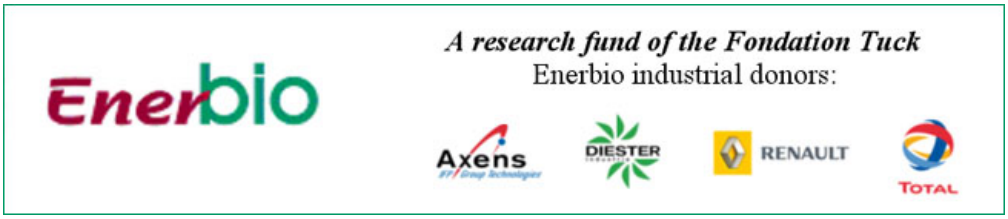
Ethanol 1ère et 2ème génération : Techno-economic evaluation of combined 1st & 2nd generation bio-ethanol production



PROJECT 2008

Title of the project	**Technico-economic evaluation of combined 1st and 2nd generation bio-ethanol production**
Acronym	Ethanol 1ère et 2ème génération
Coordinator	Lund University, Department of Chemical Engineering, P.O Box 124, SE-221 00 Lund, Sweden *Responsable scientifique : Guido Zacchi, Professor*
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Duration	30 months 2009-2011

Summary

The transition to second generation (2G) bio-ethanol production can be facilited by integrating the 2G plant with a first generation (1G) plant, allowing the two methods of production to co-exist. Integration of the two methods can be beneficial for both processes. As an example, the 2G ethanol production has an energy surplus in the form of lignin which can be used in the whole plant. It is also usually difficult to reach high sugar and ethanol concentration in the 2G ethanol production while starch or molasses based ethanol production requires dilution of the sugar. By integration the need to reach very high sugar concentration in the 2G ethanol production is alleviated. The proposition is to use a flowsheeting software, such as Aspen Plus, to model the complex process systems which will arise in a combined plant to determine the most efficient and cost effective way to integrate 2G with 1G ethanol production.

The work programme of this project consists of several deliverables. First the Aspen Plus models, which are already developed at the department, are adapted to the raw material of interest and the results are imported to Icarus Process Evaluator to perform the economic evaluation. The models will be based on experimental data available from the experimental investigations that are ongoing at the department combined with literature data. The models will then be used to investigate different possibilities to integrate the 1G and 2G ethanol production to determine the energy efficiency and the economic feasibility of the various configurations. These will also be compared with the outcome of separate 1G and 2G ethanol production plants.

The outcome of the project will be process models for integrated 1G and 2G ethanol plants and the technico-economical evaluation of the different integration alternatives. The process models will also serve as a basis for better understanding the possibilities of 1G/2G process integration. Data obtained from the study comprising consumption of chemicals, energy demand, waste streams, etc… for future Life Cycle Analysis (LCA) of the various process integration alternatives. However, LCA is not part of the present project.

Results

The main aim was first to decide the appropriate ratio between 1st and 2nd generation feedstock from an energy integration and energy utilization point of view : increasing the 1st generation input into the 2nd generation processes increases the energy efficiency of the combined process. The ratio between 1st and 2nd generation feedstock ends up at 0.37, and on an energy output/heat input perspective, the efficiency has reached a plateau which makes in unnecessary to increase the 1st generation feedstock further.
Techno-economic evaluation method: the simulation results from Aspen Plus were used to design the equipment, and the capital costs were obtained using Aspen Process Economic Analyzer (APEA, version 7.2 from Aspen Technology Inc.) or vendor quotations.

The raw material cost in terms of wheat straw and wheat kernel represents the largest part of the cost for the production (40-55 %). The contribution from the by-products (electricity, methane) to the process economy is larger and more important in the 2nd generation cases than in the integrated cases and the stand alone 1st generation case, making 2nd generation plant more sensitive towards by-product sales.
The enzyme cost ends up at about 7 % of the production cost in the 2nd generation cases and 5 % in the integrated cases and 2 % for the stand alone 1st generation plant.
The integrated systems have a lower Minimum Ethanol Selling Price (MESP) than the pure 2nd generation systems.
It is interesting to notice that the system with the best energy efficiency (SSF (Simultaneous Saccharification and Fermentation) 1G+2G) is not the systm with the lowest MESP.
A pure 2nd generation plant working with wheat straw as feedstock is not economically favourable, when only the 6-carbon sugars are fermented. The 5-carbon sugars were however fermented to biogas in the anaerobic digester as part of the waste water handling. The current prices of ethanol (110 Euros/MWh) and methane (33 Euros/MWh) favours the production of ethanol.
In the modeled plants a large electricity production influences the total energy efficiency negatively as electricity production in a condensing turbine has lower energy efficiency than the fermentation processes and heat production.
The co-products have a large impact on the process economics.
Comparison of bioethanol and bio-hydrogen process: the production cost of hydrogen is about 20 times more expensive due to low productivity and energy efficiency of the bio-hydrogen process compared to the bioethanol process.
Project outcome : new research areas are needed in order to reach market implementation of 2nd generation ethanol production. One of these areas is the biogas production from 2nd generation waste waters (new Enerbio project with the Lund University). When data are available, and the model validated, it will be implemented into the Aspen Plus models. New evaluation techniques and energy analysis of the bioethanol production will be developed in order to guide the energy integration work towards an optimum utilization of the raw material. The current models are also going to be expanded into producing both heat and solid fuel as a co-product.

Deliverables

Final report
Technical presentations :

Feasibility study of ethanol production from the combination of 1st and 2nd generation raw material. ISAF conference, Verona, October 2011
Improved process economics by combination of 1st and 2nd generation processing in the production of ethanol from the whole wheat plant. ISAF conference, Verona, October 2011
Ljunggren M, Wallberg O, Zacchi G, Techno-economic comparison of a biological hydrogen process and a 2nd generation ethanol process using barley straw as feedstock. Bioresource Technology, 102, 9524-9531, 2011
Feasibility study of ethanol production from the combination of 1st and 2nd generation raw material, manuscript submitted to Applied Energy (Elsevier)

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