SUPRABIO Newsletter – Issue 3 – July 2013

suprabio

innovative bio solutions

Sustainable products from economic processing of biomass in highly integrated biorefineries

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SEVENTH FRAMEWORK PROGRAMME

Editorial

John Vos, BTG

SUPRABIO is a €20M project, funded by the European Commission (EC) 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 SUPRABIO we are achieving that objective 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. Through our focus on the intensification of critical process steps we aim to improve the economics of building and operating biorefinery equipment appropriate for smaller and intermediate scale refining and distributed production.

The project 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.

This newsletter presents an overview of the main project achievements in the last 18 months, structured by the various processing routes.

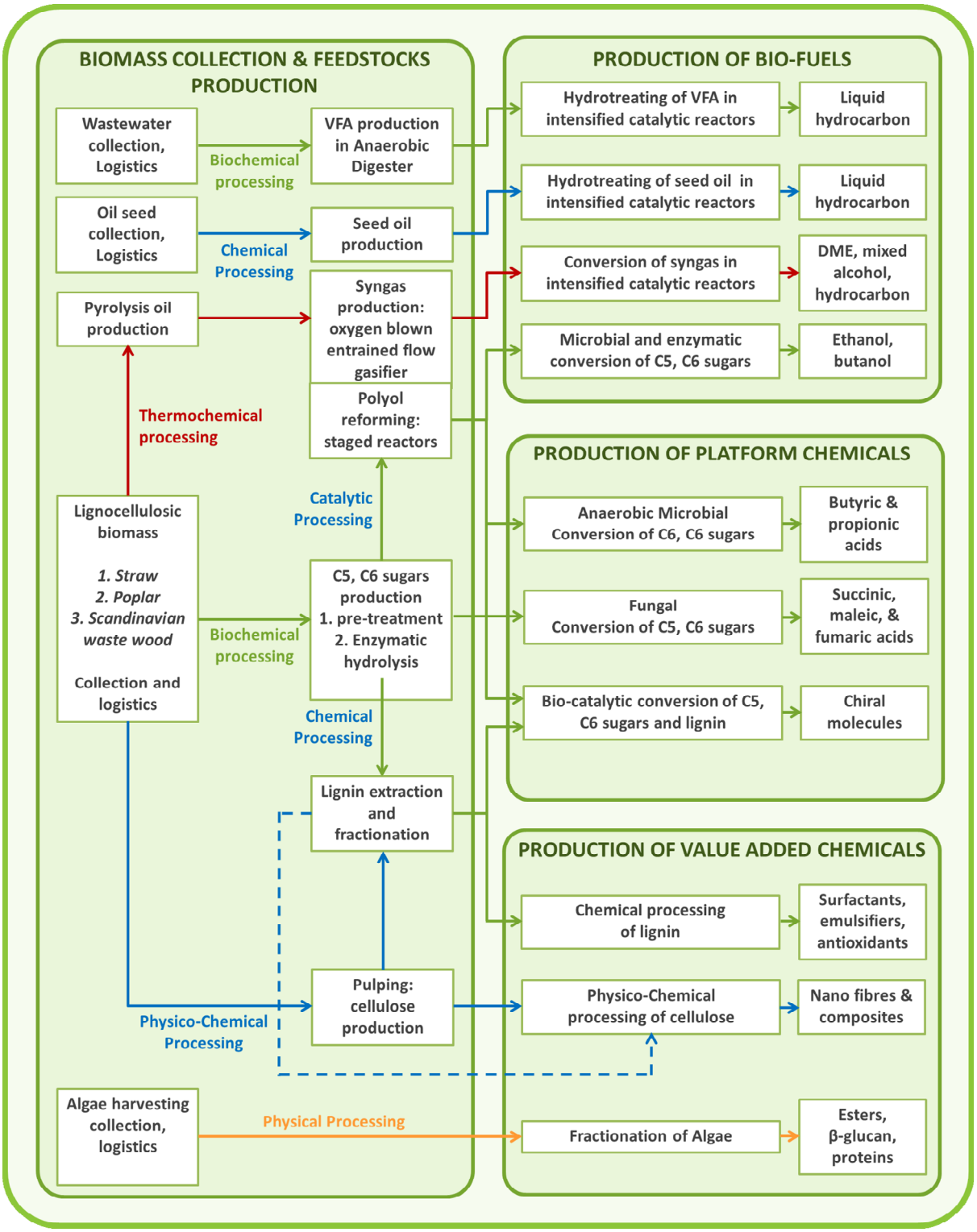
This period has seen the unfortunate withdrawal of one of our SME partners (Algetech Industries AS), which prompted the search for a suitable replacement. SUPRABIO is proud to announce that IGV GmbH has joined the consortium and taken on the work of Algetech. IGV GmbH is also an SME, working as industry-focused research institute with emphasis on applied research, analytics and training/education in the fields of microalgal biotechnology and food/ feed technology. IGV's Microalgae Biotechnology Department is system provider for the complete scale-up technology from R&D laboratory screening systems up to photobioreactors suitable for microalgae mass production at large industrial scale. We welcome Dirk Hofmeister and his team on board of the SUPRABIO project.

