IEA Bioenergy

IEA Bioenergy Task 42 Biorefinery

Welcome

The International Energy Agency (IEA) was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. It carries out a comprehensive programme of energy cooperation among OECD member countries. Its aims include to promote: systems for coping with oil supply disruptions, rational energy policies, an oil market information system, improved energy supply and demand structures, and integrated environmental and energy policies.

In recent years we have seen the first steps into the transition towards a Bio-based Economy. Multiple drivers, some policy and geographically dependent, are steering an economy where material wastes are minimized, new bioproducts are replacing their fossil counterparts, Green House Gas (GHG) emissions are reduced; while economic perspectives are developed supported by innovative policies. The recent extreme volatilities in prices (fossil oil, biomass raw materials) and strongly fluctuating demand ask for robust systems to be competitive in the long run. An economy based on innovative and cost-efficient use of biomass for the production of food, feed, bioenergy and bio-based products should be driven by well developed integrated biorefining systems.

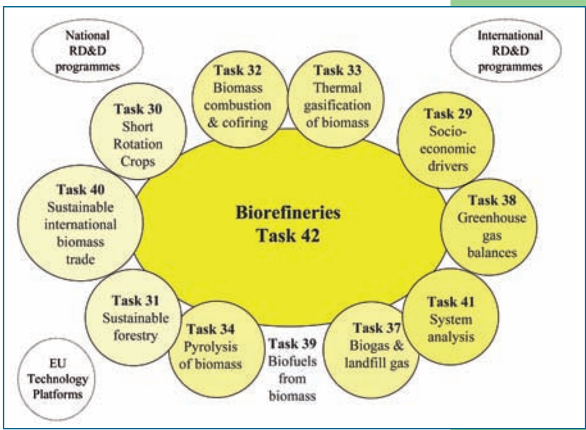


Figure 1: Role and position of Task 42 among other related Tasks of IEA Bioenergy.

IEA Bioenergy was set up in 1978 by the International Energy Agency (IEA) with the aim of improving cooperation and information exchange between countries implementing programmes for bioenergy research, development and deployment. Presently there are 13 Tasks operating under the IEA Bioenergy umbrella covering all major aspects of the bioenergy field. The relevance of biorefinery in a successful bioenergy research policy has been acknowledged by the establishment of a specific IEA Bioenergy Task 42 on biorefineries, co-producing transportation fuels, power, heat, added-value chemicals and materials from biomass. The major objective of this Task is to assess the worldwide position and potential of the biorefinery concept, and to gather new insights that will indicate the possibilities for new competitive, sustainable, safe and eco-efficient processing routes for the simultaneous manufacture of transportation fuels, added value chemicals, new materials and heat and power from biomass. This Task covers an exciting field which can have a large impact both in environmental and technological innovation policies and practices. To open up the biorefinery related potential, system and technology development is required. RD&D programmes can link industry, research institutes, universities, governmental bodies and NGOs, while market introduction strategies need to be developed.

Outputs of Task 42

Major outputs of Task 42 in its first triennium (2007-2009) are:

- Biorefinery definition and biorefinery classification system
- Country reports describing and mapping current processing potential of existing biorefineries in the participating countries, and assessment of biorefinery-related RD&D programmes to help national governments defining their national biorefinery policy goals and related programmes.
- Bringing together key stakeholders (industry, policy makers, NGOs, knowledge infrastructure) normally operating in different market sectors (e.g. transportation fuels, chemicals, energy) in multidisciplinary partnerships to discuss common biorefinery-related topics.

Multidisciplinary partnerships are needed to discuss common biorefinery-related topics, to foster necessary RD&D trajectories, and to accelerate the deployment of developed technologies. Since its onset, Task 42 has been focusing on defining biorefinery technology while assessing its potential contribution to a more sustainable and profitable production, bringing together actors in the field of science, policy and industry. Four meetings have been held and national platforms were established. Further, to inform the public and enhance national inventories and research and implementation programmes, workshops with biorefinery stakeholders have been held in Austria, Canada and Ireland.

The aim of IEA Bioenergy Task 42

The aim of IEA Bioenergy Task 42 is to initiate and actively promote information exchange on all features of biorefinery. Information exchange and cross fertilization will cover all aspects of biomass feedstock, conversion and fractionation technologies, integration of processes and use of side-streams, products, energy efficiency; economic, socioeconomic and environmental performance as well as other potential sustainability impacts (such as consequences on food production, water use and quality, changes in land-use, access to resources, biodiversity, and the net balance of greenhouse gases). This exchange of information should reduce fragmentation in this multidisciplinary and multistakeholder field. It will also result in cross-thematic synergies, among the IEA Bioenergy tasks, defining research priority needs and infrastructure.

Brochure setup

The objective of the brochure is to inform policy makers, non-governmental organisations (NGOs), researchers and entrepreneurs on the principle of biorefinery, its potential contribution to food and feed production, bioenergy and waste management, and its perspectives in the context of a growing demand for food, feed, energy and products from renewable resources. This brochure will begin with the definition of biorefineries developed by IEA Bioenergy Task 42. The heterogeneity and diversity of the biorefinery field require a uniform definition and a clear classification system. To illustrate the different biorefinery types, and their current technological status and/or development and deployment perspectives, examples from different countries will subsequently be presented. They will be linked to the classification system, in order to give a clear classified overview of both the current status and future perspectives of biorefineries worldwide. The brochure will wrap up with some general comments and a future outlook for the next triennium.

Biorefinery definition

The members of IEA Bioenergy Task 42 have agreed on the following definition for biorefinery: *"Biorefinery is the sustainable processing of biomass into a spectrum of marketable products (food, feed, materials, chemicals) and energy (fuels, power, heat)"*. This means that biorefinery can be a concept, a facility, a process, a plant, or even a cluster of facilities. This brochure gives an overview of the different types of biorefineries. The brochure will illustrate at which scale (commercial, demonstration or pilot) these biorefineries are currently operational. The port of Rotterdam, in the Netherlands, is included as an example of a cluster of facilities which together can be considered as a biorefinery.

One of the main drivers for the establishment of biorefineries is the call for sustainability. All biorefineries should be designed for sustainability along the entire value chain. This assessment should also take into account the possible unintended consequences such as the competition for food and biomass resources, the impact on water use and quality, changes in land-use, soil carbon stocks and long term fertility, net balance of greenhouse gases, impact on biodiversity.

Impacts on international and regional dynamics, end-users and consumer needs, and investment feasibility also have to be taken into consideration.

A biorefinery can use all kinds of biomass including wood & agricultural crops, forest residues, organic residues (both plant and animal derived), aquatic biomass (algae & sea weeds) and industrial wastes. A biorefinery is not a completely new concept. Many of the traditional biomass converting technologies such as the sugar, starch and pulp and paper industry use aspects connected with a biorefinery approach. However, several economic and environmental drivers such as global warming, security of supply, energy supply, high energy costs and agricultural policies have also directed those industries to further evolve their operations into biorefineries. This should result in improved integration and optimization aspects of all the biorefinery sub-systems.

A biorefinery should sustainably produce a spectrum of marketable products and energy. The products can be intermediates or final products, such as food, feed, materials, and chemicals; whereas energy includes fuels, power and heat. The main focus of biorefinery systems which will come into operation within the next years is on the production of transportation biofuels (i.e. biofuel driven biorefineries). Selection of new biofuels is based on the possibility that they can be mixed with gasoline, diesel or natural gas, and using the already existing infrastructure in the transportation sector. IEA Bioenergy Task 42 has defined that both multiple energetic and non-energetic output need to be generated for a facility to be considered as a biorefinery. The volume and prices of present and forecasted products should be market competitive.

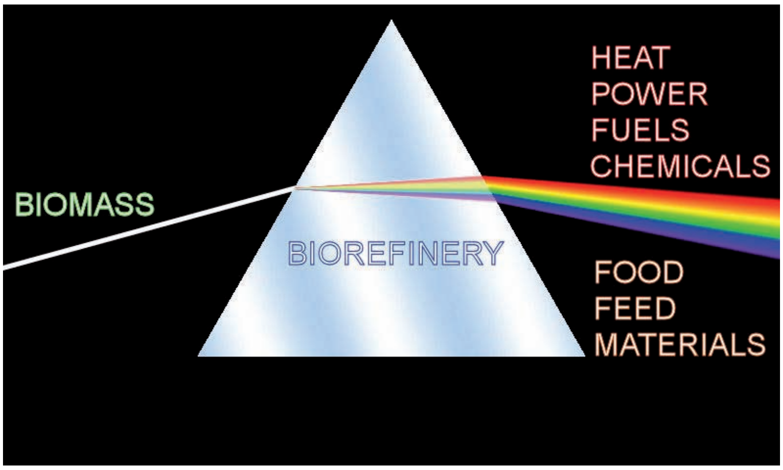


Figure 2: Biorefinery and its role in the transformation of biomass.

Effects of biorefinery

Biorefineries are expected to contribute to an increased competitiveness and prosperity by responding to the need to supply a wide range of bio-based products and energy in an economically, socially, and environmentally sustainable manner. Biorefineries show promises both for industrialized and developing countries. New competencies, new job opportunities and new markets are expected to be realized while the development of biorefineries will contribute to the realization of renewable energy, environmental and rural development goals.

Classification of biorefinery concepts

The current main driver in biorefinery development, i.e. efficient and cost effective production of transportation biofuels, is to increase the biofuel share in the transportation sector, while the co-produced bio-based products provide additional economic and environmental benefits. IEA Task 42's approach to biorefinery classification considers four main features which are able to identify, classify and describe the different biorefinery systems, viz: platforms, products, feedstocks, and conversion processes.

The platforms (e.g. C5/C6 sugars, syngas, biogas) are intermediates which are able to connect different biorefinery systems and their processes. The number of involved platforms is an indication of the system complexity. The two biorefinery product groups are energy products (e.g. bioethanol, biodiesel, and synthetic biofuels) and material products (e.g. chemicals, materials, food and feed). Feedstocks can be grouped as either energy crops from agriculture (e.g. starch crops, short rotation forestry) or biomass residues from agriculture, forestry, trade and industry (e.g. straw, bark, used cooking oils, waste streams from biomass processing). Concerning conversion processes, the classification system identifies four main groups, including: biochemical (e.g. fermentation, enzymatic conversion) [indicated in Figure 3 as red squares], thermo-chemical (e.g. gasification, pyrolysis) [yellow squares], chemical (e.g. acid hydrolysis, synthesis, esterification) [blue squares] and mechanical processes (e.g. fractionation, pressing, size reduction) [white squares]. The biorefinery systems are classified by quoting the involved platforms, products, feedstocks and – if necessary – the processes. Some examples of classifications are:

- ´C6 sugar platform biorefinery for bioethanol and animal feed from starch crops´
- ´Syngas platform biorefinery for FT-diesel and phenols from straw´
- ´C6 & C5 sugar and syngas platform biorefinery for bioethanol, FT-diesel and furfural from saw mill residues´

An overview of current platforms, products, feedstocks and conversion processes is given in Figure 3. This system is expected to evolve as new technologies are developed, and additional platforms are defined.

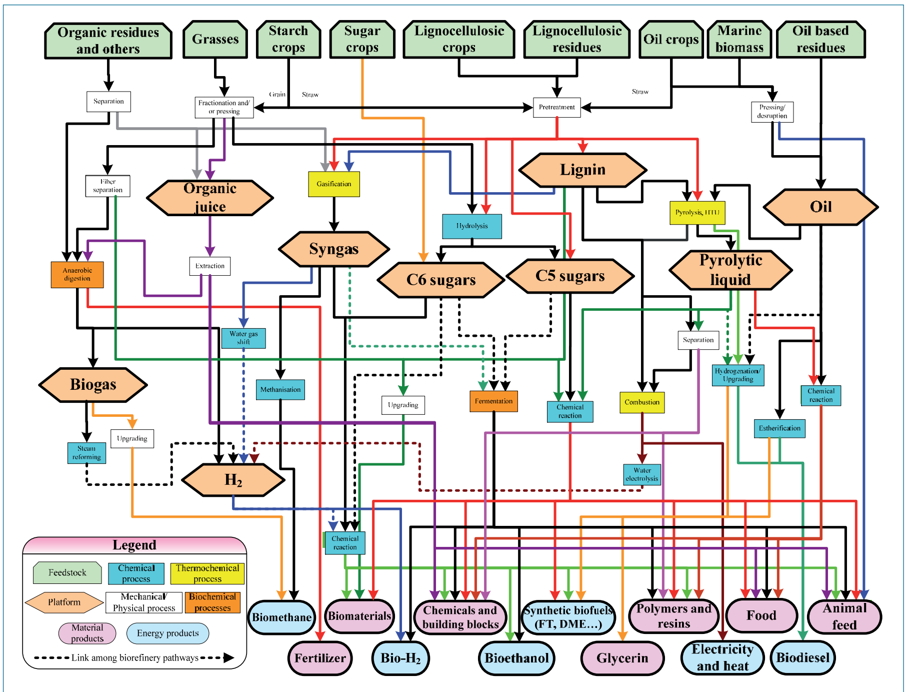
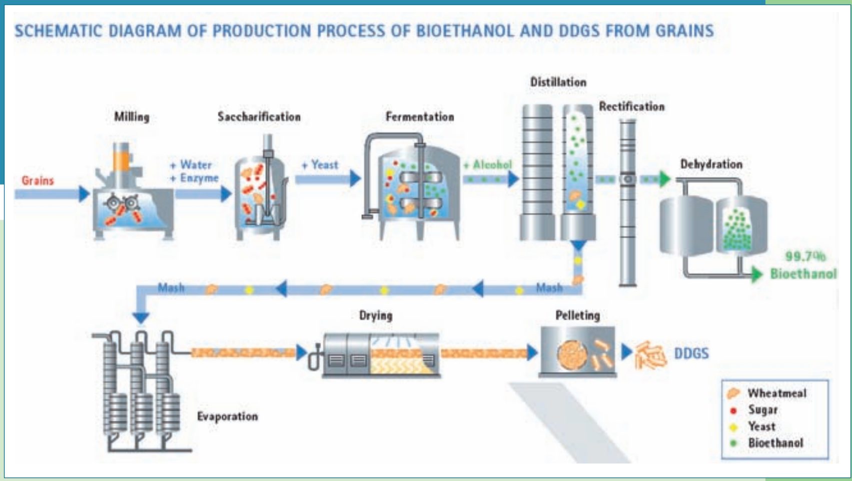


Figure 3: Overview of the biorefinery classification system.

Crop Energies AG (Germany)

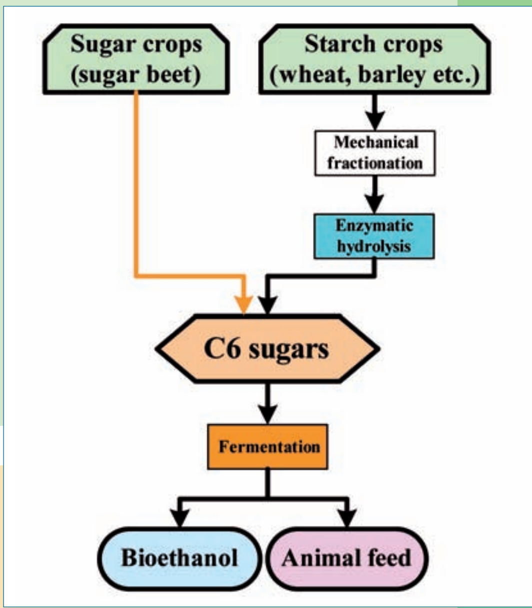
Classification: C6 sugar biorefinery for bioethanol and animal feed from sugar and starch crops
State-of-the-art: Commercial
Owner: Südzucker Bioethanol GmbH
Feedstocks: Cereals, sugar
Products: Bioethanol, feed (DDGS "ProtiGrain"), electricity



The CropEnergies Group is a leading European fuel ethanol producer. Bioethanol is manufactured by fermentation of sugar and starch crops. In Europe's largest bioethanol plant in Zeitz (capacitiy 2008: 360,000 m³), bioethanol is manufactured from cereals like wheat, barley, triticale or maize as well as sugar syrups. Ethanol production from cereals containing starch takes place in five stages:

- milling the cereals, meaning mechanical crushing of the cereal grain to release the starch component
- heating and addition of water and enzymes for conversion into fermentable sugars
- fermentation of the mash using yeast, whereby the sugars are converted into ethanol
- distillation and rectification, i.e. concentration and cleaning the ethanol produced by the distillation by removing by-products
- drying (dehydration) of the ethanol.

When bioethanol is produced only using sugar syrup, stages 1 and 2 are not needed.

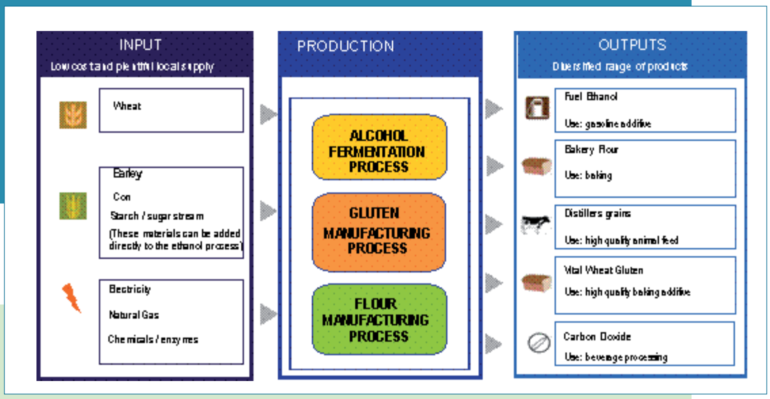


The energy efficiency of the production process in Zeitz is determined by energy use in successive production stages. An energy centre is part of the Zeitz plant, covering the plant's own energy requirement through highly-advanced cogeneration, achieving a very high energy yield, and also feeding electricity into the national grid. The Zeitz plant is located in of one of Germany's largest wheat-growing regions, in the immediate vicinity of one of the sugar factories operated by Südzucker AG. So it is exactly in the place where the raw materials required for production are to be obtained. The plant is very well connected to railway and road networks CropEnergies' research and development concentrates not only on the optimisation of existing production processes but also on the development of technical concepts for new bioethanol plants. Additionally, CropEnergies is continually looking for new starting points for alternative applications for bioethanol, like fuel cells, to establish new and profitable markets.

Contact: CropEnergies AG Gottlieb-Daimler-Str. 12, D-68165 Mannheim.
web: www.cropenergies.com.

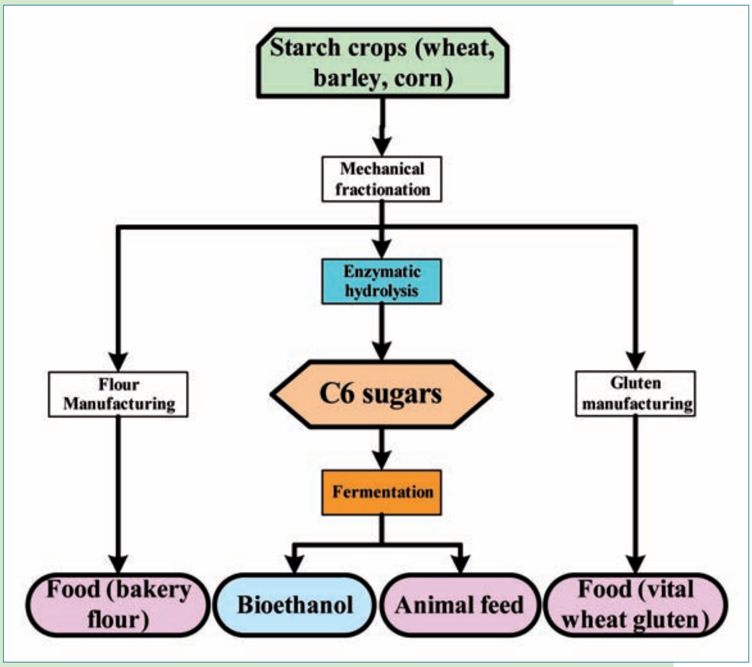
Permolex (Alberta, Canada)

Classification: C6 sugar biorefinery for bioethanol, animal feed and food from starch crops
State-of-the-art: Commercial
Owner: Permolex International, L.P.
Feedstocks: wheat
Products: bioethanol, anmal feed, food (bakery flour, gluten)



Permolex Ltd. operates a unique value-added grain fractionation facility located in Red Deer, Alberta, Canada. The facility is the first of its kind in North America, using feed grade wheat in its initial stages of production. The plant's design incorporates leading edge technologies and processes to capitalize on the benefits of integration of three traditionally independent manufacturing processes, namely a flour mill, a gluten plant and an ethanol plant. The integration allows the by-products of one process to be utilized as feedstock for the next process. The milling and processing equipment used within the plant is of a world class standard and was built by experienced designers and contractors, incorporating technology used in facilities in the United States and Europe. In addition, the facility has incorporated a co-generation plant to produce the electricity and steam required in the various processes.

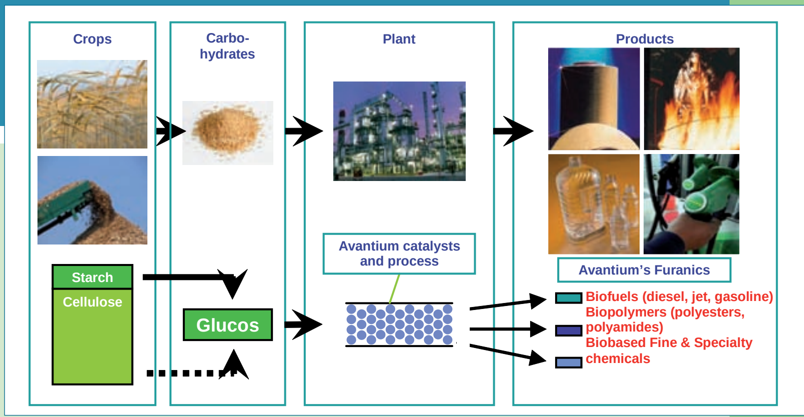
Permolex's first ethanol plant was completed in 1998 in Red Deer, Alberta. Using the wet mill process the facility produces high quality fuel grade ethanol. Ethanol has been proven to reduce green house gas emissions substantially when mixed with gasoline. New innovations in the industry are using ethanol mixed with diesel to further impact the green house gas emissions from the transportation industry, one of the primary causes of green house gas emissions.The facility produces bakery flour, vital wheat gluten, fuel grade ethanol and livestock feed. It also has the potential to produce higher protein vital wheat gluten as well as other grades of ethanol, and the remaining by-products can be further processed to produce incremental revenue streams.



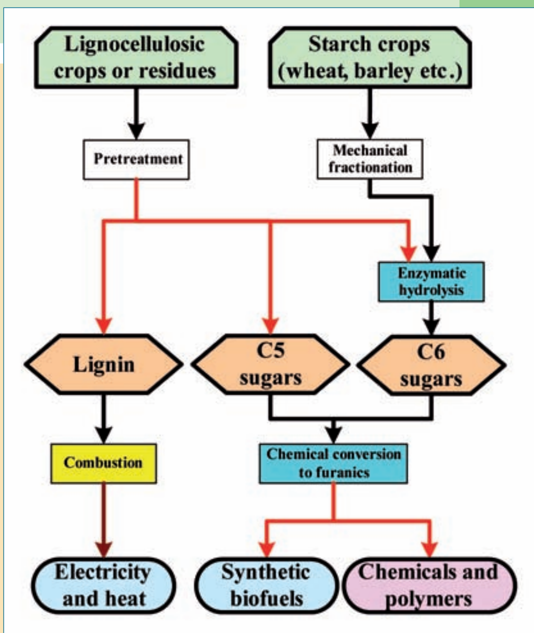
Contact: 8010 Edgar Industrial Cres.,Red Deer, Ab, Canada. Tel: (403) 347 7557, fax: (403) 346-2662, web: www.permolex.com

Avantium Furanics (the Netherlands)

Classification: C6/C5 sugars and lignin biorefinery for synthetic biofuels, chemicals and polymers, and electricity and heat from starch crops or lignocellulosic crops or residues
State-of-the-art: Concept
Owner: Avantium Technologies B.V
Feedstocks: Cellulose, hemi-cellulose, starch, sucrose
Products: Synthetic biofuels, chemicals and polymers (furan dicarboxylic acid, furan diamine organic acids, solvents, flavors & fragrances), electricity and heat
Stakeholders: Private equity funds, raw material suppliers, application developers



The Furanics process integrates the production of biofuels, biopolymers and fine & specialty chemicals with production of power, heat and hydrogen in a power or gasification plant. Furan derivatives, obtained by catalytic dehydration/etherification of carbohydrates, can serve as substitutes for petroleum-based building blocks used in production of fuels, plastics and fine chemicals. Integration with a Combined Heat & Power (CHP) or gasification plant will ensure efficient use of solid residues (lignin & humins) by co-firing with coal or biomass, thus enabling cost-effective use of excess steam and heat from the power plant. The technology which has been demonstrated at R&D level, can be used to refine biomass streams such as food processing waste, corn stover, grass, bagasse, household waste, etc. Pilot installations are planned for 2009.

