Ways to increase the calorific value of gas from gasification

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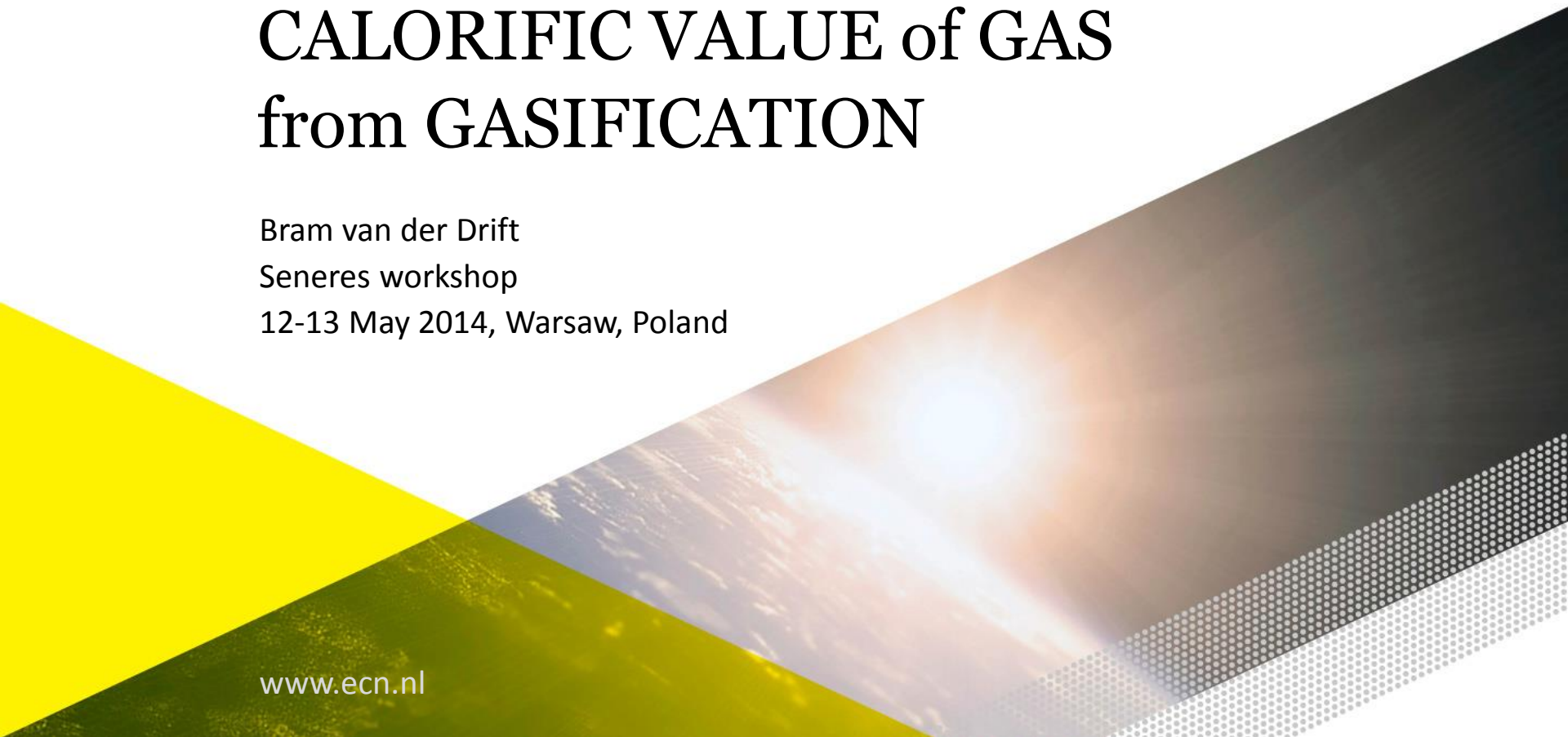
WAYS to INCREASE the CALORIFIC VALUE of GAS from GASIFICATION

