Improved Gasifier Availability With Bed Material and Additives

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June 2013
ECN-L--13-040

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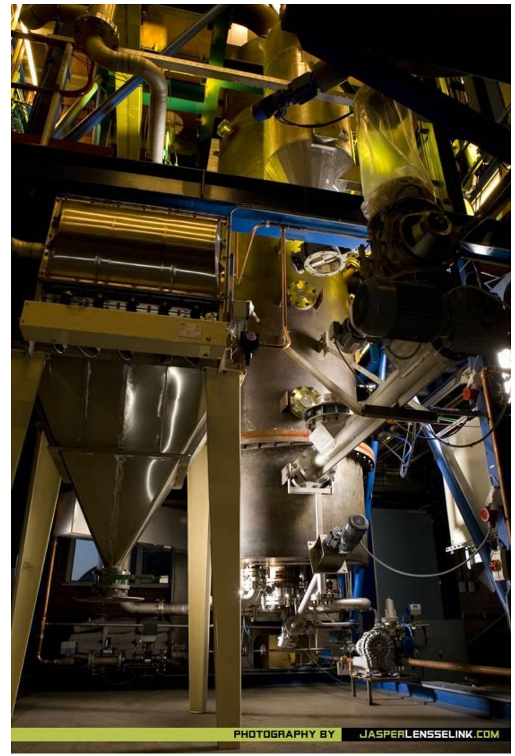
Copenhagen
3th of June 2013

Outline

- Introduction
  - ECN
  - MILENA gasifier
  - Tars
  - Research goal
- Experiments & results
  - Tar reduction
  - SEM analysis
- Conclusions



The Energy research Centre of the Netherlands (ECN)

ECN

- Largest Dutch R&D centre for renewable energy.
- Partly financed by Netherlands and EU government grants, and partly by contract R&D.
- Main products: technology licenses and contract R&D
- 600 staff

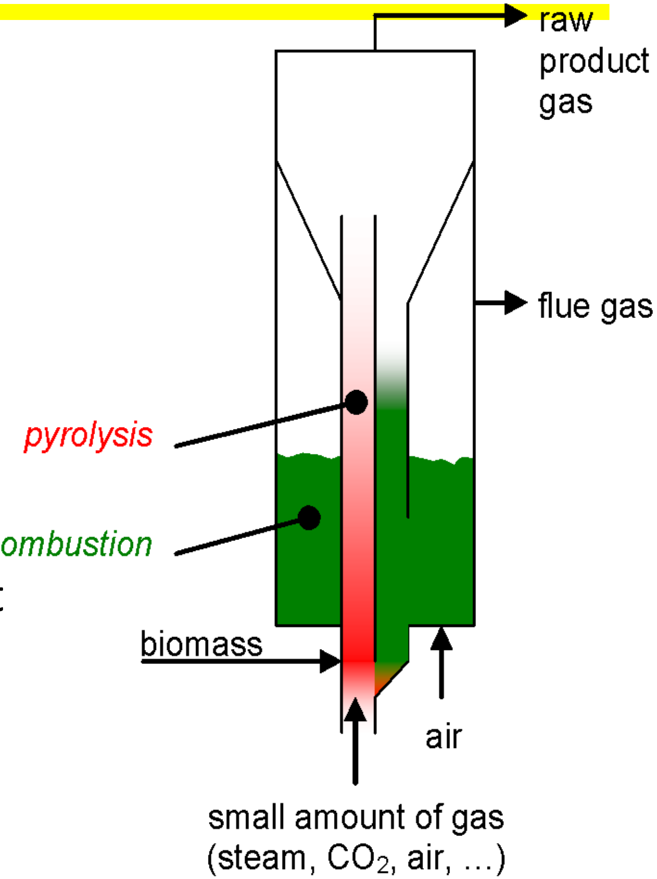
MILENA gasifier

- Dual Fluidized Bed (DFB) gasification
- High efficiency, low steam use, no ASU
- 12 – 15 MJ/Nm^3(dry basis), low N_2
- Heat transfer through bed material circulation
- 30 kWth lab scale & 800kWth pilot scale
- 12 MWth demonstrator, 2015 in operation
- Scalable (> 100 MW)

- Bed material circulation: ± 40 x biomass input
- Bed material average residence time:
  - Riser: ± 5 seconds (´reducing´ conditions)
  - Combustor: ± 12 minutes (oxidizing conditions)

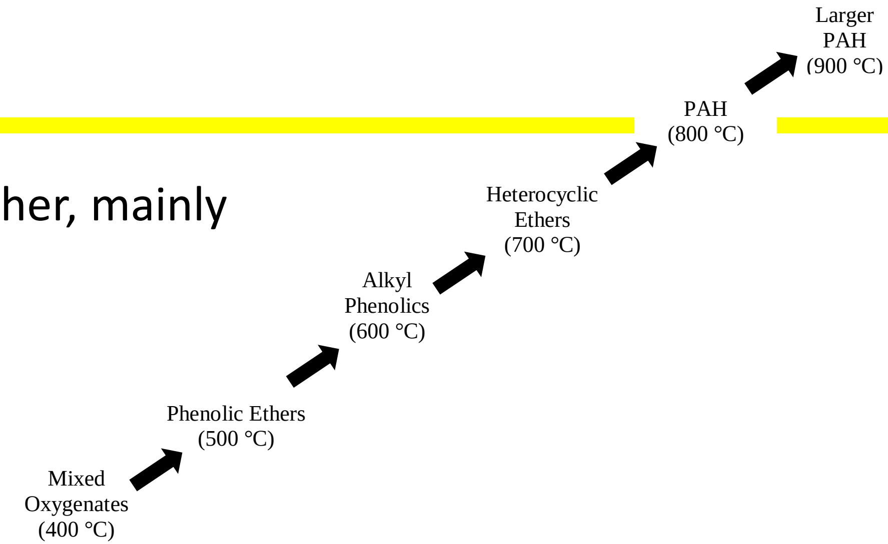
➢ More tar than DFBs with BFB gasification

➢ Less time in the riser for primary measures



Tar in product gas

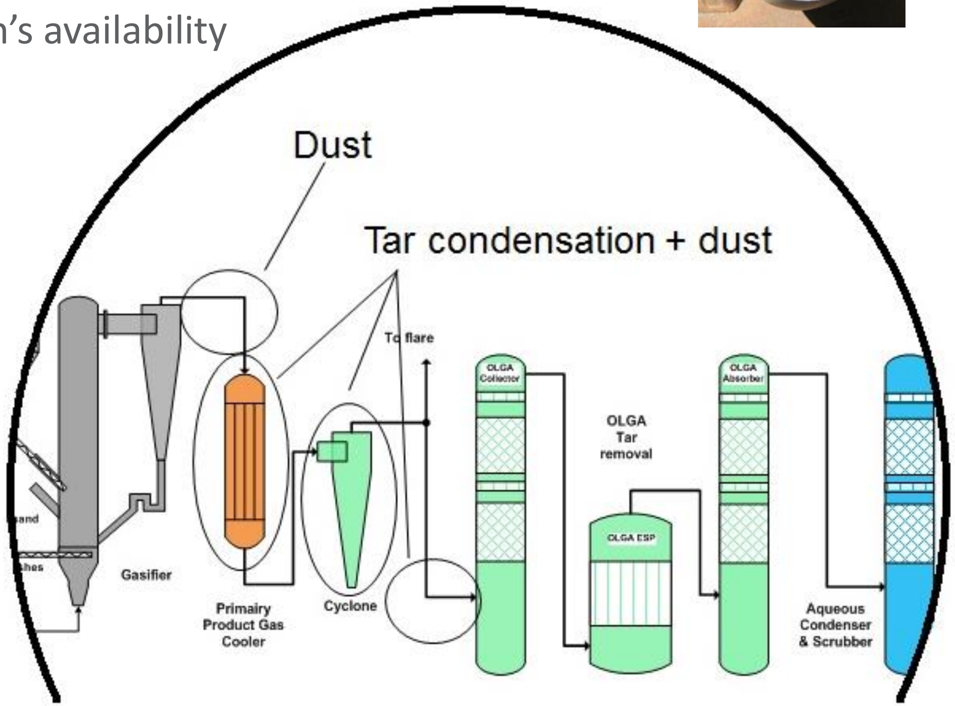
- Tar is a collective term for higher, mainly aromatic hydrocarbons
- ECN tar classification
- Heavy tars dominate dew point



