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NEUE LINERMATERIALIEN

Alterungsbeständige Polyolefine

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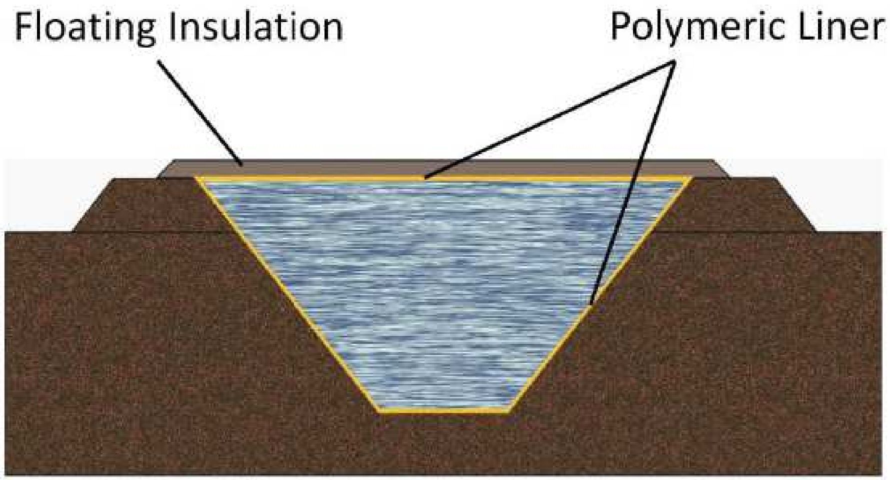
INTRODUCTION AND OBJECTIVES

State of the art



- Polymeric materials are of high relevance for pit thermal energy storages (**PE-liner, PE-foam insulation**)
- Trend of increasing size and temperature loads (**max 80°C → 95°C**)

Development needs

- **Novel liner materials** with improved durability at elevated temperatures (+ 10 to 15 °C)
- **Methods for efficient screening** of novel materials and **lifetime assessment**
- **Intensified collaboration** of partners from different levels of value creation chain and involvement of raw material suppliers

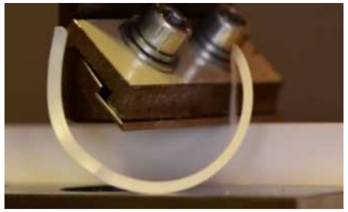
METHODOLOGY – AGEING CHARACTERIZATION

Materials, Ageing Conditions and Indicators

Materials and specimen

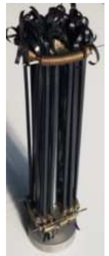
- **PE** (commercial):
  Polyethylene high density
- **PP-R** (commercial):
  Polypropylene-CoPo
- **PP-HTR** (AGRU):
  optimized PP-CoPo
- 2mm thick extruded sheets
- micro-sized specimen

Automated CNC planning



Exposure conditions

- Medium:
  - hot water or hot air
- Temperatures:
  - 95 to 135°C
- Removal:
  - at least 4 specimen per interval



Evaluated aging indicator

- **Embrittlement/failure time by tensile testing (Zwick Roell zwickiLine)**
  - Specific values: Evaluation of stress/strain curves; strain-at-break
  - Aging indicator: $\varepsilon_b < \varepsilon_y$; total embrittlement

Zwick Roell zwickiLine

METHODOLOGY – LIFETIME ASSESSMENT

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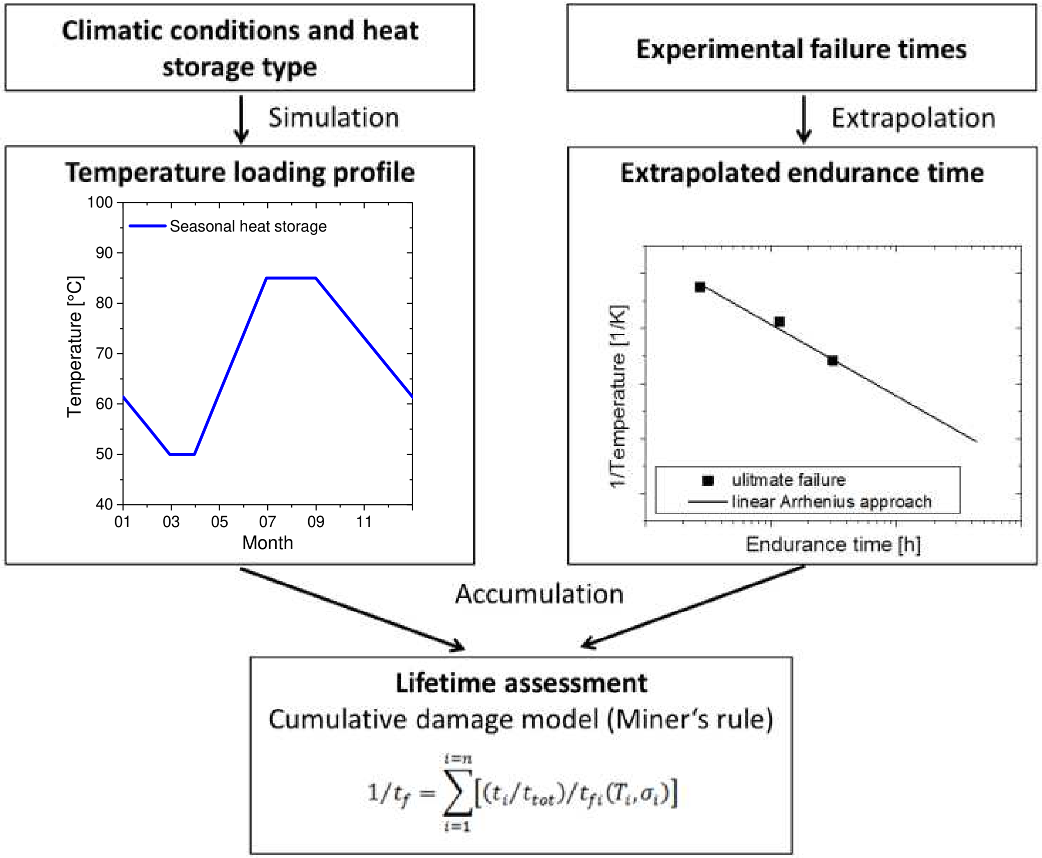
Cumulative damage model



- Temperature loading profile for seasonal heat storages (focus on pit LSTS)
- Experimental data are extrapolated to service relevant temperatures (45 to 95°C)
- Deduction of lifetime by applying a cumulative damage model

RESULTS – AGEING BEHAVIOUR OF PE

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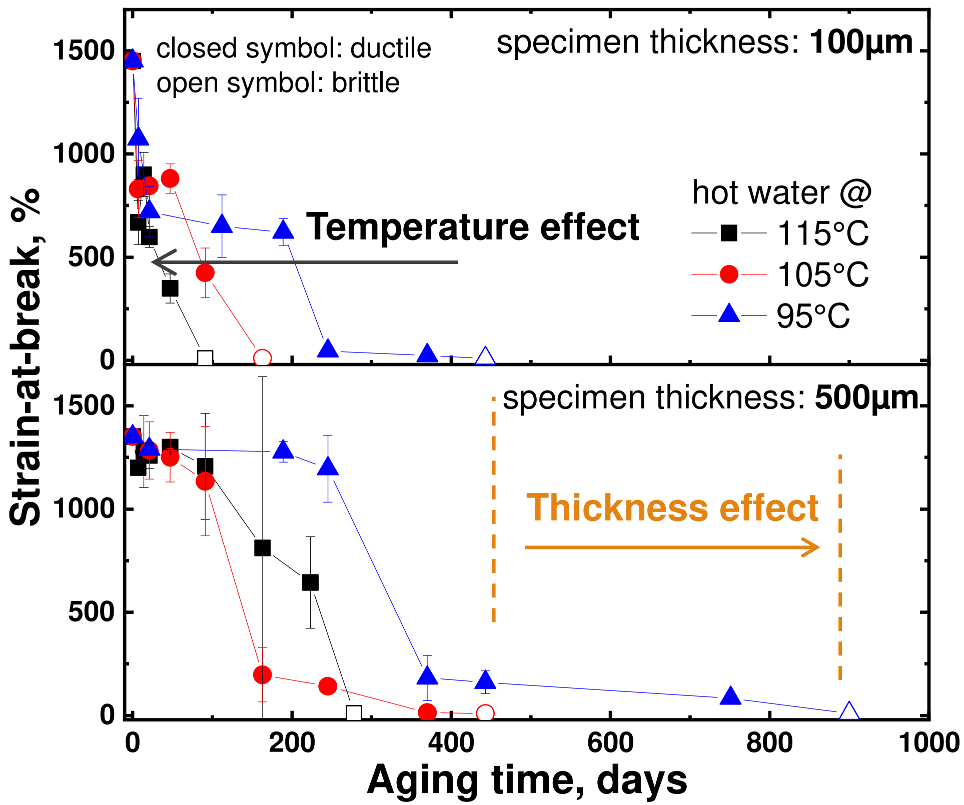
Effect of temperature and thickness on mechanical failure



