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ELECTRICITY FROM BIOMASS

State-of-the-art co-firing and stand-alone CHP technology development in the Netherlands

H.J. Veringa
H. Boerrigter
J.H.A. Kiel

Presented at the ETSF4 conference, PSI Villigen, Switzerland, 5 December 2003

Revisions		
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Made by: H.J. Veringa	Approved/Issued by: Issued:	ECN Biomass
Checked by: H. Boerrigter	H.J. Veringa	

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ETSF4 Conference, PSI Villigen, Switzerland, 5 December 2003

Hubert J. Veringa, Harold Boerrigter, Jacob H.A. Kiel
Energy research Centre of the Netherlands (ECN)
Unit ECN Biomass

CONTENT

- Introduction of ECN Biomass
- Biomass in energy policy in the Netherlands
- State-of-the-Art of co-combustion and co-firing
- Gas cleaning
- Gas cooling and fouling
- Bed agglomeration
- Pre-treatment
- Gasification at ECN

ECN BIOMASS

Energy research Centre of the Netherlands

- **650 employees (ECN)**
- **turn-over 80 M€/y**

(3) ECN Biomass – ETSF4 conference, PSI Villigen, Switzerland, 5 December 2003

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)

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DUTCH RENEWABLE ENERGY POLICY

Contribution of 10% in 2020 = 288 PJ_{th}

Technology	Biomass policy goal [PJ_{th}]		
	2000	2007	2020
Domestic wood combustion	8	8	8
Industrial combustion	5	5	5
Co-firing in fossil fuel power plants	3	→ 18	20
Distributed CHP production	2	6	→ 30
Biogas (landfills, digestion)	6	8	8
Others	-	-	4
Total	24	45	75

Contribution of biomass in 2020 = 26% (75 PJ_{th})

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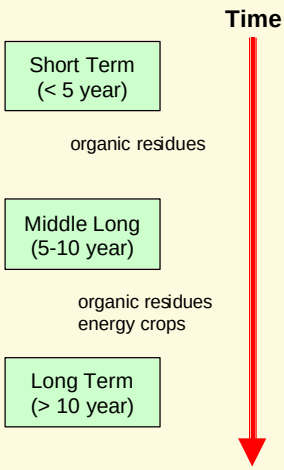
ROADMAP FOR INTRODUCTION

Netherlands energy infrastructure



Conversion system	Product
- co-firing coal plants	E + Q
- distributed CHP (combustion)	E + Q
- co-firing STEG	E + Q
- distributed CHP (gasification)	E + Q
- distributed waste conversion	E + Q
- liquid energy carriers	FT-diesel, bio-ethanol
- gaseous energy carriers	SNG, H_2, CH_4
- polygeneration	gave + E + Q
- bio-refinery	gave + E + Q+ materials + products

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CURRENT CO-FIRING ACTIVITIES IN THE NETHERLANDS

Power plant	Type of cofiring	Type of fuel	[kt/yr]	% cofiring (energy)	CO_2-em.red. [kt/yr]	Status
Gelderland-13	indirect	demolition wood	60	3	110	operational
Amer-8	direct	paper sludge	75	0.3	11	operational
Amer-9	gasification	demolition wood	150	5	170	commissioning
Borssele-12	direct	phosphor furnace gas	23	3	?	operational
Maasvlakte 1/2	direct direct	Biomass pellets[1] poultry litter	150 40	5 4	78 60	operational tested
Buggenum-7	direct	variety	?	?	?	test phase
Hemweg-8	direct	sewage sludge	75	3	92	tested

[1] Demolition wood / sewage sludge: negative view from the public (heavy metal emissions)
[2] Biomass pellets: 60 w% paper/cardboard, 24 w% waste wood, 16 w% compost

SHORT-TERM ADDITIONAL CO-FIRING ACTIVITIES IN THE NETHERLANDS (1)

EPON

- Cofiring percentage of the **Gelderland-13 power plant** 3 -> 10% (relatively clean fuels), by: 1) expanding the current indirect cofiring capacity, 2) direct cofiring, 3) upstream gasification (without add. gas clean-up).
- Cofiring of sewage sludge/high calorific waste streams in the gas-fired **Eems power plant** (1675 MW_e). Technology: upstream gasification with a very extensive fuel gas clean-up system. Maximum cofiring capacity: 100 MW_{th} (3% total energetic natural gas input).

EPZ

- Direct cofiring of 6-12 kt/yr sewage sludge in **Borssele-12 power plant**.
- Cofiring capacity expansion in **all their coal fired power plants**. Technologies: direct cofiring and upstream gasification

SHORT-TERM ADDITIONAL CO-FIRING ACTIVITIES IN THE NETHERLANDS (2)

EZH

- Increasing the quality of the Biomass pellets that are currently being cofired (5%) in the **Maasvlakte power plant** by potentially integrating an additional fuel drying process.
- Direct cofiring of 40 kt/yr poultry litter (4%) planned.

UNA

- Direct cofiring of 75 kt/yr sewage sludge (3%) in the **Hemweg power plant** in testing.
- Potentially two vacuum pyrolysis units (Pyrovac) for cofiring purposes planned. Capacity: 120 kt/yr biomass.

Demkolec

- Direct and indirect cofiring of biomass and waste streams in the **Buggenum** coal fired **IGCC plant** (253 MW_e). Plant sold and on stream again.

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"ADVANCED" FUTURE CO-FIRING CONCEPTS
Cofiring concepts and their potential

Concept	Biomass input [MW_{th}]	Net electrical efficiency biomass part [%LHV]	Necessary additional specific investment costs [Euro/kW_e]
direct cofiring	151/622	39,6	35/20
indirect cofiring	158/649	38,0	500/285
separate gasification - without fgcu (FW) -with fgcu (Lurgi)	 157/648 169/695	 38,1 35,6	 455/300 1120/730
separate pyrolysis - slow without pgcu - slow with pgcu - fast (Pyrovac)	 167/688 186/765 166/682	 35,9 32,3 36,1	 895 1240 935
separate HTU	170/697	35,4	620/490
separate combustion with steam-side integration	155/639	38,6	940/575

Base-case coal fired combustion plant:
- 600 MW_e
- Net eff.: 40 %LHV
- 6000 hrs/yr

10% / 40% cofiring

Base-case natural gas fired CC:
- 335 MW_e
- Net eff.: 55%LHV
- 6000 hrs/yr

5, 10, 20% cofiring

Cofiring in a CC by separate gasification with fgcu (Lurgi)			
Cofiring percentage [% total, energy basis]	Biomass input [MW_{th}]	Net electrical efficiency biomass part [%LHV]	Necessary additional specific investment costs [Euro/kW_e]
5 (6.1)	38	44.3	1500
10 (12.1)	75	44.3	1340
20 (23.7)	151	44.3	1180

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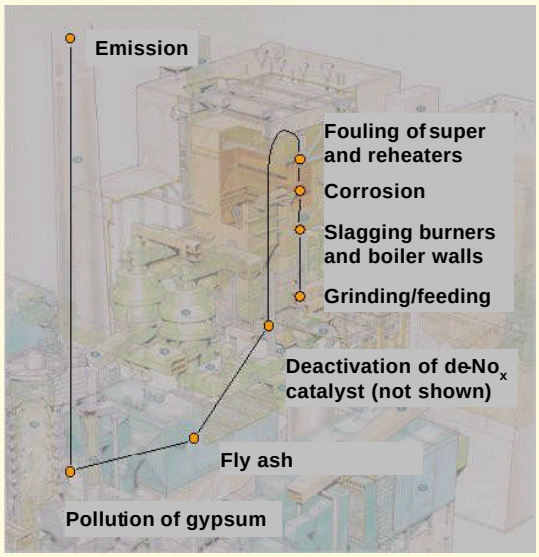
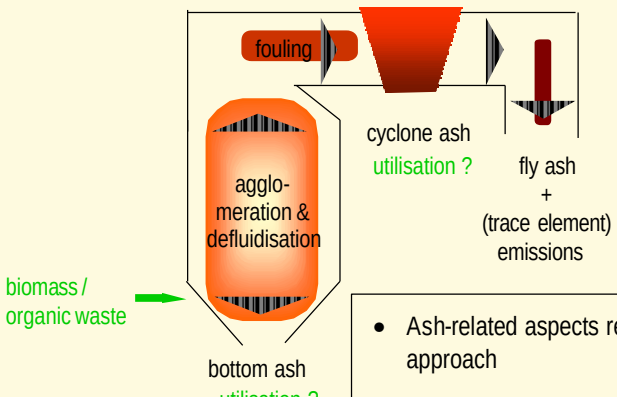
PROBLEM AREAS OF CO-FIRING IN PC BOILERS



problems:
- Pre-treatment and feeding
- Burners
- Heat transfer
- Slagging/fouling
- Bed agglomeration
- Tar
- Corrosion
- NO_x forming
- Emissions
- Ash quality
- …….

PROBLEM AREAS IN FB COMBUSTION AND GASIFICATION

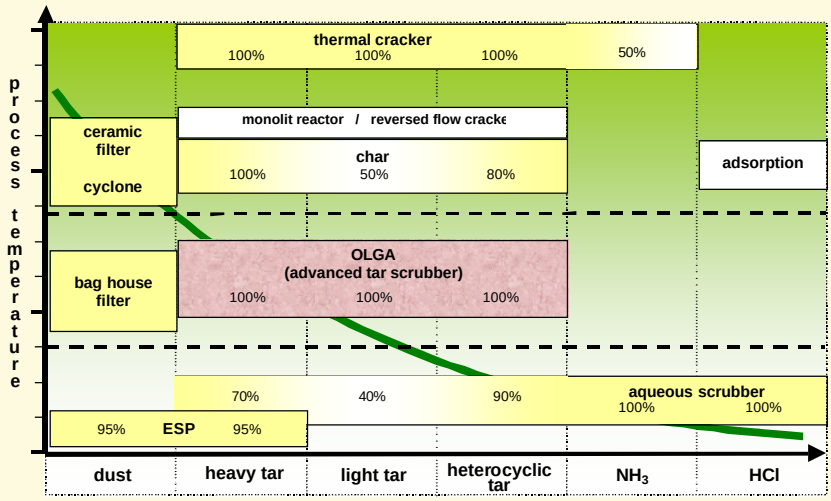


- Ash-related aspects require integral approach
- Ash behaviour & ash quality are non-additive properties

problems:
- Pre-treatment and feeding
- Burners
- Heat transfer
- Slagging/fouling
- Bed agglomeration
- Tar
- Corrosion
- NO_x forming
- Emissions
- Ash quality
- …….

OLGA TECHNOLOGY

Application of an organic scrubbing liquid



Tars removed above water dewpoint

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REASONING OF OLGA

Need for new solution

Tar is the "Achilles heel" of biomass gasification

- Water quench/washer is state-of-the-art
  - Troublesome mixture of dust, tar, and water
  - Process water contaminated with tars
- Fouling, loss of availability
- Removal efficiencies insufficient for advanced applications *(e.g. Fischer-Tropsch synthesis)*

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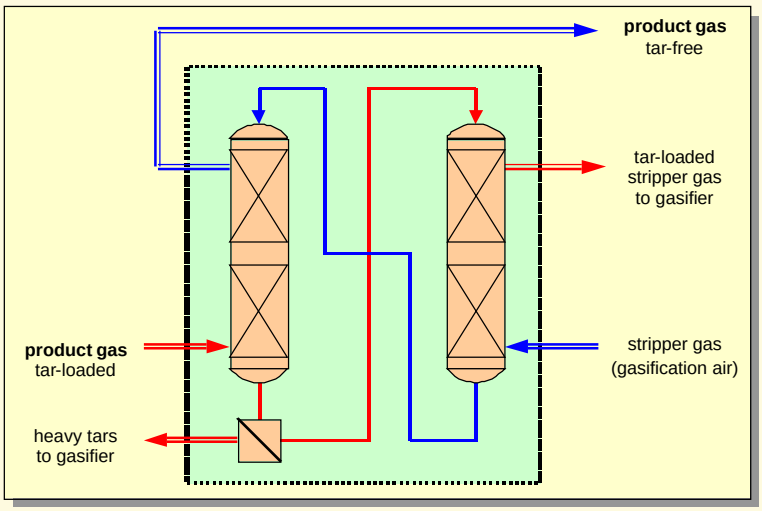
PRINCIPLES OF OLGA

Simplified process sheet



- Application of an organic scrubbing liquid
- Tars recycled to gasifier & destroyed

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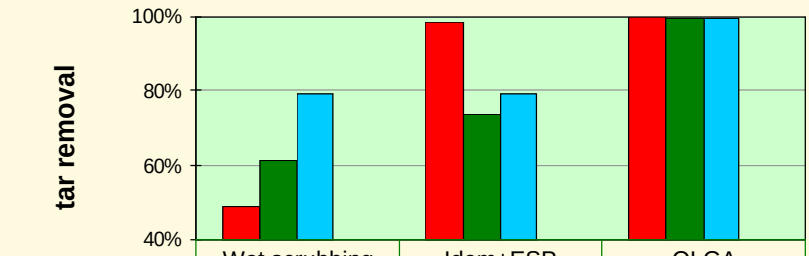
THE "TAR PROBLEM" SOLVED

OLGA tar removal performance



	Wet scrubbing	Idem+ESP	OLGA
heavy tars	49%	99%	100%
light tars	62%	74%	100%
heterocyclic	79%	79%	99%
Dew-point [°C]	180	60	-17

compared to wet-scrubbing gas cleaning

Gas quality sufficient for advanced applications!!

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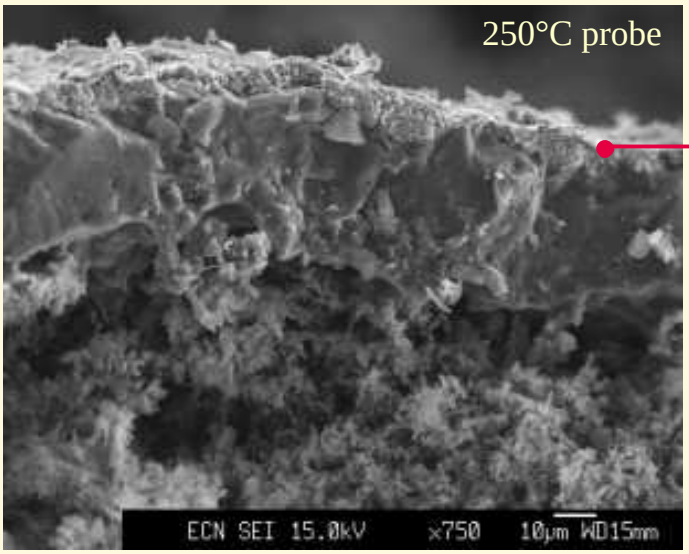
GAS COOLING and FOULING
deposition layer



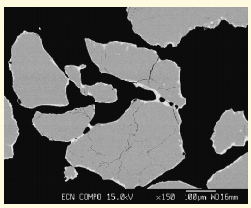
metal

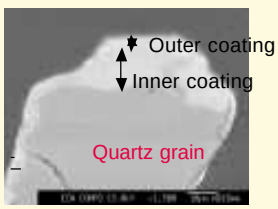
dense layer

insulating layer

BED AGGLOMERATION
Prevention through mechanistic studies

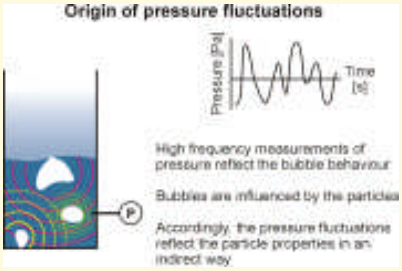
- Debottle-necking + lab-/bench-/pilot-scale experimentation
  - Bubbling fluidised-bed combustion
  - Circulating/bubbling fluidised-bed gasification
- Focus on:
  - Agglomeration mechanisms (coating-induced vs. ash fragments induced agglomeration)
  - Impact of bed material (sand, olivine, ….)
  - Fuel mixing strategies to suppress/prevent agglomeration