Tar class	Class name	Properties
1	GC undetectable	7- and higher ring compounds
2	Heterocyclic	Cyclic hydrocarbons with heteroatoms, (highly) water soluble
3	Light aromatic	Compounds that usually do not pose problems regarding condensation or water solubility
4	Light polyaromatic	2- and 3-ring compounds that condensate at intermediate temperatures at relatively high concentrations
5	Heavy polyaromatic	4 – 6-ring compounds that condense at high temperature at low concentrations, like coronene (MW = 300 g/mol)

Tar problem

- Heavy tar is problematic because:
  - Condensation of heavy tars at 400 – 500 °C
  - Dust can add to the tar problem: sticks to tar
  - Clogging and fouling reduces system's availability



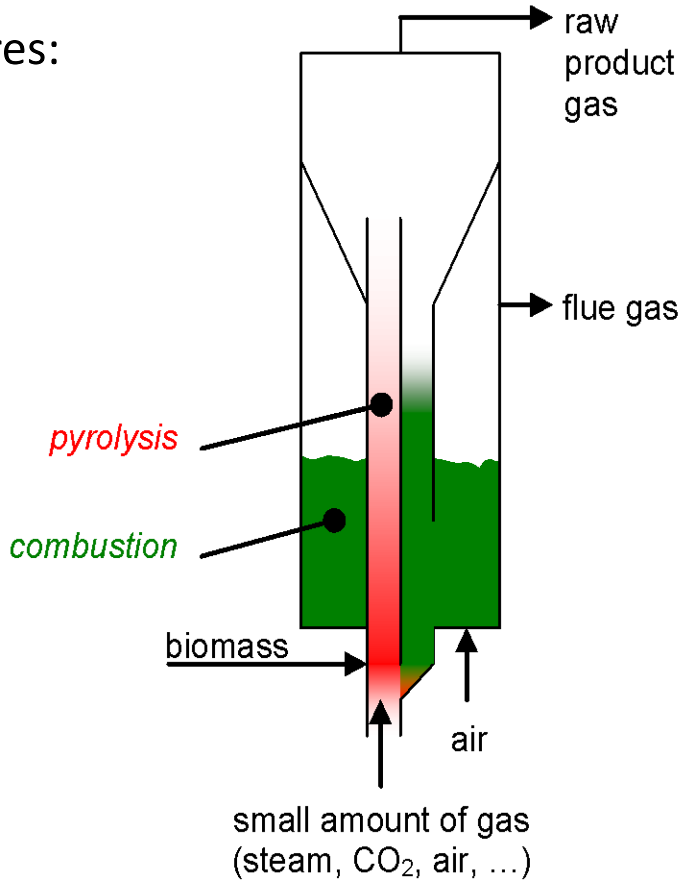
Primary measures

- Reduce tars by primary & secondary measures:
  - Primary = treatment inside the gasifier
  - Secondary = gas cleaning after the gasifier (OLGA)

➢ More tar than DFBs with BFB gasification

➢ Less time for primary measures

- Goal of research (2011 - 2013)
  - Improve availability of gasifier by:
    - Lowering and controlling tar in product gas
    - Focussing on primary measures, including:
      - Active bed material
      - Additives



