PUBLISHABLE SUMMARY - LONG VERSION - M42 - OCTOBER 2013

EuroBioRef

EUROpean multilevel integrated BIOREFinery design for sustainable biomass processing

Project context and objectives

The EuroBioRef project (European Multilevel Integrated Biorefinery Design for Sustainable Biomass Processing; www.eurobioref.org) a 4 years program coordinated by CNRS, France, was launched on March 1st, 2010. It is supported by a 23 M€ grant from the European Union 7th Framework Program (FP7). EuroBioRef deals with the entire process of transformation of biomass, from non-edible crops production to final commercial products. It involves 29 partners (industry, SMEs, academics) from 15 different countries in a highly collaborative network, including crop production, biomass pre-treatment, fermentation and enzymatic processes, catalytic processes, thermochemical processes, assessed by a life cycle analysis and an economic evaluation of the value chain.

A project closely followed by the EC, with high expectations

"EuroBioRef – How a radical re-design is strengthening economic viability in the bioeconomy". *"For most people, the bioeconomy is the way of the future. A shift towards an economy based on renewable resources not on fossil fuels is no longer just an option, it's a necessity."*

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http://ec.europa.eu/research/infocentre/article_en.cfm?item=Result%20of%20search&id=/research/star/index_en.cfm?p=ss-eurobioref&calledby=infocentre&artid=25553

Executive summary (main results obtained so far)

- **5 lignocellulosic plants** (willow, giant reed, miscanthus, switchgrass, cardoon) and **10 oil crops** (castor, crambe, cuphea, lesquerella, lunaria, jatropha, safflower, as well as sunflower, camelina and rapeseed for comparison) were grown in test fields;
- **Large test fields** are set for **willow and crambe** in Poland, **giant reed and safflower** in Greece and **castor** in Madagascar**, with ultimately the production of at least 10 t for the latter;**
- **Win-win culture rotation strategies between food and non-food crops** have been developed and proven;
- **Efficient biotech technologies** have been developed to yield platform molecules from glycerol and biomass hydrolyzates, which even outperform the current state of the art;
- **A biomass supply logistics model has been developed**, which operates in an optional mode in terms of biomass quality (new and unexplored biomass types), system efficiency and reduced operational costs. It is populated with data for willow, castor, safflower and giant reed. Scenarios have been considered based on two plant capacities, namely 50 and 500 kt of dry matter/final product;
- A **brand new pilot plant in Norway able to operate more than 50 kg of dry lignocellulosic materials per hour** has been constructed, using a **new and feedstock agnostic pretreatment process** validated at the lab scale on miscanthus, giant reed and switchgrass;
- **18 patents** were filed, mostly related to vegetable oils conversions, which means that, to date, EuroBioRef reached **0.9 Patent applications per Million Euro of public money spent;**
- **13 scientific papers** were published, and more are under preparation. Then, to date, EuroBioRef reached **0.80 publications per Million Euro of public money spent**;
- **A 20 min video on the project** is available on the EuroBioRef Website (www.eurobioref.org);
- **A book 'Biorefinery: From Biomass to Chemicals and Fuels'**, Ed. by Aresta, Michele / Dibenedetto, Angela / Dumeignil, Franck, ISBN: 978-3-11-026028-1' is available (http://www.degruyter.com/view/product/177487);
- **6 value chains corresponding to 6 different scenarios of biorefineries** integrating results and concepts developed in EuroBioRef have been designed, and are being multidimensionaly assessed, to realize demonstrations of the developed technologies, but also to test scenarios of industrial exploitation.

- On 11-12 February 2014, we organize two one-day conferences in Brussels with our sister biorefinery research projects Biocore and Suprabio '**Tomorrow's Biorefineries in Europe**', notably to present our results and propose our technologies to stakeholders. More information here: https://colloque.inra.fr/eubiorefineryprojectsfinalconf.

Outline of the main future actions

In the last period, efforts will be concentrated in the demonstration of the aforementioned value chains along which the project has been reconfigurated, and to the delivery of the exploitation plans.

Summary of the work performed and main results achieved during the M36-M42 period

6 value chains have been generated at the end of 2nd reporting period and discussed during the general assembly, which further promoted communications between the partners:

Value Chain 1: Castor oil to polymers;
Value Chain 2: Crambe/Safflower oils to polymers;
Value Chain 3: Alcohols to fuels (ATF);
Value Chain 4: Lignocellulosics to acrylates;
Value Chain 5: Syngas based products;
Value Chain 6: Integrated productions in existing Assets.

Hereafter are exposed the main strategies of the aforementionned value chains (VCs):

Value Chains 1 & 2. Both value chains are dealing with vegetable oils and are, at the moment, the most advanced ones. The purpose of VC1 is to start from castor to a high value monomer with some co-products being used as fuel. VC 2 starts with oleaginous crops (Crambe, Safflower) producing high value monomers and short fatty acids, suitable for fuel application once esterified. VC1 and VC2 have several steps in common; beside the market for end products, several transformation steps are in common. Both VCs have the possibility to start from castor, crambe and safflower. Further, a route was, *e.g.*, proposed to the Castor Oil (VC1) and combines it with the chemistry of VC2 to deliver monomers even more interesting than those initially planed in VC2.Thus, as aforementioned, due to similarities and to common outputs, these Value Chains have been merged.

Potential locations for non-edible crops new cultures in Europe.


Higher alcohols production unit.

Value Chain 3 & 5: Fuels and syngas derived products. These Value chains relate to the production of “ATF” used for aviation fuels (VC3) and to the conversion of black liquor to syngas-derived products (VC5) including alcohols. Then, VC3 is closely related with VC5 as both share the same route of syngas production *via* gasification and its consecutive conversion to alcohols. However, while VC3 considers the production of heavy alcohols/branched paraffins *via* chemistry to be blended as components of aviation gasoline and jet fuel, in VC5, two main routes are considered for the production of alcohols, the first one *via* syngas production and alcohol synthesis and the second one *via* fermentation of sugars hydrolysates with butanol as a platform molecule. The progress done so far in this VCs is satisfactory although they remain challenging. In the last period the efforts will be intensified in order to complete techno-economic analysis, business plans, bench mark with competition and LCA analysis.


Castor processing unit.


Pilot for chemical reactions.


Jet A1 test engine.

Value Chain 4: Biobased acrylates. This Value chain deals with conversion of lignocellulosic crops to hydrolysates, fermentation to 3-hydroxypropionic acid, then dehydration to acrylic acid, and in parallel fermentation of sugar hydrolysates and glycerol to *n*-butanol, to finish with an esterification in reactive distillation to produce butyl acrylate. Due to lack in technological maturity / economical viability, it has been decided to drop the demonstration of this value chain and to redistribute some useful competencies in the other value chains.

Willow chips loading.

Value Chain 6: Integration of EuroBioRef technologies in existing assets. VC6 offers a framework to consider EuroBioRef chemistries and technologies as additions to existing, preferably European plants. Several such “co-location” scenarios have been proposed as modifications of VCs 1 to 4, VC5 being a co-location model by itself. On the other hand, 11 co-location models have been identified for EuroBioRef conversions, which are not studied in any of the other VCs. The work is re-focusing on the most promising value chains. With the addition of the 2 products coming from VC4, Value chain 6 seeks to demonstrate in which cases it makes sense to add a biobased production in an existing asset (plant) and capitalize on skilled personnel, available infrastructure, and plant integration. In this case, the Integrated Biorefinery is looking at the integration of a biobased product in a fossil (or bio) existing asset.

Lignocellulosics fractionation unit.

Expected final results, intentions for use and impact

Business results are expected on:

- Demonstration of the economic and technical performance of biobased products including bio-aviation fuels and chemicals;
- Demonstration of the increase in economical performance due to use of second-generation feedstock by using the whole plant in a zero waste concept;
- Demonstration of the sustainable value chain of non-food crops cultivated in synergy with food-crops, through rotation strategies that will benefit to both food and non-food crops yields;
- Definition of final products specifications and tests of new products to be able to propose them directly to customers.

Scientific innovations are focused on:

- Methods for conceptual process design widely applied in the chemical sector towards bio-/chemical applications;
- Heterogeneous, homogeneous and enzymatic catalytic systems including fermentation and optimization of the formulations taking into account the purity of the feedstock;
- New low energy separation techniques and adaptation to biomass-derived products, which will enable lowering of the overall cost;
- New reactor technologies for minimizing production of by-products while enabling substantial energy savings;
- Co-products reutilization technologies in order to further increase attractivity of the process;
- Integrated reaction/separation technologies for optimized process design;
- Development of new purification technologies of fermentation broth using green solvents, which will further improve the overall sustainability extent.

Technical advancements are expected on:

- Crop rotations optimization for Northern/Southern Europe and Africa, selection of appropriate sustainable biomass feedstock for diverse EU environments;
- Rationalization of the chain elaborated to yield each product and global integration/optimization of the whole process;
- Quality control of a variety of feedstock for a variety of end-products to set high level standards;
- Demonstration at the lab/bench scale of sub-units and demonstration at the pilot scale of integrated chains for significant products;
- Integration of several reaction and separation steps for high selectivity and conversion, energy and Capital (CAPEX) reduction.

Sustainability assessment and performances

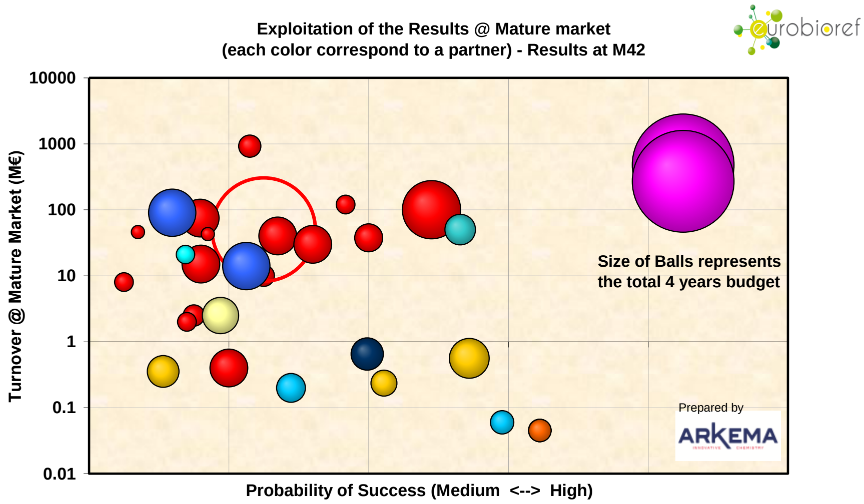
- Specific logistic methodology for cultures in Northern and Southern Europe;
- LCA methodology for evaluation of environmental performances;
- Economic modelling for assessment of economic viability;
- Sustainable assessment of the whole chain for economics.

Socio-economic impact and societal implications of the project

- Creation of specialized jobs in rural areas;
- Developing business/side businesses in local economies;
- It is estimated that 200,000 jobs could be created by the 4 EU initiatives.

Preparation of the Exploitation Plan of the project (Figure below)

EuroBioRef is preparing its exploitation plan taking into account sales from each partner in 2017 and at mature market, and self-assessing a probability of success. The workplan is adjusted accordingly in order to increase the chances to reach the market and to cross the "Valley of Death".



Currently expected turnover at mature market as a function of the probability of success assessed M42.

EuroBioRef Consortium

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Partners

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2. ARKEMA FRANCE SA /CECA, France – jean-luc.dubois@arkema.com
3. BORREGAARD Industries. Ltd., Norway
4. NOVOZYMES A/S, Denmark
5. *Partner 5 left the project without contributing and was replaced by partners 29 and 30 below*
6. CRES, Center for Renewable Energy Sources, Greece
7. HALDOR TOPSØE A/S, Denmark
8. CERTH, Centre for Research & Technology Hellas, Greece
9. PDC, Process Design Center BV, Germany
10. QUANTIS, Switzerland
11. EUBIA, European Biomass Industry Association, Belgium
12. DTI, Danish Technological Institute, Centre for Renewable Energy and Transport, Denmark
13. Technische Universität Dortmund, Germany
14. MERCK KGaA, Germany
15. FEUP Faculdade de Engenharia da Universidade do Porto, Portugal
16. RWTH Aachen, Germany – *retired from the project on 31/08/2011*
17. CIRCC, University of Bari, Italy
18. WSK "PZL-Rzeszow" S.A, Poland
19. OBRPR, Ośrodek Badawczo-Rozwojowy Przemysłu Rafineryjnego Spółka Akcyjna, Poland
20. SINTEF Materials and Chemistry, Norway
21. SOABE, Société Agricole de Befandriana-Sud & Partners Sarl, Madagascar
22. UMICORE, AG & Co KG, Germany
23. Nykomb Synergetics AB, Sweden
24. Alma Consulting Group SAS, France
25. Orgachim JSC, Bulgaria
26. Imperial College of Science, United Kingdom
27. Novance, France
28. University of Warmia and Mazury in Olsztyn, Poland
29. Technische Universität Hamburg – Hamburg, Germany – *entered the project from M24*
29. Technische Universität Hamburg – Hamburg, Germany – *entered the project from M24*
30. BKW Biokraftwerke Fürstenwalde GmbH, Germany – *entered the project from M24*

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