Multi-commodities and sustainable biorefinery based on food processing industry wastes, biogenic CO$_2$ and bioprocess wastewaters

Valeria Agostino, Istituto Italiano di Tecnologia-CSFT@Torino

INFO DAY HORIZON EUROPE – EUROPEAN PARTNERSHIPS
Bando 2024 CBE JU - Circular Bio-Based Europe Joint Undertaking
ISTITUTO ITALIANO DI TECNOLOGIA

- is a foundation established in 2003 with funding from the Italian government to promote the advancement of scientific research
- Headquarters: Genoa, Italy
- application-oriented scientific research

MAIN FIELDS:

- Computational Sciences
- LifeTech
- Nanomaterials
- Robotics

https://www.iit.it/en-US/home
TO ENSURE THE CAPTURE AND VALORIZATION OF CARBON DIOXIDE

TO IMPROVE THE EFFICIENCY IN THE USE OF WASTE FEEDSTOCKS WITHIN A CIRCULAR ECONOMY PERSPECTIVE

TO INVESTIGATE HYDROGEN PRODUCTION, STORAGE AND USE

The CSFT@POLITO, located in Turin, is focused on technologies for sustainability, energy transition and low carbon economy.
Project Details

Multi-commodities microbial-driven biorefinery based on food-processing industry wastes, biogenic CO₂ and bioprocess wastewaters

**Type of project:** Research & Innovation Action

**Project period:** 1 October 2024 - 31 March 2028

**Project focus:** Biochemicals, Cosmetics, Nutraceutics, Food&Feed

**Feedstock origin:** Agri-food industry waste, Biorefinery by-products

**Feedstock type:** Fruit& vegetables residues, biogenic CO₂; wastewaters

**CBE JU Contribution:** € 4 929 060

**Call Identifier:** HORIZON-JU-CBE-2023-R-03
(Robust and optimised industrial biotech and chemical/industrial biotech processes)
Project Details

Call Identifier: HORIZON-JU-CBE-2023-R-03
(Robust and optimised industrial biotech and chemical/industrial biotech processes)

Expected Outcome:
Successful proposals will contribute to the Industrial Strategy, Green and Digital transition and Circular Economy Action Plan, as well as to the achievement of European Green Deal objectives. Proposals will also contribute to the EU Bioeconomy Strategy implementation, developing processes with improved environmental performances, maximum resource- and energy-efficiency, and optimal cascading use of bio-based feedstock, aiming for ‘zero waste’ and ‘zero-pollution’ operations.

Project results should contribute to the following expected outcomes:

• (Industrial) biotech or chemical/(industrial) biotech processing routes with improved efficiency compared to established routes, or completely new processing routes that are currently unavailable;
• Cost-competitive bio-based products;
• Improvement of the environmental performance of bio-based processes through resource-efficient valorisation of sustainable biomass feedstock, while addressing (i.e. reduction/elimination) pollution issues in production processes;
• Significant improvement environmental performance across the value chain against specified fossil and/or bio-based benchmarks;
• Improved circularity and resource efficiency via practical application of the circular (bio)economy concept;
• Availability of a broader range of bio-based products meeting market requirements.
Scope:
Industrial biotech processes often have limitations of scaling up and continuous processing. There is an additional complexity of reduced biocatalyst robustness and poor process metrics, especially when applied in sequence with chemical pre-processing.

Proposals under this topic should:

• Identify existing, industrially relevant, bio-based process(es) (upstream and conversion steps) and identify the areas of intervention and bottlenecks to improve process flexibility, robustness, techno-economic feasibility and environmental performance. The proposal should consider the case of developing combined processes using biotech and chemical approaches synergistically in order to optimise process and/or (bio)catalyst design for obtaining bio-based products.

• Incorporate reactor design, process design, process control and optimisation as well as catalysis optimisation aspects that are relevant to also enable tandem chemical/biotech processes, and where applicable for optimisation of continuous production approaches (batch2continuous).

• Identify, optimize/engineer and test more active and robust microbial hosts and their enzymes, or other (bio)catalysts, against relevant process conditions (including physical and chemical stressors). The projects should also consider integrating the biofoundry and synthetic biology advances Ensure and assess productivity, yield, robustness, flexibility of the process.

• Overall, modifications and optimisation of the (physico)chemical steps to further optimize chemical/biotech tandem processes are also in scope and could be considered.
Project Concept

Co-creating a groundbreaking microbial-based multipurpose biorefinery to enhance the environmental impact and the cost efficiency of both existing and innovative bio-based value chains!

Sustainable feedstocks, as agri-food waste, are key starting points to further develop biorefineries in which all side streams are effectively valorized into a spectrum of products. Multipurpose biorefineries are the answer to establishing effective biofactories with improved circularity and resource efficiency!
Project Objectives

**OBJ 1**
Microbial Factory 1: novel **bio-OCTANOIC ACID** production process from agri-food wastes and Gas Fermentation effluent.

**OBJ 2**
Microbial Factory 2: novel **bio-HEXANOL** production process based on Gas Fermentation with MF1 Biogas and green $\text{H}_2$.

**OBJ 3**
Microbial Factory 3: novel anaerobic phototrophic MF1 **Biogas desulfurization** process.

**OBJ 4**
Microbial Factory 4: cost-effective microalgal **CAROTENOIDs** production using MF1 wastewaters.

**OBJ 5**
Validating the **long-term stability and flexibility** of GoodByO biocatalysts and continuous bioprocesses with **real feedstocks** at TRL5.

**OBJ 6**
*in silico* model platform to cover the integrated biorefinery **energy demand** with a RES-based power supply and **Biomethanation as intermediate energy storage** strategy.

**OBJ 7**
Assessment of **environmental benefits** of GoodByO technologies.

**OBJ 8**
Development of a credible and consolidated **roadmap for GoodByO technologies scale-up and commercialization**.
## Expected Results

### Technological Outcomes: OBJ 1 to 5

<table>
<thead>
<tr>
<th>Microbial Factory</th>
<th>Feedstock</th>
<th>Product</th>
<th>Target product/year in 500m3 reactors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- Chain elongators</td>
<td>Food-waste</td>
<td>Bio-octanoic acid</td>
<td>2000 ton</td>
</tr>
<tr>
<td>2- Acetogens</td>
<td>CO₂(biogas)+H₂</td>
<td>Bio-exanol</td>
<td>2450 ton</td>
</tr>
<tr>
<td>3- Photoautotrophic S-bacteria</td>
<td>CO₂+H₂S (biogas)</td>
<td>Desulfurized biogas</td>
<td>2.3 Mln m³</td>
</tr>
<tr>
<td>4- Microalgae</td>
<td>Wastewater &amp; light</td>
<td>Carotenoids</td>
<td>14 ton</td>
</tr>
</tbody>
</table>

### Environmental Outcomes: OBJ 7

<table>
<thead>
<tr>
<th>LCA category</th>
<th>Improvement compared to benchmarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global warning potential</td>
<td>&gt; 30%</td>
</tr>
<tr>
<td>Water Use</td>
<td>&gt; 30%</td>
</tr>
<tr>
<td>Freshwater Eutrophication</td>
<td>&gt; 30%</td>
</tr>
<tr>
<td>Land Use</td>
<td>&gt; 30%</td>
</tr>
<tr>
<td>Fossil resources</td>
<td>&gt; 30%</td>
</tr>
</tbody>
</table>

### Economical Outcomes: OBJ 6 & 8

<table>
<thead>
<tr>
<th>Bio-products</th>
<th>Target selling price</th>
<th>Benchmark selling price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bio-octanoic acid</td>
<td>&lt;3.6 euro/kg</td>
<td>3.5 euro/kg (Palm-based)</td>
</tr>
<tr>
<td>Bio-hexanols</td>
<td>&lt;5 euro/kg</td>
<td>4 euro/kg (fossil-based)</td>
</tr>
<tr>
<td>Carotenoids</td>
<td>&lt;4000 euro/kg</td>
<td>6500 euro/kg (microalgae)</td>
</tr>
</tbody>
</table>
Expected Impacts

Mid/Long-term Impacts

**Scientific**

- Increased EU technological and infrastructural research leadership in Biotech, Circular Bioeconomy and CCUs fields.
- Integration between Biorefinery and RES sectors.

**Environmental**

- Reduced EU GHG emissions
- Defossilization of EU manufacturing industry
- Reduced EU agricultural land use for animal feed production
- Reduced EU freshwater depletion
- Reduced biorefinery wastes disposal

**Industrial/Economical**

- EU global leadership in Manufacturing Biotech-Industry:
  - based on CO₂ valorization (Gas fermentation Tech);
  - based on food wastes (Chain Elongation Tech);
  - based on biorefinery wastewaters (Microalgae Tech)
- EU leadership in green H₂ chemical storage in consumer goods
- Increased EU raw material security
## Project Consortium

<table>
<thead>
<tr>
<th>№</th>
<th>Short</th>
<th>Beneficiary</th>
<th>Type</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IIT</td>
<td>Fondazione Istituto Italiano di Tecnologia (coordinator)</td>
<td>RTO</td>
<td>Italy</td>
</tr>
<tr>
<td>2</td>
<td>CC</td>
<td>ChainCraft B.V.</td>
<td>SME</td>
<td>Netherlands</td>
</tr>
<tr>
<td>3</td>
<td>KRJ</td>
<td>Krajete GmbH</td>
<td>SME</td>
<td>Austria</td>
</tr>
<tr>
<td>4</td>
<td>BRITE</td>
<td>Brite Hellas SA</td>
<td>SME</td>
<td>Greece</td>
</tr>
<tr>
<td>5</td>
<td>MUNI</td>
<td>Masaryk University</td>
<td>UNI</td>
<td>Czech Rep</td>
</tr>
<tr>
<td>6</td>
<td>CNR</td>
<td>Consiglio Nazionale delle Ricerche</td>
<td>RTO</td>
<td>Italy</td>
</tr>
<tr>
<td>7</td>
<td>POLITO</td>
<td>Politecnico di Torino</td>
<td>UNI</td>
<td>Italy</td>
</tr>
<tr>
<td>8</td>
<td>TUW</td>
<td>Technical University of Wien</td>
<td>UNI</td>
<td>Austria</td>
</tr>
<tr>
<td>9</td>
<td>CIB</td>
<td>Consorzio Italiano Biogas</td>
<td>ASSOC</td>
<td>Italy</td>
</tr>
<tr>
<td>10</td>
<td>CRES</td>
<td>Centre for Renewable Energy Sources and Saving Fondation</td>
<td>RTO</td>
<td>Greece</td>
</tr>
</tbody>
</table>
Project Consortium

- Scientific collaborations
- Previous EU proposals
- Partners in EU funded projects:
  - EngicoIn
    - https://engicoIn.eu/
  - CelbicOn
    - https://www.celbicOn.org/
  - BIKE
    - https://www.bike-biofuels.eu/
  - KAPE
  - CRES
  - TU Wien
  - KraJete
  - CIB
  - Brite
  - On Behalf of Nature.

New collaboration within GOODByO: [Image]
## Partners Expertise Complementary

<table>
<thead>
<tr>
<th>R&amp;D EXPERTISE</th>
<th>RTO</th>
<th>SME</th>
<th>SME</th>
<th>SME</th>
<th>UNI</th>
<th>RTO</th>
<th>UNI</th>
<th>UNI</th>
<th>ASS</th>
<th>RTO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biocatalyst engineering</td>
<td>IIT</td>
<td>CC</td>
<td>KRJ</td>
<td>BRITE</td>
<td>MUNI</td>
<td>CNR</td>
<td>POLITO</td>
<td>TUW</td>
<td>CIB</td>
<td>CRES</td>
</tr>
<tr>
<td>Bioprocess systems engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pilot design</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material synthesis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Process modeling &amp; simulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LCA &amp; TEA assessment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RES design</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Products development</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business model</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open Source practices</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standardization</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Market assessment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IP management</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dissemination</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Legal issues management</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU projects management</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open Science</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CBE RIA call 2023 vs other HE RIA calls: CSFT@IIT experience

CBE RIA call 2023 vs EIC Pathfinder Challenge
(2022-Carbon dioxide and nitrogen management and valorisation):
Pathfinder only 25 pages, very import the Excellence section (Novelty of the concept), lower TRLs

CBE RIA call 2023 vs single-stage HE RIA calls
(CL5-2021-D3-03-09 Carbon-negative sustainable biofuel production; CL5-2021-D3-03-03 - Hybrid catalytic conversion of renewable energy to carbon-neutral fuels; HORIZON-JTI-CLEANH2-2024-01-03 Development of innovative technologies for direct seawater electrolysis):
Both 50 pages and **very important the IMPACT section**

BUT in CBE there are 3 important additional sub-sections:

I. **Feedstock sourcing and description**

II. **Environmental performance:** - ex ante assesment identification of environmental issues - estimation of environmental sustainability performance- estimation of carbon removal

III. **Economic viability** of the products and processes to be developed (including an analysis of the value chain and potential market for the envisaged products).
Contacts:
Valeria.agostino@iit.it
Alessandro.cordara@iit.it
Fabrizio.pirri@iit.it

IIT project office:
Francesco.piacentini@iit.it
Francesca.cavallera@iit.it