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 APP162 - reports.*

General information about the project	
Project title (as used in Application)	BEnchmarking of system-level modelica-based numerical models for The estimation of the THERmal performance of CST plants and components
Project number (APP162) and acronym (max 15 characters)	TA60 - BETTHER CST
RISEnergy RI(s) accessed	CENER-SESES
Keywords (up to five, free text)	CSP; System-level numerical models; Modelica
Arrival date (in town where RI is located)	Not applicable
Departure date (from town where RI is located)	Not applicable
Starting date of Access (first day at RI)	27/10/2025
Finishing date of Access (last day at RI)	22/12/2025
Number of days not using the RI (during the above period)	Not applicable
Reason for not using RI those days (describe)	Not applicable
Number of days using the RI	Not applicable
Number of Users granted Access (group size)	Not applicable
Comments	CENER-SESES consists of a simulation environment. The access to this research infrastructure does not require personnel travelling
User	

RISEnergy

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	

User group member 5	
First name	
Last name	
Affiliation / Employer	

Country of Employer	
E-mail	
User travelling to RI?	
Comments	-

Access Summary Report - work performed and initial results

Brief description of the objectives of your project (up to 200 words)

Numerical modelling is a powerful tool for predicting the performance of CSP/STE systems and optimizing new designs and control strategies. These models are also essential for techno-economic assessments, which determine a plant's financial viability. Leveraging over twenty years of expertise in the field, ENEA is developing a new, highly modular Modelica-based simulation environment. To validate this tool, the researchers will conduct a benchmark analysis against CENER's CSTLibrary, which is part of the CENER Simulation Environment for Solar Energy Systems (SESES) research infrastructure. This collaboration aims to refine the ENEA code and enhance the overall reliability of both models. Specifically, the benchmark analysis evaluates both component and system levels of parabolic trough CSP technology. Component-level analysis enables a detailed comparison of steady-state and dynamic responses for key elements, such as the linear receiver, under predefined boundary conditions. Conversely, system-level simulations assess key performance indicators (KPIs), such as receiver outlet temperature, under realistic operating conditions. Consequently, this benchmark study aims to identify model deviations, while the subsequent analysis will uncover the underlying causes of these discrepancies.

Activities performed (up to 600 words)

This project aims at performing a benchmark analysis to validate the ENEA Modelica-based simulation environment against the well-established CENER's CSTLibrary, which is a Modelica library developed within the Simulation Environment for Solar Energy Systems (SESES) research infrastructure. This benchmark study considers the most widespread CSP technology; namely, the parabolic through collector combined with the two-tank storage system. For conducting this benchmark, reference case studies have been selected at both component-level and system-level. Particularly, the component-level simulations involve the receiver tube in both steady and transient conditions. Specifically, an encapsulated and evacuated receiver tube of a parabolic through collector is considered, which is assumed to be 600 m length. The outer diameter of the absorber tube and glass cover are 70 and 125 mm, respectively. In addition, a CERMET selective coating is assumed to be applied on the outer surface of the absorber tube. The boundary conditions of the steady state simulations are summarized in Figure 1. These simulations were run using either solar salt or thermal oil (Therminol-VP1) as heat transfer fluid. According to the imposed boundary conditions, the expected temperature at the receiver outlet in the absence of heat losses is 550 °C and 400 °C for the molten salt and the oil, respectively. Therefore, the computed outlet temperature would be somewhat lower than these ideal values. The transient simulation consists of a mass flow rate ramp (from 8 to 12 kg/s) at equal power absorbed on the receiver (see Figure 2) using solar salt as heat transfer fluid. Since the mass flow rate increases at equal imposed heat flux, the outlet temperature is expected to decrease. The dynamic response of the salt temperature will be compared evaluating the time required to reach the new steady state.

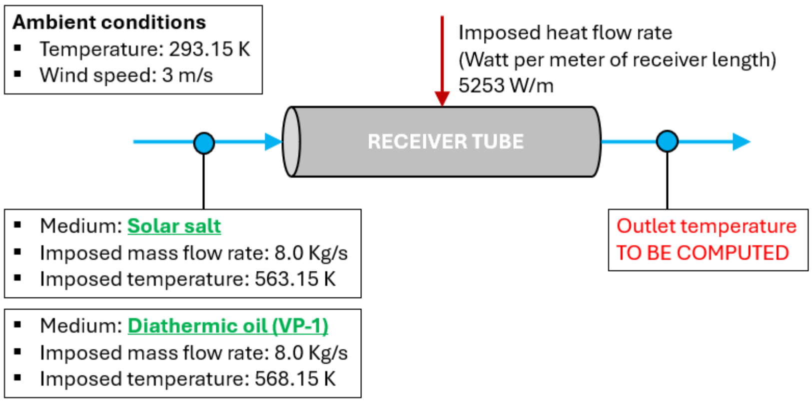

Figure 1. Receiver tube: boundary conditions for steady state simulation

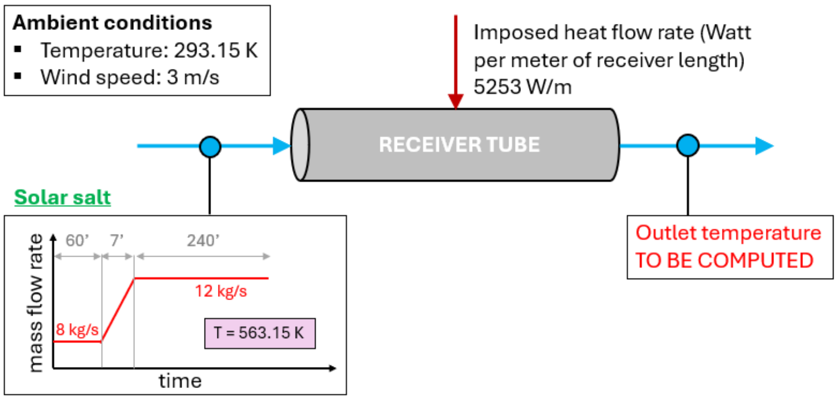

Figure 2. Receiver tube: Boundary conditions for transient simulation

Regarding the system-level case, Figure 3 shows the plant scheme with the control logic. The storge medium consists of solar salt, which also works as heat transfer fluid. Molten salt is pumped from the cold tank through the receiver tube. If the salt reaches an outlet temperature of at least 500 °C, it is routed to the hot tank; otherwise, it is recirculated back to the cold tank. The receiver tube is the same considered in the single-component case; however, 8 parallel loops are considered here. Each storage tank is 10 m height and 20 m diameter; the initial salt level is set to 5 m and the initial temperature is 290 and 550 °C for the cold / hot tank, respectively. The nominal power of the power block is assumed to 4.2 MWe. The system-level simulation last 1 day, corresponding to June 5th. The weather data source corresponds to the typical meteorological year (TMY), which has been retrieved from PVGIS [1]. The results of this simulation include the salt temperature at cold and hot tank, as well as the salt temperature at the receiver outlet, during the 24 hours of plant's operation considered here. These temperatures depend on both the computed solar heat flux absorbed on receiver and on the computed heat losses. In addition, the electric power generated by the power block is determined by the models.

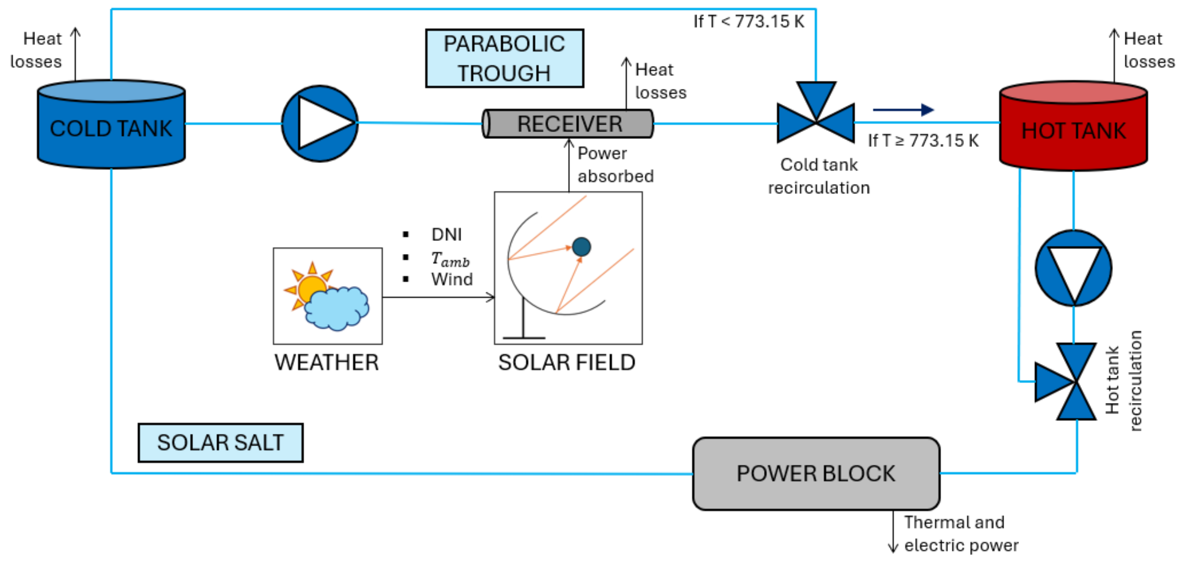

Figure 3. Plant scheme for system-level simulation

References

[1] European Commission, Photovoltaic Geographical Information System (PVGIS), available online (accessed 0671/2025) https://joint-research-centre.ec.europa.eu/photovoltaic-geographical-information-system-pvgis_en

Scientific results (up to 800 words)

In this section the results of the benchmark analysis are presented and discussed. Starting from the component-level steady-state case, Figure 4 shows the receiver outlet temperature computed by the ENEA and CENER models for both the solar salt and the Therminol VP-1. The agreement is definitely very good. In addition, the results are well in-line with expectations since the energy balance excluding heat losses predicts outlet temperatures of 550 °C for the solar salt and 400 °C for the oil. Moving to the component-level transient case, Figure 5 shows the comparison of the computed receiver outlet temperature evolution. Overall, a good agreement is observed; the different trend at the beginning of the simulation is just because of the different initialization method adopted. Looking at Figure 5, it can be noticed that the transient duration is longer in the case of ENEA model. This discrepancy arises because the ENEA code implements a 0D lumped-parameter receiver model, whereas the CENER code employs a 1D axial model. Consequently, the 0D approach cannot accurately capture the spatial temperature distribution or the transient thermal propagation along the receiver during mass flow rate ramps. Despite these limitations in the 0D approach, it dramatically reduces the computational effort making the model suitable for long time (annual) simulations. Based on the result of this transient analysis at component-level, a 1D receiver model is being developed and implemented in the ENEA simulation environment to accurately predict the dynamic response during short and fast transients.

