

Production of bioethanol from lignocelluloses.

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Development in Sweden

Sweden is one of the biggest producers of pulp and paper in Europe and a lot of wood has been used for that production for many years. In the last decade (years) the amount of wood residues for district heating and production of electricity has increased a lot. Still there are potentials to use biomass for liquid bio fuels.

In Sweden as in many other countries ethanol is the most spread alternative to gasoline and diesel. Sweden has more than 400 busses running on neat ethanol, about 15 000 FFV cars running on e85 (85 % ethanol and 15 % gasoline) and the rest of the gasoline on the market is blended with 5 % ethanol so called e5.

In general ethanol can be produced from various raw materials but in Sweden softwood is the feedstock with the biggest potential for ethanol production. Softwood residues from harvesting or residues from sawmills and other wood based production units can be used. Hard wood residues and cultivated energy crops could also be interesting feed stocks in Sweden, when pentoses can be fermented in industrial plants. In Sweden cultivated energy crops mainly means Salix (willow) and reed canary grass.

An estimation of the possibility in Sweden to produce bio fuels, power and district heating shows a big potential for growth.

A lot of activities for development of technology for biofuels are concentrated to a region in the northern part of Sweden. This region is today founded as the "BioFuel Region". The vision for the BioFuel Region (BFR) is to be a prominent region and a lighthouse for the conversion to cellulose based biofuels and be self sufficient with biofuels for the transport sector to 2030.

Bio refineries & energy combines

Ethanol production in a stand alone unit, based on cellulose raw material is hard to motivate today due to high costs. But, bio refineries and energy combines can be used to achieve synergies in production of liquid bio fuels. At the moment some regional energy companies are the most committed stakeholders in ethanol development in Sweden. Their vision is to supply energy to the inhabitants in all fields, electricity, district heating, and fuel for transport.

About ten different feasibility studies have been made in Sweden by BioAlcohol Fuel Foundation integrating ethanol production with municipality power plants, sawmills, pulp mills, wood pellets plants etc.

A bioenergy combine with a capacity of 75 000 000 liters ethanol/year can be a "normal-sized" Swedish plant. In this case roughly most of the energy demand in the municipality for transport, heating of buildings and small and medium sized enterprises are supplied from the combine excluding the need for big industries.

The same result can be reached with an ethanol plant in combination with a sawmill, including a dryer for board and deal or a plant for upgrading biofuels to pellets.

In the plan for the bio refinery and energy combine in the city of Skellefteå the production of ethanol is included. Today electricity, district heating and bio pellets are produced.

Pilot plant for technology development

The development of ethanol production from cellulose raw material has been going on for 15 to 20 years at universities in Sweden and other countries. Several process alternatives for hydrolysis of cellulose materials have been evaluated. Among them are diluted acid as catalyst in two steps or diluted acid combined with enzymes in a third step for softwood to get high yields of ethanol. For hardwood and straw probably just one step of diluted acid completed with one enzyme step is necessary.

The next step in the development was to build a pilot plant with the aims to verify and optimize the process and technology, for further development and to get basic data for production plants. The pilot plant was based on results from the bench scale unit at the Technical University of Lund.

Two universities in the region, the University of Umeå and the Technical University of Luleå, became owners of the plant due to the financial fundings of the investment from the Swedish Government. Etek Etanolteknik AB(Ethanol Technology) a development company based in BFR, has made the process design and is also responsible for the construction and the operation of the plant..

In the organization for the plant there is a scientific council, with representatives from universities and industries to support construction and operation.

Location for the pilot plant is Ornskoldsvik in the northern part of Sweden, close to an existing sulphite pulp ethanol plant. The pilot plant is a part in an existing infrastructure. The plant was inaugurated by the Swedish Prime Minister in May 2004

The pilot plant has a capacity in feedstock input of about 2 tons of dry substance/day. With the expected yield the production of ethanol will be 400-500 liters /day.

The plant is designed to be flexible for testing different processes and technologies. For softwood residues as cellulose material the basic configurations are a continues diluted acid hydrolysis process in two steps or pretreatment with diluted acid followed by simultaneous scarification and fermentation by enzymes in a third step.

The second step in the reactor is a countercurrent reactor which has a good potential to increase the yield and reduce the amount of byproducts. The reactor has basically the same design as the reactor at NREL, Golden, Co, US.

As catalyst for the hydrolysis diluted sulphuric acid or sulfur dioxide will be used.

The pilot plant is a complete industrial plant with all unit operations like hydrolysis, dewatering, fermentation, distillation and recycling of process streams.

The plant is operated 24 hours a day in periods of 2 to 4 weeks to get long time effect on deposits and build up of circulating byproducts. It is operated by personnel from the existing sulfite pulp ethanol plant. Stop periods for some days are calculated between the running periods for changes in the equipment and modifying the process design.

The products from the pilot plant are not sold on the market. The energy contents in the ethanol, lignin and residues are used in the industries at the same site.

The investment costs in the pilot plant was about 16 million Euros and the annual running cost about 1,5-2 million Euros depending on the research program. The value of using the existing infrastructure at the sulphite pulp ethanol plant is calculated to 6 million Euros.

The plant has now been in operation for more than one year and has been running with a diluted acid hydrolysis process. Most of the occurring problems have been equipment related. Also some process related problems have been troublesome as the characteristic of produced lignin. After one year the plant is modified so a no interrupted running time can be two weeks. Still we need to run the counter current reactor in step two to verify that technology at more sever conditions.

The plant is equipped with a very powerful control system. It is also possible for scientists to follow the process via internet or to pick up historical data for system analysis.

To verify the process and technology and to get more accurate design data for production plants we plan to operate and evaluate the pilot plant for at least another year before a design of a full scale production plant.

Different feed stocks like hardwood and annual crops like straw and reed canary grass will further on also be tested in the pilot plant. The first project is a EU financed project to develop and test enzymes for hydrolysis of softwood and straw. The pilot plant will be open for cooperation with partner's world wide, due to capacity in running time and personal.

Feasibility study of a production plant

Based on the design data for the pilot plant Etek also has made a study of a production plant in combination with an existing combined heat, power and wood biofuel pellets plant in the north of Sweden. The production of ethanol was set to 75 000 000 liters a year. The investment costs for the production plant were calculated to about 120 million Euros.

In a bioenergy combine with ethanol production some of the hemi cellulose and cellulose are not converted to ethanol but solved in the process water and evaporated to a liquid fuel residue, comparable with syrup or spent liquor. This residue is burned in the boiler and could in some applications correspond to the total energy need in the plant.

Most of the lignin remains as a solid product after the process. The lignin is used as a fuel in bioenergy combines, sold as an additive in wood based biofuel pellets or sold for special purposes.

The lignin fuel can be very suitable for gas turbines and as an incineration additive, because it has a low alkali content and a high energy value, 6,2 MWh/odt. In the future it may also be a raw material for “green” chemicals.

In the economic evaluation, the byproducts have a big influence.

Sweden 2005	€	
Feedstock 1)	0,24	1) Feedstock costs 12,8 €MWh
Energy	0,13	2) Energy in lignin etc
Chemicals	0,03	3) Fixed annual instalment 9,5%
Credit byproducts 2)	-0,15	
Production costs	0,05	
Capital costs 3)	0,18	
Total costs €	0,48	

Financing

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Homepage www.etek.se , www.biofuelregion.se

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