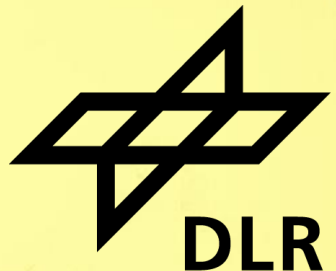


SOLAR SALT

Pushing an old Material for Energy Storage to a new Limit

Pushing an old Material for Energy Storage to a new Limit

Dr. Alexander Bonk



Stuttgart **R&D**

Molten Salt Handling



Salt Synthesis

**Purification
techniques**

**Electro-
chemistry**

**Glovebox
routines**

**Impurity
control**

**Experimental
Design**

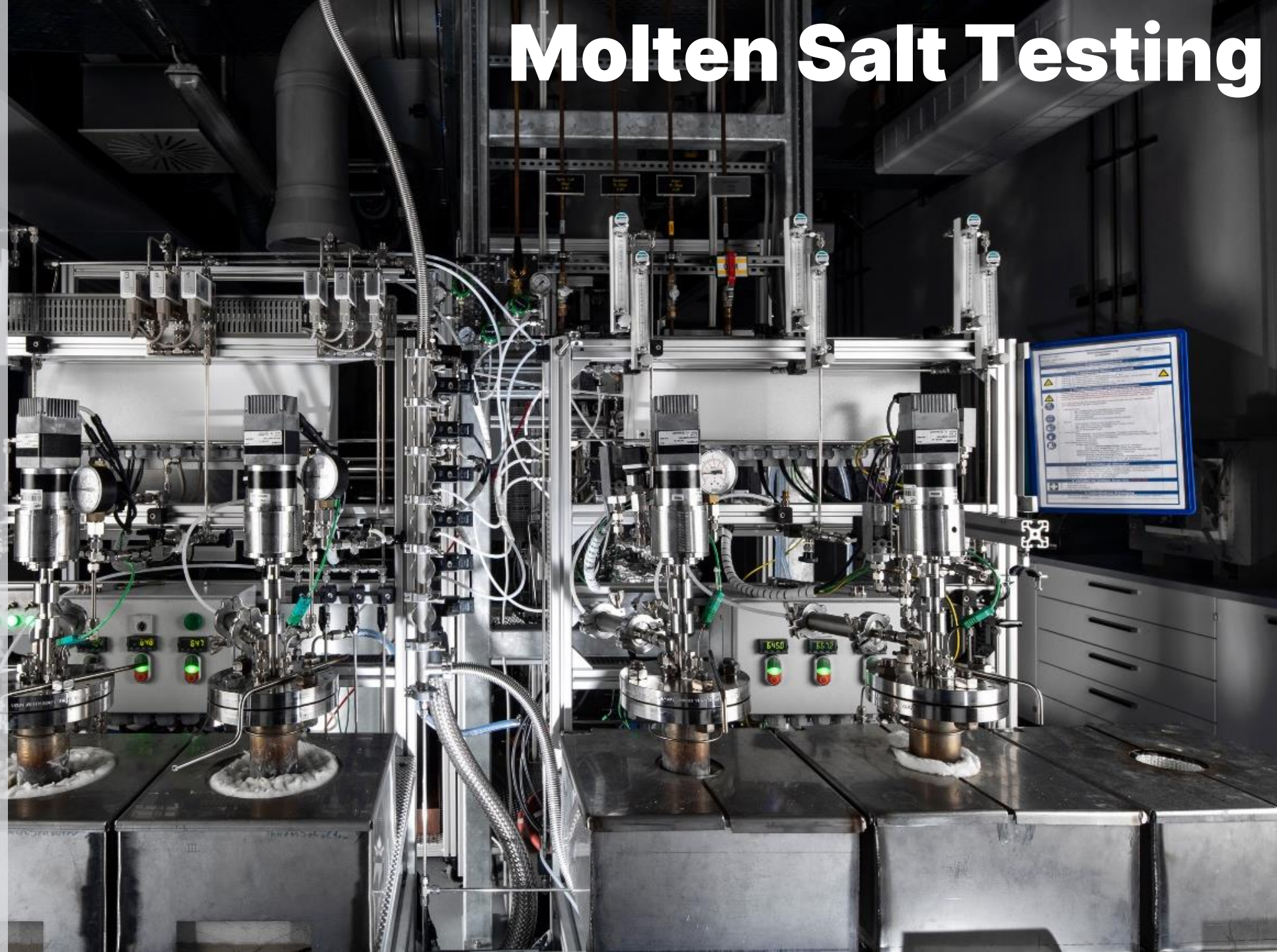
**Long Duration
Tests**

Automation

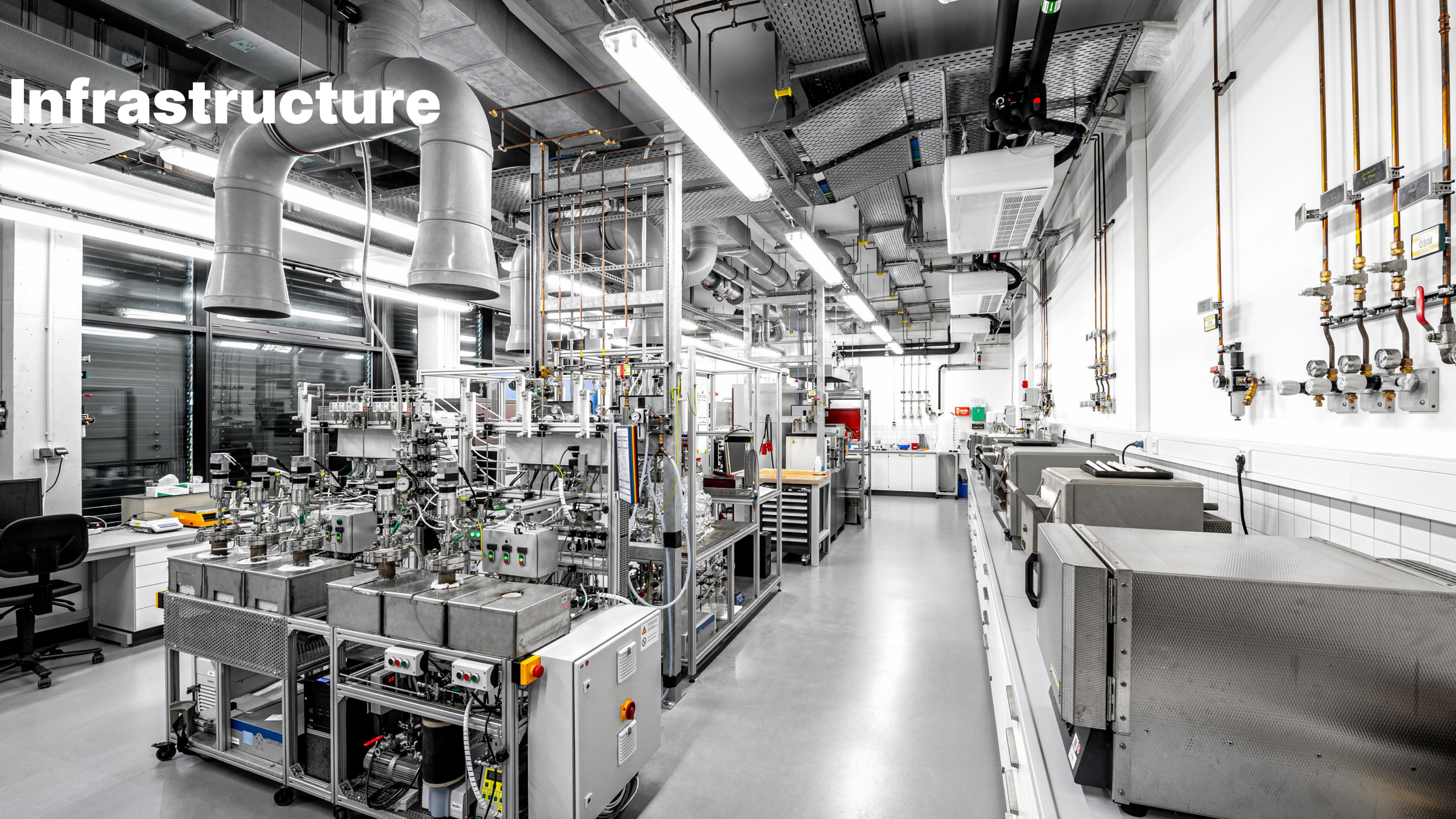
**Temp & Gas
Control**

**Process
Optimization**

