Demonstrating large-scale bioethanol production from lignocellulosic feedstocks

Project overview

The benefits of second generation biofuels production from lignocellulosic materials are significant. The main advantages include higher per hectare productivities, better GHG (green house gas) performance and avoidance of direct competition with the food market. In order to make this technology competitive with fossil fuels, significant cost reductions and technological developments are needed while the sustainability of the overall process has to be ensured.

In order to tackle this problem, the BIOLYFE project aims at improving critical process steps and demonstrating the whole supply chain, from feedstock sourcing via fuel production to product utilisation. The main result will be the construction of an efficient 2nd generation industrial demonstration unit with an annual output of about 40.000 tons of lignocellulosic bioethanol, which can then be used for process optimization through extensive testing.

BIOLYFE is co-funded by the European Commission in the 7th Framework Programme (Project No. FP7-239204). Project activities started in January 2010 with the kick-off meeting at the Chemtex R&D Centre in Tortona, Italy.

BIOLYFE Objectives

- Optimisation of feedstock supply chains for selected lignocellulosic energy crops
- Further development and application of advanced steam explosion pretreatment
- Adaptation of hydrolytic enzyme cocktails and improvement of fermentation technologies
- Industrial scale second generation ethanol production (40,000 tons of EtOH / y) and process optimisation
- Vehicle fleet test programme and creation of a functioning distribution infrastructure
- Integrated assessment of environmental and economic sustainability

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Introduction: Second generation bioethanol

Bioethanol in general is produced through yeast fermentation of plant sugars. Plants use sugars for energy storage. Sugar plants (e.g. sugar cane, sugar beet) store energy in the form of saccharose while other plants (e.g. maize, wheat, potato) store sugars in the form of starch polymers. Both saccharose and starch are easily accessible and are already widely used for the production of first generation bioethanol. However, the main components of herbaceous biomass are cellulose and hemicellulose. These are also sugar polymers and can be used for bioethanol production, but due to their role as structural plant materials, they are less accessible. For second generation bioethanol (or lignocellulosic ethanol) production, the whole plant, including cellulose and hemicellulose, is utilized, which increases hectare yields and GHG efficiency and reduces for example the competition with food production.

The main challenge in second generation bioethanol production is the efficient breakdown of cellulose to sugar monomers (hydrolysis). Due to the recalcitrant character of cellulose, feedstock pretreatment and adapted hydrolysis steps are needed to obtain fermentable sugar monomers.

These steps are currently cost and energy intensive which still limits the economic viability of second generation bioethanol. The development of a cost efficient production process, including improved cellulose utilisation, is the main challenge for the future development of second generation biofuels. BIOLYFE meets this challenge by developing advanced processes and demonstrating industrial-scale production of second generation bioethanol.

Feedstock production

The BIOLYFE project demonstrates the production of second generation bioethanol from dedicated energy crops. With this concept, feedstocks can be produced reliably and in sufficient amounts in close proximity of the bioethanol production plant which contributes to optimising both GHG and cost efficiency of the whole fuel supply chain.

A limited set of potential feedstock plants was chosen for closer assessment within the BIOLYFE project: Fibre Sorghum (*Sorghum sp.* hybrids with high cellulose contents), Miscanthus grass (*Miscanthus x giganteus* hybrid), Giant Reed (*Arundo donax*), and Switchgrass (*Panicum virgatum*). In general, these plants are characterised by high productivity and low need for care, fertiliser input and plant protection.

Within BIOLYFE, plant materials will be compared regarding their chemical characteristics. Crop cultivation will be implemented at demonstration level (around 25 ha per feedstock plant) in order to compare and optimise the whole feedstock supply chains, including sowing / planting, harvest mechanisation, as well as storage and logistics solutions. The final aim is to provide around 80,000 tons of dry biomass per year to the bioethanol production plant. Activities include:

- Definition of contract models for feedstock cultivation
- Selection of logistics partners for harvesting and transport
- Optimisation and monitoring of the logistics chain
- Quality management along the feedstock supply chain

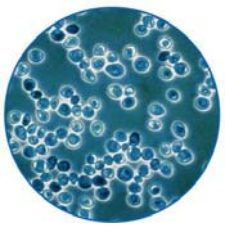
Feedstock pretreatment

The pretreatment of lignocellulosic biomass is necessary in order to increase the accessibility and solubility of cellulosic components. The aim is to reduce residence time (i.e. reduced capital costs) and enzyme consumption (i.e. reduced operating costs). Moreover, mass losses should be minimised in terms of non-fermentable products and fermentation inhibitors. Steam-explosion is currently considered one of the most effective and least costly physicochemical pretreatments for biomass. The process uses saturated steam at high pressure to destroy the biomass structure from inside the pores resulting in a physical breakage of the bonds between lignin, cellulose and hemicellulose without the addition of chemicals or high energy input.

