FINNISH BIOREFINE – NEW BIOMASS PRODUCTS PROGRAMME – RD&D ON BIOFUELS AND BIOREFINING IN FINLAND

Mäkinen, T.[1], Leppälahti, J.[2]
[1]VTT Technical Research Centre of Finland, P.O.Box 1000, FI-02044 VTT, FINLAND,
Tel. +358 20 722 6597, Email: tuula.makinen@vtt.fi
[2]Tekes, Finnish Funding Agency for Technology and Innovation, P.O.Box 69, FI-00101 HELSINKI, FINLAND,
Tel. +358 10 605 5879, Email: jukka.leppalahti@tekes.fi

ABSTRACT: The BioRefine – New Biomass Products Programme of Tekes, Finnish Funding Agency for Technology and Innovation, for 2007-2012 aims to generate new and unique expertise in the processing of biomass and apply it to the creation of processes, products and services related to biorefineries. A further objective is to promote the development and use of second-generation production technology in biofuels for transport. A broader Finnish effort to develop new biorefining competencies and technologies is coordinated under the umbrella of the BioRefine programme. The programme harnesses an extensive network of Finnish research institutes, universities and enterprises. The existing know-how of Finnish forest and energy companies forms the basis for creating new businesses and new products from biomass. Forest-industry is expected to be one of the most viable platforms for biorefining in the first stage. Activities of the programme, the main results achieved in 2007-2009 and examples of projects and demonstration activities on production and use of second-generation biofuels in Finland are presented in the paper.
Keywords: Biorefinery, biofuel, biobased products

1 INTRODUCTION

Several factors are driving the demand and markets for new biomass products like biofuels, biochemicals and other renewable products. There is a need to mitigate climate change, to reduce dependency on increasingly expensive oil, and to improve the security of energy supplies. The EU set in April 2009 in a so-called RES Directive [1] an overall binding target of a 20 percent share of renewable energy sources in energy consumption in the EU, as well as binding national targets in line with the overall EU target, and a 10 percent binding target for renewable energy in transport to be achieved by each Member State.

Cost competitiveness and environmental sustainability will be key issues in future markets for biomass-based products. Integrated production of biomass-based products in large biorefineries creates cost advantage and competitiveness, and it is expected to be the most viable in the first stage, although small distributed biorefineries may become important in the next stage.

The existing know-how of Finnish forest and energy companies forms the basis for creating new businesses and new sustainable products from biomass. The Finnish approach is on raw materials that have no influence on food prices, such as wood, forest residues, wastes and side-streams. Identifying new value chains is essential and cooperation between companies from different industrial clusters is needed for successful innovations. Finnish companies, research institutes and universities have long-term experience in the research of advanced biofuels, and they are forerunners in developing and demonstrating new technologies.

In Finland, forest-industry is expected to be one of the most viable platforms for biorefining in the first stage and their primary raw materials in biorefining are wood and forest residues.

Sustainability related to biomass production concerns mainly the protection of higly biodiverse ecosystems and of carbon stocks, such as those in forests. In Finland, 95 percent of the forests that are under forest management are certified according to the national Finnish PEFC scheme (Programme for the Endorsement of Forest Certification). The Finnish PEFC was accepted as part of the international system in 2000.

2 THE FINNISH COLLABORATIVE SCHEME ON BIOREFINING RD&D

2.1 BioRefine Programme

The BioRefine programme [2, 3, 4, 5] was launched by Tekes, Finnish Funding Agency for Technology and Innovation, in 2007 and is due to run until the end of 2012. The BioRefine programme aims:

- To develop innovative new products, technologies and services based on biomass refining and biorefineries
- To strengthen and expand existing biomass know-how in the energy and forest industries into new areas
- To promote the co-operation between companies from different industrial clusters and sectors for innovation
- To activate SMEs to work on niche products and markets
- To promote commercialisation of the products and technologies developed

The BioRefine programme is to develop business related to new value-added products or new process or business concepts that utilise biomass in a variety of forms, as well as related technologies, equipment production and services. The focal areas of the programme (Figure 1) are business development, raw materials, and product lines.

RAW MATERIALS	PRODUCT LINES
▪ Wood, forest residues, agrobiomass, industrial sidestreams, waste, recycled materials, peat and other sources ▪ Quality and treatment ▪ Production and trade ▪ Ecological sustainability and environmental issues	▪ Optimisation of biorefineries, modelling tools and services ▪ Integrated (large-scale) production in industry ▪ Small distributed biorefineries ▪ New biofuels and energy ▪ Biochemicals, fibre products and other biomass products ▪ Scale-up: pilots and demonstrations
BUSINESS DEVELOPMENT • Development of business models and concepts • Demand and competition in markets • System studies and process concepts • Techno-economic analyses	

Figure 1: Focal areas of the BioRefine programme.

The key issue in the programme is the development of business opportunities. The other two programme areas – raw materials and product lines, including technologies and services – are always viewed from the perspective of short, medium or long-term business activities.

A broader Finnish effort to develop new biorefining competencies and technologies is coordinated under the umbrella of the BioRefine programme. This entity harnesses an extensive network of national research institutes, universities and enterprises.

2.2 Future Biorefinery Programme of Finnish Forestcluster Ltd

Forestcluster Ltd. owned by all key companies and players in the Finnish forest cluster, has launched the Future Biorefinery (FuBio) research programme in 2009 [6]. This EUR 50 million programme is part of a broader Finnish biorefinery R&D effort under the umbrella of the Tekes BioRefine programme. Tekes funding for the first two-year period of the FuBio programme is about EUR 9 million, approximately 50 percent of the total budget. The other half of the budget is financed by the shareholders of Forestcluster Ltd. Moreover, Forestcluster Ltd. coordinates the joint RD&D operations of the cluster.

The five-year FuBio research programme will create new competence in processing wood biomass and stimulate the transformation of the Finnish forest cluster. The programme will develop innovations that can either be implemented as part of existing industry operations or which open entirely new applications for wood. The objective is to develop new methods enabling fractionation of wood into cellulose, hemicelluloses, lignin and extractives in their native-like form and further, to upgrade these fractions into chemicals and materials.

2.3 Biofuel Development Programme of the Ministry of Employment and the Economy

The Biofuel Development Programme of the Ministry of Employment and the Economy provides pilot and demo funding for second-generation biofuels for traffic in order to enhance their introduction to fuel markets.

The BioRefine and FuBio programmes together with the Biofuel Development Programme of the Ministry of Employment and the Economy form an extensive network of collaboration. This kind of national collaboration in studying biorefining is internationally unique and is playing a pioneering role in the world.

Additional funding especially for demonstration is sought from the EU funding sources. Finland is having an active role in execution of the EU SET Plan (Strategic Energy Technology Plan) and in its activities.

3 ACTIVITIES OF THE PROGRAMME

When Tekes started to prepare the BioRefine programme in 2006 there was already distinct interest in participation among Finnish industry and the research community. The funding opportunities, which the BioRefine programme provides, together with the special pilot and demo funding of the Ministry of Employment and the Economy have proved extremely attractive.

The planned programme budget totals EUR 137 million. However, after three years of operation the volume of the projects already reached the planned volume. By 2012, it is estimated that biorefining activities in Finland will be under study in Tekes-financed projects to a volume of about EUR 200 million. The total volume of enterprise projects is already about EUR 100 million, and the total volume of research projects, about EUR 30 million. All the research projects have industry involvement. Typically individual research projects form large project consortia.

The programme has issued three calls for research projects, the first in autumn 2007, the second in spring 2008, and the third in early 2010. The focus of the first call was on biomass-based fuels for transport, the second call focused on other biomass-based products like chemicals and materials and the third one especially on new biomass sources and waste-based biomass and research supporting the business development of SME companies. Funding decisions of the third call are expected in the middle of May 2010.