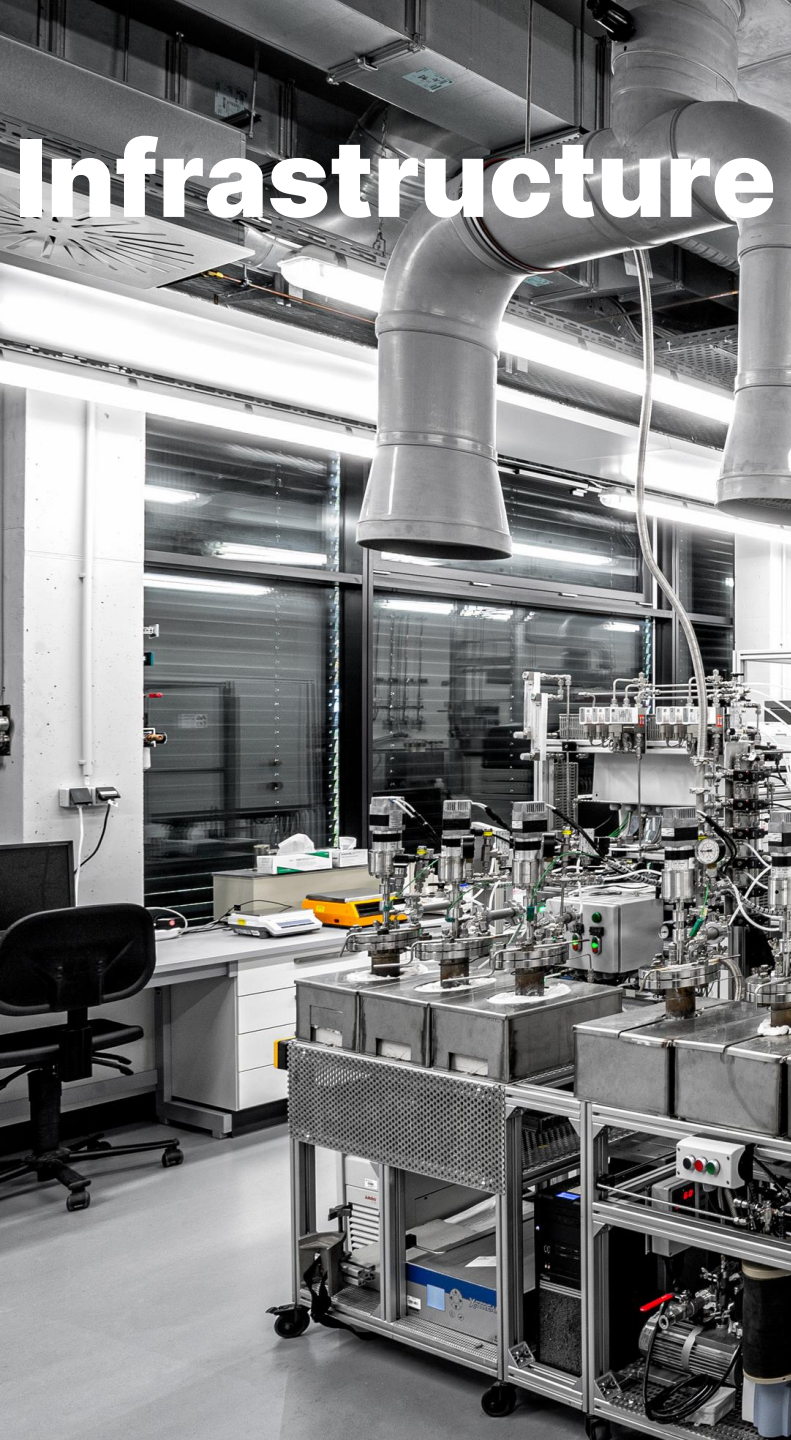
Molten Salt Testing



Infrastructure

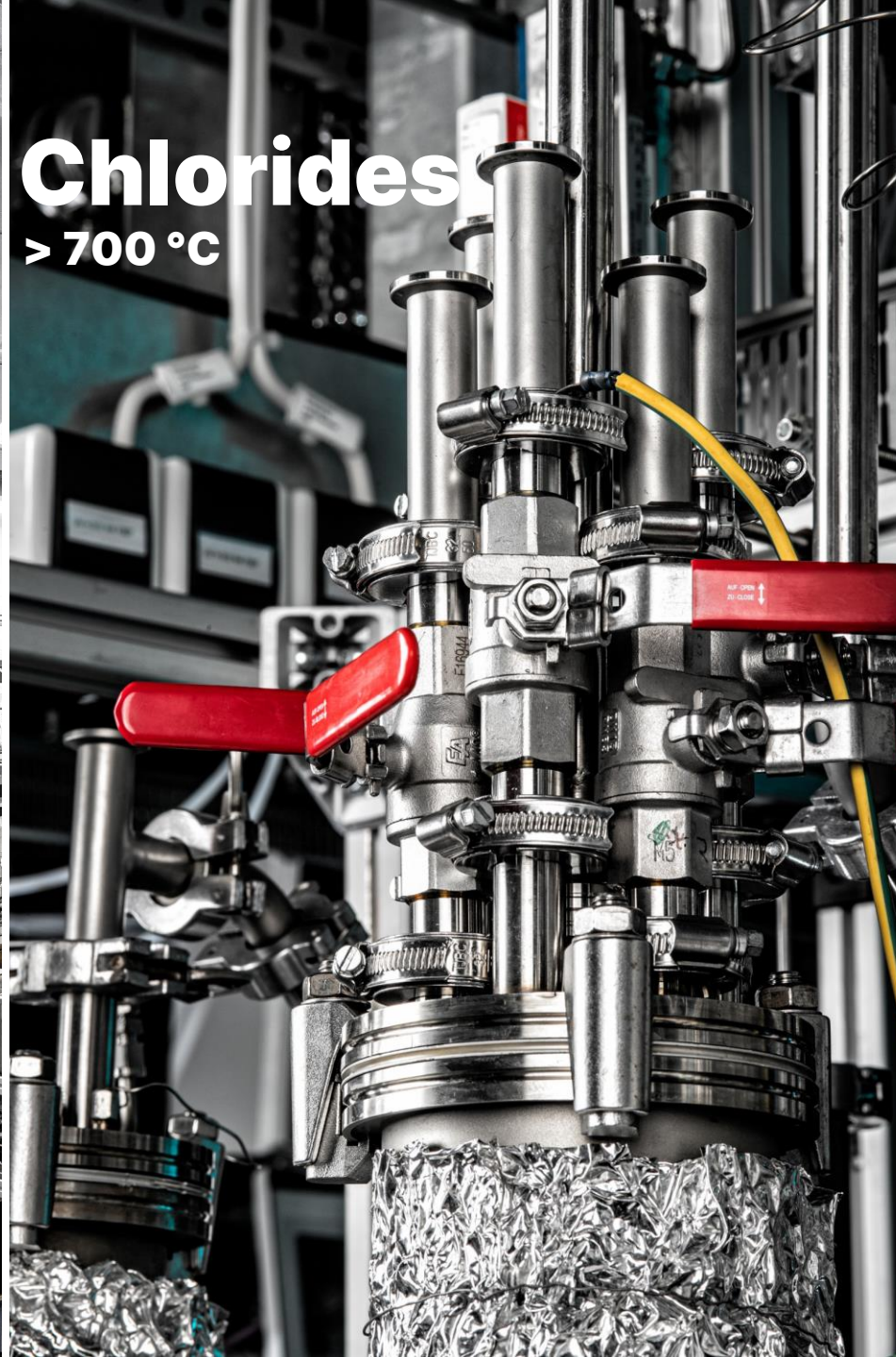


Infrastructure



Chlorides

> 700 °C



Nitrates

< 650 °C



Noor

Noor Ouarzazate Solar Complex



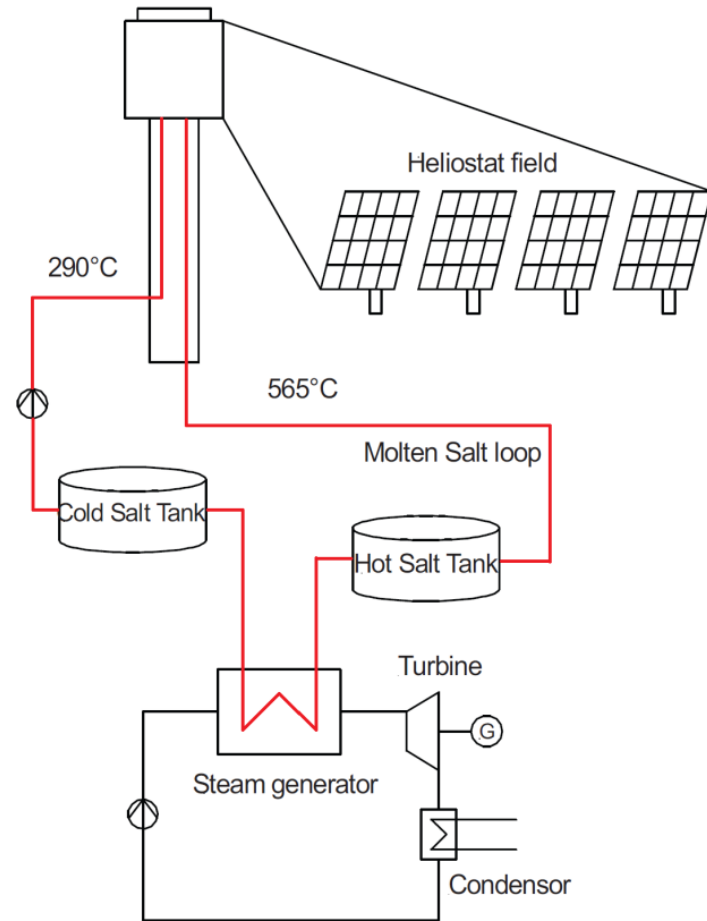
Electricity production
