SUPRABIO Newsletter – Issue 1 – January 2011

# suprabio

innovative bio solutions

## Sustainable products from economic processing of biomass in highly integrated Biorefineries

www.suprabio.eu

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SEVENTH FRAMEWORK PROGRAMME

# Editorial

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Welcome to the first newsletter for the SUPRABIO project, a € 20 million innovative, sustainable bio-refinery research project funded by the EU and the corporate sector. This project addresses the problems of declining fossil fuels and global warming by using renewable materials to produce fuels and chemicals. SUPRABIO will use biomass to achieve this goal. In order that the processes for the manufacture of fuels and chemicals from biomass are competitive and sustainable SUPRABIO will develop critical technologies such as efficient fractionation of lignocellulose, enhanced and selective microbial and fungal conversions, and economic distributed chemical processing using integrated, highly intensified modular reactors.

The research will focus on bio-resources such as straw, seed oil, algae and wastewater. These will be improved and converted to make products for consumers and industry e.g. healthcare products, cosmetics, pharmaceutical intermediates, biofuels, and materials such as polymers.

The main distinguishing features of the project are:

- Focusing on currently the most economic feedstocks; lignocelluloses from sustainable forestry and agricultural wastes, and organic waste streams from food industries and municipalities - being aware of the debate around the use of agricultural land for energy crops.
- Examining the potential of algae, because although currently very high cost, land use is not an issue and there is considerable potential for improving growth rates and the efficiency of $CO_2$ capture. Lipids from oilseed crops are also considered because whole crop processing from high lipid plants grown on less favourable land may have advantage.
- Adopting a whole Biorefinery approach to maximise the value obtained from a particular type of biomass by selecting the optimum mix of products (fuels, chemical intermediates, high added value chemicals, materials, energy).
- Focusing on the intensification of critical process steps to improve the economics of building and operating equipment appropriate for smaller and intermediate scale refining and distributed production.
- Concentrating on process optimisation and sophisticated integration that considers whole Biorefinery management issues. Thus optimisation of material and waste flow within the Biorefinery, water management and process energy requirements are all considered in addition to process technologies. In this manner optimum economic benefit will be coupled to optimum usage of biocarbon and minimal GHG emission.

Over a four-year period the 17-partner consortium will be undertaking research with the aim of developing sustainable and competitive bio-refinery processing schemes for a range of geographical and social conditions.

This first newsletter presents a snapshot of the progress made in the first 12 months. We trust you find the articles interesting, and would be pleased to receive your comments and feedback.

