Alcohol production from lignocellulosic feedstock

Summary

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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 7.000 Ford Focus flexifuel running on e85 and about 800.000 cars running on e5. It is essential to develop the hole chain from rawmaterial, production, distribution and vehicles to rules and taxexemptions.

Softwood is the feedstock with the biggest potential in Sweden for ethanol production. Softwood residues from harvesting or 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 an industrial environment. In Sweden cultivated energy crops mainly means salix (willow) and reed canary grass.

Ethanol production in a stand alone unit, based on cellulose raw material is hard to motivate today, due to high costs and low energy output. 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.

The studies show that Ethanol can be produced in a biocombine at a cost of about 40-50 € ct/l. The first step is to show that the process works in a Pilotplant now under construction and startup during spring 2004.

Background

The development of ethanol production from cellulose raw material has been going on for 15 to 20 years at the Universities in Sweden and other countries. Several process alternatives for hydrolysis of cellulose materials have been evaluated. Diluted acid in two steps and a third enzyme step seems to be the most suitable 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.

Based on results from the bench scale unit at the technical university of Lund the next step in the development is to build a pilot plant for verifying and optimising process and technology and further development.

Bioenergy combines

Regional energy companies are the most committed stakeholders in ethanol development in Sweden at the moment. They have a vision to give energy support to the inhabitants in all fields, electricity, district heating, and fuel for transport. This could be described in the following figure, representing a mediumsized municipality in Sweden with about 60.000 inhabitants.

Sweden have about 35 municipal electric and power plants producing totally 5 TWh_e/year and 15 TWh_{th}/year. By combining these power plants with ethanol production facilities bioenergy combines are created.

A bioenergy combine with a capacity of 60.000.000 liters ethanol/year is what we can call a “normal-sized” Swedish

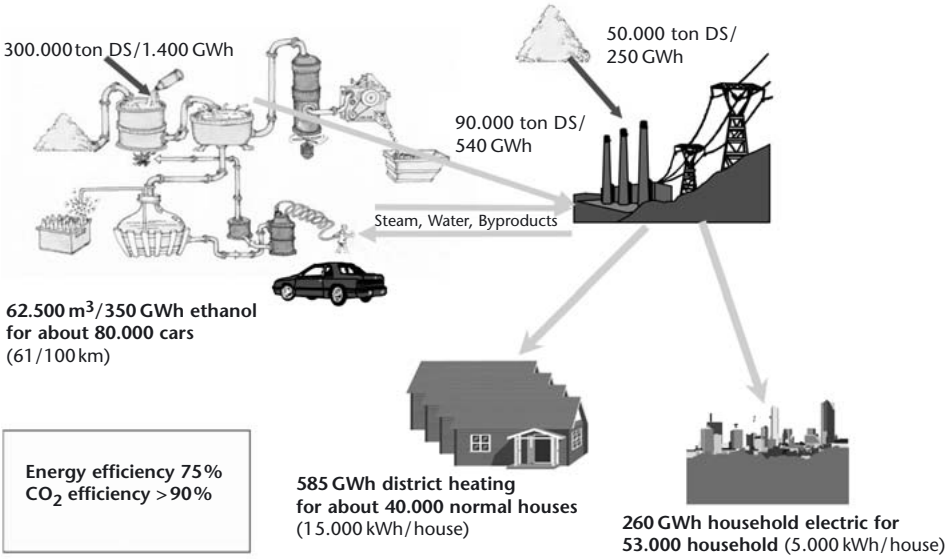

Figure 1:
Biorefinery & Energycombine (Ethanol-, Electricity-, District heating production)

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 supported from the combine excluding bigger industry. Energy saving can increase the share even more.

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.

Pilot plant

To develop the technology for ethanol production from soft wood residues, some regional energy companies formed, five years ago, a new company, called Etek EtanolTeknik (EthanolTechnology) which has made the process design of the pilot plant or Process Development Unit (PDU) that now is erected. Etek is also responsible for the construction and later on the operation of the plant. The plant will be linked to the three Universities in the region, The Univ. of Umeå, Mid Sweden Univ. and the Technical Univ. of Luleå.

Location for the pilot plant will be in Ornskoldsvik in the northern part of Sweden, close to an existing sulphite pulp ethanol plant.

The plant will have 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 litres/day.

The plant is basically designed for development of the continues diluted acid hydrolysis process in two steps with a third step for enzymatic hydrolysis and for softwood residues as cellulose material.

