After the RISEnergy Transnational Access, Users are required to submit a User Report. This should be done within 4 weeks after the Access is completed unless otherwise agreed. The User Report will be given to the User(s) by the WP2 leader. The report contains sections related to the work performed, the main results and observations that were achieved.

This document should be completed, signed, and sent by e-mail to risenergy@for.kit.edu.

Summary questionnaire for Users who have been granted Transnational Access (TA) under the RISEnergy project Horizon Europe TA scheme. More information on RISEnergy TA can be found in "General Rules" and in "Access Policy" which can be found on the RISEnergy webpage.

Please complete, sign, and send this form, together with the Cost claim by e-mail to risenergy@for.kit.edu with title: RISEnergy APP150 - reports.

General information about the project	
Project title (as used in Application)	Impacts of thermophysical properties of zeolitic imidazolate frameworks (ZIFs) and their composites on the solar energy storage performance
Project number (APPXXX) and acronym (max 15 characters)	APP150, ZIFCoTherm
RISEnergy RI(s) accessed	Austrian Institute of Technology
Keywords (up to five, free text)	sorption composite, water adsorption, heat of adsorption, thermal conductivity, specific heat capacity
Arrival date (in town where RI is located)	18.05.2025
Departure date (from town where RI is located)	03.06.2025
Starting date of Access (first day at RI)	19.05.2025
Finishing date of Access (last day at RI)	03.06.2025
Number of days not using the RI (during the above period)	2
Reason for not using RI those days (describe)	Public holiday, Bridge day
Number of days using the RI	10
Number of Users granted Access (group size)	1
Comments	/
User	

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User group leader or sole applicant (user group member 1)	
First name	
Last name	
Affiliation / Employer	
Country of Employer	
E-mail	
User travelling to RI?	
Comments	/
User group member 2	
First name	
Last name	
Affiliation / Employer	
Country of Employer	
E-mail	
User travelling to RI?	
Comments	/
User group member 3	
First name	
Last name	
Affiliation / Employer	
Country of Employer	
E-mail	
User travelling to RI?	
Comments	
User group member 4	
First name	
Last name	
Affiliation / Employer	
Country of Employer	
E-mail	
User travelling to RI?	
Comments	
Please insert more fields if your groups had more than four members.	
Access Summary Report - work performed and initial results	
Brief description of the objectives of your project (up to 200 words)	

[Please describe short the main objectives of your project]
The sorption thermal battery (STB) consists of a reversible charging (an endothermic process) and a (an exothermic process) discharging process with released heat. This heat can be used for space and domestic water heating in buildings to replace fossil fuel consumption. The efficiency of this technology is determined by the performance of the sorbents used, which is related to their structural properties and preparation procedure. The aim of this transnational access was to perform a series of thermal analyses and water adsorption experiments on ZIFs and ZIF derived carbon (ZDC) composites to determine the thermophysical and sorption heat storage properties. ZIF composites with hydrated salts showed structure degradation after being exposed to the water vapour, so these samples were not chosen for the TA. On the other hand, ZDC and their composites showed promising results and were investigated at the host institution.

The objective of the **Task 1** was determination of thermophysical properties of selected TCMs – ZIFs and ZDC and their composites with hydrated salts that are required for STB.

The objective of the **Task 2** is to determine heat od adsorption at operating conditions and sorption kinetics.

Activities performed (up to 600 words)

[Please summarise the work carried you (steps taken, instrumentation used, techniques employed, data sources consulted etc.)]

During the TA, characterization of the thermophysical properties and the heat of adsorption of selected materials was performed.

Task 1: Determination of Thermal Diffusivity and Heat Capacity
The objective of Task 1 was to determine the thermal diffusivity and heat capacity of the selected materials. A differential scanning calorimeter (DSC 204 F1, Netzsch, Germany) was used to measure the heat capacity. Prior to measurement, the materials were activated at 120 °C. A baseline was recorded using an empty crucible. The measurements were conducted under a nitrogen flow, with the sample heated from 0 °C to 150 °C. Following the sample measurement, a sapphire reference with appropriate mass and thickness was analyzed. The heat capacity was calculated using the instrument's built-in software.