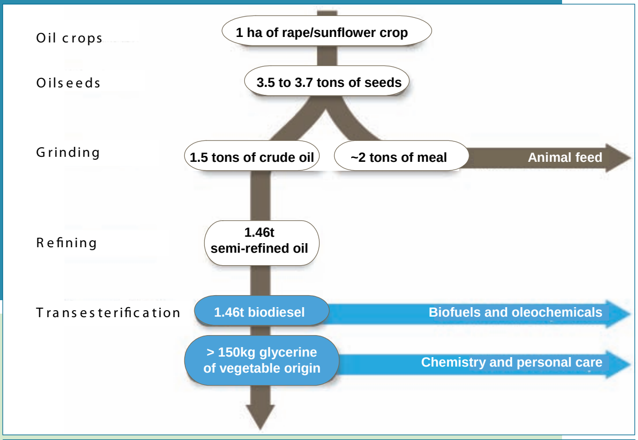


Furanics are an excellent example of the essential role of chemistry, chemical catalysis, thermal processing and engineering in the conversion of sugars and lignocellulosic biomass into biofuels, biopolymers, fine and specialty chemicals. Furanic biofuels are tailor-made and similar to current petroleum-derived fuels w.r.t. melting & boiling points, vapor pressure, energy content, miscibility, engine behavior. Existing infrastructure (e.g. pipelines, engines) can be used without adjustments and Furanics biorefineries can be integrated into existing petroleum refineries. Furanic production is done at higher temperatures, allowing faster conversion reactions in smaller reactors, with a positive water balance (250 g per kg dry biomass). The heterogeneous catalysts used are inherently recyclable. To conclude, the combined use of C5 and C6 sugars, the higher reaction rates and the smaller process footprints can lower biofuel and biopolymer costs in comparison to current pathways to produce ethanol, butanol, 1,3-propanediol and lactate.

Contact: web: www.avantium.com, e-mail: info@avantium.com

Sofiproteol (France)

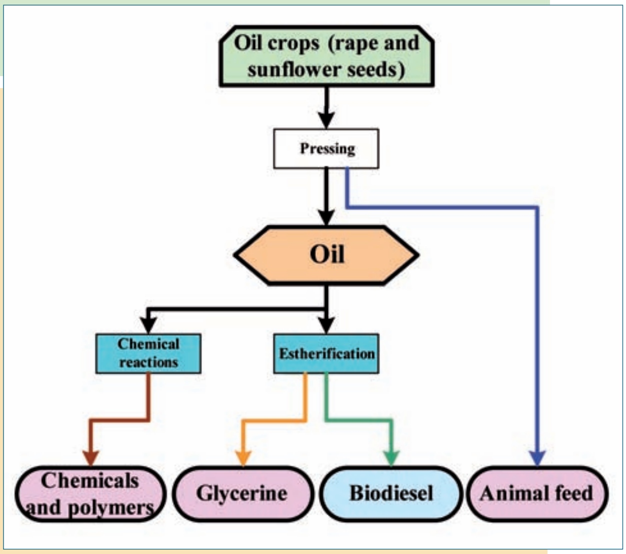
Classification: (Bio)oil biorefinery for biodiesel, glycerine, animal feed, chemicals and polymers from oil crops
State-of-the-art: Commercial
Owner: SOFIPROTEOL subsidiaries
Feedstocks: Rape, sunflower oilseed
Products: Biodiesel, glycerine, chemicals and polymers (coatings, biolubricants, biopolymers), animal feed
Stakeholders: Private equity funds, raw material suppliers, application developers



Main biorefinery products and processes from rape crop.

The SOFIPROTEOL group showcases a well structured integrated network of biorefineries centred around the transformation of 4.1 million tons a year of oilseeds (rape/sunflower) to:

- 2.5 million tons of biodiesel, through its Diester Industrie subsidiary's 11 sites across Europe, and obtained by chemical transesterification of refined rapeseed/sunflower seed oils with methanol
- 250 000 tons of glycerine, crude or refined from animal feed grade to pharmaceutical grade
- 2.3 million tons of oilseed meal used as a source of protein in animal feed.



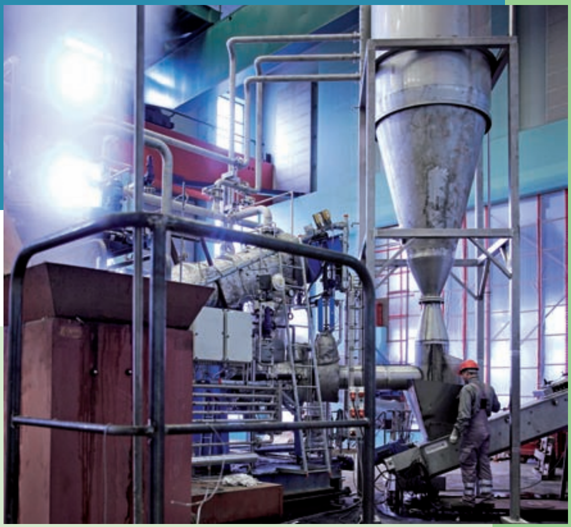
In parallel, the SOFIPROTEOL group expands the biorefinery concept to develop oil crop based products to serve the needs of both food (LESIEUR) and oleochemicals (NOVANCE, OLEON) market sectors. Tightening legal requirements for non-food applications and consumer demand have justified the development of speciality oleochemicals, with production capacity in 2007 standing at 50 000 tons a year to offer a comprehensive portfolio of oleochemical ingredients for a wide range of consumer and industrial end markets. Bioproducts are developed from the production of biodiesel, which generates glycerine, rape and sunflower seed oil medium chain fatty acid methyl esters. The facilities include 3 to 40 m^3 reactors using technologies of esterification, amidation, condensation and polymerisation to cater for a diverse range of applications such as

- Biopolymers, Coatings: vegetable based alkyd resins meeting low VOC tightening specifications and building blocks leading to biodegradable polymers
- Biolubricants: ecolabelled formulations for the automotive and industrial markets linking environmental concerns and performance
- Crop care, biosolvents: formulation aides, adjuvants and biosolvents leading to emulsions for herbicides, fungicides and insecticides with reduced environmental impact
- Chemical Intermediates: integrated production of intermediates by transformation of glycerine and/or fatty acids (e.g. oleic acid) by chemical or bio transformations.

Contact: Sofiprotéol, R&D, 12, Avenue George V – 75008 Paris. web: www.prolea.com

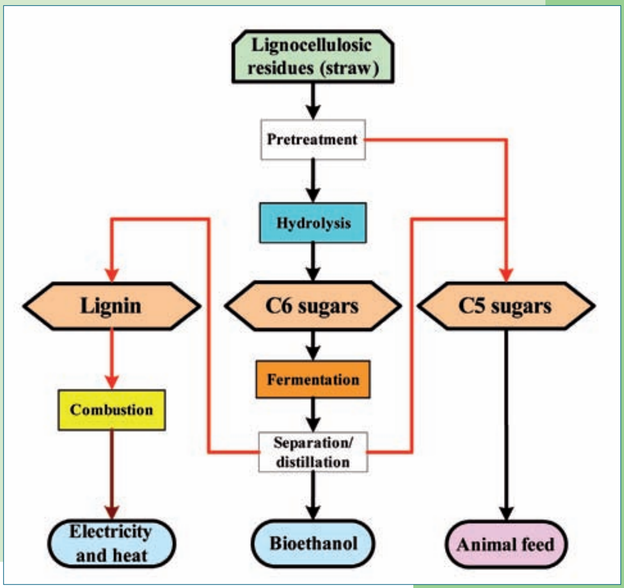
Inbicon IBUS (Denmark)

Classification: C6/C5 sugars and lignin biorefinery for bioethanol, animal feed, electricity and heat from lignocellulosic residues
State-of-the-art: Pilot
Owner: Inbicon A/S (subsidiary of DONG Energy A/S)
Feedstocks: Straw
Products: Bioethanol, animal feed (molasses with hemicellulose sugars), lignin, electricity and heat



The Integrated Biomass Utilization System (IBUS) process integrates a bioethanol plant with an (existing) power plant. Pretreatment is based on a hydro-thermal process employing only water steam followed by enzymatic hydrolysis of the cellulose rich fibres and fermented to ethanol by yeast. Pentose sugars are not necessarily fermentation to ethanol but all liquid streams are combined to give a sugar (hemicelluloses) and mineral rich product, which can be used as animal feed. Integration with the power plant ensures efficient use of solid residues (lignin) by co-firing with coal or biomass and enables cost-effective use of excess steam and heat from the power plant in the bioethanol plant. Lignin could also be pelletised and used as solid fuel elsewhere. The technology was originally developed to convert straw into bioethanol, animal feed and solid biofuel, but can be adapted to other types of biomass such as corn stover, grasses, bagasse, household waste, etc. It has been demonstrated at pilot scale. Key features of the IBUS process are:

- High dry-matter content in all process streams (20 – 40 %)
- Simple process based on hot water and enzymes
- Unique liquefaction technology and hydrolysis at high dry-matter energy conservation by integration with power plant.



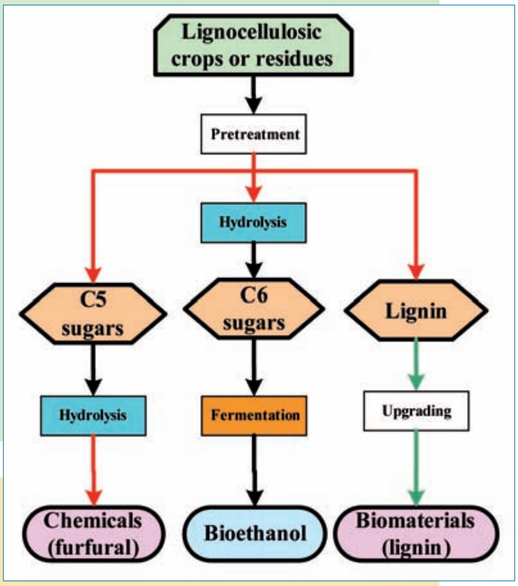
Promising continuous and energy-efficient technology for pretreatment and liquefaction of lignocellulosic biomass has been applied for a number of years. Feasibility studies show that the production price for bioethanol is close to the world market price. A demonstration plant applying the IBUS technology is under construction in the port of Kalundborg. Its capacity will be 100 tonnes of straw per day producing 4300 tonnes of ethanol per year. The scheduled start-up is autumn 2009.