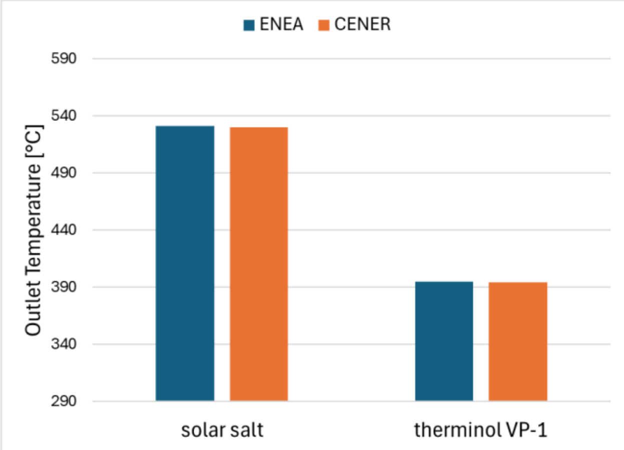

Figure 4. Computed results for steady state simulations at receiver level

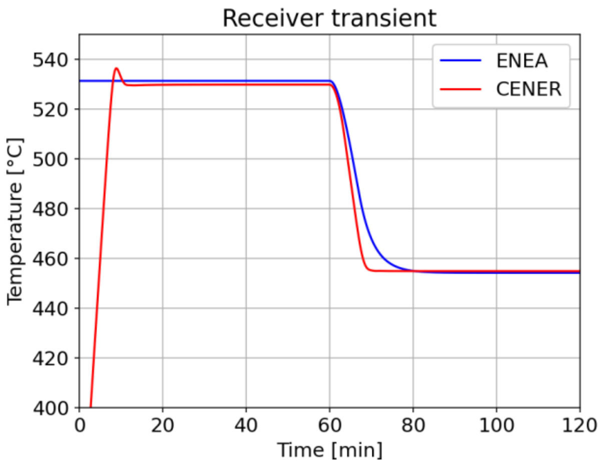

Figure 5. Computed results for transient simulation at receiver level

Regarding the system-level simulation, Figure 6 shows the receiver outlet temperature evolution during the day. It can be observed a not negligible temperature difference during the off-sun hours, at equal mass flow rate (16 kg/s, see Figure 7). This is because the ENEA model underestimates the heat losses from the receiver tube (Figure 8). In fact, this model adopts a simplification in computing the heat transfer toward the environment, which implies the linearization of the heat losses. This simplification is acceptable in the case of high irradiation (see Figure 4 and Figure 5) because the magnitude of the heat losses is much lower than the magnitude of the incoming incident solar power, but it is not accurate in the case of absence of the sun. To prove what has been stated, a simulation has been run removing the linear simplification in the ENEA model obtaining a substantial agreement with the CENER data during off-sun hours, see Figure 9.

Looking at the salt temperature at the receiver outlet during the central hours of the day, a different behaviour can be observed between the ENEA and CENER model, which is likely due to the different PID setting and implementation. Since the PID regulates the mass flow rate through the receiver tube, the latter largely differs depending on the model (see Figure 7). In the CENER model, the mass flow rate is about 30 % less than what imposed by the PID in the ENEA model. Consequently, the temperature is higher in the CENER model leading to higher heat losses (see Figure 8) during on-sun hours.

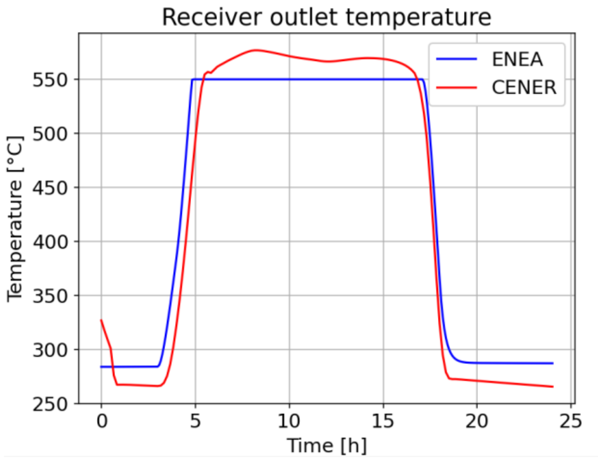

Figure 6. Computed receiver outlet temperature in the system-level simulation

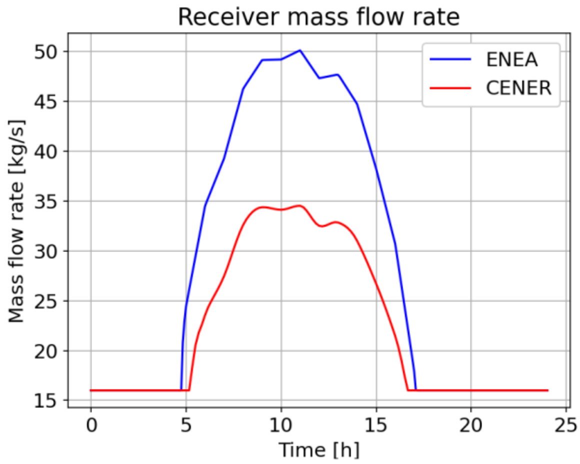

Figure 7. Computed mass flow rate flowing in the receiver in the system-level simulation

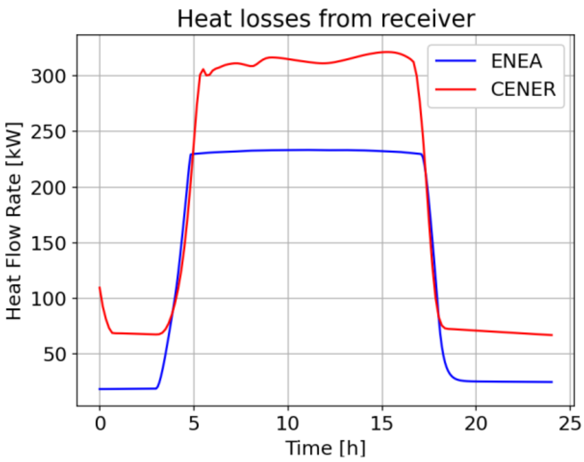

Figure 8. Computed heat losses from receiver (1 loop) in the system-level simulation

