ENERGY.
FUTURE.
ZAE.

Unlocking the potential of thermo-chemical technologies

Dieter Preßl

ZAE BAYERN

Outline

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1. ZAE Bayern | Short introduction
2. Liquid sorption systems | Potential & Challenges
3. R&D on liquid sorption systems at ZAE Bayern | Examples
4. Project MAKSOR^{E} | Absorption thermal energy storage with aqueous salt solutions
5. Summary & Outlook

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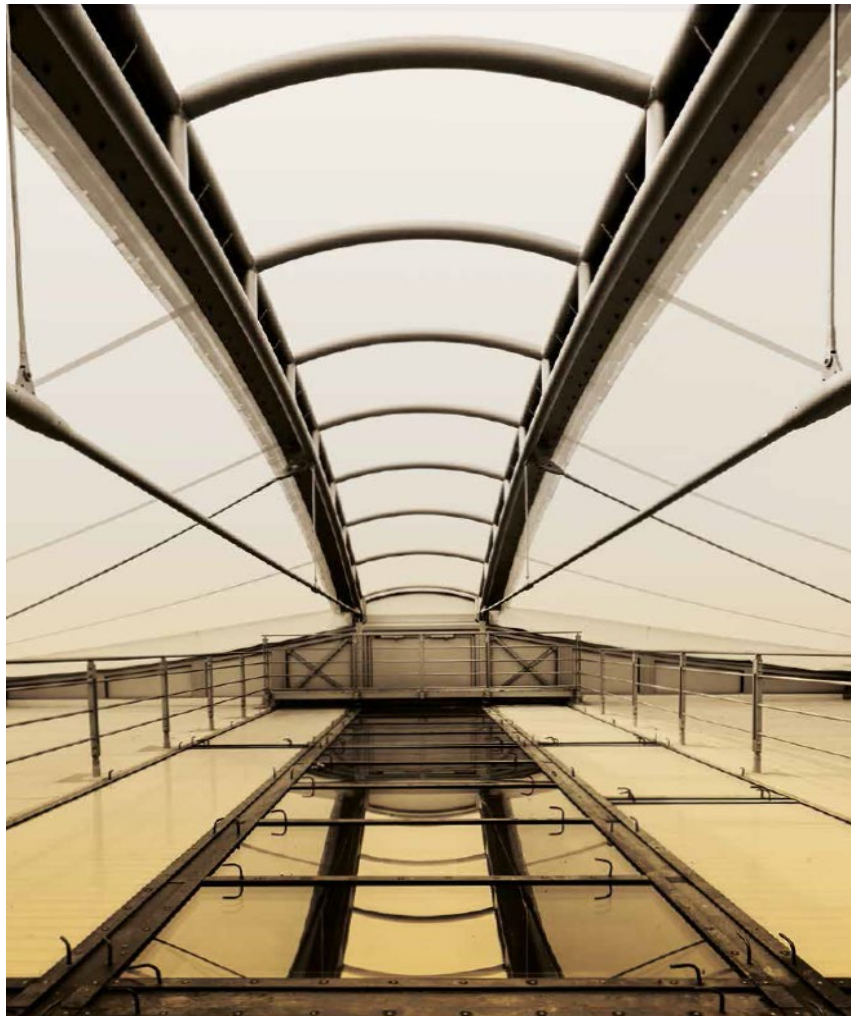
ZAE Bayern – Mission and Vision

Since 1991, ZAE Bayern has been engaged in

- Research
- Commercialisation
- Training and education
- Consulting and information

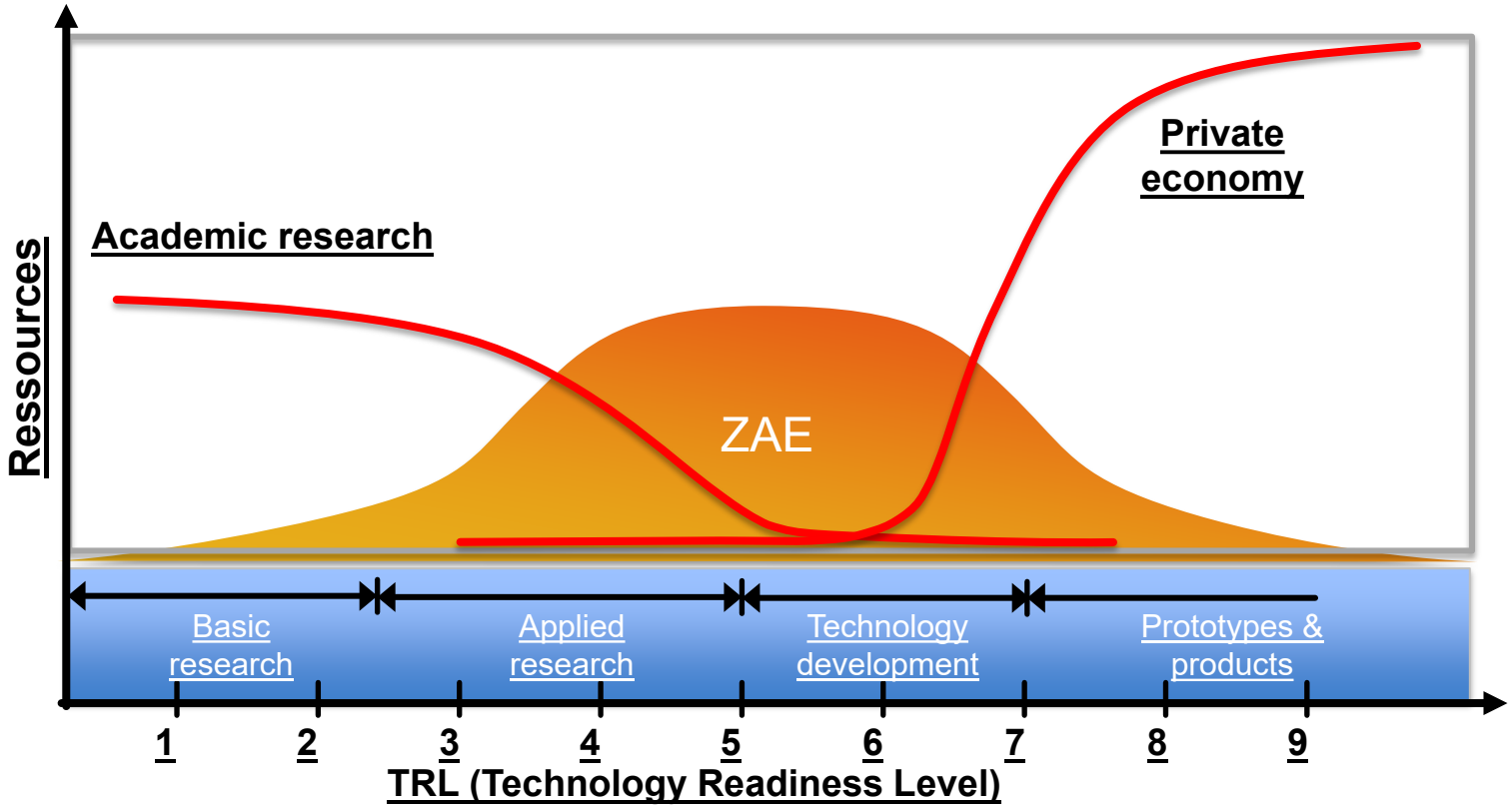
in all fields important for energy research and related topics.