Bram van der Drift

Seneres workshop

12-13 May 2014, Warsaw, Poland



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STATEMENTS

- Paradox 1: lower heating value feedstock = higher heating value gas
- Paradox 2: lower conversion = higher heating value gas
- Paradox 3: tar = higher heating value gas (also without the tar)

LHV: Lower Heating Value

HHV: Higher Heating Value

Tar: hydrocarbons larger than benzene

WORSE FUEL = BETTER GAS

not including effects of water- and ash-content, so only considering dry and ash-free feedstock (daf)

WORSE FUEL = BETTER GAS

Argument 1: Worse fuel has lower fixed carbon content

- Fixed carbon needs gasification: $C + H_2O \rightarrow CO + H_2$
- This is very energy consuming (endothermal)
- This produces “only” CO and H_2, which are low LHV gases compared to e.g. CH4

- Lower fixed carbon content = higher volatiles content
- Volatiles lead to high yield of CH_4, C_2H_4, benzene, …
- This reaction does not need much energy
- And CH_4, C_2H_4, benzene, … have high LHV value

WORSE FUEL = BETTER GAS

Argument 2: Worse fuel has higher O-content

- HHV = +34.1 [C] +132 [H] -12 [O] -12 [N] + 7 [S]
- Higher fuel-O means less has to be supplied by O_2 in the air
- This means less N_2
- Which means less N_2 dilution of the gas as well as less air is required to heat the reduced total gas volume
- So efficiency increases and gas-LHV increases

(if oxygen-blown, this arguments disappears)

WORSE FUEL = BETTER GAS

	Oxygen-blown IGCC (Shell) on coal	Air-blown indirect gasifier (MILENA) on wood
Feedstock	Coal	Wood
LHV wet feedstock	24 MJ/kg	16 MJ/kg
Gas (<5% N_2)		
LHV dry gas	10 MJ/Nm^3	15 MJ/Nm^3

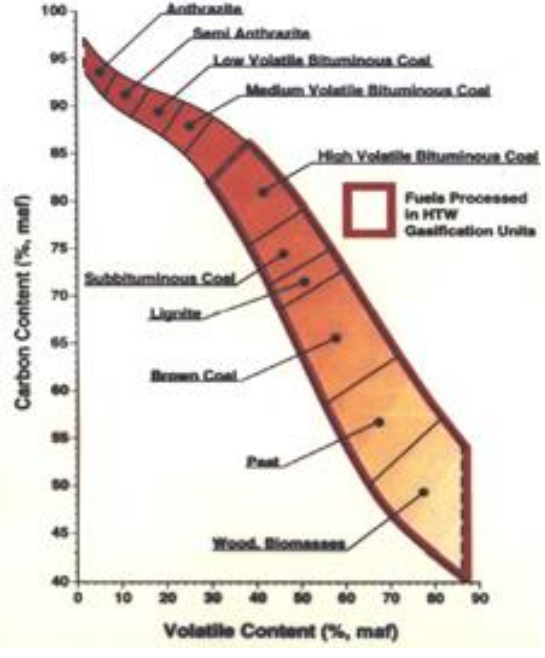
Coal: 81% C_daf, 13% ash_dry, 10% water, 33 MJ/kg HHV_daf
Wood: 50% C_daf, 1% ash_dry, 10% water, 20 MJ/kg HHV_daf

WORSE FUEL = BETTER GAS

Arguments 1 and 2 are connected

- Biomass fuels with higher volatiles content (less fixed carbon) have higher O-content (lower C-content) and thus work the same direction

- Plastics are an exception: high volatile content AND high carbon content



Source: Uhde

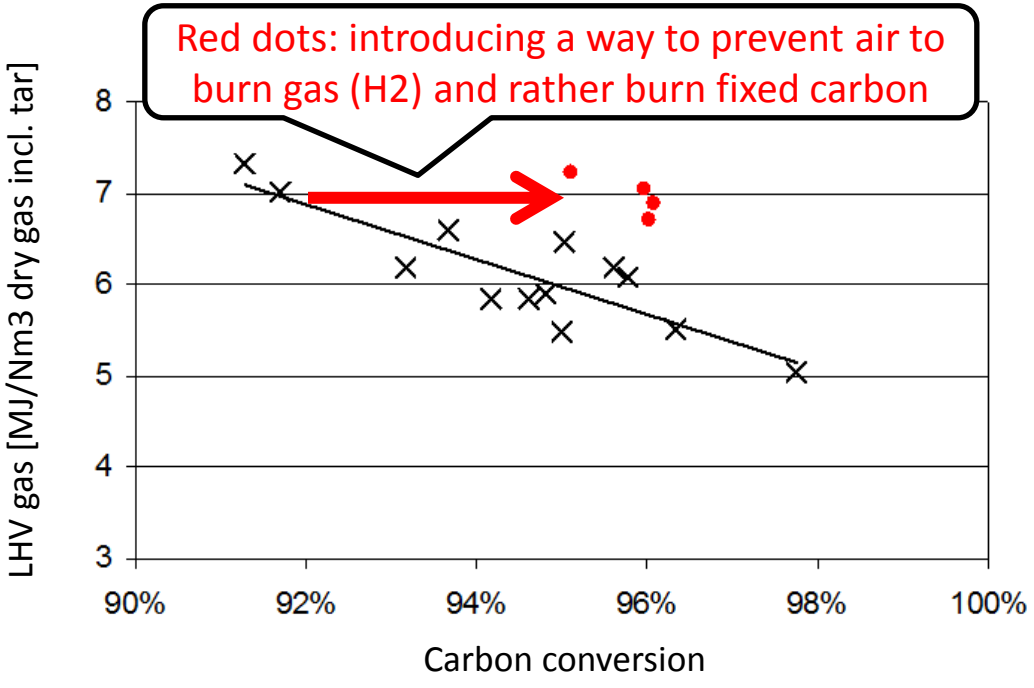
LOWER CONVERSION = BETTER GAS

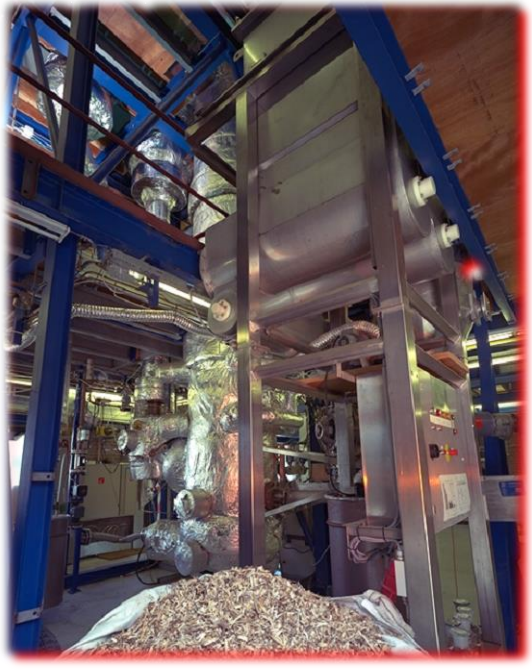
LOWER CONVERSION = BETTER GAS

- Gasification is a sequence of:
  - Devolatilisation (volatiles escape)
  - Fixed carbon conversion (real gasification)
- Volatiles lead to high LHV gas
- Fixed carbon leads to low LHV gas

- That means that gas-LHV reduces when conversion is beyond devolatilisation
- It however also means that a high gas-LHV comes with residual char/carbon, which is an energy efficiency loss
- *This has a solution*

LOWER CONVERSION = BETTER GAS





Tests performed in 0.5 MW air-blown CFB gasifier at ECN, various operating conditions, all based on clean wood, red dots are tests done with “staged gasification”: feedstock feeding 1 meter up with internal ring within reactor below to prevent feedstock to fall down and devolatilize and meet air, *Source: ECN-report ECN-C-03-053 (2003)*

TAR = GOOD

TAR = GOOD

- Tar does not come alone: tar means benzene, ethylene, methane
- Higher yield of tars therefor means a higher gas-LHV
- It however, comes with a disadvantage: the tar itself
- *This has a solution*

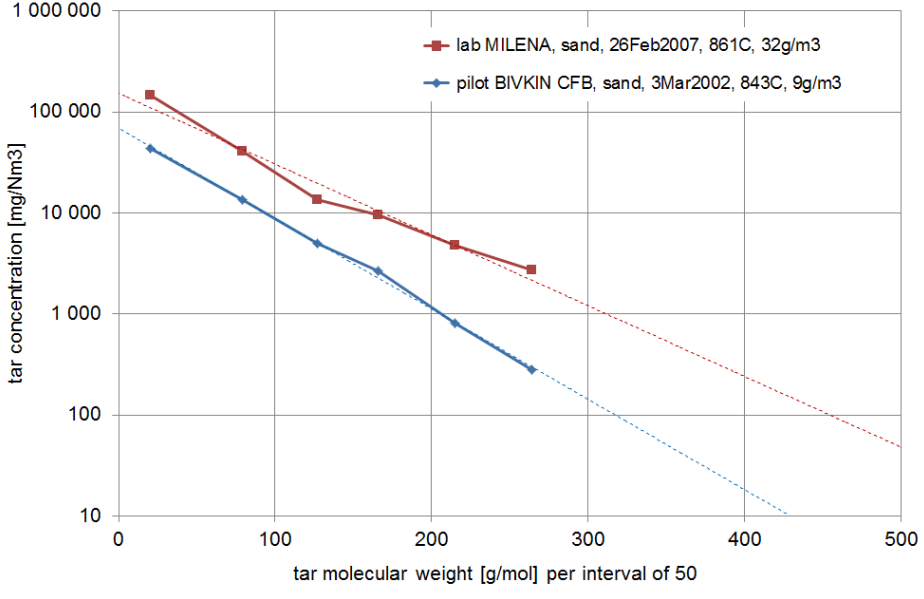


Illustration of relation between hydrocarbon molecules in gasifier gas, range from methane to heavy tars in air-blown CFB (blue) and indirect gasifier (red), tests performed by ECN

TAR = GOOD

- The presence of tar indicates a lack of catalytic reforming activity (by e.g. catalytically active bed material in fluidized bed)
- Less catalytic activity means water-gas-shift equilibrium is not reached
- Which means less $H_2 + CO_2$ and more $CO + H_2O$
- Which means more water in gas and thus higher gas-LHV on dry basis

Water-gas-shift reaction (a gas phase reaction):

$H_2 + CO_2 \Leftrightarrow CO + H_2O$

Gasification: it starts at the right side, thus shifts to more H_2 (and CO_2) if the reaction takes place

INDIRECT GASIFICATION

volatiles to gas
and
fixed carbon combustion

GASIFICATION

= *matching energy*

energy production:

fuel + air (λ > 1) → flue gas + heat

25%

energy consumption:

fuel + heat → gas + char/coke

75%

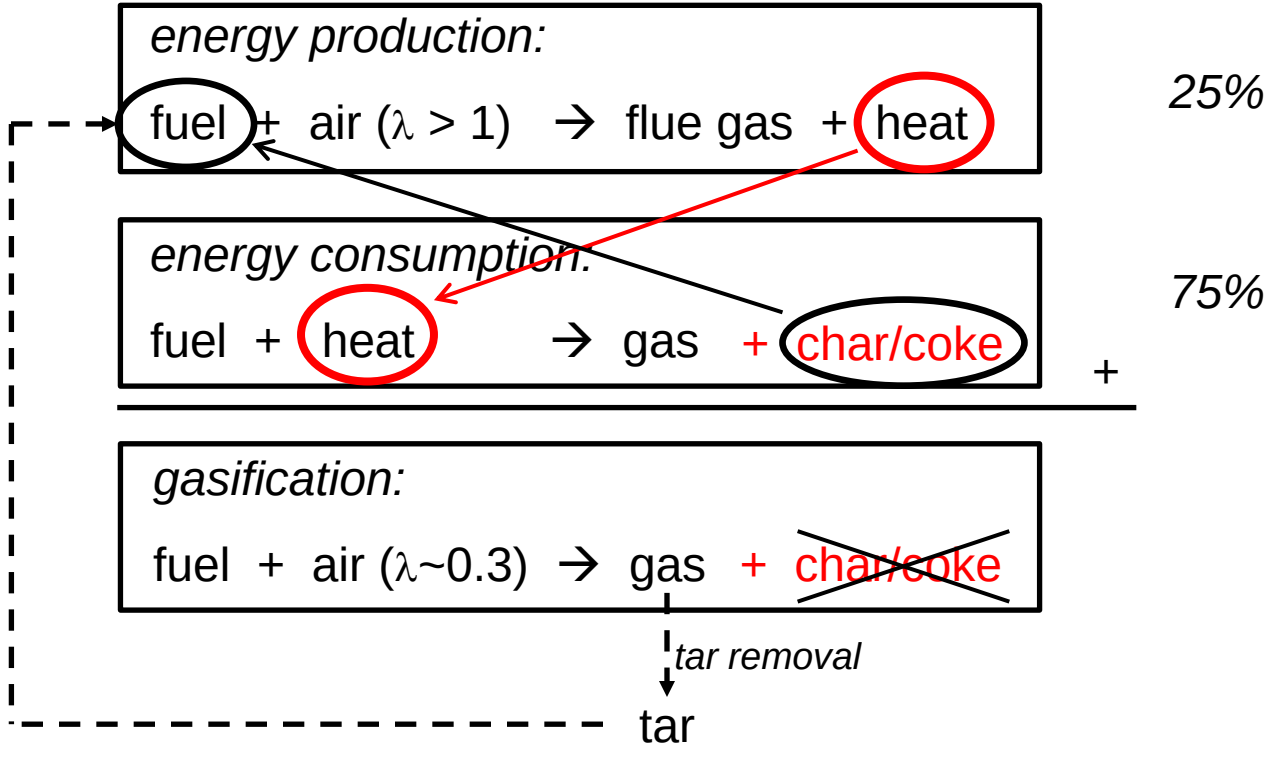
+

gasification:

fuel + air (λ~0.3) → gas + char/coke

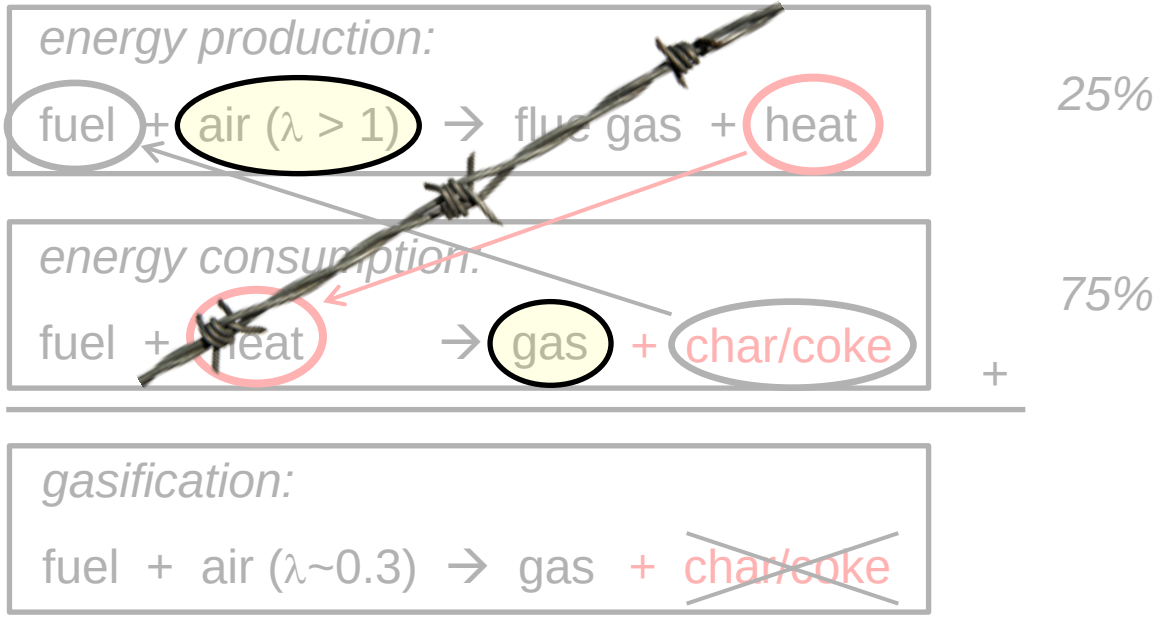
SECOND GENERATION

also called: indirect gasification



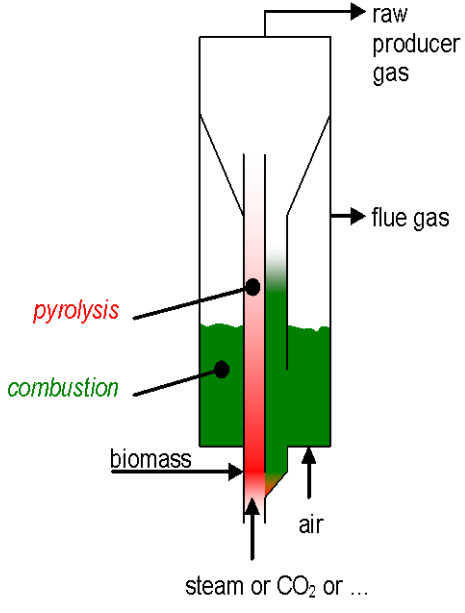
SECOND GENERATION

prevent air to meet gas!



MILENA TECHNOLOGY

- Highly efficient
- Complete conversion
- Fuel flexible, tested: wood, waste wood, grass, straw, soya residue, RDF/SRF, sunflower husks, DDB (straw residue from 2nd generation ethanol), high-ash coal, lignite
- Compact
- Cheap
- Know-how based



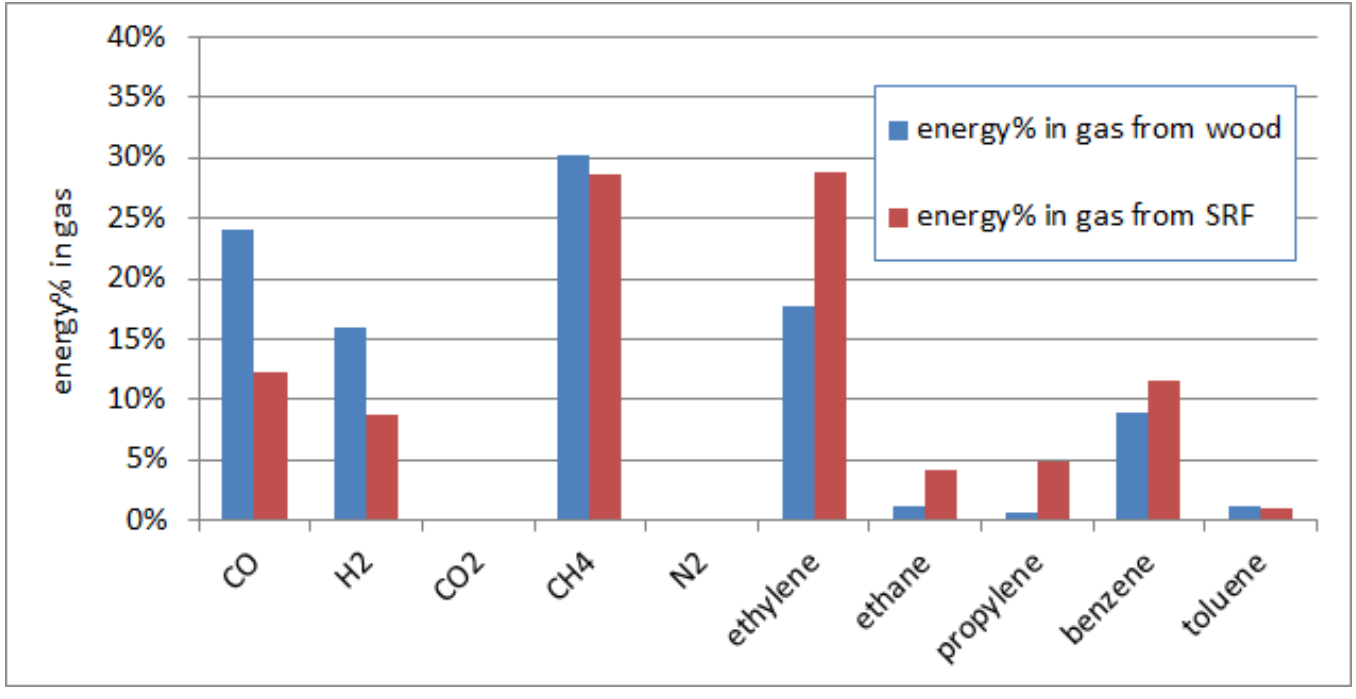
www.milenatechnology.com

PLASTICS as FUEL

WOOD and SRF

tested in MILENA indirect gasifier at ECN

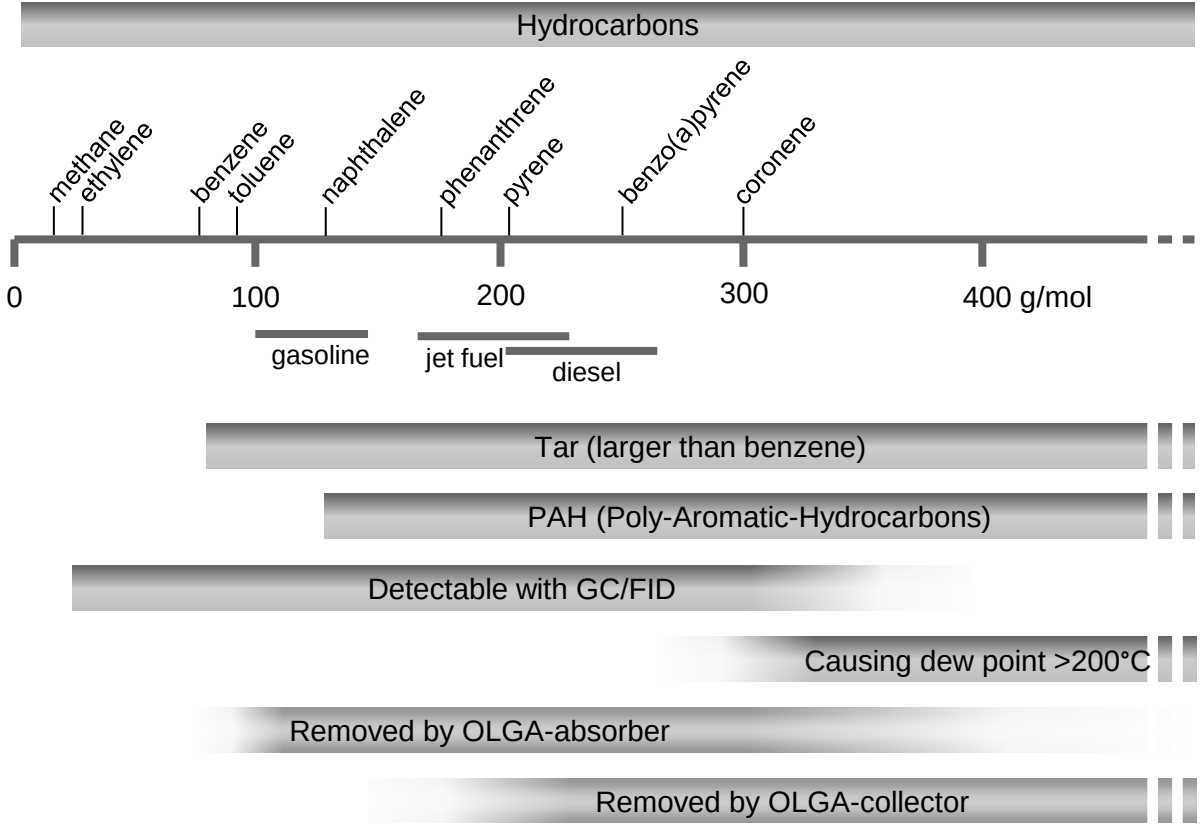
- Wood (HHV_daf=20, LHV_wet=17): 17 MJ/Nm3 LHV_dry gas (tar-free)
- SRF (HHV_daf=28, LHV_wet=21): 22 MJ/Nm3 LHV_dry gas (tar-free)



OLGA TAR REMOVAL

all the benefits of tar
but
without the tar

TAR

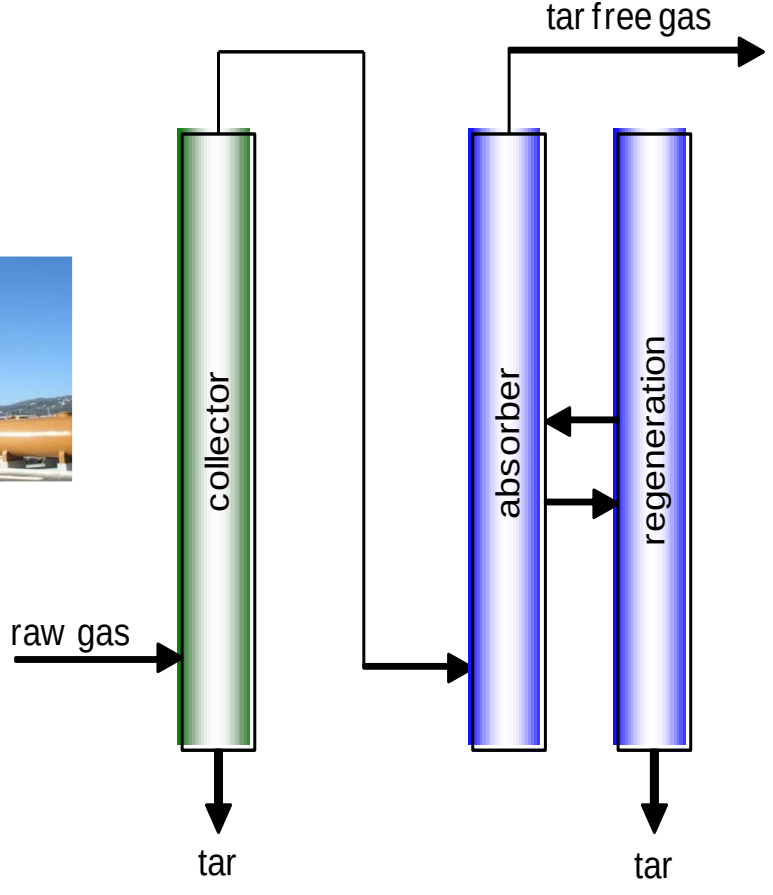

Hydrocarbons
methane
ethylene
benzene
toluene
naphthalene
phenanthrene
pyrene
benzo(a)pyrene
coronene
0
100
200
300
400 g/mol
gasoline
jet fuel
diesel
Tar (larger than benzene)
PAH (Poly-Aromatic-Hydrocarbons)
Detectable with GC/FID
Causing dew point >200°C
Removed by OLGA-absorber
Removed by OLGA-collector

OLGA TECHNOLOGY

- Complete tar removal
- Complete particles removal
- No methane removal
- No ethylene removal
- Tar recycle

DAHLMAN

www.olgatechnology.com



FINAL REMARKS

- Increasing heating value of gas from gasification:
  - Use the bad fuels (but not because of high water or ash content)
  - Do not strive for complete conversion to gas
  - Do not strive for low tar in gas

- Solve the conversion problem by combustion of residual char, preferably using the heat for the gasifier itself (=indirect gasification technology)
- Solve the tar problem by low-temperature tar scrubbing, avoiding loss of e.g. methane and ethylene and using tar heating value as energy source

- Plastics form a different category: very high yield of “monomers” like ethylene and styrene, thus very high gas heating value

THANKS FOR THE ATTENTION

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IEA bioenergy/gasification: www.ieatask33.org
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OLGA: www.olgatechnology.com / www.renewableenergy.nl
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