Other consortium news concerns the establishment of C5 Labs as a sister company to Danish SME partner BioGasol ApS focusing on the technology behind fermentation of C5 and C6 sugars simultaneously.

SUPRABIO is now well into its fourth year. To overcome the delays caused by the change of partners SUPRABIO has been awarded a 6 month extension, until July 2014. However, the bulk of the work is still to be completed by January 2014, as per the original timetable, and research is being focused and fine-tuned to reach our final targets. In February 2014, the main SUPRABIO results and findings will be presented at a large biorefinery conference, (working title *Pathways to Commercialization)*, to be held in Brussels.

We hope you find the information contained within this newsletter useful and encourage you to visit the SUPRABIO website www.suprabio.eu in order to obtain more information.

Overview of the SUPRABIO project



Biochemical processing routes - highlights

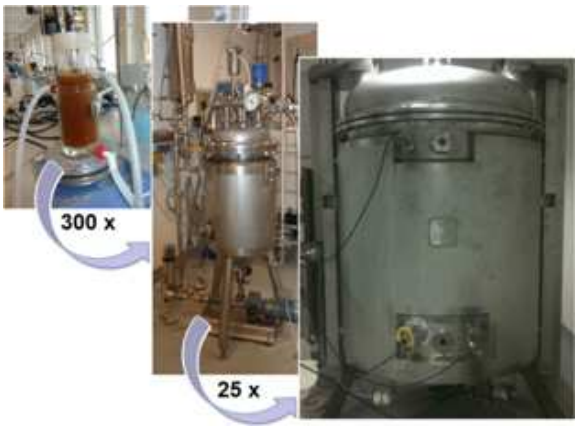
Mads Pedersen, BioGasol ApS

The biochemical route has now moved into a critical phase. Based on previous results on pre-treatment of wheat straw and poplar, the production of sugar-containing substrates from lignocellulosic biomass has started, with the intention of being able to feed the biochemical SUPRABIO processes.

Biomass pre-treatment capacity has reached 1,000 kg of raw straw per hour

Pre-treated wheat straw is now being produced at demonstration scale (up to 1,000 kg raw wheat straw being processed per hour). The sugars derived from the biomass will be fermented to form ethanol by a novel micro-organism developed by us. First the fermentation was tested in small scale fermenters, the next step is fermentation of this sugar containing substrate to produce ethanol in a 2 m^3 fermenter.

As a part of the project other micro-organisms are being produced and used. For example for the production of platform chemicals, the use of gene knock out in bacteria and fungi is taken into use for strain development, and the production of butanediol (a precursor for other fuel chemicals) is now being studied more intensively. Work has also taken place on production of chiral molecules (namely sugar fatty acid esters) from biomass sugars.