Experiments

- Lab scale MILENA experiments (2011 – 2013)
- Beech wood, standard fuel & Fuel B, mineral rich fuel

- Gas analysis by online gas monitors & µ-GC
- Solid-Phase Adsorption (SPA) tar sampling

	T gasification	T combustion	Fuel	Steam to C
	[°C]	[°C]	[kg/h]	[kg/kg]
Sand	810	849	4.5	0.65
Norwegian olivine (N olivine)	853	890	5.0	0.60
Austrian olivine (fresh) (A olivine)	876	912	4.5	0.68
Sand + Fuel B	855	898	4.6	0.68
N olivine + Fuel B	853	914	5.0	0.58
A olivine + Fuel B	846	921	4.5	0.65
A olivine (activated after 200 h)	870	924	4.5	0.65
A olivine + Additive A	867	902	4.5	0.65
A olivine +Additive A+ B	855	868	4.5	0.65

Results

- Main gas components
  - Sand is inert, no increased Water-Gas Shift (WGS) activity
  - Olivines enhance WGS

	CO	H_2	CO_2	CH_4
	[Vol $\%_{db}$]	[Vol $\%_{db}$]	[Vol $\%_{db}$]	[Vol $\%_{db}$]
Sand	45	18	15	14
Norwegian olivine (N olivine)	29	26	25	13
Austrian olivine (fresh) (A olivine)	35	21	24	12
Sand + Fuel B	31	24	21	14
N olivine + Fuel B	25	30	24	10
A olivine + Fuel B	21	29	32	10
A olivine (activated after 200 h)	22	28	33	11
A olivine + Additive A	28	27	27	11
A olivine +Additive A+ B	23	27	30	12

Results

- Tar content of product gas:

	Class 2	Class 3	Class 4	Class 5	Unknowns	Total
	[g/Nm^3]	[g/Nm^3]	[g/Nm^3]	[g/Nm^3]	[g/Nm^3]	[g/Nm^3]
Sand	1.3	0.7	27.5	**6.6**	12.9	**49.1**
Norwegian olivine (N olivine)	2.2	0.6	15.7	3.2	5.2	26.9
Austrian olivine (fresh) (A olivine)	0.7	0.5	23.1	**5.6**	8.9	**38.8**
Sand + Fuel B	1.2	0.9	27.6	**6.5**	13.7	**49.9**
N olivine + Fuel B	0.4	0.9	23.6	**5.7**	8.6	**39.2**
A olivine + Fuel B	0.1	0.4	8.0	0.6	1.9	11.0
A olivine (activated after 200 h)	0.1	0.4	7.9	0.8	1.5	10.5
A olivine + Additive A	0.4	0.4	14.8	2.8	4.8	23.1
A olivine +Additive A+ B	0.2	0.5	13.9	2.1	3.1	19.7

  – Being inert or with moderate WGS: high tar
  – High tar dew point, estimated 400 – 500 °C

Results

- Tar content of product gas:

	Class 2	Class 3	Class 4	Class 5	Unknowns	Total
	[g/Nm^3]	[g/Nm^3]	[g/Nm^3]	[g/Nm^3]	[g/Nm^3]	[g/Nm^3]
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Sand + Fuel B	1.2	0.9	27.6	6.5	13.7	49.9
N olivine + Fuel B	0.4	0.9	23.6	5.7	8.6	39.2
A olivine + Fuel B	0.1	0.4	8.0	**0.6**	1.9	**11.0**
A olivine (activated after 200 h)	0.1	0.4	7.9	**0.8**	1.5	**10.5**
A olivine + Additive A	0.4	0.4	14.8	2.8	4.8	23.1
A olivine +Additive A+ B	0.2	0.5	13.9	2.1	3.1	19.7

- Fuel B after 24 hour and standard fuel after 200 hour: active bed material!
  - Up to 85% reduction of heavy tars (class 5)
  - Dew point around ≤ 200 °C, conventional gas coolers, no HT steel
  - Not all olivines can be activated

