

ECN Activities Concerning Biofuels

1. Introduction

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At the moment, the production of biofuels to substitute fossil fuels for transport is one of the main research items in the ECN R&D portfolio. This corresponds very well with the technology developments necessary to meet the goals defined in the “European Directive on the promotion of the use of biofuels or other renewable fuels for transport” (European Parliament, 8 May 2003). This Directive aims at promoting the use of biofuels or other renewable fuels to replace diesel or petrol for transport purposes, with a view to contribute to objectives such as: meeting climate change commitments, environmentally friendly security of supply and promoting renewable energy sources. Indicative targets have been set for the use of biofuels or other renewable fuels¹. For the end of 2005 a target of 2%, on the basis of energy content², of all petrol and diesel for transport purposes is set, and for the end of 2010 a target of 5.75%. For the period after 2010 it is expected that higher targets will be set (e.g. 8% for 2020 was stated in 2001 by the Commission of the European Communities (CEC) in a proposal for the current Directive).

¹ Actually, the Directive mentions that the member states themselves shall set indicative targets using the given percentages as reference values. The Directive offers a few “escape routes” to justify lower targets. It cannot yet be foreseen in which degree the members states will deviate from the indicative targets and it is unclear what the penalty will be for unjust deviation. The first evaluation of the Directive will take place in 2006.

² The lower calorific value, also known as lower heating value (LHV), has to be used.

Directive on the promotion of the use of biofuels or other renewable fuels for transport European Parliament, May 2003 Indicative targets for diesel and gasoline substitution [% energetic (LHV) basis]		
2005	2010	2020
2	5.75	> 10 ¹

¹Concept directive (2002): 8% in 2020, however, a larger substitution potential is potentially possible.

2. Conventional and Advanced Biofuels

Conventional biofuels		
Name biofuel	Name EU directive	Production process
1. Straight vegetable oil (SVO)	Pure vegetable oil	cold pressing, extraction, refining
2. Biodiesel from seeds	Biodiesel	transesterification SVO
3. Biodiesel from waste (oils/fats)	Biodiesel	refining, transesterification
4. Ethanol from sugar crops	Bioethanol	fermentation, distillation
5. Ethanol from starch crops	Bioethanol	hydrolysis, fermentation, distillation
6. ETBE	Bio-ETBE	fermentation, synthesis
7. SNG from biogas	Biogas	digestion, CO ₂ /H ₂ O-removal
8. Hydrogen from biogas	Biohydrogen	digestion, steam reforming/wgs, CO ₂ -removal

SNG -> CNG/LNG by compression (200-250 bar)/liquefaction (-165°C) for application as transportation fuel, requiring about 5% of the energy content of the biofuel. Hydrogen will be compressed (350-700 bar) before application as transportation fuel, requiring about 8% of the energy content of the biofuel. wgs = water-gas-shift: $\text{CO} + \text{H}_2\text{O} \leftrightarrow \text{H}_2 + \text{CO}_2$.

Advanced biofuels		
Name biofuel	Name EU directive	Production process
9. Fischer-Tropsch (FT) diesel	Synthetic biofuel	gasification, wgs, synthesis, hydrocracking
10. Methanol	Biomethanol	gasification, wgs, synthesis
11. MTBE	Bio-MTBE	synthesis methanol + isobutylene
12. DME	Biodimethylether	gasification, wgs, synthesis
13. Alcohols from syngas	Synthetic biofuel	gasification, synthesis ("Ecalene")
14. SNG from syngas	Biogas, synth. Biofuel	gasification, wgs, synthesis, CO ₂ /H ₂ O-removal
15. Hydrogen from syngas	Biohydrogen	gasification, wgs, CO ₂ -removal
16. Ethanol from celluloses	Bioethanol	advanced hydrolysis, fermentation, distillation
17. HTU-diesel	Synthetic biofuel	HTU, HDO, refining
18. Pyrolysis-diesel	Synthetic biofuel	pyrolysis, HDO, refining
19. SNG from wet materials	Biogas, synth. Biofuel.	super/subcritical gasification
20. Hydrogen from wet materials	Biohydrogen	supercritical gasification
21. Hydrogen from wet materials	Biohydrogen	dark/photofermentation

Gasification = conversion, gas clean-up and gas conditioning.

HTU: hydro-thermal-upgrading; HDO: catalytical hydro-de-oxygenation

The short-term EU substitution targets (2005, 2010) probably will be met by the use of mainly the conventional biofuels biodiesel and bioethanol.

For the longer term (>2010) it is expected that advanced **syngas-derived biofuels** and (cellulosic) bioethanol will become the most important future substitution alternatives.

3. BioSyngas

Why syngas? Security of energy supply Meeting increased H ₂ -use refining processes Use of stranded natural gas resources	Why biosyngas? Climate change commitments (Kyoto) Reduction local environmental effects Limited fossil fuel resources
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Current world-wide use fossil fuel derived syngas (mainly CO and H ₂) [PJ _{th} /year]		
Syngas -> limited amount of main products -> variety of secondary products (methanol, acetic acid -> synthetic materials; ammonia -> artificial fertiliser; ...)		
Carbon monoxide (CO)	Syngas	Hydrogen (H ₂)
<ul style="list-style-type: none"> Acetic acid Phosgene Others 	<ul style="list-style-type: none"> Methanol 684 FT-synth.¹ 484 Hydro-form. Others 50 	<ul style="list-style-type: none"> Ammonia 3250 Oil refining 1400 Hydrogenation Others
12	1218	4650
Total use fossil derived syngas: appr. 5.880 PJ _{th} /year (2% total primary energy consumption) About 16% (950 PJ _{th}) by coal/oil gasification, 84% from natural gas		

¹Sasol and Mossas in South-Africa, Bintulu in Malaysia

Current Dutch fossil derived syngas use [PJ _{th} /year]		
• Ammonia 62	• Oil refining 15	• Methanol 22
Total use fossil derived syngas: appr. 100 PJ _{th} /year (3% total primary energy consumption)		

Current (fossil) syngas use is limited.

Future application potential of (renewable) syngas is huge.

Potential alternative syngas applications	
Syngas -> (intermediates ->) base chemicals, transportation fuels, SNG, power production	
Base chemicals	Transportation fuels
<ul style="list-style-type: none"> Aromatics (benzene, toluene, xylene) Olefins (ethylene, propylene, butadiene) 	<ul style="list-style-type: none"> Methanol Gasoline (MTG process) Dimethylether (DME) Fischer-Tropsch (FT) diesel Mixture of alcohols
Substitute Natural Gas (SNG) production	Advanced power production (BIG/CCs)

Especially the transportation fuel market offers an enormous future substitution potential for (bio)syngas

Biofuel-based substitution scenario for the specific Dutch situation						
	2005		2010		2020	
Diesel and gasoline consumption [P_{th}]	250 + 175 = 425		286 + 162 = 448		360 + 150 = 510	
Biofuel substitution potential [P_{th}]	8.5		25.8		51 ¹	
Biofuel	diesel	gasoline	diesel	gasoline	diesel	gasoline
SVO	5	3.5	16.5	9.3	36	15
Biodiesel (seeds)	0.1	-	0.4	-	-	-
Biodiesel (waste)	-	-	5.0	-	-	-
Ethanol (sugar/starch)	4.9	-	7.7	-	7.7	-
<i>Advanced biofuels</i> ²	-	3.5	-	7.4	-	4.6
Total	-	-	3.4	1.9	28.3	10.4
Total	5	3.5	16.5	9.3	36	15

¹ 10% substitution assumed.

² Diesel substitution mainly by syngas-derived FT-diesel, gasoline substitution mainly by cellulosic bioethanol

4. Conclusion

Large-scale application of biomass-derived syngas transportation fuels is inescapable to meet the long-term policy targets as defined in the European Directive on the promotion of the use of biofuels for transport. Furthermore, biosyngas will play a very important role to meet sustainability criteria in a variety of other market sectors, such as the gas and power sector, and the (petro)chemical sector.

5. BioSyngas Related Activities at ECN

Status, main R&D-issues, and implementation traject syngas-derived biofuels	
Specific capacity biomass gasifiers for conventional syngas applications: 50-200 MW _{th} and for potential advanced transportation fuel production: 1.000 MW _{th}	
Status	Main R&D-issues
<ul style="list-style-type: none"> · Gasification processes to produce an N₂-free and clean biosyngas at large scale are not available yet. Alternatives: O₂-blown fluidised bed, O₂-blown entrained-flow or steam-blown indirect. · Downstream conditioning and synthesis processes to produce a variety of biofuels from clean biosyngas are fully developed and commercially available. 	<ul style="list-style-type: none"> · Biomass pre-treatment and feeding · Biomass conversion behaviour at specific gasification conditions (slagging, agglomeration, ...) · Raw product gas clean-up to meet downstream (catalytic) process requirements · Quality and commercial applicability solid waste streams (ash, slag)
Implementation traject	
PoP: proven, PoC (bench-scale): 2003-2005, demo-scale: 2006-2010, commercial scale: 2010	

6. Other Biomass Related ECN Activities

At the Biomass Department of the Energy Research Centre of the Netherlands (ECN) about 50 highly qualified researchers are working on a variety of biomass related technology developments. Research activities are focussed on: 1) cofiring of biomass in coal and natural gas fired power plants (short-term), decentral biomass-based CHP production (mid-term), and the production of fuels & products from biomass (long-term). Main expertise areas are: biomass classification (i.e. ECN data-base Phyllis, www.phyllis.nl), biomass pre-treatment and feeding (i.e. torrefaction), biomass conversion (gasification, pyrolysis, combustion, biorefinery, slagging/fouling behaviour, quality and com-

mercial applicability solid waste streams), product gas clean-up and conditioning (i.e. OLGA tar removal technology), secondary (catalytic) conversion (Fischer-Tropsch synthesis, methanation, ...), product upgrading, and final product application. The activities are incorporated in an overall in-house ECN R&D strategy, supported by financial, economic and environmental system assessments and integral chain analysis.

Publications (selection)

- [1] Abstracts ECN Biomass to the “2nd world conference and technology exhibition on biomass for energy and industry” (ECN-RX-04-001), Rome, Italy, 10-14 May 2004
- [2] Green diesel from biomass by Fischer-Tropsch synthesis: new insights in gas cleaning and process design (ECN-RX--03-047)
- [3] Liquid fuels from solid biomass: The ECN concept(s) for integrated FT-diesel production systems (ECN-RX--03-060)
- [4] Status update of OLGA technology development: Pilot demonstration of tar removal, complete test facility & new OLGA research topic (ECN-RX--03-063)
- [5] Boerrigter, H.; Uil, H. den; Calis, H.-P. Pyrolysis and Gasification of Biomass and Waste, Bridgewater, A.V.

- (ed.), CPL press, Newbury, United Kingdom, 2003, pp. 371-383. Green diesel from biomass via Fischer-Tropsch synthesis: new insights in gas cleaning and process design
- [6] Bergman, P.C.A.; Paasen, S.V.B. van; Boerrigter, H. Pyrolysis and Gasification of Biomass and Waste, Bridgewater, A.V. (ed.), CPL press, Newbury, United Kingdom, 2003, pp. 347-346. - The novel "OLGA" technology for complete tar removal from biomass producer gas
- [7] Herman, S.A. and Curvers, A.P.W.M. Feasibility Study of the Use of Biodiesel for Transport Purposes in the Netherlands, ECN-CX—02-031, Petten, The Netherlands, December 2002 (confidential)
- [8] Uil, H. den et al., Conventional Bio-Transportation Fuels, An Update, 2GAVE-03.10, Utrecht, The Netherlands, May 2003
- [9] Zessen, E.van et al., Ligno Cellulosic-Ethanol, A Second Opinion, 2GAVE-03.11, Utrecht, The Netherlands, May 2003
- [10] Thuijl, E. van et al., An Overview of Biofuel Technologies, Markets and Policies in Europe, ECN-C—03-008, Petten, The Netherlands, January 2003
- [11] Uil, H. den, Processen voor de Productie van Synthesegas uit Biomassa(rest)stromen, ECN-CX—03-105, Petten, The Netherlands, December 2003 (confidential, in Dutch)
- [12] Deurwaarder, E.P. and Ree, R. van, Biofuels for Transportation, Conventional and Advanced Alternatives within a Dutch Perspective, ECN-CX—03-099, Petten, The Netherlands, December 2003 (confidential)
- [13] Thuijl, E. van, Ree, R. van, Lange, T.J. de, Biofuel Production Chains, Background Document for Modeling the EU Biofuel Market with the BIOTRANS Model, ECN-C--03-088, Petten, The Netherlands, December 2003

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