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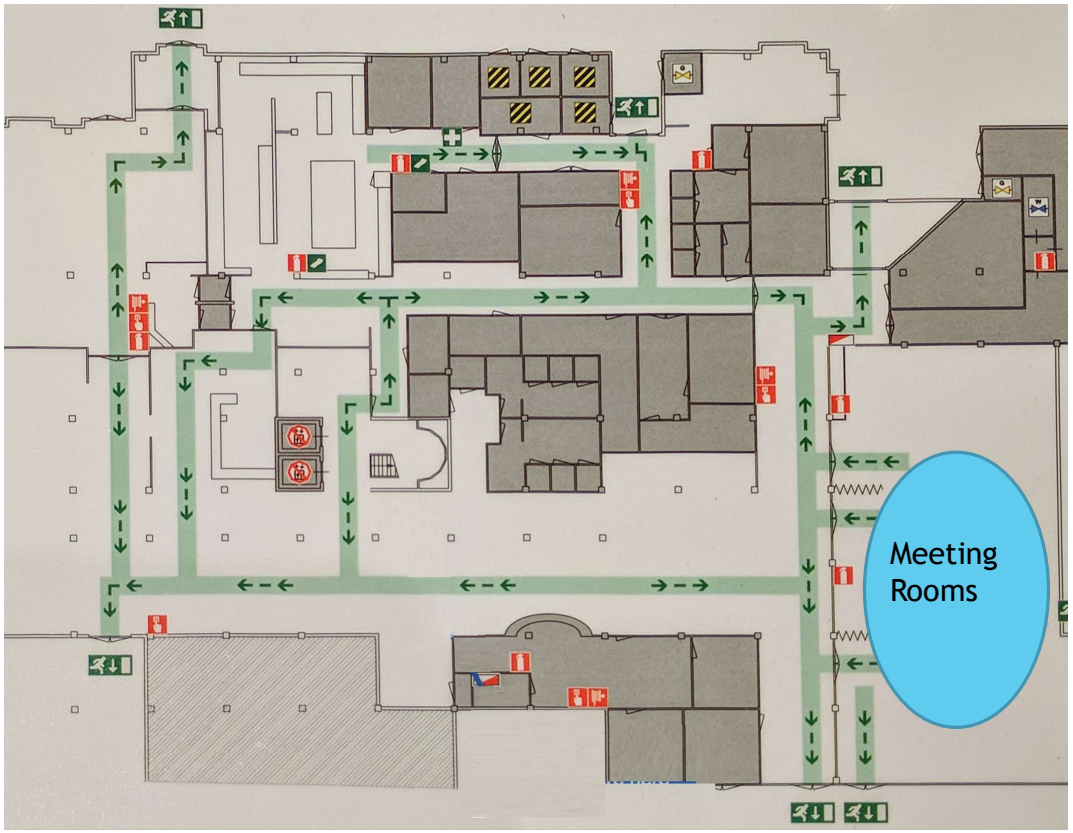
Safety Moment



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Today's Topic

'Electrification of Heat'

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

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NEM Energy – Introduction

Feb 2024

History and current locations

Established in **1929**

Boilers since **1936**

HRSGs since **1960s**

Various acquisitions **1996 – 2001**

2010 NEM Germany opens new office

2011 Siemens Acquires NEM (name change in 2018)

2014 NEM opens new HQ in the Netherlands

2015 Largest CCPP contract ever (14.4 GW)

2022 Siemens Energy HTT becomes NEM Energy B.V.

2023 NEM acquires Balcke Dürr

NEM product portfolio

Large Heat Recovery

Global experience

- Hundreds of units installed on all continents
- The most innovative OEM worldwide with special designs for fast start and cycling operations

- Efficient heat transfer
- Lower emissions
- Reliable Power supply
- Custom-made design

Modular Heat Recovery

onshore

offshore

Global experience

- More than 45 units sold during last 4 years
- Number #1 in the market for heat recovery <100 MW GT output (source: McCoy Power reports)

- Modular design
- High constructability
- Improved overall lead time
- Lowest total Installed cost

Exhaust and Diverter Systems

bypass

diverter

T-SCR

Global experience

- Close to 400 installations worldwide
- Experience in various industries from gas turbines, coal plants, and offshore installations

- Superb availability
- Long life-time
- Flexible operations
- Fast response

Heat Exchangers

Global experience

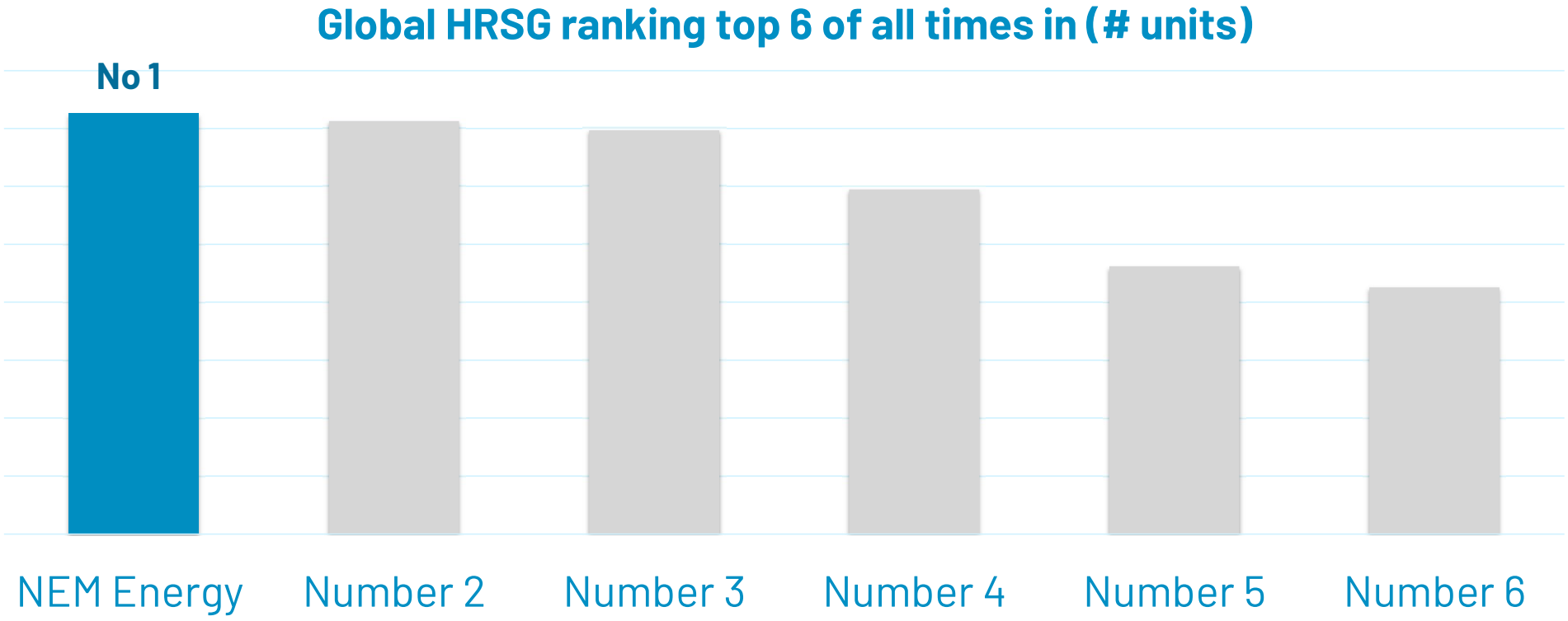
- Over 400 installations worldwide
- One of the most experienced suppliers for heat exchangers in the market