Scaling-up of fermenters at Biogasol for ethanol production at demonstration scale

The lignin residue derived from the processed biomass has been further analysed for usability within health care products, emulsifiers and surfactants. This analysis deals with the area of economically best use of residues left from a biorefinery dealing with lignocellulosic biomass. This work will give a view on the usability of the residues left from enzymatic hydrolysis and/or fermentation, thus showing the most feasible way of handling the leftovers from the processing.

For pulping of biomass, the pre-treated wheat straw has been tested along with woody biomass. Pulp with low lignin content, obtained in Year 2, has been intended to be used for production of adhesive nanocellulose composites. This work on adhesive nanocellulose composites will give insight in a new utilisation of the cellulosic biomass other than for fermentation of sugars. With this insight, the biochemical route may give whole new opportunities for utilisation of lignocellulosic biomass. Especially with adhesive nanocellulose composites, the plan is to investigate the dispersion of nanocellulose in several adhesive base systems.

Thermochemical processing routes - highlights

Costa Komodromos, Brunel University

Two possible applications of the thermochemical route in biorefinery operations are being considered in SUPRABIO. The first entails the collection of biorefinery feedstock from distributed producers of biomass in the form of pre-treated pyrolysis oil, char or lignin residues, and the subsequent processing into transport fuels via the syngas route. The second concerns the conversion of residues of biorefinery unit operations into utility energy.

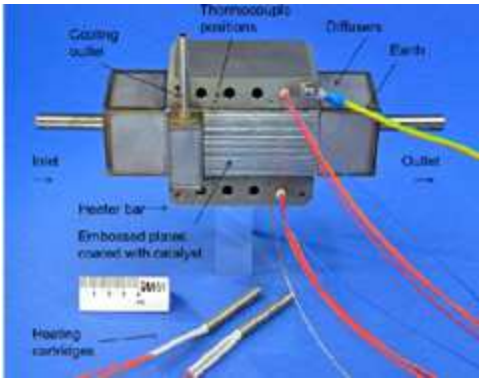
In SUPRABIO different biomass feedstocks such as poplar and waste wood, are converted into a more uniform energy carrier, biomass pyrolysis oil, which is then gasified with oxygen in a high temperature, high pressure entrained flow gasifier with integrated clean up and upgrading, to produce a synthesis gas (a mixture of carbon monoxide and hydrogen), a basic chemical platform for the chemical industry. From the syngas a wide range of biofuels can be obtained catalytically: either by Fischer-Tropsch (F-T) synthesis to produce synthetic diesel or aviation fuel, or via conversion of syngas to mixed alcohols, or dimethyl ether (DME).

Research work has been conducted on all the above pathways, and extremely good results obtained for production of DME in a single stage process. High conversions to mixed alcohols have been obtained although methane production is still an issue. For FTS, cobalt-based catalysts have been prepared and tested both in microreactors and as coatings on the multiplate reactor. The catalysts show good conversion, although selectivity to a diesel fraction is still being optimised in the laboratory.

Several tonnes of pyrolysis oil were produced at BTG for gasification tests at ETC

Production of 5 tonne batches of pyrolysis oil have been successfully achieved by BTG from poplar and from straw, and a specially developed skid-mounted oil pumping rig has been built and coupled to the ETC gasifier. Several gasification campaigns have been completed at ETC to test the coupled system, and optimisation tests are currently being undertaken to obtain stable feeding and gasification, so as to improve the overall carbon conversion in the gasifier. More details on the tests are provided in a separate article in this newsletter.

In year 4 the test programme will conclude in a practical integration of the complete thermochemical chain, to be carried out at ETC in Sweden, to produce Fischer-Tropsch hydrocarbons. Starting with the injection of pyrolysis oil (from poplar or straw), followed by gasification in the oxygen blown gasifier, the side stream demonstration will utilise the resulting syngas, which is cleaned up and reacted in a water gas shift (WGS) reactor to adjust its composition to produce the ideal H_2/CO ratio for F-T synthesis. The F-T synthesis will utilise a catalytic reactor developed in SUPRABIO, consisting of a cobalt-based catalyst coated onto a highly intensified multi-plate miniplant reactor. The plan is to perform a continuous run of 50-100 hours during which the performance of the different stages will be carefully monitored.



Water gas shift (WGS) reactor

Other processing routes - highlights

Martin O'Connell, Institut für Mikrotechnik Mainz

Significant progress has also been observed in what has been termed the "other routes" stream of work. As is inferred by the term, this is work performed within SUPRABIO but outside the framework of the bio- and thermochemical pathways. For example, substantial work has been performed in areas such as (a) volatile fatty acid (VFA) production (b) algae production and (c) hydrogenation of vegetable oils.

Wastewater, algal biomass, and seed oil offer significant potential for biofuels and high value products in an integrated biorefinery scheme via other routes. For VFA production and recovery, work performed at United Utilities has shown that it is possible to achieve up to 80% hydrolysis with caustic treatment under certain conditions. Ethanoic, propionic and butyric acids are the major VFA products but the ratios depend on the wastewater source.

50 kg/day VFA pilot plant installed by United Utilities (picture 1)

In addition, advances have been made with membrane technology which could prove to be a viable means of VFA separation and concentration. Trials performed using GBT (gravity belt thickened) filtrate as the VFA source showed a 300% increase in VFA concentration. Both rape seed oil and Jatropha oil were successfully hydrogenated and isomerised in Statoil's pilot hydrogenation equipment. These results have been taken on board for intensified reactor/catalyst development (and testing) using so-called staged reactors at Brunel University. Achievements here to date are (a) Staged-reactors incorporating a membrane system have been constructed, (b) The new reactor concept has been proven with the development and trials of a third intensified reactor system, and (c) Isothermic behaviour was observed together with a selectivity shift to the desired products. Algal process development, performed at IGV GmbH so far has succeeded in the identification of new microalgae strains suitable for large-scale production and more efficient lighting in an improved photobioreactor design. Progress has been made on the extraction of ß-glucans and fractionating of the fatty acids, EPA and DHA (laboratory scale). Finally, the University of Manchester is working on novel enzyme development and modification for high value products such as pharmaceuticals, cosmetics and paints.

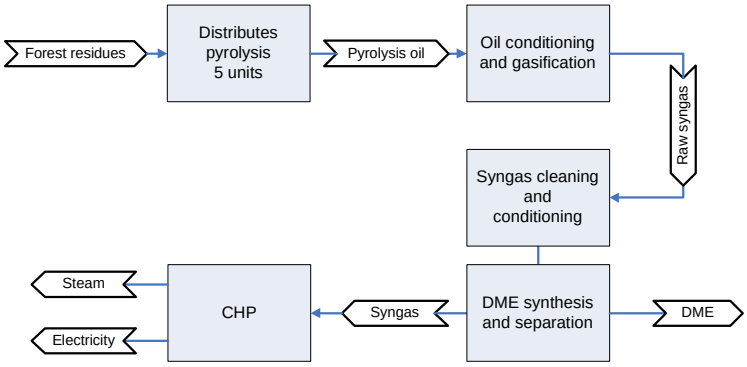
50 kg/day VFA pilot plant installed by United Utilities (picture 2)

Process integration assessment

Per Nygård, Statoil ASA

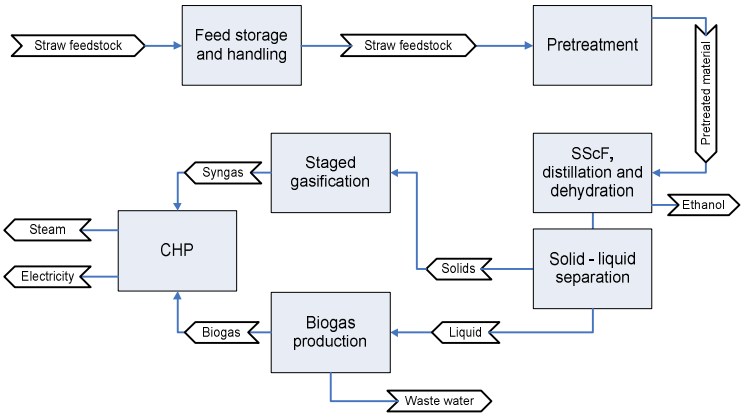
The integration assessment carried out in SUPRABIO is focused on the two principally different biorefinery concepts: biochemical and thermochemical. Here one example from each will be presented, based on experiments and technology developed within SUPRABIO, and hence not necessarily state of the art. For both concepts, performance as anticipated for year 2025 is used and the plant size is set to 400,000 tonnes dry biomass per year (input). The integrated systems have been studied using Aspen Plus modelling.