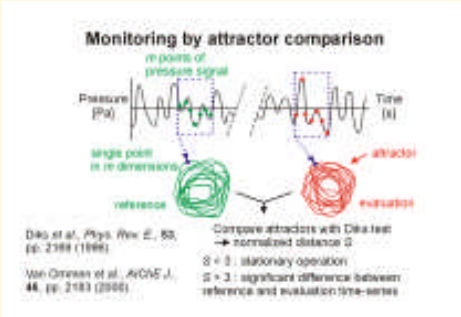




BED AGGLOMERATION
On-line monitoring and control

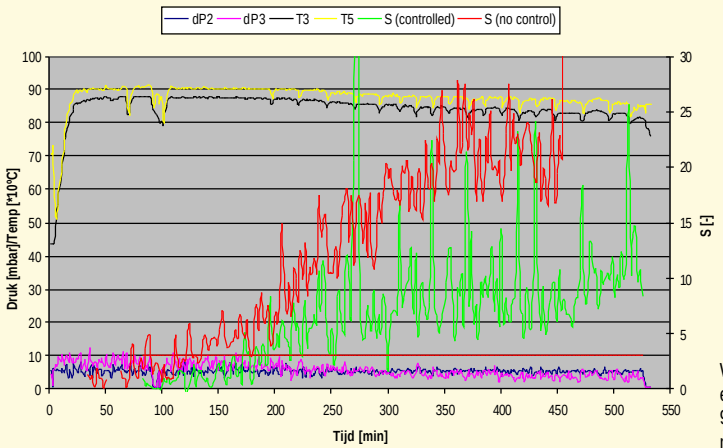
- Early Agglomeration Recognition System (EARS)
  - Monitoring by analysis and interpretation of pressure fluctuations
  - Development of effective control strategies minimising bed material make-up

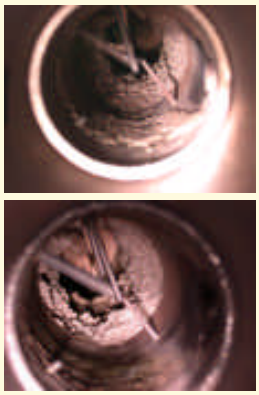




BED AGGLOMERATION
On-line monitoring and control (EARS)

- EARS allows early recognition providing time for control





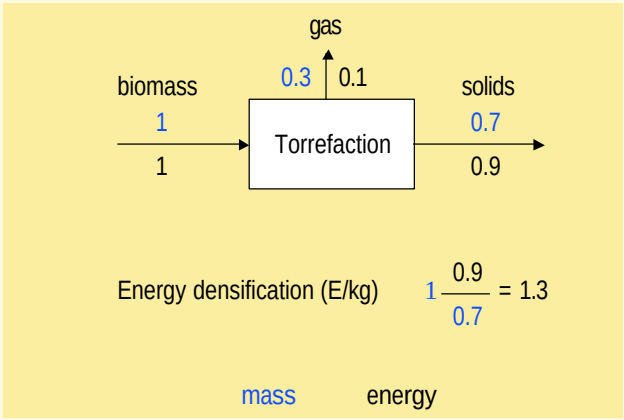
WOB combustion experiments with a 90/10 wood/straw mixture

ABOUT TORREFACTION

- Torrefaction = thermal pre-treatment at 180 - 290 °C in the absence of oxygen
- Aim:
  - to improve biomass properties in favour of end-user applications as combustion and gasification
  - To separate valuable compounds in a cascade approach
- Benefits of torrefaction:
  - Improved grinding behaviour (co-firing)
  - Hydrophobic behaviour (transport, storage)
  - Higher heating value per unit mass (transport)
  - Increased uniformity

Torrefaction is a pretreatment technology

TYPICAL MASS AND ENERGY BALANCES

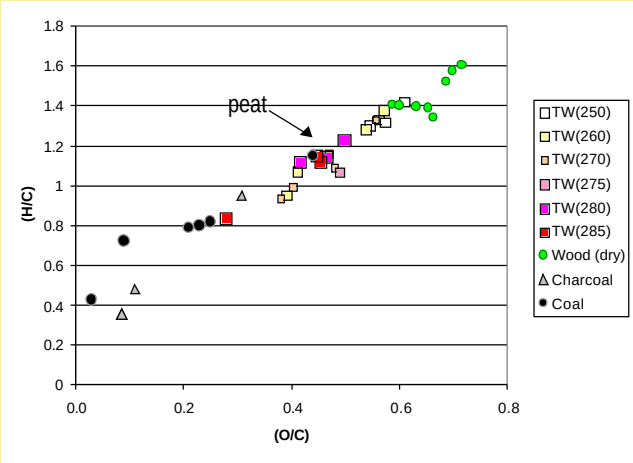


Charcoal production:
mass yield :20 - 30%
energy yield: 40 - 60%

Pyrolysis oil production:
mass yield : 60 - 70%
energy yield: 60 - 70%

Lignocellulose loses components with low energy content and so keeps the energy in the product

VAN KREVELEN DIAGRAM: BIOMASS BECOMES … COAL?



