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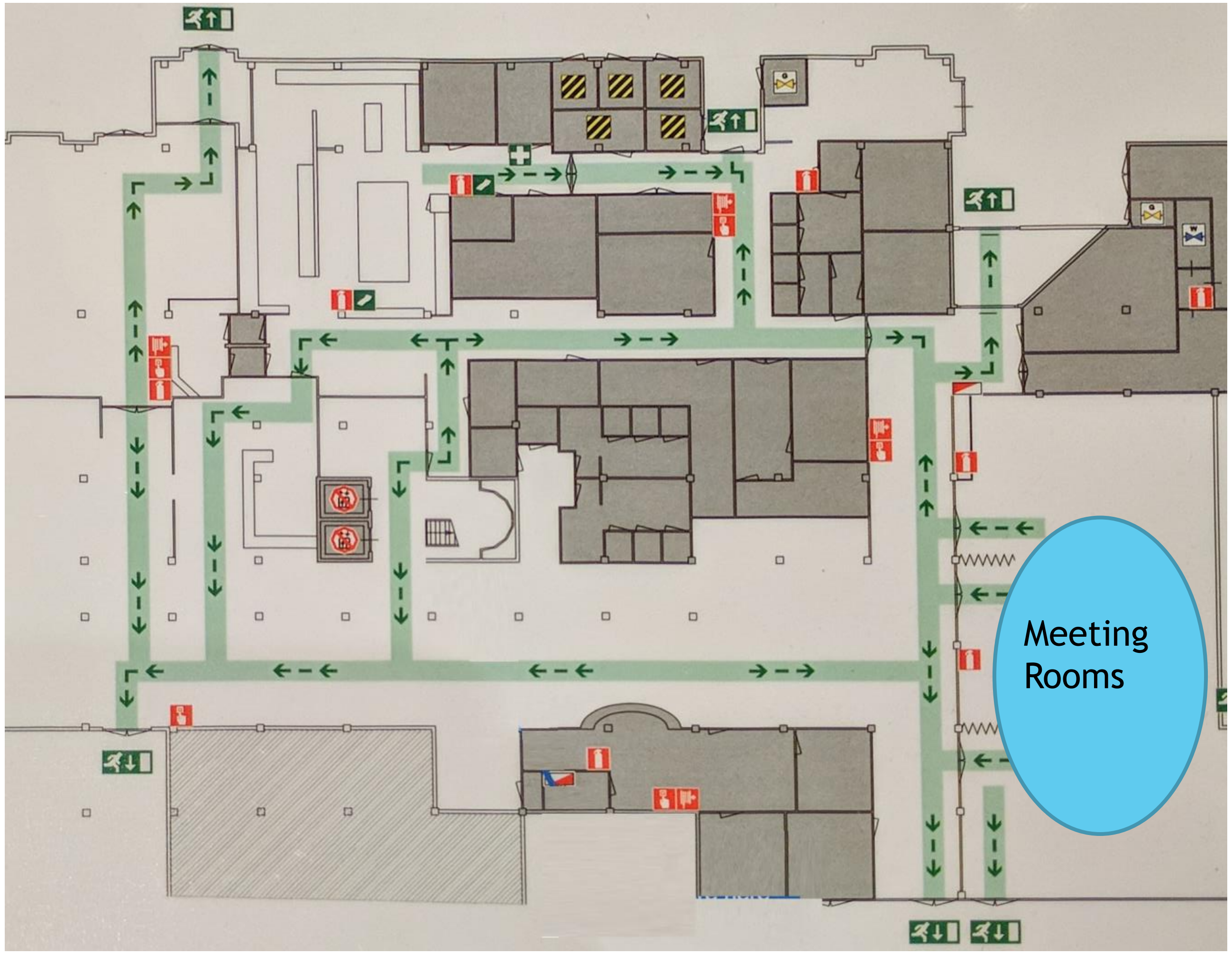

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Today's Topic

'Electrification of Heat - Thermal Energy Storage'

By Peter Rop, Head of Product Development, and Ed Roovers, Senior Key Specialist

NEM Energy


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NEM Energy – Introduction

October 2025

NEM Energy Group Portfolio

From design to aftermarket services

Heat Recovery Solutions

- Heat Recovery Steam Generators (HRSG)
- Waste Heat Recovery Units (WHRU)
- E-Heaters (development)

Exhaust & Diverter Solutions

- Exhaust gas bypass Systems
- Simple cycle exhaust stacks
- Tempered SCR systems (T-SCR)
- Guillotine dampers and blanking plates
- Stack dampers
- Louver dampers

Heat Exchanger Solutions

- Moisture Separator Reheaters (MSR)
- Rotor Air Coolers (RAC)
- Feedwater/District heaters
- Turbine Condensers
- Wet cooling towers
- Heat Exchangers with special requirements

Aftermarket Services

Providing:
Refurbishments, modifications, inspections, engineering services, LTSAs, spare parts, and more..
to:

- Heat exchangers
- HRSGs
- Exhaust & Diverters
- Boilers
- Cooling towers

LTSA=Long term service agreements

Our contribution to the energy transition

Heat exchangers
Geothermal applications for renewable power

DrumPlus™
Allowing fast start-up and flexible operation

H2 readiness
First H2 certified HRSG company in the world

Alternative Cycles
WHRU for ORC, sCO_2, and other fluids/gasses

Ultra-Light Bottoming Cycle
Reducing off-shore CO_2 emissions

Electrification of heat
E-heaters and electrical hybrids

MSRs for SMR
Small Modular Reactors for power generation and thermal storage

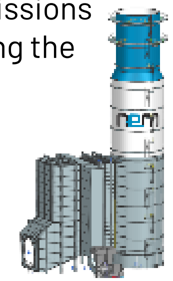
Under development

HRSGs since 1960s Highly Efficient reducing CO2

Vertical Once-Through
Highly efficient & quick installation

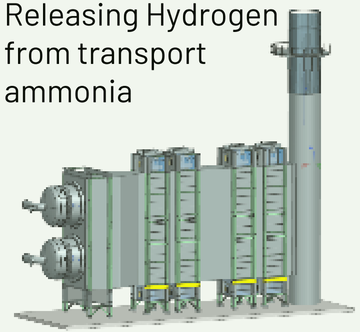
Energy Storage
OTSG in thermal storage application

T-SCR
SCR for single cycle operation
Reducing emissions and supporting the grid stability



Molten salt storage
Adding a molten salt thermal storage application

Ammonia cracker
Releasing Hydrogen from transport ammonia



Under development

Flexibility and reliability (Growth renewable energy)

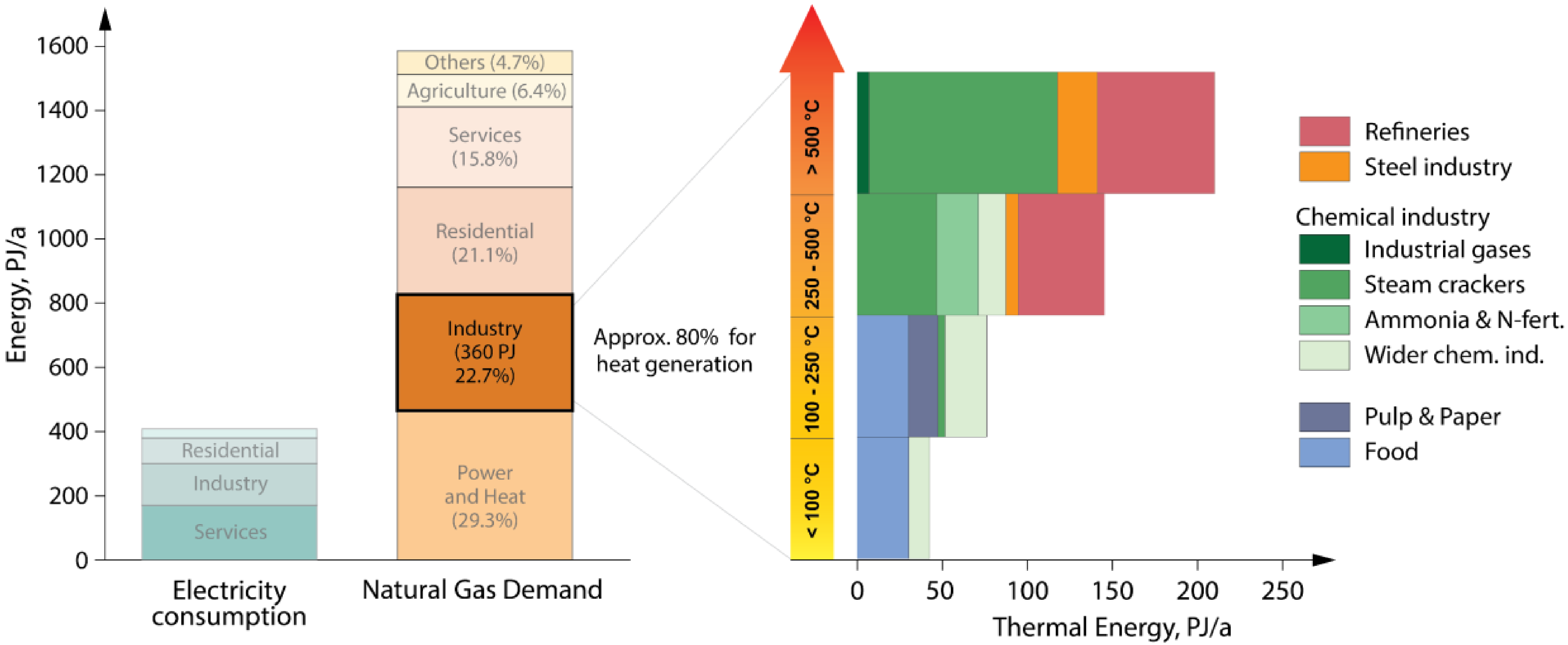
Efficiency (Lowering LCoE)

Air Quality (Minimizing NO_x)

Climate change (Reducing GHG)

Electrification of Heat – Update

Industrial Heat in The Netherlands (2018)



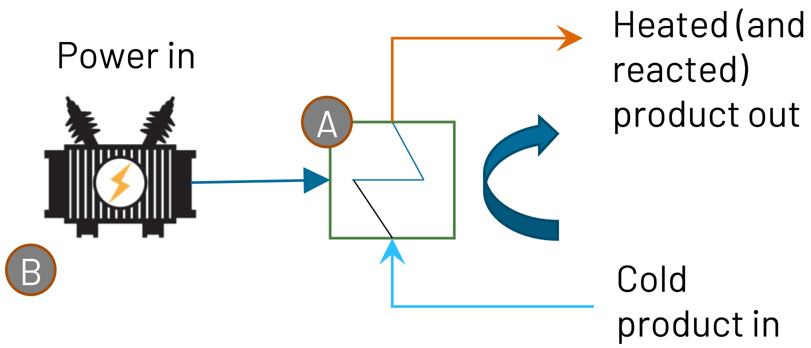
Data from CBS and IEA The Netherlands Energy Policy Review, 2020