# Content



# Project overview

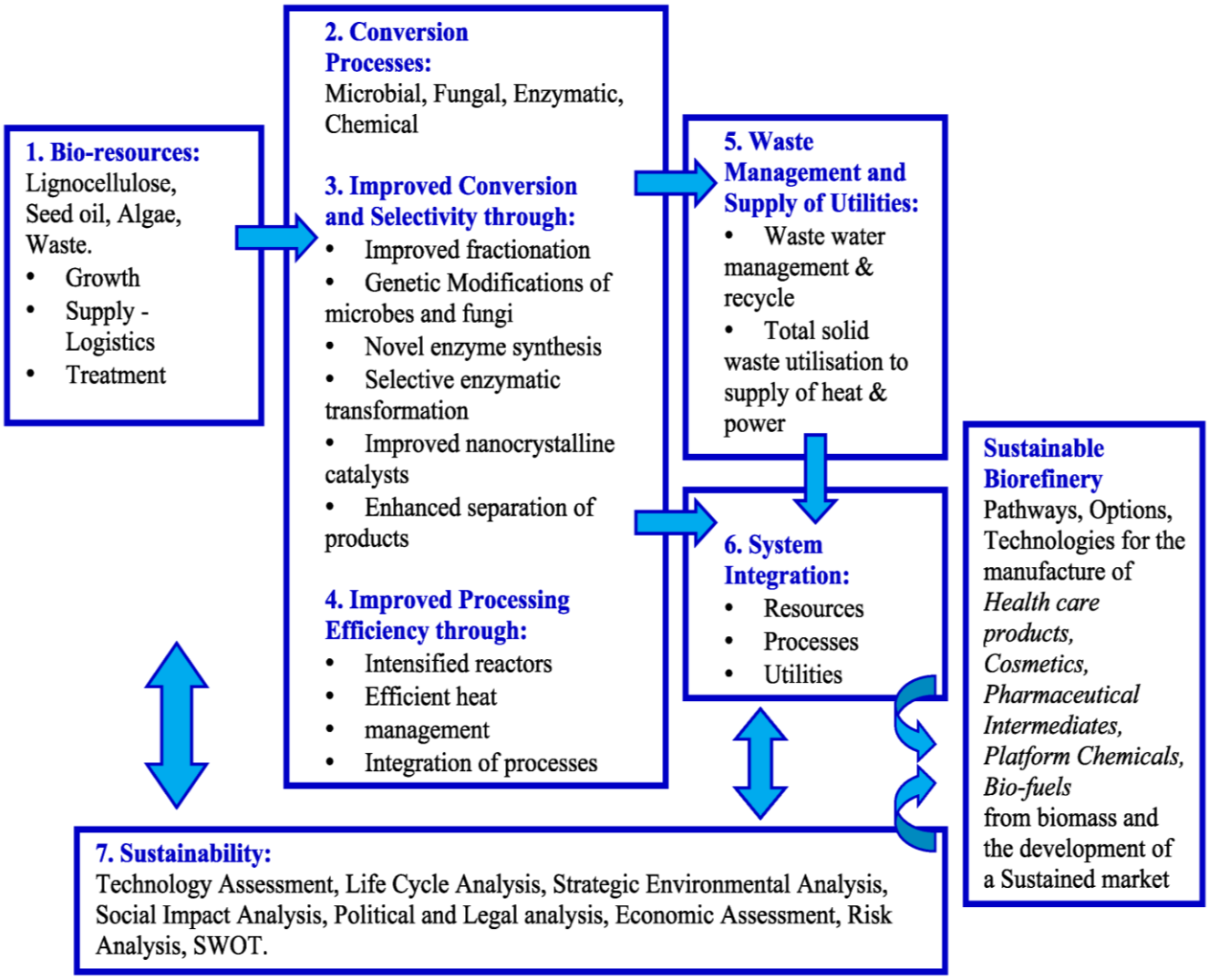
The SUPRABIO project researches, develops and demonstrates a toolkit of novel generic processes together with advanced intensification and integration methodologies that can be applied to a range of biorefinery scenarios based on sustainable biomass feedstocks.

Several feedstocks are considered in the project, including straw, seed oil, algae and wastewater. These bio-resources will be improved and converted to pharmaceutical intermediates, biofuels, healthcare products, cosmetics and nano cellulose fibre reinforced polymer composites.

Different processes will be used to convert the feedstocks into the final desired products. These processes include microbial, fungal, enzymatic and chemical processes.

Supporting economic and lifecycle assessment of the resulting gains in energy efficiency and conversion of renewable carbon, together with an implementation strategy based on a product mix with optimal value, will inform step changes that contribute to achieving a more secure and sustainable economy in Europe.

The organisation and scope of SUPRABIO is illustrated in the figure on the next page.




SUPRABIO scope and organisation

## Feedstocks pretreatment (WP1)

Refining biomass has many promising prospects depending on the substrate in use. The processing and yields also depend on the substrate. For lignocellulosic biomass (consisting of cellulose, hemicellulose and lignin) the biorefinery starts with pretreatment. This process step is crucial to opening of the structure of the biomass, leaving the biomass constituents digestible to enzymes or microorganisms.

To improve yields, the pretreatment process will be optimised to leave as much biomass as possible ready for bioconversion. So far, focus has been on optimising the pretreatment of wheat straw. This was carried out in a batch pretreatment facility, for which the optimal temperature, time and acid concentration were determined. These parameters were used as guides for pretreatment parameters in a continuous pretreatment facility able to pretreat up to 50 kg wheat straw per hour.

