Project no.: **038994 – (SES6)**

Project acronym: **Biosynergy**

Project title:
BIOmass for the market competitive and environmentally friendly SYNthesis of bio-products together with the production of secondary enERGY carriers through the biorefinery approach.

Instrument: Integrated Project

Thematic Priority: SUSTDEV 1.2.5 (Biomass)

M.0.8-B
Publishable results of the
Final Plan for Using and Dissemination of Knowledge

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WP Leader: Hans Reith

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Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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Summary

The project results provide a basis for valorization of hemicellulose and lignin in cellulose ethanol based biorefineries and other biorefinery concepts. The project activities have resulted in 4 new patents plus 2 under investigation. The achievements in other fields are mostly covered by existing IP portfolio's of the involved partners. In total 26 areas of exploitable technological knowledge have been developed in the project. All topics are subject to follow-up development and/or commercialization by project partners in co-operation with interested parties in or outside the BIOSYNERGY consortium.

The results of the project are presented in the brochure *Biorefinery Developments for Europe – Results of the Integrated project BIOSYNERGY 2007-2010*, that can be downloaded at http://www.biosynergy.eu/fileadmin/biosynergy/user/docs/Results_of_the_Integrated_Project_BIOSYNERGY_2007-2010.pdf

To promote follow up development and commercialization of the project results the present document presents a description of the 26 areas of exploitable technological knowledge developed in the project, including contact details of the involved partners. Interested parties are invited to contact involved partners directly or via coordinator ECN at the coordinates provided below.

In the project numerous dissemination activities were performed by the partners, including peer reviewed publications, presentations, posters and papers in international conferences, workshops and training activities. This document contains an overview of the main public dissemination items produced and planned by the project partners per November 2011. Publications and public reports are available via the project website www.biosynergy.eu or can be retrieved from public sources or obtained from the partners or coordinator ECN. A complete list of dissemination items incl. presentations and papers in international conferences etc. can be found on the project website www.biosynergy.eu.

To promote follow-up and exploitation of the project results, several dissemination and other activities will be continued. These include

- Continued dissemination of project results via the website www.biosynergy.eu (on-line on ECN server for at least 5 years), e-learning module http://biosynergy.gig.eu/elearning/ (on GIG server for at least 2 years), publication of new peer reviewed and other papers, presentations at conferences, contributions to training courses etc.
- Continued exchange with projects in the EC Joint Biorefinery call e.g. the IP BIOCORE (http://www.biocore-europe.org/) and other relevant projects, IEA Bioenergy Task 42 Biorefinery (http://www.iea-bioenergy.task42-biorefineries.com/) etc.

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1. Introduction

The results of the IP BIOSYNERGY are presented in the brochure *Biorefinery Developments for Europe – Results of the Integrated project BIOSYNERGY 2007-2010*. The brochure presents an overview of the main achievements and highlights of the technology development and design activities from the project as well as conclusions and perspectives towards future development. The brochure can be downloaded at
http://www.biosynergy.eu/fileadmin/biosynergy/user/docs/Results_of_the_Integrated_Project_BIOSYNERGY_2007-2010.pdf

To promote follow up development and commercialization of the project results Chapter 2 presents a description of 26 areas of exploitable technological knowledge developed in the project, including contact details of the involved partners. Interested parties are invited to contact involved partners directly or via coordinator ECN (contact details are provided in the summary).

Chapter 3 contains an overview of the main public dissemination items produced by the project partners in the framework of the project and a listing of all published and planned peer reviewed papers per November 2011. Publications are available via the project website www.biosynergy.eu or can be retrieved from public sources or obtained from the partners or coordinator ECN. A complete list of dissemination items incl. presentations, posters and papers in international conferences etc. can be found on the project website www.biosynergy.eu

Finally, Chapter 4 presents an overview of the main follow-up activities for further development and exploitation of the project results.

2. Exploitable Knowledge

The areas of developed Exploitable Knowledge are summarized in the Table on pages 5 through 9 and described in more detail on pages 10 and onwards.

Exploitable knowledge (description)	Exploitable product(s) or measure(s)	Sector(s) of application	Stage of development	Patents or other IPR protection	Contact details
WP1. Advanced physical/chemical fractionation					
1.1 Organic acid fractionation (Avidel)	Licensing or selling the Avidel fractionation technology. Cellulose, lignins, and C5 sugar syrup.	Paper industry, second generation ethanol production, and more generally, all technologies based on glucose, xylose and lignin utilization.	The lab-scale phase has been finalized, the process is at pilot and pre-industrial scale.	The Avidel technology has led to 6 different patents prior to the Biosynergy project. The technology could be considered as relatively well protected.	CIMV 134-142,rue Danton 92593 Levallois-Perret Cedex m.racine@cimv.fr Dr. B. Benjelloun-Mlayah b.benjelloun@cimv.fr Tel: +33.(0)5.34.31.82.42 Mob : +33 (0)6.31.74.75.02
1.2 Mechanical alkaline fractionation & enzymatic hydrolysis	Process concept for producing lignin and fermentable sugars from lignocellulose.	Biorefinery, agro-processing, biofuel producers.	Mechanical/Alkaline fractionation, enzymatic hydrolysis of cellulose, and cellulose isolation was conducted at bench-scale (50 L working volume).	No IPR to date. WUR-FBR know-how.	WUR-FBR P.O. Box 17, 6700 AA Wageningen The Netherlands Robert Bakker, Ph.D. robert.bakker@wur.nl Tel. +31-317-481167
1.3 Organosolv fractionation	Know-how lignocellulose fractionation, incl. optimum process conditions for cereal straws and willow.	Biofuel , biorefinery, chemical industry, paper industry.	The process has been scaled up to a 20L batch reactor. Further development aims at realization of a continuous reactor concept incl. scale up to pilot scale and demonstration.	No IPR to date. ECN know-how	ECN P.O.Box 1, 1755 ZG Petten Netherlands Dr. Wouter Huijgen huijgen@ecn.nl Tel: +31-224568162
1.4 Hydrochloric acid fractionation and hydrolysis	Process concept and know-how	Biofuel , biorefinery, chemical industry, paper industry.	Advanced technology at bench-scale.	Biorefinery proprietary know-how	Biorefinery.de Kantstraße 55 14513 Teltow Germany Dr. Jörg Beckmann Managing Director office@biorefinery.de Tel: 0049-3328-3322-0
1.5 Pressurised light acid hydrolysis C5 for furfural	Fundamental data for reaction and process design.	Biofuel / Bio-CHP industry.	Laboratory scale experiments have been performed so far showing this interesting process option.	Know-how. There are no plans to patent this part of the work. A publication has been published.	TUD Leeghwaterstraat 44 NL-2628 CA Delft The Netherlands Dr.ir. Wiebren de Jong Wiebren.deJong@tudelft.nl Tel. +31 15 2789476
1.6 Enzyme development	New commercial enzyme mixtures with increased effective activity at lower cost.	Abengoa Bioenergy (AB) as producer and consumer of enzymes produced under its own technology.	Enzyme production using ABNT licensed technology is currently in its industrialization phase	ABNT proprietary know-how.	ABNT Laura Bermúdez López abengoabioenergy@abengoa.com Tel. +34 95 493 70 00

Exploitable knowledge (description)	Exploitable product(s) or measure(s)	Sector(s) of application	Stage of development	Patents or other IPR protection	Contact details
WP2. Innovative thermo-chemical conversion					
2.1 (Catalytic) (fast) pyrolysis (bubbling fluidised bed) of lignin	Pyrolysis technology to produce pyrolytic lignin oil.	Chemical industry.	The Proof of Principle for the lignin pyrolysis technology has been delivered on gram scale. For the Proof of Concept experimental activities on larger scale (kg) are foreseen.	A patent application has been filed (outside Biosynergy)	ECN P.O.Box 1, 1755 ZG Petten, Netherlands Paul J. de Wild e-mail: dewild@ecn.nl tel: +31 (0) 224 564270
2.2 Rotating cone fast pyrolysis of biosynergy feedstocks	Pyrolysis oil.	Energy & Chemicals.	A commercial first-of-its-kind production unit is currently under development in Hengelo, the Netherlands (see www.empyroproject.eu).	Patents in place (outside Biosynergy).	BTG Josink Esweg 34 7545 PN Enschede The Netherlands G. Muggen, director. gerhard.muggen@btg-btl.com Tel: +31(0)534862287
2.3 Pyrolysis-oil fractionation for phenol formaldehyde resins	Substitute product for phenol in P/F resins.	Resin & adhesive industry.	Laboratory experiments are performed. Next step is to prove the process on continuous bench scale (~ 1 kg/hr product). For that purpose a prototype has been designed and constructed outside the BioSynergy project. Product samples are exchanged with potential end-users.	No IPR is published for the current process; patents have not been filed so far.	BTG Josink Esweg 34 7545 PN Enschede The Netherlands L. van de Beld, vandebeld@btgworld.com Tel: +31(0)534862288
2.4 Integrated aquathermolysis – fast pyrolysis concept	Furfural, levoglucosan and bio-oil.	Chemical industry.	The development has reached Proof of Concept stage for the aquathermolysis step (kg scale). The proof of concept for the pyrolysis stage is not considered problematic. Techno-economic evaluation of the concept indicates economic feasibility.	Know-how. To date no patent applications foreseen. Future process improvement may lead to patentable know-how.	ECN – Unit BCM P.O.Box 1, 1755 ZG Petten, Netherlands Paul J. de Wild e-mail: dewild@ecn.nl tel: +31 (0) 224 564270
2.5 Fast pyrolysis and catalytic fast pyrolysis	Data for upscaling and evaluation.	Bioenergy carriers and biofuel production.	Laboratory scale results are available that can be scaled up.	Preliminary results have been published and more papers are planned.	Aston University Birmingham B4 7ET UK A.V.Bridgwater a.v.bridgwater@aston.ac.uk Tel: +44 (0)121 204 3381
WP3. Advanced biochemical conversion					
3.1 Optimised operational conditions for ABE production from hemicellulosic hydrolysates	Data for process design.	Biofuel or chemical industry.	ABE production from wheat straw hydrolysates was carried out at a lab scale. Coupling fermentation and pervaporation was done at a 75L reactor scale using a synthetic fermentation medium. Pervaporation membrane surface was 0.08 m2.	So far, no patent application initiated in Biosynergy has been filed. The work continues and it is likely that the knowledge earned in the project will end up in new patents.	IFP Energies Nouvelles 1,4 avenue de Bois-Préau 92852 Rueil-Malmaison Cedex, France Frédéric Monot frederic.monot@ifpenergiesnouvelles.fr WUR-FBR P.O. Box 17, 6700 AA, Wageningen The Netherlands Arnoud Togtema Arnoud.togtema@wur.nl

Exploitable knowledge (description)	Exploitable product(s) or measure(s)	Sector(s) of application	Stage of development	Patents or other IPR protection	Contact details
3.2 Xylonic acid production from hemicellulosic hydrolysates	Data for process design.	Chemical industry.	There is currently no large scale bulk production of xylonic acid. Here we have demonstrated the feasibility of producing high concentrations of xylonic acid from biomass hydrolysates at lab scale. Work continues on the development of recombinant yeast for xylonic acid production. Scale up and separation/purification would now need to be developed.	Know-how. So far, no patent application initiated from the Biosynergy project has been filed. However, VTT holds a patent on the production of xylonic acid using recombinant yeast.	VTT P.O. Box 1000, FI-02044 VTT, Finland Marilyn Wiebe marilyn.wiebe@vtt.fi
3.3 Production of functional lignin derivates	None	-	-	-	-
3.4 Separation of alcohols (ethanol, butanol) by rotating disc contactors	Licensing or selling the technology.	Biofuel or chemical industry .	Several laboratory scale units have been designed, constructed, tested and optimized during the development of the concepts. The set of experimental data collected as well as the modeling and simulation results locate the technology at the pre-demonstration stage – i.e. as ready for experiments on industrial scale with a commercial Partner.	The major innovative values of the novel technology concepts are the subject of two Patent Applications:	GIG Anna Rogut/Jan Rogut Główny Instytut Górnictwa Pl.Gwarków 1 40-166 Katowice Poland Anna Rogut/Jan Rogut arogut@gig.eu rogutjan@yahoo.com Tel: +48-322592282
WP4. Innovative chemical conversion & synthesis					
4.1 Aromatic compounds by supercritical lignin depolymerisation	Data for lab-scale process	Chemical industry	Technology development at lab-scale.	Know-how. Scientific paper in preparation.	WUR-FBR P.O. Box 17, 6700 AA Wageningen The Netherlands Richard Gosselink, Daan van Es & Jacco van Haveren Richard.gosselink@wur.nl Daan.vanes@wur.nl Jacco.vanhaveren@wur.nl
4.2 Furfural from xylose	Data for process design (in part) / licensing, selling the process technology.	Biofuel and chemical industry.	Laboratory scale kinetic rate tests were performed and a process design was made.	A patent application is filed in The Netherlands and in the USA. Three journal articles have been published. A PhD thesis will be published by Dec. 2011.	TUD Leeghwaterstraat 44 NL-2628 CA Delft The Netherlands Dr.ir. Wiebren de Jong Wiebren.deJong@tudelft.nl Phone: +31 15 2789476
4.3 HMF from glucose	Know-how	Chemical industry	Laboratory scale	Know-how	Biorefinery.de Kantstraße 55 14513 Teltow Germany Dr. Jörg Beckmann office@biorefinery.de Tel: 0049-3328-3322-0

Exploitable knowledge (description)	Exploitable product(s) or measure(s)	Sector(s) of application	Stage of development	Patents or other IPR protection	Contact details
4.4 Succinic acid production	Licensing or selling the technology.	Chemical Industry.	Proof of-principle. Technology verification and optimisation at larger scale required.	Patent. Frits van de Klis, Daan van Es, Jacco van Haveren EP10181624 , 2010.	WUR-FBR P.O. Box 17, 6700 AA, Wageningen The Netherlands Daan van Es, Jacco van Haveren Daan.vanes@wur.nl Jacco.vanhaveren@wur.nl
4.5 2,5 FDA from furfural/HMF	Data for process design.	Chemical industry.	Proof of principle. Optimisation and scale up to pilot plant level now need to be demonstrated.	No patent application has been filed on this topic yet	WUR-FBR P.O. Box 17, 6700 AA, Wageningen The Netherlands Daan van Es, Jacco van Haveren Daan.vanes@wur.nl Jacco.vanhaveren@wur.nl
4.6 2,5 FDA to polyesters and application in PET	Data for process design.	Chemical industry. Polymer producers.	DOW has demonstrated isophthalic acid, used as comonomer in PET production, can successfully be replaced by 2,5 FDA.	None. A peer reviewed publication is planned.	WUR-FBR P.O. Box 17, 6700 AA, Wageningen The Netherlands Daan van Es, Jacco van Haveren Daan.vanes@wur.nl Jacco.vanhaveren@wur.nl
4.7 Bio-oil derived adhesive resins for wood-based panels.	Method of preparation of phenol-formalde-hyde resins using bio-oil fraction as a replacement for phenol	Formalde-hyde resins industry; Wood-based panels industry.	The processes have been developed at the lab scale and they can be readily transferred to the industrial scale based on the large scale availability of the pyrolysis oil fraction at competitive price and reactivity as compared to phenol.	Confidential protected know-how available for licensing.	Chimar 88 Them. Sofouli, 55131 Thessaloniki, GREECE Electra Papadopoulou papadopoulou@ari.gr, office@ari.gr
4.8 Use of natural surfactants in wetting agents for paper impregnation	Method of preparation of wetting agents for paper impregnation using biomass derived natural surfactants.	Wetting agents chemical industry. Paper impregnation industry. Wood-based panels industry.	The processes have been developed at the lab scale and can be readily transferred to industrial scale based on large scale availability of the biomass derived surfactants at competitive price and quality compared to their petrochemical counterparts.	Confidential protected know-how available for licensing.	Chimar 88 Them. Sofouli, 55131 Thessaloniki, GREECE Electra Papadopoulou papadopoulou@ari.gr, office@ari.gr
4.9 Lignin based adhesive resins for wood-based panels	Method of preparation of phenol-formaldehyde resins using lignin as a replacement for phenol	Formaldehyde resins industry. Wood-based panels industry.	The processes have been developed at lab scale and can be readily transferred to industrial scale based on the large scale availability of straw lignin at competitive price and reactivity as compared to phenol.	Confidential protected know-how available for licensing.	Chimar 88 Them. Sofouli, 55131 Thessaloniki, GREECE Electra Papadopoulou papadopoulou@ari.gr, office@ari.gr
4.10 Pentose-based surfactants production	Data for process design.	Chemical industry.	Pilot scale (>100litres)	The production of pentose-based surfactant is covered by ARD's patent portfolio.	ARD Route de Bazancourt 51110 POMACLE, France Boris Estrine b.estrine@a-r-d.fr

Exploitable knowledge (description)	Exploitable product(s) or measure(s)	Sector(s) of application	Stage of development	Patents or other IPR protection	Contact details
WP5. Conceptual design biorefinery pilot-plant					
5. Conceptual process design integrated biorefinery-plant at commercial-scale	Conceptual design of a biorefinery that produces ethanol, surfactants and resins from biomass fractions.	Biofuels and chemical industry.	The lignocellulosic biomass-to-ethanol technology is currently in its demonstration phase. Within Biosynergy, production of a number of chemicals from biomass fractions was tested at pilot scale, whereas some others were produced at laboratory scale.	The lignocellulosic biomass-to-ethanol technology is part of ABNT proprietary know-how	ABNT Laura Bermúdez López abengoabioenergy@abengoa.com Tel : +34 95 493 70 00
WP6. Integral biomass-to-products chain design, analysis & optimisation					
6.1 Biomass-to-products full value chain assessment tool	Process synthesis model.	Biofuel or chemical industry.	• Methodology is fully defined and can be applied to any chemical process. • Model is complete for generation and evaluation of bioethanol based biorefineries in 5 EU countries. Outputs can include socioeconomics and environmental impact.. • Model can be reconstructed and/or adapted for different processes and different products	The methodology and results are included in the final report and in the PhD thesis by K Chong. These will be published during 2011.	Aston University Birmingham B4 7ET UK A.V.Bridgwater a.v.bridgwater@aston.ac.uk Tel: +44 (0)121 204 3381
6.2 and 6.3 –The environmental profile of different biorefinery concepts The most dominating factors influencing the environmental performance of different biorefinery concepts -	Life Cycle Assessment (LCA) of the different biorefinery concepts. Analysis of the Life Cycle Impacts (LCI) of the different biorefinery concepts to understand which processes, inputs and outputs have the largest influence on environmental performance	Industry, governmental organizations, non-governmental organizations, etc..	Methodology has been developed for performance of LCA and LCI for complex, multi-product biorefinery systems Two “notes” have been written as deliverables in the framework of the IP BIOSYNERGY.	Results will be published in a peer-reviewed journal in 2012. Developed methodology and data is available for follow-up projects.	JOANNEUM RESEARCH Forschungsgesellschaft mbH RESOURCES - Institute for Water, Energy and Sustainability Elisabethstraße 16/I 8010 Graz, Austria David Neil Bird & Gerfried Jungmeier neil.bird@joanneum.at gerfried.jungmeier@joanneum.at T: +43 316 876 1423 or 1313 Alessandro Agostini European Commission - Joint Research Centre Institute for Energy Westerduinweg 3 1755 LE Petten - The Netherlands Tel: +31-22456-5258 E-mail: Alessandro.AGOSTINI@ec.europa.eu