Aim:
Realisation of an CO_2-neutral energy supply by synergetic use of **Renewable Energies** and **Energy Efficiency Technologies**



ZAE Bayern – Applied Energy Research for the Energy Economy

From basic research to full-size demonstrators



ZAE fills the gap between basic research and commercialisation of new ideas

ZAE Bayern – Scientific Divisions

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Scientific divisions

RENEWABLE ENERGIES (RE)

Locations
Erlangen|Nürnberg|Hof

Scient. director: Prof. Brabec
Head of division: Dr. Hauch

ENERGY STORAGE (ES)

Location
Garching

Scient. director: Prof. Spliethoff
Head of division : Dr. Hauer

ENERGY EFFICIENCY (EF)

Location
Würzburg

Scient. director: Prof. Dyakonov
Head of division : Dr. Ebert

FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

Technische Universität München

Julius-Maximilians-UNIVERSITÄT WÜRZBURG

ZAE Bayern – Division Energy Storage (ES)

~85 employees
~5.5 m € R&D-budget/year
~3,500 m² research facilities

Division ES
Energy Storage

Flexibility for Electricity and Heat

Technische Universität München

Lehrstuhl für Energiesysteme

Lehrstuhl für Technische Elektrochemie

EES Lehrstuhl für Elektrische Energiespeichertechnik

System Engineering
Energy concepts
Studies & scenarios

Solar Thermal & Geothermal
Solar district heat
Geothermal

Thermal Energy Storage
Heat and cold storage materials

Electric Energy Storage
Redox-Flow-Batteries
Electrolysis

Heat Conversion
Heat pumps
Chillers

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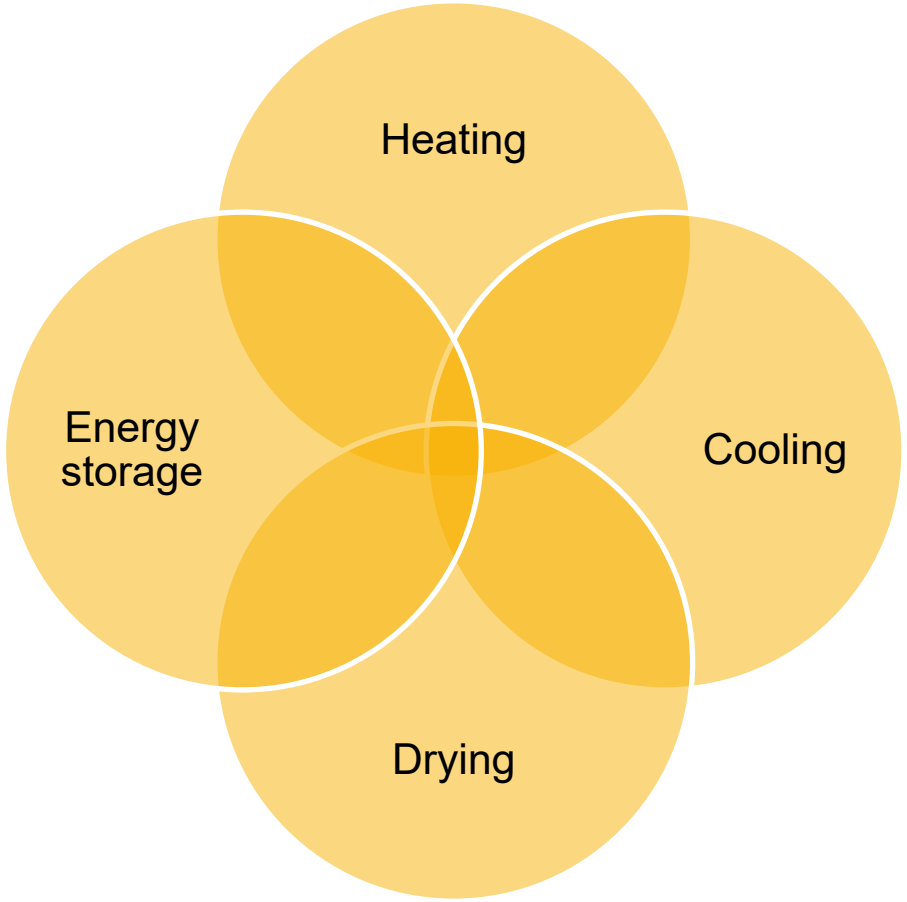
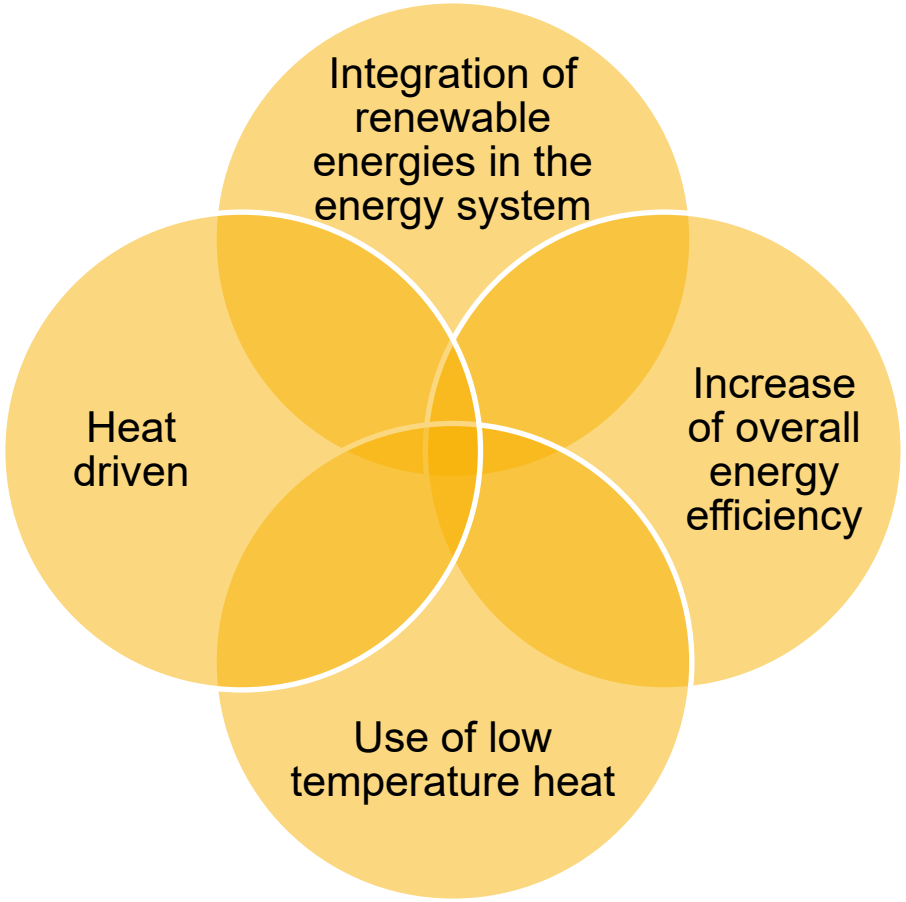
Liquid sorption systems – Potential

Wide application field



Benefits



Liquid sorption systems – Challenge „sorbent“

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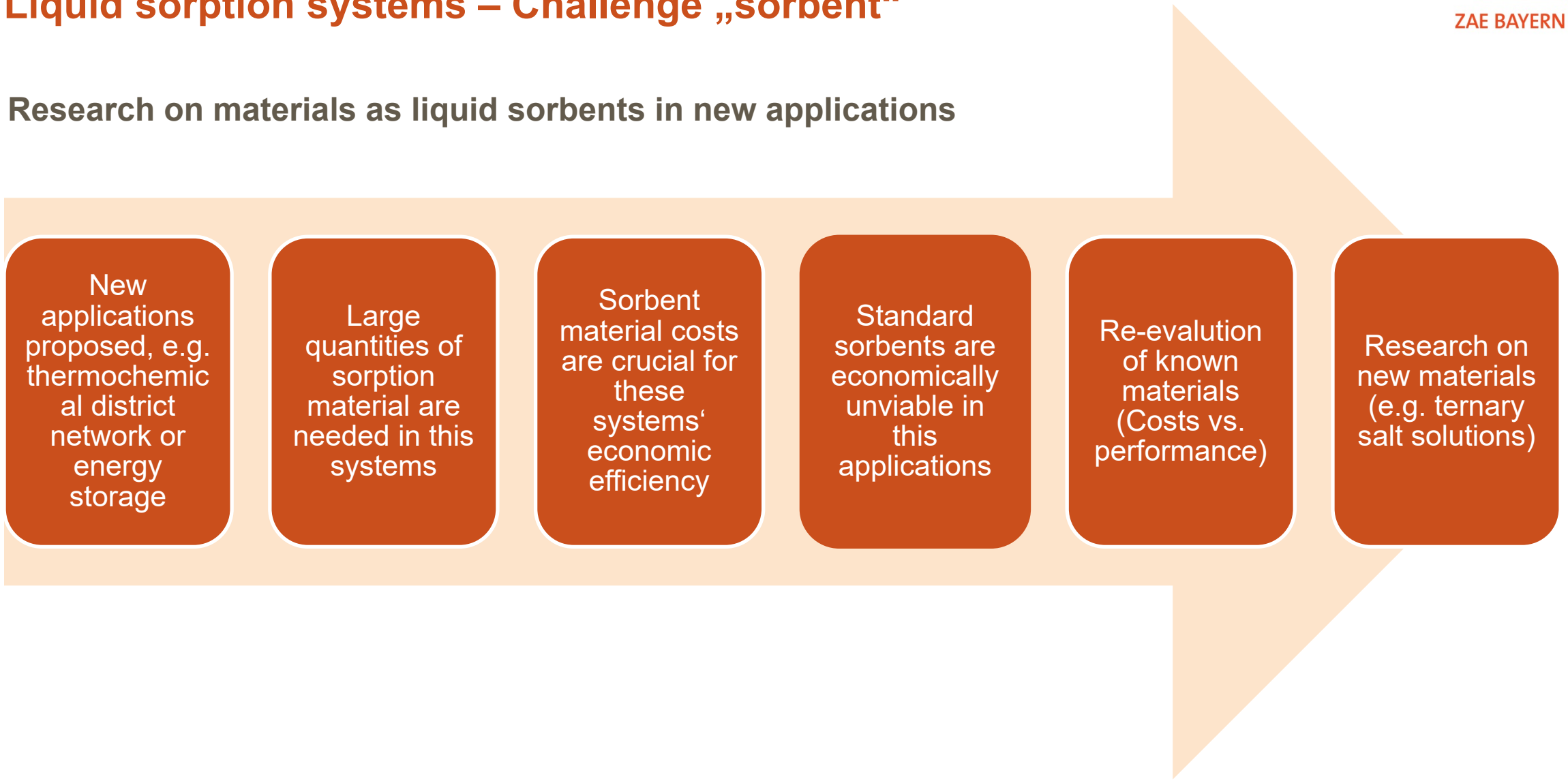
Research on materials as liquid sorbents in new applications



Liquid sorption systems – Challenges

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Ternary salt solutions as liquid sorbents

Potential advantages over binary salt solutions

- Lower material costs
- Lower vapour pressure
- Higher solubility

Example for ternary salt solution: Klimat 3930

- $CaCl_2$ + $Ca(NO_3)_2 \cdot 4H_2O$ + H_2O
- Tested in open sorption system at ZAE Bayern

But

- Performance losses expected

→ Cost saving vs. performance losses
→ Economic optimization for new applications needed

Liquid sorption systems – Challenges

Ternary salt solutions as liquid sorbents

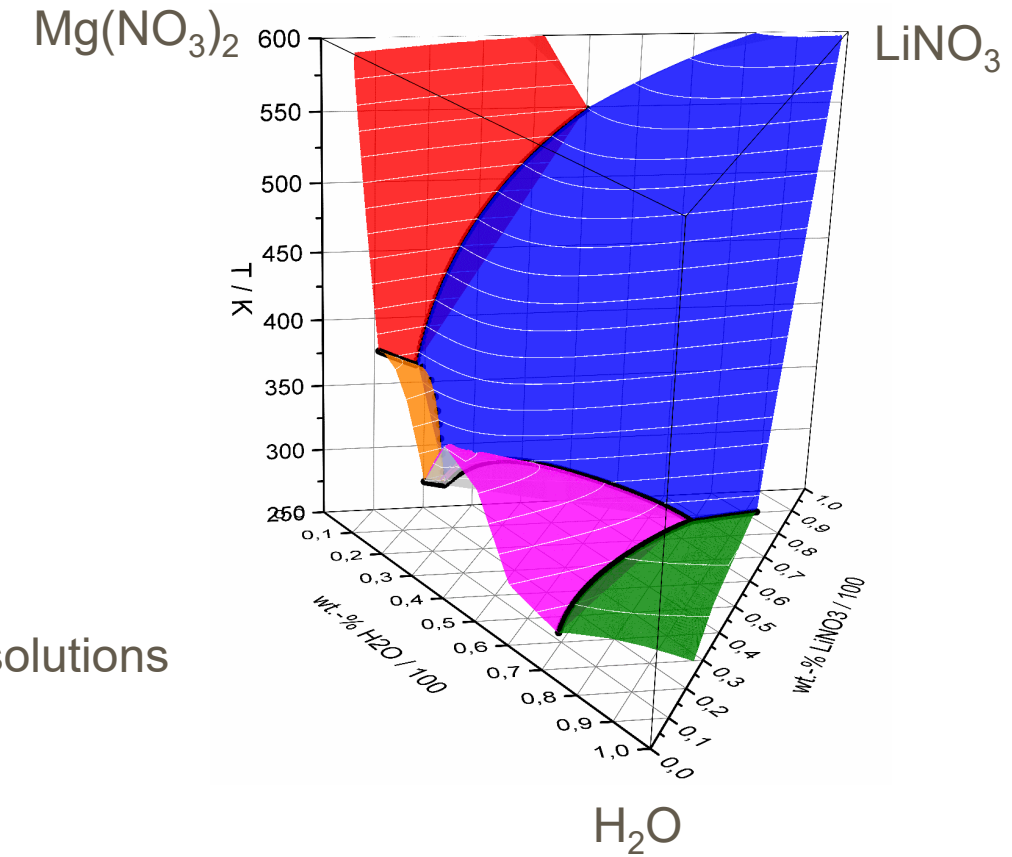
Estimation of performance in sorption systems

- Material data needed
- Experimental measurement causes high costs i.a. because of additional parameter (mass ratio)

→ Prediction of relevant data via modelling

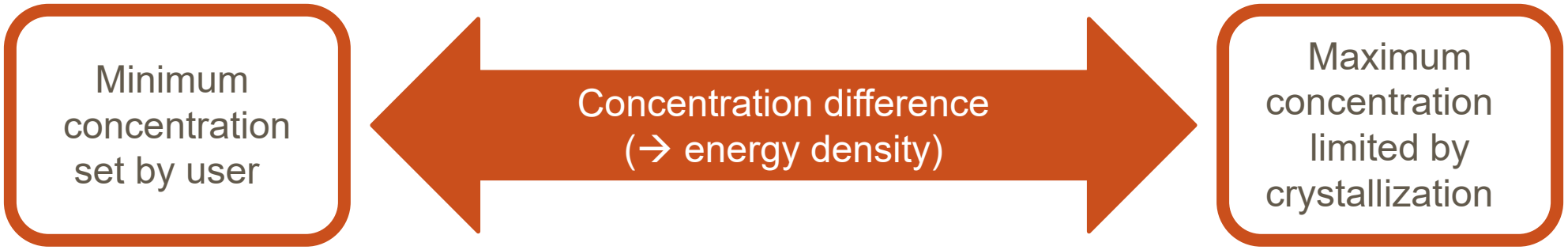
Modified BET-model

- Originally used for phase change materials at ZAE Bayern
- Calculation of essential material data for multicomponent salt solutions
- E.g. liquidus surfaces and vapour pressures



Liquid sorption systems – Challenges

Slurries to increase maximum concentration of solution in thermochemical district networks



- Slurry = temporary solid phase + permanent liquid phase
  → Higher maximum concentration

- Slurry production and transport in pipes analyzed in ZAE-Project *PC_Cools_S*
  - Material: $K_2HPO_4 \cdot 6H_2O$ / 30 % solid phase
  - Application: Cooling of buildings

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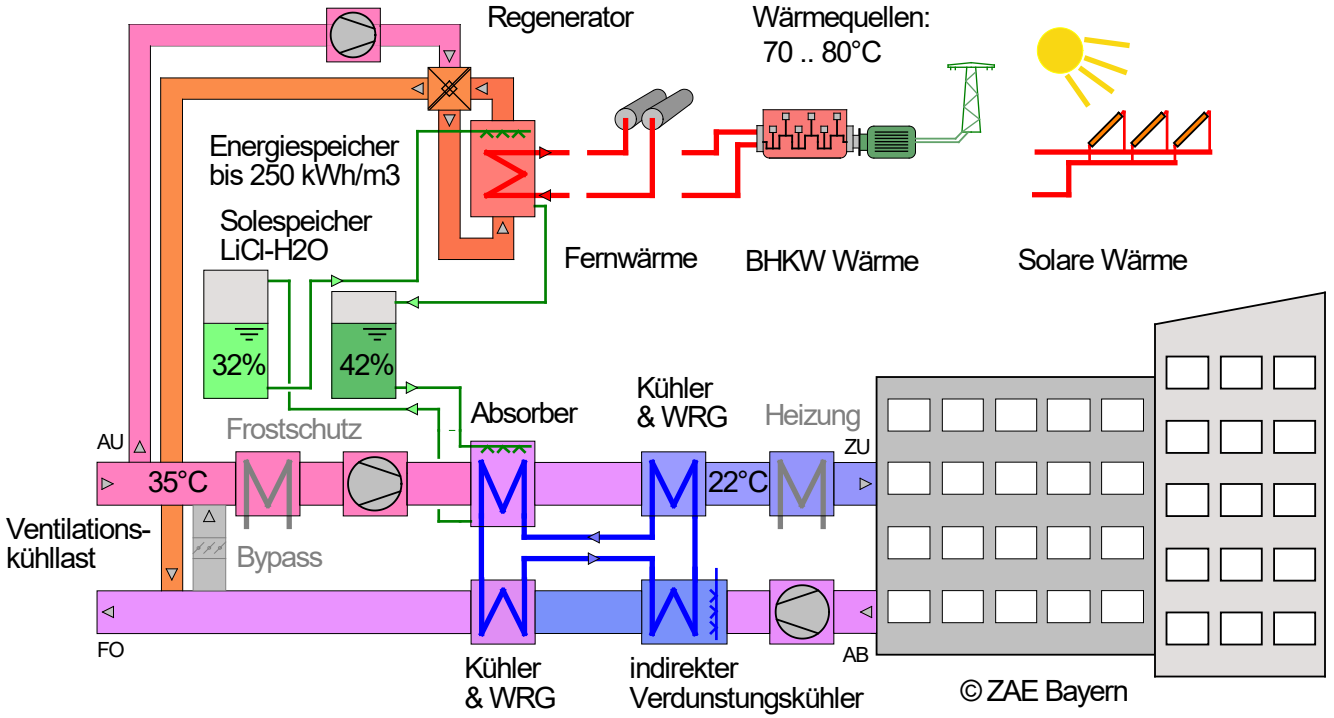
R&D on liquid sorption systems at ZAE Bayern – Examples

Demonstrator Würzburg

- Open sorption system
- Integrated energy storage
- Building air-conditioning with dry and cool air
- Powered by waste heat, solar heat or district heat



R&D on liquid sorption systems at ZAE Bayern – Examples

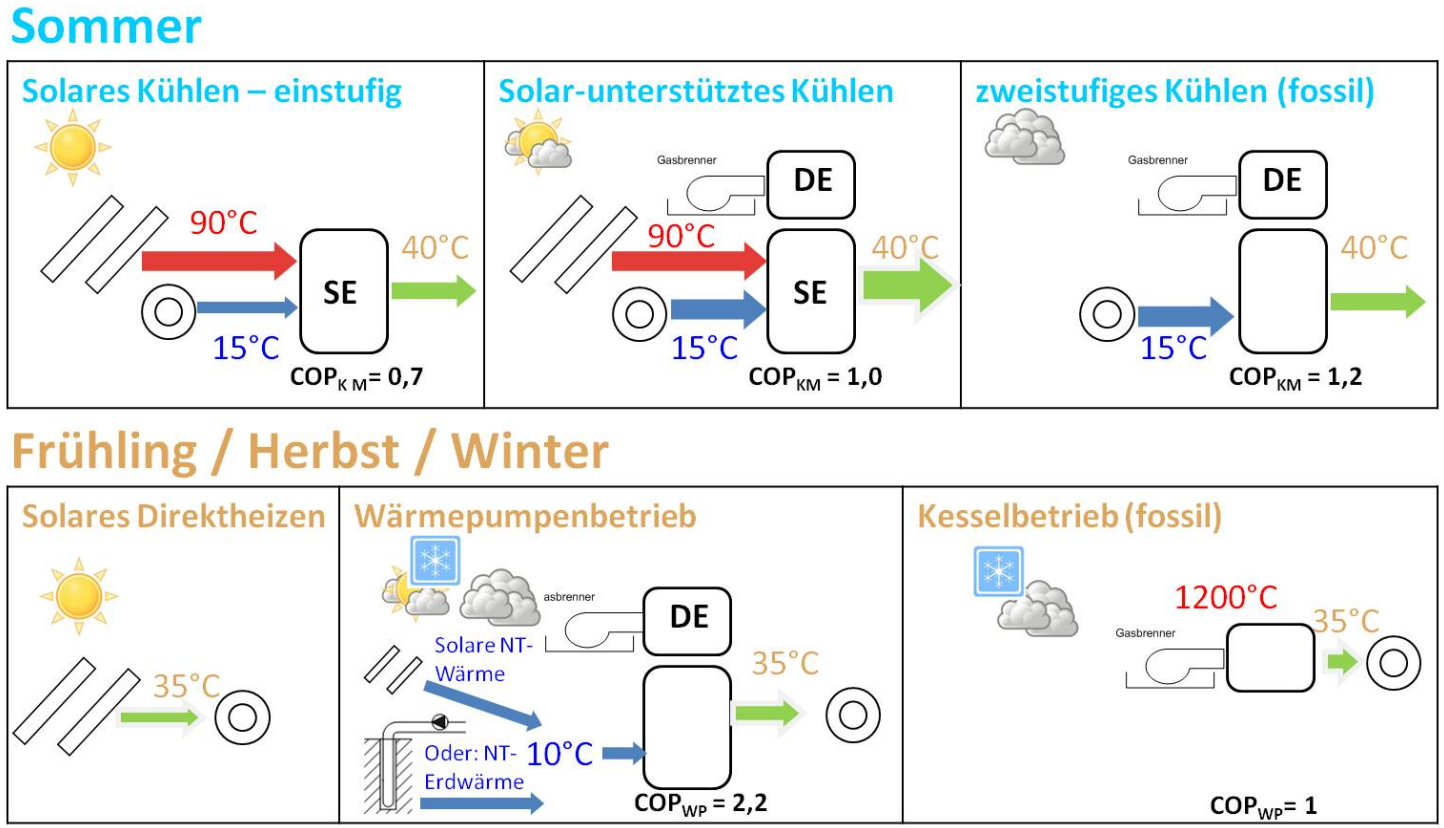
Demonstrator Würzburg

- Maximum airflow capacity: 6000 m^3/h
- Maximum cooling capacity: 40 kW

R&D on liquid sorption systems at ZAE Bayern – Examples

Demonstrator Arnstorf

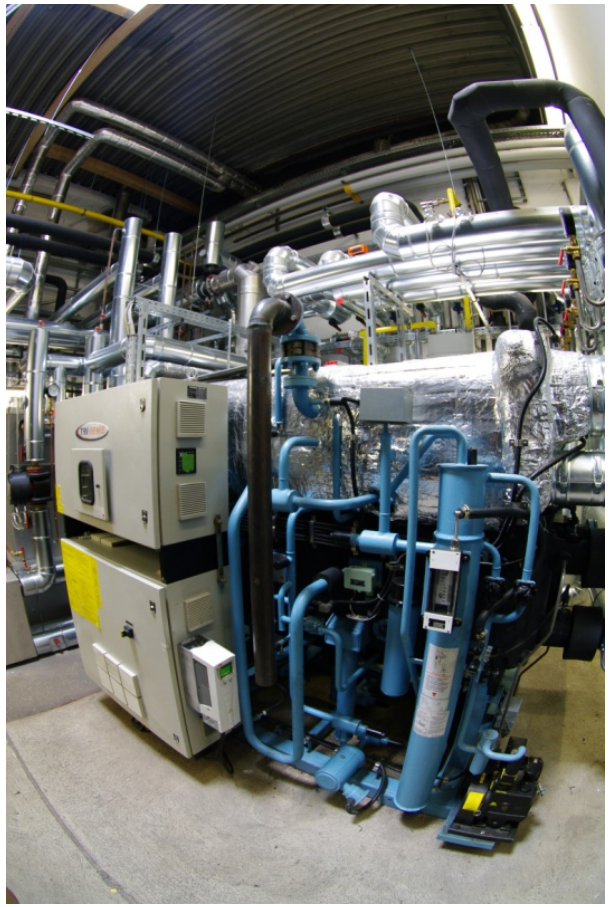
- Closed sorption system
- All-season building air-conditioning
- Single effect: Solar heat driven
- Double effect: Solar heat in combination with natural gas



R&D on liquid sorption systems at ZAE Bayern – Examples

Demonstrator Arnstorf

- Maximum heating capacity: 160 kW
- Maximum cooling capacity: 90 kW



Innovative flexible absorption chiller

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Project MAKSOR^{E}

MAKSORE = Materials and components for sorption heat storage with high energy density

- Aim:
  → 3 different storage concepts (2 x adsorption + 1 x absorption)
  → Increase energy density (compactness!) of storage systems
  → Facilitate integration in existing building stock

- Duration: 09/2014 – 03/2018

- Partners:

Karlsruher Institut für Technologie

Universität Stuttgart

ZAE BAYERN

Fraunhofer ISE

Technische Hochschule Wildau [FH] *Technical University of Applied Sciences*

Project MAKSOR^{E}

ZAE BAYERN

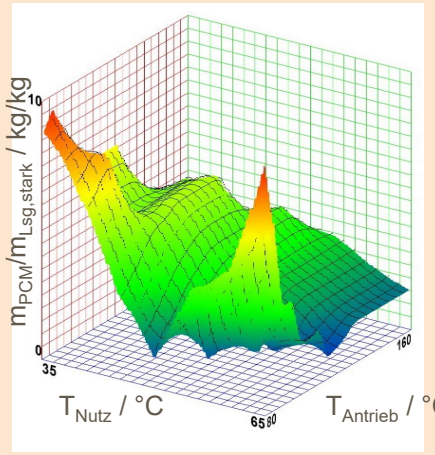
Research topics

Materials

- LiBr/H_2O: Consistent formulation of thermo-dynamic material data
- Alternative salt solutions as sorption/storage materials

System Modelling

- Theoretical energy densities for absorption heat/cold storage
- Absorption and desorption process

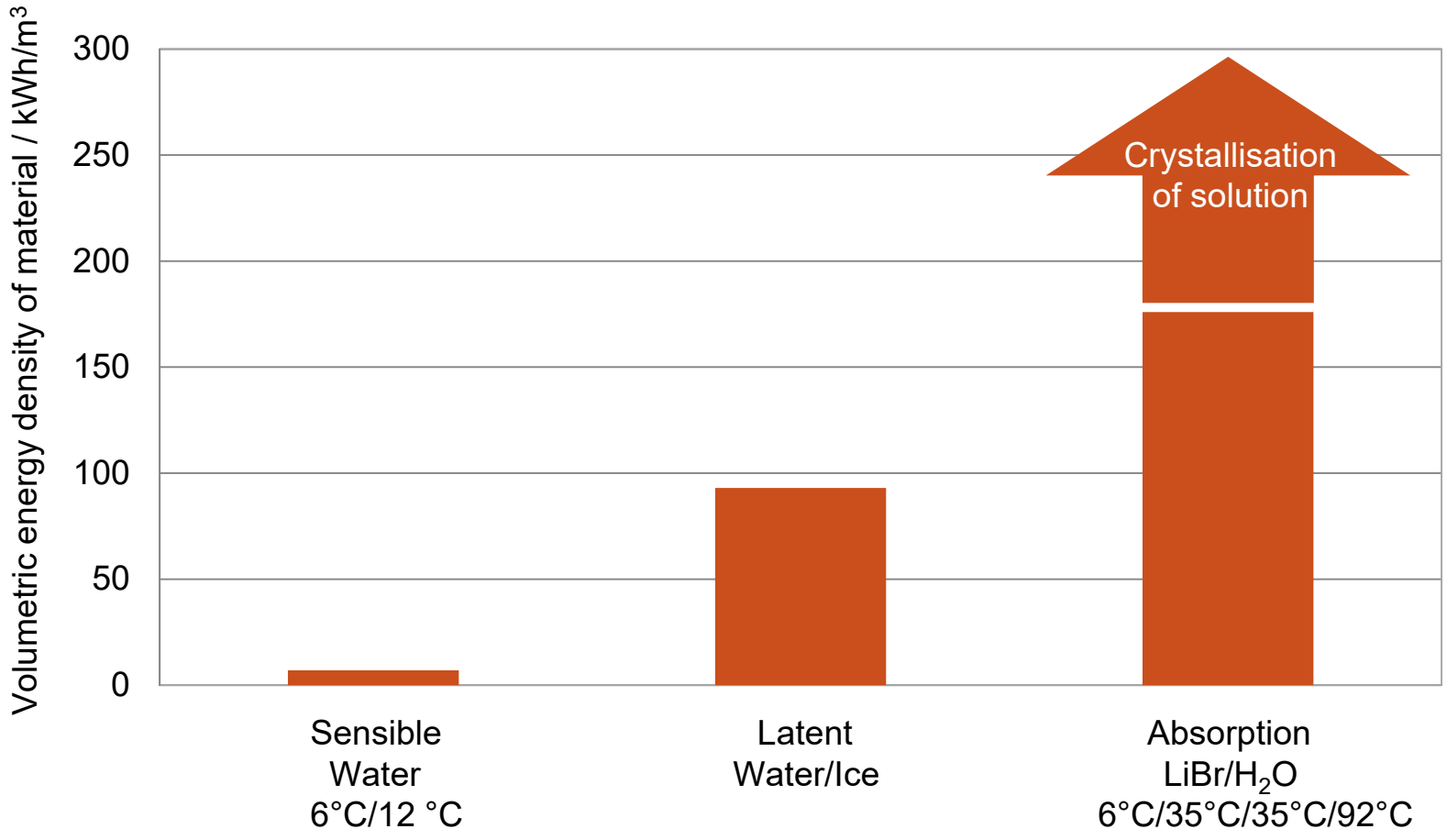


Components

- Experimental plant of an absorption thermal energy storage
- Investigation of absorption thermal energy storage

Project MAKSOR^{E}

Absorption cold storage – Motivation



Project MAKSOR^{E}

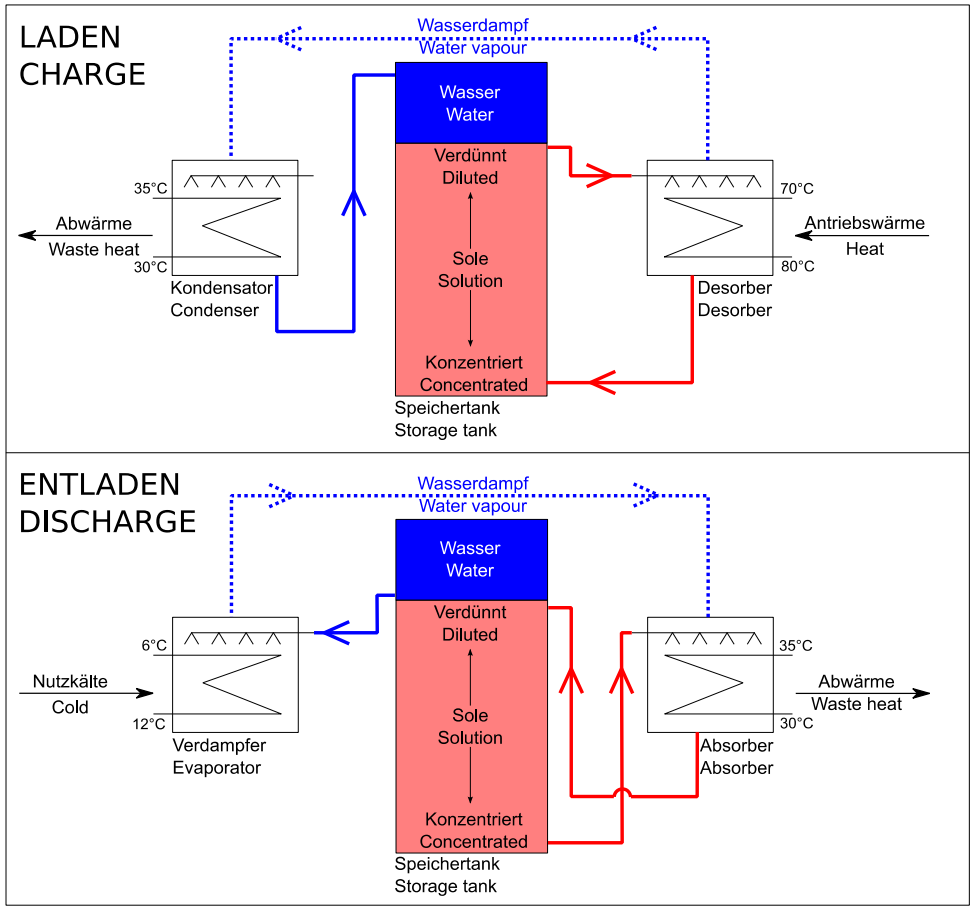
Absorption cold storage – Schematic process

Technical system

- Modified process of an absorption chiller
- Integration of an storage tank
- Crystallisation to further increase energy density

Potential application fields

Storage of
- Industrial waste heat
- Waste heat of block-type thermal power stations
- Solar heat (→ Seasonal storage)



Project MAKSOR^{E}

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Planned follow-up project: Absorption cold storage for industrial application

Materials	LiBr/H_2O: Measurement of material data for $c_{LiBr} \geq 70$ %	Absorber/ Desorber design	Geometry suited for energy storage application	Crystalli-zation	Experimental investigation on lab scale	Labor-atory plant	Compact absorption cold storage system (5 kW, 40 kWh)
	Alternative salt solutions (ternary systems!)		Experimental testing in MAKSOR^{E} plant		Experimental testing in MAKSOR^{E} plant		With crystallisation of aqueous salt solution

Status Quo: Project outlined

Next step: Recruiting of industrial partners (provider or user)

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Summary & Outlook

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- Liquid sorption technology has high potential for application in future energy system
  - Integration of renewable energies (e.g. solar heat)
  - Increase in energy efficiency (e.g. use of waste heat)

- Absorption process is highly suitable for energy storage
  - High energy densities / compactness
  - Cost efficient energy storage

- Focus of future research should be on
  - Sorption materials (i.a. multicomponent salt solutions)
  - Compact and cost efficient systems

➢ Therefore: R&D activities on liquid sorption systems have to be intensified

Thank you for your attention!

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Project MAKSOR^{E}

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Experimental plant

	Value
Volume of salt solution	0,45 m^3 (c_{LiBr} = 55 %)
Cooling capacity	5 kW*
Energy stored	80 kWh*

* Depending on operating temperatures

Experimental plant of an absorption cold storage (before installation of heat insulation)

Liquid sorption systems

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Challenges

Liquid sorption materials

- Costs
- Thermodynamic properties
  - Low vapour pressure
  - High Solubility
  - Viscosity
- Toxicity (i.a. water endangering class)
- Corrosivity

Components & Systems

- Costs (!)
- Durability
- Reliability
- Compactness