Results

- Tar content of product gas:

	Class 2	Class 3	Class 4	Class 5	Unknowns	Total
	[g/Nm^3]	[g/Nm^3]	[g/Nm^3]	[g/Nm^3]	[g/Nm^3]	[g/Nm^3]
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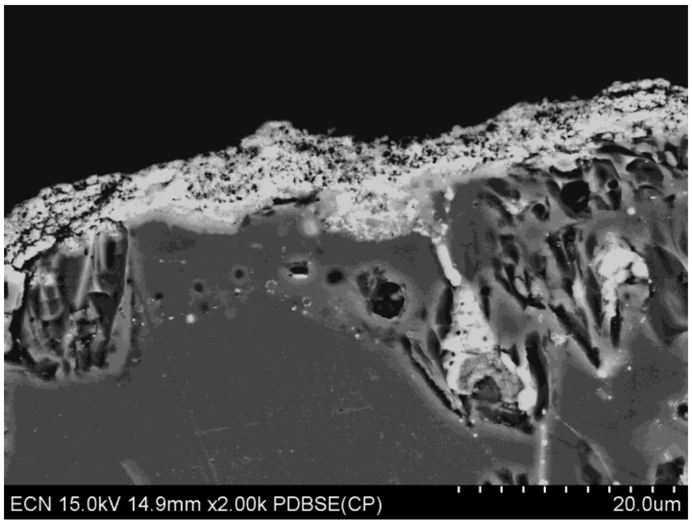
A olivine (activated after 200 h)	0.1	0.4	7.9	0.8	1.5	10.5
A olivine + Additive A	0.4	0.4	14.8	**2.8**	4.8	**23.1**
A olivine +Additive A+ B	0.2	0.5	13.9	**2.1**	3.1	**19.7**

  - Additives A & B have moderate effect
  - About 50% less tar

➢ Activated bed material & additives: usefull parameters for tar control

Results

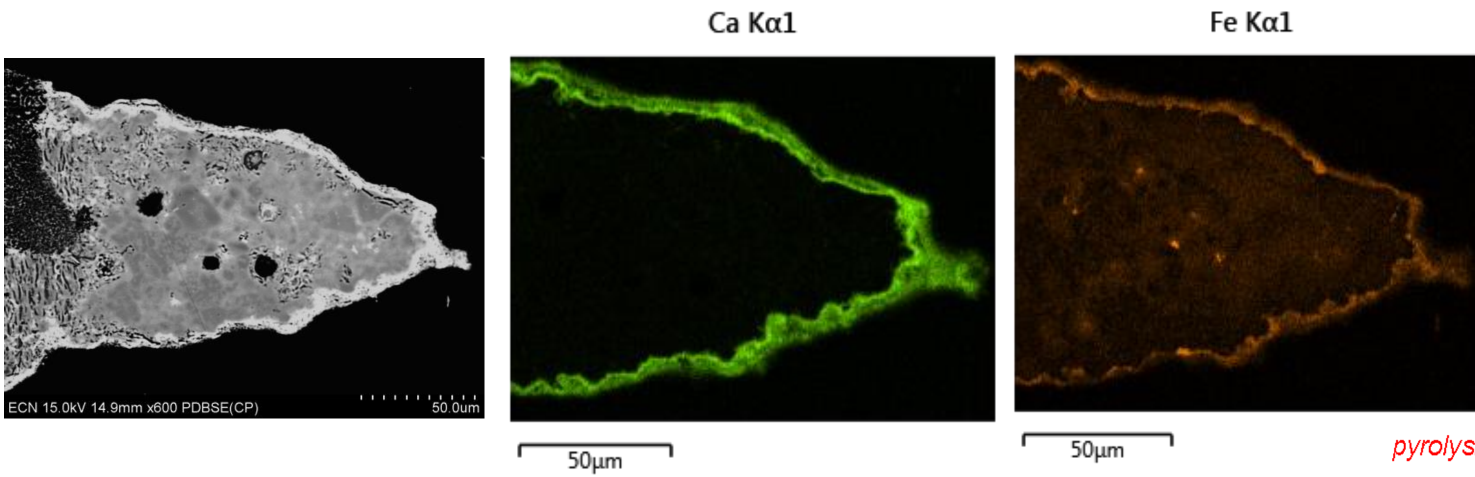
- SEM analysis of Austrian olivine:

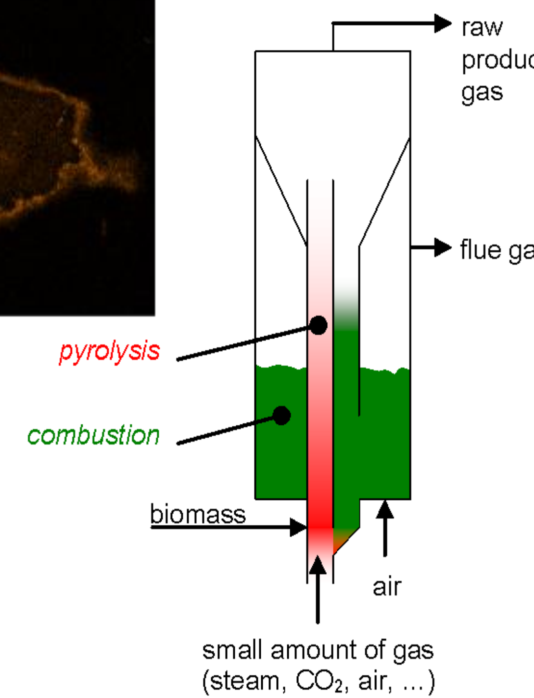


- Layer formation around olivine
- Calcium & iron rich
  - Catalysts known for WGS & tar reforming

Results

- SEM EDS mapping of active Austrian olivine:





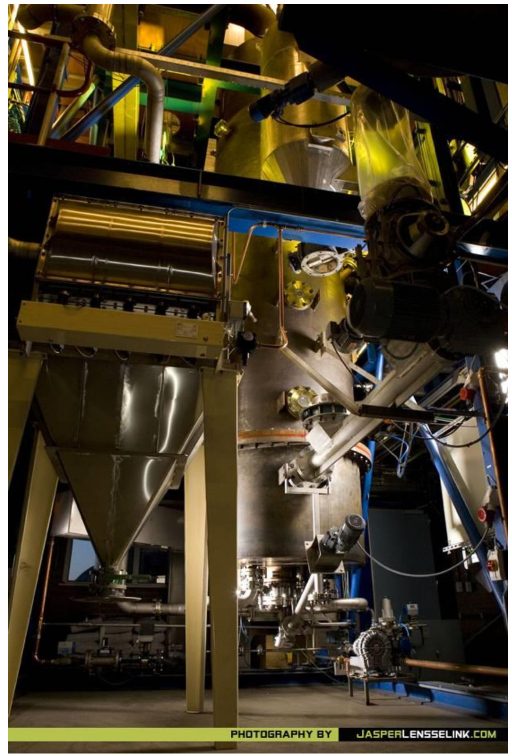
- *´Bed material state:*
  - *Riser, ± 5 s.´reducing´, combustor: ± 12 min. oxidizing)´*
- ´RedOx´ cycles:
  - Fe diffusion to surface, $Fe_2O_3 \leftrightarrow Fe_3O_4$
- Over time minerals from fuel & additives build up

Conclusions

- Despite characteristics of residence time & because of ´RedOx´ cycles of MILENA, primary measures for tar control & reduction are possible

- Availability of the system will be improved
- Not all bed materials become active towards WGS and tar reforming

- More bed materials and analysis will follow
- Pilot scale tests will verify scale-up effects




Thank you for your attention!

Questions?

- For more information come visit us at our stand

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