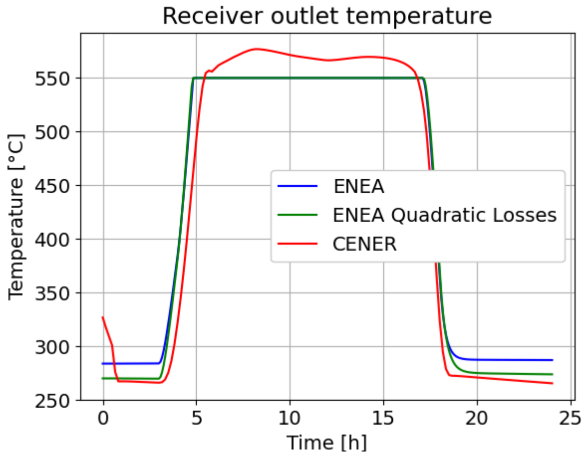

Figure 9. Computed receiver outlet temperature in the system-level simulation, including the results computed with the ENEA model removing the simplification of linearized heat losses

Finally, the power block output power evolution is shown in Figure 10. The nominal output power is almost reached in both the models, at least during on-sun hours. At night, the results differ because of the different control logic considered for this specific simulation. In the ENEA model, the power block operation is conditional on the temperature and level in the hot tank; conversely, in the CENER model, the power block only operates when the solar field is actively producing thermal power.

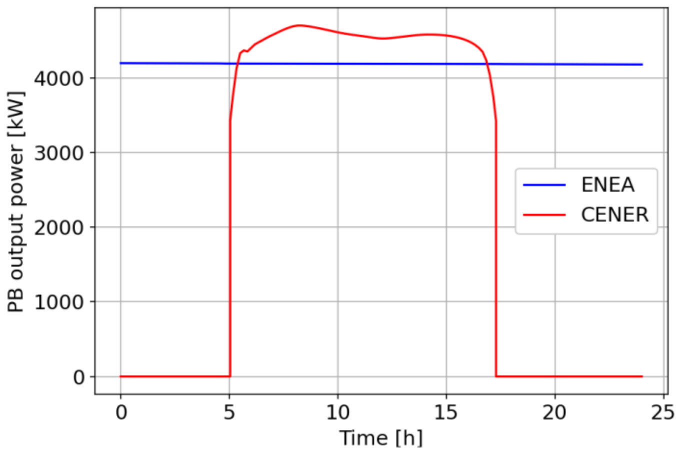

Figure 10. Computed gross output power from power block

Interpretation of the results (up to 400 words)

This project aims at performing a benchmark analysis to validate the ENEA Modelica-based simulation environment against the well-established CENER's CSTLibrary, which is a Modelica library developed within the Simulation Environment for Solar Energy Systems (SESES) research infrastructure. This benchmark study considers the parabolic through CSP technology combined with the two-tank storage system. Specifically, the benchmark study was carried out both at component-level and at system-level.

At component-level, the receiver tube is simulated in steady-state and transient conditions, under representative boundary conditions. The computed results show an overall good agreement. The main difference observed is about the dynamic response of the temperature at the receiver outlet: the ENEA model predicted a longer transient. This is because the ENEA model adopts a 0D approach instead of the 1D axial discretization implemented in the CSTLibrary. While a 0D model cannot capture spatial temperature distribution or thermal propagation along the receiver, its low computational cost makes it ideal for long-term, plant-wide annual simulations. Based on the outcomes of this benchmark, the ENEA simulation environment is being updated with a 1D receiver model, enabling high-fidelity analysis of short-term transients at the component level.

