Process integration aspects in the design of biofuels production processes

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The design of biofuel processes is realised using a computer aided process system design methodology that aim at defining the type and the size of the technologies, the way they are interconnected and the way they are operated for a given socio-economical and environmental context. The method is using thermo-economic and environomic models of sub-systems that are structured in an equipment data base. In order to build the process, the equipment are assembled to build a flowsheet that represents the conversion of the raw materials (biomass) into products and by-products. Considering the different technological options to be used to build the flowsheet, a superstructure approach is used to systematically include all the possible combinations into a single process model from which the best flowsheet will be extracted using optimization techniques.

In the process, energy is the driving force of the conversion. Therefore in the process design method, it is important to consider not only the mass flow interactions in the flowsheet but also the heat recovery and the combined heat and power production. The process integration is used to analyse, model and optimize the possible interactions between the equipments in the flowsheet.

In the biofuel production processes, optimizing the process integration is of a major importance especially in thermo-chemical processes since the resource is also the energy source. Therefore increasing the efficiency of the energy conversion will at the sime time optimize the conversion efficiency of the raw material, maximizing the fuel production per unit of biomass.

Several aspects of the process integration in biofuel production will be discussed and illustrated based on examples of synthetic natural gas and liquid fuels production from lignocellulosic biomass using thermo-chemical processes. In such processes [1, 2], the biomass (wood) is first dried and gasified before being methanised after gas cleaning. The resulting methane flow is purified by separating the carbon dioxide before being send to the gas grid.

In the process design, the process integration technique is applied for different purposes :

- Pinch analysis is used to model the possible heat recovery in the system. The resulting composite curves obtained by fixing a minimum approach temperature difference calculates the maximum heat recovery and the minimum heat requirement that is defined by the process Grand composite curve [3].
- The optimal integration of the energy conversion systems allows to calculate the minimum amount of resources that is consumed to supply the heat requirement of the process and the optimal integration of the combined heat and power production[4, 5] .
- The waste streams of the process are integrated as energy sources in the process. The process is solved using a Mixed Integer Linear Programming formulation of the process integration that allows to calculate the optimal flows in the flowsheet.
- The combined mass and energy integration method is used to optimize the design of the gas separation process and demonstrates the importance of adopting a holistic approach. In the example, the optimized membrane separation system minimizes the investment while maximizing the waste stream heat valorisation [6, 7, 8].
- Process integration is also used to integrate several processes together. It will be demonstrated the interest of integrating biological processes and thermo-chemical processes in order to practically double the fuel conversion efficiency of the systems [9].
- Resulting from the exergy analysis, we will demonstrate how the integration of heat pumps allows to further increase the fuel conversion efficiency of the system[10].
- The integration of electrolysis in the system allows to increase the productivity in-biofuel while using renewable stochastic electricity [11].
- Integrating the gas purification system and pure oxygen is used to transform the biofuel process process into a CO_2 capture system.

Biography : François Marechal

François Marechal (`mailto:francois.marechal@epfl.ch`) holds a process engineering degree (1986) and a Ph D from University of Liège in Belgium, where he realized a Ph D. in the field of process integration of industrial sites under the supervision of Prof. B. Kalitventzeff. In 2001, he moved to Ecole Polytechnique Fédérale de Lausanne in Switzerland where he joined the Industrial Energy Systems Laboratory. He is now heading a research group (`http://leni.epfl.ch/lenisystem`) conducting research in the field of energy systems engineering. His activities are focussing on the development of computer aided methods applying process integration and optimization techniques. He has produced more then 100 scientific papers in the field of energy efficiency in the industry, process system design for

biofuels and electricity production, industrial ecology and sustainable energy systems in urban areas studying the optimal integration of renewable energy resources. He is member of the scientific committee of IFP Energies Nouvelles and representative of Switzerland in the working party on the use of computers in chemical engineering of the european federation of chemical engineering.

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