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LIQUID FUELS FROM SOLID BIOMASS

The ECN concept(s) for integrated FT-diesel production systems

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Presented at the Biomass Gasification Conference (Internationale Tagung: Biomasse-Vergassung - Der Königsweg für eine effiziente Strom- und Kraftstoffbereitstellung), Leipzig, Germany, 1-2 October 2003

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Liquid Fuels from Solid Biomass

The ECN Concept(s) for Integrated FT-Diesel Production Systems

Biomass Gasification Conference, Leipzig, 2 October 2003

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ECN Biomass

(1) ECN Biomass – Biomass Gasification Conference, Leipzig, 1-2 October 2003

Content

- System definition & Assumptions
- Overall production systems
- Development of gasification concepts
- Experimental demonstration
- Conclusions & Outlook

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Concept = Choice !!

System Definition & Assumptions (1)

- Fischer-Tropsch diesel as liquid fuel
  - ultra clean and high quality fuel
  - applicable in current infrastructure/engines & future fuel cells
- FT-synthesis in the Netherlands (Rotterdam Harbour)
  - market for by-products: electricity, heat, and light FT products
- Large-scale centralised systems
  - optimised energy integration
  - economy-of-scale FT synthesis & upgrading

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Concept = Choice !!

System Definition & Assumptions (2)

- Feedstock: (clean) imported biomass
  - assumed future market price of 4 €/GJ (~65 $/ton)
- Biomass import required to achieve targeted production of renewable fuels *(in the Netherlands)*
- *High biomass-to-fuel efficiency required*
  - to reduce cost of expensive biomass fuel
  - fuel cost is major cost-driver (~50%)
- *Production of clean biosyngas is technical issue*

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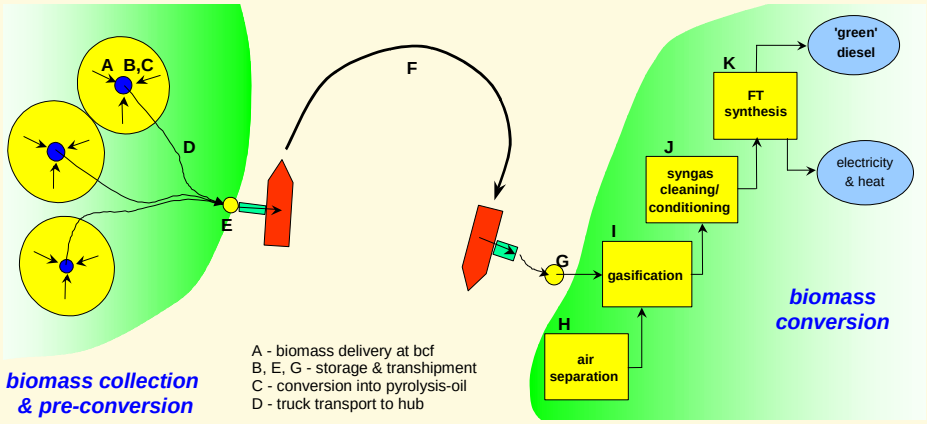
Overall Production System

Large-scale biomass import



Transport of wood logs *(alternative is conversion into pyrolysis oil)*

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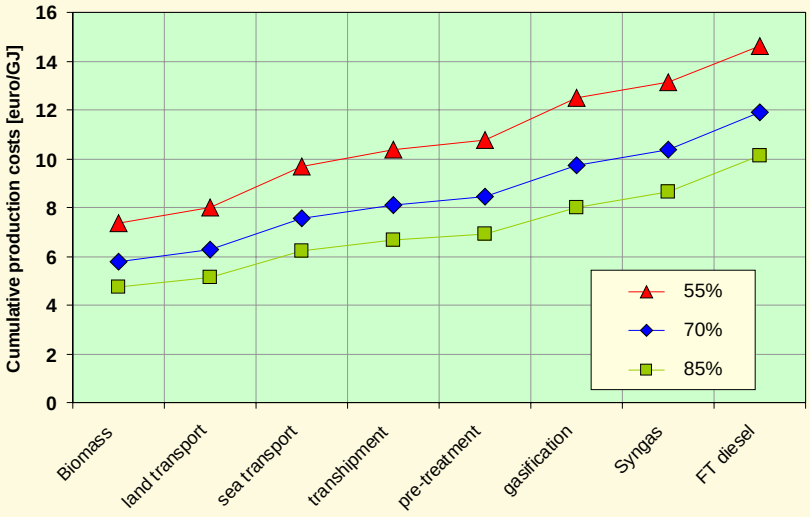
Efficiency Biomass-to-Syngas