Contact: Kraftværksvej 53, DK-7000 Fredericia, Denmark. web: www.inbicon.com

Lignol (Canada)

Classification: C6/C5 sugars and lignin biorefinery for bioethanol, chemicals and biomaterials from lignocellulosic crops or residues
State-of-the-art: Fully-integrated, continuous process pilot plant
Owner: Lignol Innovations Ltd., (subsidiary of Lignol Energy Corporation)
Feedstocks: Softwood, hardwood, annual fibers, agri-residuals
Products: Bioethanol, chemicals (furfural) and biomaterials (HP-L™ High Purity lignin)
Stakeholders: Partially supported by Sustainable Development Technology Canada (SDTC)

The Lignol technology is based on an ethanol-based organosolv process acquired from Repap Enterprises. This process has been substantially improved, now being directed towards production of fuel ethanol, HP-L™ (High Purity) lignin and valuable co-products such as furfural and wood extractives. The pre-treatment process has been integrated with enzymatic saccharification and fermentation of cellulose. The process can also be directed to production of cellulosic fibers and cellulose derivatives that can serve a number of markets. Lignol's process technology works effectively on biomass materials like hardwood, softwood, agricultural residues and energy crops. Lignol recently established a Cellulosic Ethanol Development Centre in Burnaby (Vancouver). A $10 million continuous pilot plant, to process up to 1 tonne of biomass per day, is in the final stage of commissioning. The process, which includes all stages of cellulose ethanol production, has a substantial advance on existing technology applied in the Alcell demonstration plant in New Brunswick. Lignol collaborates with industrial partners and government agencies to accelerate technology commercialization. Sustainable Development Technology Canada (SDTC) has provided financial support for the construction of a pilot plant. Recently, an agreement was signed with the US Department of Energy (DOE) for support of up to US$30 million for the construction of a commercial demonstration plant. This plant, which is being planned with Suncor Energy of Grand Junction (Colorado) has a nominal input capacity of 100 tonnes per day.



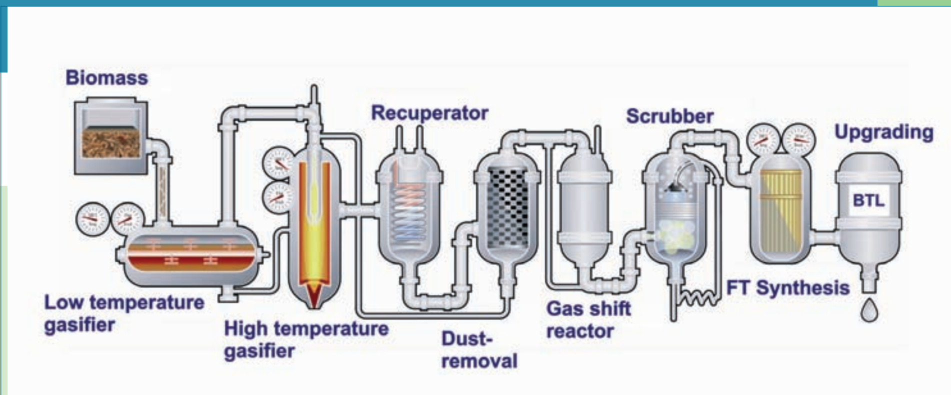
The Lignol biorefinery technology advantages include;

- Multiple revenue streams resulting in substantially better economic returns
- Potential to deploy smaller scale commercial plants which can reduce overall capital cost and risks associated with feedstock logistics/delivery
- Lignin extraction results in a relatively pure cellulose stream for saccharification which results in reduced enzyme costs
- Flexibility to process feedstocks like hardwood, softwood and annual fibers
- Environmentally attractive due to use of non-food lignocellulosic feedstocks and fossil displacement by lignin.

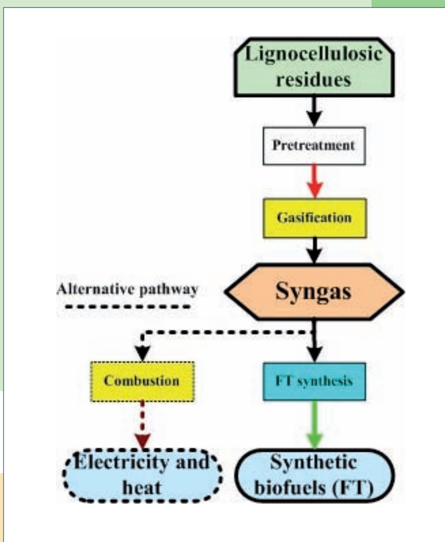
Contact: Info at web: www.lignol.ca

CHOREN (Germany)

Classification: Syngas biorefinery for synthetic biofuels (or electricity and heat) from lignocellulosic residues
State-of-the-art: Demonstration
Owner: Private investors, Shell Deutschland Oil GmbH, Volkswagen AG, Daimler AG
Feedstocks: Woody biomass
Products: synthetic biofuels (BTL diesel, BTL naphta) or electricity and heat
Stakeholders: Agriculture, forestry, chemistry, transport sectors



The center-piece of the technology is the patented Carbo-V process that allows the production of tar-free synthetic gas, a breakthrough for biomass to energy conversion. The gas consisting primarily of CO and H_2 can be used as a combustion gas for the generation of electricity, steam or heat, or for the manufacture of transport fuels (BTL). Compared to fossil diesel, the combustion of BTL diesel reduces particulate emissions (soot) by 30 to 50 % and hydrocarbon emissions by up to 90 %. It achieves superior combustion characteristics while no engine modifications are needed. But perhaps its most important attribute is the ability to recycle atmospheric CO_2 into the fuel thus closing the sustainability cycle. The first BTL production plant, the so called Beta plant, is being commissioned in Freiberg. Initially, its feedstock will mainly consist of residue wood from wood processing industry and recycled wood. Plans for supplies of dedicated biomass will be prepared. In the long term, however, biomass will increasingly come from short rotation plantations where fast-growing tree species like willow and poplar are cultivated. This limits the need for imported biomass and drastically reduces transportation costs. Gasification of biomass combined with heat and power generation is an real alternative to conventional wood-burning heat power stations with steam generators, particularly at the lower end of the output scale.

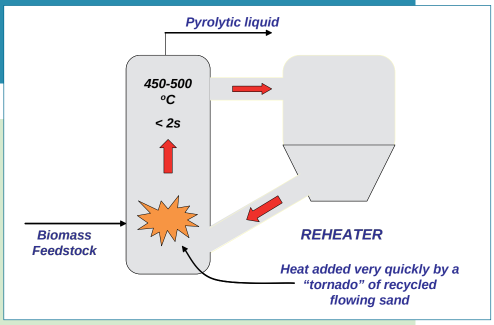


Annual capacity of the Beta plant is 18 million litres of BTL generated from 65,000 tons of wood, leading to CO_2 savings of up to 89%. It is run by a work force of 70 persons. The Sigma plant will employ some 200 personnel, producing 270 million litres of BTL from 1 million wood.

Contact: CHOREN Industries GmbH, Frauensteiner Strasse 59, 09599 Freiberg/Germany.
Tel: +49 (0)3731 26 62-0, fax: +49 (0)3731 26 62-25, e–mail: info@choren.com; web: www.choren.com

Ensyn (Ontario, Canada)

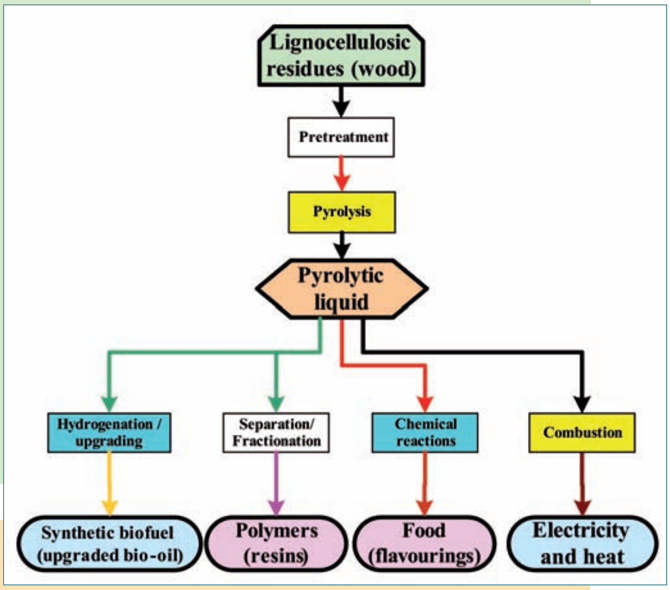
Classification: Pyrolytic liquid biorefinery for food flavourings, polymers, fuels and heat from lignocellulosic residue
State-of-the-art: Commercial
Owner: Ensyn
Feedstocks: Residual woody biomass from a hardwood flooring plant and sawmill
Products: food (flavourings), polymers (resins), heat, electricity plus (in the future) synthetic biofuels (upgraded bio-oil).



Rapid Thermal Processing (RTP)™ technology is a fast thermal process where biomass is rapidly heated in the absence of oxygen. The biomass is vapourized and rapidly cooled to generate high yields of pyrolysis oil. The process utilizes a circulating transported fluidized bed reactor system. RTP™ typically yields 65 to 75wt% pyrolysis oil from dried woody biomass. The resulting char and gases are used for process energy. Ensyn's commercial facility in Renfrew processes 100 dry tonnes per day of wood residue. The pyrolysis oil is fractionated into chemicals for engineered wood products (resins) and fuel for thermal applications, and, at a separate facility, into food flavourings. Ensyn has built and services 6 other commercial facilities in the US that generate products for the food and chemicals sectors.

The RTP™ process offers several unique benefits:

- Rapid conversion of bulky, low density solid biomass into a transportable liquid
- Minimalization of utilities and infrastructure requirements, making it ideal for both remote and existing industrial facilities
- Highly scalable to meet the needs of diverse applications
- Designs up to 1,000 metric tonnes per day can be developed
- Easy implementation due to small footprint and compact, modular construction
- Processing a wide range of feedstocks.



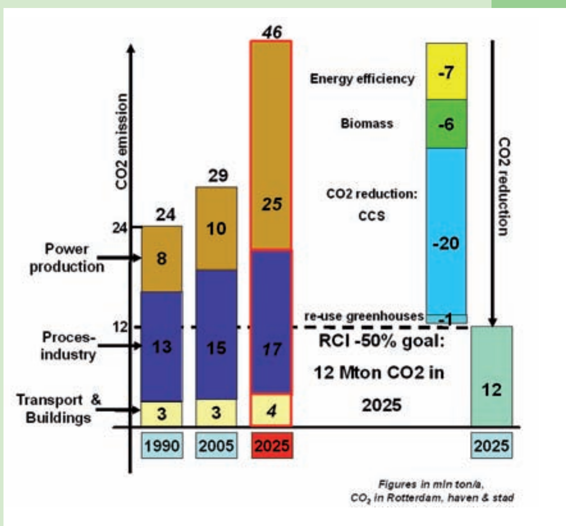
In September 2008, UOP LLC and Ensyn announced that they will form a joint venture company that will offer new technologies and build plants that will produce energy products such as heating oil, marine fuels, and "drop in" transportation fuels from lignocellulosic biomass, such as straw, corn stover corn stover, forestry residuals, and woody demolition materials. Pyrolysis liquid will be generated using Ensyn's RTP™ technology. This liquid will be upgraded using UOP technology to first produce marine oils and better heating fuels, and, by 2011, to produce green gasoline, green diesel and green jet fuel that are completely competitive to existing fuel infrastructure. The facilities, expected to be in the order of 1,000 to 1,500 dry metric tonnes in size, will be located where large amounts of residual biomass are available.

Contact: Randal Goodfellow, Ensyn. web: www.ensyn.com or e-mail: renewables@uop.com for info on the UOP/Ensyn Joint Venture

European Bio-Hub Rotterdam (the Netherlands)

Classification: Syngas platform biorefinery for fuels and chemicals from imported lignocellulosic biomass. C5/C6 sugar, lignin and protein platform biorefinery for feed, chemicals and fuels from biofuel process residues
State-of-the-art: Demonstration
Owner: Government, industry, NGOs, public
Feedstocks: Lignocellulosic biomass (densified raw biomass, intermediates, agroresidues)
Products: Base-chemicals, biofuels, (CH)P
Stakeholders: Government, industry, NGOs, general public

The Rotterdam Climate Initiative is the new ambitious climate programme in which the Municipality of Rotterdam, the Port of Rotterdam, DCMR Environmental Protection Agency Rijnmond, and Deltalinqs join forces to achieve a drastic reduction in Rotterdam's CO_2 emission. The growth of the city and the port in the coming years will significantly contribute to this goal. The Rotterdam Climate Initiative combines all of the initiatives taken by Rotterdam – the city as well as the port – to develop into a low-CO_2 city and energy port; the world capital of CO_2-free energy. With this initiative, Rotterdam expresses its ambition to reduce CO_2 emissions in Rotterdam territory by fifty per cent in 2025 as compared with 1990, and to create economic opportunities with respect to CO_2 for trade, industry and the port. In this context we find one of the major challenges for the Rotterdam harbour area is to become the Bio-Hub for Europe, importing both densified biomass and biomass-derived intermediates, giving added-value to these materials in existing and new facilities in the harbour area, and transport them throughout Europe to fulfill both the demands within the Netherlands and Europe.



Besides biofuel production facilities, great opportunities arise for facilities that valorize residues of biobased industries. That is why the Innovation Platform BioPort Rotterdam has focused on demonstration of new technologies in new combinations of value chains.

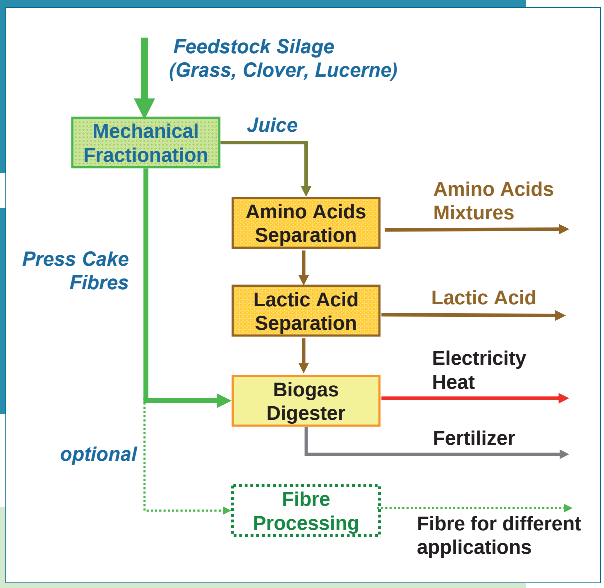
In the Netherlands in 2009 the Dutch Biorefinery Initiative (DBI) – a biorefinery-based research, development and demonstration programme, initiated by both WUR and ECN, and subsidised by the Dutch government, will start. As part of this programme it is intended to set-up integrated lignocellulosic feedstock demonstration facilities in the harbour area. Potential demonstration facilities that will be realised within this framework are (i) a 10 MWth entrained-flow gasification based syngas production platform for the co-production of base chemicals, biofuels (BtL) and power, and (ii) food and biofuel production residues (composition: lignocellulose, pectin, hemicellulose, minerals, proteins) valorization facilities co-producing proteins/amino-acids/chemicals, bioethanol and biogas (CHP).

Contact: RCI, Jan van der Zande: j.van.der.zande@portofrotterdam.com. Tel: +31-10-2521629.
Syngas: Herman den Uil, denuil@ecn.nl; residue valorization: Johan Sanders, johan.sanders@wur.nl

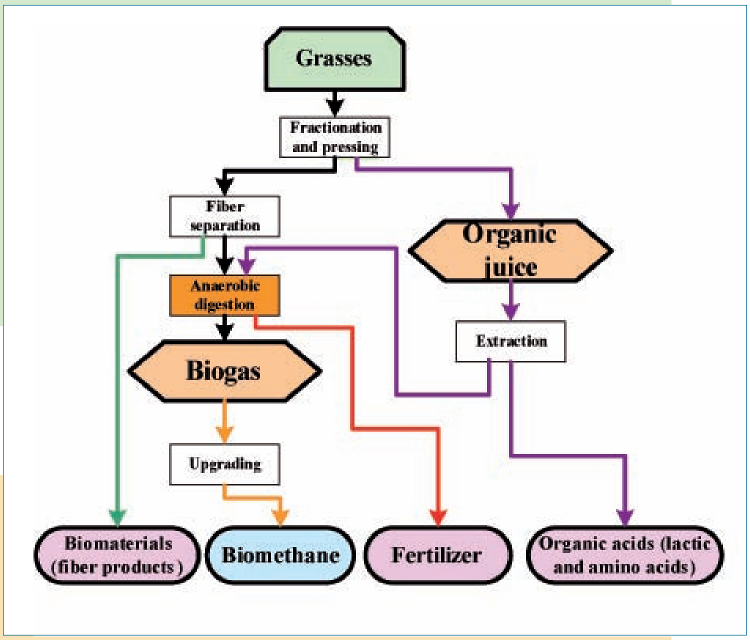
Green Biorefinery (Austria)

Classification: Biogas and organic solution biorefinery for organic acids, fertilizer, biomaterials, biomethane and electricity and heat from grasses
State-of-the-art: Demonstration
Owner: OÖ Bioraffinerie Forschung und Entwicklung GmbH.
Feedstocks: Mixtures of grass, clover, lucerne silage
Products: Organic acids (lactic and amino acids), biomaterials (fibres oproducts), fertilizer, biomethane or electricity and heat
Stakeholders: Regional government of Upper Austria, Austrian Federal Ministry of Transport, innovation, and Technology (funding programme "Factory of Tomorrow"), Energie AG Oberösterreich, OÖ Ferngas AG, Rohöl Aufsuchungs AG, Linz AG, Energy Institute at the Johannes Kepler University Linz

The OÖ Biorefinery R&D GmbH will build the demonstration plant and operate it conjointly with the involved technology developers Bioref SYS and Joanneum Research.



Out of the silage feedstock a liquid fraction is generated which is rich in lactic acid and amino acids. These two key products are being separated out of the juice and purified to marketable qualities. The solid press cake and all liquid residues are used for running an anaerobic digester producing biogas and consequently renewable energy. The demo plant is in operation since Nov. 2008 and built next to an existing biogas digester in Utzenaich (Upper Austria).

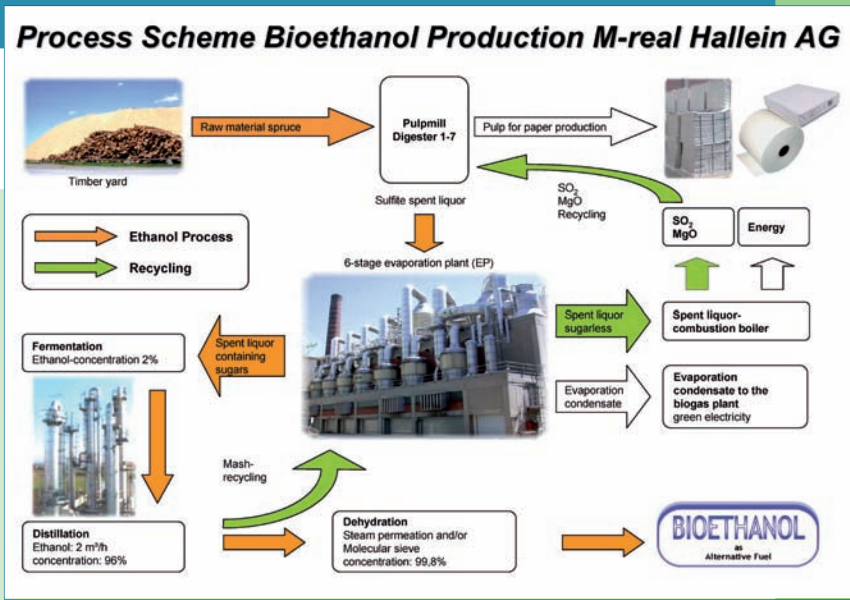


Lactic acid is an interesting building block for chemicals; amino acids mixtures out of grass hold all essential amino acids.

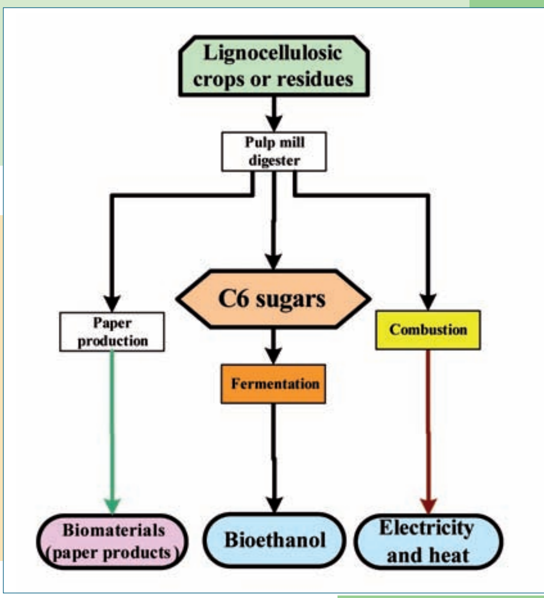
Contact: Dr. Horst Steinmüller, steinmueller@energieinstitut-linz.at
Tel: +43 702 4685656, fax +43 702 4685651, web: www.energieinstitut-linz.at

M-real, Hallein AG (Austria)

Classification: C6 sugars biorefinery for bioethanol, biomaterials, electricity and heat from lignocellulosic crops or residues
State-of-the-art: Conceptual
Owner: M-real Hallein AG, 5400 Hallein, Austria
Feedstocks: Spruce wood
Products: bioethanol, biomaterials (paper products), electricity and heat
Stakeholders: M-real Hallein AG



Pulp for the paper mill is produced by cooking spruce chips with acidic magnesium bisulfite cooking liquor. After concentration of the sulfite spent liquor (SSL) in the evaporation plant it is incinerated in the combustion boiler to produce steam and electricity, whereas magnesium oxide and sulfur dioxide are recycled to produce new cooking liquor. The concept for the production of ethanol is to ferment the wood sugars from SSL and to distil off the ethanol in the distillation plant. Afterwards the 96% ethanol is dehydrated by molecular sieves to get water free absolute ethanol. The mash will be recycled as has been described above.



Ethanol from SSL is a by-product of pulp production from wood and therefore reneweable and sustainable. Hence the ethanol is from high quality according European Pharmacopeia it can be used for technical and speciality purposes in industry or can be used as a 2nd generation fuel after blending with petrol to E85 “Bioethanol”. Studies showed that an ethanol plant would perfectly supplement the pulp and paper mill in Hallein – a future biorefinery.

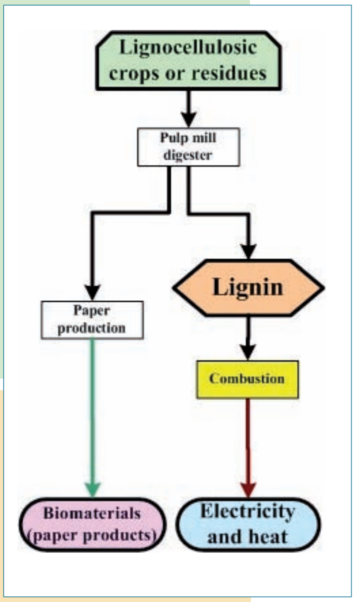
Contact: Dr. Fritz Struber, M-real Hallein AG, Salzachtalstrasse 88, A-5400 Hallein, Austria.
Tel: +43 (0) 6245 890 432, fax: +43 (0) 6245 890 558, Mobile: +43 (0) 664 6208 432
fritz.struber@m-real.com, web: www.m-real.com

Zellstoff Stendal GmbH (Germany)

Classification: Lignin biorefinery for biomaterials, electricity and heat from lignocellulosic crops or residues
State-of-the-art: Commercial
Owner: Mercer International Inc
Feedstocks: Softwood, small logs, sawmill chips
Products: biomaterials (paper products), electricity and heat
Stakeholders: Sustainable forestry, sawmill chip producers, recycled paper manufacturers, white biotechnology and bioenergy sector

Zellstoff Stendal GmbH is one of the largest and most advanced producers of virgin fibre in Europe, generating an annual output of some 620,000 tons of pulp for printing and tissue paper production. The fibres are predominantly used for reinforcement purposes to sustain minimum strength requirements in recycled paper production. The plant consists of a fibre line and a recovery plant, completed by numerous ancillary serving departments. Low quality pulpwood-logs are debarked and chipped, before being mixed with sawmill chips and being chemically digested using heat, pressure and a cooking liquor made up from sodium hydroxide (NaOH) and sodium sulphide (Na_2S). Lignin, wood's 'intercellular cement', is decomposed in order to produce separate, flexible cellulosic fibres which can be screened and bleached. The pulp is then formed into a endless web to allow for drying, sheet cutting and baling, before it will be ready for shipment to paper plants predominantly in Germany and Europe. Malodouros, sulphur (H_2S) smelling gases that are being formed during the pulping process are intensively collected and led to specially equipped high temperature furnaces for destruction. This in combination with high performance water purification processes is essential for the mill's leading environmental performance.

Chemicals used in the pulping process are captured together with the lignin (some 30% of wood mass) in the spent or black liquor. Once concentrated this liquor is fully recovered in a thermal process, where lignin is combusted for bioenergy generation, whilst the chemical components are transformed into the initial status. Thus, a practically closed chemical circuit is obtained, while the generated bioenergy allows export of surplus bioelectricity beyond the mill's own needs. In addition, part of the wide range of chemical components contained in natural (soft)wood is captured the recovery process, allowing Zellstoff Stendal to produce substantial amounts of tall oil (from tree resins), turpentine as well as natural MeOH (from the cellulose's methoxyl groups). Additional products may in the future be refined from the range of natural substances contained in natural wood, suited to replace mineral oil based chemicals and products.



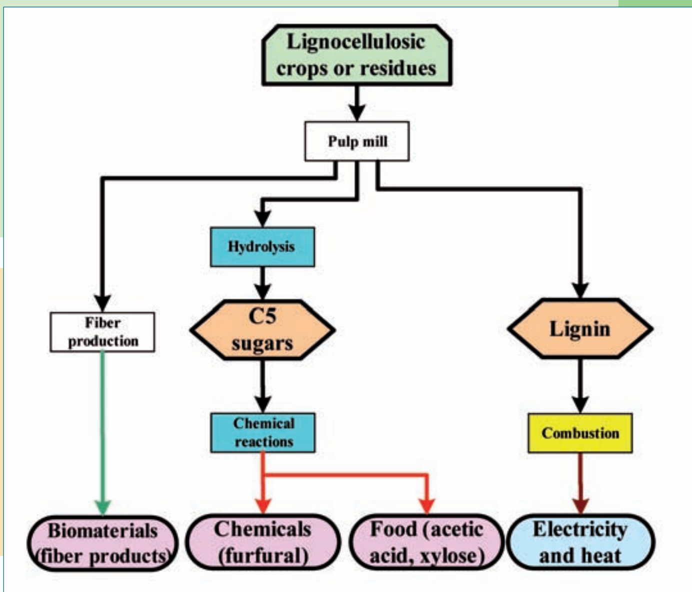
Non-fibrous wood components, lignin, are today thermally converted in two modern steam generating furnaces, ultimately feeding what is the largest bioenergy turbine on the European continent (100 MW_e). Except for marginal amounts of natural gas the whole operation is not only energy self sufficient, but does also provide some 35 MW_e of surplus electric energy that is supplied to the public grid. The pulping process allows a combined-heat-power (CHP) efficiency well beyond 70% percent, an unprecedented high performance when compared with many other biomass based energy processes. Due to the selective use of woody biomass - fibrous vs energetic and biochemical - this modern pulp mill can be viewed as nowadays largest existing biorefinery facility in operation.

Contact: Zellstoff Stendal GmbHD-39596 Arneburg. web: www.zellstoff-stendal.de, e-mail: info@zellstoff-stendal.de.

Lenzing AG (Austria)

Classification: C5 sugars and lignin biorefinery for biomaterials, chemicals, food, electricity and heat from lignocellulosic crops or residues
State-of-the-art: Running/commercial
Owner: Lenzing AG, 4860 Lenzing, Austria
Feedstocks: Beech wood
Products: Food (food grade acetic acid, xylose-based artificial sweetener), chemicals (furfural), biomaterials (cellulose fibres), electricity and heat
Stakeholders: Lenzing AG, Danisco Sweeteners

The major product from acidic Mg-sulphite cooking is dissolving pulp, which is directly used for the production of man-made cellulose fibres. It allows a more efficient utilisation of the wood by producing fine chemicals from the hemicellulose fraction. The consumption of the energy surplus from the combustion of the process lyes (mainly lignosulphonates) makes Lenzing largely independent of fossil fuels (86% of Lenzing's energy demand is covered by biogenic fuels).



The wood refinery in Lenzing has been in operation for about two decades and has significantly reduced the waste water burden. The separation and utilisation of the remaining wood ingredients from process streams other than the established still present a technical and economic challenge.

Contact: Angelika Guldt, Lenzing AG, Corporate Communications.
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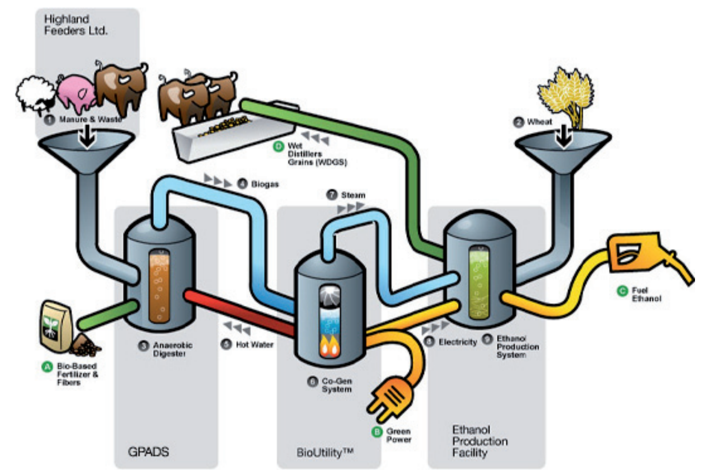
e-mail: a.guldt@lenzing.com, web: www.lenzing.com

Highmark Renewables (Canada)

Classification: C6 sugars and biogas biorefinery for bioethanol, animal feed, fertilizer, electricity and heat from starch crops and organic residues
State-of-the-art: Commercial
Owner: Highmark Renewables
Feedstocks: Wheat, manure, slaughtering waste
Products: Bioethanol, amimal feed, fertilizer, electricity and heat



Integrated BioRefinery™ Overview
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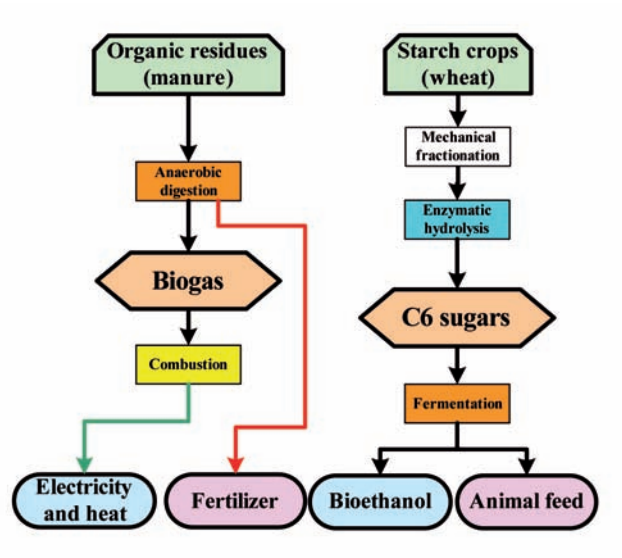
Highmark Renewables is developing the first Integrated BioRefinery™ in Canada. Their unique process converts grain (e.g. high-starch wheat) into fuel ethanol. The residual, distillers grains, is fed to cattle at a nearby feedlot. Cattle manure is used to generate biogas, which is converted to electricity and steam in a BioUtility process. The highly integrated process is targeted for the most cost and energy efficient production of fuel ethanol. The Integrated BioRefinery™ once it is in full production, will generate 40 million litres of ethanol, 10 thousand tonnes of BioFertilizer, and over 75 thousand tonnes of greenhouse gas emissions credits each year. Agricultural and food industry residues, often thought of as wastes, are converted into valuable energy and other renewable products. Highmark Renewables is proud of their technology development capability, technology portfolio, experience in developing enewable energy facilities, facility operation skills and world-class management team.

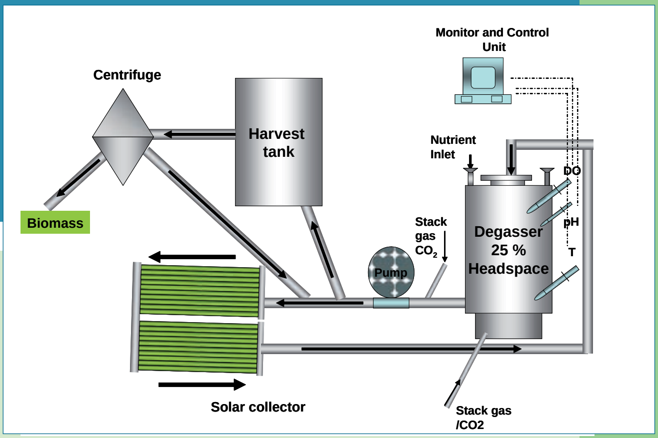


Highmark Renewables, a designer and operator of renewable energy facilities, developed the Growing Power Anaerobic Digestion System (GPADS) which can derive energy from high-solids and fibrous organic wastes (manure, industrial residues and municipal solid waste). After more than two years of operations, the system now can generate special value from tough to handle wastes. GPADS, our first large scale installation is the largest feedlot manure - energy plant in the world. It processes about 15% of the manure from a 36,000 head feedlot which is managed by our partners Highland Feeders and the Spring Creek Ranch (producers of verified premium Alberta beef). GPADS, currently producing 20 tonnes of biofertilizer along with up to 24,000 kWh of electricity each day is expected to grow four times in size while its technology may in the future be applied elsewhere. Highmark Renewables vision is to generate the maximum return on available resources with minimal risks.

Contact: Highmark Renewables, Vegreville, Alberta, Canada.
e-mail: projects@highmark.ca

WUR Micro-algae Biorefinery (the Netherlands)

Classification: Oil and organic solution biorefinery for base-chemicals, biodiesel, power and/or heat from micro-algae
State-of-the-art: Fundamental and applied research, pilot-scale
Owner: Consortium of industrial partners and WUR-AFSG
Feedstocks: Micro-algae
Products: base-chemicals, bio-fuels, (CH)power
Stakeholders: Wageningen University and Research Centre (WUR) – Agrotechnology and Food Sciences Group (AFSG), The Netherlands, AkzoNobel, Ingrepo, Essent



Phototrophic algae use solar energy for photosythesis to bind CO_2 for the production of biomass and useful components, such as oil, food and feed ingredients. Of special importance is the high biomass production capacity of some algae of probably between 20 - 50 tons of dry matter per hectare per year, making this crop even superior to e.g. beet and potato. Algal systems so far have been studied in order to derive biofuels (i.e. biodiesel) or very high added-value food and pharmaceutical components.
Within the Dutch *AlgiCoat* initiative – a project supported by the Dutch Ministry of Economic Affairs via the SenterNovem EOS-programme – a unique approach is made by developing an integral marine biorefinery chain with a focus on the fractionation of micro-algae into base-chemicals, biodiesel, and (CH)Power. AkzoNobel could use more than 200,000 tonnes per year of sustainable base-chemicals produced from algae for its production of coatings and surface active agents. As base-chemicals are higher priced than biofuels on the one hand, and large market volumes on the other hand, the co-production of these base-chemicals with the biofuels acts very favourably on the overall of economics of algal production, harvesting and processing systems. Within this project AkzoNobel and Essent have built a small demonstration plant at the Chemie Park in Delfzijl, the Netherlands, showing that algal systems can be used for the co-production of base-chemicals, biofuels and heat/power production. The related R&D activities within the project – performed by both WUR-AFSG and Ingrepo – are mandatory to generate the technological breakthroughs required for full-scale economic operation.

In the Netherlands in 2009 the Butch Biorefinery Initiative (DBI) - a biorefinery-based research, development and demonstration programme, initiated by both WUR and ECN, and subsidised by the Dutch government, will start. As part of this programme it is intended to set-up an integrated biorefinery pilot-facility in Wageningen, the Netherlands, for the cultivation and fractioning of micro-algae. This pilot-facility will be used to apply the fundamental knowledge being developed in the parallel R&D-programme, including a.o.: strain development, bioprocess optimisation, and harvesting, dewatering and downstream processing technology development. The goal of the DBI related pilot-initiative is to demonstrate three modular upscalable commercial micro-algae based biorefeneries for the production of (i) biofuels and value-added co-products, (ii) aquaculture feed, including nutrient recycling and (iii) food and food ingredients and value-added co-products.