In the first phase of the programme the main share of the projects has focused on RD&D of biofuels for transport. In the programme e.g. technologies for producing biofuels for transport via the synthesis-gas route and new liquid biofuel concepts based on integrating a fluidized-bed boiler and fast pyrolysis are developed and demonstrated. In addition to the production, also the use of biofuels is demonstrated. Greenhouse gas and other environmental impacts are assessed.

International cooperation has an essential role in developing innovative technologies, products and services. In the BioRefine programme research organisations have been encouraged to have international cooperation, the USA and Canada being one of the most important partner countries, in their projects. Currently eight research projects of totally 23 research projects have cooperation with North or South American universities or research institutes.

3.1 Examples of projects in the BioRefine programme

3.1.1 Syngas-based biofuels

Several Finnish industrial consortia are commercializing the so-called syngas route for producing biofuels for transport. In the Finnish approach biofuel production is planned to be integrated with pulp and paper production (Figure 2).

McKeough et al. [7] has assessed the performances and costs of producing several alternative biomass-derived synthesis-gas derivatives (Fischer-Tropsch liquids, methanol, synthetic natural gas and hydrogen) integrated to a pulp and paper mill. The Fischer-Tropsch-based route to transportation biofuels seemed to be the most promising of the routes considered. According to the estimates, Fischer-Tropsch-derived transportation fuels could be produced for about 50 EUR/MWh or 50 Euro-cents/litre when feedstock is available at a price of 10 EUR/MWh.

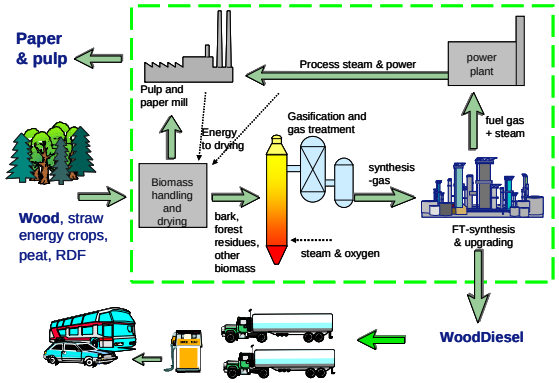

Figure 2: Integration of biomass-based diesel-oil production to pulp and paper mills (source: VTT).

The demonstration plant owned by Stora Enso and Neste Oil and located at Stora Enso Varkaus Mill, has been operational since June 2009. The demonstration facility for biomass to liquids (BtL) production utilising forestry residues includes a 12 MW gasifier. The plant is be used to develop technologies and engineering solutions for a commercial-scale plant. The demonstration process units cover all stages of biorefining, including drying of biomass, gasification, gas cleaning and testing of Fischer-Tropsch catalysts. [8, 9]

Another industrial consortium is led by UPM. UPM is cooperating with Andritz and its associated company Carbona in the development of technology for biomass gasification and synthetic gas purification. Pilot tests have been carried out at a Gas Technology Institute (GTI) facility in Chicago, USA.

In the research project coordinated by VTT Technical Research Centre of Finland the experts generate new fundamental data on the methods of producing biofuels for transport via the synthesis-gas route, with emphasis on the synthesis-gas production and gas cleaning steps. The project will both broaden and deepen the knowledge base and, in particular, will generate new fundamental data about the most critical process steps from the point of view of the realisation of the technology.

The results will be exploited in the ongoing industrial-driven development and demonstration projects. The subtopics of the research project are (1) fuel characterisation and ash behaviour in the gasification step, (2) reaction mechanisms related to gas cleaning, in particular the reactions of hydrocarbons at gasification temperatures, during hot-gas filtration and on catalytic surfaces, (3) evaluations of alternative process configurations and applications and (4) monitoring of developments elsewhere in the world.

3.1.2 Biomass based bio-oil production

Metso, UPM and VTT Technical Research Centre of Finland have developed a new concept for the production of biomass-based bio-oil by fast pyrolysis to replace fossil fuels in heating and power generation. The production has been tested at the Metso R&D Centre in Tampere, Finland, since June 2009. [10, 11]

The energy company Fortum has later joined the consortium to bring energy producer and end-product user expertise in the research and development project [12]. In this project Metso is in charge of the technological development of the pyrolysis reactor integrated into the fluidized bed boiler. UPM adds to the project expertise in the use of biomass as raw material.

The consortium has developed a bio-oil production process, in which a reactor linked to a conventional fluidized bed boiler, can first gasify solid biomass and then compress it into liquid form. Through their several months of pilot testing and utilization of the 2 MW plant at the R&D Centre the partners have improved the bio-oil production methods and the efficiency of the process. Already, more than 20 tons of bio-oil has been produced. As an alternative to heavy and light fuel oils, bio-oil decreases the burden on the atmosphere.

Bio-oil will be manufactured by UPM's renewable energy power plants which are equipped with a suitable boiler and functional raw material management. The raw material of the bio-oil is wood biomass – harvesting residues and sawdust, which is a by-product of the forest industry.

Combining bio-oil production to an existing biomass based power plant creates significant cost and efficiency advantages as well as new business. According to McKeough et al. [13] a reduction of about 20 percent in bio-oil production costs could achieved by integrating the pyrolysis process with an industrial CHP plant compared to a stand-alone pyrolysis plant.

VTT Technical Research Centre of Finland coordinates the research project on integrated utilisation chains of second generation pyrolysis. Bio-oil produced by fast pyrolysis may be utilized in generating heat for industrial and community needs. In the development work, an emphasis is placed in improving the quality control of the bio-oil production, since improved quality should make it possible to use bio-oil also for higher value purposes.

3.1.3 The 3G biorefinery demonstration plant utilising agricultural residues

Chempolis started a demonstration biorefinery plant utilizing agricultural residues in producing biomass products and biochemicals in Oulu in 2008. In the initial phase the focus has been on paper fibres and pulp, but because of growing international interest in biofuels, the company has taken a further step and started the production of bioethanol in spring 2010.

In the first test runs it was produced pulp from Chinese wheat straw for successful test runs in pilot paper machine. The test runs for non-wood and non-food cellulosic ethanol production have been completed in the first quarter of this year. The production of cellulosic

ethanol in the test biorefinery has opened up a path to commercial production based on the 3G technologies developed by Chempolis.

The 3G technologies – unlike the technologies of previous generations – enable the production of various end products utilising the energy generated in the production process. As a result, the same amount of raw material generates more revenue. Furthermore, the process is based on a closed loop system for water and chemical circulation, which makes it clean.

Among the raw materials that can be utilized are wheat, maize and rice straw, and bagasse, the residue from sugar production from sugar cane. Many types of reed, such as the common reed and reed canary grass are also suitable feedstock. [14]

3.1.4 Distributed production of bioethanol

St1 Biofuels has produced bioethanol for transport use from food industry side streams and waste since 2007. In 2010, the company has in operation several small plants in capacities about 1.5 million litres of ethanol annually.

In the St1 concept, the small decentralized production units are located close to the waste raw material supplier. The process uses waste containing starch, sugars or low concentration of ethanol as feedstock. New types of plants that extend the range of feedstocks to sorted biowaste, municipal waste and agricultural by-products, are being developed. The produced bioethanol is transported to a centralized dehydration plant for the removal of the last traces of water. The new process has been able to bring the ethanol production costs down to the level of a large production plant. [15]

3.1.5 A public transport demonstration on renewable diesel fuel

Biofuels can be helpful in combating greenhouse gas emissions, as well as local emissions. In this project the goal is to verify the feasibility of high concentration biofuels as fuels for captive urban fleets. The emissions reduction and long-term effects on bus engines of using biofuel are studied in detail to ensure that all the benefits of premium-quality renewable diesel are taken advantage of to benefit urban air quality.

The three-year trial includes around 300 buses using a blend of approximately 30 percent renewable diesel and 70 percent fossil diesel, and a small number of buses using 100 percent renewable diesel. The buses circulate in the Helsinki Metropolitan Area. The demonstration project started in 2007 and the partners are Helsinki City Transport, Helsinki Metropolitan Area Council, Neste Oil, Proventia Emission Control, VTT Technical Research Centre of Finland, Helsinki University of Technology, and Scania.

Using NExBTL, renewable diesel by Neste Oil, has a significant positive impact on emissions, as the fuel generates substantially less particulate and NOx emissions than conventional diesel fuel. Test results show that NOx emissions are cut by around 10 percent and particulate emissions by around 30 percent compared to fossil diesel. Greenhouse gas emissions as calculated over the entire life cycle of the fuel are 40-60 percent lower than those of fossil diesel when the raw materials used to produce NExBTL diesel are themselves produced in accordance with sustainability principles. [16]

3.1.6 Projects carried out by small and medium-sized companies and research institutes

The BioRefine programme has proven to be a good platform for small and medium-sized companies to carry out development projects together with research institutes and universities.

Birch distillate in biological plant protection is a new Finnish innovation. It is a by-product in slow pyrolysis process in charcoal production. However the commercialization of the product requires the EU registration that – in other hand – necessitates knowledge on the composition and active ingredients. The joint project with nine SMEs and three research institutions generates knowledge base needed to launch the birch distillate products to markets. [17]

In joint project nearly ten SMEs and a couple of big companies together with research institutes and universities develop technologies with which digestates originating from anaerobic digestion of different organic wastes and by-products can be refined to value-added and safe products for a number of uses. The refined digestates that originate from the biogas process can be utilized as fertilizers and soil conditioners. The project focuses on experimental work and theoretical assessments. [18]

A project of eight companies and four research partners focuses on biomass potentials, appropriate technologies and business opportunities for agrifood waste in the eastern part of Finland. The sources of agrifood waste vary from animal husbandry and crop production to food processing. Bioenergy generated from agrifood waste and waste-based nutrients can replace non-renewable energy sources and fertilizers, helping to mitigate climate change and reduce eutrophication. Best practices generated in the project will be applied elsewhere in Finland.[19]

3.1.7 Environmental and economic impacts of 2G biofuels

Sustainability assessment is a complicated and challenging task due to the lack of a unique, objective, and commonly agreed methodology. The aim of this project was to explore the main problems and challenges related to environmental impact assessment of biofuels. The results will be used when planning national measures for reducing greenhouse gas emissions and implementing the EU directive on promoting the use of renewable energy. [20]

4 CONCLUSION AND FUTURE PLANS

A broad Finnish effort to develop new biorefining competencies and technologies is coordinated under the umbrella of the BioRefine programme. By 2012, it is estimated that biorefining activities in Finland will be under study in Tekes-financed projects to a volume of about EUR 200 million. This entity harnesses an extensive network of national research institutes, universities and enterprises and it forms an extensive network of national and international collaboration. International cooperation will be developed further.

In the first phase of the BioRefine programme the main share of the projects has focused on RD&D of biofuels for traffic. In the programme e.g. technologies for producing biofuels for transport via the synthesis-gas route and new liquid biofuel concepts based on integrating a fluidized-bed boiler and fast pyrolysis are

developed and demonstrated. In addition to the production, also the use of biofuels is demonstrated. Greenhouse gas and other environmental impacts are assessed. All the technologies and processes under development within the BioRefine programme should be based on sustainable use of biomass. Research on other biomass-based products like chemicals and materials has increased recently.

The future focus areas and activities of the BioRefine programme are planned based on the findings of the mid-term assessment of the programme in mid 2009. National strategy and national coordination were emphasized in the discussions, in addition to the international cooperation. E.g. Finland is having an active role in execution of the EU SET Plan and in its activities. Increased activation of small and medium-sized enterprises was seen as an important objective of the programme. E.g. new biomass sources and waste-based biomass were seen important focus areas for the programme in future.

5 REFERENCES

[1] The European Union. 2009. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Official Journal of the European Union. L 140. pp. 16-62.

