Challenges in Biomass Gasification

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Your energy. Our passion.

CHALLENGES in BIOMASS GASIFICATION

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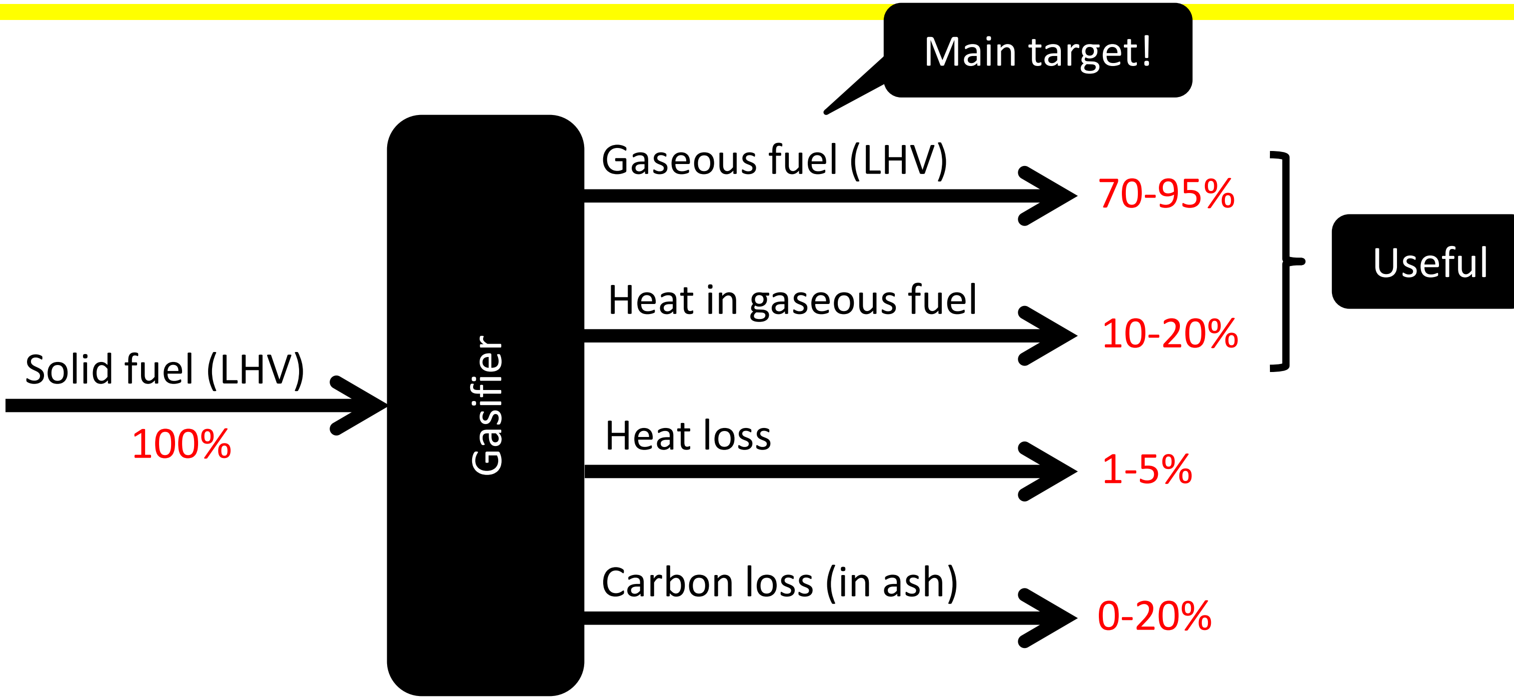
ENERGY BALANCE

gasification process (e.g. at 800°C)



LHV: Lower Heating Value
Excluding electric energy use of: pumps, fans, oxygen production (if any), …
Excluding energy recycle: e.g. air preheat and tar recycle

COMPOSITION

biomass is much different from coal

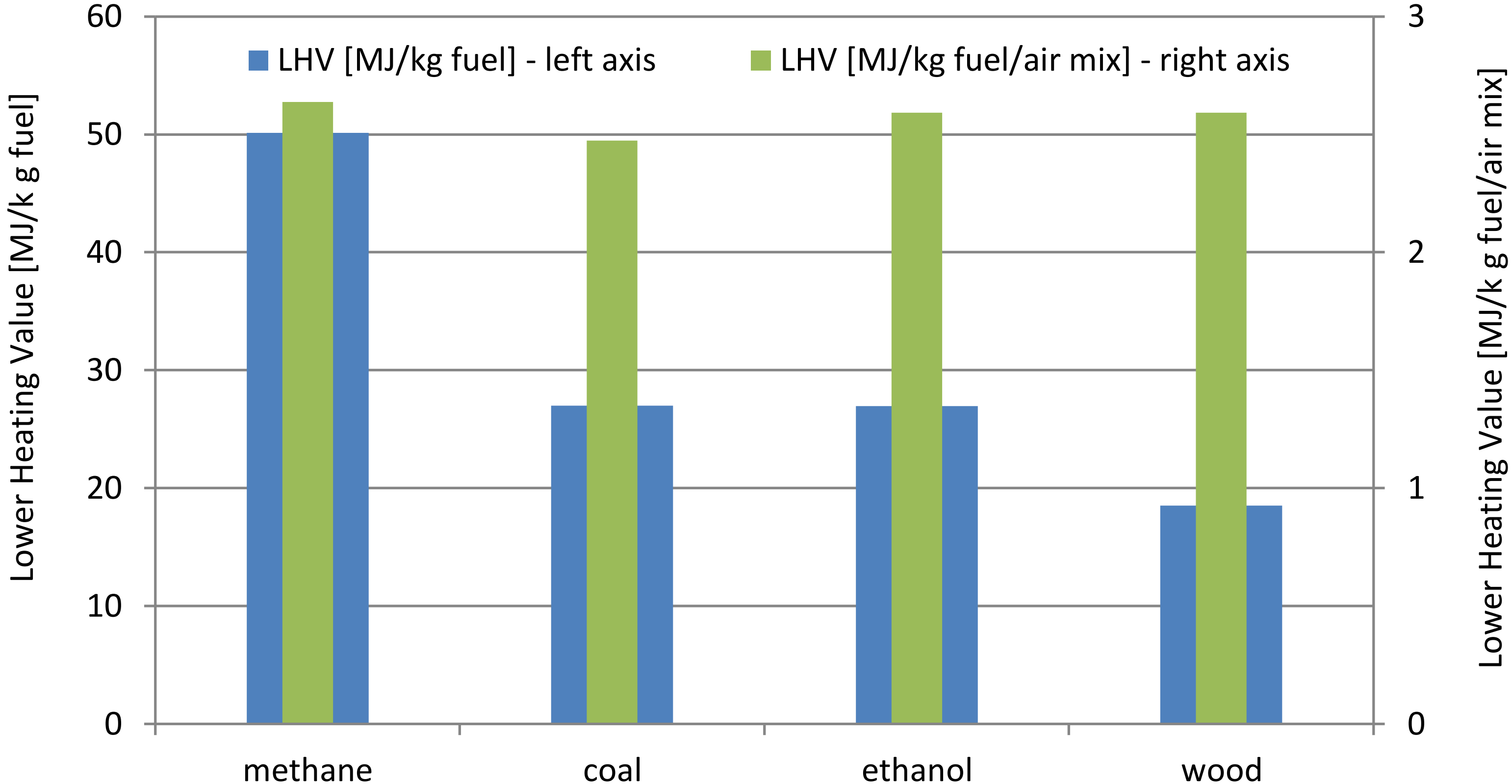
		Clean wood	Waste wood	Straw	Coal	RDF
water	wt% wet	20-60%	~20%	~20%	~10%	~10%
C	wt% daf	50.7%	50.5%	48.8%	79.2%	60-65%
H	wt% daf	6.1%	5.9%	5.9%	5.3%	8-9%
O	wt% daf	42.8%	42.6%	44.0%	13.5%	25-30%
N	wt% daf	0.28%	0.73%	0.85%	1.53%	~0.5%
S	wt% daf	0.06%	0.14%	0.14%	1.30%	~0.2%
Cl	wt% daf	0.04%	0.09%	0.43%	0.14%	~1%
volatiles	wt% daf	82%	81%	81%	42%	85-90%
HHV	MJ/kg daf	20.1	20.2	19.3	31.8	27-29
ash	wt% dry	1.6%	6%	7%	12%	10-15%
main ash components		Ca	Ca, Si, Fe	K, Ca, Si	Si, Al	Al, Ca, Si

Wet/dry/daf: based on wet/dry/dry-and-ash-free mass
RDF: Refuse Derived Fuel
Waste wood: excluding particle board

Straw: wheat, rye, barley
Coal: average Dutch coal plants
Source: www.phyllis.nl

HEATING VALUE

in combustion, differences disappear



VOLATILES

biomass has high volatile content: ~80% daf

Good:

- “Instant gas”: Good conversion at already low residence time, low temperature, low steam
- Valuable hydrocarbons in the gas (methane, ethylene, BTX)
- That also means that efficiency is better
- High calorific gas

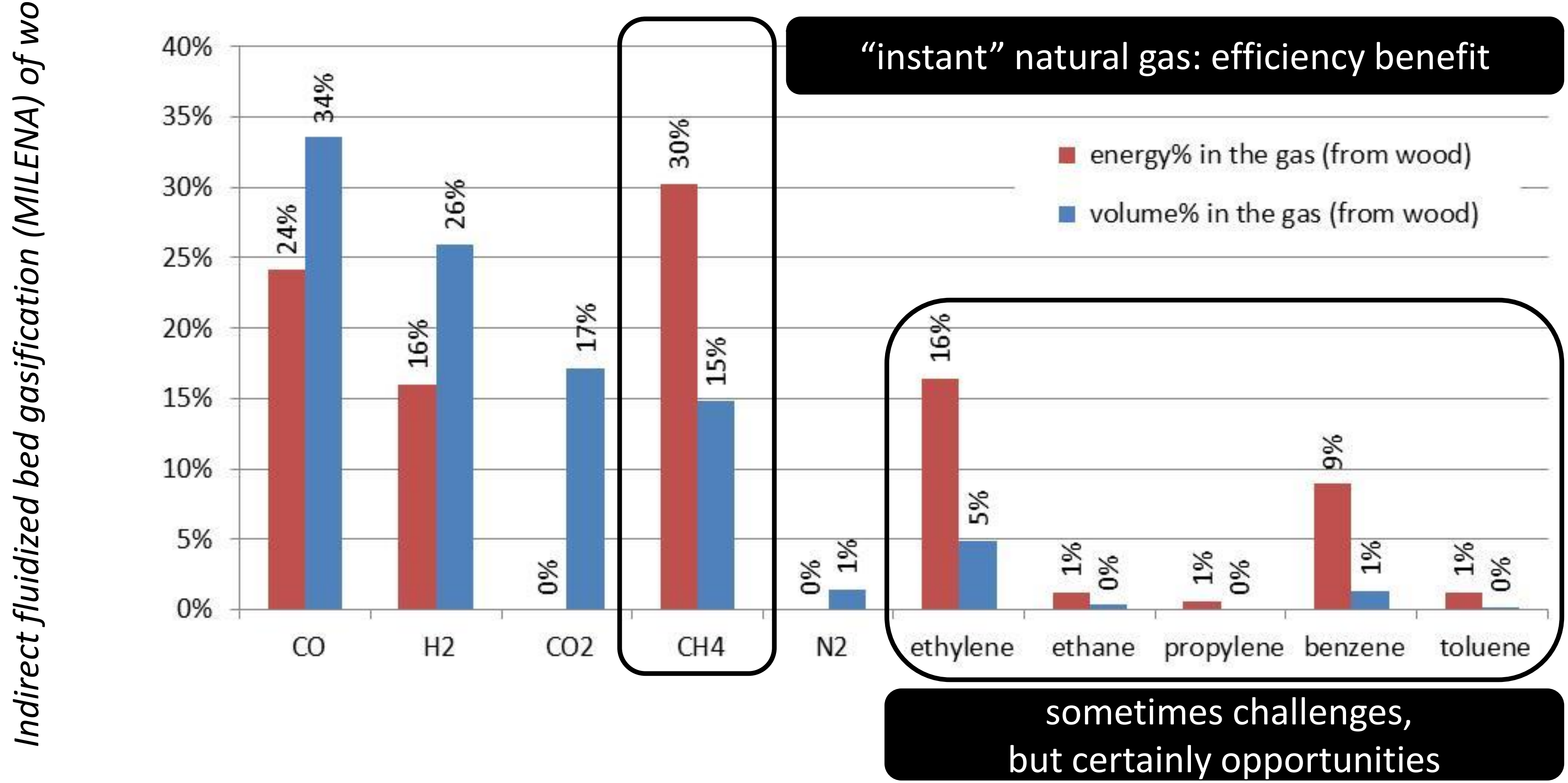
This presentation focuses on fluidized bed processes: 700-900°C

Bad:

- Quickly responding to changes in e.g. feed
- Carbon remaining is porous and reactive: spontaneous ignition
- Tars

HYDROCARBONS

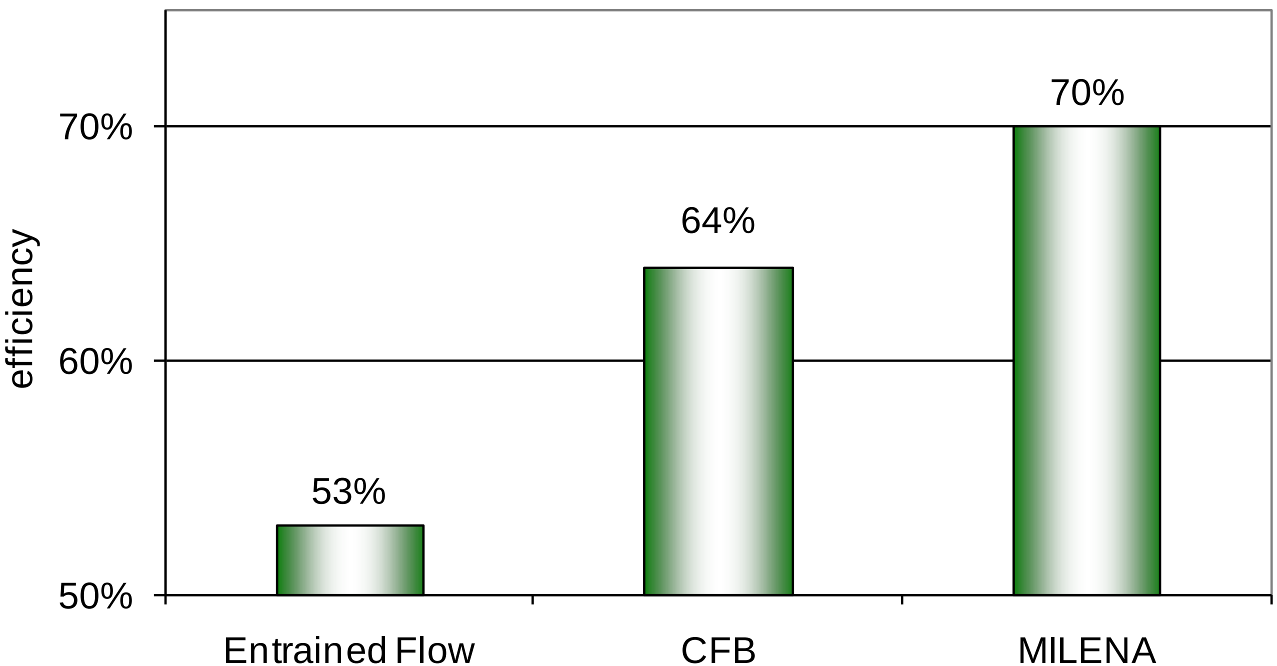
modest in volume, but dominating in energy



METHANE CONTENT is BENEFIT

efficiency from biomass to bioSNG

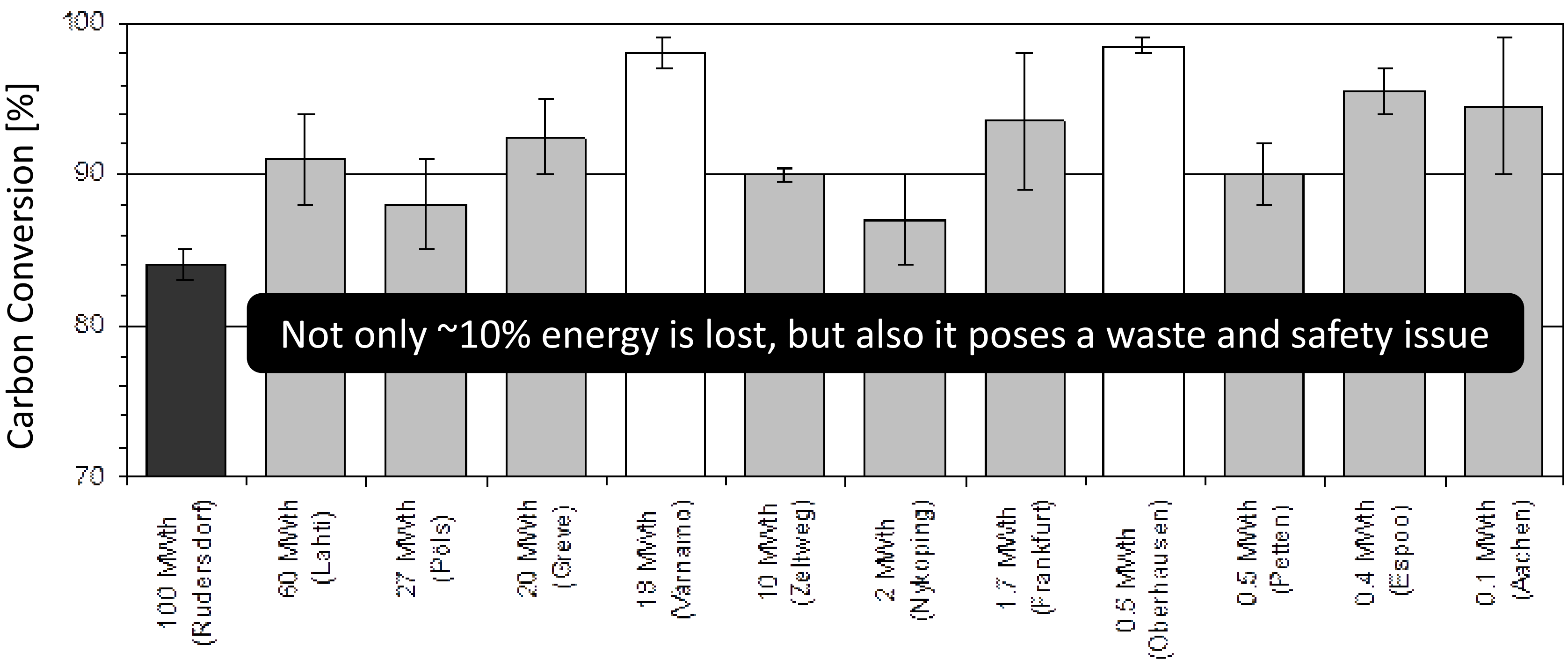
- Entrained Flow (oxygen-blown)
- CFB: Circulating Fluidized Bed (oxygen-blown)
- MILENA: Indirect Fluidized bed



