Proposal Evaluation Form

EUROPEAN COMMISSION

Horizon Europe Framework Programme (HORIZON)

Evaluation Summary Report (Review task) - PATHFINDER - CHALLENGE

Call: HORIZON-EIC-2021-PATHFINDERCHALLENGES-01
Type of action: HORIZON-EIC
Proposal number: 101070976
Proposal acronym: EPOCH
Duration (months): 48
Proposal title: Electrocatalytic Production of liquid Organic hydrogen carrier and CHemicals from lignin
Activity: HORIZON-EIC-2021-PATHFINDERCHALLENGES-01-04

N.	Proposer name	Country	Total Cost	%	Grant Requested	%
1	LULEA TEKNISKA UNIVERSITET	SE	739,142.5	21.10%	739,143	21.10%
2	AALTO KORKEAKOULUSAATIO SR	FI	580,700	16.58%	580,700	16.58%
3	UNIVERSITA DEGLI STUDI DI MESSINA	IT	468,567.5	13.38%	468,568	13.38%
4	TECHNISCHE UNIVERSITEIT DELFT	NL	469,247.5	13.40%	469,248	13.40%
5	TECHNISCHE UNIVERSITAET MUENCHEN	DE	611,560	17.46%	611,560	17.46%
6	NEXTCHEM SPA	IT	340,000	9.71%	340,000	9.71%
7	HYDROGENIOUS LOHC TECHNOLOGIES GMBH	DE	293,750	8.39%	293,750	8.39%
	Total:		3,502,967.5		3,502,969	

Abstract:
EPOCH proposes to develop a novel approach in linking green hydrogen production with the direct loading of liquid organic hydrogen carriers (LOHC) enabling a transformative logistic of green hydrogen distribution and storage. Lignin derivatives are used to be selectively oxidized. Compared to water electrolysis, EPOCH will advance the field by (1) using the nascent hydrogen at the cathode directly to load LOHCs allowing economic H2 storage and transport, and (2) converting at the anode waste lignin and its derivatives via selective oxidation. EPOCH is beyond the state-of-the-art solutions, as it does not form molecular H2 at the cathode nor generates oxygen at the anode. By modifying both cathodic and anodic reactions, EPOCH reduces the energy intensity.

EPOCH will enable better cell performance and enhanced added-value device operations by (i) improving energy efficiency, (ii) allowing cost reductions, and (iii) intensifying the process. The EPOCH device will be designed for flexible integration with biorefineries and pulp & paper industries, to valorize their lignin waste streams, thus, linking these industrial sectors and H2 economy. EPOCH will allow the production of green H2 in areas where renewable energy production (in the energy mix) is higher. Therefore, EPOCH will offer a new path to effectively decrease the carbon footprint of energy-intensive industries.

Development of the novel EPOCH electrocatalytic device requires (a) advanced components (electrocatalysts, electrodes, electrolytes and ionic liquid promoters, membranes) and (b) validation of the full module cell operation at laboratory scale. Thus, our project integrates multidisciplinary top-experts in areas such as electrocatalysis, lignin chemistry, and materials synthesis, with a large engineering company on energy transition and a SME world-leading the LOHC technology development and logistic.

Evaluation Summary Report

Evaluation Result

Total score: 4.74 (Threshold: 0)

Panel comments on proposal

This Evaluation Summary Report contains the final score decided by the Pathfinder Challenges Evaluation Committee. It comprises a collation of the comments from individual reports, or extracts from them, a comment that summarises the assessment by the Evaluation Committee as well as any additional comments. The Evaluation Committee drew its conclusions on the basis of the remote score and the outcome of its consensus discussions.
The comments from the individual evaluators are collated per sub-criterion, so in the report the comments on each sub-criterion reflect the opinions from all three evaluators. While not necessarily subscribing to each and every opinion expressed, the Evaluation Committee finds that the comments from the evaluators provide a fair overall assessment, indicating both essential strengths and weaknesses identified in the proposal.

According to the predefined scoring scale, the proposal is excellent (overall score above 4.5).

The Evaluation Committee agrees with the evaluators that the proposed topic of electrochemical synthesis of liquid organic hydrogen carriers (LOHC), while using waste lignin products of biorefineries at the anode for oxygen removal, is highly innovative, relevant and contributes well to the overall goal and the specific objectives of the Challenge.
The Evaluation Committee also acknowledges that the consortium brings together leading experts in their fields, both in academia and in industry, so to be able to implement the planned tasks. The workplan is carefully constructed, and will allow to seamlessly transfer the generated information among the partners.
The Evaluation Committee agrees with the evaluators that the economical, social and technological impacts of the proposed research can be very high. The innovation potential is well described and convincing.

Criterion 1 - Excellence

Score: **4.67** (Threshold: 4/5.00 , Weight: 60.00%)

The following aspects will be taken into account, to the extent that the proposed work corresponds to the description in the work programme:

Relevance to the Challenge: How relevant are the project's objectives in contributing to the overall goal and the specific objectives of the Challenge?

The global goal of the project is to produce a liquid organic hydrogen carrier by electrocatalytically hydrogenating the precursor. It is a relevant goal to produce green H2 targeted in the Challenge with an convincing approach less classical than producing H2 by electrolysis and then chemically storing it in a liquid carrier. In addition, the valorization of lignin derivatives, abundant and less valorized biomass, is targeted, that it is also in accordance with the Challenge's objectives. The different scales of the process are also targeted that is relevant in the global goal of the project. At last, the circular and life cycle approach of the project.

The objectives are highly relevant to the Challenge because the proposal aims to produce liquid hydrogen carrier by electrocatalytically hydrogenating the organic precursor at the cathode and plans to generate oxidized lignin derivatives at the anode. The performance of the complete device is specified concerning the competitive production costs, decrease of carbon footprint in comparison to the state-of-the-art water electrolysis and remote H2 transport, added-value of transformed lignin-derived compounds with respect to O2 production at the anode etc.

The project objectives are very clearly described and correspond well to the specific objectives of the Challenge. The idea is to develop a process, in which lignin derivatives will be electrochemically hydrogenated to liquid organic hydrogen carrier, transported and dehydrogenated to produce locally hydrogen. Lignin derivatives will be first transformed with activated oxygen species into oxidized form. The planned approach suggests to use only minimal amounts of CRM materials, perform life-cycle analysis and promote technology transfer via associated value chain partners. The cost reduction is expected in increasing energy efficiency, process intensificaiton and integration, The consideration of avoidance or minimal used of CRM is in line with specific objective and the cost for production of liquid organic hydrogen carrier.

Novelty: How novel and ambitious are the proposed technological breakthroughs with respect to the state-of-the-art? How relevant and effective are they in achieving the expected outcomes of the Challenge?

The novelty of the project is clearly highlighted through the process integration and intensification, the increased energy efficiency and cost reduction, the flexible use in biorefineries and development of advanced material and electrocatalytic processes. The well presented state-of-the-art on H2 production, lignin valorization and associated mechanisms shows the relevance of the targeted breakthroughs in terms of technologies to produce H2, the sustainable use of non-critical raw materials and the decarbonization strategy.

The general idea of the electrocatalytic device to simultaneously produce liquid organic hydrogen carriers (LOHCs) and biobased chemicals promises a technological breakthrough. However, the details of the proposed processes and configurations are not compared to the state-of-the-art concerning their novelty. Some SME companies have already offered commercial LOHC technologies.

The state-of-art has been clearly justified. The proposed research, electrocatalytic oxidation of lignin derivatives have already demonstrated, however, this approach suffers from insufficient yield. The proposed work is ambitious and contains new elements, because new membranes will be prepared together with IL-promoted electrolytes and reaction mechanism will be studied with advanced methods, which give proper performance evaluation. In addition techno-economic, logistic and environmental assessments will be made. This is good.

Plausibility of methodology: To what extent is the Research, Development and Innovation methodology described in the proposal appropriate to reach its objectives? How plausible is it that the objectives set out in the proposal are achieved within the time span of the project?

The methodology to develop novel catalysts, electrodes, membranes and ionic liquid-based promoted electrolytes with nano and molecular approaches is plausible, with a reasoned increase of the TRL of develop technologies. The proposed multidisciplinarity of the project is clearly necessary to reach the different objectives.The different crucial steps proposed in the project are timely organized and will guarantee the advancement of the project.

Several possibilities are sketched concerning the development of cathode and anode. Variants proposed for the membrane or electrolyte preparation will follow the individual cathode and anode selection. Thus, the proposal offers high variability of approaches to reach its objectives. In some cases, it lacks details or reasons for choosing particular processes and materials. The formulation of the first task of the WP1 reveals that the starting point is not yet thoroughly conceived because the partners have to analyze the current technical and logistic overview of the industrial use of LOHCs and identify the group of LOHCs to be used in the project's technology. The proposal offers a high amount of technology variants without knowledge of what variant can lead to improvement compared to the state-of-the-art. Thus, reaching the proposed objectives cannot be fully assessed.

The proposed research is very plausible, because device and instrument development are very well interconnected with theoretical and fundamental studies and the results will be verified with process simulation and system assessments (LCA, green chemistry assessment, carbon footprint). This is good. It has been credible addressed, how the stepwise implementation of different tasks is feasible during the

project life span and facilitated with intensive interconnection between different tasks.

Criterion 2 - Impact

Score: **4.83** (Threshold: 3.5/5.00 , Weight: 20.00%)

The following aspects will be taken into account, to the extent that the proposed work corresponds to the description in the work programme:

Potential Impact: To what extent the successful completion of the project may have economic and societal impact and how credible it is argued and quantified (e.g. via KPIs or equivalent)? How appropriate are the expected outcomes of the project to contribute to the potential economic or social impacts of the Challenge?

The proposed solutions will lead to a specific economic model, well-identified in the proposal, integrating and extending the network of liquid organic hydrogen carrier that can have economic and sustainable societal impacts. The measures in terms of knowledge, capacity building and communications are clearly in favor of concrete impact on the society to remove legislative, normative and operational barriers. The outcomes related to environmental objectives are particularly convincing. The impacts at short and long terms promoting the targets of HORIZON EU are interestingly highlighted in the proposal.

The high impact is excellently argued using KPIs that are quantified as the numbers or percentages of measurable parameters related to the Challenge. The high impact is also demonstrated by the multi-disciplinary chain of project partners ensuring a complex solution from cathode, membrane, electrolyte and anode to the complete electrochemical cell. The proposal provides excellent overview over the hydrogen market. The partnership with the SME Hydrogenious indeed supports the project impact in the area of hydrogen storage and transportation. It will definitively have economic and social impacts related to the Challenge.

The economic impact of the proposed research has been very clearly analyzed, argued and quantified via giving KPIs for hydrogen price in liquid organic hydrogen carrier, decrease in energy input, stability for electrocatalytic performance and increase added-value via transforming lignin with respect to oxygen evolution reaction. solar to hydrogen efficiency and numerical estimates for low catalyst concentration required. The proposed technology is flexible for small lignin biorefineries and also other industrial, such as pulp and paper industry are potential users. The idea is to integrate logistics and value chain, which is well justified. The potential economic and social impacts are well specified and estimates for short and long-term technology transfer and estimated market values have been clearly presented. The social impacts include creation of jobs, decreasing CO2 emissions, which is well justified.

Innovation potential: How adequate are the proposed measures for protection of results and any other exploitation measures to facilitate future translation of research results into innovations with societal or economic impact? How suitable are the proposed measures for empowering key actors that have the potential to take the lead in translating research into innovations?

The strategy for intellectual property right management is closely related to Data Management and a specific task is dedicated to it. The consortium agreement will identify the background IP and data needed in the project. It is a important point, but some directions are not sufficiently anticipate upstream of the proposal

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Part of the WP6 is the exploitation strategy and planning led by the project partner NextChem, a large company with core business on green chemistry and energy transition. Through the project partner LTU, the consortium will also have a close contact to the Center H2 Energy System Sweden (CH2ESS). The direct participation of two companies NextChem, Hydrogenious and the association with CH2ESS and its stakeholders will efficiently help to translate the project outputs into higher TRL levels. Further help can come from the advisory board established within the project to engage external stakeholders. The proposed measures for protection of results are adequate.

The protection of the results is planned via patenting the technology. Consortium agreement will identify the background IP. This part has been well argued. The way how to facilitate the future translation of the research results into innovations with economic impact is appropriate, because the analysis of markets, availability of lignin residues and end-users as well as barriers have been clearly identified, including e.g. market, legislative, and operational barriers and social acceptance. The need for subsidizes and political environment for fuel prices have been clearly addressed. The description of how to empower the key actors includes involvement of SMEs and to activate them for start up new business, business models will be created and piloting and demonstration will promoted. This is good and the description is credible.

Communication and Dissemination: How convincing and wide reaching are the proposed measures and plans for public/stakeholder engagement and for raising awareness about the project outcomes, including through Open Science, with respect to their potential to establish new markets and/or address global challenges?

The main targeted audiences of the project are correctly identified (researchers and academia, industrials professionnals, end-users including general and policymakers). A detailed plan of actions based on "how-actions-target KPIs) is relatively convicing. However, the open-access approach is cited but not sufficiently developed in the proposal. The industrial impact and market awareness are clearly identified and the internal/external communications will help the potential development through new markets.

The communication and dissemination strategy is described in detail and it is included also in the wok plan (in WP6). The particular activities, such as special issues of Catalysis Today, dissemination seminars, involvement of governmental actors make the plan convincing.

The efficiency of communication and dissemination in raising awareness about the project outcomes has been very well addressed and

different ways to communicate and disseminate have been identified, e.g. establishment of website, scientific publications, promoting open access practices, several platforms and industry associations have been named to whom the contact will be established. The sizes and number of different groups and events have bene well justified. These are good. Data management plan is very clear.

Criterion 3 - Quality and efficiency of the implementation

Score: **4.83** (Threshold: 3/5.00 , Weight: 20.00%)

The following aspects will be taken into account, to the extent that the proposed work corresponds to the description in the work programme:

Quality of the applicant/consortium (depends if mono or multi-beneficiaries): To what extent do(es) the applicant/consortium members have all the necessary high quality expertise for performing the project tasks?

The consortium is composed of complementary and pluridisciplinary expertises on catalyst development for biomass conversion, the development of catalysts and electrocatalytic solutions, heterogeneous catalysis, enzymatic hydrolysis, circular economy, green chemistry and business. This consortium has all the expertise to perform the proposed project. They globally have access to the essential infrastructure needed in the project such as advances techniques of caracterization, electrolyzers, chemical engineering, database and code source/software, etc.

The project consortium includes five academic institutions and two industrial partners. It ensures different views to the expected outputs, from understanding the processes to applicability of the developed technology on the market. Moreover, the partners have complementary expertise. Thus, all the different tasks (cathode, membrane, electrolyte, anode, a complete electrochemical cell) will be led by highly qualified scientists and the available research infrastructure is vast.

The consortium has very appropriate complementary expertise for performing the project tasks and knowledge in e.g. engineering, techno-economic analysis, catalysts, logistics, eletrochemistry, membranes, IL-based technologies and operando characterization. Access to infrastructure has been clearly justified.

Work plan: How coherent and effective are the work plan (work packages, tasks, deliverables, milestones, timeline, etc.) and risk mitigation measures in order to achieve the project objectives?

The work plan is coherent with clear link between each workpackage. The tasks are clearly timely defined and are based on the expertise of each partner. An important number of deliverables is proposed to guarantee the advances in the project. They are in accordance with the objectives of the project. The risk mitigation measures are convincing on both technical and organizational aspects.

The work plan takes into account all the necessary steps for the construction of electrochemical cell and it includes also the tasks of techno-economic and life cycle analyses or logistic. The whole work plan structure is well conceptualised. The risk related to the project aims is identified and the actions for its mitigation are proposed.

Overall the work plan has a logical structure and milestones and deliverables are clearly addressed, which is good. The interconnection between different workpackages has been very clearly justified. The tasks have been very clearly described. The risks have been clearly identified. It has been proposed in the contingency plan to use even ultra-low loading of noble metals, if the non-noble metal catalysts give too low activity. This is a shortcoming and decreases the novelty.

Allocation of resources: How appropriate and effective is the allocation of resources (person-months and equipment) to tasks and consortium members?

The person-months allocation is well-balanced between each partner, in a function of the corresponding taks. The budget is appropriate on travel, equipment and others goods, works and services. The requested equipment (electrochemical flow cells, testing rig, etc) is well-justified.

The allocation of person-months to different WPs corresponds to the partners' expertise. The equipment available to the partners matches their needs and tasks.

The allocation of resources is appropriate. The allocation of the person months is well justified for the planned tasks and balanced. The justification of the required resources is very well justified giving enough details and clear.

Scope of the application

Status: **Yes**

Comments (in case the proposal is out of scope)

Not provided

Exceptional funding

A third country participant/international organisation not listed in the General Annex to the Main Work Programme may exceptionally receive funding if their participation is essential for carrying out the project (for instance due to outstanding expertise, access to unique know-how, access to research infrastructure, access to particular geographical environments,

possibility to involve key partners in emerging markets, access to data, etc.). (For more information, see the HE programme guide)

Please list the concerned applicants and requested grant amount and explain the reasons why.

Based on the information provided, the following participants should receive exceptional funding:

Not provided

Based on the information provided, the following participants should NOT receive exceptional funding:

Not provided

Use of human embryonic stem cells (hESC)

Status: **No**

If YES, please state whether the use of hESC is, or is not, in your opinion, necessary to achieve the scientific objectives of the proposal and the reasons why. Alternatively, please state if it cannot be assessed whether the use of hESC is necessary or not, because of a lack of information.

Not provided

Use of human embryos

Status: **No**

If YES, please explain how the human embryos will be used in the project.

Not provided

Activities excluded from funding

Status: **No**

If YES, please explain.

Not provided

Do no significant harm principle

Status: **Yes**

If Partially/No/Cannot be assessed please explain

Not provided

Exclusive focus on civil applications

Status: **Yes**

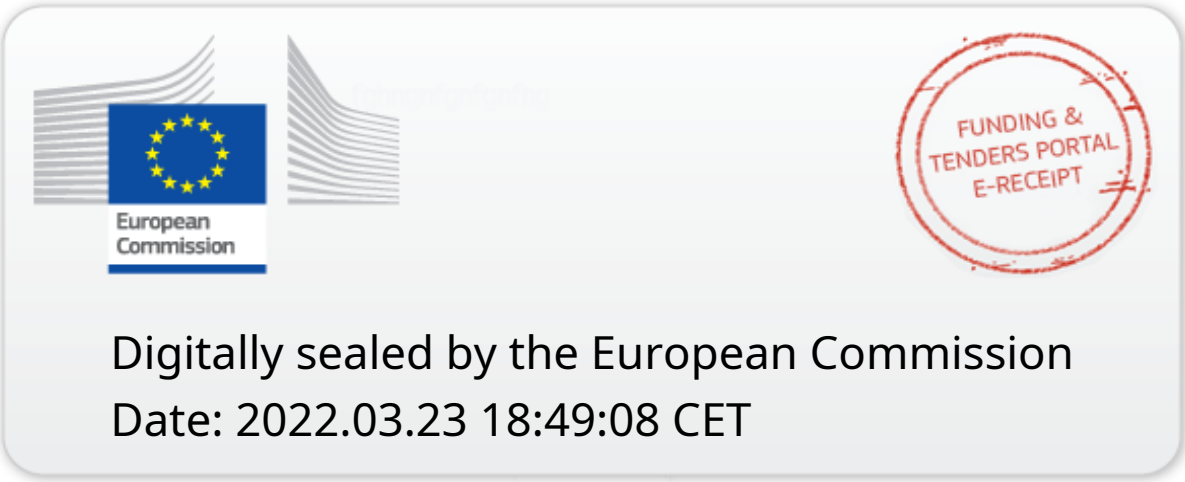
If NO, please explain.

Not provided

Artificial Intelligence

Status: **No**

If YES, the technical robustness of the proposed system must be evaluated under the appropriate criterion.



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