General information about the project	
Project title (as used in Application)	Use of concentrated solar energy in Additive Manufacturing and post-treatment of metal components for energy applications
Project number (APPXXX) and acronym (max 15 characters)	APP197, SOL-AM
RISEnergy RI(s) accessed	CNRS-PROMES
Keywords (up to five, free text)	Concentrated Solar Energy, Additive Manufacturing, Thermal shock
Arrival date (in town where RI is located)	1st stay: 30/09/2025 | 2nd stay: 07/01/2026
Departure date (from town where RI is located)	1st stay: 31/10/2025 | 2nd stay: 06/02/2026
Starting date of Access (first day at RI)	1st stay: 01/10/2025 | 2nd stay: 08/01/2026
Finishing date of Access (last day at RI)	1st stay: 31/10/2025 | 2nd stay: 05/02/2026
Number of days not using the RI (during the above period)	18 days (1st stay: 1 day | 2nd stay: 17 days)
Reason for not using RI those days (describe)	Days of unfavourable weather conditions
Number of days using the RI	26 days (1st stay: 22 days | 2nd stay: 4 days)
Number of Users granted Access (group size)	8 researchers / 4 users
Comments	Although the project has 8 researchers, 4 are participants in the research stays in the RI. The remaining researchers are involved in sample preparation and characterization, as well as the publication of the results obtained.
User	
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	
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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	

User group member 6	
First name	
Last name	
Affiliation / Employer	

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User group member 7	
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User travelling to RI?	
Comments	
User group member 8	
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)

This project aims to investigate, for the first time, the feasibility of applying Concentrated Solar Energy (CSE) to the thermal treatments required in the final fabrication stages of metallic components produced by Material Extrusion (MEX) additive manufacturing. The objective is to enable the sustainable production of high-quality metallic parts suitable for structural and functional applications, particularly in Concentrated Solar Power (CSP) systems and other energy technologies.

Metal parts are manufactured using MEX 3D printing, while the thermal debinding and sintering processes are carried out and optimized using a solar furnace of the RI. The study seeks to establish the main technological parameters governing solar-assisted sintering and to analyse the factors influencing the resulting microstructure, mechanical properties, and performance.

Additionally, components produced by both MEX and Selective Laser Melting (SLM) are subjected to CSE-induced thermal shocks to simulate real operating conditions of solar receivers. Their structural integrity, quality, and service viability are evaluated in order to assess the potential of solar-assisted thermal processing for advanced additive manufacturing technologies.

Activities performed (up to 600 words)

Metallic components were manufactured using both Material Extrusion (MEX) and Selective Laser Melting (SLM) additive manufacturing technologies in the home facilities of the research group. Nickel-based superalloy specimens with different geometries and dimensions were produced to evaluate the influence of processing parameters and component size on subsequent solar thermal treatments.

The experimental work carried out at the PROMES-CNRS laboratory focused primarily on the optimisation of solar-assisted thermal debinding and sintering processes for MEX-printed parts. Thermal treatments were performed using one of the Medium Size Solar Furnaces (MSSF), consisting of a 2-m vertical-axis parabolic concentrator equipped with a reaction chamber, which enabled operation under controlled atmospheres (Ar and N_2–5%H_2) to minimise oxidation during high-temperature treatments.

Samples were positioned at the focal zone of the 2-kW solar concentrator, and temperature evolution during treatments was monitored using type-K thermocouples connected to a temperature recording system. Heating ramps and treatment temperatures were controlled through manual operation of the shutter, allowing the adjustment of heating rate, treatment duration, and maximum temperature. Several experimental campaigns were conducted to analyse the influence of key processing parameters, including debinding and sintering temperatures, dwell times, heating rates, thermal cycle plateau temperatures, treatment atmosphere, and sample geometry. When required, controlled solar-beam sweeps were applied to ensure uniform heating of samples larger than the focal spot.

In addition to debinding and sintering optimisation, preliminary thermal post-treatment tests based on concentrated solar energy (CSE) were carried out on a limited number of specimens manufactured by both MEX and SLM technologies. These initial tests were intended to explore the feasibility of applying solar-induced thermal shocks to additively manufactured components. However, due to unfavourable weather conditions during the second experimental campaign, it was not possible to conduct an in-depth or systematic study of the components' behaviour under thermal shock conditions. As a result, these activities were restricted to exploratory trials, without detailed analysis of thermal shock resistance or long-term in-service behaviour.