8000 MW biosyngas in Rotterdam harbour



Technology:

CFB + tar cracker

biomass costs:
4 €/GJ

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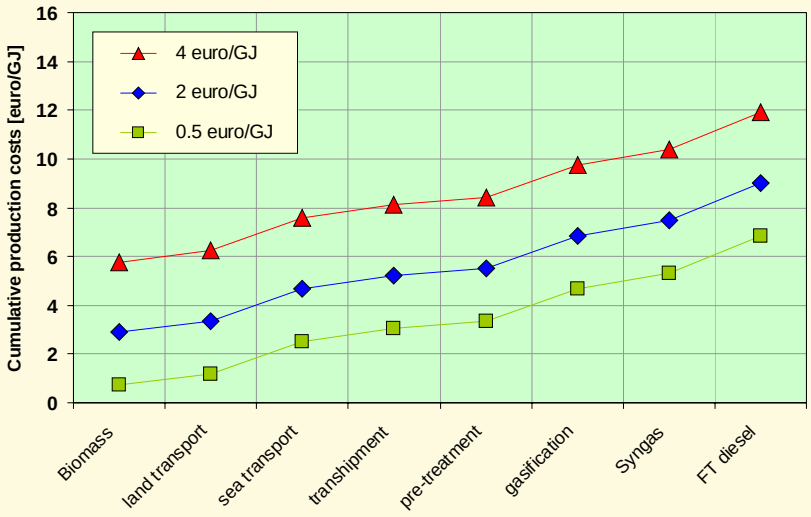
Biomass Feed Cost

8000 MW biosyngas in Rotterdam harbour



Technology:
CFB + tar cracker, 70% gasification efficiency

Contribution biomass feed to fuel costs:

4 €/GJ = 49%
2 €/GJ = 23%
0.5 €/GJ = 11%

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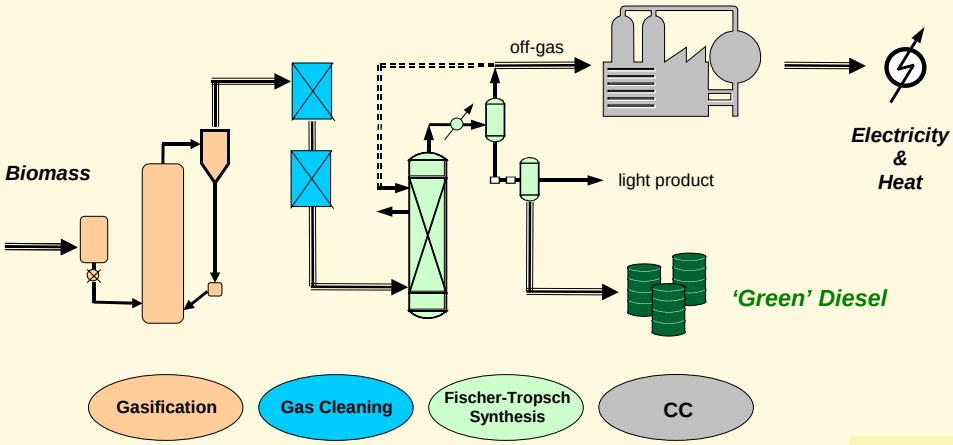
Gasification & Fischer-Tropsch

Integrated system



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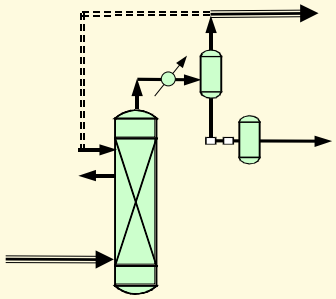
Fischer-Tropsch synthesis

Specifications feed gas

Impurity	Removal level
$H_2S + COS + CS_2$	< 1 ppmV
$NH_3 + HCN$	< 1 ppmV
HCl + HBr + HF	< 10 ppbV
alkaline metals	< 10 ppbV
solids (soot, dust, ash)	essentially completely
organic compounds (tars)	below dew point
- class 2 (hetero atoms)	*< 1 ppmV*