Biomass becomes like peat!

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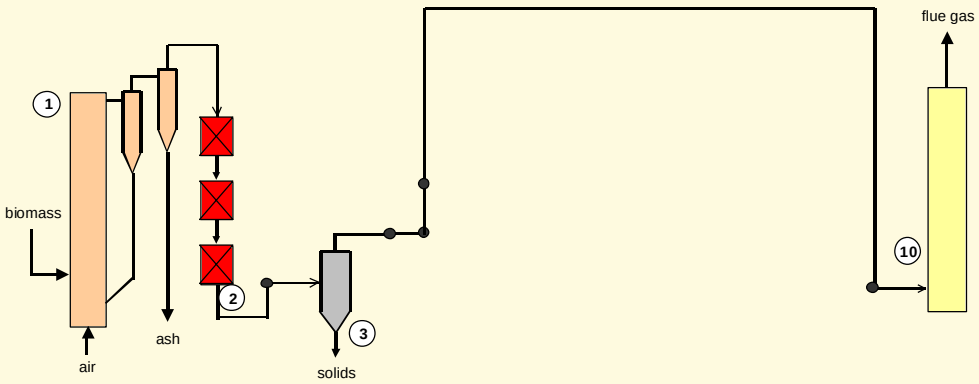
GASIFICATION RESEARCH at ECN

direct combustion or co-firing



(1) 500 kW_{th} circulating fluidised bed (CFB) gasifier; (2) three-stage gas cooler to cool to ~300/350°C; (3) cyclone at 300°C; (10) low-NOx burner.

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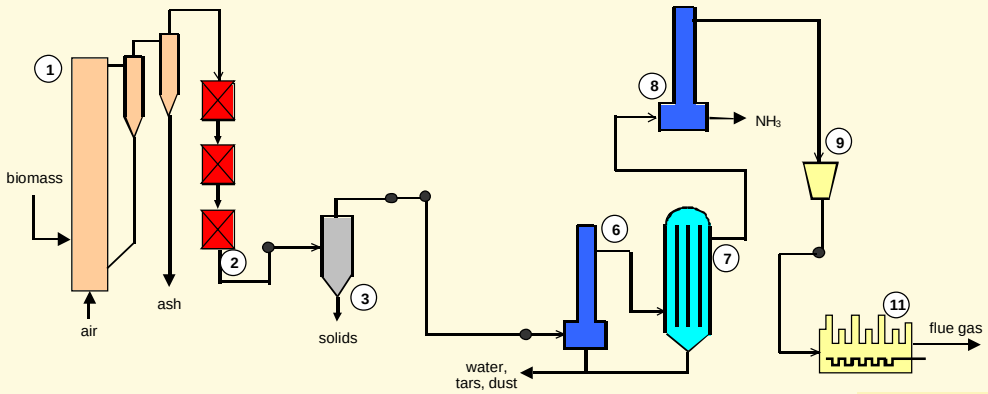
GASIFICATION RESEARCH at ECN
CHP application with gas engine



(1) 500 kW_{th} circulating fluidised bed (CFB) gasifier; (2) three-stage gas cooler to cool to ~300/350°C; (3) cyclone at 300°C; (6) water (NH_3) scrubber; (7) wet Electro-Static Precipitator (ESP); (8) stripper; (9) booster; (11) gas engine