The further optimisation of continuous pretreatment of wheat straw for biorefinery will be based on work carried out on the pretreated biomass, e.g. for utilisation of lignin, cellulose and hemicellulose for various purposes. Thus, prior work on the extraction of lignin has been studied to assess how to obtain the optimal conditions for best possible utilisation of lignin from wheat straw.

Another road to light up within the field of biorefinery is the production of algae. Algae production is important to biorefinery due to the content of lipids, fatty acids and glucan, however, production costs are too high. To reduce costs, new facilities have been built to carry out research on various algae strains. The use of wastewater, $CO_2$, flue gases as well as nutrients will be tried to promote faster growth and thereby reduce total costs.

The quantities of biomass not utilised in other biorefinery processes, can be pyrolysed cost-efficiently to produce e.g. transportation fuels, and facilities for pyrolysis oil production will be installed. Also a gasifier is under construction for gasification of various biomass fractions (lignin, char and pyrolysis oil).

*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.*

*Continuous pretreatment facility. Operates with capacity of up to 50 kg per hour at BioGasol (Ballerup, Denmark).*

## Second-generation biofuels (WP2)

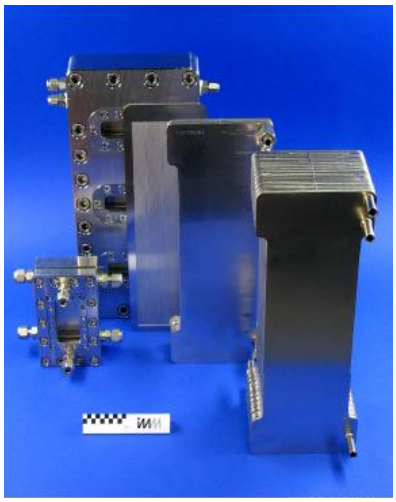
The current debate over biofuels produced from food crops has pinned a lot of hope on second-generation biofuels produced from crop and forest residues and from non-food energy crops.

The production of biofuels from lignocellulosic feedstocks can be achieved through two very different processing routes both currently at the demonstration phase:

- Biochemical — in which enzymes and other micro-organisms are used to convert cellulose and hemicellulose components of the feedstocks to sugars prior to their fermentation to produce ethanol;
- Thermo-chemical — where pyrolysis/gasification technologies produce a synthesis gas (CO + $H_2$) from which a wide range of long carbon chain biofuels, such as butanol, synthetic diesel or aviation fuel, can be reformed.

SUPRABIO is examining these methods for the production of liquid biofuels:

- Production and identification of novel efficient bacterial strains for fermentation of C5 and C6 sugars to biofuels such as ethanol and 2,3 butanediol.
- Development of catalytic processes for conversion of syngas to mixed alcohols, to dimethyl ether (DME), and for the conversion of mixed polyols to value added chemicals.
- Development of catalytically coated microchannel structured reactors (see photo) and preparation of coated catalysts for Fischer-Tropsch (F-T) synthesis to diesel-like products.
- Hydrogenation of volatile fatty acids produced from anaerobic enzymatic hydrolysis process with sewage sludge as a substrate, to hydrocarbons.



*Catalytically microchannel coated structured reactors*

Screening for more efficient bacterial producers for fermentation to bioethanol has been carried out, and a series of enrichment trials have been conducted, aimed at developing more robust strains with high in vivo tolerance to pretreated biomass. A total of four different bacterial strains capable of converting sugars from pretreated biomass have been isolated, and genetic analysis of the four isolates has been initiated. Literature screening for potential 2,3 butanediol producer candidates has been carried out and promising results have been obtained in the preliminary screening.

A review of the literature on catalytic syngas conversion to DME, F-T and mixed alcohol has been carried out. For DME, the best-published results show a yield of around 81% (conversion and selectivity of 90%) using an MgO modified HZSM-5 zeolite and $Cu/ZnO/Al_2O_3$ catalyst. Most workers operate at high pressure (30-50bar) and moderate temperature (~250$^{o}$C). The acidity of the catalyst plays an important role in syngas to DME conversion. Initial development of the microchannel reactors has been carried out and coating trials have been performed with promising results.

