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# Heat Integration in a Combined 1st and 2nd Generation Bioethanol Production Process: Targeting the cost reduction, environmental impact, and energy consumption

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This paper provides a renewability assessment of Bioethanol Production 1st and 2nd Generation Combined Process based on the exergy concept and the heat integration approach. The sustainable development should be guided by appropriate methods and metrics that are able to qualitatively and quantitatively measure the performance of combined first (1G) and second (2G) generation bioethanol production technology.

The production process involves several steps, including the modeling and operation settings for biomass Cleaning, Preparation and Extraction unit, Clarification unit, Juice concentration unit, Fermentation unit, Utility plant, Distillation, Dehydration unit and Pre-treatment and Hydrolysis unit. The simulation process was carried out using Aspen Plus® software.

Reducing the energy used in bioethanol biorefineries is an important step towards reducing both the cost and environmental impact of the process. Heat recovery via Pinch technology approach was used to analyze the energy utilization and to investigate possible energy savings in an integrated 1G and 2G bioethanol production plant.

The results indicated the global exergy efficiency (38.78 %) of the process. Consequently, the average unitary exergy cost was 2.57. Concerning, the environmental impact results, it was found the $CO_2$ equivalent index in exergetic base (130.28 g$CO_2$/MJ products), that is the relation between the estimated global $CO_2$ emissions emitted in the atmosphere and the exergy of the products for this integrated baseline configuration, when both, bioethanol and surplus electricity, are considered as products. Furthermore, the environmental exergy indicator "λ" was applied to quantified the renewability processes for the analyzed technological pathway. It was shown that the renewability exergy index ($\lambda$=0.62) was environmentally unfavorable ($\lambda < 1$), indicating that the exergy of the products could not be used to restore the environment to the prior conditions to the occurrence of the process. Lastly, it is observed that heating costs could be reduced by 20-30% and cooling costs by 12-24% via heat integration.

***Keywords:*** Exergy analysis, Lignocellulosic biomass, Sugarcane bagasse, Biochemical route, Cellulosic bioethanol (second-generation ethanol), Heat integration, Global $CO_2$ emissions.

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