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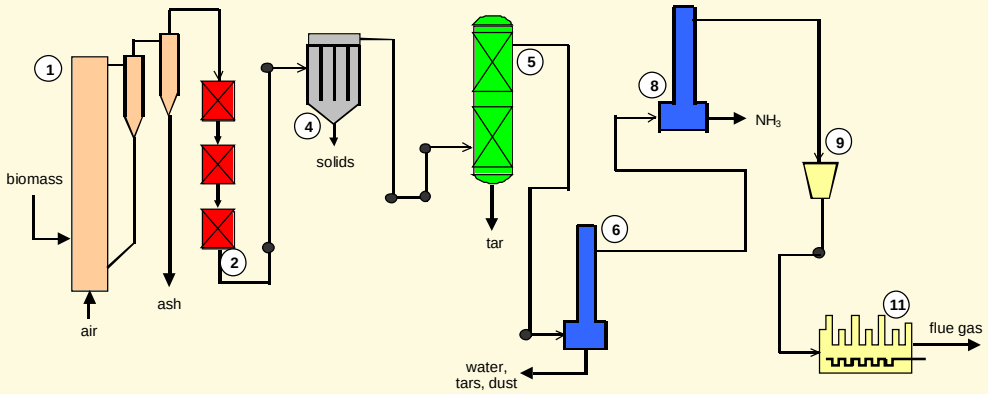
GASIFICATION RESEARCH at ECN
application for turbine, fuel cell, synthesis



(1) 500 kW_{th} circulating fluidised bed (CFB) gasifier; (2) three-stage gas cooler to cool to ~300/350°C; (3) cyclone at 300°C; (4) hot gas filter with sinter metal candles at ~350°C; (5) OLGA tar removal unit; (6) water (NH_3) scrubber; (8) stripper; (9) booster, (11) gas engine or SOFC or Fischer-Tropsch reactor.

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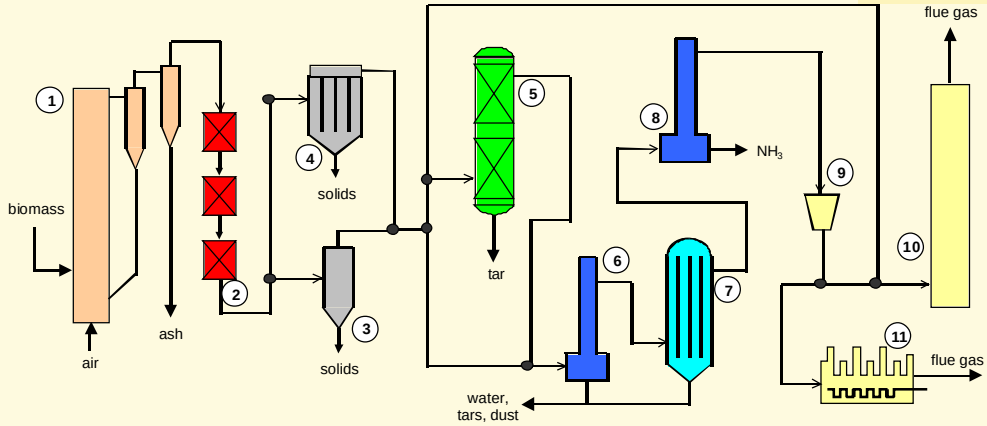
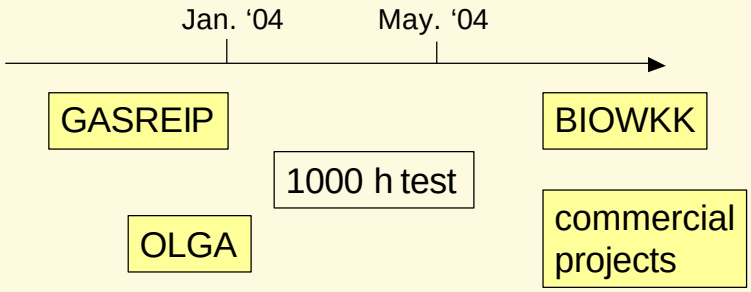
GASIFICATION RESEARCH at ECN
complete system



(1) 500 kW_{th} circulating fluidised bed (CFB) gasifier; (2) three-stage gas cooler to cool to ~300/350°C; (3) cyclone at 300°C; (4) hot gas filter with sinter metal candles at ~350°C; (5) OLGA tar removal unit; (6) water (NH_3) scrubber; (7) wet Electro-Static Precipitator (ESP); (8) stripper; (9) booster; (10) low-NOx-burner; and (11) gas engine or SOFC or Fischer-Tropsch reactor. The black circles indicate valves.