A forest residue to DME thermochemical process has been integrated with a waste management system producing steam and electricity. In this concept, pyrolysis is performed in distributed plants close to the feedstock, and the pyrolysis oil produced is then subsequently transported to a central gasification plant where the final fuel product is manufactured. The aim of the heat and power generation step is to produce sufficient amounts of electricity and steam for the process; The electricity generated is used within the biorefinery, and surplus electricity is exported to the grid. First and preliminary analysis of the integrated concept shows an overall net energy efficiency of about 25%.



Thermochemical biorefinery process concept

In the biochemical process, a wheat straw to ethanol process has been integrated with a waste management system producing steam and electricity. The solids are converted via the staged gasification process being developed by BTG in SUPRABIO, where a target is to recover minerals from the inorganic fraction. The use of a gas turbine in the combined heat and power (CHP) unit has been compared to the use of a gas engine and also a fluidised bed boiler, converting the solids directly to steam. The waste water is sent to a water treatment, including the activated sludge process and reverse osmosis, before recycling to the biorefinery. First and preliminary analysis of the integrated concept shows an overall net energy efficiency of about 52% (gas turbine).



Biochemical biorefinery process concept

An economic evaluation will be performed for the different concepts, and compared to a fuel market analysis. The market analysis will also include discussion of the energy and fuel complex as a whole.

Sustainability assessment

Nils Rettenmaier, IFEU

The objective of the sustainability assessment (a dedicated work package within SUPRABIO) is to provide a multi-criteria sustainability evaluation of the entire value chain by taking into account technological, environmental, economic, social, political and institutional aspects. In the past 18 months, significant progress was made. A major focus was put on collecting process data from partners. Based on these data, Statoil and BioGasol prepared technological assessments for the biochemical and thermochemical processes (two internal reports are now available) and compiled mass & energy flow balances. These mass & energy flow balances are the starting point for most of the subsequent sustainability analyses work.

Having assessment methodologies in place since the beginning of year 3, work in the past 18 months was mainly related to the preparation of the respective assessment tools (e.g. software tools for life cycle assessment and process economic assessment) which are now ready to digest the collected mass & energy flow data. First and preliminary lifecycle assessment (LCA) results were presented at the SUPRABIO progress meeting in June 2013 in Sarpsborg, Norway.

Regarding the analysis of local environmental impacts, the analysis of social & political aspects and the SWOT analysis (analysis of strengths, weaknesses, opportunities and threats), partners were able to produce preliminary results. After fine-tuning the methodology for the analysis of local environmental impacts (now better aligned with LCA), IUS has conducted a first round of analyses for the biomass provision step which clearly show that the use of dedicated crops (such as imported palm oil or Jatropha oil for hydrogenation) might have undesirable local environmental impacts on soil, water, flora, fauna and biodiversity. The use of biomass residues (such as straw and wood residues), however, leads to fewer impacts. Wuppertal Institute has looked into social impacts of the SUPRABIO biorefinery concepts by applying a top-down screening of potential social hotspots at country and sector levels using the Social Hotspots Database (SHDB) model. The SHDB data indicate a risk of forced labour at the biomass provision level not only for emerging / developing economies but, surprisingly, also for EU Member States. This issue will be followed up by a comprehensive literature review, but it also shows that social assessment is still in its infancy and that databases should always be taken with a pinch of salt. Regarding the SWOT analysis, IUS has compiled an interim report that focused very much on the biomass conversion step (i.e. the biorefinery) and revealed quite a number of success and failure factors for each process which subsequently could be taken into account by the process developers.