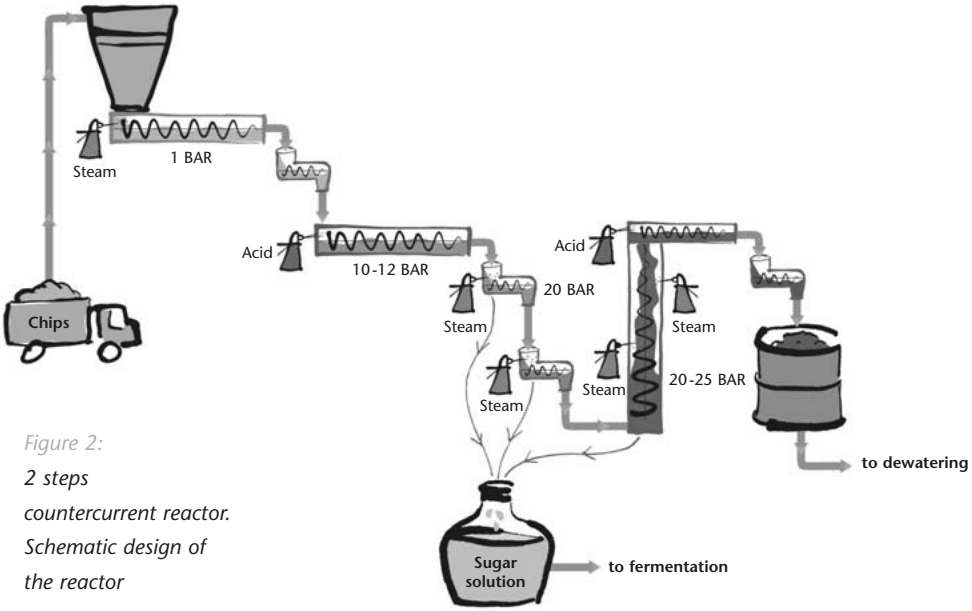

Figure 2:
2 steps countercurrent reactor. Schematic design of the reactor

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. *(Fig. 2)*

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

The second step, the countercurrent reactor, can be replaced or changed to a co current reactor.

The pilot plant will be a complete industrial plant with all unit operations like hydrolysis, dewatering, fermentation, distillation and recycling of process streams.
The process can be shown as follows:

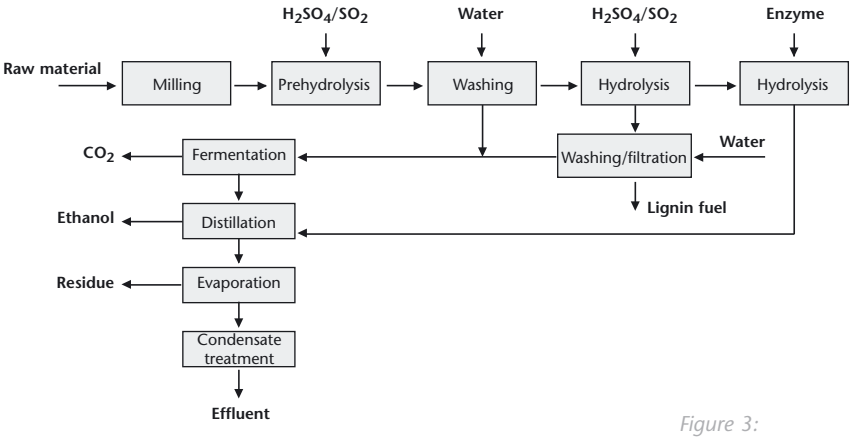

Figure 3:
Schematic process design of ethanol production from wood. Figures in ton per odt (ton dry matter) raw material.

The plant will be operated 24 hours per day in periods of 3 to 4 weeks to get long time effect on deposits and build up of circulating byproducts. It will be operated by personnel from the existing sulfite pulp ethanol plant.

The products from the pilot plant will not be sold on the market. The energy content in the ethanol, lignin and residues will be used in the boiler at the same site.

A one week stop between the running periods is calculated for cleaning, make changes in the equipment for an other process design or just evaluate the earlier results.

Start up of the plant will be in Decembre 2003 and in April 2004 the hole process will be running. To verify the process and technology and to get more accurate design data for production plants, we need to operate and evaluate the pilot plant for about two years before the design of demonstration plant with the capacity 30 - 60.000.000 litres/year.

Production plant

In a bioenergy combine with ethanol production some of the hemicellulose 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 as a biofuel for special purposes. The lignin fuel is very suitable for gas turbines and as an incineration additive, because it has low alkali content and high energy value 6,2 MWh/odt. In the future it may also be a raw material for "green" chemicals.

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 was calculated to about 145 million Euro.

In the economic evaluation, byproducts have a big influence as can be seen in *Fig. 4*.

	US$/litre ethanol
Raw material	0.18
Energy	0.13
Chemicals	0.03
Credit by products	-0.12
Production costs	0.05
Capital costs	0.14
Total	**0.42**

Figure 4:
Production costs for ethanol from cellulose

Financing of the pilot plant

Both the basic design of the pilot plant, the study of a full scale production plant and the investment in the pilot plant has been financially supported by the Swedish National Energy Administration, regional EU-funds, local governments and private and regional energy companies. The investment costs in the pilot plant is about 17 million Euro and the annual running cost about 1,5 - 2 million Euro depending on the research program. An existing infrastructure at the sulphite pulp ethanol plant of a value of 6 million US $ will also be used.

Further development in the pilot plant

Different feed stocks like hardwood and annual crops like straw and reed canary grass will also, further on be tested in the pilot plant.

The pilot plant will be open for cooperation with partners all over Europe and other countries.

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