Chemtex has developed a continuous process consisting of two treatment steps with different residence time. With this system, biomass is disrupted with the same effectiveness as in the standard steam explosion procedure while steam consumption as well as inhibitor formation is decreased. Within BIOLYFE, this pretreatment is tested with the selected feedstocks and pretreated materials are characterised thoroughly. The final aim is to optimise the pretreatment of selected feedstocks with a view to increasing the efficiency of following processing steps.

Hydrolysis & Fermentation

By adding hydrolytic enzymes to the feedstock, plant polymers (cellulose, hemicellulose, etc.) are broken down to their sugar monomers which are then available for fermentation. The hydrolysis of cellulose is challenging due to its recalcitrant character. Further optimisation of this step is necessary in order to increase sugar yields and process efficiency while minimising enzyme consumption and costs.



Hydrolysis of cellulose and hemicelluloses yields a variety of sugars of which glucose and xylose are most important. Yeast (*Saccharomyces cerevisiae*) is then used to ferment these sugars to ethanol. In order to maximise the efficiency of the overall process, the fermentation of both glucose and xylose is desirable. In the BIOLYFE project, the yeasts are able to co-ferment glucose and xylose at the same time. Hydrolysis and fermentation are often run separately but simultaneous saccharification (= hydrolysis) and fermentation (SSF) offers the opportunity to reduce both the overall complexity of the process and capital costs. In addition, the immediate utilisation of hydrolysis products (i.e. sugars) prevents inhibition of enzyme activity through product accumulation. In BIOLYFE, a pre-hydrolysis step is applied before the feedstock is treated in a SSF reactor where the hydrolysis is completed and sugars are fermented at the same time.

The main aim of BIOLYFE is to optimise the whole process (pretreatment, hydrolysis and fermentation) in an integrated manner. This is necessary because especially the applied pretreatment method largely impacts the efficiency and design of following process steps. BIOLYFE activities therefore include:

- Optimisation of hydrolytic enzyme cocktails for pre-hydrolysis and SSF
- Testing performance of genetically modified yeast in co-fermentation and SSF, and optimisation of the SSF process
- Hydrolysis and fermentation experiments to gain feedback on pretreatment methods

Production plant

The main aim of BIOLYFE is the design and construction of an industrial-scale second generation bioethanol production plant with an output of 40,000 tons ethanol per year. The plant will be situated in Italy and Chemtex will take care of the operation and data collection.

The goal is to demonstrate the full production process, from feedstock cultivation to product utilisation, while integrating BIOLYFE results regarding feedstock pretreatment, hydrolysis and fermentation technology. This includes steam explosion pretreatment, an efficient pre-hydrolysis step, and SSF with co-fermentation of glucose and xylose. Performance indicators to be achieved are to produce more than 0.25 g of ethanol per 1 g dry feedstock input, to produce more than 100 l of ethanol per hectare cultivated and final product costs below 0.5 EUR per litre. This plant will also offer the unique opportunity to test process parameters and new technology components at significant industrial scale.

Product utilisation

In order to demonstrate the full supply chain for second generation ethanol and to increase the visibility of the technology, BIOLYFE includes the setup of a fuel distribution infrastructure and a E85 fuel pump. The final goal is to promote Flexi Fuel Vehicles (FFV) among local end-consumers, both private users, and public and company fleets. In addition, the produced fuel will be tested with a dedicated test fleet.

Sustainability

BIOLYFE provides a multi-criteria evaluation of the sustainability of the BIOLYFE technology by taking into account technological, environmental, economic and social aspects. This integrated assessment will generate descriptions and conclusive assessments of sustainability of both the basic and the optimised bioethanol systems. In addition, SWOT analyses will be performed in order to reveal the most sustainable pathways for bioethanol from lignocellulosic material.

Dissemination

BIOLYFE dissemination activities include:

- Project website: www.biolyfe.eu
- Quarterly newsletters and other publications
- Handbook on 2nd generation bioethanol production
- 3 international BIOLYFE conferences
- Public events at the production site and at the fuel pump
- Agricultural information events on feedstock production

The BIOLYFE partnership

Chemtex Italia (Coordination)

Chemtex, the engineering company of the M&G group, is a global organization that specializes in delivering innovative and value-added project solutions based on state-of-the-art technologies for its clients in the energy, biofuels, environmental, petrochemical, chemical and fibers industries. With a team of more than 1000 experts and professionals located in offices in China, India, Italy and the USA, Chemtex offers a full range engineering, project management, global sourcing and construction management solutions.

Environmental protection is a priority for the conservation of natural resources and the health of our planet Chemtex recognizes its responsibility as a global company and is fully committed to reducing the environmental impact of technologies and production plants.