- Customization abilities
- Challenging thermodynamic design
- Highly stress- resistent components
- Fully integration into existing systems

Providing a lifetime of service for all our products

NEM Energy all time number 1 player

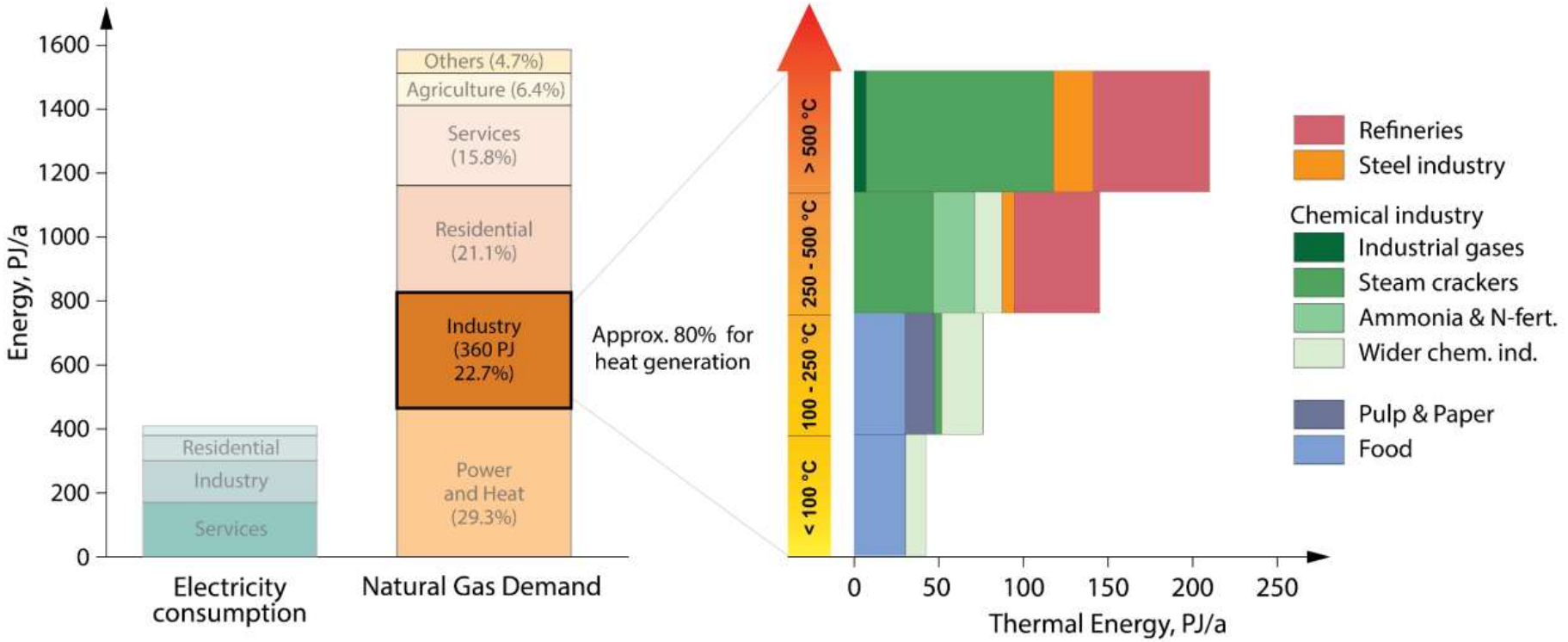
The largest installed base by number of units installed



Source: McCoy 1980 thru 2022 data

Electrification of Heat – Introduction

Industrial Heat in The Netherlands (2018)