In the coming period, the individual elements of the sustainability assessment will be completed and methodological development and preparatory work for the final integrated assessment will continue.

Dissemination and exploitation

John Vos, BTG

Important channels to disseminate SUPRABIO results and findings, beyond this newsletter and the website, are conference presentations and publications in peer-reviewed articles. The first scientific articles have been published, with many more scheduled for the final period. Best efforts will be made to ensure "open access" to these scientific articles.

Preparations have started to organise a large biorefinery conference (working title *Pathways to Commercialization)*, on Tuesday 11 and Wednesday 12 February in 2014 at Le Plaza Hotel in the Rogier area in Brussels. This will be a joint initiative of the three sister projects funded under the sustainable biorefineries topic i.e. BIOCORE, EUROBIOREF and SUPRABIO. At the 2-day conference, representatives from the project consortia will provide a summary of their scientific and technical research, discuss pathways to commercialization that consider social, environmental and economic factors that are critical to commercialization of their biorefinery concepts, and will inform policy decisions. Day 1 of the conference will be dedicated to policy factors influencing biorefinery commercialization, and will be targeting policy makers as well as non-governmental agencies and stakeholders. Day 2 will be dedicated to presentations on the exploitation of results and be focused more towards industry.

Concerning exploitation, an Exploitation Plan is under development that sets out partner's exploitation strategies and details the many exploitable results emerging from SUPRABIO. In parallel, an assessment of SUPRABIO biorefinery product options in selected markets is being carried out. The work has already led to protectable IP and is expected to deliver concrete business opportunities. The findings will constitute an important input to the joint final conference.

Pyrolysis oil gasification test campaign

Evert Leijenhorst, BTG

ETC (Sweden) and BTG (Netherlands) carried out successful experiments with entrained flow gasification of pyrolysis oil. Several tons of pyrolysis oil were made from pine wood in BTG's pilot plant in Enschede (NL), and shipped along with a dedicated fuel pump skid to Piteå (Sweden). Using the pump skid, the pyrolysis oil was then gasified in the pressurised entrained flow biomass gasifier (PEBG) at the ETC research facilities.

Pyrolysis oil pump skid

The pyrolysis oil pump skid was specifically designed to comply with the requirements of the PEBG. Important aspects were the realisation of a steady continuous flow of the acidic, pyrolysis oil into a pressurized environment. The data acquisition of the pump skid **was** fitted with dedicated algorithms to allow fine tuning of both viscosity and feed flow.

The PEBG pilot plant was designed for high process temperatures (1200 - 1500 °C) and with a thermal throughput of maximum 1 MW_{th} and pressures up to 10 bar (g). The dimension of the PEBG gasifier was 0.52 m (inner diameter) with a length of 1.67 m with a conical shaped outlet. The reactor ceramics, mainly Al_2O_3 (63 wt%) and SiO_2 (31wt%), were slowly heated up (below 100 °C/h in order to avoid thermal stress) to 1000 °C by an electrical heater. Pyrolysis oil was fed to the gasifier using an internal atomization nozzle. Oil and atomization gas (nitrogen) entered the reactor on a central mounted spray burner lance, which in turn was surrounded by a cooling water jacket. The oxygen was supplied by jets surrounding the fuel inlet. The produced synthesis gas was cooled in a water quench along with some residual solids. The system pressure was controlled by a regulating valve on the syngas outlet pipe after the quench. About 7 hours of pyrolysis oil gasification was carried out in the PEBG plant at a fuel feeding rate of 60 kg/hr, 3 bar absolute pressure and oxygen enrichment conditions (70 wt% Oxygen) with an equivalence ratio between 0.45 and 0.50.

