EUROBIOREF PUBLISHABLE SUMMARY (LONG VERSION) – 18M – September 2011

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 28 partners (industry, SMEs, academics) from 14 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.

"The concept of this project is based on several principles that must be included in the new integrated and flexible biorefinery that bridges the gap between the agriculture and the chemical industries by providing a stream for a variety of biomass feedstock and producing a menu of finished green chemical products adapted to the future sustainable bio-economy-based European society."

Summary of the work performed and main results achieved during the first 18 Months of the project

The following is a summary of the already disclosed main results obtained during the first 18 Months of the project, *i.e.*, during the period from March 2010 to September 2011.

In this period, we grew various non-edible crops in field tests, while encountering some issues in accessing seeds for cultivating some of them. The project thus started seeking for seed providers, with also the aim of diversifying the potential crop candidates. The project is especially developing a strategy for culture rotations and combinations in order to find synergies between edible and non-edible crops. Furthermore, we investigate ways of creating additional revenues for farming communities generated from new business, to increase local development and sustainability of the production. In addition, the growing of low-input (water, fertilizers, pesticides…) perennial crops and woody species was also started for supplying the conversion units with lignocellulosic material. These latter can now be very efficiently pretreated, as the consortium developed an efficient and versatile fractionation technology at the lab scale. The first vegetal oils extractions were performed from castor, jatropha and lunaria. Further, one of the original aspects of this project is to value a strong integration of the thermochemical, chemical/catalytic and biochemical processes, which work in synergy for transforming the whole crop. In this respect, several products were synthesized based on research on catalytic processes, and the first samples were tested for formulating aviation fuels and high value applications, such as chemicals and polymers. For evaluating the sustainability of the developed solutions, we started the development of some specific tools for life cycle assessment taking into account harmonisation efforts with major sister projects in the EU. As another strong point, this assessment is not restricted to the carbon footprint, but also integrates the socio-environmental and economic impact assessments. EuroBioRef is also developping a strong power of dissemination and education. The first EuroBioRef Summer School "*The concept of biorefinery comes into operation"*, aiming at the effective training of young researchers from academia and staff from industry on the most up-to-date scientific and technological aspects of biorefineries, took place on the 18-24th September 2011, in Castro-Apulia in Italy, with the edition of a textbook planned in Feb. 2012.

Outline of the new results obtained in the March-August 2011 period

The above-described actions were pursued during the last six months period, and in the followings are given the main new achievements, in the continuity and on top of those reported for the first 18

months of the project.

As a very strategic point, it has been decided after extensive analysis that EuroBioRef biorefineries should definitely be chemicals/materials-driven, meaning that the best part of the crops are being used to make high value chemicals and products, and that the residues are being used to produce energy, either consumed on-site or being exported under various forms. This is a rethinking of commonly admitted biorefineries concepts that are strongly biofuels-driven.

In the various test fields in Poland, Greece (example in Fig. 1) and Madagascar, lignocellulosic plants (willow, giant reed, miscanthus, switchgrass, cardoon) and oil crops (castor, crambe, safflower, lunaria, jatropha, as well as sunflower and rapeseed for comparison) are grown according to smart rotation strategies, and most of them have already harvested for feasibility evaluations and, when relevant, for further downstream applications in the biorefinery. The skeleton for the logistics model for these raw materials has been developed, and a first version of the model was tested and is being refined to be able to handle multiple feedstock/multiple product situations.

Fig. 1. Field trials for oil crops in Greece, July 2011.

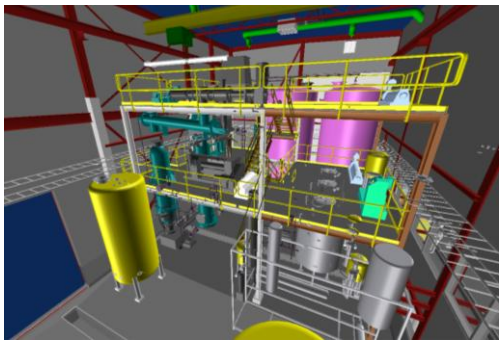

Fig. 2. Model of the lignocellulosics fractionation pilot plant planned in Norway.

Three different kinds of lignocellulosic materials (miscanthus, giant reed and switchgrass) were successfully tested in a new pretreatment process, showing its remarkable versatility. This motivated the construction of a brand new pilot plant in Norway (Fig. 2) that will be able to operate 50 kg of dry lignocellulosic materials per hour from Q2 2012. Concerning oil plants, economical issues were identified with jatropha, of which the cultivation by farmers seems not sufficiently attractive, unless a cooperative model could be established, in wich farmers would bring their production of jatropha seeds or extraction and paid on the basis of the oil market. Its interest, however, relies in its possible use as hence for crop protection against stray cattle, wind and for limiting erosion. In addition to the extraction and characterization of various oils, fatty acids were produced by saponification of Lunaria oil and a study on enzymatic splitting of triglycerides was initiated, in order to obtain fatty compounds suitable for downstream processing. In this respect, 3 patents were filled in on metathesis technologies, and 2 on oxidative cleavage. Further, we highlighted that bi-functional molecules can be efficiently obtained, which opens interesting perspective for our products to reach the monomers market.

Fig. 3. Gasification unit in Greece.

Upgrading of the solid co-products issued from primary transformation of biomass is also being evaluated, for example by gasification, in specifically designed/constructed units (Fig. 3). Further, a short list of the most relevant jet fuel properties has been prepared and the testing schedule has been fixed. Viscosity and density properties of firstly received samples were evaluated. Various options for modification of test stand fuel supply system were analyzed and the most suitable version was chosen. The test combustion chamber was prepared for investigation of bio-aviation blending/combustion performances, and is now ready.

All the results obtained so far by the partners dealing with (bio)chemical transformations are continuously and methodically gathered, sorted and analyzed through conceptual process design, which enables selecting *a priori* the most viable options. This enables time-saving in technology development by discarding non-optimal options and retaining the most promising ones at their very early stage of development.

An interactive LCA database, which combines a user-friendly interface (for non-specialists) with a rigorous LCA approach, has been partially developed and tested. In parallel, and as a complementary assessment tool, a basic framework for biorefinery costs modelling has been developed, which will

enable economical viability classification of the various possible biorefineries configurations. The socio-economic assessment has included a detailed selected case study, designed to provide insights about best practice that can be transferred to the assessment of socio-economic impacts more broadly. Further, assessments of economic barriers to biorefineries have identified financial obstacles for commercialization of pilot scale technologies perceived as high risk, and funding gaps in capital financing of biorefinery projects.

At last, the aforementioned EuroBioref summer school "*The concept of biorefinery comes into operation"* was a real success, with high qualities lectures followed by young researchers from academia and staff from industry coming from various parts of the World. The conference summaries and slides will soon be available on the website and a textbook will be released in Feb. 2012.

These multilevel, multidisciplinary achievements are keystones for the further developments of the concept that will be translated to a full set of demonstrations in the next months.

Expected final results, intentions for use and impact

Business results are expected on:

- Demonstration of the economic and technical over performance of biobased products including bio-aviation fuels and chemicals commodities markets. The project will thus boost commercialisation of biobased products and propose new bio-aviation fuel blends especially for passengers transportation companies;
- Demonstration of the increase in economical performance due to use of second-generation feedstock. By using the whole plant in a zero waste concept, a cost reduction of the final products is expected;
- Demonstration of the sustainable value chain of non-food crops cultivated in synergy with food-crops. The project proposes cultures rotation strategies that will benefit to both food and non-food crops yields, thus strongly limiting or even suppressing unethical competition between them;
- 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. This will increase knowledge in the field and it will be possible to further adapt the developed methodologies to other reactions;
- Heterogeneous, homogeneous and enzymatic catalytic systems including fermentation and optimization of the formulations taking into account the purity of the feedstock. New catalytic reactions. This is a main core innovation that will enable the development of biorefineries by efficiently enabling chemical transformations, while proposing families of catalysts that are specifically adapted to biomass & biomass-derived products specificities;
- 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. This will have a strong impact on the EU agricultural background/landscape/practice and rentability;
- Rationalization of the chain elaborated to yield each product and global integration/optimization of the whole process including logistics and up-front life cycle analysis for selection of economically sustainable products and process routes;
- Quality control of a variety of feedstock for a variety of end-products to set high level standards;
- Elaboration of multidisciplinary processes combining heterogeneous/homogeneous catalysis with enzymatic catalysis, which will impact on the way of thinking further developments of

biorefinery processes, by giving evidences of the benefits of such interweaving;
- Demonstration at the lab/bench scale of the sub-units described in the project and demonstration at the pilot scale of integrated production chains for significant products. Some demo will be also done at the industrial level. This will also give a concrete evidence and then promote further deployment of the technologies;
- Integration of several reaction and separation steps for high selectivity and conversion, energy and investment costs savings.

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.

This assessment is crucial, and a strong collaborative harmonization effort between the aforementioned 4 sister projects (EuroBioRef + Biocore + Suprabio + Starcolibri) in the EU will enable selection and definition of common criteria to be able to directly and reliably compare between competing processes/technologies.

Socio-economic impact and societal implications of the project

- Creation of specialized jobs in rural areas, where usually the scope of the available jobs is limited to more manual and non technological ones;
- Developping business/side businesses in local economies;
- It is estimated that 200,000 jobs could be created by the 4 EU initiatives.

EuroBioRef Consortium

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3. BORREGAARD Industries. Ltd., Norway
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5. METabolic Explorer S.A., France
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10. QUANTIS, Switzerland
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