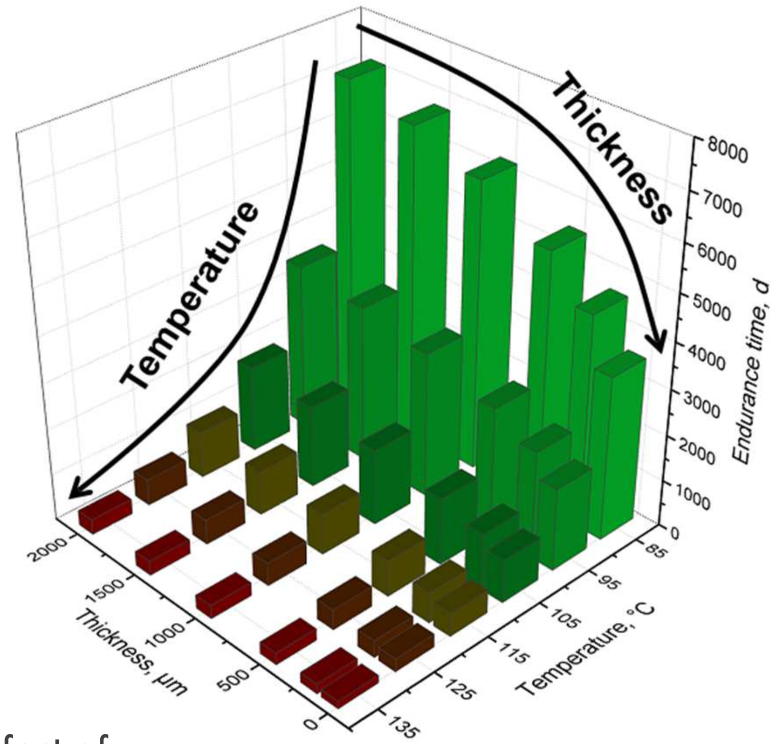
- Hot water is more critical than hot air
- Decrease of strain-at-break → below yield → failure
- Temperature effect: 3x faster for ↑20°C
- Thickness effect: 5x slower for 20x thicker (0.1 to 2 mm)

Lifetime: 15 years for 2 mm thick PE liner

- Storage type medium
  min/max. temperature: 50/85°C
- slightly lower lifetimes than Paranowska and Pedersen, 2016 (DEN)
- different aging setup & failure criterion
  (both media vs. more critical fluid)

RESULTS – AGEING BEHAVIOUR OF PP-R (RANDOM COPO)

Endurance and predicted lifetime



less effect of thickness (micro-macro: ~2x)

- Hot air is more critical (!)

Lifetime for PP-R 2mm

Storage type min/max. temperature, °C	**Predicted lifetimes, years**
low 40/75	47
medium 50/85	34
high 60/95	20

PP-R >2x better than PE-HD (!)

RESULTS – OPTIMIZED PP-HTR LINER (AGRU)

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Hot air ageing behaviour (endurance time)

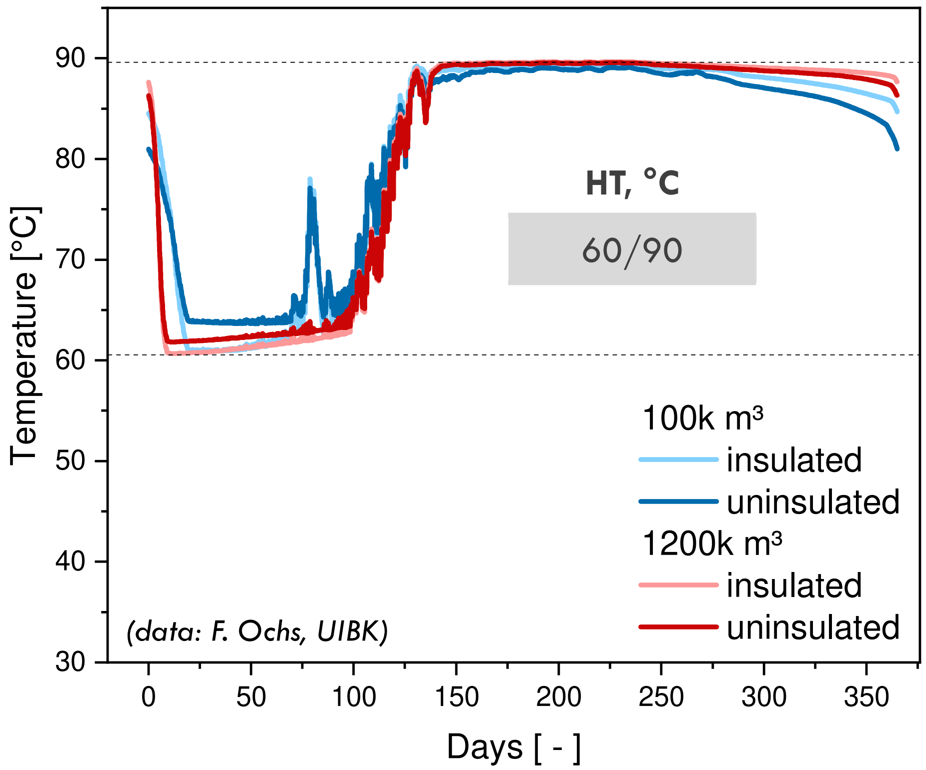
Material	95 °C	105 °C	115 °C	125 °C	135 °C
	Endurance times of 100 µm specimen in dry air [d]				
PP-R	**1,333**	**917**	**604**	**283**	**138**
PP-HTR	>1,875	>1,875	**1,334**	**583**	**338**