2.4 GWh/d

Storage Capacity
5530 MWh

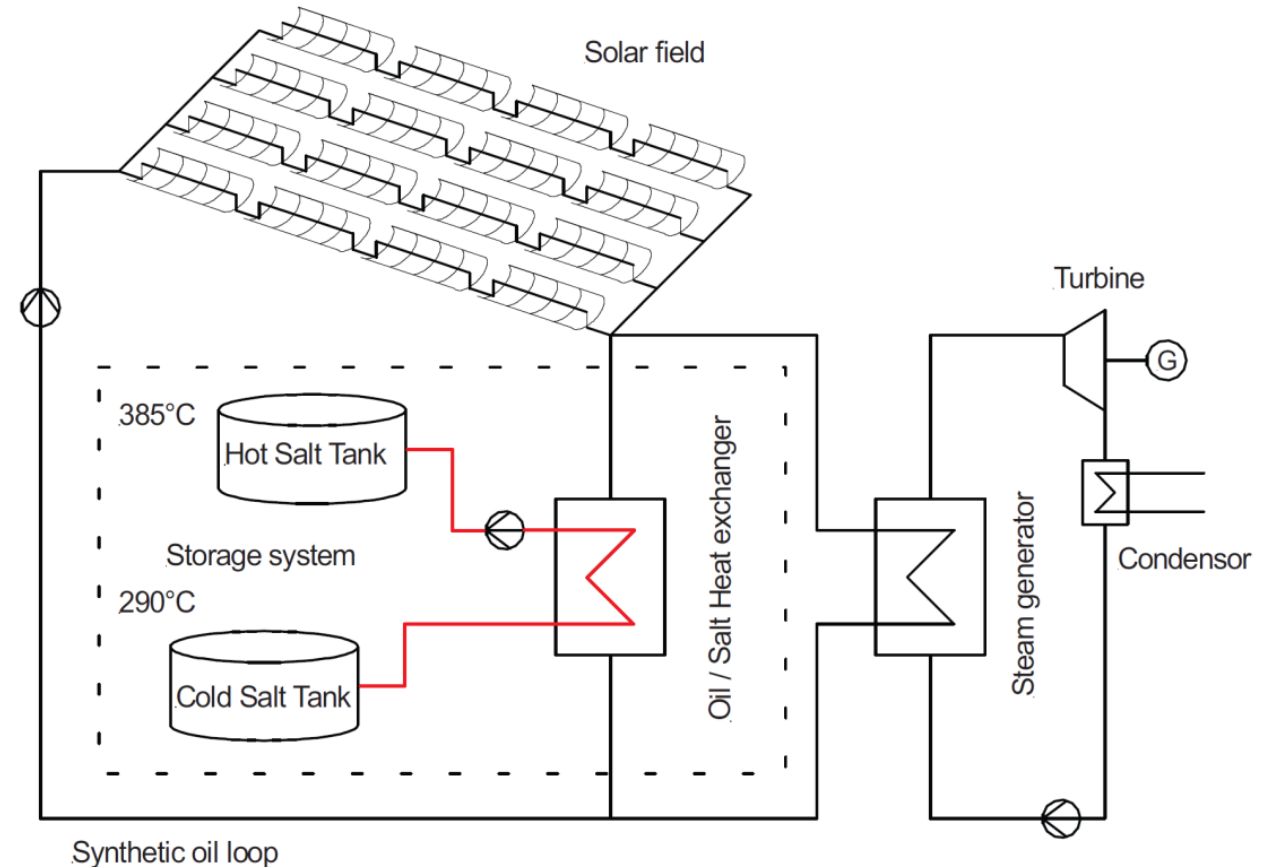
Salt Inventory
140.000 t

Storage Duration
5 h + 7 h

Direct vs. Indirect storage

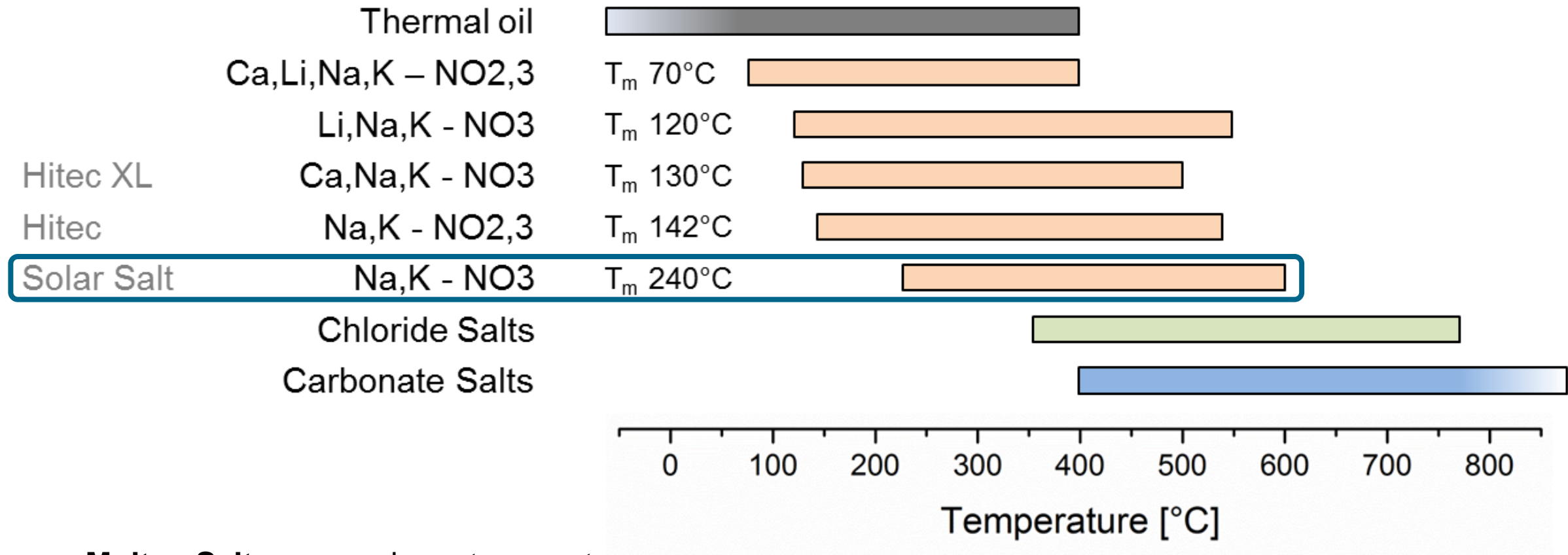


Direct Storage Medium
For Solar Tower Plants
(Storage medium = HTF)



Indirect storage system
e.g. parabolic trough / Fresnel
(storage medium \neq HTF)

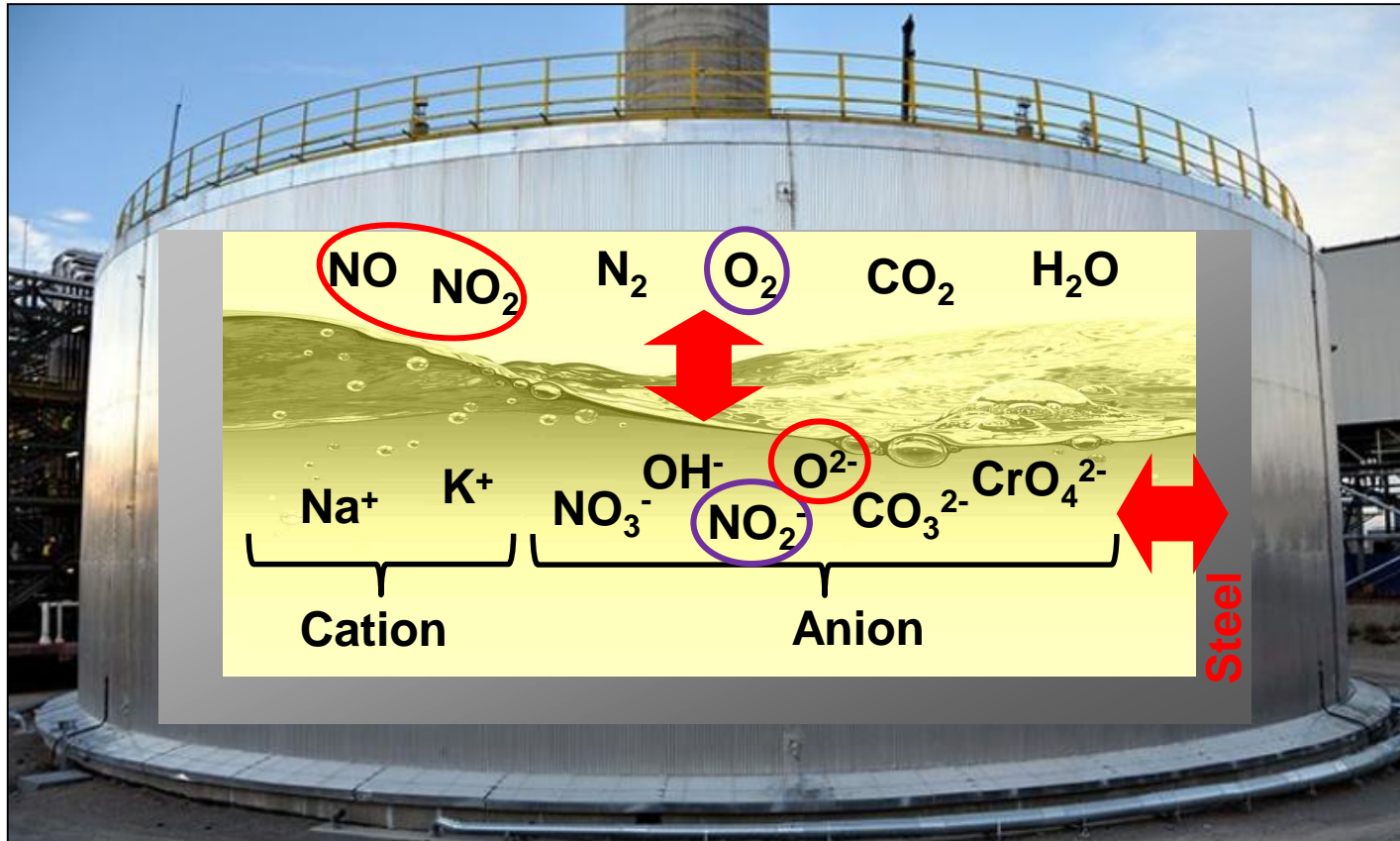
Heat Transfer & Storage Media



- **Molten Salts** cover a large temperature range
- Carbonates and Chlorides can extend the range to temperatures up to >800°C
- **Potential application is affected by storage medium**

Molten Salt Chemistry – A quick guide

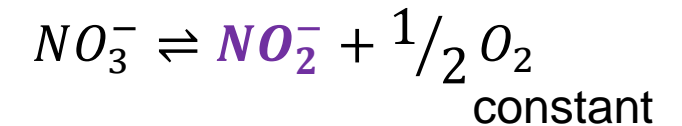
Solar Salt: 60 wt% NaNO_3 – 40 wt% KNO_3



The Nitrite (NO_2^-) Ion:

Change in thermophysical properties

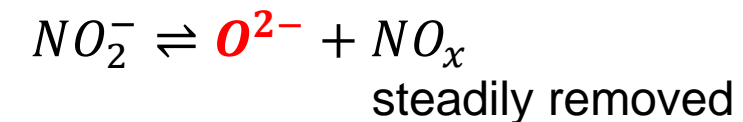
Melting point, High-Temp-limit



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

Enhances Corrosion

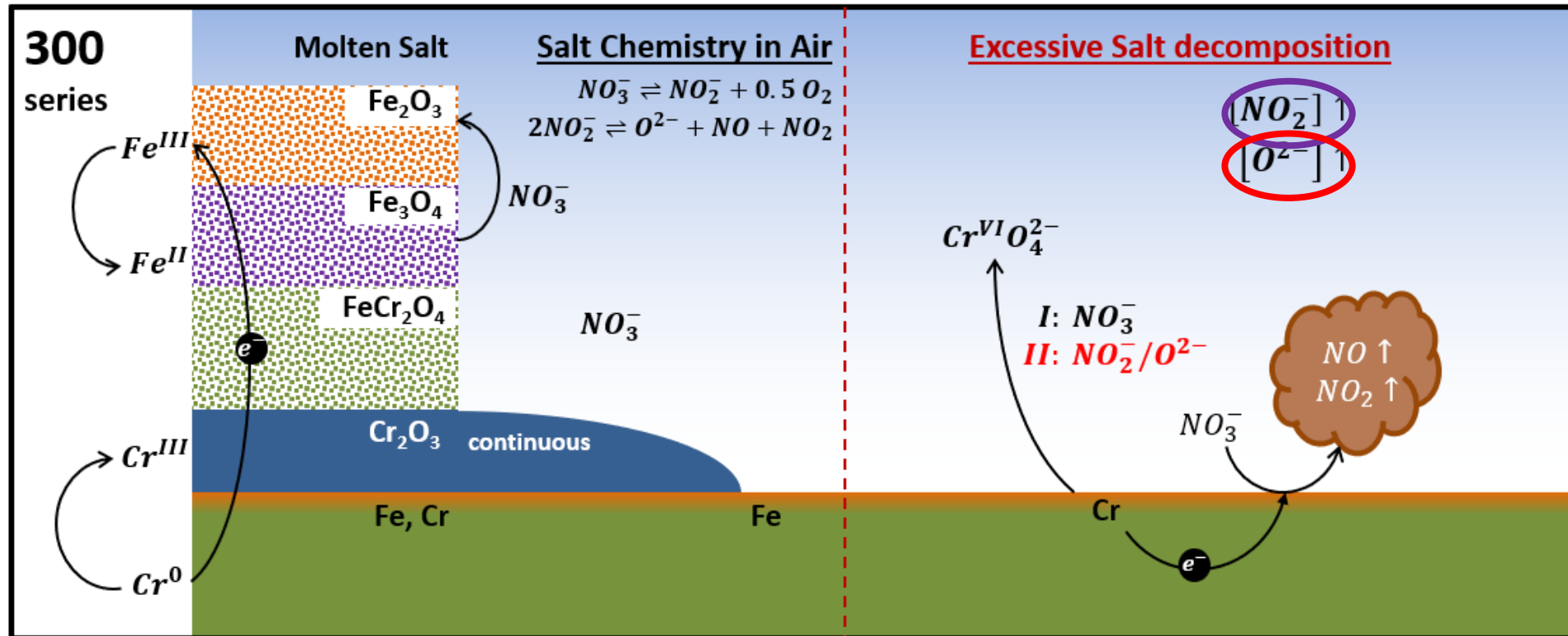
Lifetime



Federsel, K., Wortmann, J., Ladenberger, M. (2015) Energy Procedia, 69, pp. 618-625; Nissen, D.A., Meeker, D.E. (1983), Inorganic Chemistry, 22, pp. 716-721; Bradshaw, R.W., Dawson, D.B., De La Rosa, W., et al. (2002) Report SAND2002-0120; Bauer, T., Pfleger, N., Laing, D., et al. (2013) Chapter 20 in "Molten Salt Chemistry: from Lab to Applications"

Molten Salt Chemistry – A quick guide

Corrosion in decomposing nitrate melts



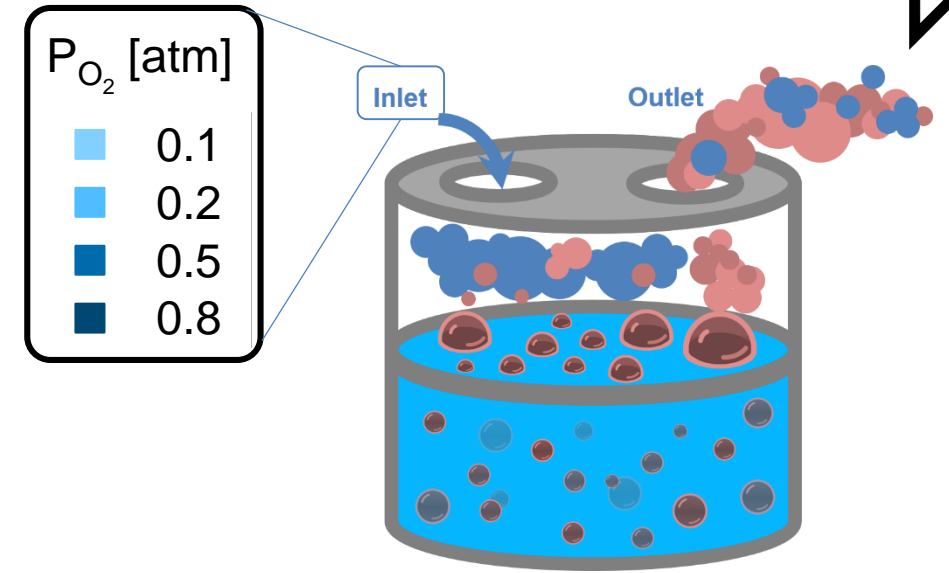
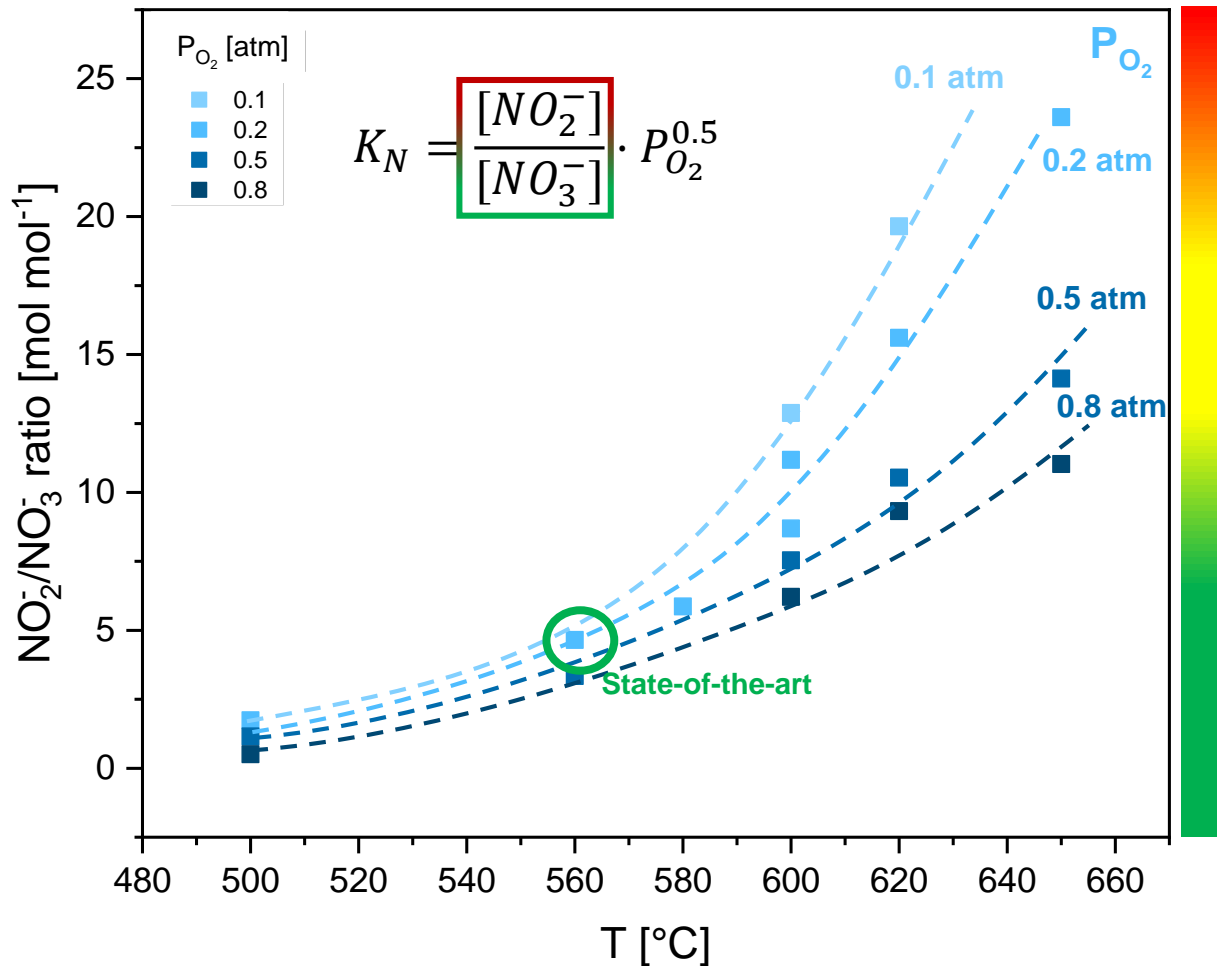
Salt decomposition
aggravates corrosion

Salt stabilization
suppresses corrosion?!?

A. Bonk, D. Rückle, S. Kaesche, M. Braun, T. Bauer, Impact of Solar Salt aging on corrosion of martensitic and austenitic steel for concentrating solar power plants. *Solar Energy Materials and Solar Cells* **203**, (2019).

Molten Salt Chemistry - A quick guide

O_2 stabilizes Nitrate Salts

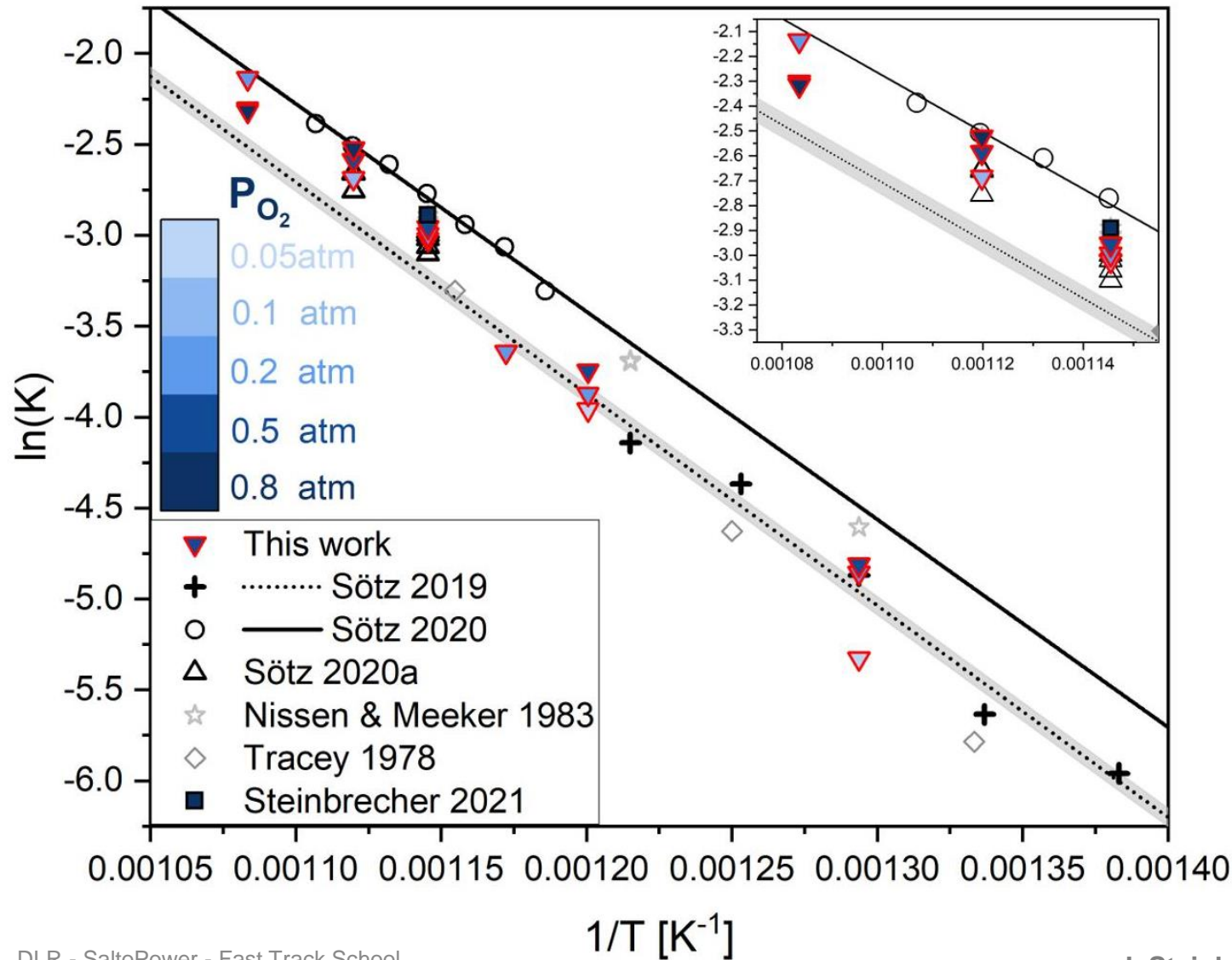


Thermodynamic Data at different P_{O_2}

- Data acquired for **10-80% O_2** in N_2 (1 bar)
- Side reactions at high temperatures affect thermodynamics
- Higher **P_{O_2}** stabilizes molten salt

Solar Salt

60wt% NaNO_3 - 40wt% KNO_3



Stability Analysis

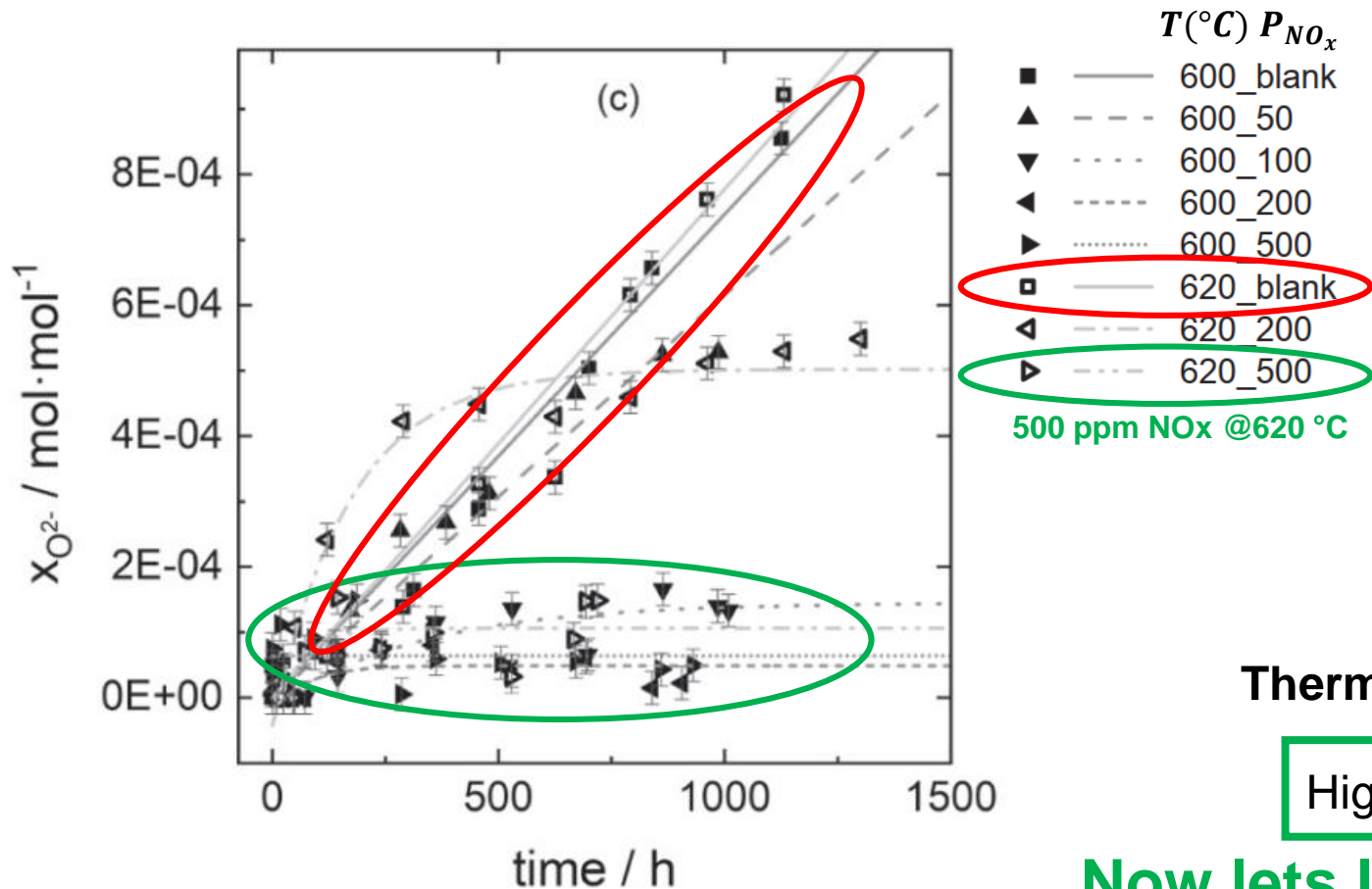
**Degradation
Mechanisms**

Thermodynamics

Kinetics

Impact of Nitrous Gases on Oxide Ion Concentrations

Oxide ions in Salt



Impact of NOx gases on stability of Solar Salt

- No effect on nitrate-nitrite equilibrium
- Oxide ion content decreases with increasing NOx content
- Corrosivity potentially decreases with increasing P_{NO_x}

Thermodynamic Data at different P_{NO_x}

High P_{NO_x} suppress oxide ion formation

Now lets look at the impact on corrosion

Source: V. Sötz et al. (2020)
<https://doi.org/10.1016/j.solener.2020.09.041>

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E
S
:store
S



**Heating
Technology**

Storage testing

**Innovative
concepts**

**Operating
Experience**

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Instrumentation

**Joining
Technology**

**Pipe & Valve
Integration**

Qualification