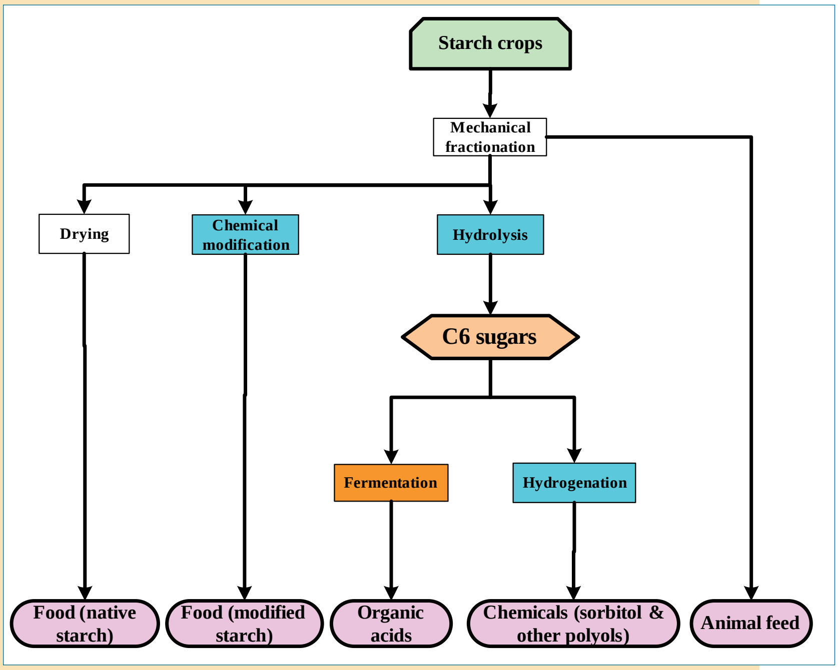
Contact: Hans Mooibroek, WUR-AFSG, project coordinator AlgiCoat. Tel: +31 317 480214
e-mail: hans.mooibroek@wur.nl; rené.wijfels@wur.nl, web: www.afsg.wur.nl, www.algae.wur

Roquette Frères (France)

Classification: C6 sugar biorefinery for starch, chemicals and animal feed from starch-rich crops
State-of-the-art: Commercial
Owner: 100% family Roquette owned firm
Feedstocks: maize, wheat, potatoes, peas and micro-algae
Products: food, feed, paper-board, pharmacy-cosmetology and biochemistry industries

The Roquette Group, with 30 establishments around the world including 18 production sites, employs over 6000 staff of which 3600 in France. Turnover in 2007 exceeded €2.5 billion. Roquette processes over six mln tonnes of renewable raw materials. Roquette is the world leading polyol manufacturer (sorbitol, mannitol, maltitol, etc.) and ranks among the leading injectable substance (dextrose essentially) manufacturers. It acquired a world class manufacturer of cationic starches for the papermaking industry, developing groundbreaking biopolymers to replace fossil and other classical chemicals. On the human nutrition front, Roquette is Europe's leading manufacturer of maltodextrins.

Keen to innovate, diversify, assert its independence and confirm its position of leader, the Roquette Group choose to develop two strategic axes: plant based chemistry and nutrition health. BioHub® and AlgoHub®, received subsidies from Oséo Innovation, a French innovation fund, investing over € 40 million a year in R&D and over 10% of turnover in facilities and equipment. Roquette is intent on raising the public's awareness of the need to develop bio-based products as a sustainable alternative to non renewable fossil fuel derivatives. It has embraced the US Department of Energy's drive to replace 25% of the chemical industry's fossil derived raw materials with plant-derived alternatives by 2030.This notion of plant chemistry blends seamlessly into the green chemistry agenda that aims to cut back or eliminate substances harmful for human beings or the environment. This explains the Group's move to develop research and innovation programs around two goals: (i) Developing new polymers with the GAÏAHUB® program; (ii) Developing new and primarily biotechnology derived molecules, with its BioHub® program. New BioHub® products are active and intermediate synthetic ingredients (biomonomers, biosolvents, bioplasticizers, biosequestering agents, etc.). Roquette is running the BioHub® program through a partnership with several industrial firms including a number of chemical companies. Over the past two years, the BioHub® program spawned demonstration plants manufacturing isosorbide and derivatives. It allied to DSM in 2008 to develop a new biotechnological manufacturing process for succinic acid, a biodegradable intermediate polymer used in agricultural films. A plant producing several hundred tons of succinic acid will be operational by the end of 2009.



Contact : Roquette Frères, 62080 France. Tel: +33(0)321633600, web: www.roquette.com
www.biohub.fr www.algohub-roquette.com

General comments

This brochure shows that, while biorefineries are already a commercial reality, they demonstrate immense potential for the nearby future. Political and economic considerations can influence the speed and extend of biorefinery implementation. In our opinion biorefinery thinking and application is an absolute necessity to come towards the sustainable co-production of Food, Feed, Chemicals, Materials, Fuels and (CH)Power, to feed the current and future Bio-based Economy.

Future outlook

Many additional biorefineries can be expected to be introduced in a variety of market sectors in the short term (up to 2013) by upgrading of existing industrial infrastructures. In this brochure several examples of these types of biorefineries are given. The new biorefinery concepts are still mostly in the R&D, pilot or small-scale demonstration phase, still far from commercialisation. These new biorefinery concepts are expected to be implemented into the market at the medium term (2013-2020). However, current economic conditions (low oil prices, credit crisis and recessions in part of the global economy) could severely slow down this market implementation.

For a successful market implementation of an integrated biorefinery concept, all composing process unit operations must be technically mature, and the full biomass-to-products chain must have no adverse environmental impacts and economically profitable. Except in cases where organic residues are used as feedstock, biomass production should be part of the development and implementation of integrated biorefinery concepts. Specific biomass crops are being developed to produce a maximum amount of products with a minimum amount of inputs (e.g. fertilizer, energy).

Because of the variety in biorefinery concepts and the variety in maturity of the composing sub processes, a financial support framework should be long term, extending from R&D activities, as well as for pilot-plant activities, demonstrations, and the development of deployment strategies.

Initiatives presented in this brochure follow the approach of what can be made from a given feedstock. An alternative approach may design chemicals and materials together with their production methods that fit the application of the product in a backward integrated (petro-) chemical industry. It is thought that while the resource based approach fits current (petro)chemical business and production models, the design approach will lead to a real transition in the area of the production and design of chemicals and materials. This backward integrated approach will be at first applicable in specialty chemical markets but there are also long term opportunities in bulk markets.

Current status of biorefineries in the participating countries

An overview of selected demo and pilot plants is given in Table II on page 23. All pilot plants and R&D-initiatives within the Task 42 Participating Countries have been published in the country reports presented on the website of the Task (http://www.iea-bioenergy.task42-biorefineries.com).

General SWOT analysis Biorefineries

The continued development of biorefineries will lead to the use of new feedstocks, higher conversion efficiencies, new technologies and co-products. Opportunities will inevitably arise in all areas of our present economies. Research and development will feed in rural economic development, new industrial areas and an opening in existing and newly created markets.

Developing technologies that are based on high yielding, low input feedstocks or wastes offer the hope to be even more sustainable. Biorefining is a technology that is dependant upon continued innovation presenting opportunities to all sectors. The building of a bio based economy has the capacity to not only move the world through present difficulties but will also result in industries with very small environmental footprints.
In this section we address the strengths, weaknesses, opportunities and threats of Biorefineries and indicate the role Task 42 can play to support the development of Biorefineries.

Table I: SWOT analysis on biorefinery

Strengths	**Weaknesses**
• Adding value to the use of biomass • Maximizing biomass conversion efficiency – minimizing raw material requirements • Production of a spectrum of bio-based products (food, feed, materials, chemicals) and bioenergy (fuels, power and/or heat) feeding the full Bio-based Economy • Strong Knowledge Infra Structure available to tackle both non-technical and technical issues potentially hindering the deployment trajectory • Biorefinery is not new, it builds on agriculture, food, and forestry industries	• Broad undefined and unclassified area • Involvement of stakeholders of different market sectors (agro, energy, chemical, ...) over full biomass value chain necessary • Most promising biorefinery processes/concepts not clear • Most promising biomass value chains, including current/future market volumes/prices, not clear • Studying and concept development instead of real market implementation • Variability of quality and energy density of biomass
Opportunities	**Threats**
• Biorefineries can make a significant contribution to sustainable development • Challenging national, European and global policy goals– international focus on sustainable use of biomass for the production of bioenergy • International consensus on the fact that the biomass availability is limited so that the raw materials should be used as efficiently as possible – i.e. development of multi-purpose biorefineries in a framework of scarce raw materials and energy • International development of a portfolio of biorefinery concepts, including composing technical processes • Strengthening of the economic position of various market sectors (e.g. agriculture, forestry, chemical and energy)	• Economic change and volatility in fossil fuel prices • Fast implementation of other renewable energy technologies feeding the market requests • Bio-based products and bioenergy are assessed to a higher standard than traditional products (no level playing field) • Availability and contractibility of raw materials (e.g. climate change, policies, logistics) • (High) investment capital for pilot and demo initiatives difficult to find, and existing industrial infrastructure is not depreciated yet • Changing governmental policies • Questioning of food/feed/fuels (land use competition) and sustainability of biomass production • Goals of end users often focused upon single product

Table II: Overview Biorefinery pilot and demo facilities in partner countries (selection)