Project 6-25 Technology Validation, 2018, Royal HaskoningDHV

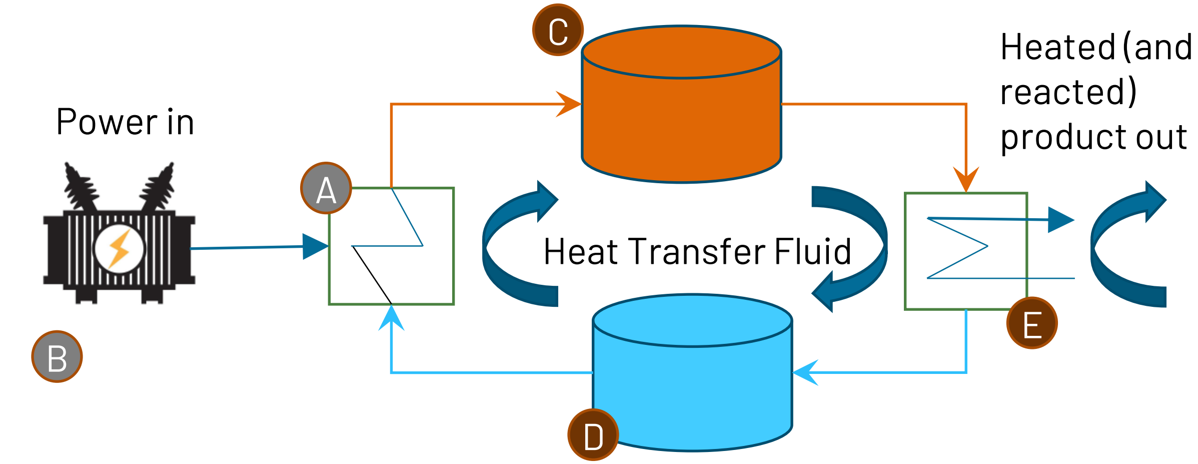
The process industry is one of the most challenging sectors to defossilise, efficient use of electricity is crucial!

Electrification of heat principles

1. Direct electrification of heat



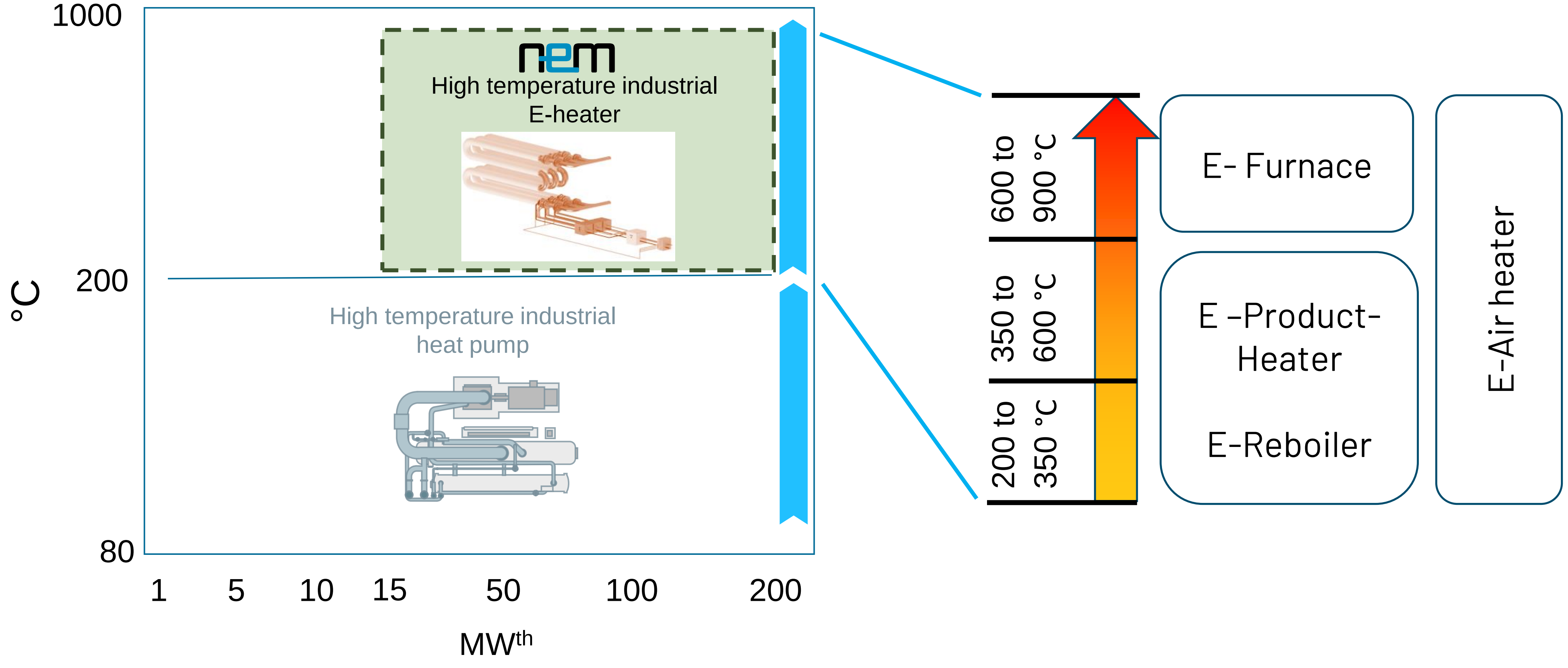
2. Indirect electrification of heat, with Thermal Energy storage



Decoupling demand from grid supply enables continuous operation of processes at best price/ maximizing use of renewable energy

High temperature & industrial scale E-heater

Output range industrial heat pump & electric heater



3 Vectors of E-Heater development @ NEM

3 electric heating principles targeted (there are more like microwave or (sp)arc)

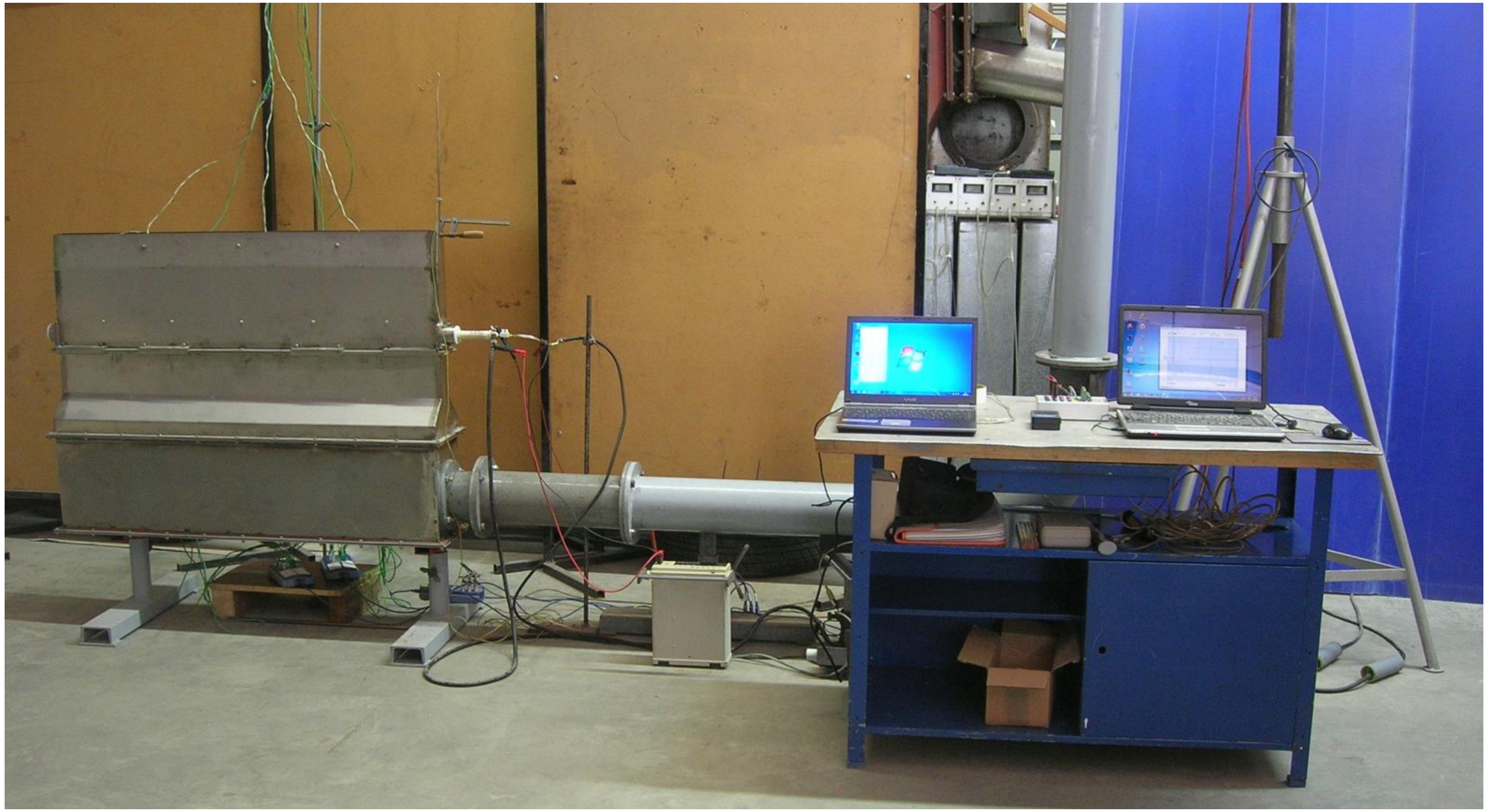
- Resistive heating
- Inductive heating
- Radiative heating

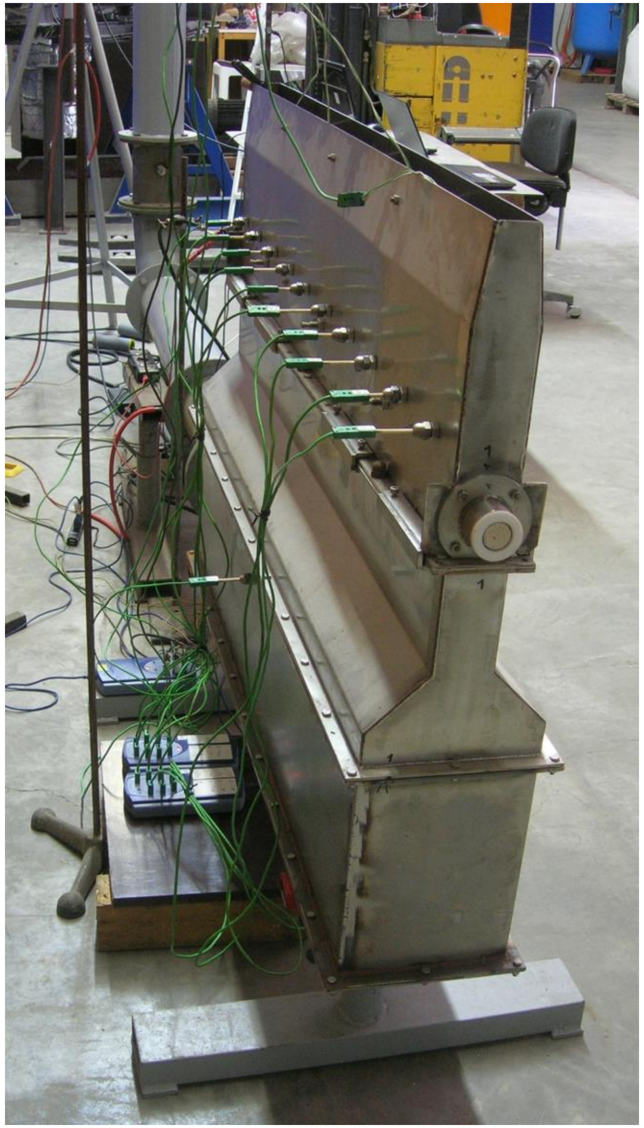
These look most promising considering size, fluid handling, operating conditions of fluid, maturity etc.

Important design aspect is how to keep the electrics separated from the operating fluid (no direct contact, no electric conductors having to penetrate pressure parts etc.)

Other main issue: large power means high voltage preferred (>10kV) to keep currents, cables, transformers limited. High electric insulative strength req'd i.e. large distances between conductors and "ground". Also supports have to be appropriate like glass or ceramics.

Testing newly developed Resistive heating elements





Testing newly developed Radiative heating elements

NEM participation in NL – R&D Consortia

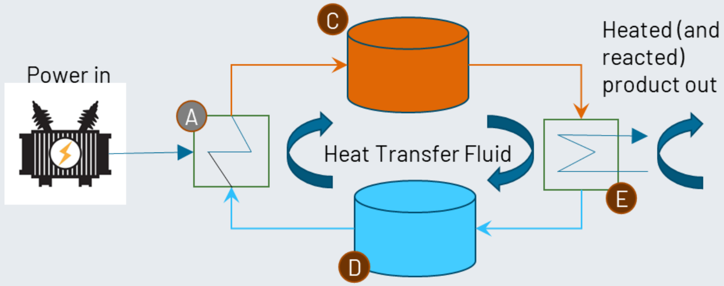
ECHOED	HyCarb
RVO funded project (MOOI call)	NWO funded project
Electrification of rWGS reactor	Sustainable production of fuels and chemicals with Green Hydrogen and - Electrons
Budget: 6 mio €	Budget: 46 mio €
10 Consortium Partners: • Lead: TNO • Academia • Petrochemical Industry • OEM's • Distribution system operator	48 Consortium Partners: • Lead: TNO • Academia • Petrochemical Industry • OEM's
NEM contribution: Design & demonstration of: • Resistive electric heating, • Radiative electric heating, • Molten Salt heating, all for endothermic reactor	NEM contribution: Design & demonstration of: • Impedance - & inductive electric heating for endothermic reactor

Thermal Energy Storage

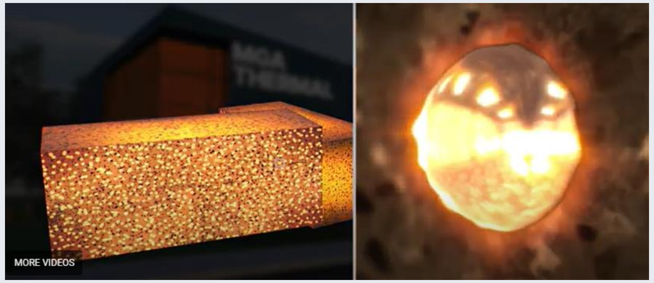
Three types of TES

Sensible heat storage	Latent heat storage	Thermo-chemical storage
Temperature change in bulk medium	Phase change in bulk medium	Reversable chemical reaction or sorption processes in bulk medium

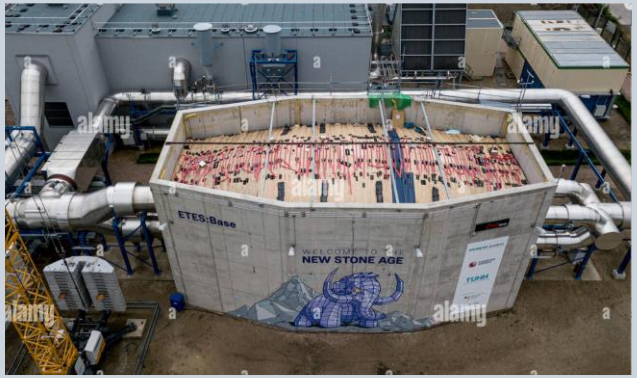
Liquid

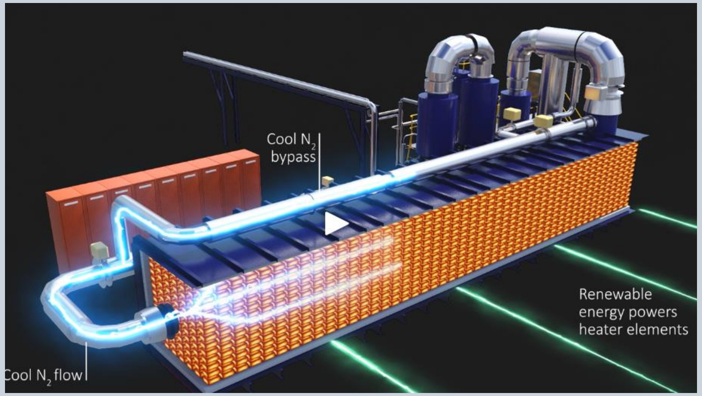


Solid <-> liquid

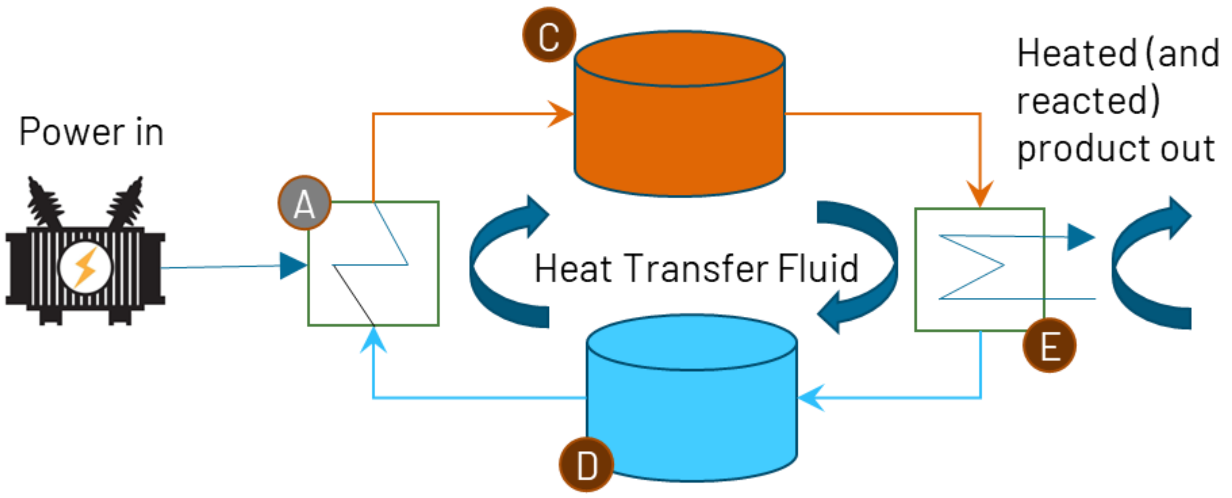


Solid





Why molten salt TES



Technology agnostic, but some clear advantages for molten salt TES

- Energy and Exergy storage (conservation): constant temperature during discharge
- High density heat transfer fluid
- Proven technology (a.o.) in Solar Thermal industry (CSP)

Molten Salt fact sheet

- Solar salt: 60-40%wt $NaNO_3$ – KNO_3 mixture
- Low cost bulk chemicals e.g. for fertilizer industry (~ 900 USD/MT)
- Completely liquid above 236 °C; completely solid below 221 °C
- Industry std. (bulk) operating temperature window: 260 - 565 °C
- Salt decomposition threshold 600 °C
- Non flammable & non-toxic
- Low vapor pressure
- High energy density (KJ/m3)
- High chemical stability (no refill over plant life time)

Proven technology in Solar Thermal Plants (CSP)

GemaSolar, 15MWe, Seville, Spain (Left) & Cerro Dominador, 110 Mwe, Atacama desert, Chile (Right)

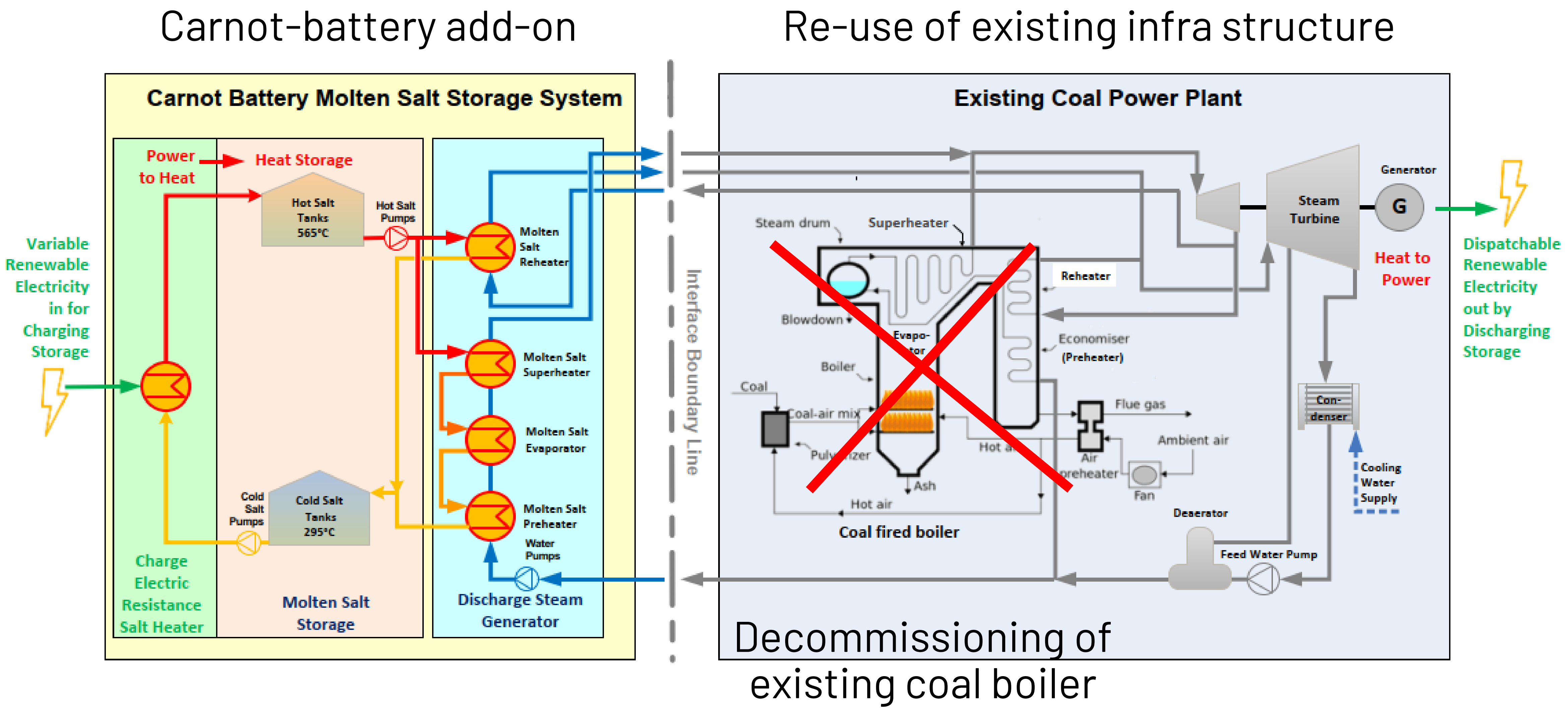
Proven technology in Solar Thermal Plants (CSP)