The production of volatile fatty acids (VFA) from sewage sludge has focused on optimisation of the fermentation parameters to achieve maximum VFA yield. Inverted Phase Fermentation, a new development from United Utilities, is a sludge thickening process based on flotation with nascent carbon dioxide and this provides more efficient process for obtaining VFA. Significant parameters include: the microbial culture employed in the fermentation; the enzyme kinetics and the biodegradability of the substrate.

## Platform chemicals & enzymatic catalysis (WP3)

*Enzymatic catalysis*

Biocatalysis involves the use of enzymes to catalyse chemical reactions. Enzymes are biological catalysts present in all living organisms. For example, enzymes present in saliva help to breakdown the food we eat. Enzymes can accelerate reactions by factors of as much as a million or more. Without them the reactions needed for life would

take place too slowly for life to exist. As well as speeding up reactions, enzymes are very specialised and they generate hardly any waste.

Enzymes can be exploited to work on chemicals they would not naturally catalyse. University of Manchester (UNIMAN) is currently investigating the production of Levodopa, a drug used to treat Parkinson's disease. The enzyme UNIMAN has selected for this purpose is used in nature to breakdown amino acids. However, UNIMAN has identified a chemical from biomass, which could be converted by this enzyme into Levodopa.

*Acid fermentation and Pilot Plant*

Currently, 7 butyric and propionic acid-producing bacterial strains are being adapted to the pretreated biomass delivered by Biogasol. Several strains are now close to the 50% benchmark (50% biomass, 50% mineral medium).

Many filamentous fungi naturally produce a wide range of organic acids including citric acid and carbon 1,4 diacids (e.g. succinic acid, malic acid and fumaric acid) and fungi as production organisms can produce specific products in very high amounts. These acids can serve as building blocks for biochemicals. A collection of fungi has been screened for their natural ability to produce organic acids, and an *Aspergillus carbonarius* strain has been selected. Testing this strain for growth in the pretreated biomass from project partner Biogasol is underway, and a protocol for genetic manipulation of the strain in order to construct strains with enhanced production of carbon 1,4 diacids has been developed.

*A 20 litre pilot plant is expected to be ready for experiments with microbial cultures in spring 2011.*

*The plant includes a stainless steel fermentor with a computerised controller for mixing, feeding, temperature, pH, redox potential, level/foam and dissolved oxygen. The plant is certified for operation with the genetically modified organisms that will be developed during the project.*

## High value added products (WP4)

In this workpackage, Borregaard deals with the development of novel nano-composites, based on nano-fibres and polypropylene or polyethylene. In the first trials, nano-composites has been made in small scale extrusion and injection moulding with success. The nano-fibres stayed intact in the polypropylene matrix and no degradation was observed. Furthermore, an improved dispersion of nano-fibres was obtained using compatibilizers in the composite recipe. Chemical surface modification of nano-fibres resulted also in better dispersion of nano-fibres in polypropylene matrix. The mechanical tests showed that the nano-composite (nano-fibre+polypropylene) is stiffer than the reference (propylene) and the stiffness of the nano-composite increases with loading of nano-fibres in the polypropylene matrix.

Algetech has selected microalgae strains on bases of cultivability, yield and extractability of the Omega-3 fatty acids EPA/DHA (Eicosapentaenoic Acid and Docosahexaenoic Acid) and immune modulating beta-glucans. Preliminary evaluation has been carried out of new measurement technology including in-line sensors suitable for controlling important algae cultivation parameters such as nutrient status, live cell rate and cell density. The technology will be studied in a small-scale photobioreactor.

## Process integration (WP5)

To achieve a biorefinery concept with the highest efficiency and lowest costs an important goal is to optimise heat, materials and energy flows (for the overall biorefinery) by integrating process operations. The efficiency can be further increased by utilising all waste material to generate the necessary energy (heat, electricity) to operate the biorefinery.