Name	Feedstock	Products	Description (oa technology, capacity, status)	Classification	Info
Austria					
Green Biorefinery Upper Austria	Grass/clover/ lucerne silage	Amino acids mixtures, lactic acid, biogas, fertilizer	Separation of lactic and amino acid mixtures from silage juice by nano-filtration, electro dialysis and ion exchange). Biogas production from press cake; Demonstration scale (1t/h silage feed input)	Biogas and organic solution biorefinery	Dr. H. Steinmüller steinmueller@energieinstitut-linz.at; Dr. Michael Mandl michael.mandl@joanneum.at
Canada					
Iogen Corporation demonstration plant Ottawa	Straw	Cellulosic ethanol, electricity, lignin	Fractionation, enzymatic hydrolysis and ethanol fermentation since 2004. 30 t/d feedstock and 2 mln l/y of ethanol	C6/C5 sugars and lignin biorefinery for bioethanol and chemicals	www.iogen.ca/ info@logen.ca
Lignol Innovations Corporation pilot plant	Wood, straw	Cellulosic ethanol, lignin, acetic acid, furfural and xylose	Organosolv-based fractionation and hydrolysis, enzymatic saccharification and fermentation	C6/C5 sugars and lignin biorefinery for bioethanol, chemicals and biomaterials	www.lignol.ca/ info@lignol.ca
Enerkem Westbury Industrial Demonstration Plant	Decommissioned electrical poles, forest residues, selected MSW	Second generation ethanol, green chemicals: methanol, acetic acid and acetates	Gasification and catalytic synthesis Operating since 2009 Ethanol capacity of 5 million litres	Syngas biorefinery for second generation ethanol and green chemicals	www.enerkem.com westbury@enerkem.com
Enerkem Sherbrooke Pilot Plant and Research Facility	MSW, forest residues, straw, plastics, demolition wood, treated wood	Second-generation ethanol, syngas, and methanol	Gasification and catalytic synthesis Operating since 2003 Ethanol capacity of 475,000 litres	Syngas biorefinery for second generation ethanol and green chemicals	www.enerkem.com sherbrooke@enerkem.com
Syntec Biofuels Inc.	Wood, energy crops, agriculture residues	Ethanol, methanol, n-butanol and n-propanol	Gasification and catalytic synthesis and steam reforming – Syntac B2A technology	Syngas biorefinery for second generation ethanol and green chemicals	www.syntecbiofuel.com
Denmark					
Inbicon Pilot and Demo Facility	Straw and other agricultural residues	Ethanol, feed (C5-molasses), heat and power, solid biofuel	Pilot facility based on biochemical conversion since 2004. Input 1 t/h. Demonstration plant under construction (start-up 2009). Input 30,000 t, output 4,300 t/yr of ethanol	C6/C5 sugar and lignin platform biorefinery for bioethanol, feed, heat, power from lignocellulosic residues	www.inbicon.com miper@dongenergy.dk
Maxiflex Pilot Facility	Straw and other lignocellulosic residues	Ethanol, biogas, solid biofuel, fertilizer	Pilot facility based on biochemical conversion. Input 0.5 t/h and output 40 l/d of ethanol. Start-up 01.09.2009	C6/C5 sugar and lignin platform biorefinery for bioethanol, biogas, solid fuel and fertilizer from lignocellulosic residues	www.biogasol.com rsp@biogasol.com
France					
SICA Atlantique Demonstration Plant	Rapeseed, ethanol	FAEE	Fatty Acid Ethyl Esters demo plant (10 000 t/y), to be started - end of May		
Solvay Demonstration Plant	Glycerol	Epichlorhydrine	ECH production 10 000 t/y from biodiesel residue glycerol		
BioAmber (ARD-DNP) Demonstration Plant	Glucose	Succinic acid	To be started		www.bio-amber.com/
Futurol (Procethol 2G) R&D/Pilot Plant	Lignocellulose	Ethanol			
Germany					
CHOREN Industries GmbH, Freiberg	Wood	FT/BtL-biofuels	Carbo-V process, feedstock pre-treatment, gasification, FT-synthesis, BtL 15.000 t/a (sundiesel) demo plant	Wood-Biorefinery	Dr. Ines Bila www.Choren.de. Ines.Bilas@choren.com
Green Biorefinery Havelland	Alfalfa and wild mix grass	Valuable proteins, amino acids, lactic acid, fodder	Green biorefinery (30kt/yr): production of green juice for high valuable proteins and lactic acid, demo plant, scheduled in 2009	Green Biorefinery	www.biopos.de kamm@biopos.de
Emsland-Stärke GmbH, Wietzendorf	Potato starch, biomass	Bioproducts and bioenergy	Private, Public (federal funding), demonstration & commercial	Whole crop biorefinery	Uwe Hildebrand
Netherlands					
Core Bio-MCN/ Biorefinery Cluster	Glycerol, solid lignocellulosic biomass	Biomethanol, biodiesel, bio-DME, biogas, biopower	200 kt/yr biomethanol demo-plant under construction. Gasification, catalytic syngas technology; expected expansion to 1-2 Mt, incl. production of diverse energy carriers	Syngas biorefinery for biomethanol and other biofuels from glycerol and lignocellulosic biomass	www.biomcn.nl www.groningen-seaports.com
Cargill/Nedalco Sas van Gent	Wheat, corn	Food (starches, starch derivates, wheat proteins, glucose), bioethanol	1st-generation bioethanol plant: 2.2 Ml/a (2005); 2nd-generation demo plant converting xylose to bioethanol: 2.0 Ml/a (end 2008)	C6/C5 sugar platform biorefinery for food ingredients and bioethanol from wheat and corn	www.nedalco.com
Greenmills – Port of Amsterdam	Used vegetable oils, greases, other organic biodegradable residues	Biodiesel, glycerine, biogas, bioethanol, compost	Integrated demo production of 200 Ml/a biodiesel, 10 MWe power, 25 Mm^3/a biogas	Bio-oil, C5/C6 sugar bio-refinery for biodiesel, ethanol, biogas, power and heat from organic residues	www.greenmills.nl
ECN MILENA and PATRIG Pilot facilities	Lignocellulosic biomass (e.g., wood, agricultural residues)	MILENA: methane rich product gas PATRIG: torrified biomass	M: Indirect gasification (800 kWth) since 2007, producing tars, methane, ethylene, benzene. P: 50-100 kg/h torrefaction plant based on novel moving-bed technology, since 2008	Syngas and torrified wood biorefinery for biofuels (ao SNG), chemicals, power and heat from lignocellulosic biomass	M: Bram van der Drift vanderdrift@ecn.nl P: Jaap Kiel; kiel@ecn.nl

Future (2010-2012) Activities

We conclude that Biorefineries can make a significant contribution to sustainable development by adding value to the sustainable use of biomass. They can produce a spectrum of bio-based products (food, feed, materials, chemicals) and bioenergy (fuels, power and/or heat) feeding the full Bio-based Economy. This should be realized by maximizing biomass conversion efficiency, so minimizing raw material requirements, while at the same time the economic positions of various market sectors (e.g. agriculture, forestry, chemical and energy) are strengthened. There is an international consensus on the fact that the biomass availability is limited so that the raw materials should be used as efficiently as possible – i.e. development of multi-purpose biorefineries in a framework of scarce raw materials and energy.

One of the key parameters to make Biorefineries a successful endeavour is bringing together key stakeholders normally operating in different market sectors (e.g., agriculture and forestry, transportation fuels, chemicals, energy, etc.) in multi-disciplinary partnerships to discuss common biorefinery-related topics, to foster necessary RD&D trajectories, and to accelerate the deployment of developed technologies (platform function).

The target for the next triennium is the addition of at least two more countries. The Task is open for other countries to join – the more partners, the more work that can be done. Task 42 can contribute to the successful emergence of biorefineries by identifying the most promising bio-based products – i.e. food, feed, added-value materials (a.o. fibre-based) and chemicals (functionalised chemicals and platform chemicals (building blocks)) to be co-produced with bioenergy, to improve overall process economics, and minimise the overall environmental impact. The preparation of a review and guidance document on approaches that can be used for sustainability assessment of biorefineries and a Strategic Position Paper concerning "Adding Value to the Sustainable Utilisation of Biomass on a Global Scale – Biorefinery" for policy makers have been proposed.

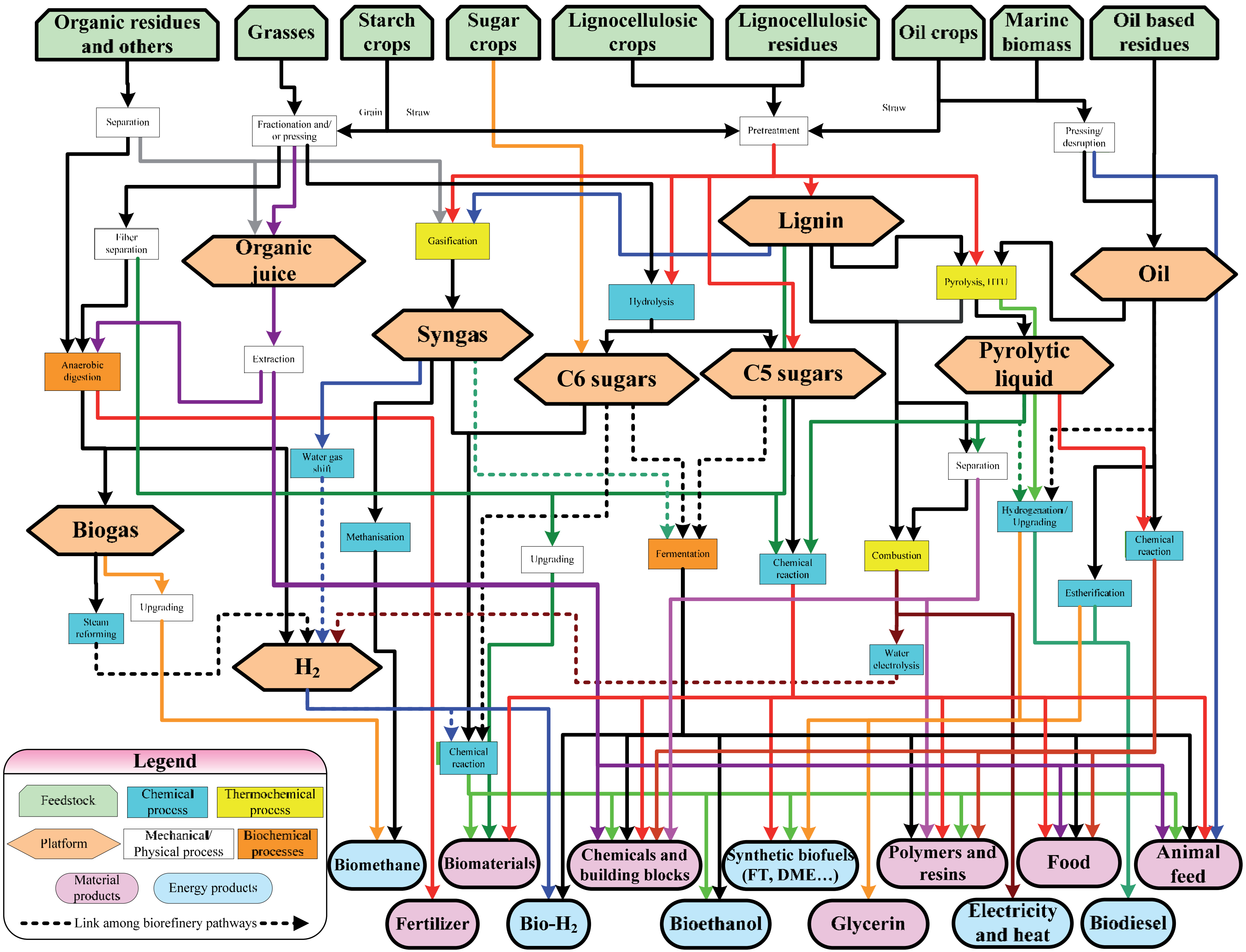
Further Reading:

1: Biorefineries - Industrial Processes and Products; Status Quo and Future Directions. 2005 Kamm, B., Gruber, P.R. / Kamm, M. (eds.) 2 Volumes, Hardcover - Practical Approach Book - ISBN-10: 3-527-31027-4, ISBN-13: 978-3-527-31027-2 - Wiley-VCH, Weinheim. 934 Pages.

2: NSF. 2008. Breaking the Chemical and Engineering Barriers to Lignocellulosic Biofuels: Next Generation Hydrocarbon Biorefineries. Huber, G.W. (Ed.) University of Massachusetts Amherst. National Science Foundation. Chemical, Bioengineering, Environmental, and Transport Systems Division. Washington D.C. 180 Pages.

3: Cherubini, F., 2009. Life Cycle Assessment of biorefinery systems based on lignocellulosic raw materials – concept development, classification and environmental evaluation. Graz (Austria): Graz University of Technology, Joanneum Research.

4: Ree, R. van & E. Annevelink, 2007. Status Report Biorefinery 2007. Wageningen, AFSG report 847, 110 pp..



Organic residues and others
Grasses
Starch crops
Sugar crops
Lignocellulosic crops
Lignocellulosic residues
Oil crops
Marine biomass
Oil based residues
Separation
Fractionation and/ or pressing
Grain
Straw
Pretreatment
Straw
Pressing/ desruption
Fiber separation
Organic juice
Gasification
Lignin
Oil
Hydrolysis
Pyrolysis, HTU
Anaerobic digestion
Extraction
Syngas
C6 sugars
C5 sugars
Pyrolytic liquid
Water gas shift
Separation
Methanisation
Biogas
Upgrading
Fermentation
Chemical reaction
Combustion
Hydrogenation/ Upgrading
Chemical reaction
Estherification
Steam reforming
Upgrading
H_2
Water electrolysis
Chemical reaction
Legend
Feedstock
Chemical process
Thermochemical process
Platform
Mechanical/ Physical process
Biochemical processes
Material products
Energy products
Link among biorefinery pathways
Biomethane
Biomaterials
Chemicals and building blocks
Synthetic biofuels (FT, DME…)
Polymers and resins
Food
Animal feed
Fertilizer
Bio-H_2
Bioethanol
Glycerin
Electricity and heat
Biodiesel

Participants

- Austria
- Canada
- Denmark
- European Commission
- France
- Germany
- Ireland
- Netherlands

For the last year (2009) of the first triennium the number of partners in Task 42 is increased to 10 with the addition of Italy and Australia.

Colofon

This brochure has been prepared within the framework of IEA Bioenergy Task 42 on Biorefinery.

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WWW.IEA-Bioenergy.Task42-Biorefineries.com