Solana 280MWe (gross) Solar thermal facility, 6 hrs storage, Arizona, USA

TES use case #1: Retired coal plant conversion

Angamos: 2x pulverized coal units, 488 MWe (Net)

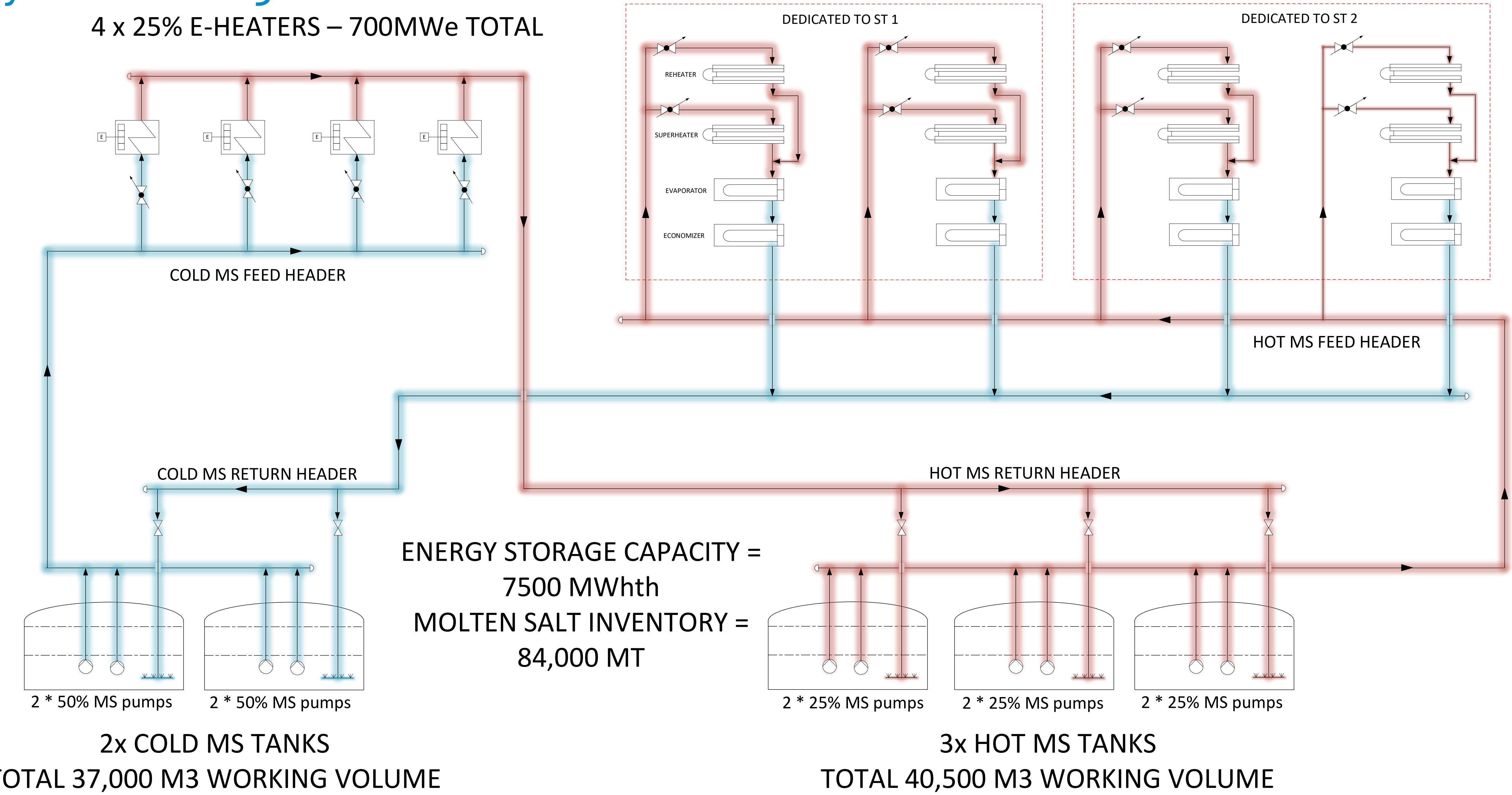
Conversion of retired coal plant into Renewable energy storage plant