The areas of Exploitable Knowledge are described in more detail in the following pages per topic and per partner.

Exploitation knowledge 1.1 – ARD
Organic Acid Fractionation (Avidel)

Result description
During the program, we have tested alternative feedstocks versus the reference biomass, which is the wheat straw. We have demonstrated that the best raw material for the cellulose and by-product production is the straw because of the composition of the different fractions. For instance, compared to poplar, the wheat straw produced a better quality of biobased fractions (cellulose, hemicellulose and lignin, that lead to better valorisation. We have, at pilot-scale, validated a mass balance which was a key issue for the competitiveness of the AVIDEL process.

Possible market applications
This technology can be used as general fractionation technology in order to obtain cellulose, lignins, and C5 syrup from a wide range of biomass.

Stage of development
The lab-scale is now over, the process is at pilot and pre-industrial scale.

Intellectual property rights published
Neither patent nor publication has been generated during the project.

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Exploitation knowledge 1.2 – WUR-FBR
Mechanical Alkaline Fractionation & Enzymatic Hydrolysis

Result description
A conceptual process was developed and validated to conduct alkaline fractionation at mild temperatures (< 100˚C) at atmospheric pressure, by using sodium hydroxide as a catalyst, and by integrating this with mechanical pretreatment process steps, such as refining and extrusions. This fractionation technology was shown to lead to extensive solubilisation and recovery of lignin (70%), and a cellulose/hemicellulose fraction that exhibits a high enzymatic degradability (80% or higher). During the project the effects of processing conditions on chemical composition of fractionated wheat straw were established, along with the yield of products. Furthermore, an isolation procedure for lignin was developed and the properties of lignin that was isolated were studied, and tests on applications for fractionated lignin were conducted.

Possible market applications
The main target is the biorefinery sector that produced fuels and products from fermentation of C5 and C6 sugars. In addition, the chemical sector can profit from the technology, as lignin can for example be used as replaced of phenol from petrochemical origin.

Stage of development
Mechanical/Alkaline fractionation, enzymatic hydrolysis of cellulose, and cellulose isolation was conducted at bench-scale (50 L working volume).

Intellectual property rights published
So far, no patent application initiated of the Biosynergy project has been filed. The work continues and it is likely that the knowledge earned in the project will end up in new patents.

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Exploitation knowledge 1.3 – ECN
Organosolv Fractionation

Result description
ECN has developed an organosolv process for fractionation of lignocellulosic biomass. By this technology, the major constituents of the biomass, i.e. cellulose, hemicellulose and lignin, are separated from each other to enable further processing into materials, fuels and/or chemicals. Optimized process conditions for fractionation of cereal straw and willow wood have been established. The process has been scaled up successfully from a 0.5L autoclave reactor to a 20L batch reactor. Further development will include: application tests of products formed (2011), realisation of a continuous reactor (2011-2013), followed by scale up to pilot scale (2014) and demonstration (>2015). The know-how developed includes production of high-purity lignin and cellulose pulp readily hydrolysable with enzymes to (fermentable) sugars, including optimal process conditions for cereal straw and willow. The exploitation considered would probably be a transfer of know-how or joint further development of the technology with interested parties.

Possible market applications
Organosolv fractionation produces three fractions:

- Cellulose:
  - Materials (e.g. pulp for papermaking)
  - Raw material for sugars from which fuels (e.g., bioethanol) and chemicals can be produced (bio)chemically via fermentation or chemical conversion
- Hemicellulose derivatives: Furfural, Sugar monomers and oligomers
- Lignin:Materials, Raw material for chemicals including phenolics

The technology is suitable for fractionation of lignocellulose into its main fractions in biorefineries. The main target sectors include the biofuels industry processing lignocellulose to produce 2nd generation fuels and/or chemical industries, including fermentation industries. Furthermore, the results are of interest for pulp and paper industries for biorefinery oriented developments and expansions.

Stage of development
The process has been scaled up successfully from a 0.5L autoclave reactor to a 20L batch reactor. Further development will be aimed at realization of a continuous reactor (2011-2013) followed by scale up to pilot scale (2014) and demonstration (>2015).

Intellectual property rights published
ECN does not hold patents in this area. So far no patent applications have been filed based on results from the BIOSYNERGY project. In follow up R&D IP opportunities will be actively explored and developed which will be partly based results achieved in BIOSYNERGY

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Exploitation knowledge 1.4 – Bioref
Hydrochloric Acid Fractionation and Hydrolysis

Result description
In the project Biorefinery.de GmbH developed a technology for hydrochloric acid fractionation and hydrolysis of lignocellulose biomass. HCL-based hydrolysis is a fractionation technique that does not require the use of enzymes for supplying monomeric sugars. This fractionation technique is carried out at low temperature in a two-step process with increased HCl-concentrations, and leads to formation of a mixed C5-C6 sugar hydrolysate. The HCl-based fractionation is applicable to all lignocellulosic feedstocks.

Possible market applications
The technology is suitable for lignocellulosic biomass pretreatment and fractionation for biorefinery purposes. The technology can potentially be applied in the biofuel , biorefinery, chemical industry, paper industry, etc.

Stage of development
Advanced technology at bench-scale.

Intellectual property rights published
Biorefinery proprietary know-how

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Exploitation knowledge 1.5 – TUD
Pressurised Light Acid Hydrolysis C5 for Furfural

Result description
Tests have been performed in laboratory scale (glass) equipment showing that milder conditions can be applied for biomass hydrolysis using certain chlorine salts in aqeous solution next to light acidic conditions. The solid residue enriched in cellulose/lignin may have advantages in downstream thermo-chemical processing by e.g. gasification.
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Possible market applications
Biofuel production with initial C5 valorisation in a biorefinery concept.

Stage of development
Laboratory scale experiments have been performed so far showing this interesting process option.

Intellectual property rights published
There are no plans to patent this part of the work. A journal publication has been written and has been published in Bioresource Technology.

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Exploitation knowledge 1.6 – ABNT
Enzyme Development

Result description

Results of the work carried out by ABNT within Biosynergy led to the identification of supplementation enzymes that make possible an increase of the specific activity. Reduction of the cost of the culture media for the enzyme production process was also achieved during the project.

Possible market applications

Enzymatic hydrolysis of cellulose into its composing sugars

Stage of development

Enzyme production using ABNT licensed technology is currently in its industrialization phase

Intellectual property rights published

ABNT proprietary know-how

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Exploitation knowledge 2.1 – ECN
(Catalytic) (Fast) Pyrolysis (BFB) of Lignin

Result description
ECN has developed a bubbling fluidised bed pyrolysis methodology to pyrolyse lignins and lignin-containing biorefinery residues. The methodology involves a specific feeding protocol, the use of a proprietary catalyst and the fractionated collection of the pyrolysis products. The products are a phenolic bio-oil and a bio-char. Depending on the type of lignin and the pyrolysis conditions up to 60 wt% bio-oil and up to 50 wt% bio-char can be produced.

Possible market applications
Part of the pyrolytic lignin bio-oil or the bio-oil as a whole can be used to replace phenol in resin applications to enhance the quality of bio-asphalt or as a feedstock for phenolic specialty chemicals. The bio-char is a potential additive for soil improvement and an activated carbon precursor for filter applications.

Stage of development
The Proof of Principle for the lignin pyrolysis technology has been delivered on gram scale. For the Proof of Concept experimental activities on larger scale (kg) are foreseen.

Intellectual property rights published
A patent application has been filed.

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Exploitation knowledge 2.2 – BTG
Rotating Cone fast Pyrolysis of Biosynergy Feedstocks

Result description
Pyrolysis oil was produced out of the BioSynergy feedstocks. Mass & energy balances were developed to determine the performance of BTG's process on the feedstocks under consideration. All feedstocks could be pyrolysed, the oil yield and quality differed for the used feedstocks.

Possible market applications
Pyrolysis oil is currently primarily used as fuel for energy production. Research is ongoing to use pyrolysis oil as source for chemicals and fuels.

Stage of development
A commercial first-of-its-kind production unit is currently under development in Hengelo, the Netherlands. (see www.empyroproject.eu).

Intellectual property rights published
BTG's pyrolysis technology is protected by patents. Within BioSynergy no additional IPR concerning the pyrolysis technology has been developed. Patents are owned by daughter company BTG-BTL.

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Exploitation knowledge 2.3 – BTG
Pyrolysis-oil Fractionation for Phenol Formaldehyde Resins

Result description
Pyrolysis oil contains a significant fraction of phenolic components. These components could be used to (partly) substitute petrochemical phenol in the production of P/F resins. Research topic was mainly to obtain a fraction suitable for use in the P/F resin production. Optimization work has been done to improve both the overall product yield as well as the product quality.

Possible market applications
The product can be used as substitute for phenol in the P/F resin production. Typical applications for P/F resins are in the OSB industry.

Stage of development
Laboratory experiments are performed. Next step is to prove the process on continuous bench scale (~ 1 kg/hr product). For that purpose a prototype has been designed and constructed outside the BioSynergy project. Product samples are exchanged with potential end-users.

Intellectual property rights published
No IPR is published for the current process; patents have not been filed so far.

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Exploitation knowledge 2.4 – ECN
Integrated Aquathermolysis – Fast Pyrolysis

Result description
Aquathermolysis selectively hydrolyses hemicellulose, dehydrates C5 sugars to furfural and leaches out soluble ash minerals at a temperature around 200°C and a reaction time of 10 – 60 minutes. From the dried hemicellulose-free and ash-free lignocellulose residue, levoglucosan can be produced from the cellulose part by pyrolysis. The residual bio-oil is less acidic and contains less water when compared to regular bio-oil. Yields up to 7 wt% (based on the dry biomass feed) furfural and 11 wt% (based on the dry biomass feed) of levoglucosan have been obtained. BTG was not involved in this route. BTG offered to perform a pyrolysis test on the aquathermolised material. However, this material was not available in the required quantities.

Possible market applications
Furfural is a versatile chemical that is widely used in the chemical industry. Levoglucosan is a potential building block for a variety of products such as bio-plastics, medicins and food-additives. However, at present the market for levoglucosan is very small because there is hardly any production capacity.

Stage of development
The development has reached Proof of Concept stage for the aquathermolysis step (kg scale). The proof of concept for the pyrolysis stage is not considered problematic. Techno-economic considerations for the whole aquathermolysis – pyrolysis concept suggest economic feasability. The whole biomass can be valorised in a limited number of chemicals and fuels. Basically, the aquathermolysis – pyrolysis concept could be regarded as a bio-oil based power (CHP) plant with the co-production of added-value chemicals. Combustion of the methane from the anaerobic digestion of the aquathermolysis filtrate contributes to the overall heat requirements of the process.

Intellectual property rights published
At the moment no patent applications are foreseen, but necessary improvements in the field of extraction and purification of levoglucosan merit further R&D that may lead to patentable insights.

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Exploitation knowledge 2.5 – Aston
Fast pyrolysis and catalytic fast pyrolysis

Result description
Extensive experimental results are available for both fundamental and applied research results from fast pyrolysis and catalytic fast pyrolysis of biomass, pretreated biomass and agro-wastes

Possible market applications
Fast pyrolysis and catalytic fast pyrolysis for production of intermediates for biofuel production and for improved energy carriers.

Stage of development
Laboratory scale results are available that can be scaled up.

Intellectual property rights published
Preliminary results have been published and more papers are planned during 2011.

A Fivga will submit her PhD later in 2011

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Exploitation knowledge 3.1 – IFPEnergiesNouvelles / WUR-FBR
Optimised operational conditions for ABE production from hemicellulosic hydrolysates

Result description
A *Clostridium* strain was selected from collections for its ability to produce ABE from steam exploded hemicellulosic hydrolysates. The conditions for ABE production in batch fermentations were defined. They can include a detoxification step prior to cultivating the strain. The final ABE concentration was 17.5 g/L and the average productivity 0.25 g/l.h.
From ABE selectivity and flux, pervaporation membranes suitable for continuous ABE removal were selected. On-line ABE removal by pervaporation coupled to ABE fermentation was possible without any operational troubles.

Possible market applications
The second generation biofuel sector is the main target. However, since acetone and butanol can be separated, they can also be used as chemicals produced from biomass.

Stage of development
ABE production from wheat straw hydrolysates was carried out at a lab scale. Coupling fermentation and pervaporation was done at a 75L reactor scale using a synthetic fermentation medium. Pervaporation membrane surface was 0.08 m^2.

Intellectual property rights published
So far, no patent application initiated of the Biosynergy project has been filed. The work continues, *e.g.* on other C5 fractions at IFP, and it is likely that the knowledge earned in the project will end up in new patents.

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Exploitation knowledge 3.2 – VTT
Xylonic acid production from hemicellulosic hydrolysates

Result description
Biological conversion of xylose in biomass hydrolysates to xylonic acid was demonstrated in batch using the bacterium *Gluconobacter oxydans*. Simple detoxicification of the hydrolysates was applied, as needed. Up to 55 g xylonic acid l^{-1} could be produced, at rates up to 1.1 g l^{-1} h^{-1}, depending on the concentration of xylose in the hydrolysate and level of inhibitors present.
Production of xylonic acid from pure substrate was demonstrated with genetically engineered yeast strains (e.g. *Saccharomyces cerevisiae*).

Possible market applications
Xylonic acid has applications as a chelator, dispersant, and clarifying agent. In addition, applications as a polymer (polyamide or hydrogel) modifier, as precursor of 1,2,4-butanetriol, and as an antibiotic or health enhancer are being developed. Xylonic acid could substitute for gluconic acid in some applications.

Stage of development
There is currently no large scale bulk production of xylonic acid. Here we have demonstrated the feasibility of producing high concentrations of xylonic acid from biomass hydrolysates at lab scale. Work continues on the development of recombinant yeast for xylonic acid production. Scale up and separation/purification would now need to be developed.

Intellectual property rights published
So far, no patent application initiated from the Biosynergy project has been filed. However, VTT holds a patent on the production of xylonic acid using recombinant yeast.

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Exploitation knowledge 3.3 – VTT/WUR-FBR
Production of functional lignin derivates

Result description
-

Possible market applications
n.a.

Stage of development
n.a.

Intellectual property rights published
n.a.

Contact details
n.a.

Exploitation knowledge 3.4 – GIG
Separation of alcohols (ethanol, butanol) by rotating disc contactors

Result description
The generic system of Rotating Bed Reactors-Contactors (RBRC) for facilitated, selective mass transfer in multiphase reactive systems was developed and tested at laboratory scale. The units operating at isobaric conditions are characterized by low energy consumption and enable integration of conversion, separation and concentration processing stages in bio-processes such as ethanol and ABE fermentation. The novel design has shown the high potential for the intensification of the biological and chemical conversions for reactions with kinetics restricted by the dissolution rates of the gaseous substrates in liquid–solid slurries

Possible market applications
The Rotating Bed Reactors-Contactors are directly addressed to application in biorefineries as well as in chemical technologies which involve important separation-product recovery units. The RBRC could replace the expensive, difficult to operate, membrane separation processes (pervaporation, pertraction) – especially those addressed to the recovery of volatile products from multi-phase, gas-liquid-solid reactive slurries. Combined RBRC systems and membrane elements allowed to create the innovative concept of the vortex membrane bioreactors. This solution can be competitively applied as the novel type of bioreactors for syngas fermentation to liquid fuels.

Stage of development
Several laboratory scale units have been designed, constructed, tested and optimized. The set of experimental data collected as well as the modeling and simulation results locate the technology at the pre-demonstration stage – i.e. as ready for experiments on industrial scale with a commercial Partner. The aim is to continue development in the project BIOIMMERSE [1] in which the Vortex Membrane Bioreactor and the Rotating Disc Contactors concepts will be used in a demonstration system for direct synthesis gas fermentation to ethanol and the market potential for their application will be analysed in detail.

Intellectual property rights published:
The technology concepts developed in BIOSYNERGY are subject of two Patent Applications:
1. **Wirowe bioreaktory membranowe** (**Vortex membrane bioreactors**) application no. in GIG: 26/2010, 30 Dec, 2010.
2. **Obrotowe reaktory-kontaktory do selektywnego odzyskiwania-zatężania składników mieszanin** (**Rotating Bed Reactor Contactors (RBRC) for selective recovery and concentration of liquid mixture components)** application no. in GIG: 27/2010, 30 Dec 2010. Both patent applications were elaborated and broadened in Sept. 2011 in order to include the Intellectual Property to be used in the BIOIMMERSE project. The modified applications will be formally applied for in the European Patent Office.

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[1] The project BIOmimetic Innovative MeMbrane rEactoRs for Sustainable production of liquid Eco-fuels (BIOIMMERSE) (budget 3.2 M€) is anticipated to be supported by the European Institute of Innovation and Technology (http://eit.europa.eu/) in the framework of the InnoEnergy Innovation Projects call.

Exploitation knowledge 4.1 – WUR-FBR
Aromatic compounds by supercritical lignin depolymerisation

Result description
Supercritical depolymerisation of organosolv lignin from hardwood and wheat straw yields 10-12% monomer phenolics, 20-30% oligomers, 10% gases and 40% char. Conversion has been substantially improved during the project. During the process the phenolic compounds were separated from the residual char by adiabatic expansion of the CO_2 based fluid.

Possible market applications
The phenolic oil can be used as wood adhesive for gluing fibre boards. The char might be used for bio-bitumen, active carbon or carbon fibres.

Stage of development
Technology development at lab-scale.

Intellectual property rights published
Scientific paper in preparation.

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Exploitation knowledge 4.2 – TUD
Furfural from xylose

Result description
Research was directed towards obtaining improved understanding of the chemical pathways from C_5 sugar to furfural (and loss products) by performing kinetic studies. The impact of halogen ions was established under dilute acid conditions. Yields and selectivities of furfural generation were optimized in a tubular reactor based on sugar solutions (including an industrial source from a project partner). Based on these findings an integrated process concept was formulated.

Possible market applications
Furfural production industry based on C5 sugar streams available from acidic biomass pre-processing can benefit from the concept process developed at TUD. Broad industrial interest has been shown for the novel process.

Stage of development
Laboratory scale kinetic rate tests were performed and a process design for a biorefinery part concerning furfural from pentoses syrups was made.

Intellectual property rights published
A patent application is filed in The Netherlands (ref. nr. 2005588) and in the USA (ref.nr. US 12/944,403), called “Process for the production of Furfural from pentoses” (inventors: G. Marcotullio and W. de Jong).

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Exploitation knowledge 4.3 – Bioref
HMF from glucose

Result description
In the project biorefinery.de GmbH focused its activities on the production of hydroxymethylfurfural (HMF) from glucose and fructose. The results are relevant for the production of platform chemicals and derivatives, such as Furane-2,5- dicarboxylic acid and 2,5-Bis-(hydoxymethyl)furan. The process is now consistent and the yields of HMF obtained are equivalent with the best results published to date on these topics.

Possible market applications
By processing biomass-derived feedstocks, that are inexpensive and abundantly available, the production of HMF is now a technology that could be further moved toward practical application e.g. in the chemical sector.

Stage of development
Laboratory scale

Intellectual property rights published
Know-how

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Exploitation knowledge 4.4 – WUR-FBR
Succinic acid production

Result description
Starting from (crude) levulinic acid as a starting material, a chemo-catalytic route for the production of succinic acid was developed: using nitric acid as the oxidant and specific promoters, an isolated yield of 50 % of succinic acid can be obtained. Compared to biotechnological processes the process has the advantage that the space time yield is approximately 20 times as high as for the biotechnological process, whereas the downstream processing is also simple.

Possible market applications
Succinic acid is a promising building blocks for a variety of chemicals e.g 1,4 butanediol or NMP, and a potential building blocks in plastics e.g. polybutylene succinate.

Stage of development
Proof of-principle. Technology verification and optimisation at larger scale required.

Intellectual property rights published
Frits van de Klis, Daan van Es, Jacco van Haveren *Succinic Acid from Biomass*, EP10181624, 2010.

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Exploitation knowledge 4.5 – WUR-FBR/Bioref
2,5 FDA from furfural/HMF

Result description
A procedure for synthesising 2,5 FDA dimethylester form HMF in methanolic sulotion has been improved compared to the state of the art. The reaction has been upscaled with a factor ten and the amount of catalyst needed has been reduced with a factor 10. Mass balances have been determined more accurately. A new procedure for synthesing HMFA (hydroxymethyl furoic acid) has been established.

Possible market applications
2,5 FDA and also HMFA can be regarded as promising building blocks in the synthesis of biobased polyesters or polyamides.

Stage of development
Proof of principle. Optimisation and scale up to pilot plant level now need to be demonstrated.

Intellectual property rights published
No patent application has been filed on this topic yet

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Exploitation knowledge 4.6 – WUR-FBR/DOW
2,5 FDA to polyesters and application in PET

Result description
Progress beyond the state of the art has been obtained by developing technology at WUR-FBR for the synthesis of high molecular weight polyesters based upon 2,5 FDA. The physical and mechanical properties of the homopolymer of 2,5 FDA and 1,4-butane diol have been determined.

Possible market applications
2,5 FDA based polyesters potentially can substitute PET bases materials in applications like drinking bottles, fleece textiles or aramid fibres for bullet proof clothes. In addition to this engineering plastics for automotive applications can be based upon such polyesters.

Stage of development
DOW has demonstrated isophthalic acid, used as co-monomer in PET production, can successfully be replaced by 2,5 FDA.

Intellectual property rights published
None. A peer reviewed publication is planned.

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Exploitation knowledge 4.7 – Chimar
Bio-oil derived adhesive resins for wood-based panels

Result description
The composite wood panel industry relies on phenol-formaldehyde (PF) adhesives for obtaining panel products suitable for demanding “exterior-use” applications. Phenol is a petrochemical whose availability and price depends on petroleum oil reserves and price volatility.

In this project, a method of preparing PF adhesives by partial replacement of the phenol with the phenolic fraction of biomass pyrolysis oil has been developed and evaluated by producing wood-based panels at the lab scale and by comparing their performance with the performance of panels produced with conventional adhesives.

Possible market applications
The developed processes (bio-oil PF synthesis and application) may be applied in the formaldehyde adhesives industry and in the wood-based panels industry thereby reducing their reliance on petrochemicals (increasing their sustainability).

Stage of development
The processes have been developed at the lab scale and they can be readily transferred to the industrial scale based on the large scale availability of the pyrolysis oil fraction at competitive price and reactivity as compared to phenol.

Intellectual property rights published
Confidential protected know-how available for licensing.

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Exploitation knowledge 4.8 – Chimar
Use of natural surfactatnts in wetting agents for paper impregnation

Result description
The surface appearance and physical-mechanical characteristics of wood-based panels are improved by covering their surface with special paper grades impregnated with aminoplastic resins of the urea-formaldehyde and/or melamine-formaldehyde type in combination with chemical additives (e.g. hardeners, de-foaming agents, surfactants, wetting agents), which help to improve the characteristics and performance of the impregnated papers.

In this project, a method of preparing wetting agents for paper impregnation using biomass derived surfactants was developed and evaluated. These natural materials were proved to be effective surfactants for paper impregnation with aminoplastic resins as compared to the conventional petroleum-derived surfactants.

Possible market applications
The developed processes (preparation of wetting agents with natural surfactants and their application in paper impregnation) may be applied in the wetting agents chemical industry, in the paper impregnation industry and in the wood-based panels industry thereby reducing their reliance on petrochemicals (increasing their sustainability).

Stage of development
The processes have been developed at the lab scale and they can be readily transferred to the industrial scale based on the large scale availability of the biomass derived surfactants at competitive price and quality as compared to their petrochemical counterparts.

Intellectual property rights published
Confidential protected know-how available for licensing.

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Exploitation knowledge 4.9 – CHIMAR
Lignin based adhesive resins for wood-based panels

Result description
The composite wood panel industry relies on phenol-formaldehyde (PF) adhesives for obtaining panel products suitable for demanding "exterior-use" applications. Phenol is a petrochemical whose availability and price depends on petroleum oil reserves and price volatility.

In this project, a method of preparing PF adhesives by partial replacement of the phenol with lignin derived from straw has been developed and evaluated by producing wood-based panels at the lab scale and by comparing their performance with the performance of panels produced with conventional adhesives.

Possible market applications
The developed processes (lignin-PF synthesis and application) may be applied in the formaldehyde adhesives industry and in the wood-based panels industry thereby reducing their reliance on petrochemicals (increasing their sustainability).

Stage of development
The processes have been developed at the lab scale and they can be readily transferred to the industrial scale based on the large scale availability of the straw lignin at competitive price and reactivity as compared to phenol.

Intellectual property rights published
Confidential protected know-how available for licensing.

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Exploitation knowledge 4.10 – ARD
Pentose-based surfactants production

Result description
During the project, ARD developed high yield production conditions of pentose-based surfactant from various hemicellulosic hydrolyzates (issued from steam exploded wheat straw, from acid organosolv pretreatment, or directly from biomass). Depending the raw material chosen, the operating conditions need to be adapted so as to maintain the efficiency of the process. The surfactants produced displayed interesting efficiencies in the application tests performed and also can be valuable ingredients in the preparation of wetting agents in the wood industry. The exploitation considered must be considered as a transfer of know-how probably after a licensing in of the ARD's patent portfolio concerning surfactants.

Possible market applications
Surfactant market (detergents and I&I cleaning)

Stage of development
Pilot scale (>100litres)

Intellectual property rights published
The production of pentose-based surfactant is covered by ARD's patent portfolio.

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Exploitation knowledge 5. – ABNT
Conceptual process design integrated biorefinery-plant at commercial-scale

Result description
The biorefinery business is considered a way to increase the competitiveness of the biomass to ethanol process in the long term. Valorization of biomass fractions not converted into ethanol is necessary to make the process competitive. Several promising bioproducts have been identified within Biosynergy and increased competitiveness of some integrated biorefinery scenarios has been seen. However, there is still uncertainty based on the current status of technology and future prices of bio-based products. In any case, further research and development is required for commercial implementation of these concepts.

Possible market applications
Biofuels and chemicals production.

Stage of development
The lignocellulosic biomass-to-ethanol technology is currently in its demonstration phase. Within Biosynergy, production of a number of chemicals from biomass fractions was tested at pilot scale, whereas some others were produced at laboratory scale.

Intellectual property rights published
The lignocellulosic biomass-to-ethanol technology is part of ABNT proprietary know-how

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Exploitation knowledge 6.1– Aston
Biomass-to-products full value chain assessment tool

Result description
Process synthesis model for generating and evaluating over 16000 processes for production of biofuels and chemicals.

Possible market applications
The methodology is applicable to any chemical process and product.

Stage of development
- Methodology is fully defined and can be applied to any chemical process.
- Model is complete for generation and evaluation of bioethanol based biorefineries in 5 EU countries. Outputs can include socioeconomics and environmental impact..
- Model can be reconstructed and/or adapted for different processes and different products

Intellectual property rights published
The methodology and results are included in the final report and in the PhD thesis by K Chong. These will be published during 2011.

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Exploitation knowledge 6.2 and 6.3 – JOANNEUM RESEARCH ./ EC-JRC Institute for Energy

The environmental profile of different biorefinery concepts - main benefits and impacts
The most dominating factors influencing the environmental performance of different biorefinery concepts - Considerations for generating maximal environmental benefits

Result description

1. Life Cycle Assessment (LCA) of the different biorefinery concepts.
2. Analysis of the Life Cycle Impacts (LCI) of the different biorefinery concepts to understand which processes, inputs and outputs have the largest influence on environmental performance

Possible market applications

Highlights which processes, inputs and outputs influence the environmental performance of a biorefinery so that policy can be designed to favour some concepts over others and processes can be altered to improve environmental benefits. The methodologies can be applied in Industry, governmental organizations, non-governmental organizations, etc..

Stage of development

Methodology has been developed for performance of LCA and LCI for complex, multi-product biorefinery systems.
Two "notes" have been written as deliverables in the framework of the IP BIOSYNERGY.

Intellectual property rights published

Results will be published in a peer-reviewed journal in 2012. Developed methodology and data is available for follow-up projects.

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3. Dissemination of Knowledge

3.1 Overview

Over the whole project duration numerous dissemination activities were performed by the partners, including peer reviewed publications, oral presentations, posters and papers in international conferences, workshops and training activities. The main cumulative dissemination items of the project include:

- 30+ Peer reviewed publications
- 95 Papers and posters at international conferences (plus 22 related publications)
- 6 Public workshops on Project results
- 8 plenary project meetings including 8 internal workshops for consortium partners. Plus a large number of Work package workshops.
- 8 project Newsletters
- Public website www.biosynergy.eu
- Roadshow consisting of:
    - Biosynergy Video and corresponding Storyboard. The video is available at the website www.biosynergy.eu and at http://www.youtube.com/watch?v=UjV6HFDj6pk
    - Biosynergy poster
    - Biosynergy Partner profiles packages
- Project Brochure
- Final brochure presenting project highlights, entitled *Biorefinery Developments for Europe – Results of the Integrated project BIOSYNERGY 2007-2010*, that can be downloaded at http://www.biosynergy.eu/fileadmin/biosynergy/user/docs/Results_of_the_Integrated_Project_BIOSYNERGY_2007-2010.pdf
- E-learning module accessible at: www.biosynergy.gig.eu/elearning , open for free access as guests.
- Contributions to workshops, lecture programs and other events
- Training course on Biorefineries
- Training was provided to 5 BSc students, 15 MSc students and 6 PhD students.
- The R&D in the project laid the foundation for 4 PhD theses by: Angelika Lingitz (Joanneum), Gianluca Marcotullio (TUD), Katie Chong and Antzela Fivga (Aston University)
- A significant number of Researcher Exchanges and Technical Excursions were organized

The listed items are available via the project website www.biosynergy.eu or can be retrieved from public sources or via the partners or coordinator ECN. Section 3.2 lists the published and planned Peer Reviewed Papers per November 2011. A complete list of dissemination items incl. presentations and papers in international conferences etc. can be found on the project website www.biosynergy.eu

3.2 Published and Planned Peer-Reviewed Papers

- Bouxin,F.; S. Marinkovic, J. Le Bras, B. Estrine, Direct conversion of xylan into alkyl pentosides; Carbohydrate Research, 345 (17), p.2469, Nov 2010 doi:10.1016/j.carres.2010.09.003
- Capote, R.; R. Arjona, P. Ollero, 2011. Technoeconomic and environmental assessment of ethanol production via biochemical conversion of lignocellulosic biomass by enzymatic hydrolysis. Submitted to Biomass and Bioenerg, Special Issue.
- Chong, K. and Bridgwater, A.V., "A methodology to generate, analyse and compare biorefinery process chains". Proc. Bioten Conference, CPL Press 2011, pp 229-443.

- Christou, M., I. Namatov, I. Eleftheriadis, and C. Panoutsou, 2009. How well structured are biomass resource assessments? The cases of cereal straw and woody biomass. Renewable Energy Journal. Submitted for publication.
- Dautzenberg, G.; Gerhardt, M.; Kamm, B.; Bio based fuels and fuel additives from lignocellulose feedstock *via* the production of levulinic acid and furfural. *Holzforschung*, Vol. 65, pp. 439–451, 2011, DOI 10.1515/HF.2011.081
- De Jong, W. and Marcotullio G., (2010) Overview of biorefineries based on co-production of furfural, existing concepts and novel developments, International Journal of Chemical Reactor Engineering: Vol. 8: A69.
- De Wild, P.J.; H. den Uil, J.H. Reith, J.H.A. Kiel, H.J. Heeres, "Biomass valorisation by staged degasification; A new pyrolysis-based thermochemical conversion option to produce value-added chemicals from lignocellulosic biomass", J. Anal. Appl. Pyrolysis 85 (2009) 124–133.
- De Wild, P.J.; H. den Uil, J.H. Reith, A. Lunshof, C. Hendriks, E.R.H. van Eck, H.J. Heeres, " Biomass valorisation by a hybrid thermochemical fractionation approach", International Journal of Chemical reactor Engineering, Vol.7, 2009, Article A51. http://www.bepress.com/ijcre/vol7/A51.
- De Wild, P.J. and Huijgen, W.J.J. (2010) Bubbling fluidised bed pyrolysis of wheat-straw derived organosolv lignin for phenolic chemicals, submitted for publication.
- De Wild, P.J.; Reith, J.H.; Heeres, E. 2011. Biomass pyrolysis for chemicals. Biofuels (Future Science), 2011, Vol.2, p.185-208.
- Fivga A. and Bridgwater AV, "Evaluation of various biomass types for suitability for fast pyrolysis processing", Proc. Bioten Conference, CPL Press 2011, pp 475-491,
- Gosselink, R.J.A., Teunissen, W., van Dam, J.E.G., de Jong, E., Gellerstedt, G., Scott, E.L., Sanders, J.P.M. Lignin depolymerisation in supercritical carbon dioxide/acetone/water fluid for the production of aromatic chemicals. Bioresour. Technol. Submitted for publication.
- Huijgen, W. J. J.; Reith, J. H. & Den Uil, H. (2010) Pretreatment and fractionation of wheat straw by an acetone-based organosolv process, Industrial & Engineering Chemistry Research, 49/20, pp. 10132-10140
- Kamm, B.; Gerhardt, M.; Leiß, S.; The biorefinery concept: Thermochemical production of building blocks and Syngas, In: M.Crocker (Eds.), Thermochemical Conversion of Biomass to liquid Fuels and Chemicals, Energy and Environment Series No. 1, Chapter 3, pp. 46-65, Cambridge, U.K., Royal Society of Chemistry, 2010.
- Marcotullio, G.; M.A. Taveres Cardoso, W. De Jong, A.H.M. Verkooijen, "Furfural Destruction Kinetics During Sulphuric Acid-Catalyzed Production from Biomass", International Journal of Chemical reactor Engineering, Vol. 7, 2009, Article A67. http://www.bepress.com/ijcre/vol7/A67/
- Marcotullio, G.; W. De Jong, Chloride ions enhance Furfural formation from D-xylose in dilute aqueous acidic solutions. Green Chemistry, 2010, Vol. 12, 10, 1739-1746
- Marcotullio, G. and De Jong, W. (2011) Furfural formation from D-xylose: the use of different halides in dilute aqueous acidic solutions reveals more about the mechanism of reaction and allows for exceptionally high yields, Carbohydrate Research, Vol. 346,11, 1291-1293.
- Marcotullio G.; Krisanti E.; Giuntoli J.; de Jong W. (2011) Selective production of hemicellulose-derived carbohydrates from wheat straw using dilute HCl or $FeCl_3$ solutions under mild conditions. Thermo-gravimetric analysis of the solid residues, Bioresource Technology, Vol. 102, 10, 5917-5923.
- Marinkovic, S.; B. Estrine Direct conversion of wheat bran hemicelluloses into n-decyl-pentosides; Green Chem., 2010, 12, 1929–1932
- Marinkovic, S.; J Le Bras, V Nardello-Rataj, M Agach B Estrine, Acidic pretreatment of wheat straw in decanol for the production of surfactant, lignin and glucose Submitted to International Journal of Molecular Science (special issue on Green Chemistry, guest editor J . Clark.
- Martel, F.; B. Estrine, R. Plantier-Royon, N. Hoffman, C. Portella, Development of Agriculture Left-Overs: Fine Organic Chemicals from Wheat Hemicellulose-Derived Pentoses. Topics in Current Chemistry, 2010, Volume 294/2010, 79-115, DOI: 10.1007/128_2010_54

- Mattinen, M.-L.; Suortti, T., Gosselink, R., Argyropoulos, D. S., Evtuguin, D., Suurnäkki, A., de Jong, E., and Tamminen, T. (2008). "Polymerization of different lignins by laccase," BioResources 3(2), 549-565.
- Mattinen, Maija-Liisa; Karin Struijs, Tapani Suortti, Ismo Mattila, Kristiina Kruus, Stefan Willför, Tarja Tamminen, and Jean-Paul Vincken.(2009) "Modifications of lignans by Trametes hirsuta laccase" BioResources 4(2), 482-496.
- Nygård Y.; Toivari M, Penttilä M, Ruohonen L, Wiebe MG. (2011) Bioconversion of D-xylose to D-xylonate with Kluyveromyces lactis. Metabolic Engineering 13: 383–391.
- Papadopoulou, E.; A. Hatjiissaak, B. Estrine, S. Marinkovic, Novel use of biomass derived alkyl-xylosides in wetting agent for paper impregnation suitable for the wood-based industry. Eur. J. Wood Prod., 9 December 2010.
- Seguin, A.; S. Marinkovic, B. Estrine, New pretreatment of wheat straw and bran in hexadecanol for the combined production of emulsifying base, glucose and lignin material, Submitted to Carbohydrate Polymers
- Toivari, M.H.; Ruohonen, L., Richard, P., Penttilä, M., Wiebe, M.G. (2010) Saccharomyces cerevisiae engineered to produce D-xylonate. Applied Microbiology and Biotechnology 88: 751-760.
- Turkia, H.; Siren, H., Pitkanen, J.P., Wiebe, M., Penttila, M. (2010) Capillary electrophoresis for the monitoring of carboxylic acid production by Gluconobacter oxydans. Journal Of Chromatography A 1217: 1537-1542.
- Van de Klis; F., van Es, D.S.; van Haveren, J. *Succinic acid from Biomass*, European patent application 10181624.7 (2010).
- Van Es, D.; S Marinkovic, X Oduber, B Estrine, Use of Furandicarboxylic Acid and its Decyl Ester as additives in the Fischer's glycosylation of decanol by D-glucose, Submitted to The Scientific World Journal

Public reports:

- Harmsen, P.F.H.; Huijgen, W.; Bermudez, L.; Bakker, R. (2010). Literature review of physical and chemical pretreatment processes for lignocellulosic biomass. Wageningen : Wageningen UR Food & Biobased Research, (Report 1184). Available at http://www.biomassandbioenergy.nl/filesdwnld/Literature%20review_FBR.pdf
- *Biorefinery Developments for Europe – Results of the Integrated project BIOSYNERGY 2007-2010.* The brochure can be downloaded at http://www.biosynergy.eu/fileadmin/biosynergy/user/docs/Results_of_the_Integrated_Project_BIOSYNERGY_2007-2010.pdf

Planned peer reviewed papers and papers in preparation

- Agostini, A., N. Bird, G. Jungmeier, A. Lingitz, K. Chong, A. V. Bridgwater, L. Canella: Life cycle assessment of lignocellulosic biorefinery concepts. Renewable and sustainable energy reviews.
- ARD: 1 publication in preparation on the work performed in 2010 on surfactants (WP4 and WP7).
- ECN, Univ. of Southampton: paper on results anaerobic digestion R&D with aquathermolysis effluent.
- ECN, Aston: Joint paper on the effect of biomass pretreatment on the quality of the pyrolysis products.
- Knoop, R., W. Vogelzang, J. van Haveren, D.S. van Es, “Synthesis of FDA based polymers”, BioMacromolecules.
- Knoop, R., W. Vogelzang, J. van Haveren, D.S. van Es, “Mechanical properties of FDA based polymers”, J. Appl. Polym. Phys.
- Lopez Contreras, A.M., Sperber, B., Houweling-Tan, B. “Fermentation of dried distillers grains and soluble (DDGS) for acetone, butanol and ethanol production”. Biotechnology for biofuels.

- Rudolph Christian, Mirko Gerhardt, Birgit Kamm, Kinetische Untersuchung der heterogenplatinkatalysierten Oxidation von 5-Hydroxymethylfurfural zu Furandicarbonsäure. Preparation for Submission to Chemie, Ingenieur Technik. ; Chemical Engineering &, Technology.
- Schönicke, Petra, Kamm, Birgit, Untersuchung zur enzymatischen Hydrolyse von Steam-Explosion Stroh, Preparation for Submission to Chemie, Ingenieur Technik.; Chemical Engineering &, Technology.
- Thornley, P., A.V. Bridgwater and K. Chong.In preparation: The impact of European biorefineries on agriculture and employment, Submitted to Energy policy.
- Thornley, P. and A.V. Bridgwater, 2012. The role of sustainable biorefineries in the European energy future, European Energy Conference 2012.
- Toivari, M., Nygård, Y., Kumpula, E.-P., Vehkomäki, M.-L., Benčina, M., Valkonen, M., Maaheimo, H., Andberg, M., Koivula, A., Ruohonen, L., Penttilä, M., Wiebe, M. (2011) Metabolic engineering of *Saccharomyces cerevisiae* for bioconversion of D-xylose to D-xylonate. *Metabolic Engineering* (in press)
- Toivari MH, Nygård Y, Richard P, Penttilä M, Ruohonen L, Wiebe MG (2011) Microbial D-xylonate production. Applied Microbiology and Biotechnology (invited review, In preparation)
- TUD: PhD thesis by Gianluca Marcotullio “The chemistry and technology of furfural production in modern lignocellulose-feedstock biorefineries”. December 2011.
- Van der Klis, F., J. Stoutjesdijk, J. van Haveren, D.S. van Es, “HNO3 oxidation of HMF and levulinic acid.” Eur. J. Org. Chem.
- WP1 partners: Paper on results achieved in the field of pretreatment in WP1
- WP5 partners: ABNT and ECN: paper on biorefinery modelling results WP5

4. Exploitation of project results and follow-up activities

The project results provide a good basis for valorization of hemicellulose and lignin in cellulose ethanol based biorefineries and other biorefinery concepts. In total 26 areas of exploitable technological knowledge have been developed in the project. All topics are subject to follow-up development and/or commercialization by project partners in co-operation with interested parties within or outside the BIOSYNERGY consortium. The results achieved in BIOSYNERGY are being followed up in various ways. The main follow-up activities are summarized here.

Significant progress was made in the area of lignocellulose pre-treatment and fractionation. Five pre-treatment technologies were optimized for wheat straw and compared by technical benchmarking. All technologies lead to significant fractionation of lignocellulose into its components cellulose, hemicellulose and lignin for further processing. Successful scale-up was performed by partner ARD of the AVIDEL concentrated acid organosolv technology in a pilot plant in Pomacles, France, in co-operation with the Compagnie Industrielle de la Matière Végétale (CIMV; http://www.cimv.fr/). This work included improvement of enzymatic cellulose digestibility and subsequent fermentation to bioethanol. This work is being followed up by CIMV in the framework of the IP BIOCORE (http://www.biocore-europe.org/) which aims at the development and demonstration of an industrial lignocellulose biorefinery concept based on organosolv fractionation technology including demonstration on industrial pilot scale. ECN is further developing the ethanol/water organosolv technology in the IP BIOCORE and a national project. Partners WUR-FBR and Biorefinery.de perform follow-up development in various projects. WUR-FBR is optimizing pretreatment concepts towards fermentative production of lactic acid and itaconic acid based on lignocellulose-derived sugars in the framework of the international public-private BE-Basic Programme (2010-2014; website: http://www.be-basic.org/).

In the area of thermo-chemical conversion a major result of the BIOSYNERGY project was the development (proof-of concept) of a 2-stage process consisting of a hot pressurised water treatment ('aquathermolysis') and subsequent fast pyrolysis. Products are chemicals furfural, levoglucosan and phenolics as well as gases and biochar for various applications. The process is further developed by ECN in the national Dutch R&D program CatchBio (http://www.catchbio.com/home) in the field of catalytic conversion of biomass into useful fuels, chemicals and pharmaceuticals.

BTG achieved good progress in the area of upgrading the fuel quality of fast pyrolysis oil via dewatering and filtration. These results are further developed and exploited by BTG in follow-up projects for application of upgraded bio-oils as diesel fuel and the development and implementation of the BTG Bioliquids Refinery concept for Pyrolysis based biorefinery.2 One follow up activity is the EMPYRO demonstration project (supported by the EC via FP7) which aims for commercial demonstration of the fast pyrolysis concept from biomass supply, through the pyrolysis conversion step, to oil application. Developing and demonstrating the recovery of acetic acid from biomass is part of the project (source: http://www.btg-btl.com/index.php?id=86&rid=53&r=projectdev).