To evaluate and design such efficient Biorefineries, it is important to identify potential bottlenecks, as well as material and energy flows for the overall refinery concept. A preliminary evaluation of potential bottlenecks has been done, and a preliminary overview of the mass flows in question has been established, with very simple mass balance for two biorefinery sizes (25,000 tons/yr and 750,000 tons/yr). The information gathered on refinery streams is connected and systemised, and this information will provide a practical framework for the planning, design and more efficient use of resources. The results achieved from the systematisation will be actively used to provide feedback to the development of process technologies regarding optimum operational conditions. It will also be used to facilitate the formulation of a utilities management strategy.

Biorefineries can significantly increase the competition for water resources. Optimal utilisation of wastewater, by cleaning and recycling to the biorefinery, is necessary to minimise the water demand. The project goal is to at least reduce the water demand by 75%. United Utilities is therefore reviewing the utilisation of water in biorefinery concepts in order to gain an understanding of the water quality issues and water use patterns.

## Pilot scale demonstration (WP6)

Regarding the integration of the processes in industrial pilot scale demonstration, the first results are now emerging. So far, progress has been made in production of cellulose nano fibers. Using a plate refiner, it is now possible to grind raw pulp opening the fibre walls without cutting and shortening the fibres. This process has proven to be efficient at the scale required.

The integration of pretreatment, hydrolysis, fermentation and algae production unit operations at pilot scale will start when the individual processes demonstrated run efficiently. Integration is scheduled for the second half of the project.

*Preparing to scale up the hydrolysis and fermentation at BioGasol.*

## Sustainability assessment (WP7)

Renewable energy, including biofuels, has become an essential element of the EU´s energy and climate strategy. In recent years, however, this strategy was questioned and criticised by different stakeholders, including scientists, NGO's and even public authorities. Concerns were raised regarding the sustainability of biofuels, mainly in terms of negative environmental and socio-economic impacts. As a consequence, a number of sustainability criteria were included in the EU Renewable Energy Directive (2009/28/EC). These sustainability criteria have to be met by economic operators in order for biofuels to be counted towards the legislative targets and a.o. to qualify for support schemes.

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 legal aspects. The most sustainable biorefinery pathways for the simultaneous production of biofuels, biomaterials and biochemicals will be identified.

To date, activities focused on providing all definitions, settings and system descriptions. This is to ensure a coherent analysis throughout the entire project. Statoil, responsible for process integration, is currently establishing a software model for all biorefinery pathways. Once quantitative data will be available, the model will provide full energy and mass balances which will then feed into the assessment of environmental, economic and social performance of the biorefinery pathways.

## Cooperation with other biorefinery projects

The SUPRABIO project is part of a major biorefinery research initiative of the European Commission that was launched early 2010. Within this initiative, research and industry organisations are developing new ways to convert biological feedstock into energy and valuable material using biorefinery technology. The research programme is carried out through four complementary projects, commonly referred to as the "biorefinery sister projects". The sister projects – SUPRABIO, EuroBioRef, BIOCORE and Star-Colibri – are committed to closely co-operate in order to harmonise their approach to biomass feedstocks characterisation and to assessing the sustainability of their products. In addition, the sister projects aim to organise common dissemination events where the progress of these major biorefinery initiatives will be presented.

More information on these projects can be found at the following websites:

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|---|---|---|---|
| SUPRABIO: | www.suprabio.eu | BIOCORE: | www.biocore-europe.org |
| EuroBioRef: | www.eurobioref.org | Star-Colibri: | www.star-colibri.eu |

## Inter-project Working Group "Dissemination"

To boost the impact of dissemination activities, the dissemination managers of the 4 sister biorefinery projects (Ms. Aurélie Faure from BIOCORE, Ms. Eibhilin Manning from EUROBIOREF, Ms. Jasmiina Laurmaa from Star-Colibri and Mr. John Vos from SUPRABIO) have set-up an informal inter-project dissemination working group. Where practically possible and feasible, the working group will develop joint activities, over and above what is being organised within the frame of the individual biorefinery projects.

As a first major activity, the working group "dissemination" organises a Networking Event at the Renewable Energy House in Brussels on 7 February 2011. The agenda for the event includes presentations, panel discussions and a networking cocktail. Presentations will be given on European policies and initiatives relevant to biorefineries, on each of the four biorefinery projects mentioned above, on larger national biorefinery initiatives in France, Germany and The Netherlands, on the AFORE project and on the IEA Bioenergy Task 42 Biorefineries.