[2] Tekes. 2010. BioRefine 2007–2012. The BioRefine programme web pages. www.tekes.fi/eng/biorefine

[3] Mäkinen, T. & Leppälahti, J. 2009. Review of the Finnish BioRefine – New Biomass Products Program. Environmental Progress & Sustainable Energy. Vol. 28, No. 3, pp.470-474.

[4] Mäkinen, T & Alakangas, E. (eds). 2009. BioRefine Programme Yearbook 2009. Tekes Review 264/2009. Available at www.tekes.fi/eng/biorefine

[5] BioRefineNews. 2009. The BioRefine Programme Review. October 2009. Available at www.tekes.fi/eng/biorefine

[6] Forestcluster. 2010. Future Biorefinery. The FuBio programme web pages. http://forestcluster.fi/en/Future_Biorefinery

[7] McKeough, P. & Kurkela, E. 2007. Detailed comparison of efficiencies and costs of producing FT liquids, methanol, SNG and hydrogen from biomass. Presented at the 15th European Biomass Conference & Exhibition, 7-11 May 2007, Berlin, Germany.

[8] Stora Enso 2009. Press Release: Stora Enso and neste Oil inaugurate biofuels demonstration facility at Varkaus in Finland. http://www.storaenso.com/media-centre/press-releases/2009/06/Pages/stora-enso-and-neste-oil.aspx

[9] Neste Oil. 2009. Press Release: Neste Oil and Stora Enso inaugurate biofuels demonstration facility at Varkaus in Finland. http://www.nesteoil.com/default.asp?path=1;41;540;1259; 1260;11736;12772

[10] Metso. 2009. Press Release: Metso and UPM develop biomass based bio-oil production. http://www.metso.com/news/newsdocuments.nsf/Web3NewsDoc/C89A8AC3F77ABD29C22575CF003111F5?OpenDocument&ch=ChMetsoWebEng&id=C89A8AC3F77ABD29C22575CF003111F5&

[11] UPM. 2009. Press Release: Metso and UPM develop biomass based bio-oil production. http://w3.upm-kymmene.com/upm/internet/cms/upmcms.nsf/prv/Metso_and_UPM_develop_biomass-based_bio-oil_production?OpenDocument

[12] Metso. 2009. Press Release: Metso, Fortum, UPM, and VTT are jointly developing a clean energy alternative with domestic bio-oil. http://www.metso.com/news/newsdocuments.nsf/web3newsdoc/4AA4186AD7B97A4AC225767E00305FBF?OpenDocument&ch=ChMetsoWebEng&

[13] McKeough, P. & Solantausta, Y. 2003. Technoeconomic assessment of production of pyrolysis oil, Intermediate report for Tekes project "New Product Alternatives for Pyrolysis Technology", VTT Processes, December 2003.

[14] Chempolis/Tekes. 2009. Third generation demonstration biorefinery in operation. Article on the Tekes web pages. http://www.tekes.fi/en/community/Success%20stories/416/Success%20story/667?name=Third+generation+demonstration+biorefinery+in+operation

[15] St1 Biofuels 2009. The company web pages. http://st1.eu/index.php?id=2876

[16] Neste Oil. 2009. The company web pages. http://www.nesteoil.com/default.asp?path=1,41,11991,12243,12326,12711

[17] Development of slow pyrolysis business operations in Finland – Hidaspyro. 2009. BioRefine Programme Yearbook 2009. Tekes Review 264/2009. Available at www.tekes.fi/eng/biorefine

[18] Processing biogas plant digestates into value-added products – Biovirta. 2009. BioRefine Programme Yearbook 2009. Tekes Review 264/2009. Available at www.tekes.fi/eng/biorefine

[19] Value chains for biorefineries of wastes from food production and services – ValueWaste. 2009. BioRefine Programme Yearbook 2009. Tekes Review 264/2009. Available at www.tekes.fi/eng/biorefine

[20] Environmental and economic implications of second generation biofuels for transportation – Biovaiku. 2009. BioRefine Programme Yearbook 2009. Tekes Review 264/2009. Available at www.tekes.fi/eng/biorefine

6 LOGO SPACE