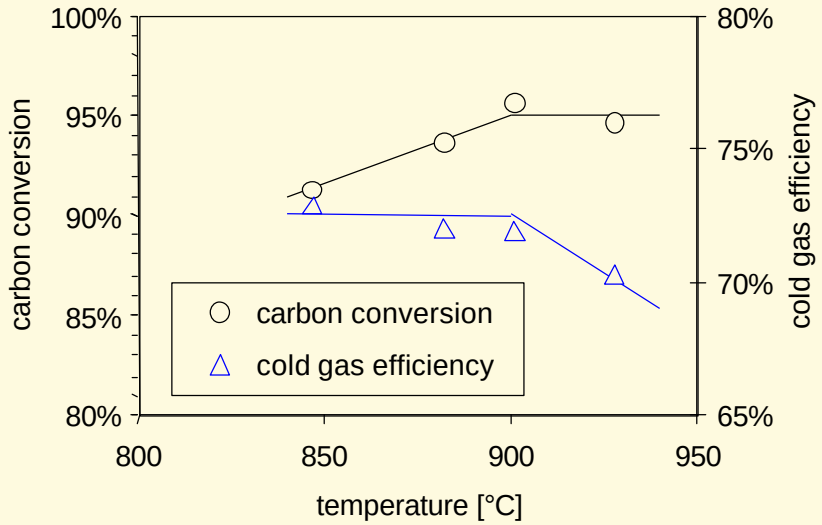
NEAR FUTURE



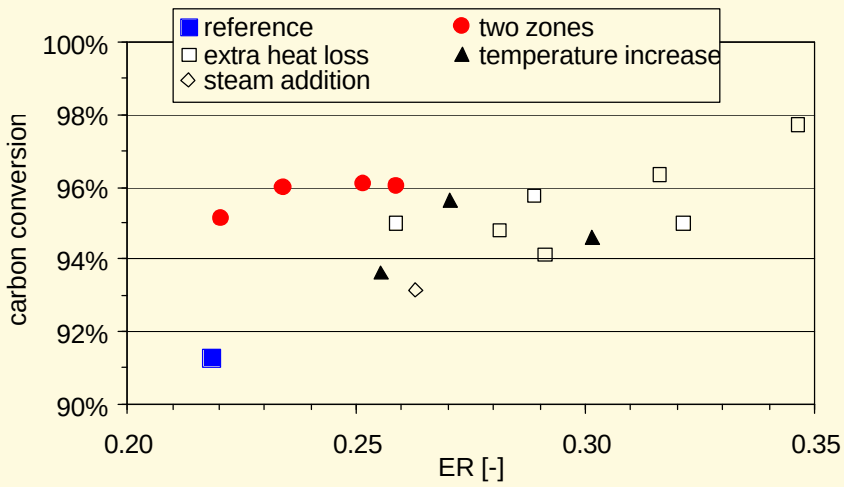
Partners 1000 hour test:

- Essent
- HoSt
- HABO
- Dahlman
- ECN
- NOVEM

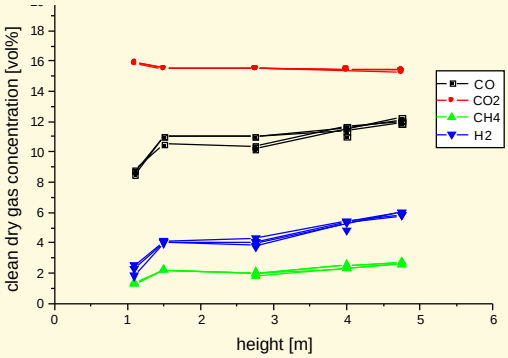
CFB GASIFICATION
carbon conversion (1)



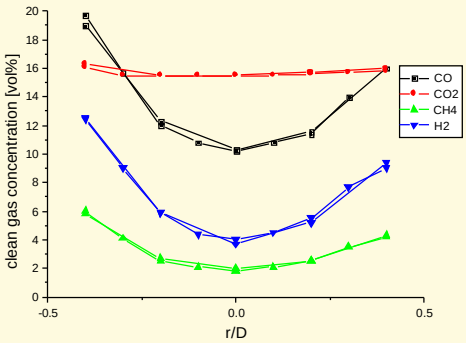
CFB GASIFICATION
carbon conversion (2)



CFB GASIFICATION
concentration profiles



axial profile (centre of riser)



radial profile (2.8 m height)

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