At system-level, the benchmark focused on simulating a CSP plant based on the parabolic through technology, coupled with a two-tank storage system, along a reference day; namely, June 5th. A general agreement between the computed results was observed, net of the different implementation of the control strategy for the specific case of study. During off-sun hours, the ENEA model underestimated the heat losses from the receiver tube because of the linear simplification adopted in computing the heat transfer from the absorber tube to the environment. Removing such simplification leads to a much better agreement between the models during off-sun hours. Note that the linear simplification is acceptable while considering high irradiation conditions since the heat losses correspond to a small share of the incoming heat flux.

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

- The ENEA Modelica-based simulation environment was validated against the CSTLibrary for a selection of case studies. The CSTLibrary is a well-established Modelica library developed by CENER within the SESES research infrastructure.
- The benchmark activity highlighted key differences between the models, stemming primarily from simplifications in the ENEA model, specifically its 0D receiver dimensionality and the use of linear approximations for heat loss estimation.
- This work represents the preliminary phase of the ENEA simulation environment's verification and validation process. Moving forward, participation in EU initiatives will be pursued to ensure access to cutting-edge simulation infrastructures.

Data Management

- The data will be used to prepare contributions for international conferences, in coordination with CENER.
- Computed data will be archived using ENEA's IT infrastructure.
- The person responsible for the data is Walter Gaggioli, the heat of the *Smart Sector Integration* division at ENEA.

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

No difficulties were encountered in accessing the research infrastructure. This was due, in part, to the nature of the CENER-SESES facility, which does not require physical access by the applicant's personnel.

Intended publications

- The project outcomes will be presented at the next SolarPACES conference. A submission to the conference proceedings is also being considered.
- A submission to a peer-reviewed journal is planned, following an extension of the current study to include an annual economic viability analysis of various CSP plant layouts.

Expected impact

- This successful benchmark has enhanced the credibility of both the ENEA and CENER models, making them more attractive to potential users, including researchers, industry partners, and policymakers.
- Guidelines for accurately simulating CSP plants in a Modelica-based environment are being developed and will be released as part of an extended study

Conclusions / additional comments

This project offered a unique opportunity to compare results obtained from the new simulation environment under development at ENEA with a state-of-the-art code. Due to the limited timeframe of 8 weeks, only a selection of case studies was benchmarked. Moving forward, participation in other TA initiatives should be pursued to accumulate the necessary duration for a comprehensive benchmark analysis.

Did you complete the European Commission User questionnaire https://ec.europa.eu/eusurvey/runner/RIsurveyUSERS?

☒ *Yes* ☐ *No*

Feedback - HSE, Ethics and Satisfaction

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

	1 (excellent)	2	3 (neutral)	4	5 (poor)
Practical information on how to apply for Transnational Access and the overall application process	☒	☐	☐	☐	☐

Comment

	1 (excellent)	2	3 (neutral)	4	5 (poor)
Information provided, once your project was accepted, on how to proceed	☒	☐	☐	☐	☐

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. ☒ *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* ☒ *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* ☒ *No*
Please specify	
Health and safety issues	Did you encounter any health or safety issue during your research? Please provide details. ☐ *Yes* ☒ *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* ☒ *No*
Please provide details	
Environment & Ethics	Did your research deal with endangered fauna and/or flora and/or protected areas? Please provide details. ☐ *Yes* ☒ *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* ☒ *No*
Please provide details	
Environment & Ethics – Dual use	Does your research have the potential for military applications? Please provide details. ☐ *Yes* ☒ *No*
Please provide details	
Environment & Ethics – Misuse	Does your research have the potential for malevolent /criminal/terrorist abuse? Please provide details. ☐ *Yes* ☒ *No*
Please provide details	
Environmental issues	Were any potentially dangerous substances (materials / gases etc.) released into the environment (atmosphere, water, or land)? Please provide details. ☐ *Yes* ☒ *No*

Please provide details	
Ethics issues	Are there any other ethics issues that should be taken into consideration? Please specify ☐ *Yes* ☒ *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): ☐
Comment	
Suggestions for facilities not included in RISEnergy which you would use for your research	
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	

1 (excellent)	2	3 (neutral)	4	5 (poor)
☒	☐	☐	☐	☐

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?	see rating below
[*Please provide details*]	

1 (excellent)	2	3 (neutral)	4	5 (poor)
☐	☐	☒	☐	☐

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.*

Your full name: I

Your signature: