Bio-ethylene production: from reaction kinetics to plant scale

Ilenia Rossetti[1], Antonio Tripodi[1], Mattia Belotti[1], Gianguido Ramis[2]

[1] Chemical Plants and Industrial Chemistry Group, Dip. Chimica, Università degli Studi di Milano, CNR-ISTM and ISTM Unit Milano-Università, via C. Golgi 19, 20133 Milano, Italy
[2] Dip. Ing. Chimica, Civile ed Ambientale, Università degli Studi di Genova, via all'Opera Pia 15°, Genoa, Italy

Abstract

Ethylene production from renewable bio-ethanol has been recently proposed as sustainable alternative to fossil sources. The possibility to exploit diluted bioethanol as less expensive feedstock was studied both experimentally, using different catalysts at lab-level, and through preliminary process design. In this work, a full-scale plant simulation is presented, built on a detailed reaction kinetics. Rate equations for the primary and side reactions are revised and implemented with a process simulation package, using a range of thermodynamic methods as best suited to the different process stages. The catalyst loading within the reactor can be effectively distributed according to the underlying kinetic, and the overall plant layout let foresee the best routes for the material recycles. The detailed reaction modeling and the choice of the thermodynamic models are essential to obtain reliable predictions. Setting a target yield of 10^5 t/year of polymer-grade ethylene, the reactive section must be fed with 76 t/h of diluted ethanol and operated under 400 °C; the energy needed amounts to 17 MW_{el} plus 73 MW_{th}.
85% of the fed carbon mass is found as ethylene, 12% remains as ethanol and a 2% as longer olefins. Considering also the recycle of ethanol the carbon conversion and recovery increases to the value of 97.6%.
The global ethylene recovery is 90.7%: most of the loss takes place in the last stage due to the non-condensable purification and to the adopted strategy of having low reflux ratio – and then a closed cryogenic balance – in the last purification column.
Full heat integration of the process with upstream bioethanol production and purification sections allows process intensification and consistent energy savings.
This newly designed process sets the sustainable ethylene production on a detailed and reassessed computational basis.

Corresponding author:

Title:	Prof.
First name:	Ilenia
Name:	Rossetti
Company:	Università degli Studi di Milano
Street:	Via C. Golgi 19
ZIP code Town:	20133, Milan, Italy
Email:	ilenia.rossetti@unimi.it
Phone:	+390250314059

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