Pressurized entrained flow gasifier (PEBG)

The temperature increased up to about 1300 °C during the gasification test. Hydrogen, carbon monoxide and carbon dioxide were the main gas components with H_2/CO ratios quite stable during the gasification test (0.70). At the end of the test the hydrogen concentration was 27.4 %, the CO concentration was 39.3 % and the CO_2 concentration was 31.8 %. At the end the methane concentration was below 1.5 % and the ethylene and acetylene was both below 0.15 %, where acetylene had a slightly higher concentration than ethylene. It will be important to further characterize the gas with respect to trace elements since the catalysts used for conversion of synthesis gas are very sensitive to certain elements such as H_2S, COS, halides, alkali metals and metal carbonyls. Reducing the amount of N_2 added to the gasifier and increasing the pressure is also very important for downstream catalytic conversion and should also be carried out in future work.

Calculation of cold gas efficiency and carbon conversion require accurate syngas mass flow measurements. However, this was not achieved and the syngas flow was estimated based on helium trace experiments. The carbon conversion was estimated to 84.8 ±4.9 %. A higher conversion is desired for commercial application and the range observed here could be explained by the fact that all of the carbon in the fuel was not converted to gas and thereby ends up in the slag and/or the quench water. Also, the operating conditions were not optimized in this gasification trial; this will be carried out in future work. For comparison, in 2002 pilot gasification tests of bio oil in an entrained flow concept was carried out at the UET site in Freiberg (Germany). Interestingly, it was found that as much as 10 wt-% of the bio oil used ended up as soot, which reduce the carbon conversion significantly from 100%. In laboratory scale entrained flow gasification tests of wood powder it was observed that up to 40 g soot was formed per kg fuel, i.e. 4 wt-%. Future work should focus on longer testing (days) and finding optimum operating conditions from an investigation of the effect of parameter changes such as variation in oxygen equivalence ratio, fuel load and pressure.

In 2013, ETC's gasification train will be expanded to include a newly developed synthesis reactor. Once the full gasification train is operational, a second test campaign will be conducted, demonstrating at a single site the whole chain from pyrolysis oil feedstock to synthetic biomass-based end-products like methanol, Fischer-Tropsch diesel or dimethyl ether (DME), made via medium scale economic processing utilising intensified catalytic reactors developed jointly by Brunel University, London and IMM in Germany.

Standards for bio-based products

Nils Rettenmaier, IFEU

At the closure of the recent European Biomass Conference & Exhibition, held in June 2013 in Copenhagen, the Chairman concluded a.o. that there is a "need for standards to support market and trade". Such standards may facilitate the development of lead markets, e.g. in the field of bio-based products, where standards are seen as essential elements in aggregating initial demand, in particular for new bio-based products.

Following mandates by the European Commission, the European Standardization Committee CEN initiated a Technical Committee on the standardisation of bio-based products. Technical Committee CEN/TC 411 was formed in 2011 under the secretariat of the Netherlands Standardization Institute NEN.

The main objective of TC 411 is to develop standards for bio-based products covering horizontal aspects. There is no intention to present threshold or default values. This is to be done by specific product standards or by political decision. The work of TC 411 has been divided into five Working Groups (WG):

CEN/TC 411/WG 1	Terminology
CEN/TC 411/WG 2	Bio-solvents
CEN/TC 411/WG 3	Bio-based content
CEN/TC 411/WG 4	Sustainability criteria, life cycle analysis and related issues
CEN/TC 411/WG 5	Certification and declaration tools

Since the EC stressed the need to consider environmental and other sustainability criteria for European standards and other standardization deliverables, sustainability plays a vital role in TC 411's work. Having a vast expertise in the field of life cycle assessment (LCA) and sustainability criteria, SUPRABIO's IFEU is involved in CEN/TC 411/WG 4.

New partner: IGV GmbH

IGV GmbH was founded in 1960 as practice oriented research institute for the milling, baking and food industry. Key business activities are industry related biotechnological and technical research, product and services.

IGV's photobioreactors are based on a more than 30 years of expertise in optimisation of microalgae cultivation processes and photobioreactor engineering.

IGV's Microalgae Biotechnology Department is system provider for the complete scale-up technology from R&D laboratory screening systems up to photobioreactors suitable for microalgae mass production at large industrial scale, with capacities ranging from 2L reactor vessels to 160,000L photobioreactors.

Contacts & partner overview

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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.

IGV GmbH / IGV Biotech
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