## Inter-project Working Group "Sustainability"

Similarly, to ensure a harmonised approach, the projects have initiated co-operation in an inter-project working group focusing on sustainability assessment.

Sustainability assessment is one of the key aspects to be harmonised, as SUPRABIO, EuroBioRef, BIOCORE all cover a multi-criteria evaluation of the three dimensions of sustainability (environment, economy and society) using the same or similar assessment techniques. Even though internationally standardised assessment techniques such as life cycle assessment will be applied in the projects, the degree of freedom they offer in terms of methodological or data choices might lead to incomparable evaluations.

IFEU took the lead in the inter-project working group on harmonisation of sustainability assessment, which aims at harmonising assessment techniques, methodologies and common input data (e.g. on emissions or prices of commodities) across the three projects. Up to now, two telephone conferences have been held and an interim report on the work progress has been prepared.

## Selected biorefinery events

**Networking Event of the joint FP7 Biorefinery Projects**

European Renewable Energy House, Rue d'Arlon 63-65, Brussels (Belgium), 7 February 2011

This networking event will give industry and research partners from European biorefinery projects the opportunity to interact with European policy makers active in the field of the bio-based economy and to learn more about current biorefinery initiatives. The event will include information session and discussions, followed by an informal networking cocktail. The Networking Event is a joint initiative of the biorefinery projects funded under the FP7 Energy Work Programme for 2010. For more information, please contact John Vos at vos@btgworld.com.

**Nordic Wood Biorefinery Conference**

Hotel Clarion Sign, Stockholm, Sweden, 22-24 March 2011

The 3rd Nordic Wood Biorefinery Conference will present the latest ideas and developments in biorefinery separation and conversion processes as well as new biobased 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 the conference website.

**Star-COLIBRI Expert Forum Conference on Biorefineries**

Budapest (Hungary), 11-13 April 2011

The Star-COLIBRI Expert Forum Conference on Biorefineries will bring biorefinery research and industry stakeholders from all sectors together to discuss research priorities in the Joint European Biorefinery Research Road Map. For more information, please contact Jasmiina Laurmaa of the Star-COLIBRI project at j.laurmaa@europabio.org.

**Bioenergy III - Present & New Perspectives on Biorefineries**

The Gran Melia Salinas, Lanzarote, Canary Islands (Spain), 22-27 May 2011

The conference will address the state-of-the-art challenges of biorefineries with conversion processes into fuel products and chemicals and their technical, scientific, social and economic barriers. It will evaluate progress that has been made in establishing biorefinery concepts, research and development, life cycle analysis and identifying industrial successes and best practices, and discuss the most promising future directions. For more information, visit the conference website.

**RRB7 -7th International Conference on Renewable Resources and Biorefineries**

Oud Sint-Jan Conference Centre, Bruges (Belgium), 08-10 June 2011

RBB7 aims at bringing together academic researchers, industrial experts, policymakers and venture capital providers to discuss the challenges emerging from the transition towards a biobased 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 the conference website.

# Project consortium

The SUPRABIO consortium includes seventeen leading European organisations in the areas of biomass, biofuels, biocatalysis, biotechnology and sustainability from nine European countries: three industrial companies, eight small and medium enterprises, three research institutes and three universities.


*Map of the project partners*


*The project team at the first progress meeting, hosted by BTG.*

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


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

**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.

**Instititut für Energie- und Umweltforschung Heidelberg (IFEU)**

Life Cycle Assessment.

**Algetech Industrier AS (Algetech)**

Micro Algae 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.

**International Lignin Institute (ILI)**

Characterisation of lignin, nanomaterials, development of healthcare products.

**Wuppertal Institute for Climate, Environment and Energy (WI)**

Sustainability, societal and legal aspects.

**AlgoSource Technologies (AST)**

Process optimisation for algae production.

**GreenValue**

Fractionation and extraction of lignins, healthcare products.