UNIVERSITY OF TWENTE.

Ethanol production from lignocellulosic material via enzymatic hydrolysis

PPD-183

Contents

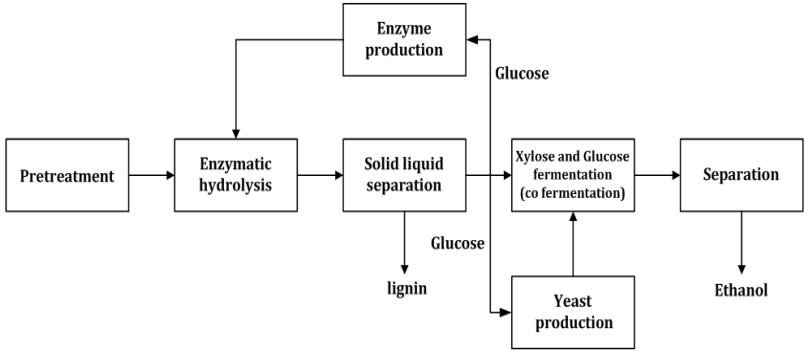
- Overview of the process.
  - Main steps
- Alternative routes.
  - Pretreatment methods
  - Hydrolysis and Fermentation concepts
  - Separation schemes
  - Summary
- Material and Energy balances.
- C-balance and E-balance
- Economic evaluation

Overview of the process

treatment	Hydrolyze	Ferment
• Cellulose • Hemicellulose • Lignin	• C6 (glucose) • C5 (xylose) • Lignin	• Ethanol • Lignin

Capacity: feed = 200 t/h or biomass; >240 ktpa ethanol

Overall Block Scheme

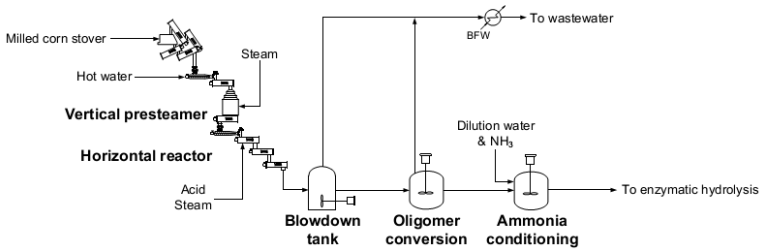


Lignin is burned in a boiler for steam and power

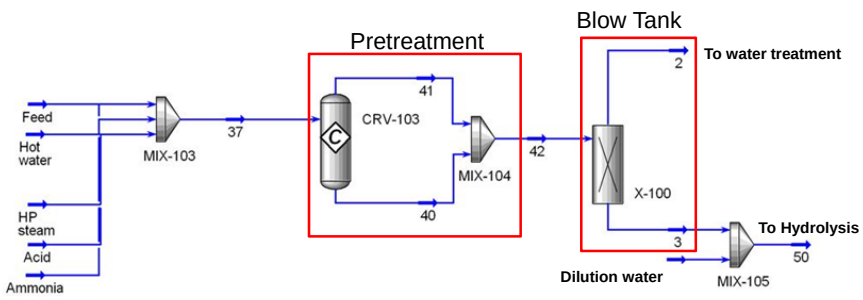
PROCESS + ALTERNATIVES

Alternatives - Pretreatment

- Companies and Institutes
  - Abegona , Spain: Acid catalyzed steam explosion (Demo)
  - Inbicon, Denmark: Liquid Hot water, acid catalyzed (Demo)
  - Iogen, Canada: Steam explosion (Commercial , 70000 t/yr EtOH)
  - NREL, USA : Mechanical , Hot water, acid catalyzed steam.



PFD- Pretreatment



Conversion

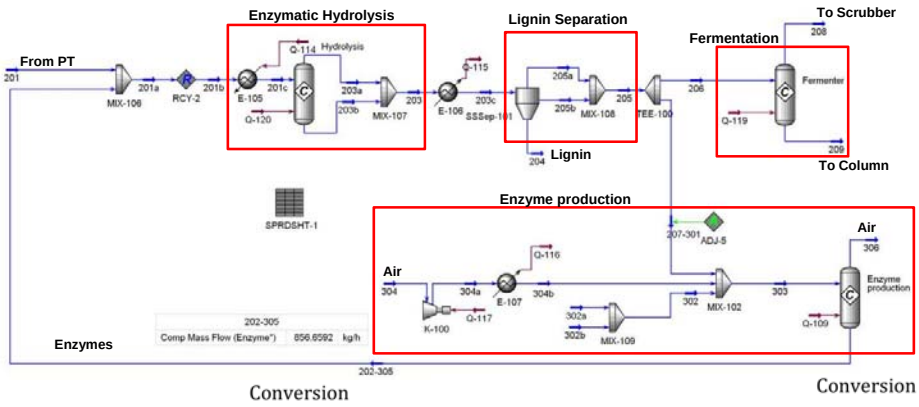
$C_5H_8O_4 + H_2O \rightarrow C_5H_{10}O_5$ 85%

(Hemicellulose) (Xylose)

$C_5H_{10}O_5 \rightarrow C_5H_4O_2 + H_2O$ 8%

(Hemicellulose) (Furfural)

PFD-Hydrolysis and Fermentation



Conversion

$C_6H_{10}O_5 + H_2O \rightarrow C_6H_{12}O_6$ 95%

(Cellulose) (Glucose)

Conversion

$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$ 90%

(Glucose) (Ethanol)

$3\ C_5H_{10}O_5 \rightarrow 5\ C_2H_5OH + 5\ CO_2$ 80%

(Xylose) (Ethanol)

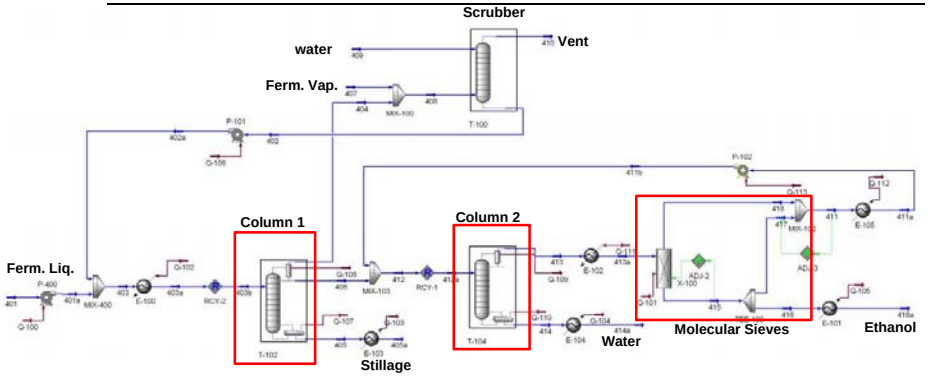
Separation Schemes

- Conventional Distillation (azeotrope)
- Dehydration Technology

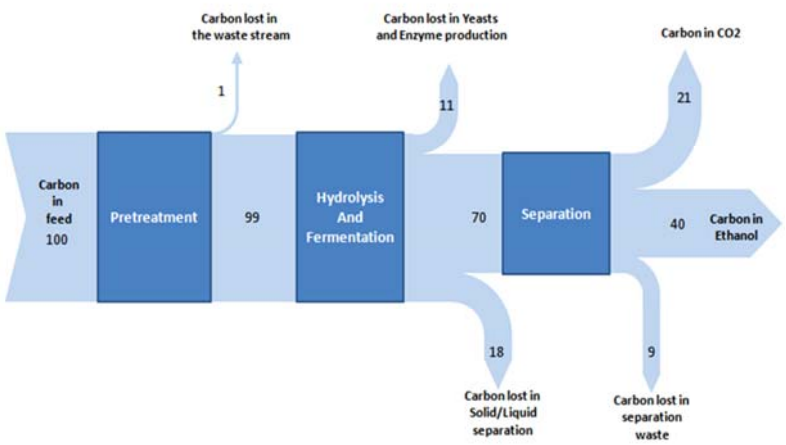
Source: (Sánchez, Moncada et al. 2006)

Dehydration technology	Azeotropic distillation	Extractive distillation	Molecular sieve	Pervaporation
Energy consumed (kcal/kg ethanol)	2,959	2,555	2,297	1,732
Solvent used	Benzene	Ethylene glycol	do not use	do not use
			Sud Chemie (Commercial)	Sulzer

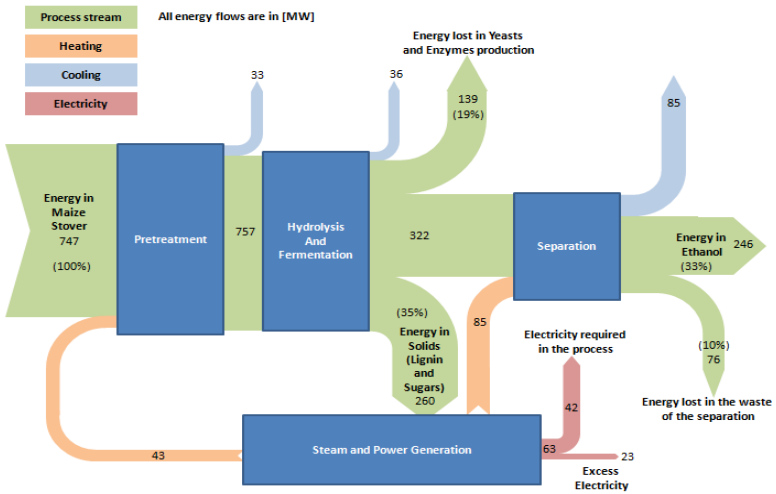
PFD-Separation



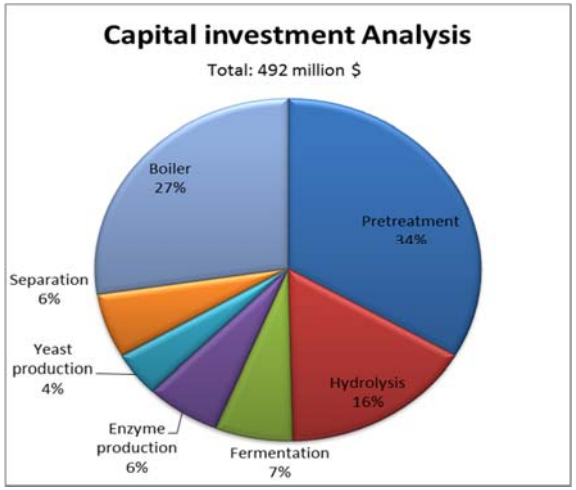
Process analysis: C-balance



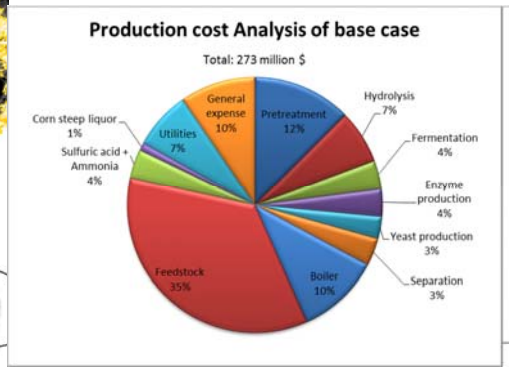
Process analysis: Energy-balance

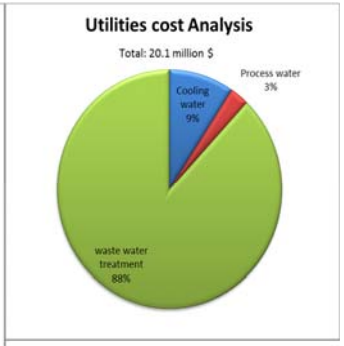


CAPEX (base case)



Operating Costs (base case)



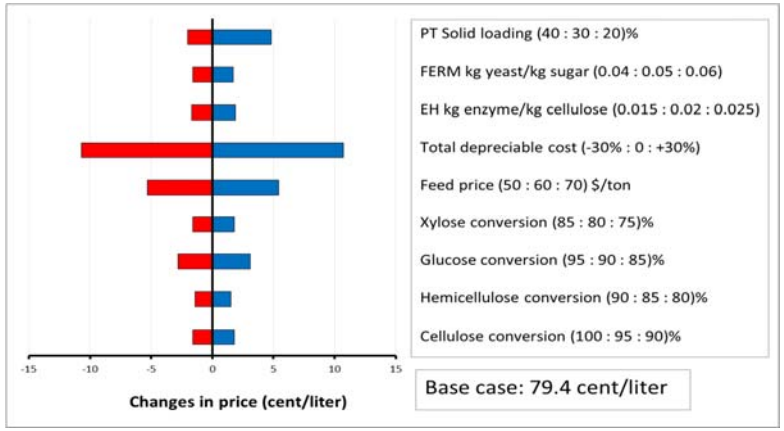


Sales versus production costs (base case)

	Annual production	Price	Value (M$)
Ethanol	265 kton	993 $/ton	262.6
Electricity	180 million kWh	0.06 $/kWh	10.8
Total sales			**273**
General expense			26.1
Total manufacturing cost			247.3
Total production cost			**273**

Minimum ethanol price needed is 993 $/ton (0.79 $/l).
market price is 660 $/ton

Sensitivity!



Press Release

DSM, Corporate Communications
email media.contacts@dsm.com
www.dsm.com

Emmetsburg, Iowa (USA) / Heerlen (NL),
3 September 2014

29E

POET-DSM's cost-competitive fuel cuts emissions, creates jobs, improves energy security

First commercial-scale cellulosic ethanol plant in the U.S. opens for business

Project LIBERTY converts baled corn cobs, leaves, husk and stalk into renewable fuel. The plant has now officially started up, processing its first batch of biomass into cellulosic ethanol and is moving forward toward continuous operation. At full capacity, it will convert 770 tons of biomass per day to produce ethanol at a rate of 20 million gallons per year, later ramping up to 25 million gallons per year.

Fast facts about Project LIBERTY:

- Capital costs are $275 million.
- Fuel from Project LIBERTY represents a GHG reduction of 85%-95% over gasoline.
- The plant employs more than 50 people directly, and biomass harvesting is creating another 200 indirect jobs in the community. In addition, hundreds of people were involved in the construction of the plant.
- The state of Iowa has estimated a $24.4 billion impact on the state over 20 years.
- Project LIBERTY will consume 285,000 tons of biomass annually from a 45-mile radius of the plant.
- Farmers remove approximately 1 ton of residue (~25%) per acre.
- Project LIBERTY will spend approximately $20 million annually purchasing biomass from area farmers, providing additional income to the farmers.
- Project LIBERTY will produce up to 25 million gallons of cellulosic bio-ethanol annually.

http://www.dsm.com/corporate/media/informationcenter-news/2014/09/29-14-first-commercial-scale-cellulosic-ethanol-plant-in-the-united-states-open-for-business.html#

Comparison

	DSM	PPD-183	PPD-183 Best case
Capacity-biomass	32 ton/h	200 ton/h	200 ton/h
Capacity-ethanol	9.4 ton/h	30 ton/h	46 ton/h
Cost of biomass	70 $/t	75 $/t	
CAPEX	275 M$	500 M$	

THANK YOU