Following solar processing, part of the specimens has already undergone advanced physical, microstructural, and mechanical characterisation at the home laboratories of the research team, while additional characterisation is currently in progress. Metallographic preparation procedures have been applied to a first set of samples, and microstructural observations have been conducted using optical microscopy and scanning electron microscopy (SEM), with further analyses ongoing. Additional tests are being carried out to evaluate densification, porosity evolution, and the relationship between processing conditions, resulting microstructure, and mechanical performance, which will be further refined as the second experimental campaign is fully analysed.

The combination of additive manufacturing, solar-assisted thermal processing, controlled-atmosphere treatments, and post-processing characterisation has already enabled the preliminary identification of the technological parameters required for solar debinding and sintering of Ni-based superalloy components. Ongoing experimental and characterisation work will further consolidate these results, providing the basis for a comprehensive assessment of the feasibility and performance of additively manufactured metallic parts processed using concentrated solar energy.

Scientific results (up to 800 words)

This study represents the first systematic investigation of the feasibility of applying Concentrated Solar Energy (CSE) to the thermal debinding, sintering, and post-treatment of metallic components manufactured by Material Extrusion (MEX) additive manufacturing, specifically on nickel-based superalloys relevant for energy applications. The experimental campaigns carried out at the PROMES-CNRS research infrastructure have provided initial scientific and technological outcomes that demonstrate the potential of CSE as an alternative and sustainable heat source for advanced metallurgical processing.

One of the main scientific outcomes achieved so far is the successful implementation of solar-assisted thermal debinding and sintering of MEX-fabricated Ni-based superalloy components using the Medium Size Solar Furnace (MSSF). The experiments confirmed that the high energy density and fast heating capabilities of concentrated solar radiation enable reaching the temperature ranges required for both debinding and high-temperature sintering within very short times. Results indicate that controlled heating ramps and dwell times can be achieved through manual shutter operation, allowing sufficient process stability despite the intrinsic variability of solar input.

The influence of key processing parameters—including maximum temperature, heating rate, dwell time, and atmosphere (Ar and N_2-5%H_2)—on the densification behaviour of MEX parts has been established. Initial microstructural observations show a clear dependence of porosity evolution and sintering necks growth mechanisms on sintering temperature and atmosphere, confirming that oxidation control is a critical factor during solar-assisted processing of highly reactive metallic systems. The use of controlled inert and reducing atmospheres inside the reaction chamber proved essential to limit surface oxidation and to promote effective particle bonding during sintering.

Another relevant outcome is the validation of the feasibility of treating samples with different geometries and dimensions using CSE. The application of controlled solar beam sweeps allowed the homogeneous heating of specimens larger than the focal spot, demonstrating the adaptability of the solar furnace for processing components with sizes and shapes relevant for real engineering applications. This capability represents a clear advantage of CSE-based treatments compared to other high-energy-density technologies, such as lasers, which are often limited to small interaction areas.

Preliminary thermal shock experiments were initiated to explore the capability of the solar facility to reproduce rapid temperature variations representative of service conditions in solar energy systems. Due to unfavourable weather conditions during an important part of the second experimental campaign, only a limited number of exploratory tests could be conducted, and a systematic investigation of the thermal shock behaviour of the components could not be completed at this stage. Consequently, the results obtained are considered preliminary and mainly confirm the technical feasibility of performing such tests using concentrated solar radiation, while a more comprehensive assessment will require dedicated future experimental campaigns.

Advanced physical, microstructural, and mechanical characterization has been initiated and is currently ongoing following the completion of the second experimental campaign. Preliminary metallographic and microscopy studies (optical microscopy and SEM) have already provided valuable insights into densification levels, residual porosity distribution, and microstructural homogeneity achieved after solar sintering. Further analyses are underway to deepen the understanding of structure–property relationships and to quantify mechanical performance as a function of solar processing conditions.

Overall, the scientific results obtained at PROMES-CNRS demonstrate that concentrated solar energy is a viable and promising heat source for the thermal processing of additively manufactured nickel-based superalloy components. The outcomes achieved so far lay the groundwork for establishing robust technological windows for solar debinding and sintering. Ongoing characterization and data analysis will allow the consolidation of these findings and support a comprehensive assessment of the service viability, performance, and sustainability of CSE-assisted additive manufacturing routes for high-temperature energy applications.

Interpretation of the results (up to 400 words)

The experimental results obtained during the solar processing campaigns confirm that concentrated solar energy (CSE) can be effectively applied to the thermal debinding, sintering, and post-treatment of metallic components manufactured by additive manufacturing, particularly MEX-processed nickel-based superalloys. The successful completion of these processes within the required temperature ranges demonstrates that CSE provides sufficient energy density and heating rates to replace or complement conventional furnace-based treatments, supporting the feasibility of more sustainable high-temperature metallurgical routes.

The observed dependence of densification behaviour, porosity evolution, and microstructural development on key processing parameters—such as maximum temperature, dwell time, heating rate, and treatment atmosphere—confirms that solar-assisted sintering follows mechanisms comparable to those reported for conventional thermal processing, while offering the additional advantage of rapid heating and reduced processing times. The results also highlight the critical role of atmosphere control in preventing oxidation during solar treatments, particularly for highly reactive nickel-based alloys, demonstrating the importance of controlled inert or reducing environments to achieve optimal microstructural quality.

Preliminary thermal shock tests using concentrated solar radiation were initiated to explore the potential of the solar facility to reproduce rapid temperature variations representative of service conditions in energy systems. However, due to unfavourable weather conditions during the second solar experimental campaign, the number of tests performed was limited and did not allow a detailed or systematic analysis of the components' behaviour under thermal shock. Consequently, these trials are interpreted mainly as feasibility demonstrations of the testing methodology rather than as a comprehensive evaluation of thermal shock resistance.

Overall, the results obtained demonstrate the technological viability of integrating additive manufacturing and concentrated solar energy for the processing of advanced metallic components intended for energy applications. Beyond confirming feasibility, the study provides an experimental basis for defining processing windows and operational guidelines for solar-assisted debinding and sintering of Ni-based superalloy parts. Ongoing characterisation and extended data analysis are expected to further consolidate these conclusions and support the future development of optimised and environmentally sustainable manufacturing routes for complex high-temperature components in concentrated solar power and related sectors.

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

During the TA stay at the PROMES-CNRS research infrastructure, two experimental campaigns were successfully carried out, representing the first systematic application of Concentrated Solar Energy (CSE) to the thermal debinding, sintering, and preliminary post-treatment of nickel-based superalloy components manufactured by additive manufacturing. The feasibility of using the Medium Size Solar Furnace (MSSF) for high-temperature processing under controlled atmospheres was demonstrated, confirming CSE as a sustainable and energy-efficient alternative to conventional furnace-based treatments.

The main scientific and technical achievements include the definition of processing windows for solar-assisted debinding and sintering of MEX-fabricated parts, together with the validation of controlled-atmosphere operation (Ar and N_2–5%H_2) to minimise oxidation during high-temperature treatments. Controlled solar beam sweeping strategies were successfully implemented to ensure homogeneous heating of samples with different geometries and dimensions, demonstrating the adaptability of the solar facility to realistic component configurations.

Exploratory CSE-induced thermal loading tests were also conducted on selected MEX- and SLM-produced components to assess the feasibility of applying rapid solar-driven thermal cycles. Although unfavourable weather conditions during the second campaign limited a systematic evaluation of thermal shock resistance, the capability of the facility to generate controlled transient thermal conditions was successfully demonstrated.

The main outputs include a comprehensive experimental dataset currently under advanced microstructural and mechanical characterisation, which will support publications in high-impact journals and presentations at international conferences. These results confirm the technological viability of integrating additive manufacturing and

CSE, with strong potential impact on future research initiatives and advanced energy applications.

Data Management
*A*ll experimental and analytical data generated within the project are being stored and managed under the responsibility of Dr. Ana Romero (user group leader), who acts as the data custodian during and after the project. For the purpose of this project, data includes: (i) physical test specimens and reference samples, (ii) experimental parameters recorded during solar processing campaigns (temperature profiles, atmospheres, heating rates, treatment conditions), and (iii) all supporting documentation such as raw datasets, graphs, laboratory notebooks, photographs, videos, microscopy images, and technical reports. Digital data are stored in secured institutional storage systems and shared within the research team through controlled-access collaborative folders that allow download permissions while restricting editing of validated experimental records. This approach ensures data integrity, prevents accidental loss or modification, and facilitates coordinated analysis by all project members. Following project completion, the validated datasets and associated metadata will be preserved in institutional repositories of the participating organizations for long-term storage and *future scientific use, in accordance with institutional data-management policies and open-science practices when applicable.*

Difficulties during the TA related work (up to 250 words)
The main difficulty encountered during the TA work was related to unfavourable weather conditions during a significant part of the second experimental campaign, which reduced the effective operating time of the solar facilities. As concentrated solar processing directly depends on stable and sufficiently high solar irradiation levels, this limitation particularly affected the execution of some planned tests, especially those involving rapid and repetitive thermal shock cycles, contemplated in the last part of the project. Due to the variability and intermittency of solar input during those days, it was not possible to perform a systematic and statistically representative evaluation of the thermal shock resistance of the additively manufactured components. Consequently, the thermal loading experiments were restricted to exploratory trials aimed at demonstrating the technical feasibility of generating controlled transient thermal conditions using concentrated solar radiation. To mitigate this limitation, the research team prioritised the most critical experiments requiring the high energy density and controlled-atmosphere capabilities of the Medium Size Solar Furnace, ensuring the completion of the core objectives related to solar-assisted debinding and sintering. Importantly, full access to all required equipment, facilities, and technical support at PROMES-CNRS was guaranteed throughout the stay. No major instrumentation failures or accessibility issues occurred. Therefore, the challenges encountered were exclusively

related to meteorological variability inherent to solar-based research, and they resulted only in minor adjustments to the scope of the thermal shock assessment, without compromising the overall objectives of the project.

Intended publications

The results of the project are expected to generate several scientific publications in high-impact international peer-reviewed journals (Q1/Q2, JCR) in the fields of additive manufacturing, materials processing, and concentrated solar energy. Additional dissemination will take place through presentations at leading international conferences such as EUROMAT, AMEC, Euro PM, and WorldPM, facilitating visibility within both academic and industrial communities.

Publications will address: (i) solar-assisted debinding and sintering of MEX-processed Ni-based superalloys, (ii) comparative performance of MEX and SLM components under solar thermal shock conditions, and (iii) sustainable high-temperature processing using concentrated solar energy. Two manuscripts based on the experimental datasets generated during the TA campaigns are currently in preparation.

Likewise, the results will be presented at high-level academic and scientific meetings, symposia and colloquia, focused on disseminating knowledge in science and technology, such as the presentation that was made on 12/01/2026 at Fundación Ramón Areces entitled 'Concentrated solar energy for sustainable materials' in which some preliminary results of this work were shown (Figure 1) and which to date already has 190k views (https://www.youtube.com/watch?v=F4S6e_qvUs8).

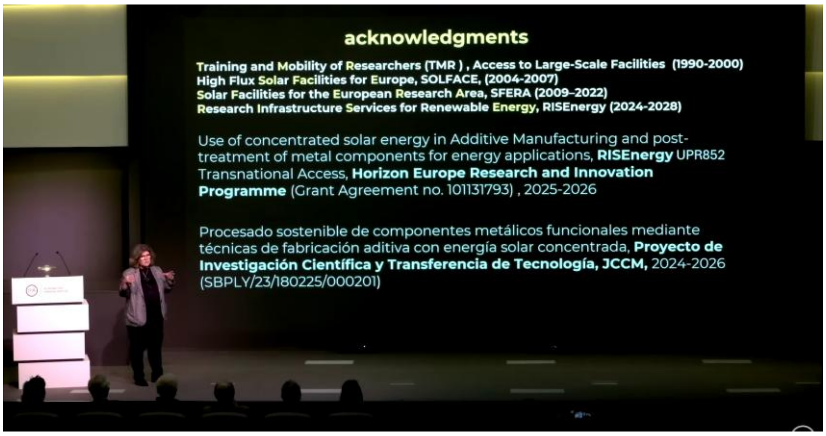

Figure 1. Conference at Fundación Ramón Areces presenting some results obtained in the present TA project.

Furthermore, the outcomes of the TA project constitute a core component of an ongoing PhD thesis focused on solar-assisted processing of additively manufactured Ni-based superalloys. The research stays at PROMES-CNRS provide the necessary international collaboration framework for the doctoral candidate to apply for the International Doctorate Mention, strengthening the European dimension of the research. The work will also be presented at doctoral seminars and specialised PhD workshops, contributing to advanced training, knowledge transfer, and the development of highly qualified researchers in sustainable high-temperature energy technologies.

Expected impact
The expected results will contribute to advancing sustainable high-temperature manufacturing technologies by demonstrating the feasibility of integrating additive manufacturing and concentrated solar energy for metallurgical processing. This approach can reduce the environmental impact and energy consumption associated with conventional thermal treatments while enabling the production of high-performance components for energy systems, particularly concentrated solar power (CSP) applications. The project is expected to strengthen European research competitiveness in advanced manufacturing and renewable-energy-based materials processing, while supporting future collaborative proposals at national and European levels. The generated knowledge, experimental methodologies, and processing parameters will also facilitate technology transfer activities, the development of innovative prototypes, and new industrial collaborations related to high-temperature components.
Conclusions / additional comments
The TA activities have successfully demonstrated the technical feasibility and scientific relevance of using concentrated solar energy for the thermal processing and testing of additively manufactured metallic components. Despite weather-related limitations, specifically in the second stay, the experimental campaigns were completed successfully, generating valuable datasets that are currently being analysed and prepared for publication. The collaboration with the host research infrastructure has significantly strengthened ongoing research lines and opened new opportunities for future projects and long-term scientific cooperation. The authors would like to acknowledge and thank the European initiatives that support transnational access to large research infrastructures, particularly the RISEnergy programme, whose framework has enabled the development of this work. Funding schemes of this type play a key role in fostering high-quality collaborative research, facilitating access to unique experimental *facilities, strengthening international cooperation, and accelerating the development of innovative and sustainable technological solutions, specifically in the energy and materials sectors.*
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

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

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

One relevant gap identified from the perspective of this project is the limited availability of facilities dedicated to large-scale or pre-industrial validation of solar-assisted high-temperature manufacturing processes. While current infrastructures provide excellent experimental capabilities at laboratory and pilot scale, access to demonstration-scale facilities (TRL 5–6) would significantly facilitate the transition of solar-assisted processing routes towards industrial deployment.

In addition, integrated in-situ high-temperature characterisation systems under concentrated solar irradiation (e.g., real-time dilatometry, high-temperature mechanical testing, or in-situ phase monitoring) would greatly enhance the scientific value of solar processing experiments. Such capabilities would allow direct correlation between solar flux conditions, thermal cycles, and microstructural evolution.

Finally, access to complementary facilities focused on advanced non-destructive evaluation (e.g., X-ray tomography under high-temperature conditions) and thermo-mechanical fatigue testing representative of real CSP operating environments would strengthen the validation of components manufactured for energy applications.

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
To enhance the impact of future TA programmes and support progression towards higher TRL levels, several actions could be considered. First, the implementation of flexible scheduling mechanisms for solar-dependent facilities could mitigate risks associated with meteorological variability, allowing users to complete critical experiments under optimal irradiation conditions. Second, structured follow-up schemes (e.g., short complementary access calls or continuity grants) would help consolidate experimental results and facilitate the transition from feasibility demonstration (TRL 3–4) to validation in relevant environments (TRL 5–6). Third, stronger integration between TA users and industrial stakeholders within the RISEnergy ecosystem could accelerate technology transfer. Dedicated matchmaking events, industrial challenge calls, or co-funded pilot demonstrations would increase the programme's impact. Finally, enhanced support for joint publications, shared data platforms, and coordinated dissemination actions would improve visibility and reinforce long-term collaboration among users of different RIs.

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] Through this questionnaire.	
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*] Doesn't know/No answer	

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:

Your signature: