PERFORM
PowER platFORM

SUCCESSFUL FIRST INTERMEDIATE REVIEW

From June 24 to 26, the PERFORM consortium celebrated its month 18 meeting and underwent its first review by the European Commission and SPIRE 2030 organisations.

During the first day, partners were invited to showcase their advances to date. **Avantium**, as the leader for work package 1 related to **feedstock platform analysis**, described the seven analytical methods developed for this, included in the first deliverable report. They carried out as well pre-treatment methods based on early assessment of detrimental impurities.

INSTM presented the conclusions for the work in the **Electrode Platform Innovation** and the milestones achieved: synthesis of more than 10 electrodes for anodes/cathodes and ranking of their behaviour, competitive technologies report submitted, lab-scale catalyst screening for both line of reactions (paired electrosynthesis and paired tandem electrosynthesis) performed.

The work package 3: **System Platform Innovation**, led by **TNO**, explained that the process design specifications were delivered, the reactor modeling, design, and sizing was completed, and the reactor and test system are under construction. Likewise, proof of concept and lab-scale optimization was obtained for maleic acid, valeric acid, glucaric acid, and adipic acid.

Regarding **Hysytech** tasks in work package 4 related to **PowerPlatform demonstration**, it was announced that the basic engineering has already started.

For the **process assessment**, the **University of Hohenheim** has already collected the first required data for developing environmental life cycle assessment, life cycle costing, and process simulation.

In work package 6 the activities carried out in terms of **techno-economic analysis** and market assessment were further explained by **AVA BIOCHEM** which has already performed a preliminary cost analysis at the beginning of the project based on a technical assessment to identify critical process parameters to be improved and to guide the process development along the project for both investigation lines, so a financially viable solution is developed at the end of the project.

From their part, **Sustainable Innovations** reviewed the advancement in terms of key performance indicators for **dissemination** and the next routes to follow in terms of **exploitation**.

Finally, **TNO, as coordinator** of the project, closed the presentations by explaining the milestones achieved and the next steps to make in terms of management.

The **Italian Industry embraces Green Chemistry workshop** was organised by Gruppo Interdivisionale di Green Chemistry della SCI, CNR-SCITEC and Consorzio Italbiotec and the presentations addressed the new **European Green Deals** related to chemistry.

On behalf of the PERFORM consortium, Stefano Alini, CEO and Innovations and Research Director at RadicalGroup

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Interview with Roman Latsuzbaia, Scientist at TNO and responsible for PERFORM System Platform Innovation

Q: Which are the milestones achieved to date that you would highlight?

A: Electrochemical conversion has the potential to combine the use of renewable electricity and renewable resources, such as biomass, to contribute to the transition towards a more sustainable chemical industry. PERFORM projects aims to develop a Perform Power Platform, where the feasibility of two electrochemical transformation routes to make value added chemicals from biobased sources will be demonstrated. The Power Platform will be a flexible system where, in the future, other electrochemical conversion routes can be tested and help in bringing electrochemical conversion technologies closer to implementation.

The objective of work package 3 dedicated to System Platform Innovation is to develop and optimize the operation of an electrochemical reactor and downstream processing technologies for the target compounds.

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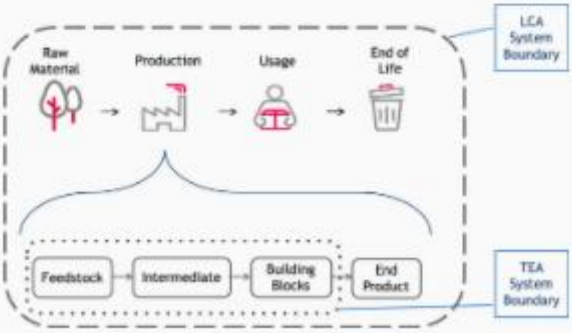
PERFORM TECHNO-ECONOMIC ANALYSIS AND MARKET ASSESSMENT



In Work Package (WP) 6, led by AVA BIOCHEM, the economics of the PERFORM project will be assessed, as well as the market where the technology is developed for. The results of these will be input for the exploitation plan of WP 7. All these tasks are very closely related to WP 3 and WP 4, where the system platform innovation is set up and the power platform is demonstrated (main innovations of the project). A major partner during the whole process of TEA is University of Hohenheim, who is doing the Life Cycle Assessment (LCA).

The technologies assessed (and which are developed in two different electrochemical lines) are as follows:

End product of value chain	Functional unit	Reference system
Maleic acid	The production of 1 kg MA from furfural	Current commercial production process
Valeric acid	The production of 1 kg VA from levulinic acid	Current commercial production process
Adipic acid	The production of 1 kg AA from glucose through the intermediate glucaric acid	Current commercial production process

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Interview with Rosalba Passalacqua, Senior Researcher at INSTM and responsible for the Electrode Platform innovation.

Q: What are the main responsibilities of INSTM within the project?

A: To answer this question, it is useful to recall that the general objective of the PERFORM project is contributing to establish a new **technological infrastructure**. This infrastructure is aimed at the highly selective transformation, by the electrochemical way, of raw materials from **biomass** into intermediates for the chemical industry, thus reducing the dependence of our society from the traditional compounds derived from fossil fuels and at the same time, integrating **renewable energy resources** into industrial production.

To establish this new low carbon route for **chemical production** integrating removable energy sources and alternative bio-based carbon sources, the focus was pointed on a specific investigation of two target paired reactions.

These reactions lead to the preparation of some platform **molecules** deriving from biomass (**Maleic** Acid, **Valeric** Acid, for the reaction line 1 and **Glucaric** Acid, and **Adipic** Acid for the reaction line 2).

These small molecules have been selected thanks to their functional groups and associated reaction sites and could be utilised as building blocks for higher-value chemicals and materials. The novelty lies in the approach used to effect this transformation: using **electrochemistry**.

The **two paired reactions**, carried out by PERFORM, involve electron transfer in the **oxidation** and **reduction** reactions with significant advantages concerning the current industrial processes. It is possible to eliminate the use of high O_2 pressure or hazardous chemical oxidants, used in chemical oxidation, or suppress the by-products production typical of microbial fermentation. In the electrochemical route, the reactions can be operated under mild conditions, and via tuning the electrode potential and using appropriate catalysts, a high product selectivity can be obtained.

To promote and carry out the electrochemical reactions, suitable electrocatalysts are required. INSTM role dials with **researching, developing, and creating these new highly selective and efficient electrocatalytic materials capable of transforming the renewable bio-based raw materials** (Furfural, Levulinic Acid, Glucose) into the corresponding intermediates (Maleic Acid, Valeric Acid, Glucaric Acid, Adipic Acid).

Therefore, we can conclude that INSTM works at the heart of the PERFORM project, and is responsible for the key innovation point of the project, for which it is providing the **synthesis, development and upscaling** of all the catalysts involved in the target reactions.

Setting up an efficient electrocatalyst is not a simple operation, catalysts are more and more high-

Setting up an efficient electrocatalyst is not a simple operation, catalysts are more and more high-tech, a sophisticated composite material based on nanostructures having *dynamic properties* (that is a suitable behaviour during the reaction) *chemical properties* related to the chemical state of the active phase, acidity, and surface composition/structure and *physical properties* such as surface area, porosity, density, and mechanical strength.

These properties are interdependent between them; therefore, a clear understanding of their relationships is necessary to optimize a catalyst. Moreover, it is necessary to meet further requirements related to the industrial use of the materials concerning stability, cost, resource availability, scalability, poisoning, the **environmental impact** of exhausted catalyst and recovery.

Q: How is INSTM coordinating the Electrode Platform Innovation?

INSTM periodically collects data from the activities carried out by all work package (WP2) partners, analyses, integrates them, highlights their critical or particularly interesting elements, and reports them to all partners by convening specific technical workshops both face-to-face and online. The problems are discussed within the WP2 partners, or a broader audience if the subjects involve other WPs, updating from time to time the direction plan on which to focus the research activity. INSTM also takes care of drawing up periodic technical reports on the progress of the project, deliverables, and milestones. The documentation is uploaded to the SharePoint to make it available to partners for consultation.

Interview with Wim de Schepper, Researcher in Separation and Conversion Technology – Electrochemical technologies at VITO.

Q: For the time being VITO has worked on the Separation and purification units for single cell reactors, what are the next steps and what challenges the company will be facing?

A: The work on downstream processing (DSP) has been a close cooperation between the project partners Hysytech, Avantium, Novamont, RadicalGroup, Perstorp, AVA Biochem, INSTM, TNO and VITO.

Numerous **technology screening tests** have been performed on different synthetic mixtures mimicking the actual process fluids. Very diverse DSP technologies such as **freeze crystallization, extraction, precipitation, distillation** were shown to be promising as well for separation of target molecules and solvent regeneration. Encouraging results were obtained for **electrolyte recycling and concentration of products** in single technology screening tests. Some examples include the separation of sulfuric acid electrolyte from the valeric acid product for line 1 and the separation of glucaric acid from glucose for line 2. Both separations were found to be technically feasible with **electrodialysis and nanofiltration.**

A few challenges remain however, specifically the **separation of maleic acid from sulfuric** acid remains challenging both in terms of materials requirements and performance of the unit operations. The real operational conditions that will occur in the PERFORM pilot and the actual composition of the generated streams remain uncertain for both line 1 and 2 and can be tuned to some extent. A scenario analysis will be used to assess performance under different conditions and to anticipate undesired process conditions including possible high impurity of target molecules maleic, valeric, glucaric and adipic acid.

Our next steps entail **continued process characterization** in the lab and material selection to allow for pilot construction and demonstration of both PERFORM reaction lines.

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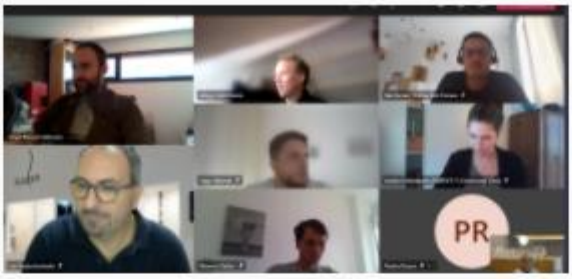

On October 21, PERFORM joined forces with similar initiatives: SIMPLIFY, DESTINY, and LIBERATE, by holding a first online meeting to seek synergies among the projects and boost the communication & dissemination strategies. Check out more about these projects:

SIMPLIFY

Sonication and Microwave Processing of Material Feedstock (SIMPLIFY) is an innovation action in which leading European industries and university groups in process intensification, ultrasound, microwave, multiphase processes, polymerization and crystallization team up to address the domain of electrification of chemical industry. In four years, a consortium of 11 European organizations, led by KU Leuven, will focus on intensified processes, where alternative energy sources enable flexible continuous technologies to achieve localized ultrasound and microwave actuation of multiphase, flow reactors powered by electricity from renewable sources for the purpose of high-value product synthesis.

The DESTINY project aims to realize a functional, green and energy saving, scalable and replicable solution, employing microwave energy for continuous material processing in energy intensive industries. The target is to develop and demonstrate a new concept of firing for granular feedstock to realize material transformation using full microwave heating as alternative energy source and complement to the existing conventional production. The DESTINY system is conceived as cellular kilns in a mobile modular plant with significant advantages in terms of resource and energy efficiency, flexibility, replicability, scalability and a reduced environmental footprint.

DESTINY

Liberate

The LIBERATE project aims at designing of an electrochemical plant to demonstrate the commercial opportunities of converting low cost lignin feedstock in high value bio sustainable chemicals such as vanillin, antioxidants or polyamide.

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