Optimized PP-HTR:

- **~2x better durability than PP-R; ~4x better than PE**
- even better behavior in moist air (factor: 1.5x)
- unique behavior in hot water (at 135°C >4x better than in dry air)

RESULTS – OPTIMIZED PP-HTR LINER (AGRU)

High temperature load profile and lifetime

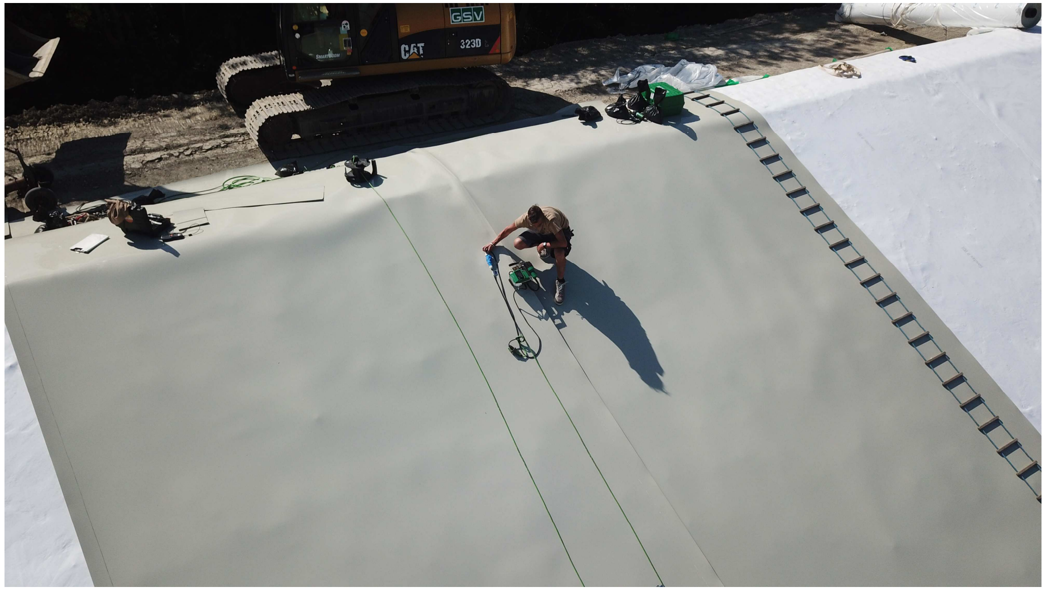


Expected lifetime

100k m³		1200k m³	
insulated	uninsulated	insulated	uninsulated
lifetime [years]			
33	35	31	32

RESULTS – OPTIMIZED PP-HTR LINER (AGRU)

Upscaling – mock up in Høje Taastrup (DEN)



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SUMMARY AND CONCLUSIONS

- Testing method for efficient screening of novel materials based on micro-sized specimen successfully implemented
- Long-term stability of established PE liner grades is limited
  - especially in hot water
- Novel PP-HTR materials (based an well-established hot water pipe grades) allow for significant improvement of durability
  - much better than PE under “high temperature” load conditions
  - hot water is less critical
- Upscaling of novel PP-HTR liner and evaluation on mock-up and full scale level
  - successful installation
  - evaluation of performance in “real” environment