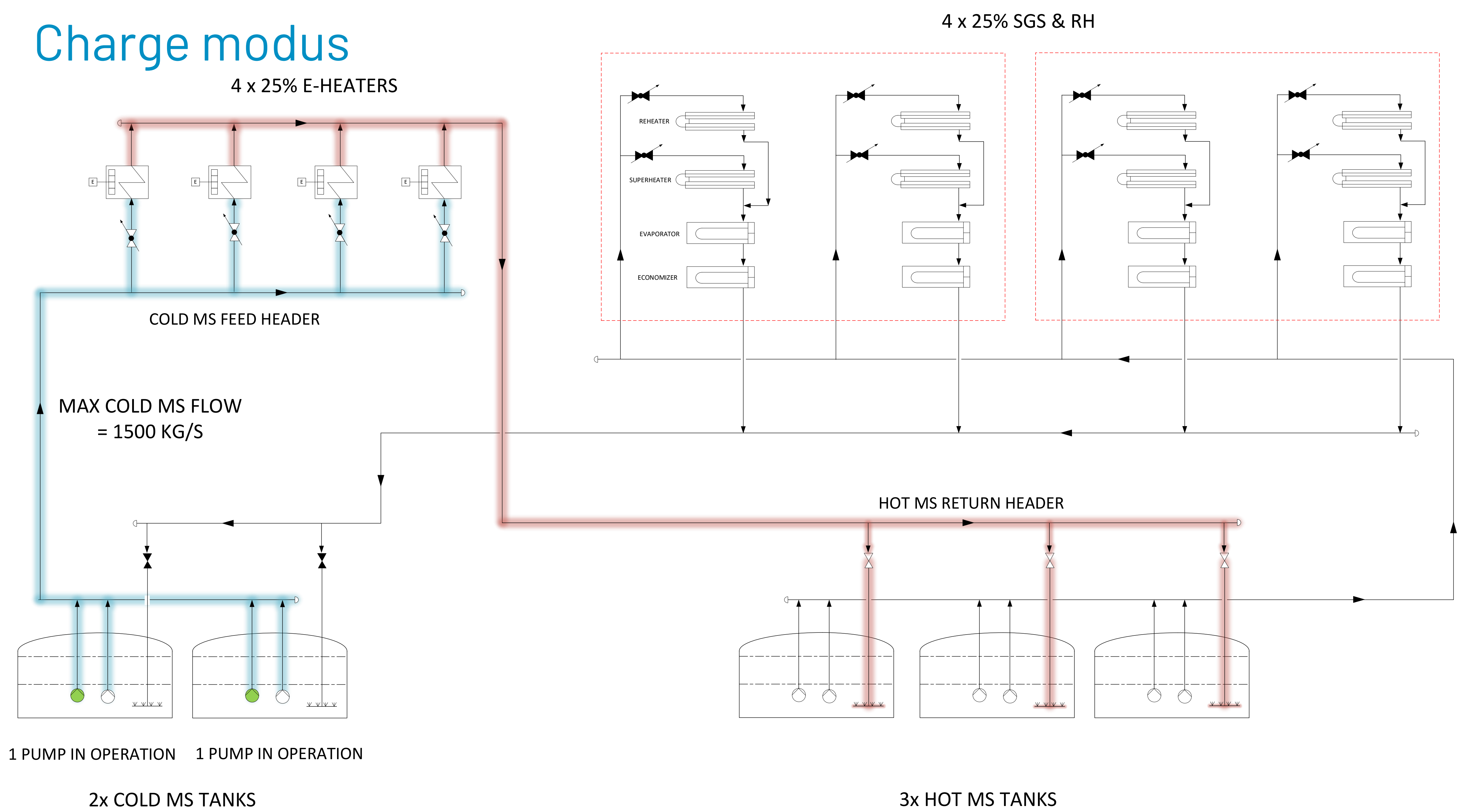
System design overview

4 x 25% SGS & RH - 1200MWth TOTAL

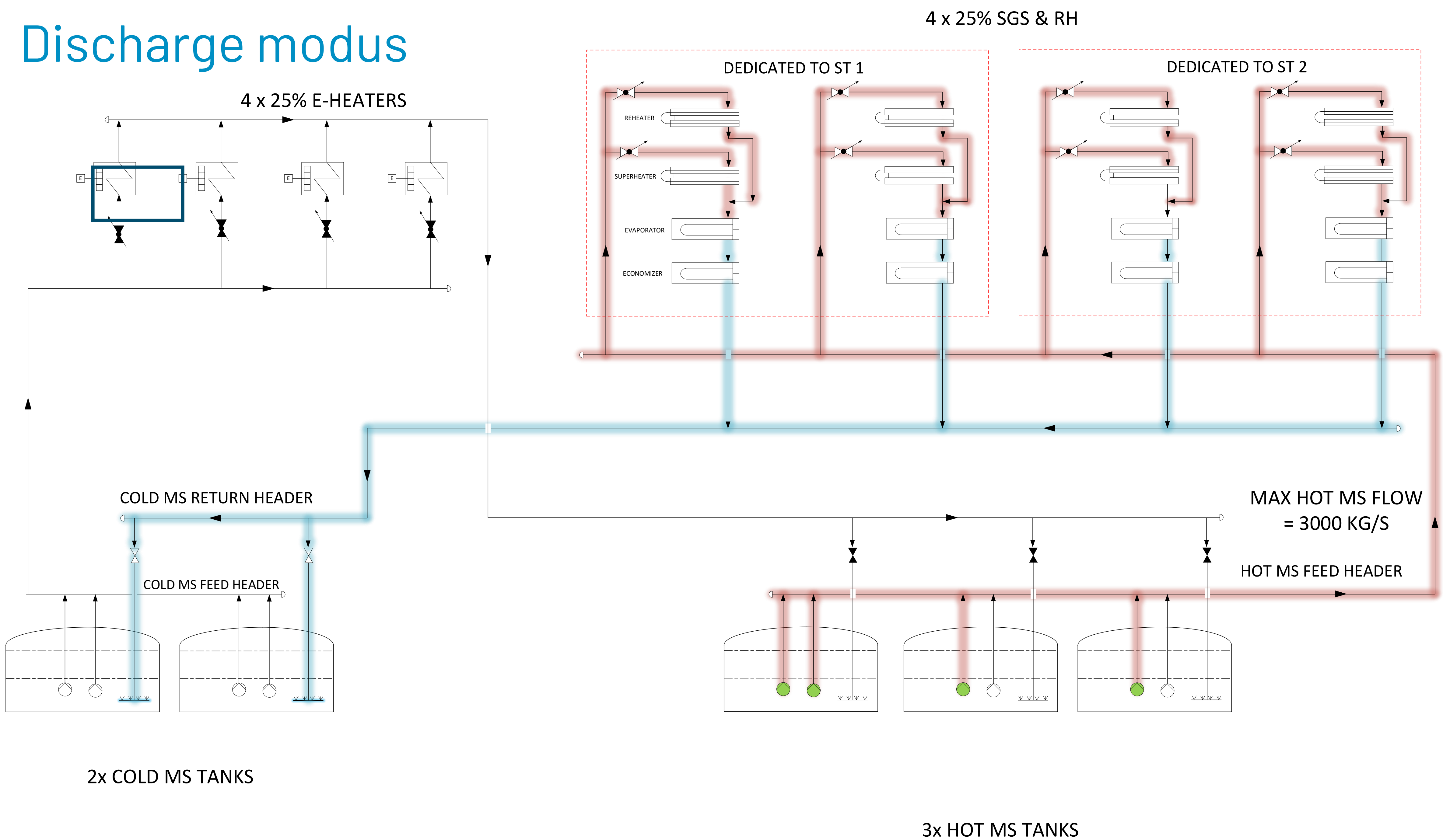
4 x 25% E-HEATERS – 700MWe TOTAL

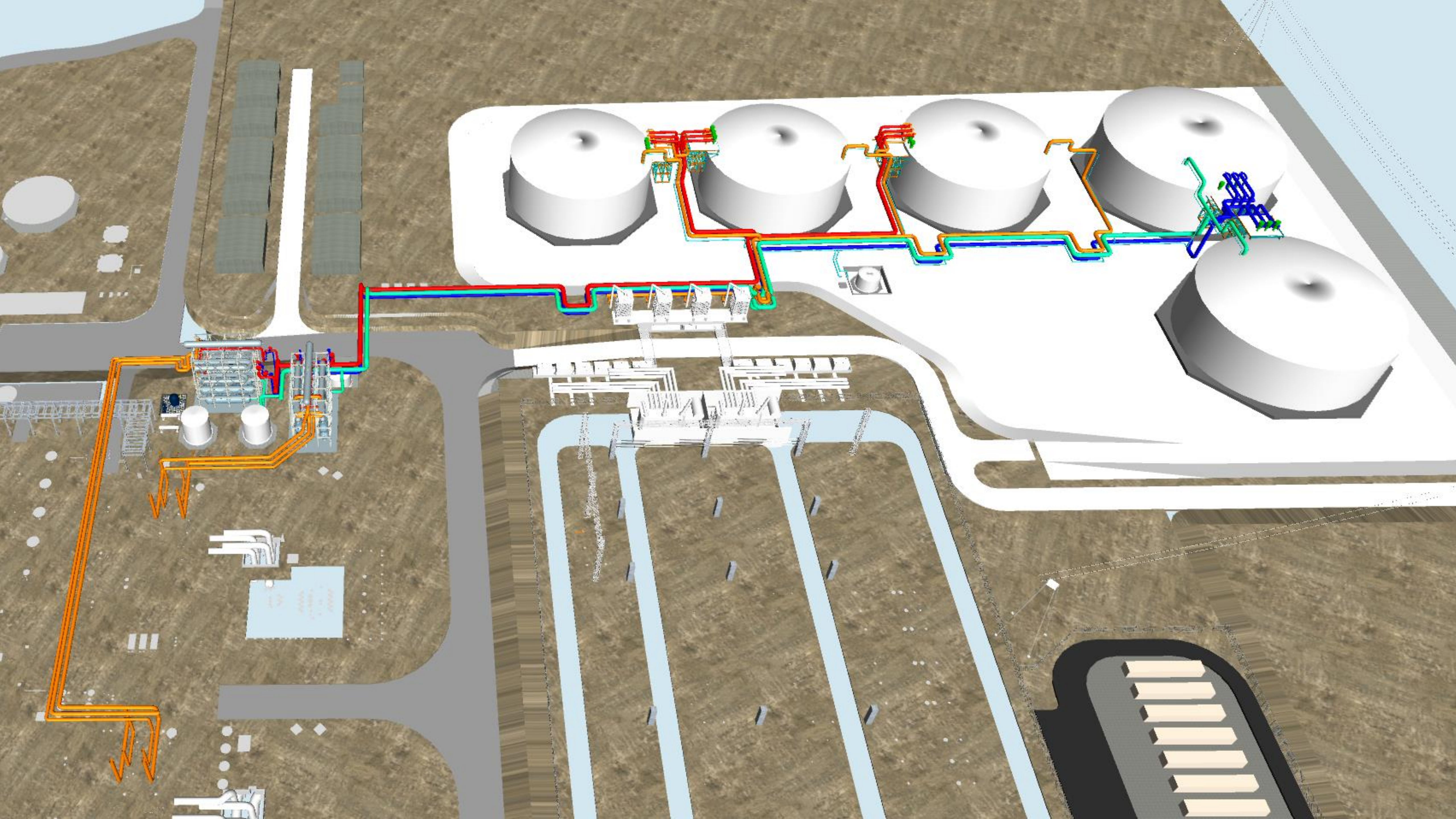


Charge modus



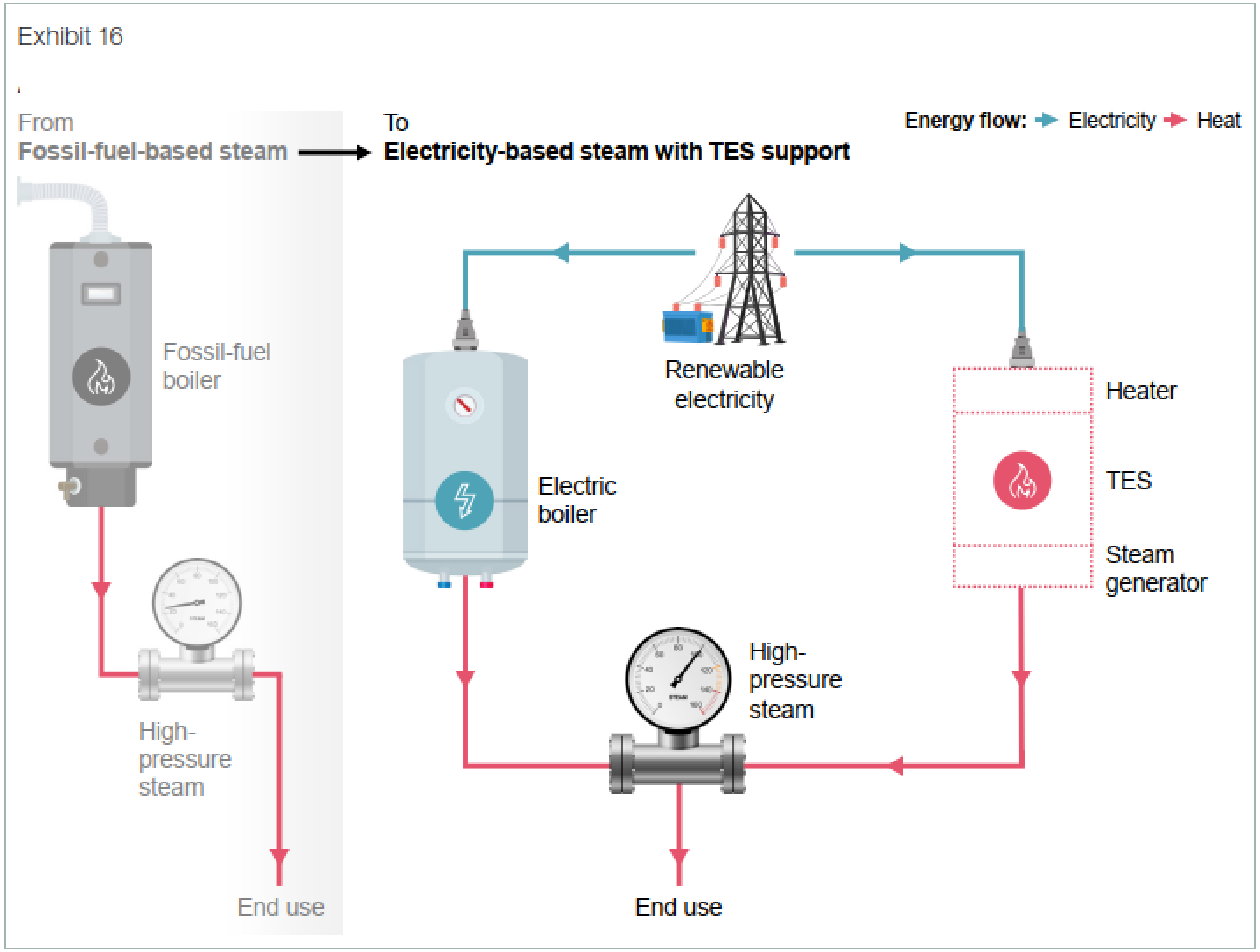
Discharge modus





TES use case #2: Green steam for specialty chemical site

Steam supply system old & new design concept



Courtesy: LDES Council / McKinsey

New Plant design concept:

- E-boiler (P2H)

- Molten Salt E-heater (P2H)
- Molten Salt Thermal Energy Storage (TES)
- Molten Salt Steam Generator (H2H)

Concept & operation either as:

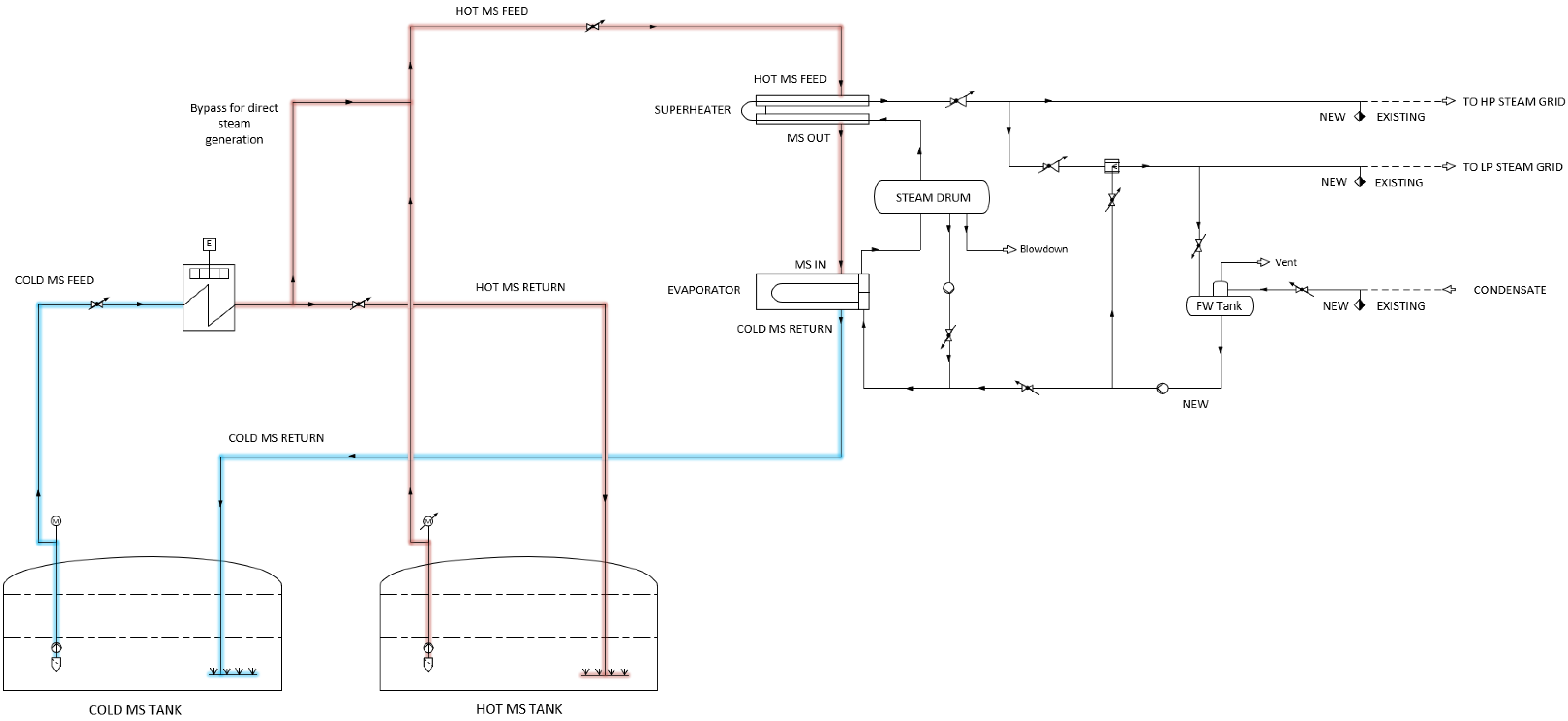
1. TES only
2. E-Boiler only (no energy arbitrage)
3. Hybrid: TES + E-Boiler

24/7 operation feasible in all options

3 variants for on-site green steam & LCOE analyses

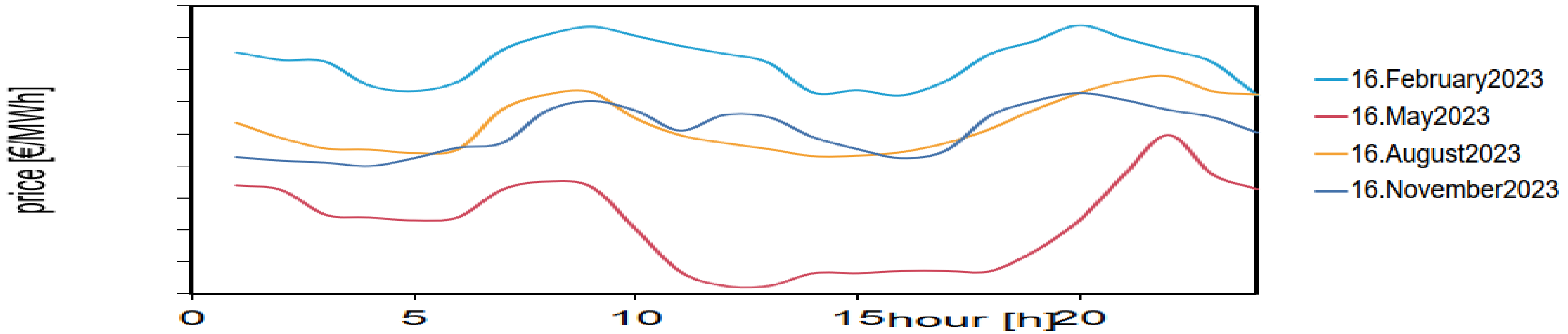
	TES 24/7	Hybrid 24/7	E-Boiler 24/7
Plant Concept	E-Heater (P2H) MS TES, with Solar Salt (*) MS SGS + SH (H2H)	E-Heater (P2H) E-Boiler (P2H) MS TES MS SGS + SH (H2H)	E-Boiler (P2H)
Steam generation	12 hrs from TES 12 hrs directly from E-Heaters	12 hrs from TES 12 hrs from E-Boiler	24 hrs from E-Boiler
Power Tariff	30% Reduced 12/24 charging tariff	30% Reduced 12/24 charging tariff	Full average annual tariff
Grid surcharge	Renumeration for flexibility @ 10 €/MWh	Renumeration for flexibility @ 10 €/MWh	Full tariff @ 25 €/MWh
TES Charging	12 cheapest hrs.	12 cheapest hrs.	n.a.

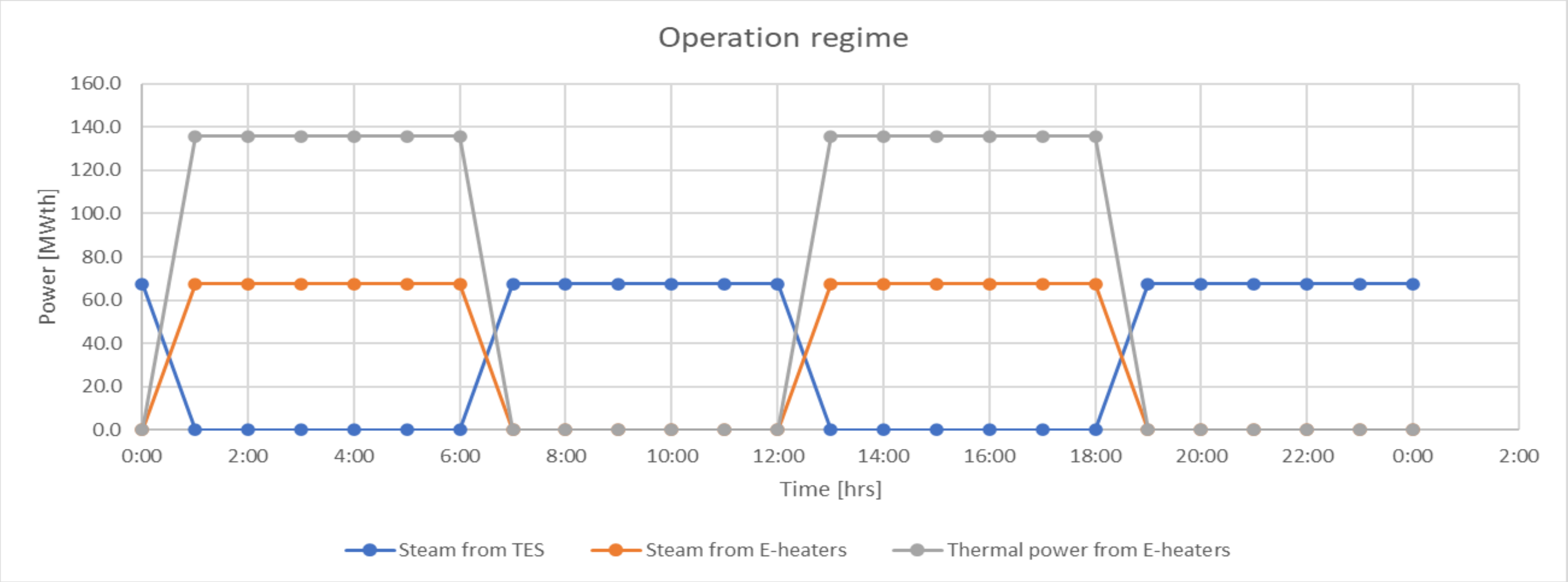
PFD for 24/7 TES



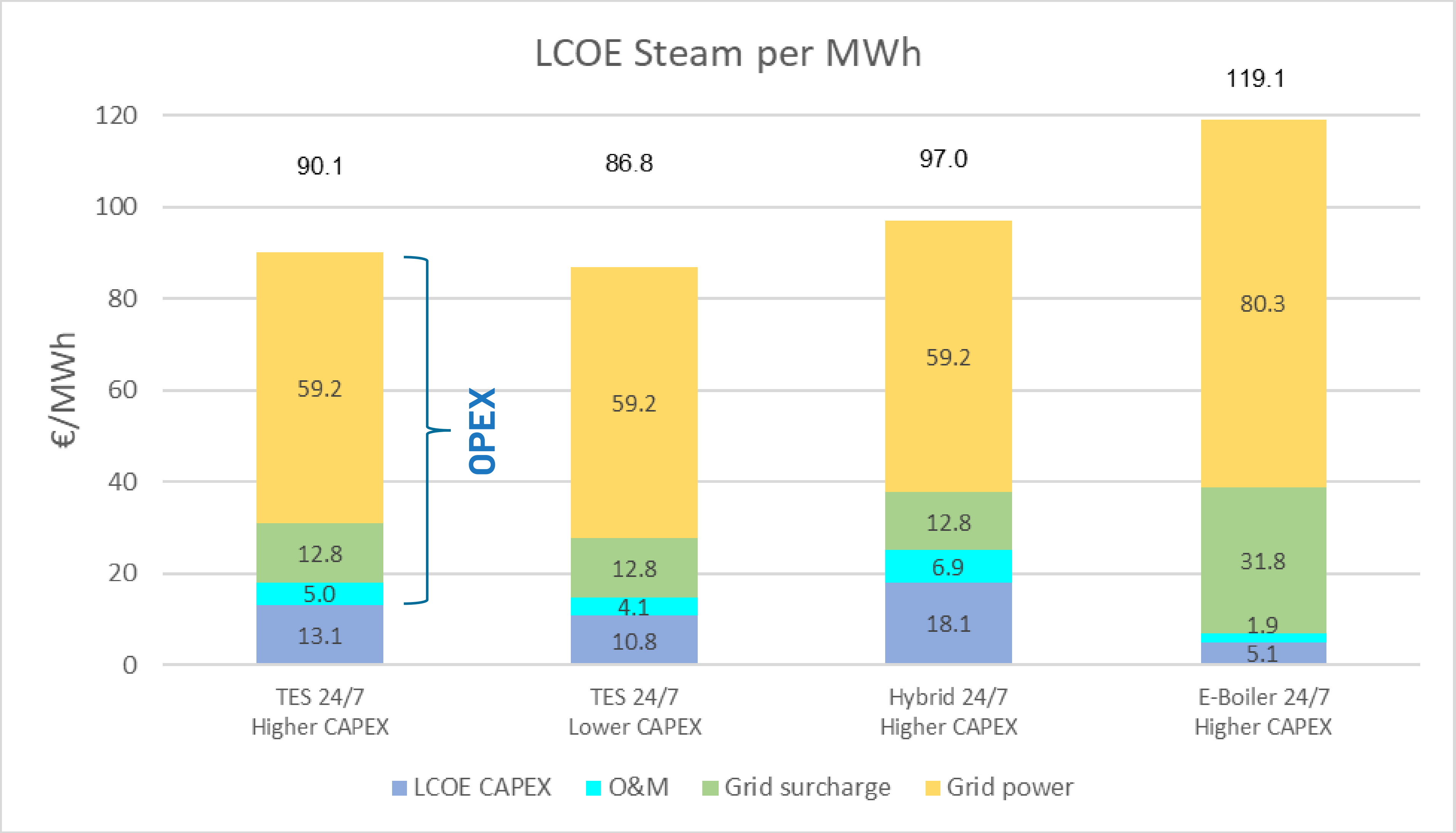
Typical TES 24/7 spring day operation scheme