Aston University is continuing to develop catalytic pyrolysis as one stage in a multi-step process to synthesize biofuels as well as for partial upgrading for production of a refinery compatible feed material to take advantage of the economies of scale and experience in conventional refineries. Project partner CEPSA is following up the project results in several internal projects.

[2] http://www.btg-btl.com/uploads/documents/2010-07%20BTG%20and%20BTG-BTL%20pyrolysis%20based%20biorefinery.pdf; BTG-BTL BV is a spin-off of BTG Biomass Technology Group BV.

In the area of fermentation development, ABE (Acetone-Butanol-Ethanol) could be efficiently produced from hemicellulose hydrolysate from wheat straw. Significant progress was made on laboratory scale offering a good starting point for further R&D, scale-up and commercialization. Further work on optimization of production strains and product separation is needed. These are RTD topics in ongoing projects at WUR-FBR and IFP Energies nouvelles. For instance, IFP Energies nouvelles has been working on a project on the production of ABE from other C5 fractions (project 100% funded by IFP Energies nouvelles).

Membrane pervaporation (on pilot scale) and Rotating Disk Contactors (on lab scale) were shown to offer a realistic alternative to distillation for extraction of ethanol and butanol. Work on membrane pervaporation and Rotating Disk Contactors is being followed up by WUR-FBR and GIG respectively. GIG aims to continue development in the project BIOIMMERSE in which the *Vortex Membrane Bioreactor* and the *Rotating Disc Contactors* concepts elaborated in BIOSYNERGY will be used in a demonstration system for direct synthesis gas fermentation to ethanol and the market potential for their application will be analysed in detail. For this project (budget 3.2 M€) support is anticipated from the European Institute of Innovation and Technology (http://eit.europa.eu/) in the framework of the InnoEnergy Innovation Projects call. The project will be targeted at using synthesis gas from biomass gasification as well as synthesis gas produced in Underground Coal Gasification (UCG) processes as raw material. Besides GIG two industrial partners including a global ethanol producer and an industrial group engaged in UCG will take part as industrial observers – partners.

Improved production rates and yields were achieved in the bioconversion of xylose to xylonic acid by VTT. This work is being followed up by VTT in the IP BIOCORE (http://www.biocore-europe.org/), while the physiology of microbial xylonic acid production is being studied with funding from the Academy of Finland. It is anticipated that these studies will have broader application in the improvement of biotechnological platforms for the production of biobased chemicals, particularly polymer precursors, and fuels.

Excellent results were achieved by TUD for conversion of xylose to the platform chemical furfural with much improved product yields. TUD has designed and patented a novel process for production of furfural with increased efficiency and energy consumption reduction by 85-95% compared with current industrial processes.[3] TUD aims to further develop and commercialize the developed process in co-operation with industrial partners. Follow up is ensured by contacting a broad range of industries interested in valorizing their biomass residues and C5 sugar syrup streams. A new PhD student has started her studies, financed by a Thai university. Moreover, a new project proposal has been submitted together with an industrial partner in Europe.

Major highlights were achieved in the development of reaction chemistries and process designs for a number of platform chemicals and products. Simplified, efficient processes with much improved yields were developed for the production of polymer grade Furan DiCarboxylic Acid (2,5-FDCA) (>99.9% purity) from cellulose with glucose and HMF as intermediates. 2,5-FDCA was successfully polymerised to colourless polymer powders or transparent fibres that can replace the polymer PolyEthylene Terephthalate (PET). Foreseen follow-up steps for market implementation include application R&D and obtaining approval/ testing for food contact. Work in this field is being followed up by WUR-FBR. Lab-scale synthesis and property characterization is pursued in various projects directed at specific markets or applications. Furthermore, based on the knowledge obtained within this project WUR-FBR will be involved in a substantial Dutch Polymer Institute (DPI) project on further developing bio-based polyesters, including 2,5-FDCA based polymers. In addition, WUR-FBR is further developing pathways to produce 2,5-FDCA from lignocellulosic biomass, through the production of HMF as intermediate in the framework of the Dutch BE-Basic Programme (2010-2014) (http://www.be-basic.org/).

[3] A patent application is filed in The Netherlands (ref. nr. 2005588) and in the USA (ref.nr. US 12/944,403), called “Process for the production of Furfural from pentoses” (inventors: G. Marcotullio and W. de Jong).

Knowledge gained by partner Dow will be followed up in projects in the area of sustainability to which the Dow Chemical company has recently made a commitment (http://www.dow.com/sustainability). A recent example of the continued effort in this area is the announcement of a JointVenture that will work on the production of sugar cane-derived ethanol for use as a renewable feedstock source, bringing new, biomass-based feedstock to Dow while diversifying the Company's raw material streams from traditional fossil fuels (http://www.dow.com/stories/sugar-cane-ethanol/).

A major highlight is the development of two new processes for the production of alkyl polypentosides from pentose streams. The first process uses unpurified pentose streams from organosolv pretreatment or steam explosion of wheat straw for the production of short tail (C4 and C5), "green" surfactants with high yields and significant cost savings. This process was successfully scaled up with high isolated product yields (>90%). The cost target was confirmed and standard application tests were performed successfully. The second process uses direct conversion of wheat straw to pentoside surfactants with high yield at low cost. The achieved confirmation of the cost target indicates that access to the surfactants market is feasible. ARD is following up the activities in this field aimed at further development and licensing of the technology in co-operation with an industrial partner.

Chimar Hellas successfully used alkyl pentoside surfactants produced by ARD for the synthesis of a wetting agent suitable for the paper impregnation industry that now is available commercially (http://www.chimarhellas.com/).

The application of lignin from straw and phenolics-enriched fraction from wood bio-oil in resins is considered close to the market. Significant progress was made in this area by partners Chimar Hellas and BTG. Promising results were obtained by Chimar for direct application of (organosolv) lignin and the phenolic fraction from bio-oil in phenol/formaldehyde (PF) resins for wood-based panels. Up to 25 wt% phenol substitution was shown to be possible while performing adequately relative to a standard PF resin. The work with lignin is followed-up by Chimar in the IP BIOCORE project and self funded projects. BTG achieved good results in the production of phenolics enriched fractions by extraction of pyrolysis oil. Recovery of chemicals from pyrolysis oil is followed up by BTG among others in the context of the SBIR (Small Business Innovation Research) program supported by the Dutch government (source: http://www.btg-btl.com/).

The lignin fractionation and depolymerization work of WUR-FBR is followed-up in the IP BIOCORE with a focus on organosolv lignin for the production of resin and polymer building blocks. WUR-FBR is coordinating the thermo-chemical conversion WP in this IP. Furthermore, the experience obtained with thermal lignin depolymerisation within this project has resulted in a new project on catalytic lignin depolymerisation in the framework of the Dutch CatchBio project (http://www.catchbio.com/).

The project results were integrated in the conceptual design of an innovative cellulose ethanol based biorefinery by scale-up and expansion of the Abengoa Bioenergy BCyL cellulose ethanol demonstration plant design with sections for upgrading of pentoses and lignin. Five different cellulose ethanol based biorefineries were modelled and their economic performance compared. The main conclusion from this work was that the biorefinery approach indeed increases the competitiveness of the biomass to ethanol process and that the valorization of side streams is required to make the whole process competitive. The biorefinery technologies developed in the BIOSYNERGY project can thus support the further development and commercialization of cellulose ethanol plants.

The developed biorefinery concepts could be implemented or further developed in ongoing and new cellulose ethanol pilot and demonstration projects. The Abengoa Bioenergy BCyL demonstration plant in Salamanca, Spain, is operational since the second half of 2009. Furthermore Abengoa Bioenergy is constructing a 2G ethanol plant in Hugoton, KS, USA with a capacity of 25 Million gallon of cellulose ethanol per year from corn stover. Furthermore results from the project may be used in the Lignocellulosic Ethanol Demonstration (LED) project, which aims to design, construct and operate the

first biofuel commercial facility in Europe using second generation technology, consisting of a lignocellulosic biomass to ethanol plant located in Lacq, France. In this project, in addition to the design and construction of the cellulose ethanol demonstration plant, R&D activities will be performed aimed at commercial application of lignins. The LED Project is a European project supported through the Seventh Framework Programme for Research and Technological Development (source: project website http://www.ledproject.eu/en/project).

The process synthesis based techno-economic model that was developed by Aston in the project is being developed further in thermal processing for biofuels and applications have been made to continue to improve the underlying database and hence accuracy of the model.

The developed LCA methodology for multi-product biorefinery systems is available for follow-up projects in co-operation with industry, governments and NGO's. Joanneum Research intends to use the LCA results for Life Cycle Assessment related activities in the framework of IEA Bioenergy Task 42 Biorefinery (http://www.iea-bioenergy.task42-biorefineries.com/) and other projects.

The results of the techno-economic and environmental modeling carried out in WP6 will be used by JRC as a source of data on biorefinery performances to support the European Commission policy making process. In particular the techno-economic data might by used as a source of data for the implementation of the EU Strategic Energy Technology Plan (SET-Plan) and the Strategic Energy Technology Information System (SETIS). The environmental modeling data and results will be used by JRC for policy support in the framework of the Renewable Energy Directive, more specifically they can be used as a base for the calculation of default values of future biofuel pathways.