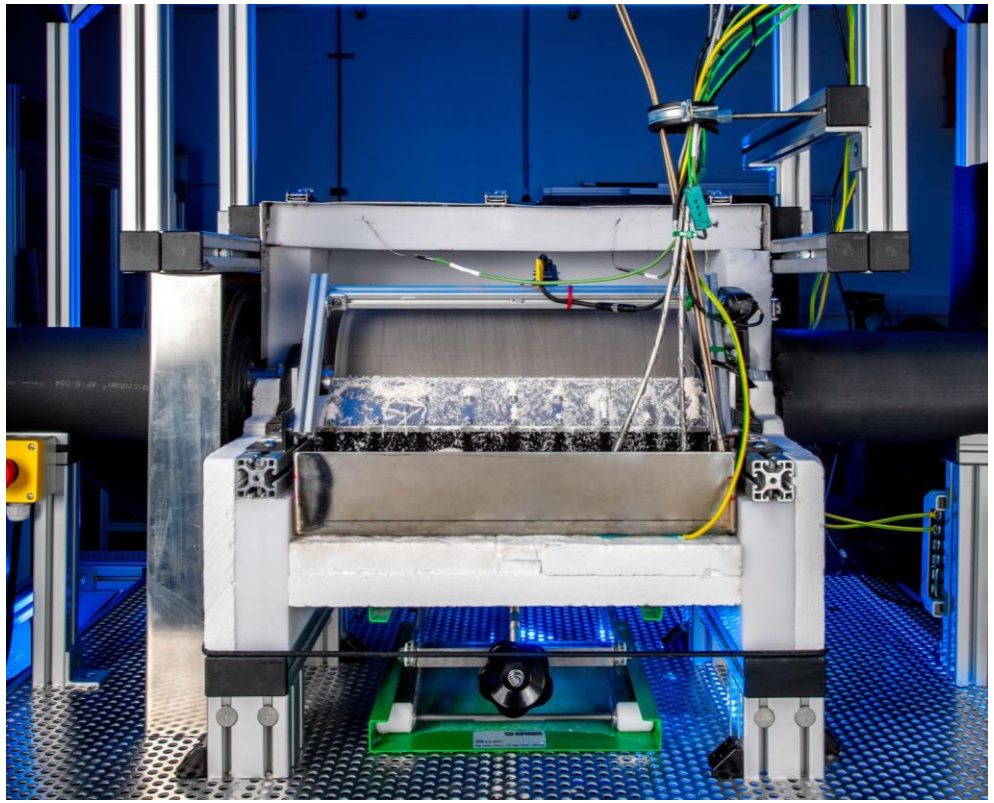


- Total separation of thermal power and storage capacity
- Thin solid PCM layer for high surface specific heat transfer
- Heat transfer controllable by adjusting the rotational speed

Previous Test Rig and Results

Proof of Concept

- Low temperature PCM and liquid water as HTF
- Transferred heat >1.5 kW at ΔT=5 K



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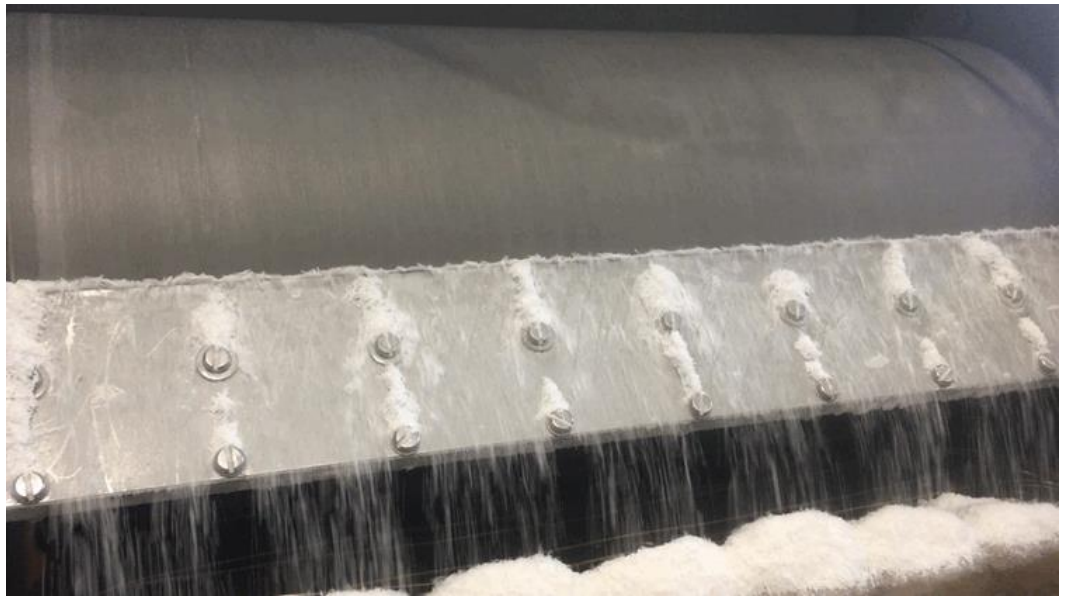