Recent and future investments in Research and Development, mostly related to bio fuels and the need for innovation in renewable resources, will not only be the seed of growth in future years, but also an important heritage for future generations. Chemtex believes that preserving resources and being more efficient will be the true keys for success in the global marketplace.

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Novozymes, Denmark

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ENEA, Italy

ENEA is the Italian National Agency for New Technologies, Energy and Sustainable Economic Development. It is one of the largest scientific and technological state-owned Italian institutions (2700 employees and 1500 researchers) with a specific mission in applied research, technology transfer, high-tech services, studies, tests, training and education to both public and private bodies and enterprises. ENEA has twelve R&D Centres in Italy and a R&D budget of roughly 130 million euro per year (personnel cost not included). In the field of second generation biofuels, ENEA has been involved in the development and demonstration of technologies since the early 90's. In the Research Centre "La Trisaia" (in the south of Italy) ENEA can build on experience with the construction of several technological platforms for the conversion of wastes and biomass, comprising a number of bench scale, pilot scale and demonstrative scale plants.

The main research activities of the Department TER-ENE-BIO involved in the BIOLYFE project are currently focused on the production of both gaseous and liquid biofuels from lignocellulosic biomass through two thermal pretreatment processes: steam explosion and gasification. In particular, significant research and demonstration activities have been carried out in recent years for the production of bioethanol through steam explosion and enzymatic hydrolysis.

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Lund University, Sweden

Lund University is one of the largest universities in Sweden with more than 39000 students. Lund University has a long experience in lignocellulose to ethanol conversion, with an active participation in several EU projects. The department of Chemical Engineering (CE) has about 50 employees and an annual turnover of about 5 Million Euro. In the field of renewable energy, research activities focus primarily on process technology; including pretreatment of lignocellulose, fermentation technology, separation technology, techno-economic evaluations, environmental engineering and process simulations.

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Agriconsulting, Italy

Established in 1996 by a group of agricultural entrepreneurs, Agriconsulting shareholding still coincides with the Company operational management, relevant experts in this sector, thus ensuring high levels of efficiency in the provision of specialised consulting.

Agriconsulting´s reputation - in Italy and in more than 100 countries all over the world – is based on the passion of people serving in it and in their direct knowledge of the context.

Through a multidisciplinary, hands-on, practical experience, Agriconsulting is in a position to cater for any requirements in the planning, design and management of development initiatives in agriculture, rural development, environment and natural resources management, spatial planning. geographical information services, agrifood supply chain development, support to small and medium sized enterprises. institutional support and vocational training.

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WIP Renewable Energies, Germany

WIP Renewable Energies has been active in the clean energy and environment sectors for over three decades, providing a range of technical expert and non-technical services to both industrial and public sector clients at the international level.

In the field of bioenergy WIP is involved in several projects which have the overall aim to support the development of the European bioenergy sector through the stimulation of new biofuel markets. WIP offers project development, project management, technical supervision and realisation of both large- and small-scale projects, which involve the coordination of international consortia.

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IUS, Germany

IUS is a consulting company specialised in environmental and spatial planning as well as landscape architecture with more than 20 years of practice. In three locations in Germany, IUS employs 25 persons, senior scientists (biology ecology), qualified consultants, skilled landscape architects and well trained members of staff. With its experience in stock-taking measures to provide data for Environmental Impact Assessments (EIA) the team is specialised in national and international EIA, Strategic Environmental Assessment (SEA) according to European regulations and directives as well as SWOT and biomass potential analyses. Currently, IUS dedicate themselves to capacity building in Life Cycle Assessment (LCA) in order to expand their role as a leading institute in environmental research. IUS works for national and international clients.

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Subcontractors

Taurus Energy, Sweden

Taurus Energy has developed a new method for the production of ethanol from forestry and agricultural waste. The method, which is protected by 9 internationally patented microbiological processes, makes it possible to produce ethanol with the help of renewable raw materials that previously could not be exploited. Taurus Energy's method means considerable environmental benefits, at the same time as production costs for ethanol are reduced dramatically compared to existing methods.

www.taurusenergy.eu

ETA Florence Renewable Energies, Italy

ETA Renewable Energies develops, with its multidisciplinary and international team, projects within the framework of the European Commission, establishing and supporting international cooperation initiatives, while collaborating with global teams of experts and companies.

www.etaflorence.it

IFEU, Germany

IFEU, the Institute for Energy and Environmental Research, was founded in 1978. Since then IFEU has established itself as an independent centre of excellence for environmental research. Its expertise covers areas like environmental implications of transport, energy supply and renewable energy sources, life cycle assessment, air pollution control, sustainable development, environmental impact assessment, and environmental management.

www.ifeu.de

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