Day-ahead tariff fluctuations

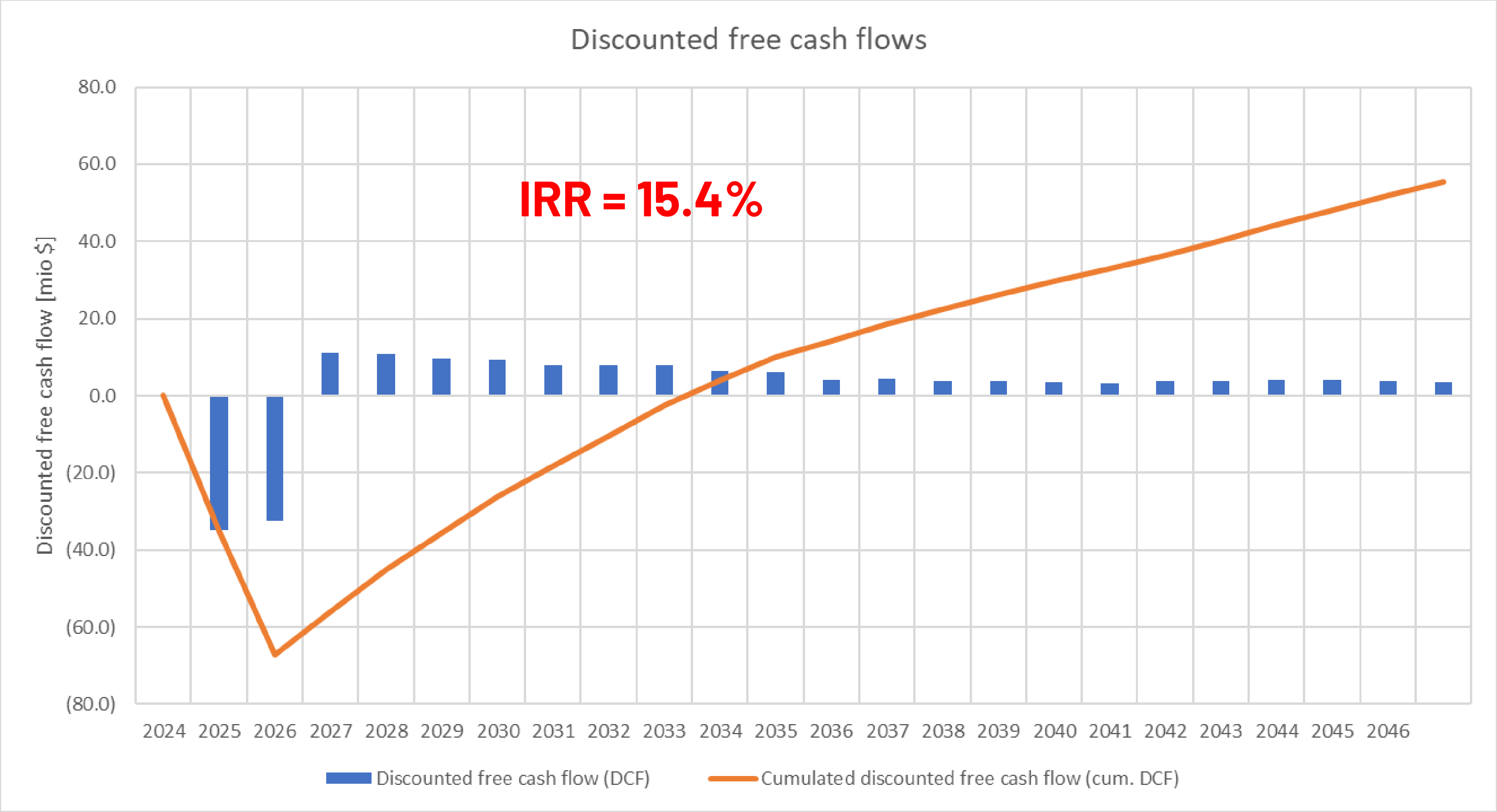




LCOE Comparison TES / Hybrid / E-Boiler (all 24/7)



Economics of TES 24/7



TES use case #3: Endothermic reactors; design challenges

Main –technical- challenges

General goal: enabling indirect heating for endothermic reactors with molten salts

For the MS reactor:

1. Providing sufficient temperature level for reaction → Salt selection → MS Bulk temperature increase

For the MS Heater:

2. Scale up to industrial sizes @ high power density → MS Degradation in film/boundary layer in the MS heater

General:

3. Ensuring lifetime of (metal) components → Corrosion due to interaction with (reaction products of) MS

4. Avoidance of Molten salt freezing & leakages
5. Pre-heating & start-up

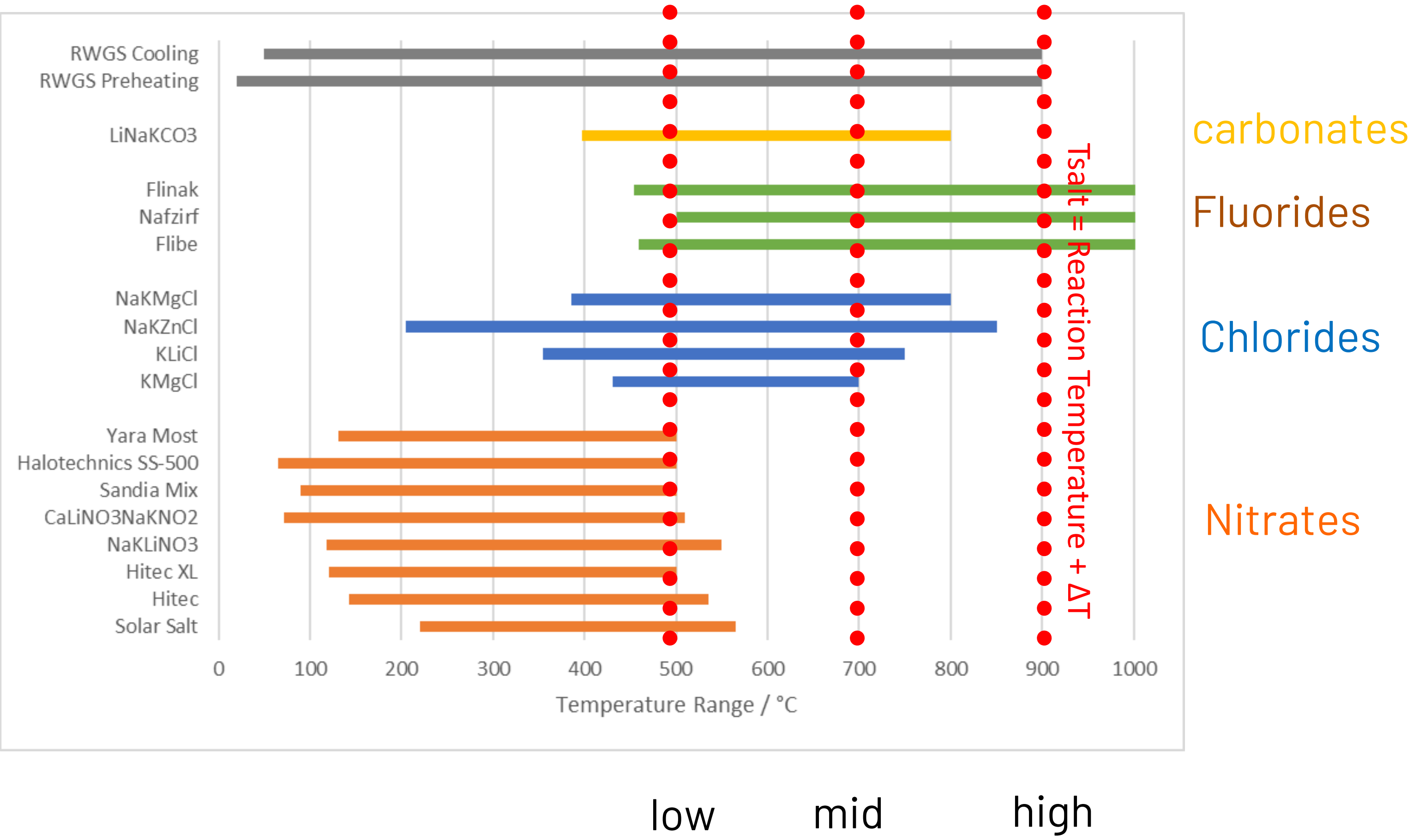
Salt selection

Categorization according temperature level of process – to match catalyst performance