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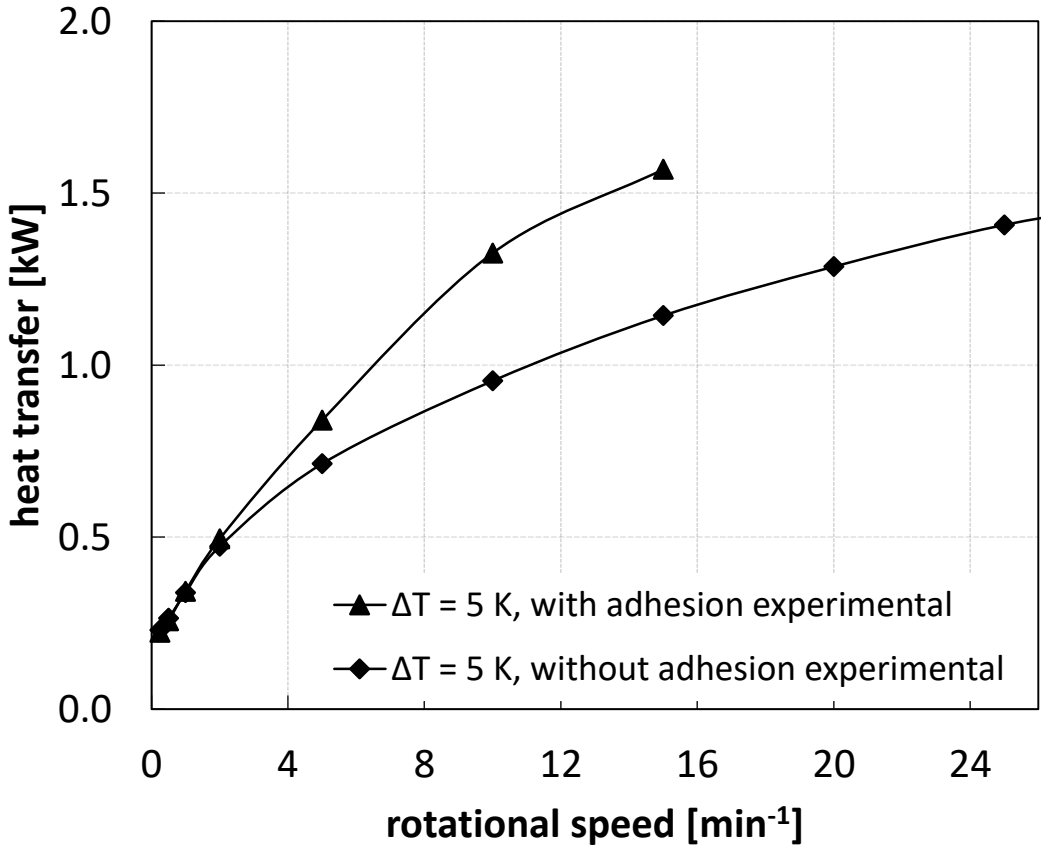
Experimental Investigation

- Transferred heat depends on rotational speed
- Adhesion increases heat transfer by up to 60%



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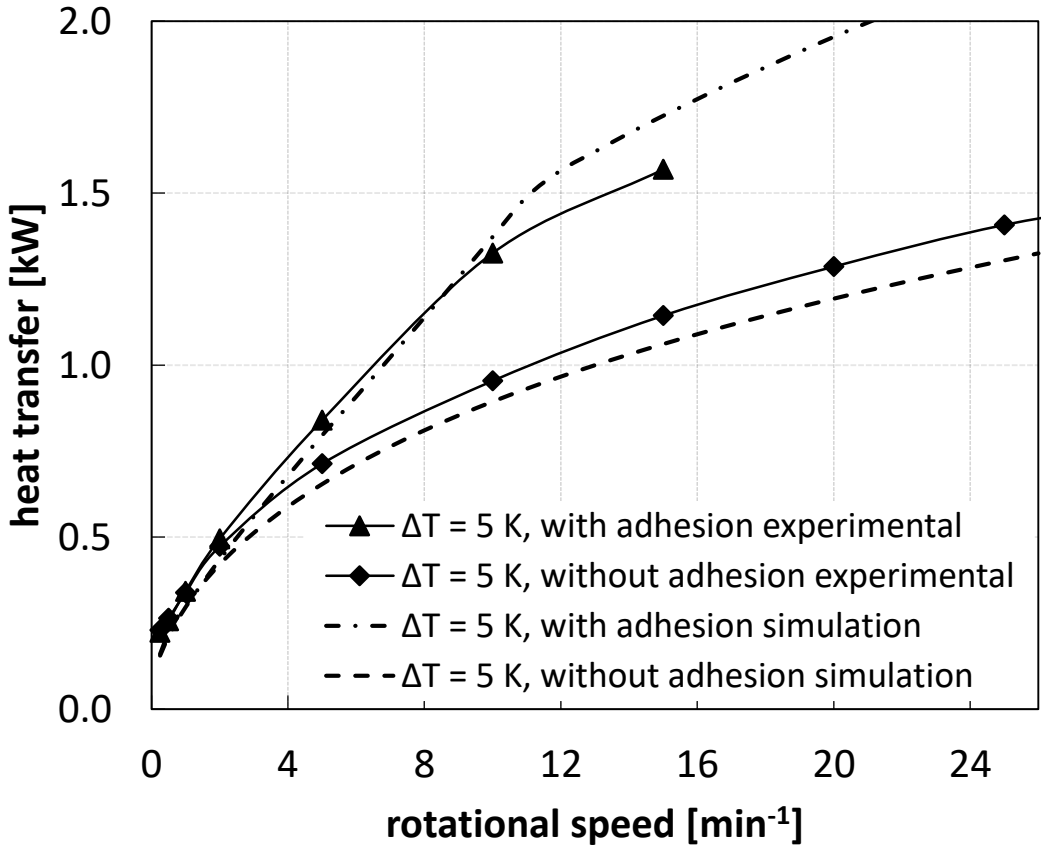
Validated Simulation Tool

- Transient 1-D numerical simulations
- Model error of 8% on average



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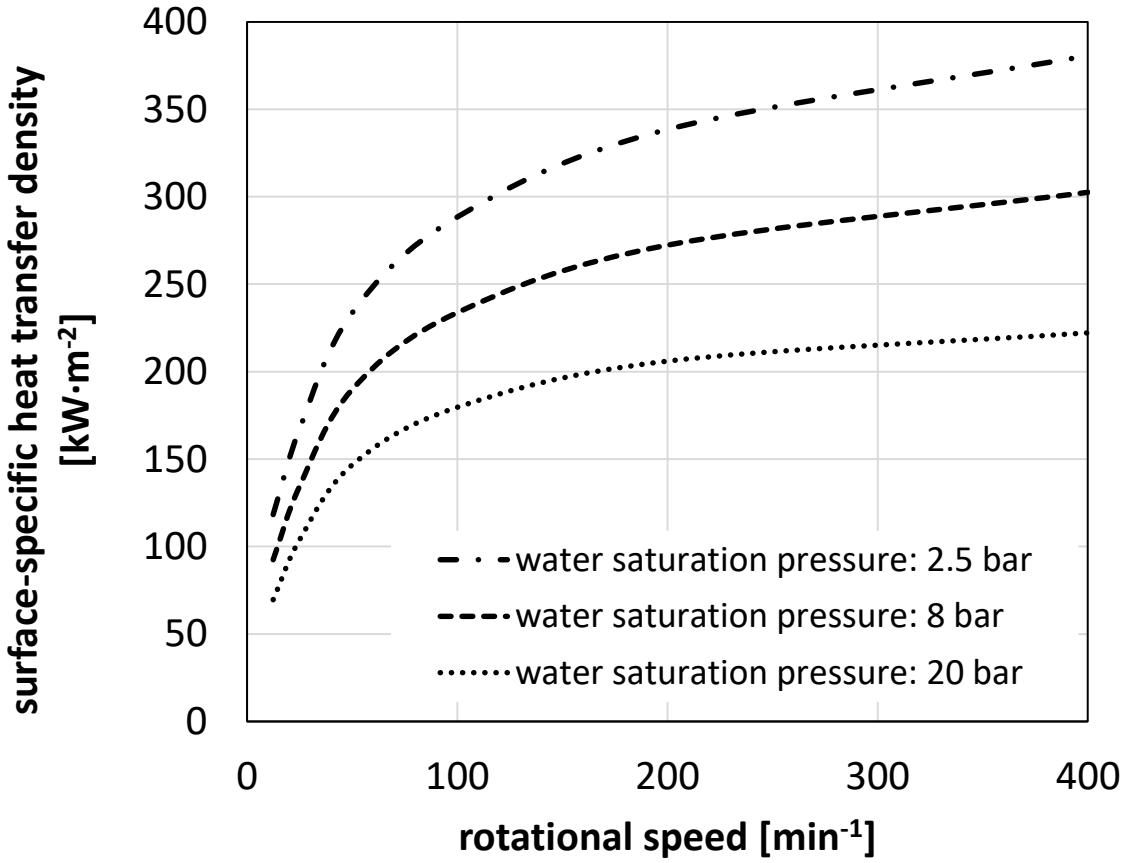
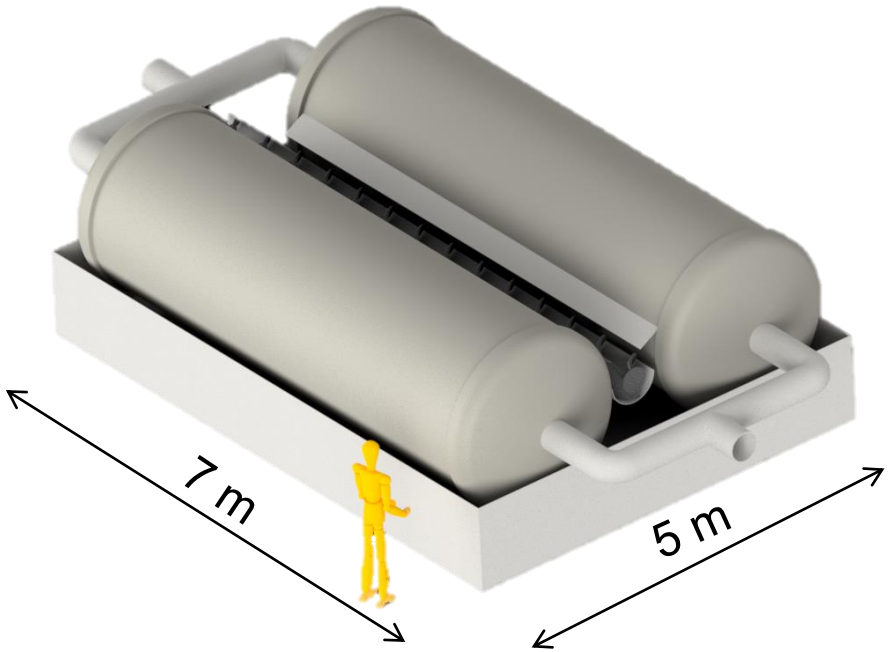
Simulation of High Temperature System

- Heat transfer density of above to 340 KW·m^{-2}



Potential of high temperature system

Thermal power of a Rotating Drum using $NaNO_3$ as PCM



15 MW at 20 bar saturation pressure

20 MW at 8 bar saturation pressure

25 MW at 2.5 bar saturation pressure

- Suitable for medium scale industries
- Further scalable into powerplant scale
- Required surface area comparable to current steam generators

Scaleability of high pressure systems

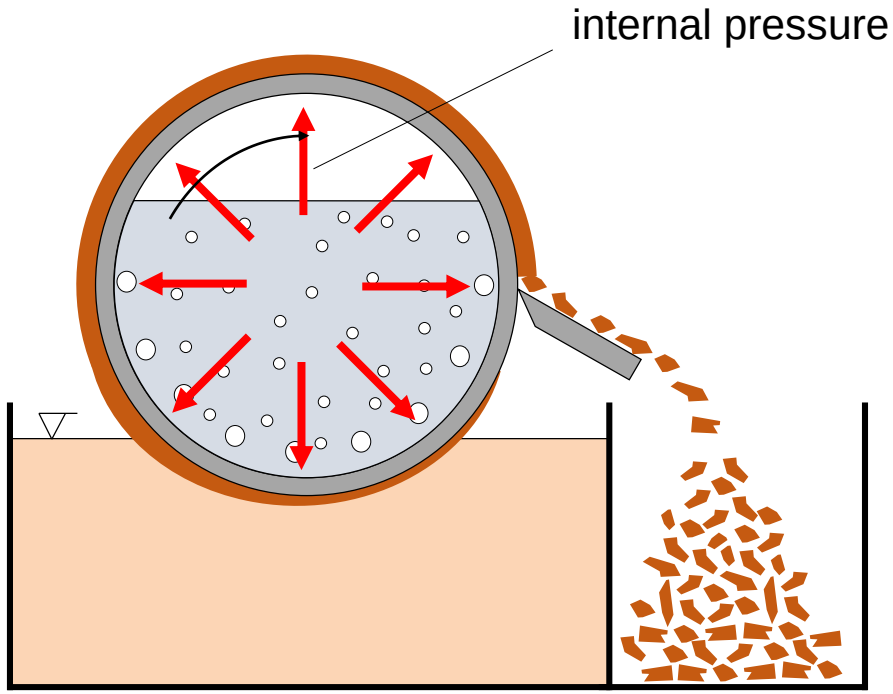
Drum shell wall has to withstand internal pressure

- Barlow‘s Formula (Kesselformel):

$$s = \frac{p \cdot D}{2 \cdot \sigma}$$

s = required shell thickness
p = internal pressure
D = drum diameter
σ = yield strength of material

- Drum shell wall harms heat transfer significantly



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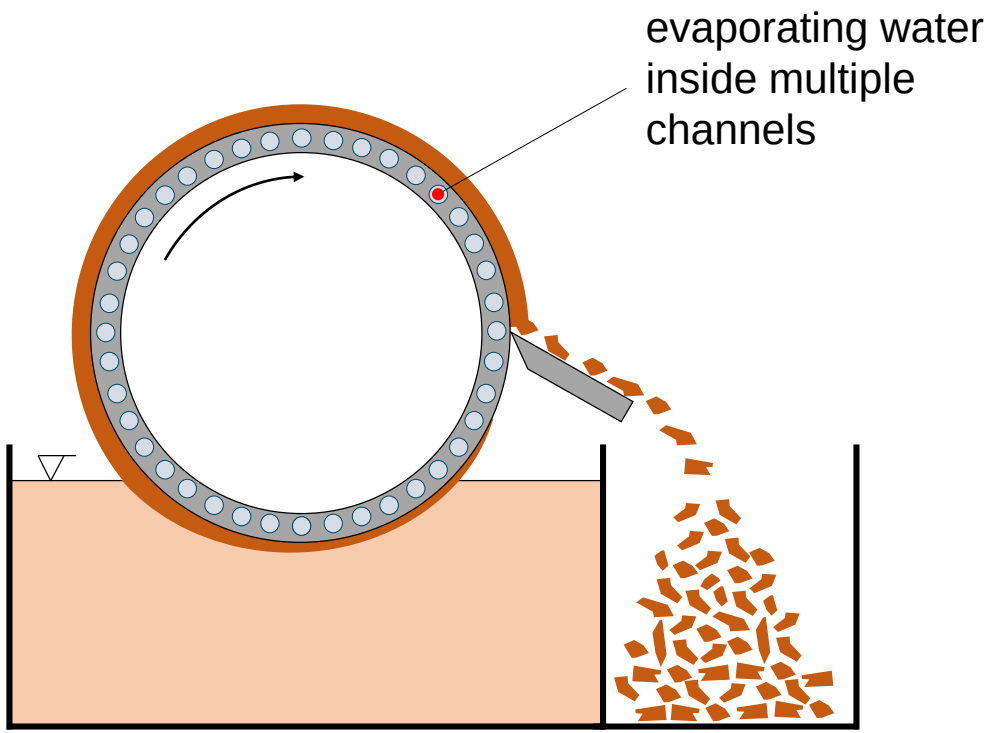
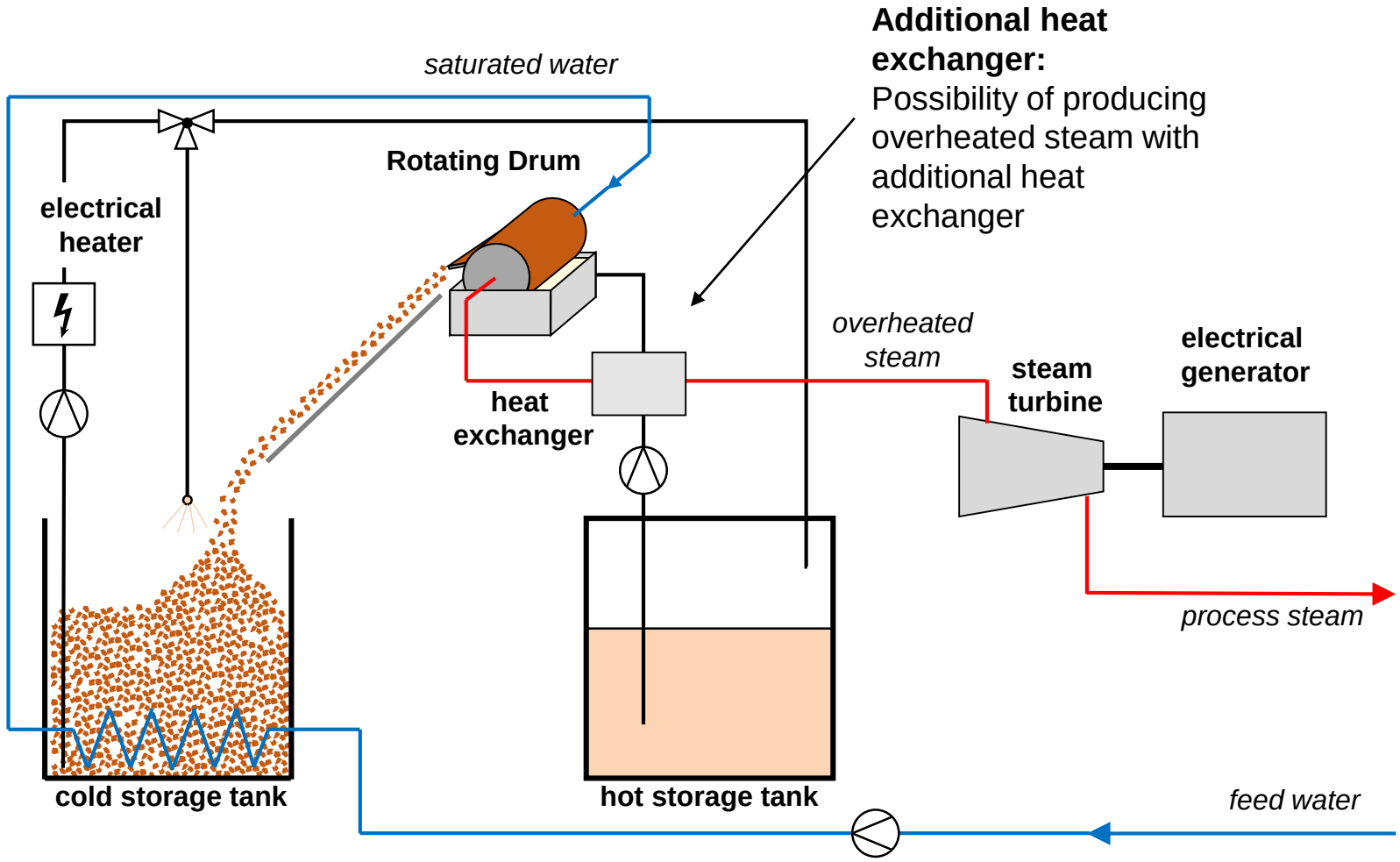
Solution: Multiple Channel Drum

- Multiple small channels within the drum shell
- Freely scalable design

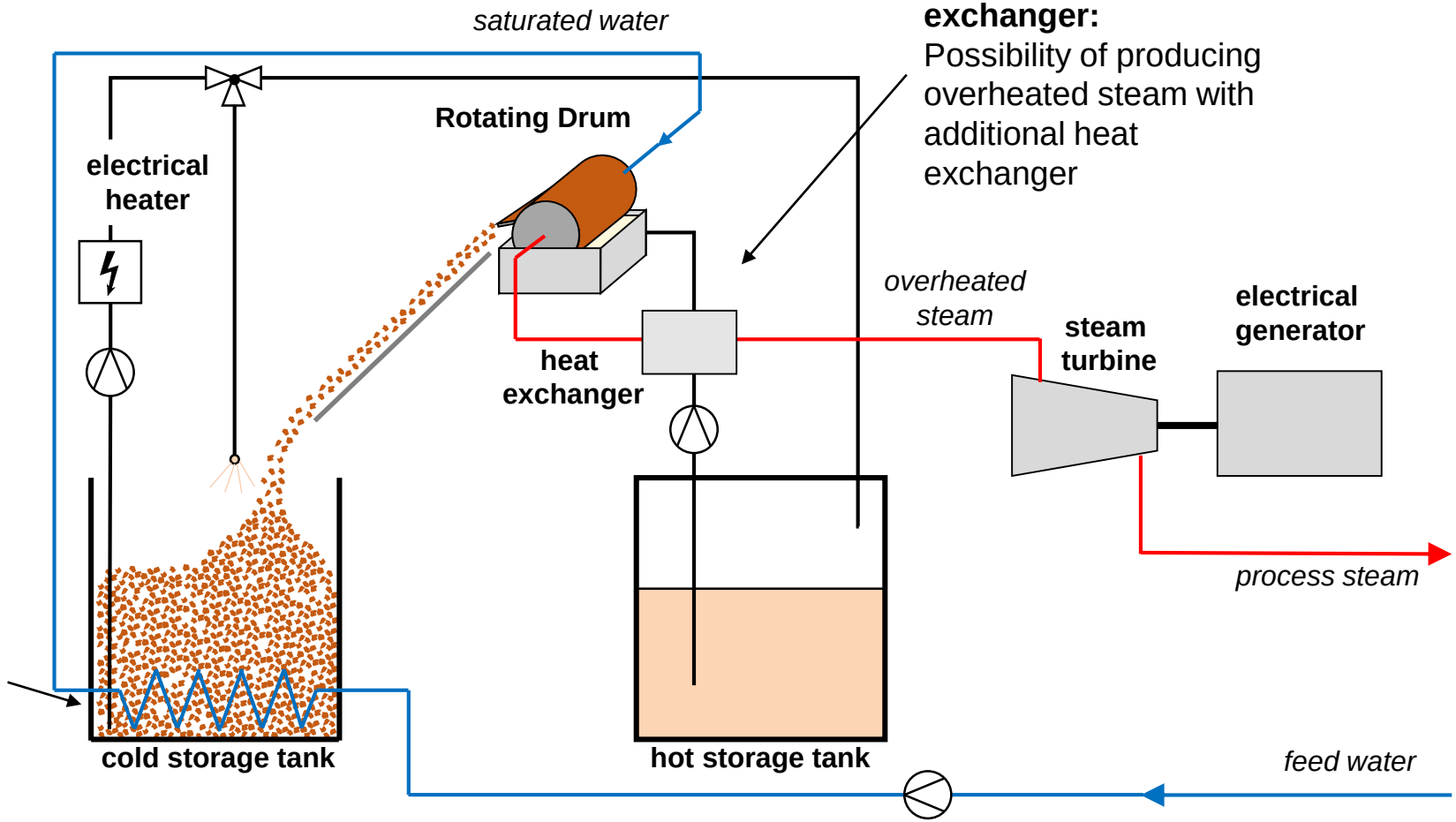


Full steam (co-)generation system



Full steam (co-)generation system

Additional heat exchanger:
Possibility of producing overheated steam with additional heat exchanger



Feed water preheating:
Further increase in efficiency and storage density by integrating a preheater into the cold storage tank

Full steam (co-)generation system

Integration of High Temperature Heat Pumps:
Up to 25 % of storable energy can be charged at a temperature slightly above the melting temperature

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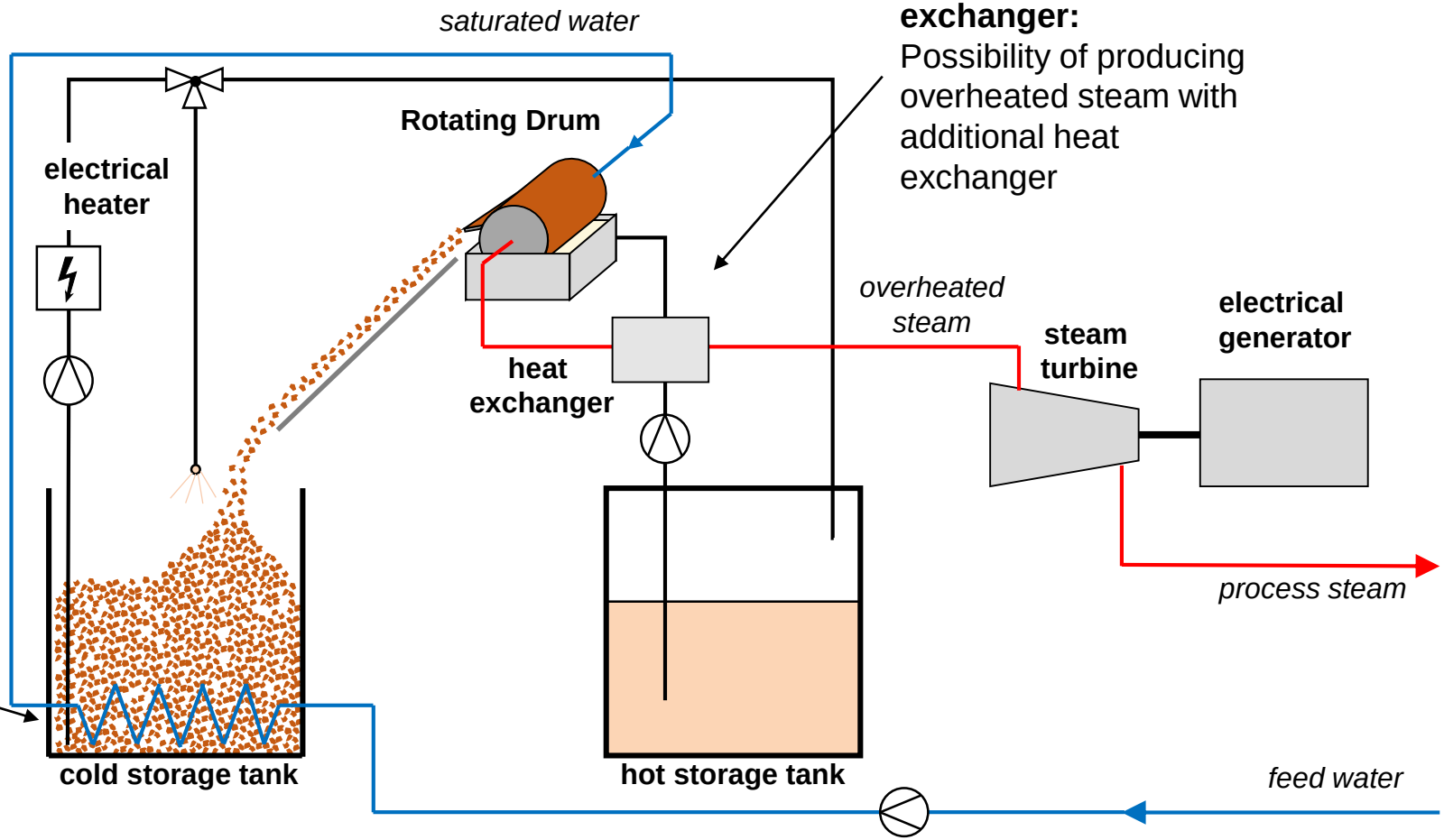
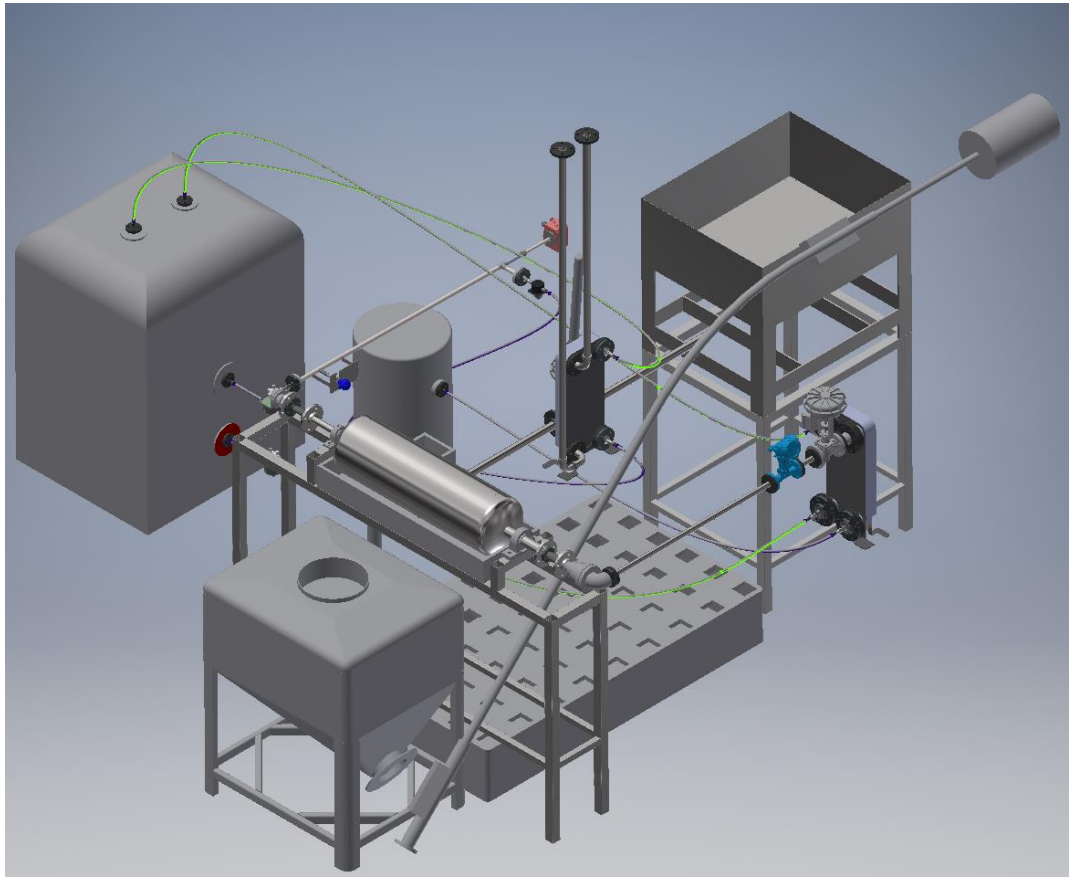


Test rig under construction

Test Rig performance parameters

- Saturated steam generation
- Storage material: $NaNO_3/KNO_3$(eu)
- Steam parameter: 8 bar (abs), 170°C
- Discharge power > 100 kW_{th}
- Charging power > 10 kW_{el}
- Storage capacity > 50 kWh_{th}
- **Commissioning and first tests in January 2023**



Impressum

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