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 APPXXX - reports.

General information about the project	
Project title (as used in Application)	**B**reakthrough in Hot Gas Cleaning **o**f Biomass-derived **S**yngas from **U**pdraft Gasification by Use of a **N**ovel Steam Reforming Catalyst for Complete **T**ar Removal in an **O**ptimized Two Reactor Approach
Project number (APPXXX) and acronym (max 15 characters)	APP142 - BIOSUNTO
RISEnergy RI(s) accessed	ENEA
Keywords (up to five, free text)	Biomass, Hydrogen
Arrival date (in town where RI is located)	31.03.25
Departure date (from town where RI is located)	4.04.25
Starting date of Access (first day at RI)	31.03.25
Finishing date of Access (last day at RI)	4.04.25
Number of days not using the RI (during the above period)	0
Reason for not using RI those days (describe)	-
Number of days using the RI	5
Number of Users granted Access (group size)	2
Comments	The RI was operated also on 31.03.25 and 4.04.25 by the RI owner to start and complete the testing plan.

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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	-
Affiliation / Employer	-
Country of Employer	-
E-mail	-
User travelling to RI?	YES/NO
Comments	-
User group member 4	
First name	-
Last name	-
Affiliation / Employer	-
Country of Employer	-
E-mail	-
User travelling to RI?	YES/NO
Comments	-
Please insert more fields if your groups had more than four members.	
Access Summary Report - work performed and initial results	

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

[Please describe short the main objectives of your project]

Based on the actual state of the art concerning tar abatement technologies in biomass gasification to solve the tar problem it was concluded, that there is a need for testing of novel advanced catalysts and processes for catalytic tar removal. Due to the development progress in the field of steam reforming catalysts and the availability of a novel steam reforming catalyst in fixed bed form that was assessed to be suitable for steam reforming of tar model compounds on laboratory scale (s. State of the Art in the proposal), it was proposed to test its performance in real tar abatement under real biomass gasification conditions at the pilot plant PRAGA at ENEA in Trisaia (Italy) under varying operating conditions. The determination of the tar abatement activity of this catalyst was to be performed by an analysis of the tar content in the input and output syngas stream treated by the catalytic reactor according to the tar protocol. Target of this measurement campaign was to specify the optimum operating parameters and indicate the technical feasibility of lowering the temperature for tar reforming from > 800°C down to temperatures between 650 - 750°C.

Activities performed (up to 600 words)

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

According to the detailed description of the project proposal 1 L of a novel steam reforming caralyst – C&CS 1250 A – in tablet form (4 x 4 mm) was delivered to the research infrastructure ENEA at Trisaia to fill the catalytic reactor in the PRAGA plant on March 31, 2025 using 1 L dolomite as guard bed in the reactor. In addition, on this day, a check-up of the functionalities of the updraft gasifier was performed.

On March 31, 2025 the gasification campaign was started by gasification of hazel nut shells by air and steam as gasifying medium. After having achieved stable gasification conditions syngas from the extraction point 5R (s. details of the PRAGA plant in Cerone et al., 2024, https://doi.org/10.1016/j.enconman.2020.113116) was extracted. The syngas was then condensed by the impinger train according to the tar protocol (TS 15439:2006). Isobutanol was used as solvent for tar trapping in the impinger bottles. After achieving an average temperature of 756°C of the catalytic reactor located in the extraction line downstream of the gasifier extraction of syngas at the extraction point 5R and passing this gas through the catalytic reactor was realized. A gas hourly space velocity (GHSV) for the dolomite and Nickel catalyst bed of each 1600 h^{-1} to collect in a sufficiently long time interval in the impinger train condensable tars was applied. The composition of the output gas exhibiting a temperature of 200 – 205°C was measured after gas drying. Additionally, three impinger train measurements were performed at an operating temperature of the catalytic reactor of 724°C, 699°C and 675°C by using the extraction point 6R and applying a GHSV value of 1900, 3100 and 3800 h^{-1} for each the dolomite and Nickel catalyst bed, respectively.

On April, 1, 2025, the second hazel nut shell gasification test was started and after having reached stable gasification conditions syngas was extracted from another extraction point at the duct of the main producer gas stream upstream of the biodiesel scrubber at an average operating temperature of the catalytic reactor of 651°C and applying a GHSV for the dolomite and catalytic reactor of each 2000 h^{-1}. An extraction of the producer gas at this point before entering the catalytic reactor using the impinger train and after passing the catalytic reactor using the impinger train was realized by additionally measuring the corresponding dry gas composition of the outlet gas of the catalytic reactor.

As the colour of the collected solutions of all impinger bottles after passing of the extracted syngas from the main stream through the catalytic reactor was still transparent, whereas the colour of the corresponding collected impinger solutions before entering the catalytic reactor was brown, it was decided to increase the extracted syngas volume flow to adjust a higher GHSV value of 2500 h^{-1} at 702°C and at 710°C for the catalytic reactor.

After that the extracted syngas flow rate was further increased to adjust a GHSV value of 3500 h^{-1} for the catalytic reactor at 662°C. After passing this stream through the impinger train to trap the tars the dry gas composition was measured. After collection of the impinger bottle solutions according to the tar protocol a clear solution was obtained again.

On April 2,3,4, 2025, the collected impinger solutions from top of the gasifier were prepared to start measurement on gravimetric tars to determine the corresponding tar inlet content. The collected transparent solutions of the impinger bottles from tar trapping of the 8 outlet gas streams of the catalytic reactor were measured by GC-MS using an FID detector. For quantification naphthalene, dodecane and 2-furaldehyde were used as standard for aromatics, hydrocarbons like alkanes and cycloalkanes and furanic compounds, respectively.

In HPLC, the molecules were quantified with standard solutions of acetic acid and 2-furaldehyde.

Scientific results (up to 800 words)

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

Target of this work was to specify the optimum operating parameters and to indicate the technical feasibility of lowering the temperature for tar reforming from > 800°C down to temperatures between 650 - 750°C by using the novel steam reforming catalyst C&CS #1250 A from C&CS catalysts and chemical specialties GmbH in the catalytic reactor consisting of 1 L of a dolomite guard followed by 1 L of the Nickel catalyst C&CS #1250 A located downstream of the updraft gasification plant PRAGA.

In total, in the performed updraft gasification campaign, eight tar conversion results were determined, one at the extraction point 5R at 757°C, three at the extraction point 6R at 3 different GHSV values (1900, 3100, 3800 h^{-1}) and 3 different operating temperatures (724, 675 and 699°C) and four tar conversion results were determined in syngas from the mean extraction point in dependence on the operating temperature (651, 662, 702, 710°C) and the GHSV value (2000, 3500, 2500, 2500 h^{-1}).

The tar content results measured by GC-MS in the collected solutions of the three tar conversion measurements at an operating temperature of the catalytic reactor of 724°C, 699°C and 650°C at a tar inlet content in the extracted dry syngas of 54.1 g/Nm3 (by GC-MS) and 60 g/Nm3 (gravimetric tar) at the extraction point 6R show tar conversion of 99.9, 99.8 and 99.4%, respectively. Practically complete tar conversion was achieved at 699°C even by increasing the space velocity up to 3100 h^{-1}. A space velocity of 3800 h^{-1} may be a limiting value, especially at an average operating temperature of 675°C.

At the extraction point 5R the tar inlet content of 36.9 g/Nm^3 (by GC-MS) and 90 g/Nm^3 (gravimetric tar) of the extracted syngas is reduced by the dolomite-C&CS #1250 A two bed-catalytic reactor by 100% (99.96%) at a space velocity of 1600 h^{-1} and confirms the complete tar conversion at a lower tar inlet content as expected.

The appropriate tar conversions in the syngas extracted from the main extraction point, where a tar inlet contents of 45 g/Nm^3 (by GC-MS) and 99 g/Nm^3 (gravimetric tar) were measured, show abatement values by the two beds-catalytic reactor of 100% (99.99%) at 702°C, reproduced by 100% (99.97%) at 710°C at an applied space velocity of 2500 h^{-1} in both cases.

At a lower operating temperature of 651°C at a space velocity of 2000 h^{-1} and at a similarly low operating temperature of 662°C, even by increasing the space velocity to 3500 h^{-1}, 100% tar conversion were achieved in both cases (99.97% and 99.99%, respectively).

These results clearly indicate the feasibility of operating the novel tar reforming catalyst C&CS #1250 A at a relatively low operating temperature of 650°C and indicate a substantial energy saving versus typically operated secondary tar reforming reactors at temperatures of > 800°C. Based on the gained data it is recommended to operate the catalytic reactor in a space velocity range of 2000 – 3000 h^{-1} (+/ - 500 h^{-1}).

Concerning the tar abatement at this relatively low operating temperature of 651 and 662°C, in both cases an increase of the gas yield by 15.6% was measured. The increase of Hydrogen production by 22.3% and 24.3%, respectively, and the increase of CO_2 production by 109,4% and 104.5% indicate the main tar abatement products and also a high intrinsic water gas shift activity of the catalyst.

The obtained tar conversion results of the novel steam reforming catalyst C&CS #1250 A also indicate a superior tar conversion in comparison to the gained results of 99.5% at a tar inlet content of 56.7 g/Nm^3 dry syngas in the previous work of Cerone et al., 2024 (https://doi.org/10.1016/j.ijhydene.2024.07.290) using a Ce_2O_3-Al_2O_3 supported Nickel catalyst downstream of dolomite in the catalytic reactor.

Interpretation of the results (up to 400 words)

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

The obtained real tar measurement results in updraft gasification of hazelnut shells at tar inlet contents of the extracted syngas of 45 g/Nm^3 show, that complete tar removal is feasible at 650°C by using a dolomite guard bed upstream of a bed of the novel tar reforming catalyst C&CS #1250 A. The dolomite guard acts as HCl and H_2S guard to protect the Nickel catalyst C&CS #1250 A against poisoning. A space velocity of up to 3000 h^{-1} is recommended for low temperature tar reforming. At an increased tar inlet content of 54 g/Nm^3 it is recommended to operate the catalyst at an operating temperature of 700°C to achieve practically complete conversions by recommending a space velocity range of 2000 – 3000 h^{-1}.
The complete tar conversions at the low temperature of 665°C and 662°C at the tar inlet content of 45 g/Nm^3 indicate a superior catalytic performance versus the found performance of the examined CeO_2-Al_2O_3 supported Nickel catalyst in the past that was operated at a higher operating temperature of 750°C to achieve a tar conversion of 99.5% at a tar inlet content of 56.7 g/Nm^3.
Therefore, the obtained results in this measurement campaign show that low temperature tar reforming is feasible at this tar inlet content by using a combination of a dolomite guard bed and the Nickel Catalyst C&CS #1250 A in hot gas cleaning in the above indicated space velocity range. This reduction of the operating temperature for tar reforming from > 800°C to 650°C presents substantial energy savings in this two bed catalytic reactor configuration. The recommended space velocity range for low temperature tar reforming is also within the range of typical fixed bed catalytic reactors and, therefore, competitive in terms of the catalyst operating costs.

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]

In this measurement campaign a novel steam reforming catalyst C&CS #1250 A was successfully tested in tar reforming of hazelnut-derived syngas in the updraft gasification plant PRAGA at ENEA in Trisaia.
Complete tar abatement was measured at a low temperature of 650°C in a dolomite – C&CS #1250 A catalytic reactor configuration at a relatively high tar inlet content of 45 g /Nm^3 indicating the feasibility of low temperature tar reforming at typical space velocities.
In future work long-term testing of this dolomite – C&CS #1250 A combined reactor over longer time on stream campaigns would be necessary to assess the long-term tar abatement performance. In addition, measures for catalyst regeneration after long-term operation such as steaming in a two reactors configuration - reactor A & reactor B - need to be examined to allow continuous tar abatement in hot gas cleaning of biomass-derived syngas in industrial plants.
The results of this measurement campaign will be presented on the European Biomass conference 2025 in Valencia and on the European Fuel Cell and Hydrogen Conference 2025 in Capri. The corresponding abstracts with the titles "Efficient Hydrogen-Rich Syngas Production from Biomass Gasification Using a Novel High-Performance Catalyst for Double-Step Steam Catalytic Tar Reforming" and "Hydrogen Production from Lignocellulosic Agro-Residues via Thermo-Catalytic Pathway" were submitted.

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 of the project comprise chemical analysis data obtained during the tar measurement campaign at the PRAGA plant at ENEA and the chemical and physical characterisation data of the catalyst supplied by C&CS. ENEA will store chemical data concerning the process carried out in its PRAGA plant, including thermal and mass measurements, stream chemical analysis. C&CS will store data on catalyst production, characteristics and modification after testing.

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.]

There were no problems to complete out the research project.

Intended publications

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

It is intended to publish the main results in the International Journal of Hydrogen Energy.

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 obtained tar reforming results at the tar inlet contents of 45 Nm^3/h and 54 Nm^3/h show that hot gas cleaning in updraft gasification is feasible and, in addition, at distinct lower operating temperatures of 650 – 700°C versus the state of the art recommendation of > 800°C. This broadens the range of gasification types and gasification feedstocks that can be applied for energy and fuel production and lead to more energy-efficient gasification processes.
Further process intensification, e.g. by use of catalytic filters by combining hot gas filtration with catalytic steam reforming is possible with lower filter costs as new filter materials (e. g. silicon carbide based) should be applicable to be tested on their long-term stability at 650°C.
In addition, in actually favoured gasifier types generating tar contents of < 10 $g/Nm^3/h$ and using wet scrubbing technology followed by a tar trapping unit for complete tar removal a simplification of gas cleaning and an increase of the gas yield can be achieved by catalytic hot gas cleaning leading to a more energy-efficient process, e.g. for biogenic hydrogen production, fuel synthesis or electricity production, respectively.

Conclusions / additional comments

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

No further comments.

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

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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					

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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

[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.] Field testing in a slip stream of a continuously operating gasification plant.

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] Integration of a continuously operating gasification plant for field testing.

Feedback – Pro-active Innovation Support

RISEnergy

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]* Not applicable.	

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: