SUPRABIO Newsletter – Issue 2 – January 2012

suprabio

innovative bio solutions

Sustainable products from economic processing of biomass in highly integrated biorefineries

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SEVENTH FRAMEWORK PROGRAMME

Editorial

Lesley Hanna, SUPRABIO project manager, wishes you a warm welcome to the 2nd SUPRABIO newsletter!

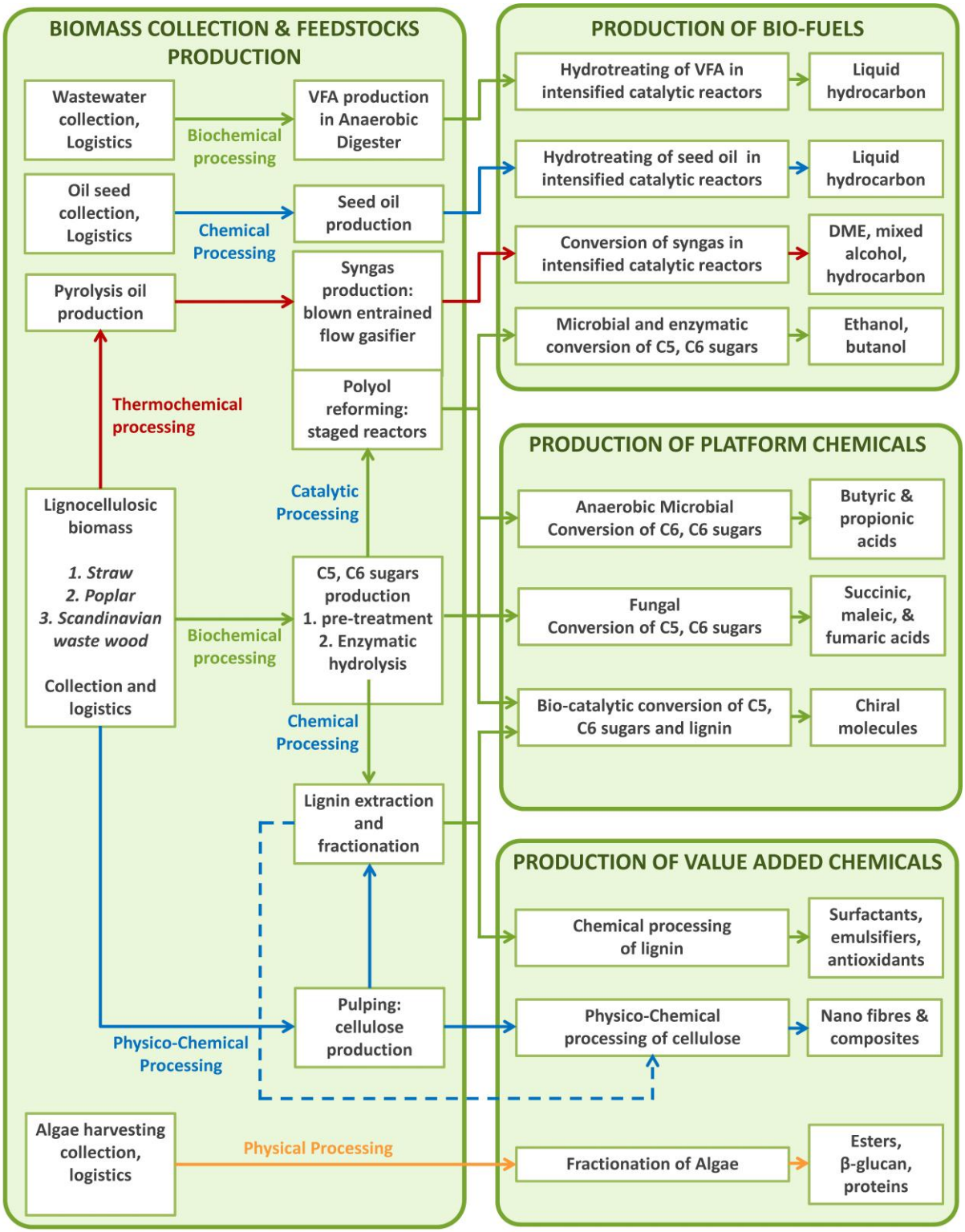
SUPRABIO is a €20M project, funded by the European Commission and aimed at finding improved methods of producing fuels, chemicals and materials from biomass. The consortium of 16 partners from 8 European countries is committed to making biorefineries a realistic proposition within Europe; reducing our dependence on fossil fuels for transport and energy by moving towards the use of biomass feedstocks to produce the products we need.

Within the project we are achieving that aim by working on a number of fronts with the aim of producing a toolkit of processes which can be used in a variety of applications. The team utilises a range of biomass sources (lignocellulose, algae, waste and seed oil) and convert those to useful products using various routes (chemical, microbial, fungal and enzymatic) looking to optimise the conversion at every stage and prove that success with practical demonstrations. SUPRABIO also concentrates on an integrated and sustainable approach including waste management within the biorefinery, with a firm undertaking to look at sustainability along the entire value chain. The rest of this newsletter tells of our progress as we reach the halfway point of the four-year project.

This year has seen the coordination and management of the project change from the University of Oxford to Brunel University, London. This change was prompted by the move of the Coordinator, Prof. Ashok K. Bhattacharya, from Oxford to Brunel. As a result the personnel within the project have remained largely unchanged, although the project does now have a new project manager to assist the partners with the administration of the project and it is in that capacity I have been invited to write this editorial. I am delighted to have been invited to join the team of this exciting and challenging research project and hope to play my part in its continuing success.

Brunel University, London is a dynamic institution with nearly 15,000 students and 1,660 academic and related staff operating in a vibrant culture of research excellence. Brunel University comprises of 8 academic schools and 7 specialist Research Institutes, conducting research ranging from social sciences to engineering to health and social care. Brunel University is now recognised as a major force in the UK higher education scene. The University maintains close links with industry in teaching, research and technology transfer. It has a turnover of about 80 million pounds from teaching and research funding.

Overview of the SUPRABIO project



Biorefinery Feedstock Production

Mads Pedersen, Biogasol ApS

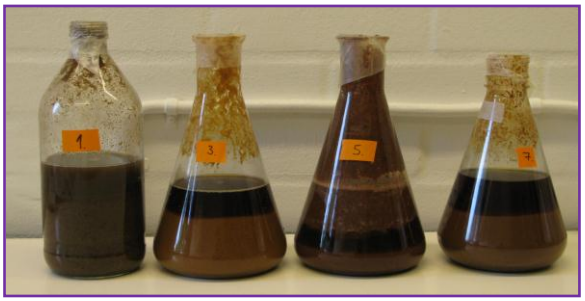
The first task involves production, collection, pre-treatment and conditioning of biomass feedstocks to produce intermediates for subsequent processing in the biorefinery processes. Solid biomass types to be used in the project include wheat straw and poplar. Both biomasses are of lignocellulosic structure (i.e. mainly consisting of cellulose, hemicellulose and lignin), but the amount of each biomass constituent varies between the two. The ability to utilize both substrates (a grass biomass and a woody biomass) will demonstrate the feedstock flexibility of the technology and will increase the geographical area in which the technology can be deployed whilst decreasing the radius from which biomass needs to be sourced.

Wheat straw is the main lignocellulosic substrate for biorefinery. Wheat straw consists of 31-39 % cellulose, 22-24 % hemicellulose and 16-25 % lignin depending on species and conditions.

In 2011 the wheat straw pre-treatment process was fully optimized, to be able to tailor the treatment for production of various bio products. From the data obtained, the optimal pre-treatment parameters for a given product distribution specification can now be found, saving time and money when client specifications have to be met. Next, the conditions for poplar are to be handled in a similar manner.

The monosaccharides derived from the cellulosic and hemicellulosic parts of the biomass will be mainly used for fermentation into valuable products, elsewhere in the project. The cellulose fraction will be subjected to enzymatic hydrolysis prior to further processing. The lignin fraction was extracted, yielding the first batch of SUPRABIO lignin. Optimal conditions for extraction and the purity have been studied and determined. The SUPRABIO lignin will be used to produce valued added chemicals.

Within algae production, the photosynthetic activity of various algae strains was studied, and scaling up of the algae production process was started. The cost reduction potential was assessed and it was found that there is a significant economic benefit using biorefinery waste for microalgae production.



Samples of pretreated wheat straw. The biomass changes visually but also chemically with different pretreatment conditions. The optimal pretreatment conditions depend on the end product.

Concerning the thermo-chemical conversion pathway, the construction of the pyrolysis oil feeding and pressurized gasification facilities was continued, and testing of these facilities was started.

To conclude, the full utilisation of all biomass types to be fed to the biorefinery is on track.

Production of advanced biofuels

Costa Komodromos, Brunel University

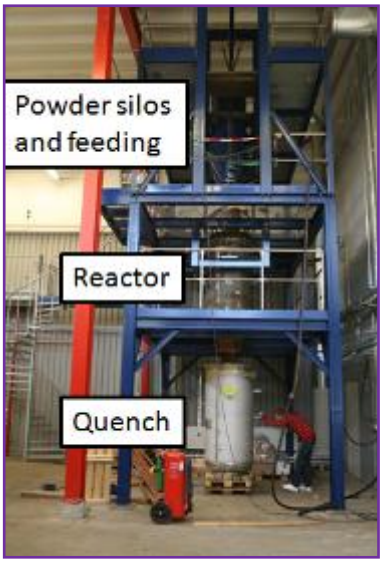
The production of biofuels from lignocellulosic feedstocks, specifically crop and forest residues and non-food energy crops, is a core part of the project. The approach taken is to research both biochemical and thermochemical routes.

In the **biochemical route**, the main emphasis is to develop improved, higher efficiency ethanol fermentation process routes by combining the hydrolysis and fermentation stages. Simultaneous saccharification and fermentation (SSF) refers to the process of releasing of sugars from lignocellulose while simultaneously fermenting the released sugars into ethanol. The primary advantages of combining hydrolysis and fermentation are:

- Reduced end product inhibition of released sugars acting on hydrolyzing enzymes
- Reduced investment costs.

The main achievement has been to develop a fully scalable reactor system, which has been tested in different sizes. It is currently being tested in 100L scale. In addition to the ethanol platform, research has been in progress on developing new strains for fermenting sugars to 2,3-butanediol (BDO), which can subsequently be converted to n-butanol via dehydration to methyl ethyl ketone. Developing high specificity strains to obtain high yields of 2,3 BDO is technically challenging.

In the **thermochemical route**, different biomass feedstocks are converted to a more uniform energy carrier, pyrolysis oil, which is then gasified with oxygen in a high pressure entrained flow gasifier to produce a synthesis gas (syngas, a mixture of carbon monoxide and hydrogen), a basic chemical platform for the chemical industry. From syngas a wide range of biofuels can be obtained catalytically either by Fischer-Tropsh synthesis to produce synthetic diesel or aviation fuel, or via conversion of syngas to mixed alcohols, to dimethyl ether (DME).



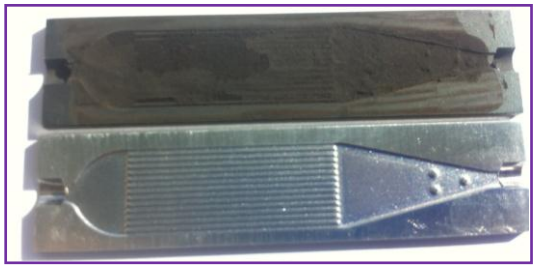
The entrained flow gasifier

For DME production, considerable development is in progress on developing catalytic processes for direct production of DME from syngas, as opposed to the conventional 2-stage route via methanol. This requires engineered catalyst formulations, and advanced formulations were developed that are showing very promising results.

Further research focuses on improved processes for converting imported plant seed oils such as Jatropha and rapeseed, as well as algae oils, into green diesel. This involves hydrogenation of the oils (akin to hydrotreating in petroleum refineries) over suitable catalyst, a reaction which can release considerable heat in the reactor and this can limit the conversion. Temperature control is vital to achieving good yields of the desired products.

In addition to these feedstocks and processes, SUPRABIO utilises a valuable by-product from sewage sludge, volatile fatty acids (VFA). These are intermediates in the anaerobic digestion processes used to the waste water industry, and when concentrated and recovered, can be hydrogenated to hydrocarbon fuels.

In all these catalytic reactions, the rapid diffusion of reactants and products to and from the catalyst surface, and the removal of reaction heat, are critical requirements in order to "intensify" processes, that is, to downsize plant and to improve yields per pass. Normally, when catalytic processes are downsized it leads to increased process costs due to loss of economy of scale. The approach adopted in SUPRABIO is to combine novel reactor designs whose internal surfaces consist of very thin metal plates coated with thin layers of nanocrystalline catalysts, which simultaneously improves mass transfer of reactants and products and allows for rapid dispersal of reaction heat.



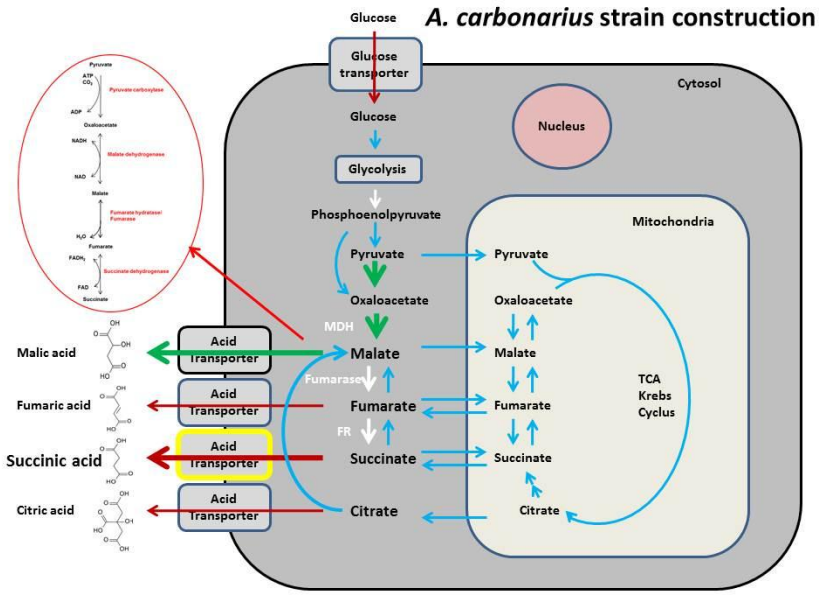
Catalytic reactor plate

These novel microstructured reactors are fully modular so that they can be scaled up simply by inserting more plate assemblies. The reactor construction also allows for cooling fluids to be circulated throughout the catalytic plates to remove reaction heat rapidly. These catalytic reactors enable us to downsize processes and at the same time reduce capital costs.

Production of platform chemicals

Mette Lübeck, University of Aalborg

During the first year of research, a filamentous fungus, Aspergillus carbonarius, was selected for production of carbon 1.4-diacids which are valuable as platform chemicals. A protocol for genetic manipulation of the A. carbonarius strain in order to construct strains with enhanced production of the carbon 1.4- diacids was developed. In the second year, this system was used to introduce three different genes involved in 1.4 diacid production in the strain with the aim of elevate the natural production. The resulting genetic modified strains harbour either 1, 2 or all 3 of these genes, and at present the strains are being tested for elevated acid production. In addition, the wildtype strain was tested for growth in pre-treated biomass delivered from the project partner Biogasol. The pre-treated biomass contains a mix of both C5 and C6 sugars and our strain are able to utilize both types of sugars. The results showed that the strain could grow in 25 % of the biomass but was inhibited in higher concentrations. The wildtype strain is currently tested for tolerance to different concentrations of the 1.4-diacids and can tolerate more than 4% (40 g/l) of each of the acids, without any growth inhibition.



Aspergillus carbonarius strain construction

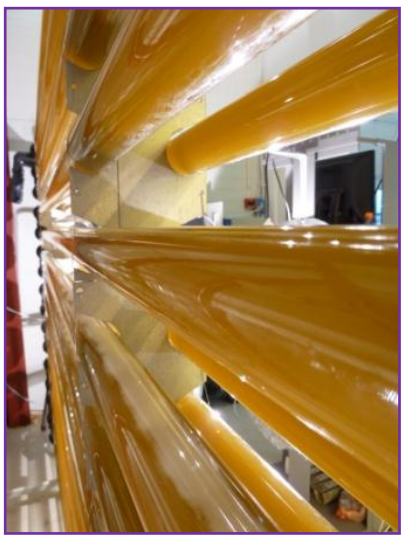
Production of high value-added chemicals

Majvi Brandbu, Borregaard Industries Ltd

Nanocellulose in PP/PE: Based on promising results from explorative small-scale trials, conducted in the first 12 months, Borregaard has done further investigation. Trials were scaled up, allowing production of sufficient amounts for mechanical testing. Processing nanofibre-PP/PE (Polypropylene / Polyethylene) mixtures was successful and without clogging or problems occurring during feeding, melt extruding and injection moulding. In parallel, pre-treated pulp from Biogasol was purified to be used as raw material for nanofibre production. The results showed that a sufficiently pure cellulose pulp could be obtained by cooking and bleaching at certain conditions. The metal analysis on the pulp showed a relatively high content of silicates which can be problematic for nanofibre production. The mechanical tests showed improvements, but at a significantly lower level than expected. In addition, price levels on existing and competing products are of far lower value than expected. With the price level of microfibrillated cellulose (MFC) after compound cost breakdown, we see no potential for further development of MFC in PP/PE. This forces a change of action; Borregaard will investigate dispersion and potential of nanofibres in less hydrophobic matrices which will still give high added value products.

Centrifuged algae biomass

The objective of Algaetech Industries AS is to develop, together with its partner GAVITA AS, an efficient use of electrical energy in terms of artificial light for irradiating microalgae culture for maximizing productivity. Suitable methods have been developed and tested in laboratory to measure the influence of different light intensities and spectral qualities on photosynthetic yield. Preliminary results in larger scale are achieved. Selection of the most suitable light qualities for growing individual algal species targeted in the project will continue as well as finding the optimal combination of light intensity and cell density to obtain highest productivity per photo bioreactor (PBR) volume. Results acquired through small scale experiments will be tested in and verified in 150 and 1000 litre PBR. Selected species of microalgae have been cultivated, and the content of total carbohydrates and β-glucan have been analysed for algae grown in exponentially growth phase and stationary phase. Harvested biomass samples from cultivation experiments have been sent to Algaetech sub-contractor Møreforsking for lipid analyses. Testing of different extraction methods for β-glucan from microalgae showed no difference between uses of sulphuric acid and distilled water.



Photobioreactor (PBR)

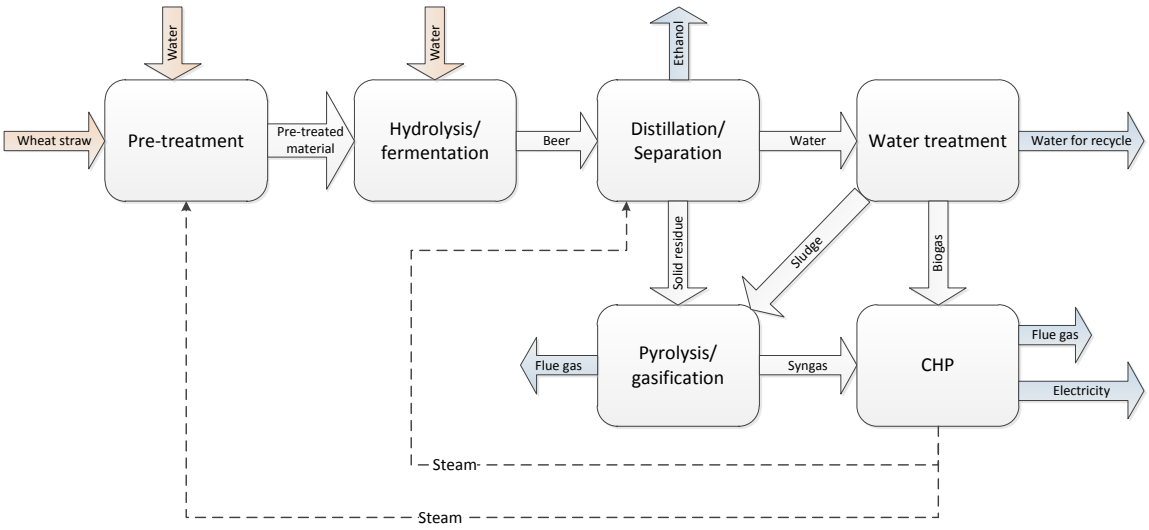
Process integration

Per Nygård, Statoil ASA

The integration assessment is focused on the two principally different biorefinery concepts: Biochemical and Thermochemical. The sizes studied has been revised and set to 40,000 and 400,000 tonnes dry biomass/year for the biochemical concept, while for the thermochemical concept it has been set to 200,000 and 400,000 tonnes dry biomass/year. For both concepts the small is for an early implementation in 2015, while the larger is for a more integrated configuration in 2025. The main end-products are fuels, but in the integrated configuration a few value added products are also considered. In particular for the biochemical biorefinery concept several of the processes are immature and a major focus has been to validate and establish process data for all necessary processing steps. High quality data is important for reliable evaluation of the biorefinery concepts.

To achieve a biorefinery concept with the highest efficiency and lowest costs an important goal is to optimise materials and energy flows for the overall biorefinery. Integration can potentially be done between processes, but more importantly within one process route by utilising waste material to generate the heat and electricity required to operate the biorefinery. A simulation of the water and heat flow through a process from wheat straw to ethanol was carried out using a preliminary heat and mass balance model. The preliminary results suggest that by employing an effective water and energy management strategy, water and heat consumption in the biorefinery could be significantly reduced.

To enable more comprehensive process and integration evaluations detailed models will be developed in Aspen Plus. Models based on preliminary data have been developed for the main routes to fuel, both for the biochemical and the thermochemical concepts. A schematic overview of the ethanol concept is shown in the figure below. The coming year the models will be updated with more accurate process data. The models and the achieved results will be actively used to provide feedback to the development of process technologies regarding e.g. optimum operational conditions.



The wheat straw - to - ethanol concept

Pilot scale process demonstration and integration

Mads Pedersen, Biogasol ApS

SUPRABIO includes three industrial pilot scale demonstrations, for the production of ethanol or 2,3-butanediol, cellulose nanofibre, algae and derivatives. Work on these pilot scale demonstrations has now started, based on the results of the work described above.

With regard to the production of nanocellulose fibres, a pre-treatment unit was installed and a fibrillation unit is under construction. Pretreatment of wheat straw was scaled up and is being demonstrated in a 1 t/hr pilot plant. This unit is being optimized for the production of pre-treated biomass to serve as biorefinery feedstock. In SUPRABIO ethanol/butanol production by saccharification of cellulose simultaneously with fermentation of the outcome as well as fermentation of the hemicellulose constituents is being aimed at.

The cultivation of algae and their production condition are to be studied over a full year for monitoring any variations due to seasonal and climate changes.

Preparing to scale up the hydrolysis and fermentation at BioGasol (Balleup, Denmark).

Sustainability assessment

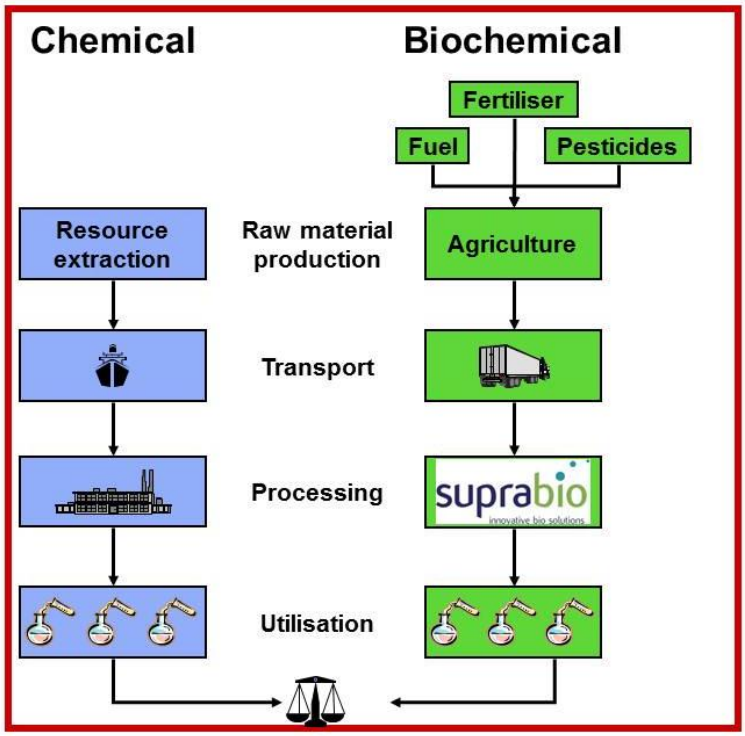
Nils Rettenmaier, Instititut für Energie- und Umweltforschung Heidelberg

In the context of biomass use for bioenergy and -to a lesser extent- bio-based products, sustainability and sustainability criteria are on everyone's lips. In order to ensure that the proposed biorefinery concepts are environmentally friendly, socially acceptable and economically viable, the SUPRABIO project comprises an ex-ante sustainability assessment of all investigated bio-based products. The objective is to provide a multi-criteria evaluation of the sustainability of the entire value chain by taking into account technological, environmental, economic, social, political and institutional aspects.

In 2011 considerable progress was made. After a fruitful internal workshop, held in March 2011, all definitions, settings and system descriptions were finalized and compiled in a report. This report forms the basis for all subsequent detailed analyses and ensures a coherent evaluation throughout the project. The main effort was dedicated to two additional reports, completed in October 2011: 1) an interim report on technological assessment and 2) an interim report on the proposed methodologies for the individual elements of the sustainability assessment:

- life cycle assessment (LCA)
- elements of environmental impact assessment (EIA)
- process economic assessment
- market analysis
- social and political assessment

Due to the requested harmonisation of sustainability assessment between SUPRABIO and its sister projects BIOCORE and EUROBIOREF, as requested by the Commission (see below), some fine-tuning of the methodologies may be necessary. In 2012, partners will focus on data acquisition, an interim SWOT analysis and further methodological development in terms of the final integrated assessment.



System boundaries

Inter-project working group 'Sustainability'

Nils Rettenmaier, Instititut für Energie- und Umweltforschung Heidelberg

In order to ensure that the sustainability assessment is done based on a common ground, the EC has requested that an effort be made towards harmonisation across the three FP7-funded biorefinery projects BIOCORE, EUROBIOREF and SUPRABIO. The three sister projects all cover a multi-criteria evaluation of the three dimensions of sustainability (environment, economy and society) using the same or similar assessment techniques. In June 2010, IFEU took the lead of the newly formed inter-project working group, which aims at harmonizing assessment techniques, methodologies and common input data (e.g. on emissions or prices of commodities) across the three projects. In 2011 an intensive exchange of information including deliverables and draft methodological reports took place, culminating in a physical meeting in October 2011. At this meeting, the proposed methodologies for the three dimensions of sustainability were discussed and sub-groups were formed which will finalize the harmonisation activities in early 2012.

News from biorefinery sister projects

The **Star-COLIBRI** project (Strategic Research Targets for 2020 – Collaboration Initiative on Biorefineries) ended in October 2011 with the organisation of a high-level policy maker conference on biorefineries, held at the prestigious Solvay Library in Brussels. This conference brought together a panel of high-level speakers to discuss key policy priorities in the field of biorefinery, from the upcoming bio-economy strategy to the flagship initiative on a resource-efficient Europe. One of the highlights of the Star-Colibri event was the official publication of the Joint European Biorefinery Vision for 2030 and the European Biorefinery Joint Strategic Research Roadmap for 2020.

The **BIOCORE** project (Biocommodity refinery) organised a biorefining summer school in the Paris region, covering both information on the fundamental principles and technologies of biorefining and in-depth training modules. The videos of the training modules are available at www.biocore-europe.org.

Another BIOCORE milestone was the pilot scale production of second-generation (2G) bio-ethanol from wheat straw, in collaboration between CIMV S.A. (France) and DSM Bio-based Products & Services B.V. (The Netherlands). CIMV first converted wheat straw into cellulose, hemicellulose using its pilot facility in Pomacle (Marne, France) and supplied DSM with refined cellulose. Using proprietary thermostable enzymes, DSM (Delft, The Netherlands) converted the cellulose into glucose, which was then used as feedstock for fermentation converting the glucose into bio-ethanol. In a final step, Arkema S.A. will use the ethanol to produce ethylene, a precursor of PVC.

The **EUROBIOREF** project (EUROpean multilevel integrated BIOREFinery design for sustainable biomass processing) deals with the entire process of transformation of biomass from crops production to final commercial products in a chemicals/materials-driven biorefinery concept. The best part of the crops will be used to make high value chemicals and products; the residues will be used for energy applications. Some of the main results achieved to date are as follows.

Lignocellulosic plants and oil crops are grown according to rotation strategies. A logistic model has been tested and is being refined to enable handling of multiple feedstock/multiple products.

Miscanthus, giant reed and switchgrass were successfully pre-treated, and a new pilot plant in Norway (capacity 50 kg/h) is underway. Concerning oil plants, cultivation of Jatropha was found unattractive. Various oils were extracted and characterized; fatty acids were produced by saponification of Lunaria oil. A study on enzymatic splitting of triglycerides has been initiated to obtain fatty compounds.

Upgrading of the solid co-products is also being evaluated, e.g. through gasification. Further, for jet fuel application, viscosity and density properties of firstly received samples were evaluated. The test combustion is now ready for investigating bio-aviation blending/combustion performances.

Conceptual process design models, which enable selection of the most viable options at their very early stage of development, have been developed.

In addition, an interactive LCA database has been tested and a basic framework for biorefinery costs modelling has been developed. As part of socio-economic assessment a case study, highlighting best practices, was prepared and financial obstacles for commercialisation were identified. Finally, the summer school "The concept of biorefinery comes into operation" was a real success. A textbook will be released in June 2012. More information is available at www.eurobioref.org.

Selected biorefinery events

Ph.D. Courses at Aalborg University in Denmark
Copenhagen Institute of Technology, Aalborg University Copenhagen, Lautrupvang 15, 2750 Ballerup, Denmark

The Section for Sustainable Biotechnology at the Department of Biotechnology, Chemistry, and Environmental Engineering of Aalborg University is offering two one-week PhD courses in June 2012, as follows:

- Anaerobic digestion for waste treatment and renewable energy production, 4-8 June
- Biorefineries for the production of fuels, chemicals and feed, 11-15 June

For further information: Please visit www.sustainablebiotechnology.aau.dk or contact Section Secretary Stephanie REDMOND, Phone: +45 99402595, Email: srs@bio.aau.dk.

RRB8 -8th International Conference on Renewable Resources and Biorefineries
Centre de Congrès Pierre Baudis , Toulouse (France), 4-6 June 2012

RBB8 aims at bringing together academic researchers, industrial experts, policymakers and venture capital providers to discuss the challenges emerging from the transition towards a bio-based economy and to present new developments in this area. RBB7 will be organised as a twin conference with the 3rd international biorefinery conference in collaboration with DECHEMA. For more information visit www.rrbconference.com.

20th European Biomass Conference and Exhibition (EU BC&E 2012)
Milano Convention Centre, Milano, Italy, 18 - 22 June 2012

"Setting the course for a bio-based economy" is the topic of the 20th European Biomass conference and Exhibition. During the conference the following topics will be addressed: biomass resources; R&D on biomass conversion technologies for heating, electricity and chemicals; R&D on processes for solid, liquid and gaseous fuels from biomass; Industrial demonstration and business concepts; Biomass policies, markets and sustainability.
For more information and registration visit www.conference-biomass.com.

Nordic Wood Biorefinery Conference
Finlandia Hall, Helsinki, Finland, 23-25 October 2012

The 4th Nordic Wood Biorefinery Conference will present the latest ideas and developments in biorefinery separation and conversion processes as well as new bio-based products from the wood biorefinery: energy, chemicals and materials. NWBC will gather expert speakers from the chemical, energy, pulp and paper industry and the global research community. For more information, visit http://www.vtt.fi/nwbc2012.
Deadline for abstract submissions: March 31, 2012 (papers) and May 15, 2012 (posters).

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The SUPRABIO project is co-ordinated by Brunel University. In addition to their project management and coordination activities, Brunel University is mainly active in catalytic processing of polyols and syngas, nanotechnology and process integration.

An overview of the other partners and their role is the project is presented on the next page.

Brunel University
Project coordination, catalytic processing of polyols and syngas, nanotechnology and process integration.

Borregaard Industries Ltd (Borregaard)
Demonstration of nanocellulose fibres and composite production.

United Utilities Water PLC (United Utilities)
Enzymatic hydrolysis, algae and carbohydrates digestion, waste management. Digestion of biorefinery residue. Demonstration of mixed alcohol production.

Statoil ASA (Statoil)
Catalytic processing, demonstration of liquid hydrocarbon production from oils, Process integration.

BioGasol ApS (BioGasol)
Pre-treatment of biomass. Metabolic engineering of production organisms. Demonstration scale production.

BTG Biomass Technology Group BV (BTG)
Gasification of biorefinery residues for process heat, and electricity, syngas clean up and conditioning.

Institut für Mikrotechnik Mainz GmbH (IMM)
Development of microchannel, integrated catalytic reactors and mini-plants.

Institut für Energie- und Umweltforschung Heidelberg (IFEU)
Life Cycle Assessment.

Algetech Industrier AS (Algetech)
Microalgae production in photobioreactors.

Aalborg University (AAUK)
Genetic manipulation of anaerobic microbes and fungi, bioconversion C5, C6 sugars to platform chemicals.

University of Manchester (UNIMAN)
Selective enzymatic conversion of C5, C6 sugars, lignin fractions and lipids to platform pharmaceutical platform chemicals.

Institut für Umweltstudien - Weibel & Ness GmbH (IUS)
Environmental Impact Assessment Strategic Environmental Assessment and SWOT analysis.

Energy Technology Centre, Piteå (ETC)
Process optimisation for the gasification of charcoal, lignin, slurry in Entrained Flow Gasifier.

Wuppertal Institute for Climate, Environment and Energy (WI)
Sustainability, societal and legal aspects.

AlgoSource Technologies (AST)
Process optimisation for algae production.

GreenValue SA (Greenvalue)
Fractionation and extraction of lignins, healthcare products