High (Tsalt≈900)
- Fluorides only

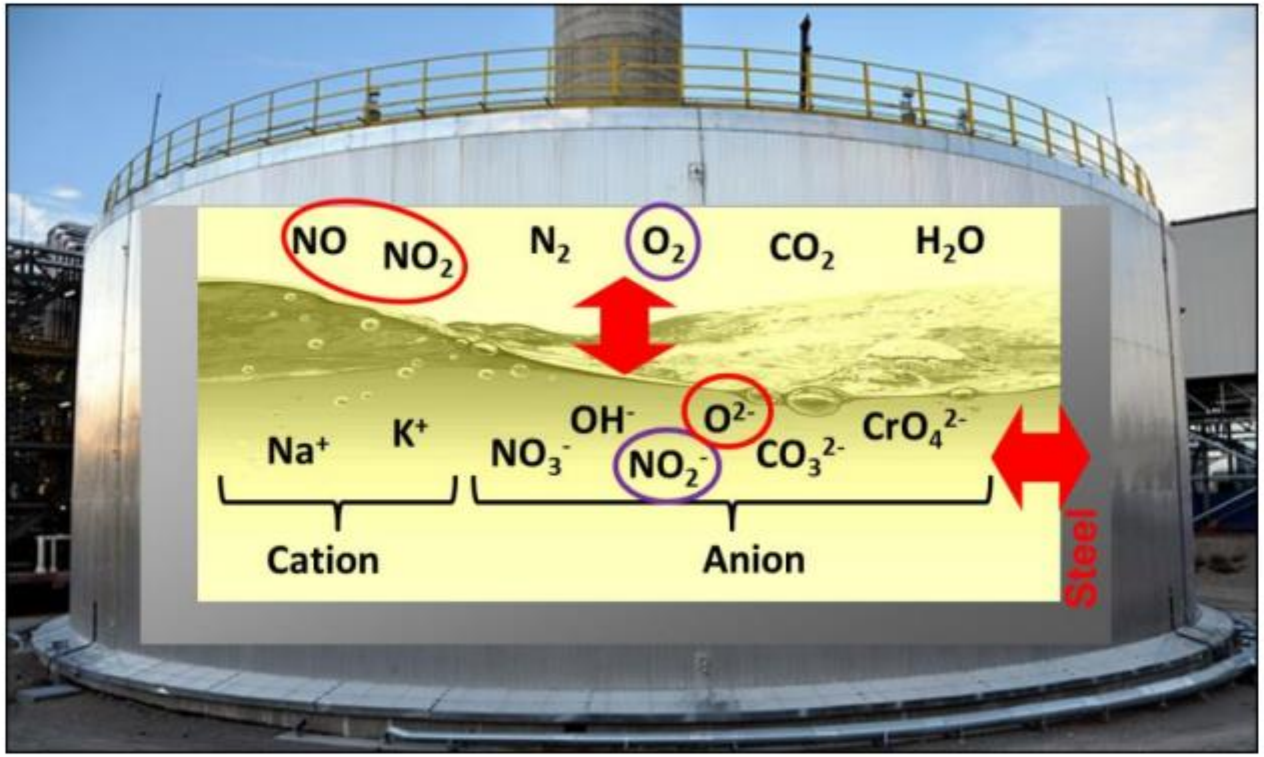
Mid (Tsalt≈700)
- Fluorides, carbonates, chlorides

Low (Tsalt≈500)
- Nitrates



Molten Salt chemistry – A quick guide

Solar Salt –$NaNO_3$ (60wt%) , KNO_3 (40wt%)



The Nitrite (NO_2^-) Ion:

Change in thermopyhsical properties

Melting point, High-Temp-limit

$$NO_3^- \rightleftharpoons NO_2^- + {}^1/_2\, O_2$$

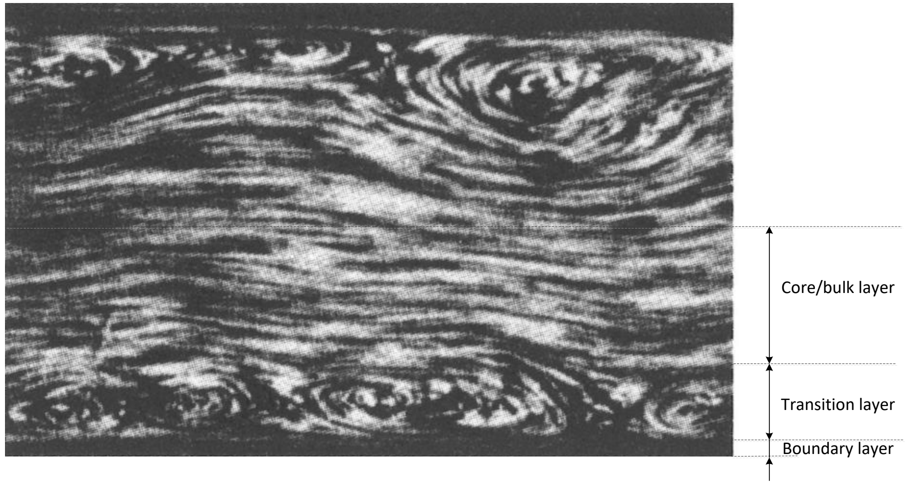
The Oxide (O^{2-}) Ion:

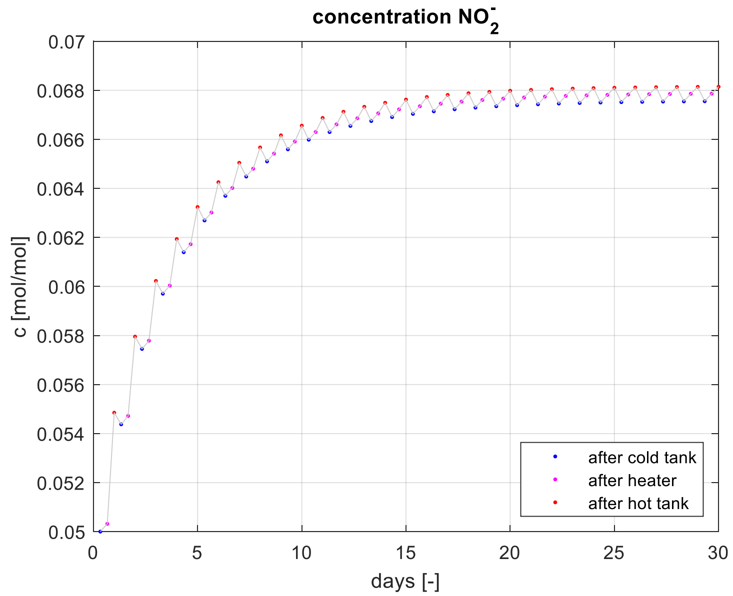
Enhances Corrosion

Lifetime

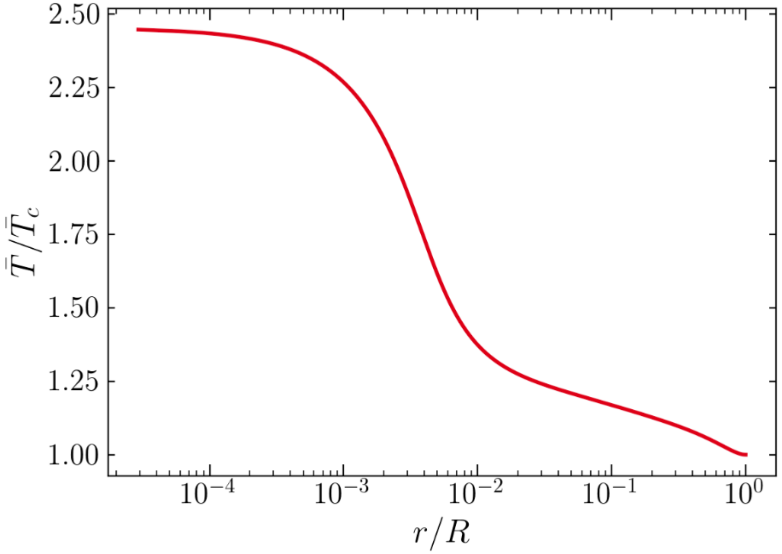
$$2NO_2^- \rightleftharpoons O^{2-} + NO_x$$

Maximum allowable bulk - & film temperature study
Thermo-chemical problem





- Global high in MS temperature in the boundary layer (film) of the MS heater
- Accelerated decomposition reactions in film compared to bulk in heater & tank
- High(er) concentration of decompositions products in film
- High(er) metal corrosion rates in heater tubes
- Partly (!) reverse reactions (back to Nitrates) in hot tank, but higher film temp. in heater results in higher % Nitrides in bulk.
- Higher bulk temperature -> shift of equilibrium to higher % Nitrites



Balancing high Film & Bulk temperature for:
high power density heater design and optimum reactor kinetics
vs
Corrosion & decay in MS properties.

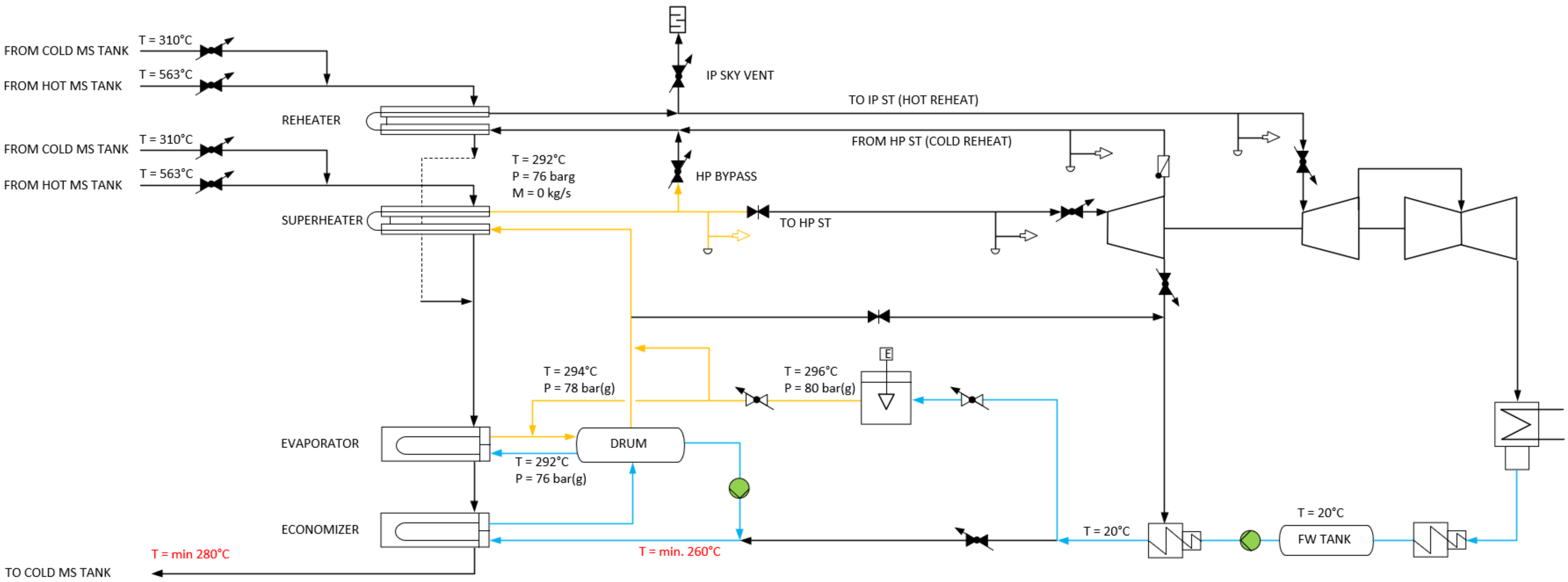
Avoidance of Freezing & Leaking of Molten Salt

Wrong selection of valve or stem seal

Electric tracing on all MS vessels, piping & valves

Pre-heating

PREHEAT I: Preheat SGS with Aux Steam




That's all Folks!

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