INTER STORES

Karlsruher Institut für Technologie

Applied Geology

Martin-Luther-Universität Halle-Wittenberg

Environmental impact and optimisation potential of sTES

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European Geothermal Congress 2025

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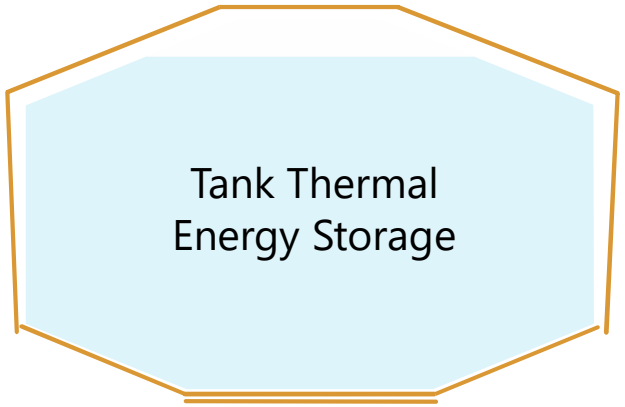
Motivation

- Seasonal Thermal Energy Storage (sTES)
  - Significant primary energy and emissions reduction, but often high costs and thermal losses.
- Construction material requirements
  - Must balance cost-effectiveness, durability, technical reliability and environmental performance.
- Life Cycle Assessment (LCA) relevance
  - Provides a systematic assessment of environmental impacts and optimisation strategies.

Motivation

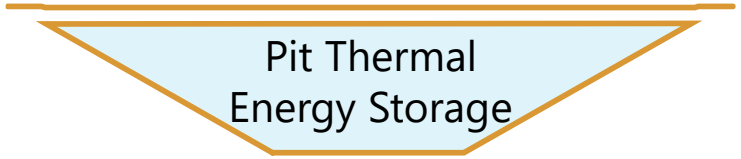
- Research gap
  - Existing studies focus on ATES and operational impacts; the construction phase is underexplored.
- Unified objective of different sTES
  - Balance seasonal heat demand fluctuations, enable efficient use of renewable heat sources, and reduce fossil fuel consumption.
- Environmental impact
  - TTES, PTES, WGTES are sTES like ATES and BTES; understanding their impacts and optimisation potential needs a comprehensive view of all systems combined.

Application Cases

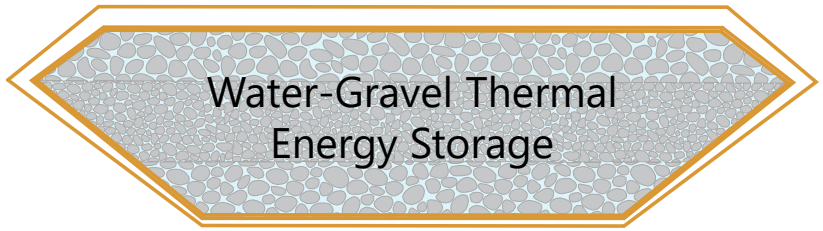


Sealing

HDPE



HDPE

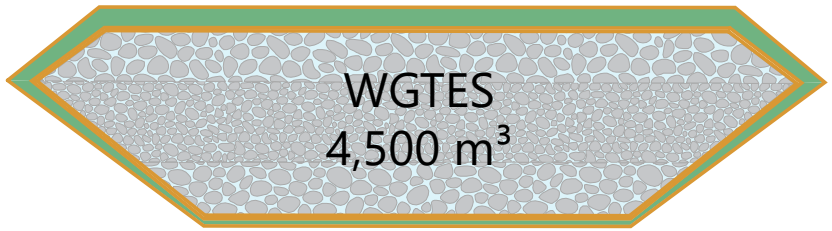


HDPE
Polypropylene

Application Cases

Sealing	Insulation
HDPE	Foam glass gravel Expanded glass granulate

HDPE	Polymer foam

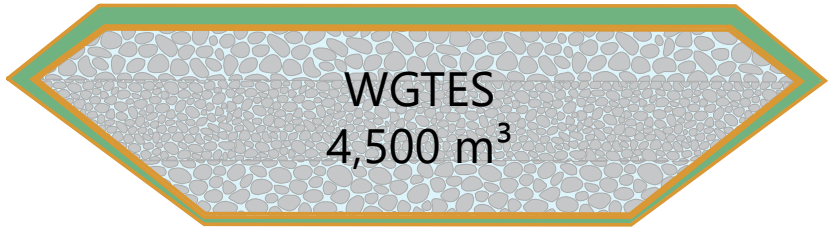


HDPE Polypropylene	Foam glass gravel Expanded glass granulate

Application Cases

Sealing	Insulation	Static elements
HDPE	Foam glass gravel Expanded glass granulate	Steel Concrete

HDPE	Polymer foam	–



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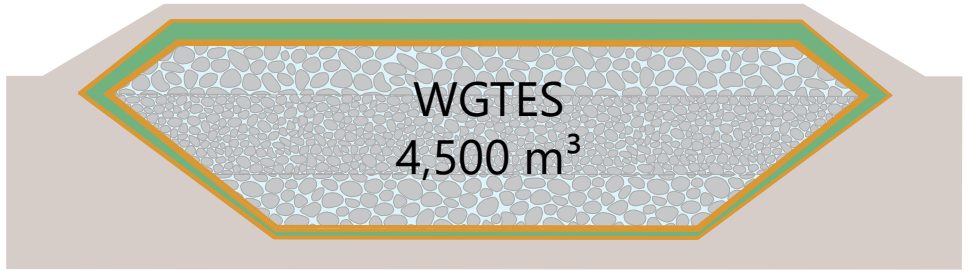

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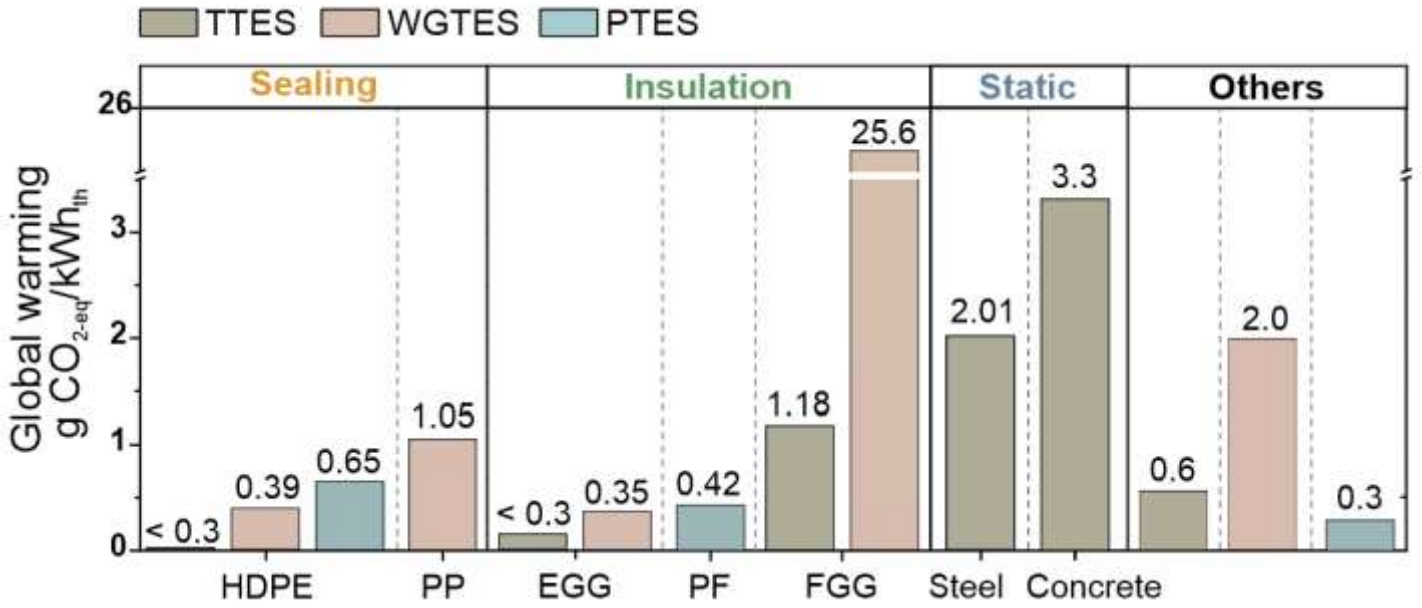
Environmental impacts

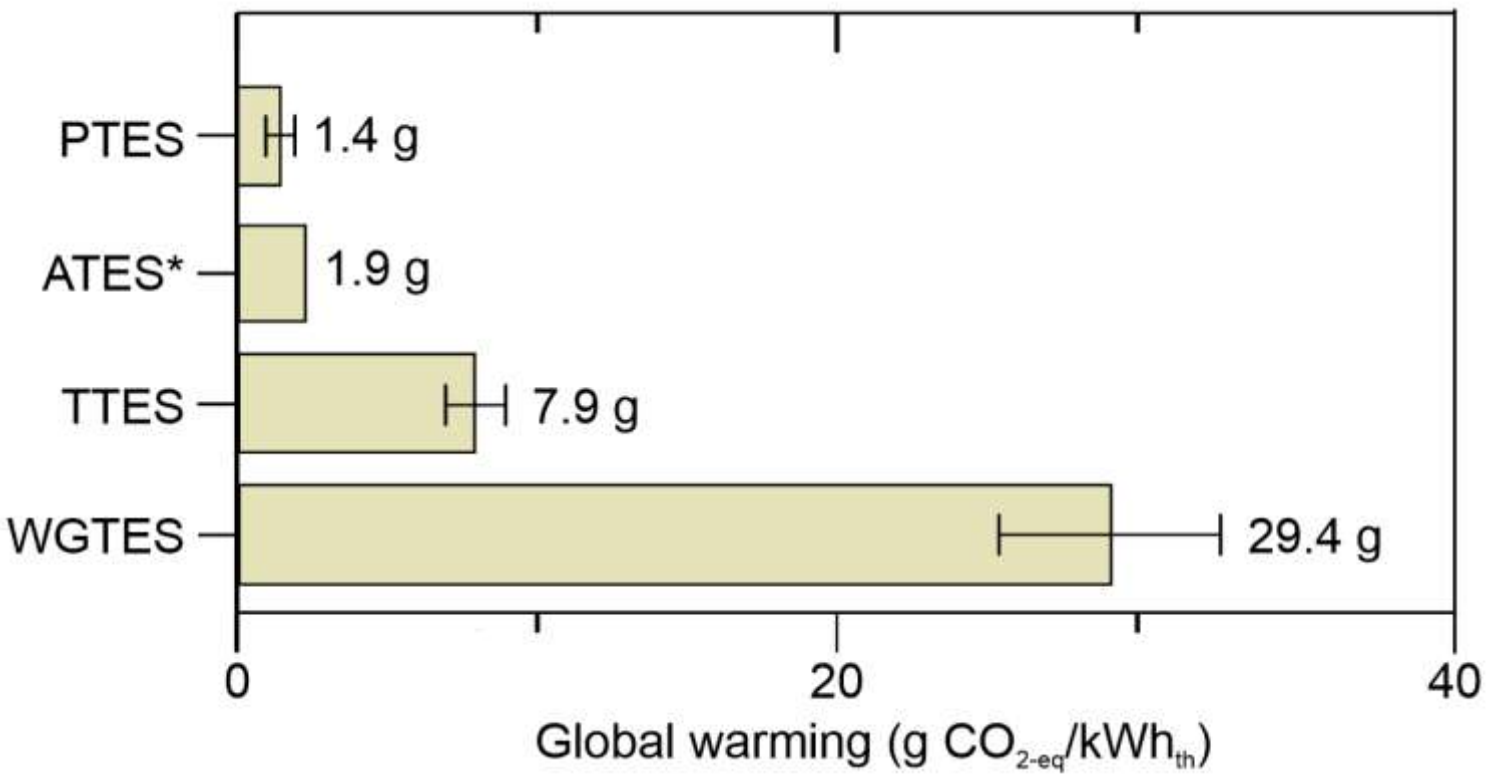
Material contributions to environmental impacts of global warming



Life cycle inventory of the three sTES

Components	TTES in t	WGTES in t	PTES in t
HDPE	0.9	3.6	113
Polypropylene	-	2.3	-
Expanded glass granulate	149	102	-
Polymer foam	-	-	72.7
Foam glass gravel	16.7	101	-
Steel	27	-	-
Concrete	898	-	-

Evaluation of global warming



** R. Stemmle, et al. (2021) Environmental impacts of aquifer thermal energy storage (ATES), Renew. Sustain. Energy Rev.*

Conclusions

- Environmental impact of sTES
  - Construction-phase emissions range from 1.4 to 29.4 g $CO_{2\text{-eq}}/kWh_{th}$, with WGTES having the highest and PTES the lowest impact.

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- Optimisation potential
  - Minimising concrete, steel, and foam glass gravel, using water as filling material, employing underground construction methods, and optimising large storage volumes to reduce surface-to-volume ratio enhance environmental performance.

Conclusions

- Environmental impact of sTES
  - Construction-phase emissions range from 1.4 to 29.4 g $CO_{2\text{-eq}}/kWh_{th}$, with WGTES having the highest and PTES the lowest impact.
- Optimisation potential
  - Minimising concrete, steel, and foam glass gravel, using water as filling material, and optimising large storage volumes to reduce surface-to-volume ratio enhance environmental performance.
- Further research
  - A full life cycle perspective, including operation and end-of-life, is essential to avoid burden shifting.

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Thank You

For Your Attention

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