Thermal diffusivity was measured using a laser flash apparatus (LFA 467, Netzsch, Germany) equipped with a xenon lamp. The measurements were carried out at 30 °C under a helium flow of 10 mL/min. A known mass of the material was placed on a sapphire holder and pressed to obtain a uniform, crack-free surface. The sample thickness was measured using a micrometre. Prior to measurement, the samples were degassed at 120 °C in a drying oven. The sapphire crucibles with the samples were then placed in the instrument, and measurements were performed at 30 °C. A total of 5 flashes was used for the determination of thermal diffusivity.

Task 2: Determination of Heat of Adsorption
The objective of Task 2 was to determine the heat of adsorption using simultaneous thermal analysis (STA 449 F1, Netzsch, Germany). A known amount of the sample was placed in an open aluminium crucible, weighed, and positioned in the instrument. Prior to measurement, the samples were degassed at 120 °C for 2 hours until a stable dry mass was obtained. The measurement was performed at 30 °C under nitrogen flow and 30%

relative humidity (RH). The heat of adsorption was calculated by analysing the area of the DSC signal.

Scientific results (up to 800 words)

[Summarise the (initial) outcomes of your study at the RI(s).]

During the Transnational Access (TA), significant progress was made toward the characterization of thermophysical properties and the determination of the heat of adsorption for various ZDC composites.

Task 1: Determination of Heat Capacity and Thermal Diffusivity

Differential Scanning Calorimetry (DSC) and Laser Flash Analysis (LFA) were employed to determine the specific heat capacity (cp) and thermal diffusivity of the materials at 30 °C, corresponding to the target operating temperature. All samples showed comparable cp values, mostly around 1 J/g·K, with small variations depending on the salt content and type. ZDC-90 and ZDC-90 LiCl composites exhibit cp from 1.076 – 1.091 J/gK, with higher cp as the LiCl content increases. Similar results were found for ZDC-94 LiCl composites, with values from 1.051 - 1.193 J/gK. On the other hand, CaCl2 composites exhibit lower cp values from 0.9 – 0.968 J/gK with the increase of salt ontent.

Thermal diffusivity was measured after pre-treatment at 120 °C. Results showed a decreasing trend with increasing LiCl content in ZDC-90 samples, while $CaCl_2$ composites generally resulted in higher diffusivity values. This may indicate a trade-off between salt loading and thermal conductivity. The thermal diffusivities for ZDC-90 and its composites vary from 0.353 – 0.19 mm^2/s with the increase of salt content. Similarly, in the case of ZDC-94 and its composites, the thermal diffusivity values vary from 0.298 – 0.251 mm^2/s.

In **Task** 2, the heat of adsorption, used to evaluate the energy storage density (ESD), was determined under relevant operating conditions (30 °C, 30% RH) using DSC. Unlike typical desorption-based measurements at elevated temperatures, this approach provides more realistic ESD values for actual system operation. Results show that LiCl composites, especially at higher loading (40 wt.%), exhibited the highest heat of adsorption (up to ~2090 J/g), indicating strong potential for low-temperature thermochemical energy storage. Composites with CaCl2 showed ESD from ~580 to 1200 J/g, generally lower heat of adsorption compared to LiCl analogues ~880-2086 J/g.

Interpretation of the results (up to 400 words)

[Discuss the data obtained and describe the major scientific conclusions drawn.]

Task 1 provided important insights into the thermophysical properties of the studied ZDC composites. The determination of specific heat capacity (cp) required careful interpretation of DSC heat flow signals and the selection of a suitable sapphire reference, which was critical to ensure the accuracy of the results. Despite the inherent challenges in measuring thermal diffusivity for porous, powdered materials, particularly the difficulty in achieving uniform compaction in the sample crucible, the measurements yielded consistent values within an acceptable range. These data enable reliable estimation of the thermal conductivity of the materials, an important parameter for evaluating their performance in thermal energy systems.

Task 2 evaluated the adsorption performance of the materials under relevant operating conditions (30 °C, 30% RH). The results demonstrated significantly enhanced heat of adsorption for the LiCl composites, with values exceeding 2000 J/g in the highest salt-loading samples. These values surpass those typically reported in the literature under comparable conditions, confirming the strong potential of these materials for low-temperature thermochemical energy storage.
Composites with $CaCl_2$ exhibited lower heat of adsorption, attributed primarily to reduced water uptake under the tested conditions. Nevertheless, their performance still falls within a range that may be applicable for moderate energy storage needs.
An increase in the content of hygroscopic salt within the composites correlated with an increase in water uptake and, consequently, higher heat of adsorption. Overall, these findings highlight the potential of porous ZDC composites for thermochemical energy storage. The results serve as a foundation for future research focused on shaping these materials, an essential step toward the development of scalable and practical storage systems.

Main achievements during the TA related work (up to 250 words)

[Describe the main achievements during your stay at the site(s), Outputs (results, publications, models, etc.), conclusions, next steps, potential impact]

The TA enabled essential on-site measurements to evaluate the thermophysical and sorption properties of ZDC composites for thermochemical energy storage. Using materials prepared at the home institute, experiments focused on determining heat capacity, thermal diffusivity, and heat of adsorption under relevant conditions (30 °C, 30% RH).
One of the main achievements was confirming that composites with LiCl, and $CaCl_2$, exhibit favourable thermal and sorption performance. LiCl composites reached high heats of adsorption, indicating strong potential for low-temperature thermochemical storage applications. Despite challenges related to measuring porous powders, thermal diffusivity and cp values were consistent and suitable for estimating thermal conductivity. Additionally, all tested composites showed good hydrothermal stability across multiple cycles, supporting their long-term applicability.
The results will form the basis of a peer-reviewed open access scientific publication and are being incorporated into an ongoing PhD thesis. They also contribute to analytical modelling and future material optimization strategies. The results will be also presented in a new IEA TCP ES Task on TES materials, specifically the subtask Database for TES materials, which is led by NIC (Dr. Alenka Ristić).
In conclusion, ZDC composites, particularly those with LiCl, show promise as low-temperature thermochemical materials. Next steps will include material shaping, scale-up synthesis, and prototype testing. This work lays the groundwork for developing efficient, scalable energy storage systems with relevance to sustainable heating and waste heat recovery.

Data Management

[Describe the further usage and storage of project data. State where the data will be kept and name a person responsible for the data. Define data]

The data obtained during this project refers to all measured and processed experimental results, including thermal and sorption properties (e.g., specific heat capacity, thermal diffusivity, heat of adsorption), raw measurement files, and related analytical outputs. This data will be used for scientific research purposes, including open access publication in peer-reviewed journals, integration into a doctoral thesis, and as a foundation for further material development and modelling. All data will be securely stored at both the host

institution and the sending institution. To ensure long-term retention, data is secured by automatic backups and cloud storage solutions for at least 10 years. Comprehensive metadata and documentation will accompany the datasets to facilitate reuse and ensure transparency in line with FAIR and Open Science principles.

Difficulties during the TA related work (up to 250 words)

[List problems and issues, you had, completing out your research project: Did you get access to all the necessary equipment, facilities, databases, etc.?
If not, please specify the problems that occurred and list equipment the was not working or accessible.]

No problems or issues were encountered during the TA. All equipment, facilities and databases were accessible to the user at any time.

Intended publications

[Explain where and how you expect to publish the outcomes of your project work. Include also anything already published (What and where?)]

The research on ZIF-derived composites forms an integral part of an ongoing PhD project and will be included in the doctoral thesis. In addition, the most significant results, particularly those related to the thermophysical and sorption properties of the materials, are intended for open access publication in a peer-reviewed scientific journal in the field of energy storage or materials science.

Expected impact

[The impact the expected results will have on current and future research or practice, public safety, European standardization, competitiveness, integration and cohesion and on sustainable growth any follow on proposals, projects, collaborations, commercialisation]

The results obtained during this TA will have a meaningful impact on both current and future research and practical implementation in the field of thermochemical heat storage (TCHS). By providing high-quality experimental data and methodological insights, this work contributes to the growing knowledge base necessary for the design and optimization of new thermochemical materials.

The achievements support future research and innovation, particularly in the development of powdered ZIF-derived composite materials, and help identify promising candidates for practical applications in low-temperature thermal energy storage.
Investigated materials demonstrate promising performance characteristics and scalability potential. This project aligns with the goals of the European Green Deal, especially in promoting energy efficiency, use of renewable heat, and reduction of fossil fuels consumption. They also contribute to sustainable growth by encouraging the use of resource-efficient and recyclable materials in energy systems. The results will contribute as a foundation for future collaborations and projects. And results will be also shown at different international conferences, e.g. 1st Summer School TCM Friends Academy under EERA Energy Storage in Ljubljana this year and EuroSun2026.

Conclusions / additional comments

[Provide any other comments you might have on your work]

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We successfully measured the heat capacity, thermal diffusivity, and heat of adsorption for a series of ZDC materials and their composites. The obtained results provide valuable insight into the thermophysical and adsorption properties of these materials, which will serve as a foundation for future development and optimization of thermochemical energy storage systems.

Key outcomes of the study include:

1. An improved understanding of heat capacity measurements for powdered thermochemical materials.
2. Refined protocols for sample preparation and measurement conditions in laser flash analysis (LFA), enabling reliable and reproducible procedures that can be adopted by other research groups.
3. A detailed investigation of the heat of adsorption in selected thermochemical composites, offering guidance for both material selection and system-level design.

Based on the results of this research, future applications to RISEnergy calls will focus on the study of shaped composite materials and their integration into scalable storage configurations.

Did you complete the European Commission User questionnaire https://ec.europa.eu/eusurvey/runner/RIsurveyUSERS?
x *Yes* ☐ *No*

Feedback - HSE, Ethics and Satisfaction

Please rate on a scale from 1 (excellent) to 5 (poor). Feel free to provide additional comments

Practical information on how to apply for Transnational Access and the overall application process	1 (excellent)	2	3 (neutral)	4	5 (poor)
	x	☐	☐	☐	☐
Comment					
Information provided, once your project was accepted, on how to proceed	1 (excellent)	2	3 (neutral)	4	5 (poor)
	x	☐	☐	☐	☐
Comment					

Support received at the site(s) regarding technical/scientific matters and logistics	Have you got sufficient support from the RI staff during the project? If not, please, specify the problems. x *Yes* ☐ *No*
Please specify any problems	
RI extension / upgrades required	In your opinion, is the RI needed to be upgraded? If yes, please give an explanation. ☐ *Yes* x *No*

Please specify	
Problems with local regulations	Have you had any problems with regulations of the visited RI owner (HSE, lab working hours, etc.)? If yes, please, specify ☐ *Yes* x *No*
Please specify	
Health and safety issues	Did you encounter any health or safety issue during your research? Please provide details. ☐ *Yes* x *No*
Please provide details	
Environment & Ethics	Did your research involve the use of elements that may cause harm to the environment, to animals or plants? Please provide details. ☐ *Yes* x *No*
Please provide details	
Environment & Ethics	Did your research deal with endangered fauna and/or flora and/or protected areas? Please provide details. ☐ *Yes* x *No*
Please provide details	
Environment & Ethics	Did your research involve the use of elements that may cause harm to humans, including research staff? Please provide details. ☐ *Yes* x *No*
Please provide details	
Environment & Ethics - Dual use	Does your research have the potential for military applications? Please provide details. ☐ *Yes* x *No*
Please provide details	
Environment & Ethics - Misuse	Does your research have the potential for malevolent /criminal/terrorist abuse? Please provide details. ☐ *Yes* x *No*
Please provide details	
Environmental issues	Were any potentially dangerous substances (materials / gases etc.) released into the

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	environment (atmosphere, water, or land)? Please provide details. ☐ *Yes* x *No*
Please provide details	
Ethics issues	Are there any other ethics issues that should be taken into consideration? Please specify ☐ *Yes* x *No*
Please provide details	

Overall impression of communication and interaction after finishing your TA and related work	1 (excellent)	2	3 (neutral)	4	5 (poor)
	x	☐	☐	☐	☐

Comment
Suggestions for facilities not included in RISEnergy which you would use for your research
[Please provide suggestions for specific type of facilities missing (RI gaps) or measurement / experiments you would like to perform which can not be done on current RISEnergy facilities.]
Suggestions how RISEnergy can improve future TA programme, how to make the TA more impactful and how to enable the achievement of high TRL levels
[Your suggestions]

Feedback - Pro-active Innovation Support

Awareness	Did you know about the pro-active innovation support of RISEnergy? ☐ Yes ☒ No
[Please specify how you learned about the pro-active innovation support]	
Personal experience	Have you taken advantage of or benefited from the pro-active innovation support? ☐ Yes ☒ No
[Please provide details]	

Information/service provided by the pro-active innovation support?	1 (excellent)	2	3 (neutral)	4	5 (poor)

	☐	☐	☒	☐	☐
[Please provide details]					

I declare that the above provided information and especially that information on the number of days visited the RI is correct.

☒ *I have read the RISEnergy privacy policy for participation in the RISEnergy TA and consent to participation and the associated data processing.*