Perspectives for bioethanol production in the Netherlands: feedstock selection and pretreatment options

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In a recent directive, the European Commission has stipulated a wider use of renewable transportation fuels-from 2% of total fossil fuel use in 2005 to 5.75% in 2010. As a result, there is a rapidly growing interest in the use of alternative feedstocks for bioethanol production in Europe. As part of a broader technical and economic feasibility study, we conducted an assessment of potential feedstocks and pretreatment methods for large scale lignocellulose-to-bioethanol production in the Netherlands.

Grass from roadside maintenance: a potential feedstock for bioethanol in the Netherlands

Feedstocks in the Netherlands

- Although the Netherlands is a relatively small country, the total amount of ligno-cellulosic biomass (incl. residues)is estimated at 12 M dry tons yr^{-1}. If this entire amount were available as a feedstock an amount of approx 2.5 M tons of bioethanol could be produced per year.
- Most biomass types are dispersed over the country and many have other markets, therefore it is likely that a lignocellulose to ethanol plant will have to use a variety of biomass to secure feedstock availability.
- For further technology development a focus on the three feedstocks is considered: grass from maintenance of roadsides and nature parks, wheat milling residue, and willow (Table 1). These biomass residues are representative for the range of potential feedstocks available in the Netherlands on both short and long term.
- For the longer term (> 10 years), and as production scale increases, the feedstock range should be broadened with additional agro-industrial and other residues, energy crops and/or imported biomass.

Table 1: Composition and availability of lignocellulosic feedstocks in the Netherlands

		Willow	Grass[1]	Grass[2]	Wheat milling residue
Lignin	(%; dry wt)	23	15	25	5
Cellulose + hemicellulose	(%; dry wt)	50	75	46	40-45
Starch	(%; dry wt)				20
Protein	(%; dry wt)				15-20
Ash	(%; dry wt)	0.3	5-20	8	5
Moisture	(%; wet wt)	45	50		14
Availability	(ton d.m.)	variable	275.000		500.000
Current market price	(€/ton d.m.)	70	-30		80
Potential Ethanol yield[3]	(kton y^{-1})	variable	58.6		161.2

[1] roadside; [2] nature parks; [3] conversion of cellulose and starch; 110% hydrolysis yield; 47% ethanol from sugars

Pretreatment options

- A qualitative evaluation of pretreatment methods for enzymatic hydrolysis was performed to identify technologies with good development perspectives
- The most commonly researched pretreatment processes-e.g. strong and weak acid hydrolysis and steam pretreatment, still suffer from major drawbacks including formation of inhibitors, requirement for regeneration of acids and high operational temperatures and pressures.
- Two pre-treatment processes i.e. mild alkaline pretreatment at low temperature and weak acid hydrolysis in pressurized hot water, were identified for further development. These two processes are expected to generate high yields of sugars, cause low formation of inhibitors, and appear to have modest investment costs (Table 2).
- A system evaluation[1] for an integral lignocellulose-to-bioethanol plant (156 kton bioethanol/yr) showed that for all feedstocks, costs of cellulase for enzymatic hydrolysis and capital investments are the major cost drivers. A sensitivity analysis showed that if cellulase costs can be reduced 10-fold and capital costs by 30%, the production cost of bioethanol could be reduced to 0.33-0.43 €/l which is comparable to the current cost of fuel ethanol from corn of 0.34 €/l.

Table 2: Qualitative evaluation of pretreatment technologies

Criteria*: / Pretreatment process:	Potential sugar yield	Formation of inhibitors	Need for recycling chemicals	Formation of residues	Low investment cost	Applicable to different biomass types	Proven at pilotscale	Low operational costs
Weak acid	++	--	--	-	+/-	++	++	+
Strong Acid	++	--	--	-	-	++	++	+/-
Steam Explosion	+	--	++	+	-	+/-	+	_
Organosolv	++	++	--	+	--	+	++	_
Wet Oxidation	+/-	++	++	+	+	?	-	?
Mechanical pretreatment	-	++	++	++	+	-	-	--
Alkaline pretreatment	++/+	++	--	-	++	+/-	+/-	?
Carbonic acid/hot water	++	++	++	++	+	?	_	?

Follow-up Research

The project has resulted in the definition and commitment of a 4-year R&D-project which is implemented by a consortium of industry and the R&D sector. This project will address a number of R&D issues including optimization of pre-treatment and enzymatic hydrolysis, pentose fermentation and CHP of non-fermentable residues. The ultimate goal of the project is the pre-design of an integrated pilot plant for conversion of ligno-cellulosic biomass to ethanol and heat & power.

1 Reference: Reith J.H. et al, 2002. Co-production of bio-ethanol, electricity and heat from biomass residues, 12th European Conference on Biomass for Energy, Industry and Climate Protection, Amsterdam

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