- class 2 tars: phenol, pyridine, thiophene
- organic compounds include also BTX

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Gasification Concepts

Requirements

Clean and conditioned biosyngas:

- Tars, NH_3, HCl, H_2S, COS, alkalines, solids removed
- Maximum 15 vol% inert *(nitrogen, CO_2, also: hydrocarbons)*
- All chemical energy in H_2 and CO
- Ratio H_2/CO = 2 *(overall consumption ratio)*
- Biosyngas @40 bar *(FT synthesis pressure)*

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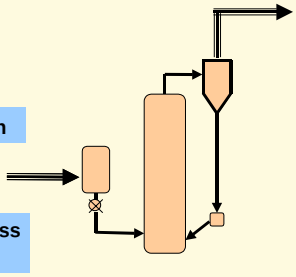
Air-blown CFB Gasification

Implication for cleaning and conditioning

Main Constituents	*[vol%, dry]*	*[LHV%]*
CO	18	27.8
H_2	16	21.1
CO_2	16	-
N_2	42	-
CH_4	5.5	24.1
C_2H_4 (ethene)	1.7	12.4
C_2H_6 (ethane)	0.1	0.8
BTX	0.53	10.5
sum of tars	0.12	2.8
TOTAL	*100*	*100*

dilution

energy loss for FT



CFB gasifier, 850°C, air-blown, atmospheric, wood, 15 wt% moisture

Impurities	*[mg/m_n^3]*
NH_3	2200
HCl	130
H_2S	150
all COS, CS_2, HCN, HBr	< 25
dust, soot, ash	2000

catalyst poisons

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Gasification Concept (1)

CFB gasification + Tar cracker

CFB Gasifier → Tar Cracker 1300°C → Wet Cleaning & Filters → Gas Conditioning → FT synthesis

- Oxygen-blown CFB gasification
- Gasification pressure 20 bar
  - high electricity consumption for syngas compression
- Gas conditioning:
  - compressing from 20 to 40 bar
  - CO_2 removal
  - H_2/CO ratio adjustment

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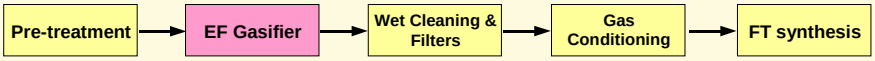
Gasification Concept (2)

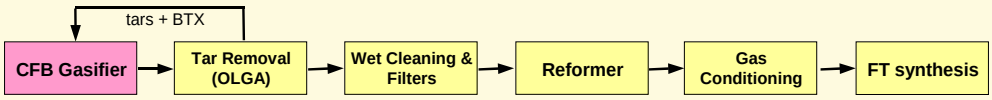
EF gasification of pre-treated biomass



- Pre-treatment of solid biomass
  - pulverisation
- Oxygen-blown EF gasification @40 bar
- Gas conditioning:
  - CO_2 removal
  - H_2/CO ratio adjustment

Gasification Concept (3)

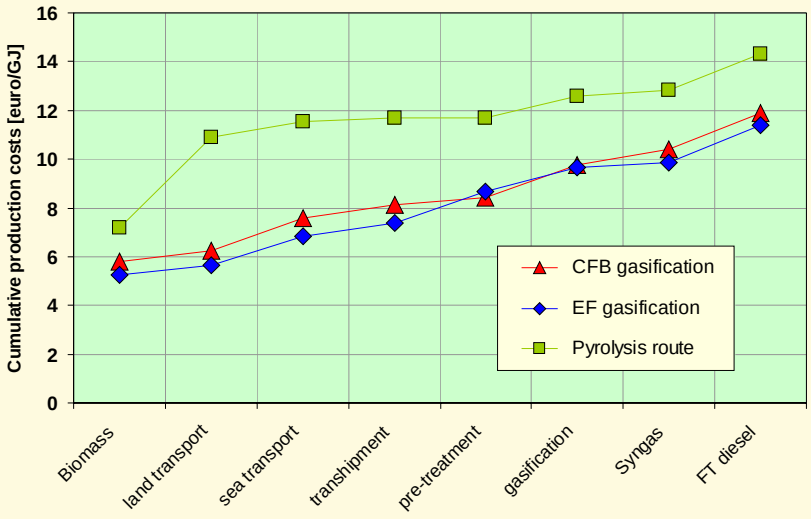
CFB gasification + OLGA + Reformer



- Oxygen-blown CFB gasification @20 bar
- Removal of tars & BTX and recycle to gasifier
- Reforming of hydrocarbons to H_2 and CO
- Gas conditioning:
  - compressing from 20 to 40 bar
  - CO_2 removal
  - H_2/CO ratio adjustment

Production Routes

8000 MW biosyngas in Rotterdam harbour



Efficiencies

CFB: 70%
EF: 77%
Oil: 70x81=57%

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Three ECN concepts

From paper to practice…

- Demonstration of fluidised bed gasification concepts
- Integrated with gasification, gas cleaning, and Fischer-Tropsch synthesis tests

- EF gasifier not available at ECN *(but elsewhere)*
- Issues with EF of solid biomass are:
  - feeding of pulverised wood
  - cost of pre-treatment

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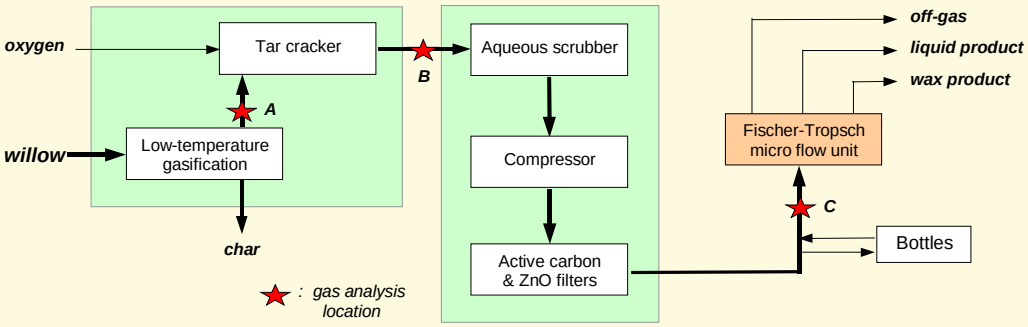
Integrated Test (1)

Low-temperature gasification + Tar cracker



First Production of FT-liquids from wood: December 2001

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AGAF

Advanced **G**as **A**pplication **F**acility

- Processing of product gas
- Compressor - up to 60 bar
- Active carbon filter
- Sulphur removal filter (ZnO)

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Gas Compositions

Destruction of tars and hydrocarbons

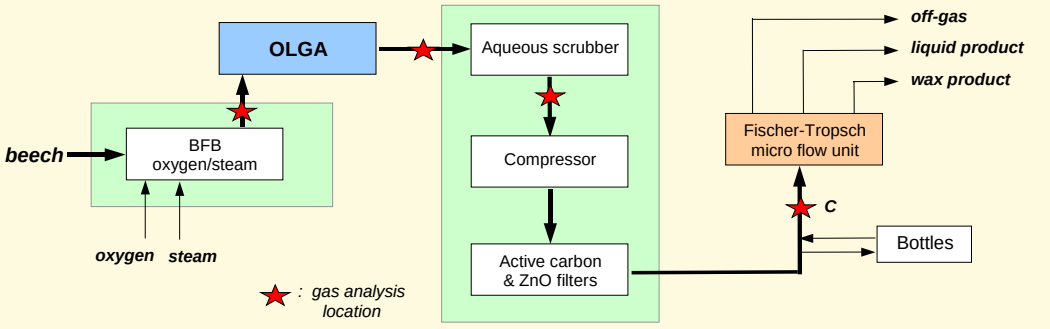
Gas		Raw biosyngas	Cracked biosyngas	FT feed gas
CH_4	[vol%]	6.42	0.01	0.01
C_2H_4	[ppmV]	5936	< 5	< 5
C_2H_6	[ppmV]	7359	< 5	< 5
BTX	[ppmV]	1266	< 5	< 5
Tars	[ppmV]	+/- 50%	< 10	< 10
NH_3	[ppmV]	~	516	0.02
H_2S	[ppbV]	~	23789	< 10
COS	[ppbV]	~	47578	278
CS_2	[ppbV]	~	207	< 10
TOTAL	*[vol%]*	*100.0*	*100.0*	*100.0*

(Experimental data)

1. high-temperature tar cracker
2. wet scrubbers
3. active carbon en ZnO guard beds

Integrated Test (2)

BFB(O_2) Gasification + OLGA tar removal



Demonstrated in March 2003

Gas Compositions

Tar removal with OLGA

Gas		Raw product gas	OLGA gas	Scrubber gas	FT feed gas
CH_4	[vol%]	9.11	9.06	9.05	9.42
C_2H_4	[vol%]	3.08	3.21	3.21	3.00
C_2H_6	[vol%]	0.25	0.25	0.21	0.25
C_2H_2	[vol%]	0.16	0.17	0.17	0.15
benzene	[ppmV]	6813	5018	4507	101
toluene	[ppmV]	710	377	282	19
SPA tars	[ppmV]	4114	< 10	< 10	< 10
NH_3	[ppmV]	~	1304	8.5	0.06
HCl	[ppmV]	~	0.67	< 0.3	< 0.3
H_2S	[ppbV]	~	~	116496	< 10
COS	[ppbV]	~	~	4030	50
CS_2	[ppbV]	~	~	940	30
TOTAL	*[vol%]*	*100.0*	*100.0*	*100.0*	*100.0*

(Experimental data)

1. OLGA tar removal
2. wet scrubbers
3. active carbon en ZnO guard beds

POTTOR

Fischer-Tropsch Reactor

- Shell reactor - operated by ECN
- Fixed-bed reactor

Technical Feasibility Proven

FT synthesis with biomass-based feed gas

Two tests for >500 h *(**December 2001 & March 2003**)*:

1. Low-temperature gasification + Tar cracker
2. Oxygen/steam BFB gasification + OLGA tar removal

   + wet cleaning with scrubber, compression, active carbon & ZnO filters, and FT synthesis unit

Successful:

- Carbon-14 dating of FT products proves biomass origin
- No loss of catalyst activity and selectivity

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"Product in Bottle"

Gas cleaning issue solved

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Conclusions

ECN Biomass-to-Syngas concept(s)

- High conversion efficiencies are essential at expected costs of imported biomass (4 €/GJ)
- Large-scale centralised integrated production systems
- Gasification costs only minor cost driver (~15%)
- Biomass-to-Fuel process costs ~6 €/GJ
- Three feasible ECN Concepts for biosyngas production
  - CFB gasification + tar cracker
  - EF gasification of pre-treated biomass
  - CFB gasification + tar recycle + reformer

Outlook

Ongoing ECN research activities

CFB gasification

- Pilot-demonstration of CFB + OLGA gas cleaning
- Tar cracker studies at >1100°C *(soot formation)*

EF gasification

- Pressurised feeding of solid biomass
- Pre-treatment of solid biomass *(to reduce E-consumption)*
- Selection of EF technology *(slagging vs. non-slagging)*
- Slagging behaviour of biomass ash

OLGA pilot

on ECN site

- Installed July 2003
- Commissioning ongoing
- Test programme: Dec'03 – Jan'04

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Justification & Acknowledgement

Parts of the presentation are based on results of the projects (reports in preparation):

- *Gas Cleaning for Biomass Gasification Fischer-Tropsch Systems* by ECN, Shell, and Utrecht University.
- *Large-scale Syngas Production from Imported Biomass* by Shell, ECN, BTG, Ecofys, and Utrecht University.

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More information

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Publications can be found on:
www.ecn.nl/biomassa

Visit also: "Phyllis" - *internet database for biomass, coal, and residues: www.phyllis.nl*

"Thersites" – *internet database for tar dewpoint calculations: www.thersites.nl*

ECN Biomass

Mission

Contributing to the implementation of biomass (and waste) in the Dutch and global (energy) infrastructure by means of short-term, mid-term, and long-term research, technology development, and knowledge dissemination.

ECN Biomass is a business unit of the Energy research Centre of the Netherlands (ECN)

ECN Biomass

Research Clusters

Power Generation

➔ Slagging, fouling, co-combustion, co-firing, ash-quality

Combined Heat and Power

➔ gasification, combustion, gas clean-up, prime-movers

Fuels and Products

➔ liquid fuels, gaseous energy carriers, syngas, bio-refinery, co-generation

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