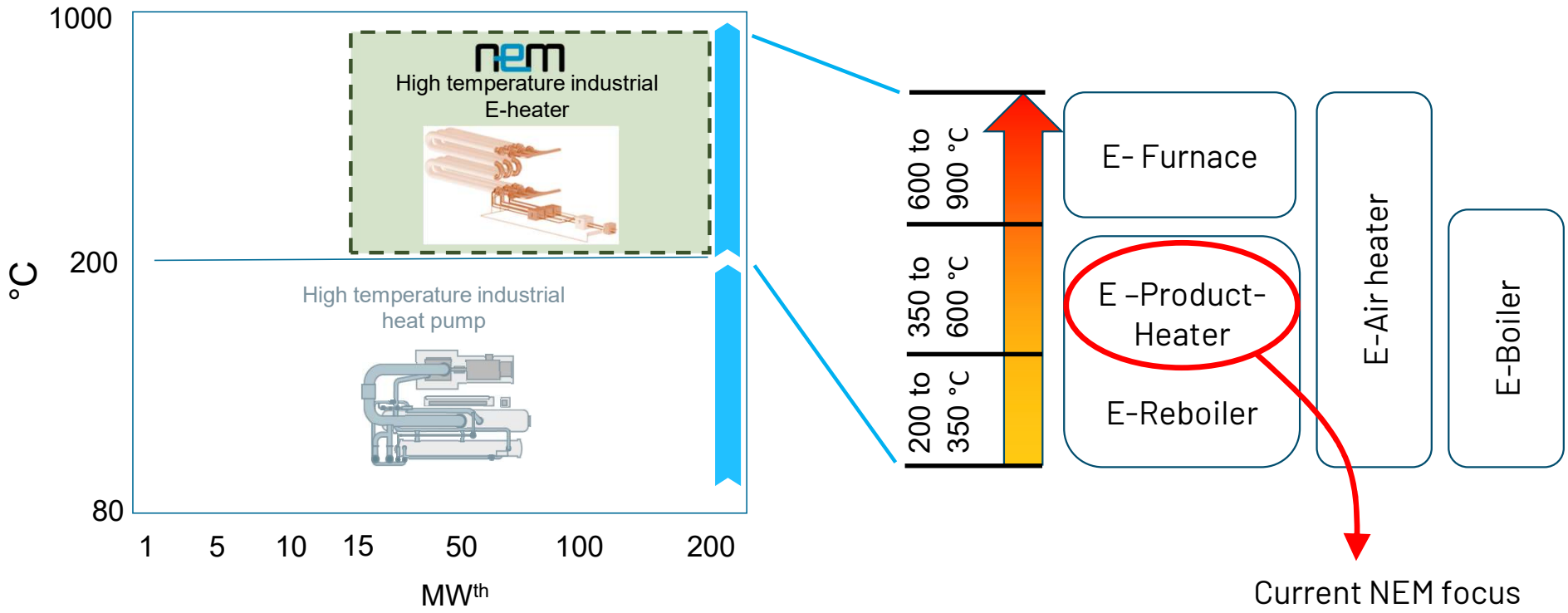


Data from CBS and IEA The Netherlands Energy Policy Review, 2020

Project 6-25 Technology Validation, 2018, Royal HaskoningDHV

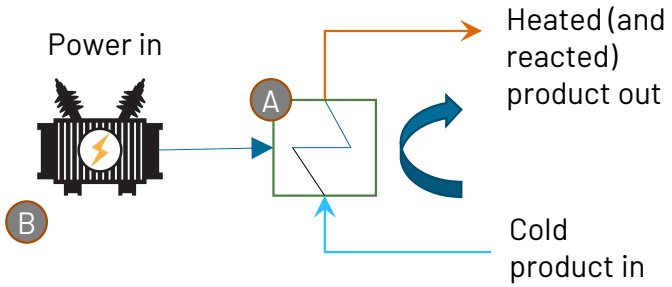
Focus on High temperature & industrial scale E-heater

Output range industrial heat pump & electric heater

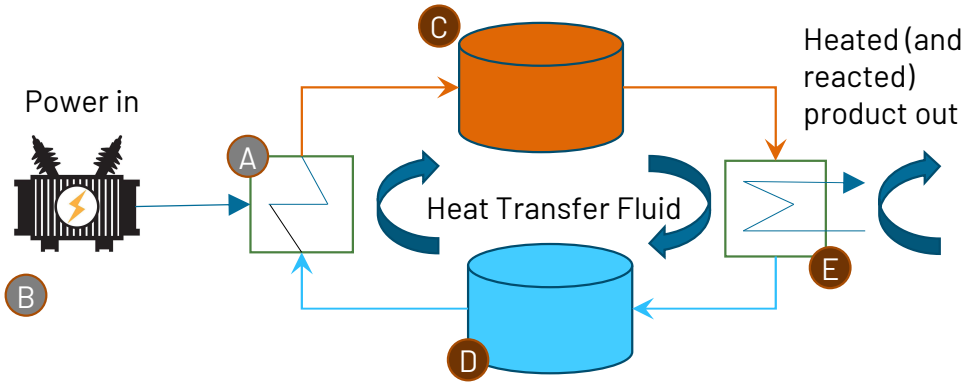


Electrification of heat principles

1. Direct electrification of heat



2. Indirect electrification of heat, with TES



Description

Power to Heat:

A
- Electric –product- heater (OEM)
- Electric Furnace (OEM)
- Electric Steam Boiler (OEM)

B HV/MV Transformer, power switches & controls (Integrator)

Thermal Energy storage (TES), e.g. with molten salt

Storage system process design (Engineer)

C Hot Storage tank (Integrator)

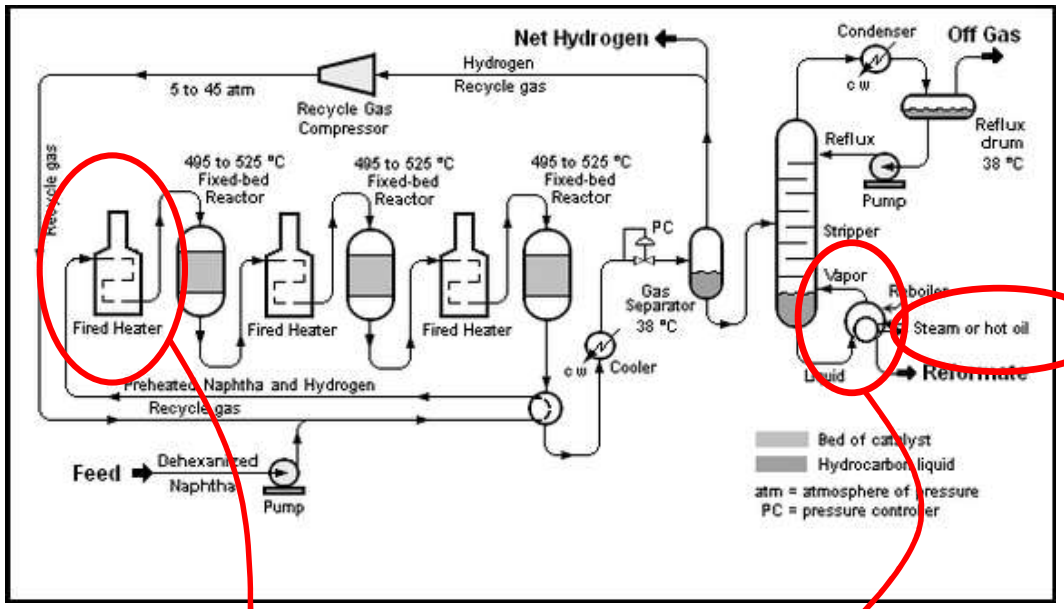
D Cold Storage tank (Integrator)

Heat to Heat:

E
- Steam generator (OEM)
- Product heat Exchanger (OEM)

Potential use cases in Petro-chem

Typical catalytic reforming unit



Fired or steam Product Heaters & Reboilers:

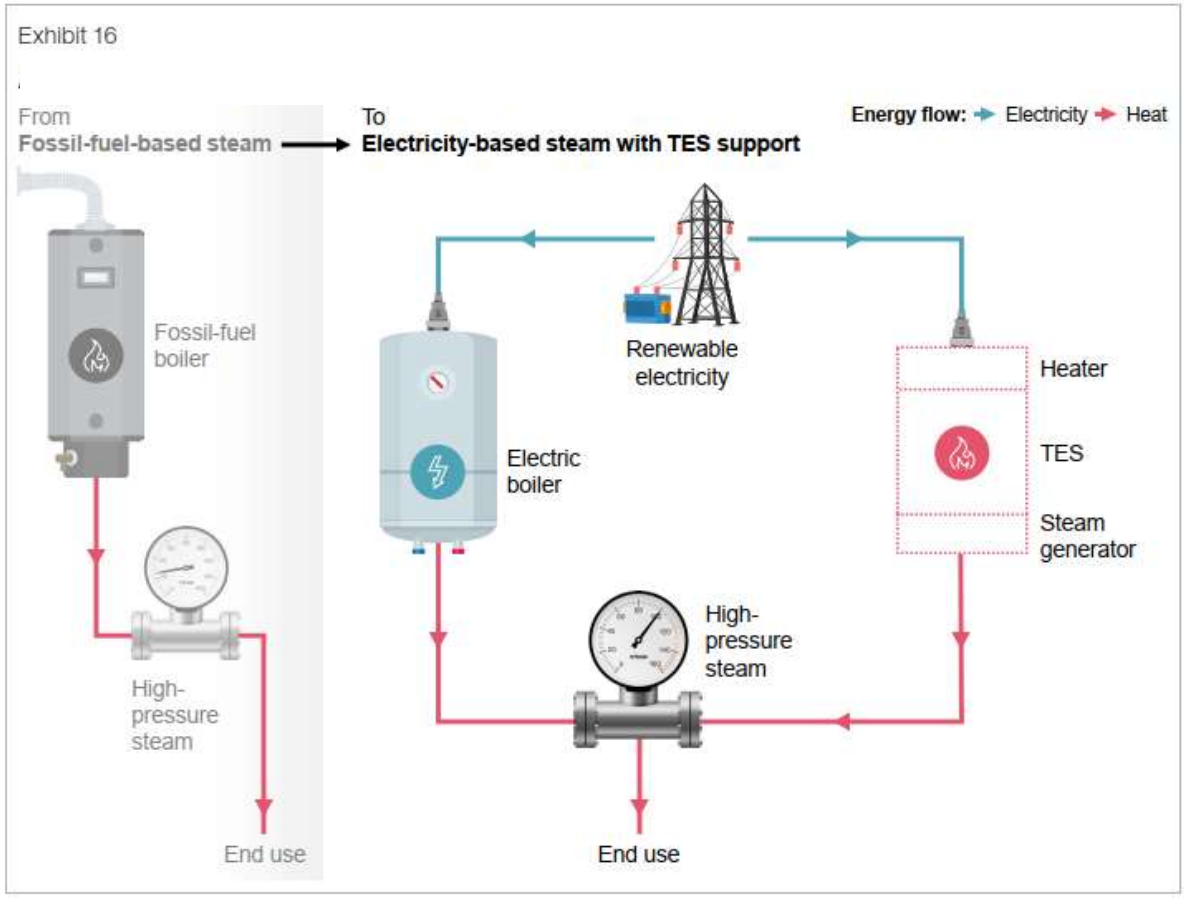
Local: replacement with Electric Heater

Central: with Steam & HTF grids

Steam or HTF grids:

Electrification with E-boilers/heaters

Potential use case: HP sat. steam grid & TES for Energy Arbitrage



Courtesy: LDES Council / McKinsey

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:

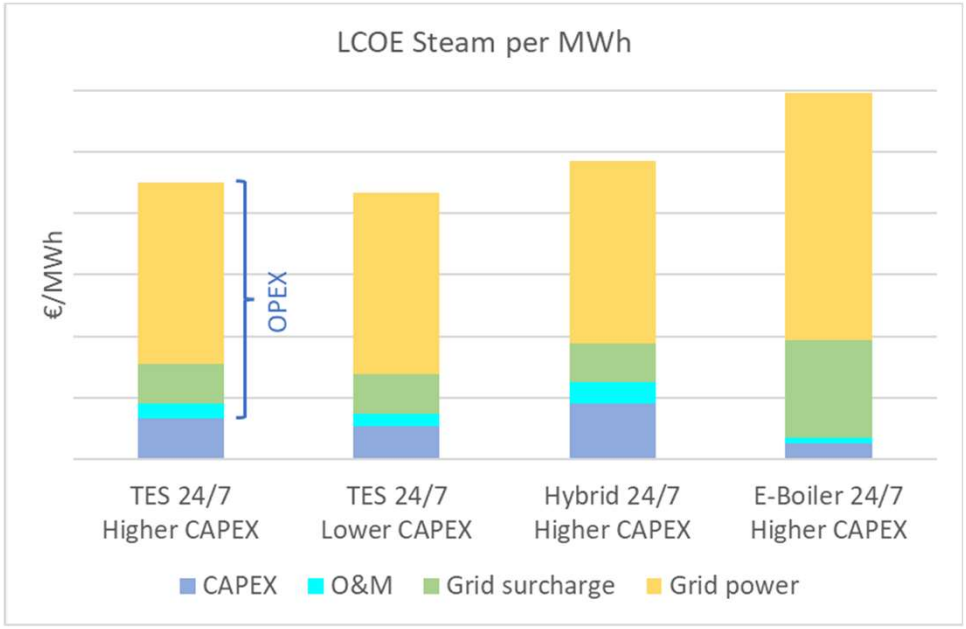
1. TES only
2. E-Boiler only (no energy arbitrage)
3. Hybrid: TES + E-Boiler

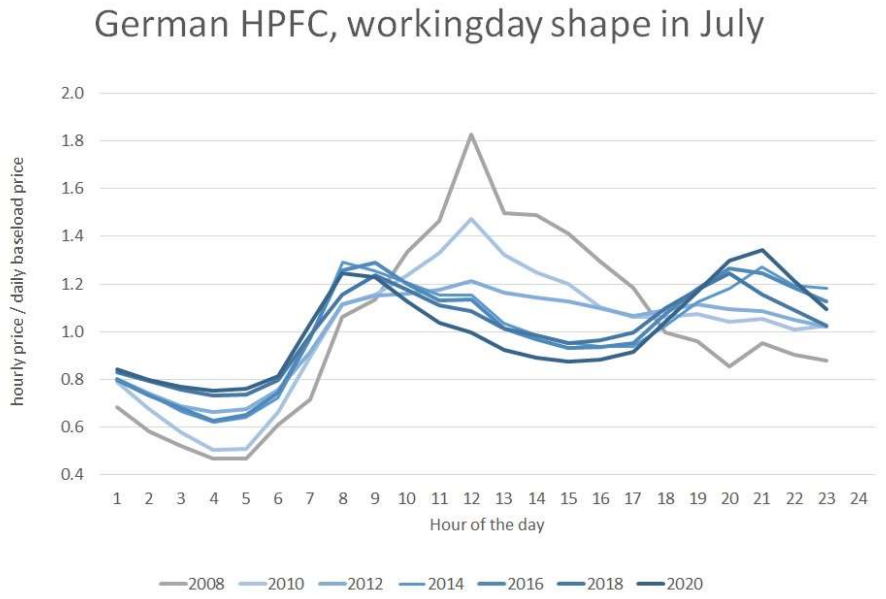
24/7 operation feasible in all options

Potential use case #2: HP sat. steam grid for Energy Arbitrage

Comparison of LCOE for different plant design concepts / operations

Advantage of energy arbitrage (= charging during cheap hours) clearly visible in significantly lower LCEO for TES in comparison with E-Boiler (no energy arbitrage), despite higher CAPEX.





Typical example of power price fluctuations over the day

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.

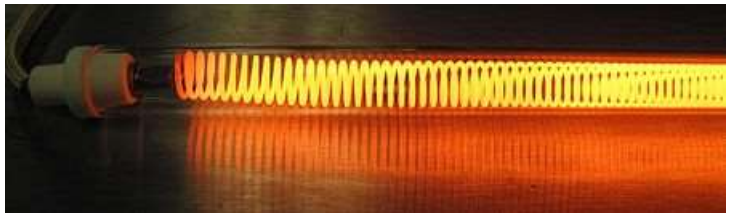
Important design aspect is how to keep the electrics separated from the operating fluid (no direct contact, no electric conductors having to penetrate pressure parts etc.)

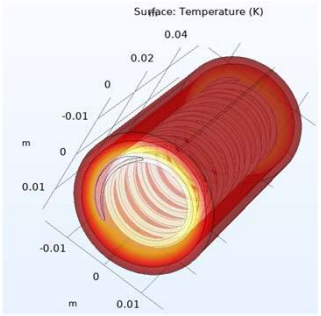
Other main issue: large power means high voltage preferred (>10kV) to keep currents, cables, transformers limited. High electric insulative strength req'd i.e. large distances between conductors and "ground". Also supports have to be appropriate like glass or ceramics.

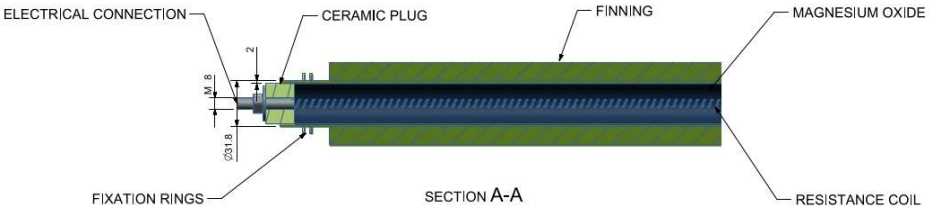
Resistive E-Heater: how does it work

Special high temperature wire conducts electricity, because of its resistance gets hot. The wire is placed inside a tube, surrounded by heat-conducting electric insulating material. So wire is protected and supported, heat conducted to outside surface of tube, fluid flows around the tubes and gets heated.

- Max. operating fluid temperature: 700-750°C
- Good for modular set-up, easy to replace, lifetime expectancy of elements moderate
- Heating from inside out, into fluid, so large pressure vessel req'd i.e. difficult for high pressure; also: penetration of heating elements through pressure part walls necessary
- Max. voltage limited, so probably transformer needed, more copper in cabling etc.
- For low power applications very mature technology, proven, large supplier base



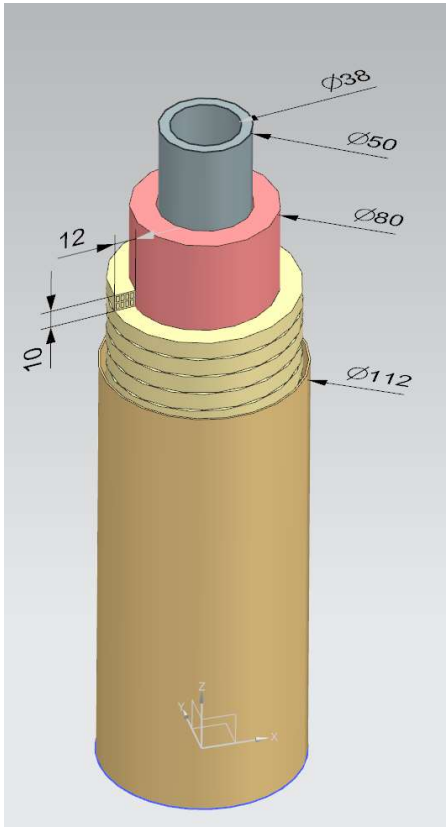




Inductive E-Heater: how does it work

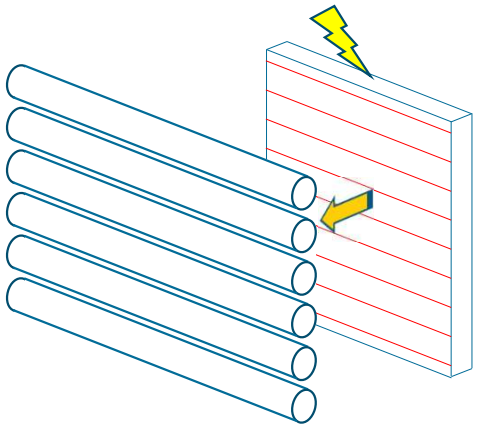
An electric coil is wound around a pipe or tube bundle, AC current is used to make a fluctuating magnetic field, which in turn induces eddy currents in the metallic wall of the pipe/tubes and causes heating.

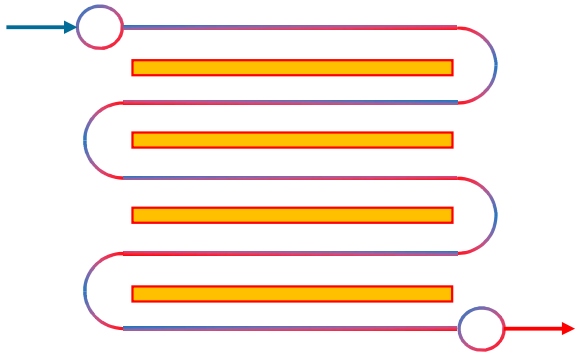
- Max. operating fluid temperature: 1000°C
- Easy for higher voltage <25 kV; lot of generator and transformer technology can be applied as well as existing production
- Heating from outside in, into fluid, so pipe/tubes can easily be designed for high pressure
- Not easy to modularize due to large specific iron core, needed for intensive magnetic field, lifetime expectancy is long
- Active cooling of coil req'd, so external loss i.e. efficiency <100% (and extra CAPEX for cooling system); already applied on generators, so off-the-shelf



Radiative E-Heater : how does it work

- An electric coil is wound on both sides of a heat resistant ceramic panel.
- The coil consists of metal strip, and operates at max. 1200°C.
- Ceramic panel hangs vertically on internal grid.
- Heating from outside in, into fluid, so pipe/tubes can easily be designed for high pressure.
- Easy for higher voltage <25 kV.
- Easy to modularize by sandwiching alternately heating panels and tube walls
- The ceramic panels help radiating, not only the wires, drastically increasing power density.

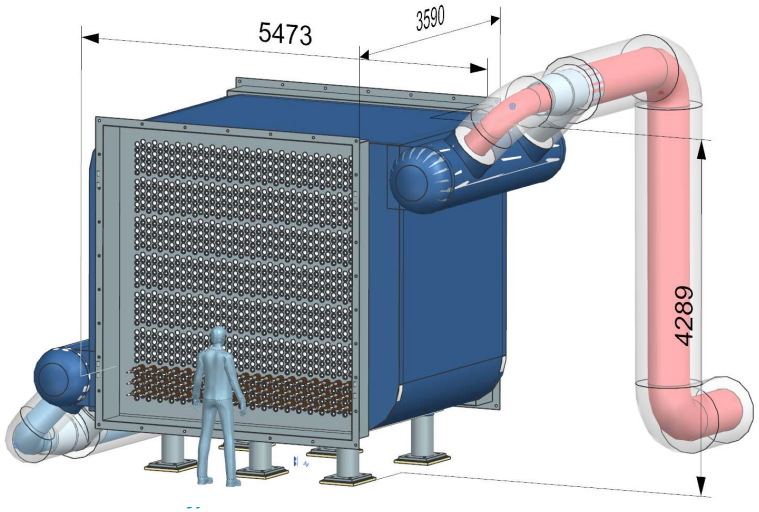




E-Heater comparison table

	Resistive	Inductive	Radiative
COP	1	0.85-0.9	1
Max. fluid temperature	700-750	1000	700-750
Max power per shell	200 MWe	80-100 MWe	200 MWe +
Heat flow	Inside out	Outside in	Outside in
Voltage	15kV	25kV	15kV
High pressure	No	Yes	Yes
Fluid	Liquid & Gas	Liquid	Liquid (& Gas)
Suited for fouling fluids	No	Yes	Yes
Electrics penetration into pressure part	Yes	No	No

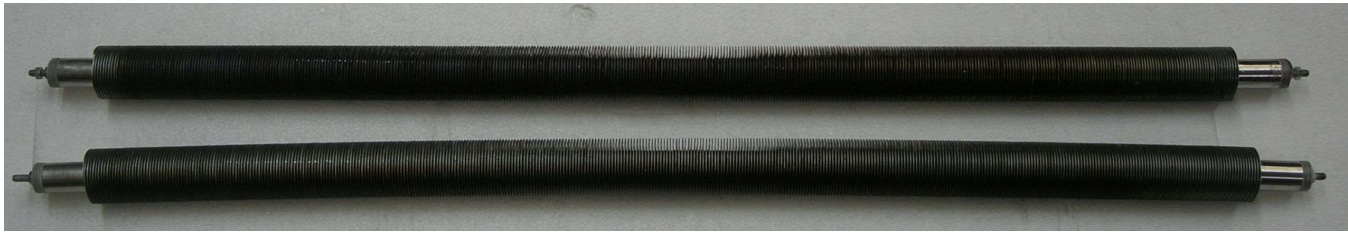
Resistive Electric Heater design



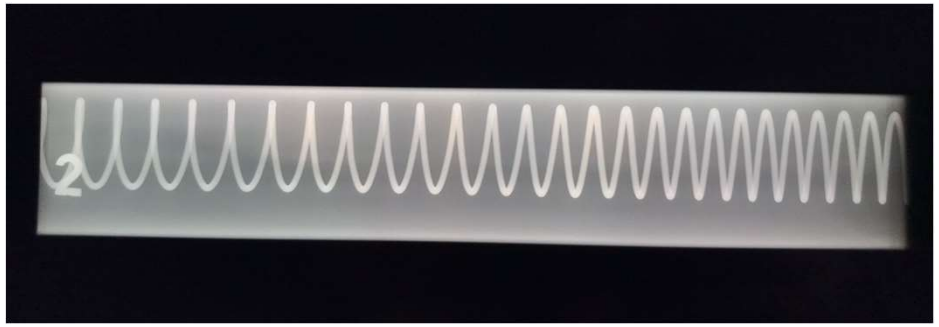
E-Heater specs

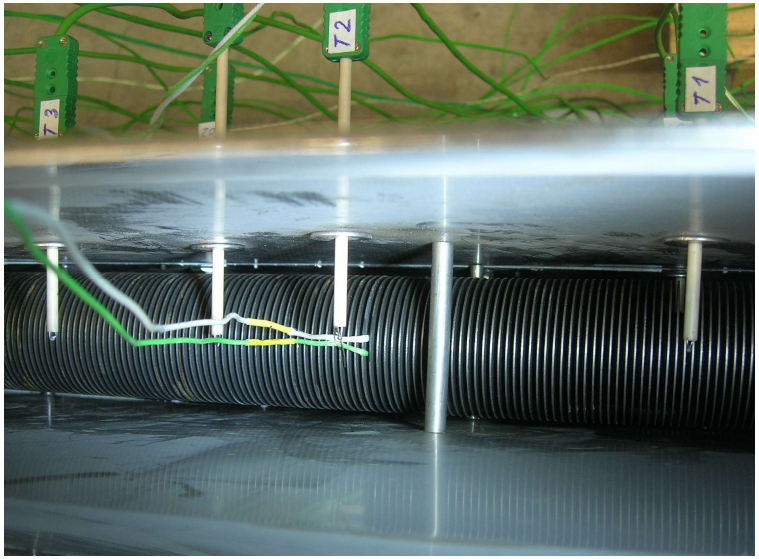
Power	(up to) 200 MWe
Voltage	15kV / 50Hz / 3 phase star
Current	(up to) 13000 A
Media	Molten Salt, air
Media temperature	(up to) 600°C+
Mat'l casing	(e.g.) SS347H
Mat'l tubes	(e.g.) I825
Mat'l finning	(e.g.) SS347H

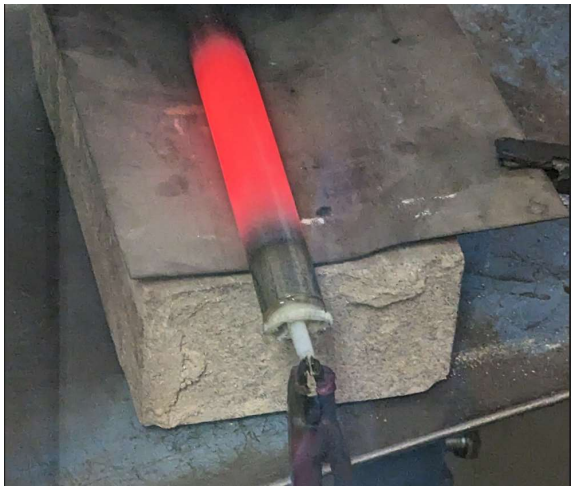
Testing newly developed Resistive heating elements



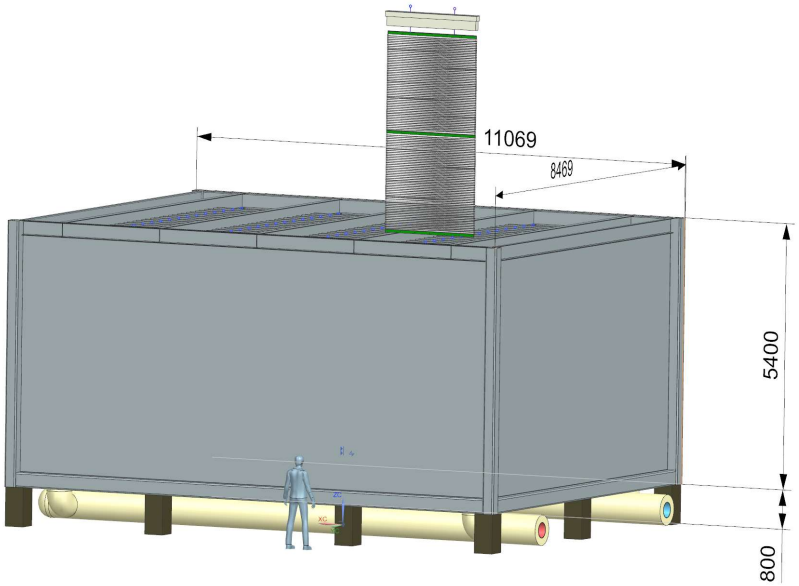
Testing newly developed Resistive heating elements

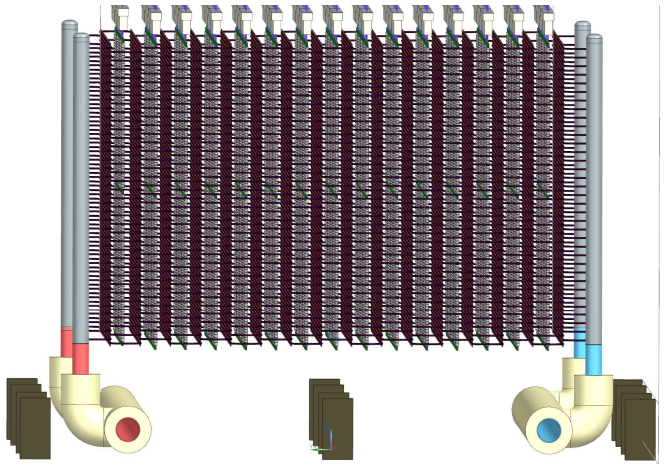




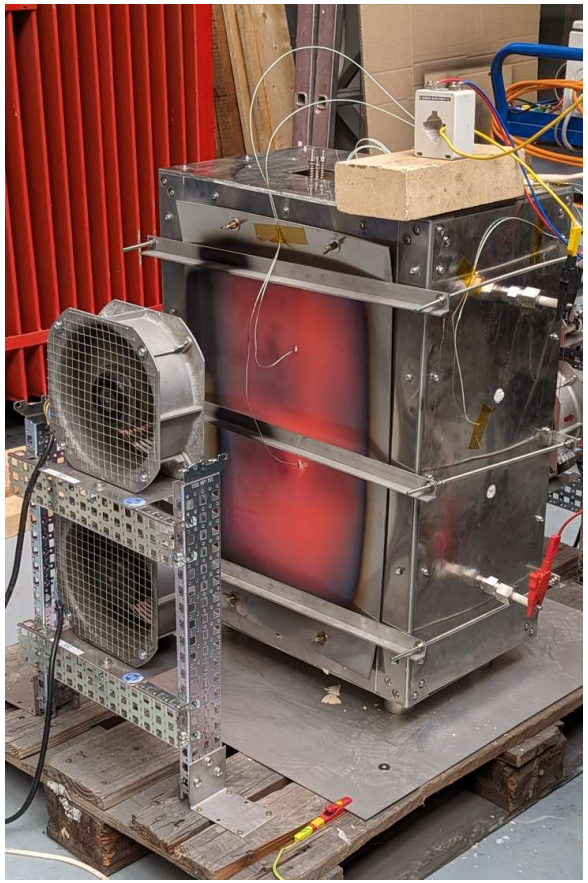


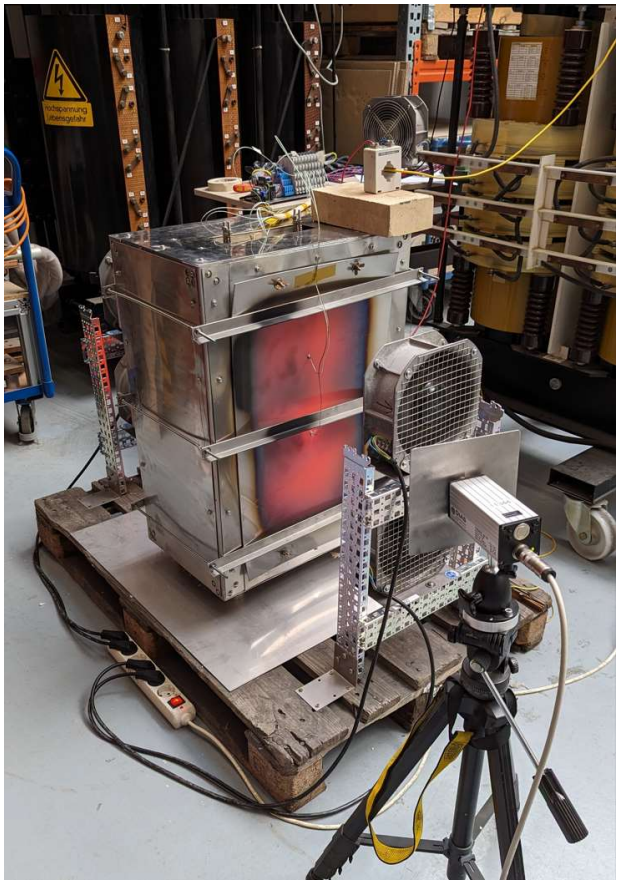
Radiative Electric Heater design





Testing newly developed Radiative heating elements



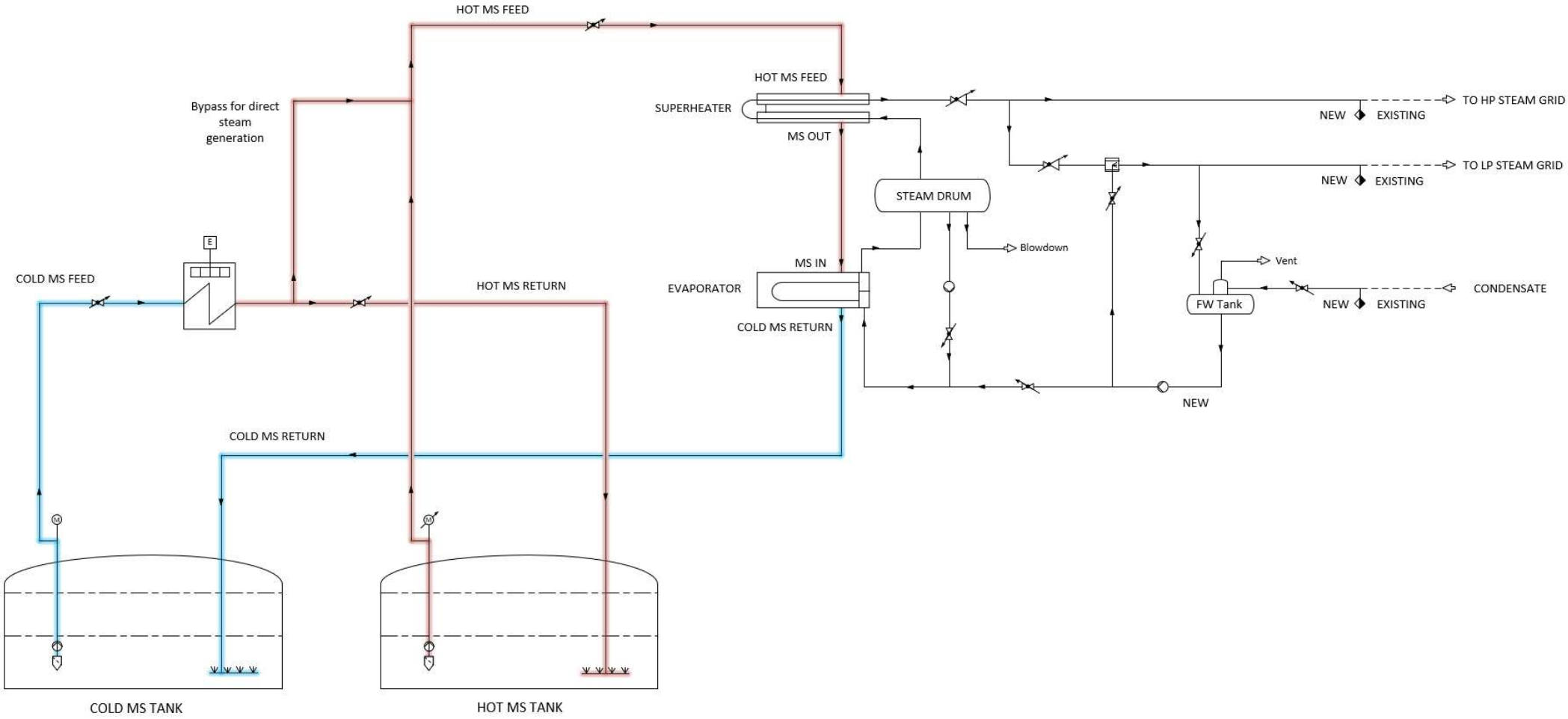


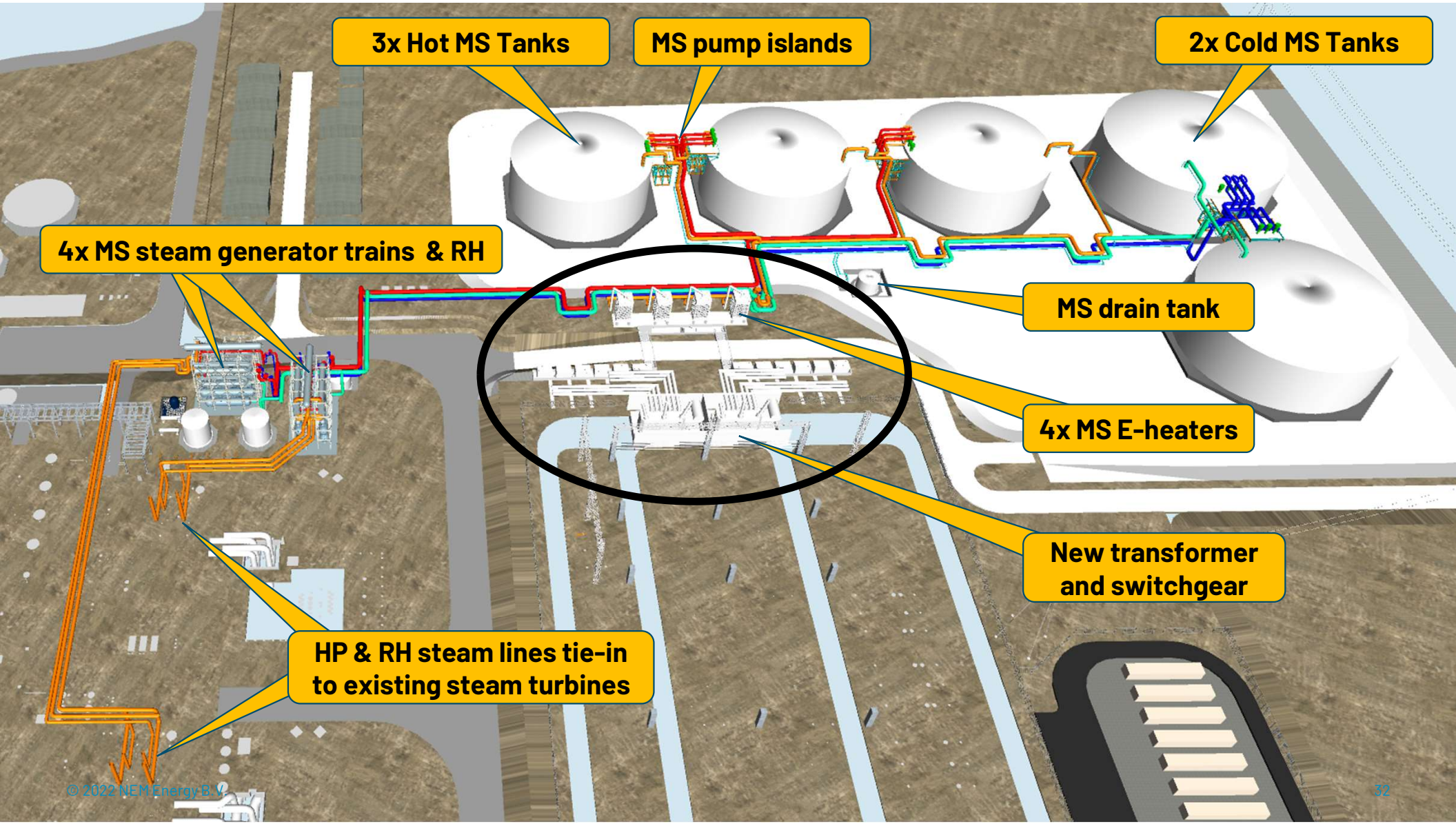
Thermal Energy Storage

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: 280 - 565 °C
- Salt decomposition threshold 600 °C
- Non flammable & non-toxic
- Low vapor pressure
- High energy density (120 kWh/MT or 208 kWh/m3)
- High chemical stability (no refill over plant life-time)

PFD for TES for HP / LP steam grid





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