C. M. van der Meijden et.al., Biomass and Bioenergy 34, pp 302-311, 2010.

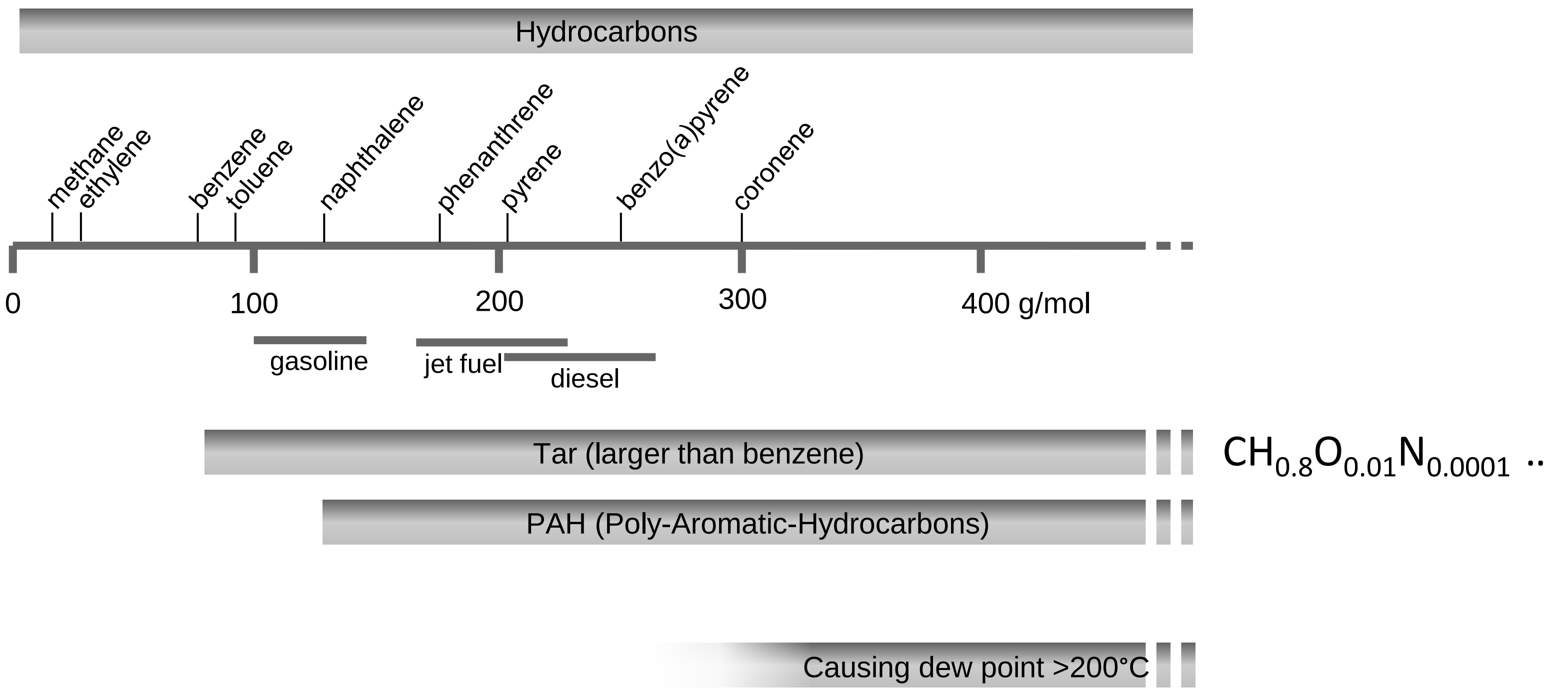
CIRCULATING FLUIDIZED BED

carbon conversion of CFB gasifier plants (2002 study)



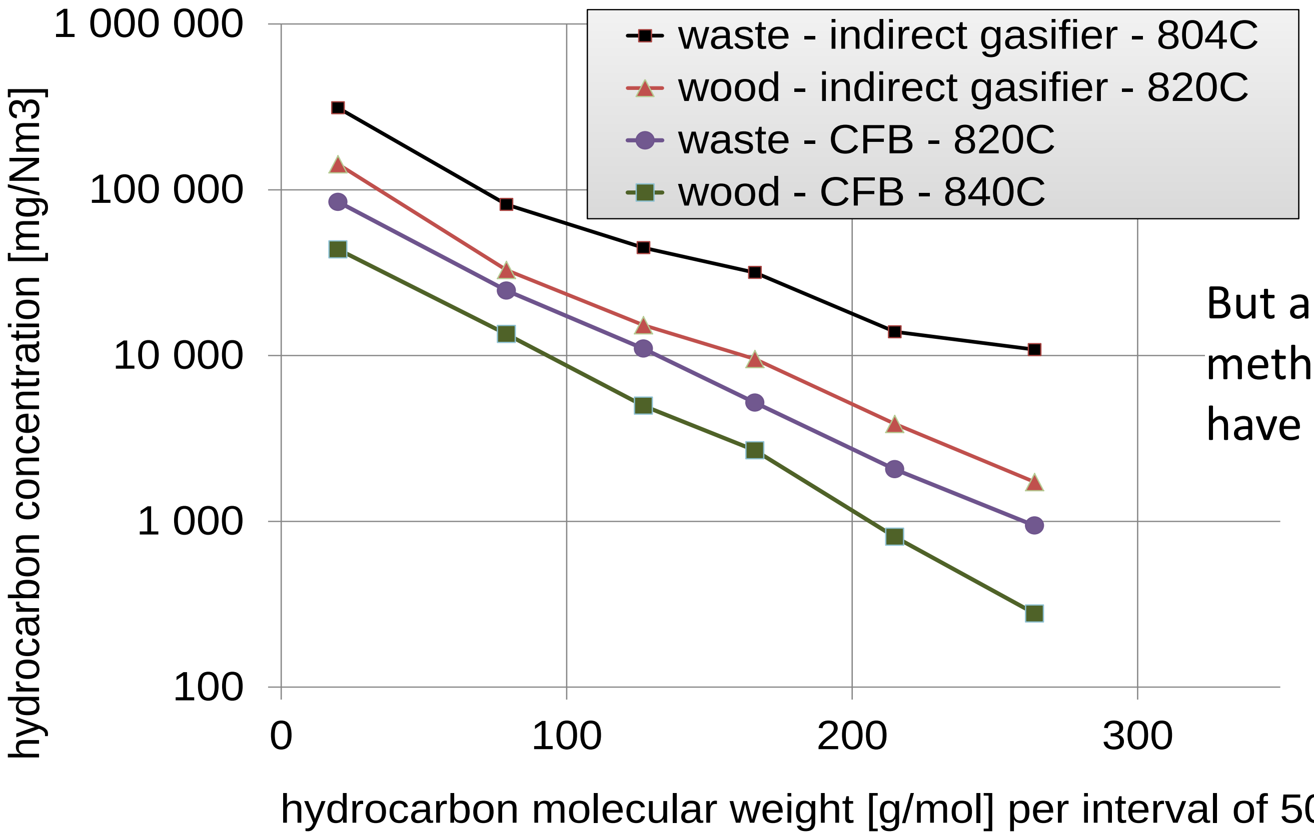
TAR

defined as hydrocarbons larger than benzene



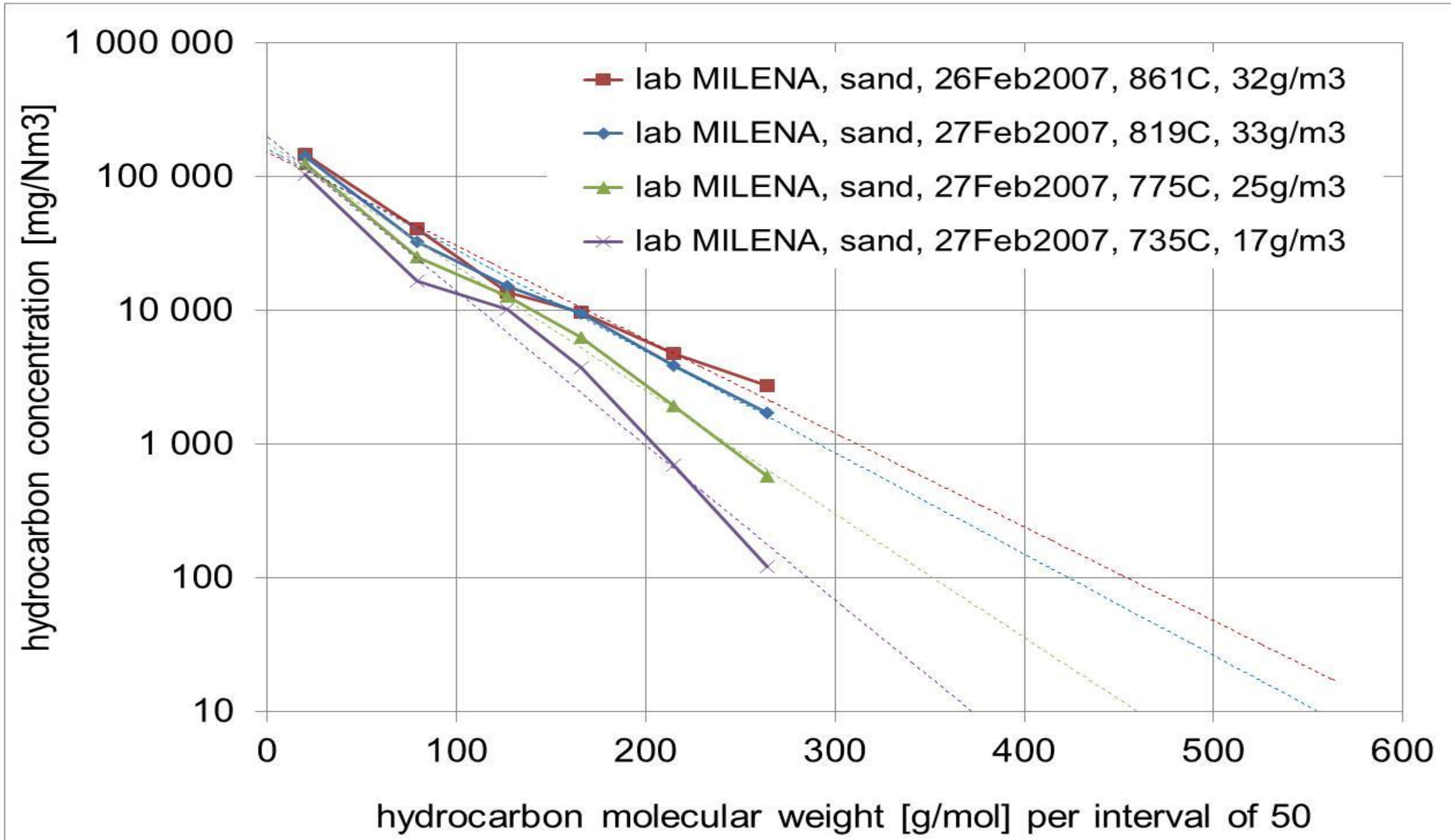
TAR

larger molecules = lower content



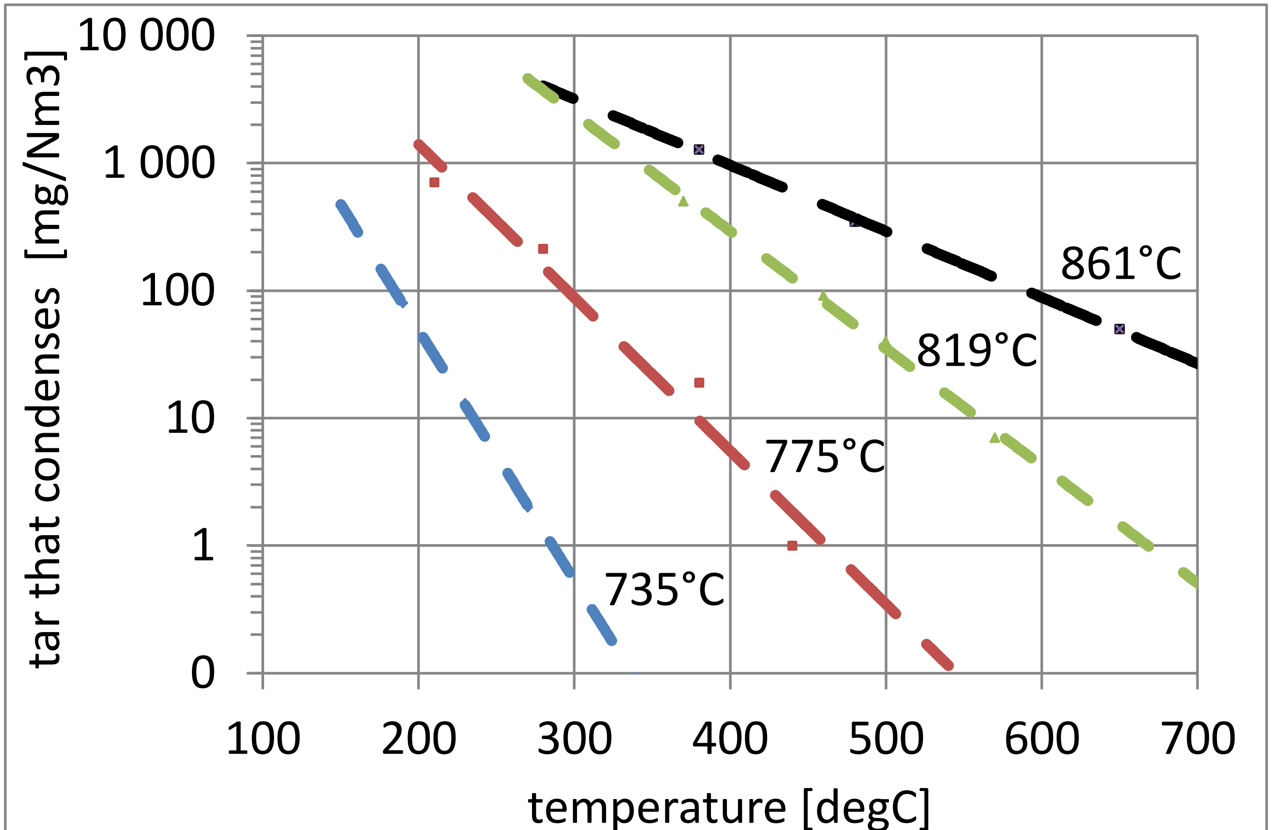
But also: if you want methane, you will have to deal with tars

TARS EVALUATION
e.g. evaluate effect of gasifier temperature



TARS EVALUATION

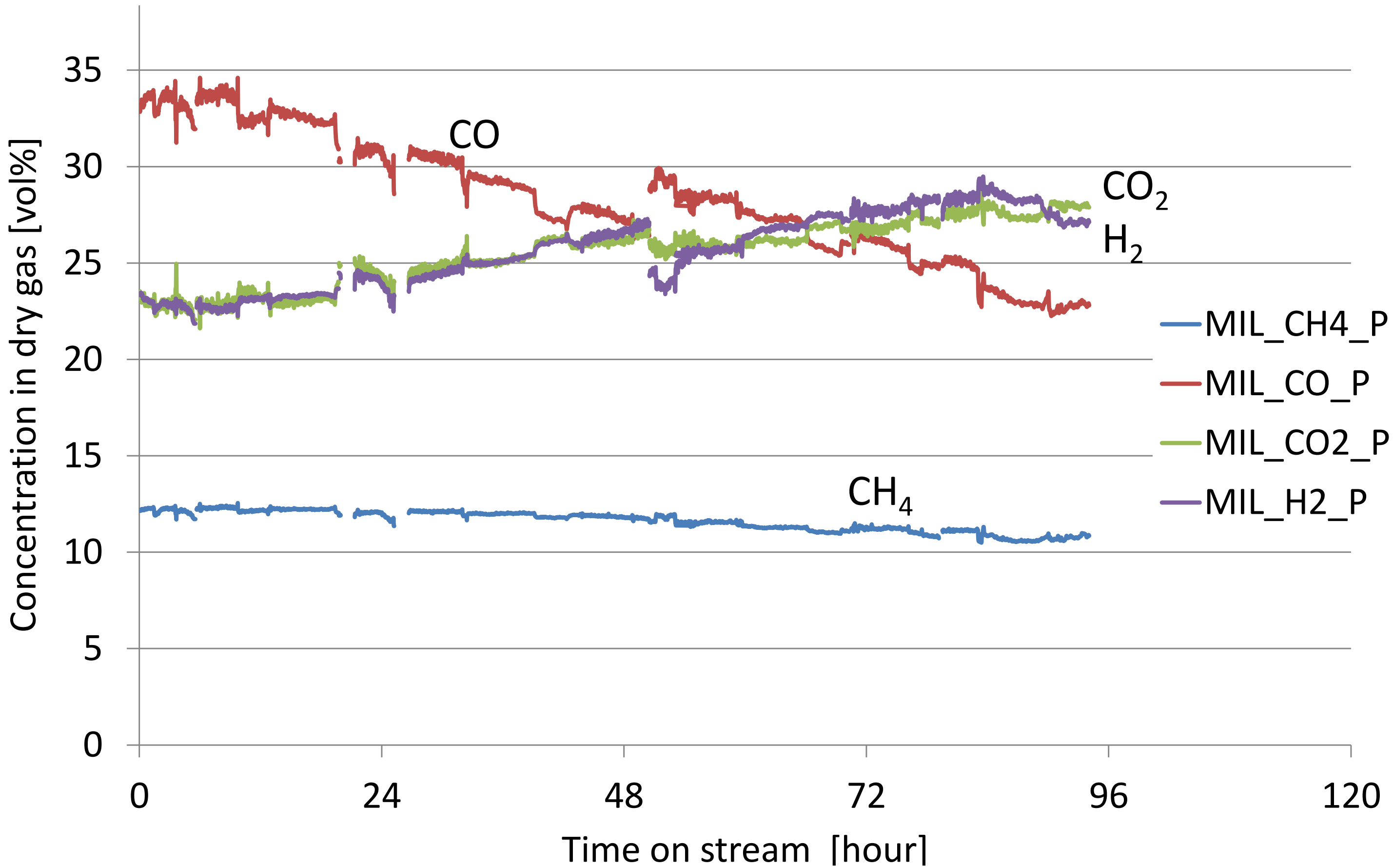
condensation behavior on “cold” surfaces



COMPOSITION NOT CONSTANT

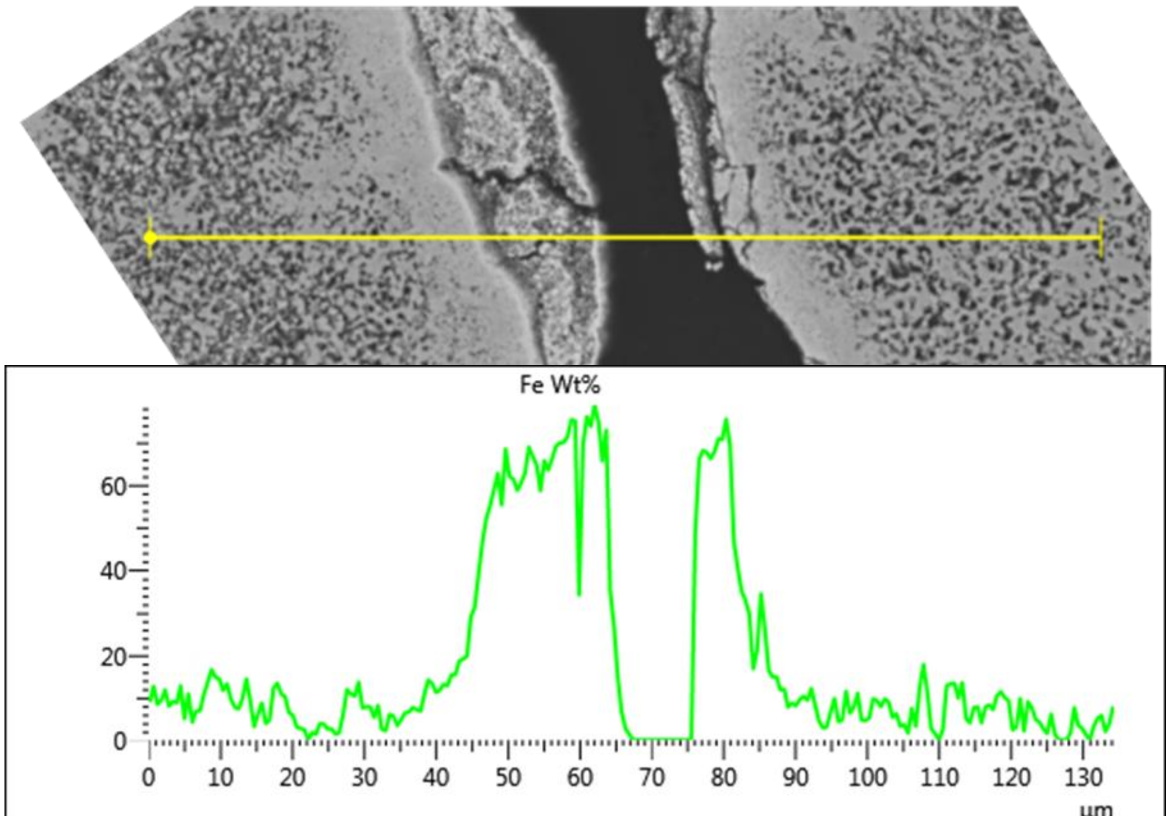
during operation the bed material (olivine) "activates"

Indirect fluidized bed gasification (MILENA) of wood ~800°C



BED MATERIAL ACTIVATION

caused by migration of Fe to the surface



TAR REMOVAL

- Catalytic conversion
  - Ideal in sense that it removes tar before cooling
  - Sensitive to poisons like S (limits fuel flexibility)
  - Inevitable also destroys part (~30%) of methane
- Plasma conversion
  - Simple from operational point-of-view
  - Consumes power (~$^{1}/_{3}$ of what is being produced)
- Scrubbing with water
  - Tar dew point is water temperature
  - Produces nasty mixture of tar, particles, water
- Scrubbing with biodiesel
  - Applied in Austrian indirect gasifier plants
  - Consumption biodiesel (~1 kg biodiesel/kg tar)
  - Only works when little tar (filter upstream and acceptable biodiesel consumption)
- Scrubbing with another liquid
  - Example: OLGA

POTASSIUM (K)

Good:

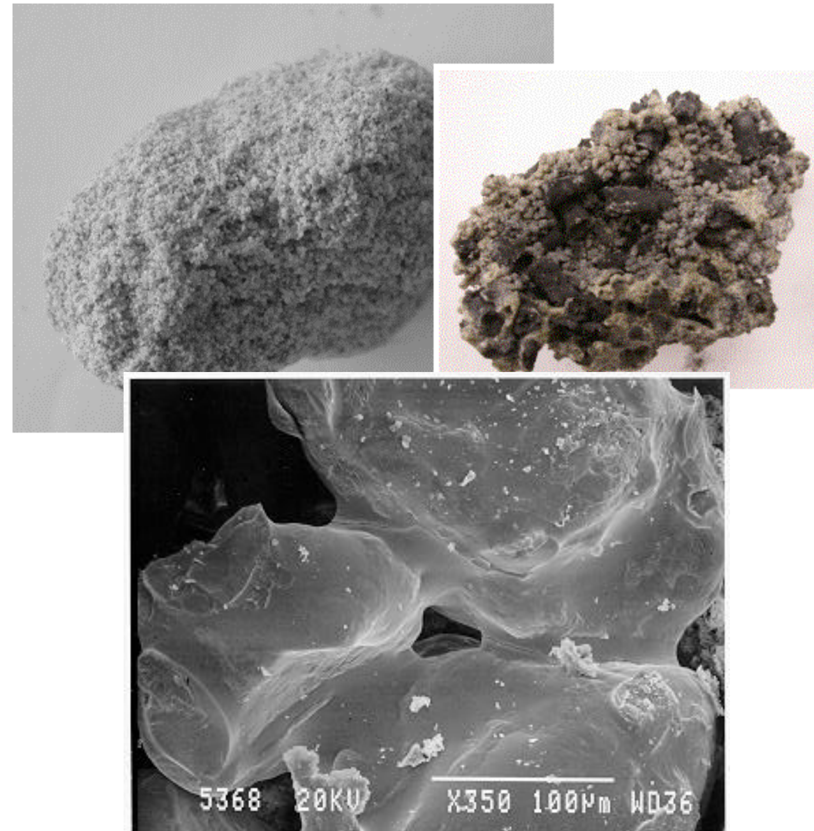
- Acts as catalyst for conversion and tar reduction, allows lower temperature
- Responsible for bed material activation

Bad:

- Danger of agglomeration/melting in gasifier
- Downstream fouling by condensation of volatile salts

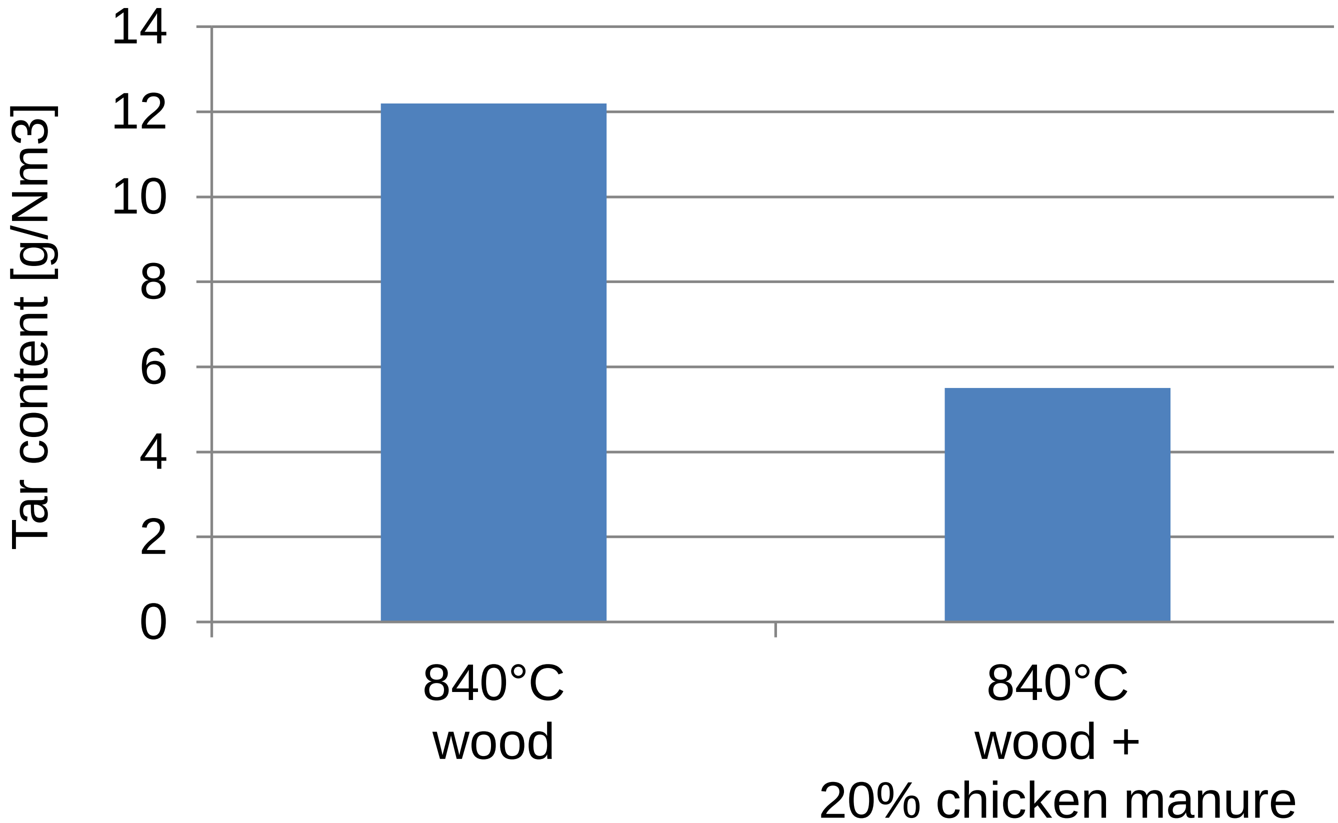
AGGLOMERATION

- Lower temperature
- Prevent hot spots
- Add K-getter (clay material)
- Add more surface and blow away



WHAT CHICKEN MANURE CAN DO

the good thing about Potassium



WHEN GOING CHEMICAL…

sulphur removal is not just removing H2S

- Sulphur has many forms (numbers for clean wood in N_2-free gas):
  - H_2S 200 ppmv
  - COS 20 ppmv
  - Mercaptans 5 ppmv
  - Thiophene 10 ppmv
  - Benzothiophene 3 ppmv
  - Dibenzothiophene 1 ppmv

- Activated carbon can remove this, but:
  - It will also absorb BTX and thus soon is saturated/needs regeneration
- HDS (HydroDeSulphurization) will convert the organic S, but:
  - Olefins will hydrogenate too (e.g. ethylene to ethane), exothermic
  - Water Gas Shift reaction will occur too, exothermic
  - So, temperature control is challenge

WHEN GOING CHEMICAL…

hydrocarbons is more than tar and methane

- Significant amounts of olefins (mainly ethylene) and single aromatics (BTX)
- Known for their coke forming tendency
- Also: benzene emissions from engine exceed limits (e.g. Germany)

- BTX:
  - Can be reformed, but needs upstream S-removal to protect reformer catalyst, and upstream activated carbon does not make sense since it absorbs the BTX
  - Can be separated and used/sold, enables downstream activated carbon S-removal

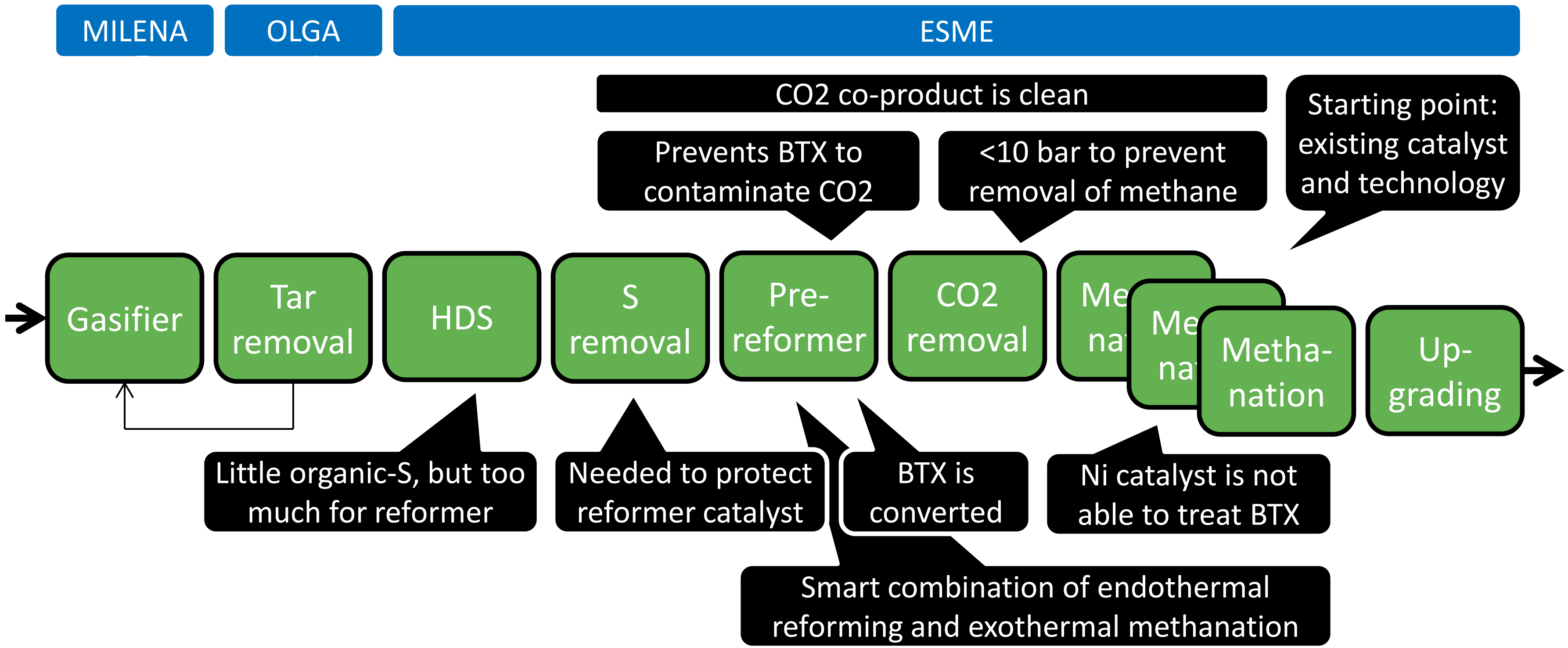
- Ethylene:
  - Can be converted to ethane, which is much easier to handle for catalysts
  - Can be converted into aromatics, and separated
  - Can be separated

GREEN GAS (bioSNG)
our process choices

MILENA – OLGA – ESME

ECN

ECN process for biomass-to-bioSNG



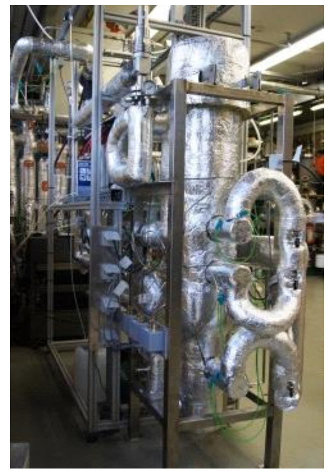
Gasifier: Fluidized Bed Gasifier operating at temperature below 1000°C
HDS: HydroDeSulphurization (converting organic S molecules into H_2S)
BTX: Benzene, Toluene, Xylene (~90%/9%/1% in case of fluidized bed gasification at ~800°C)

MILENA – OLGA – ESME

ECN process for biomass-to-bioSNG

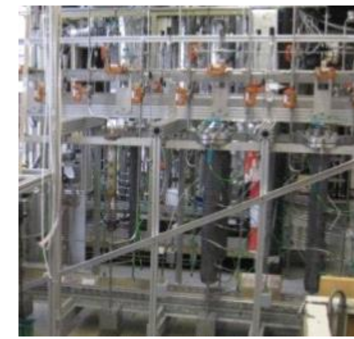
MILENA gasifier

OLGA tar removal



HDS reactor

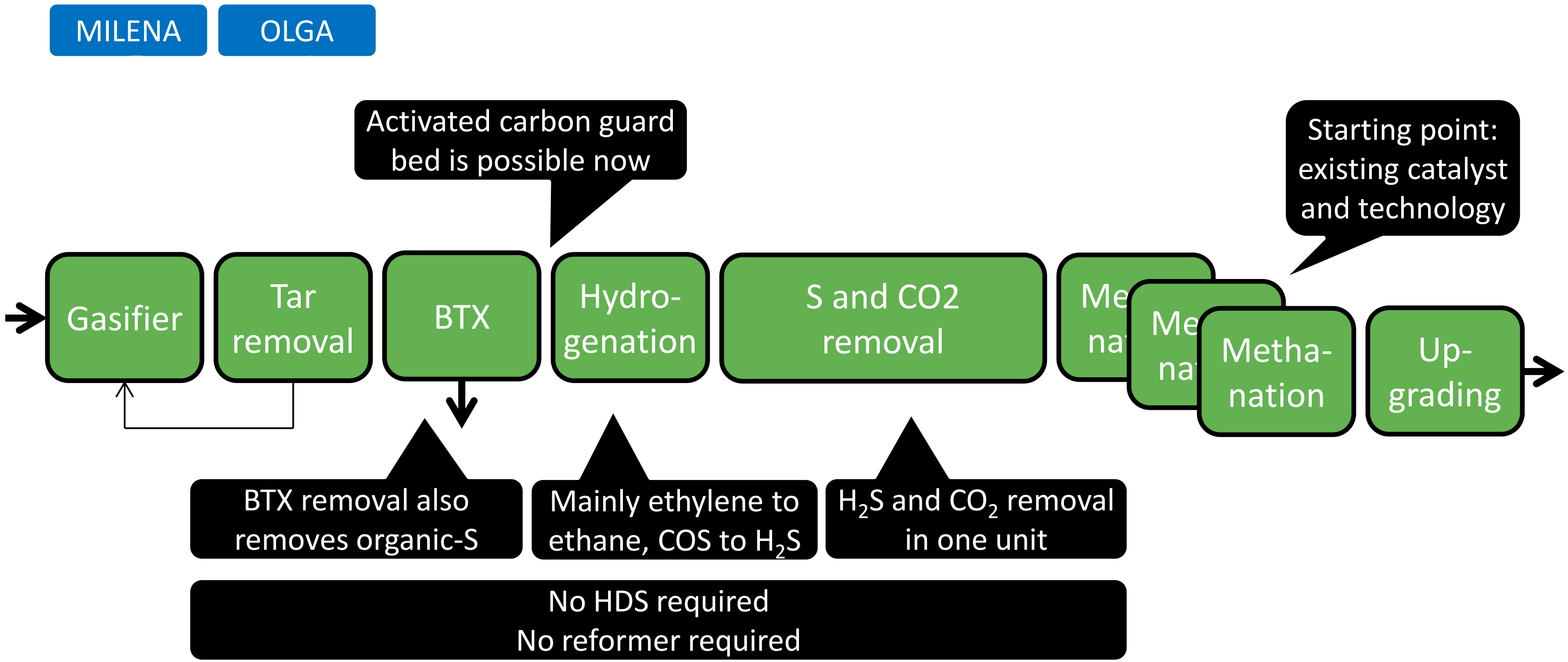
Further gas cleaning



Methanation reactors

70% efficiency from wood to bioSNG

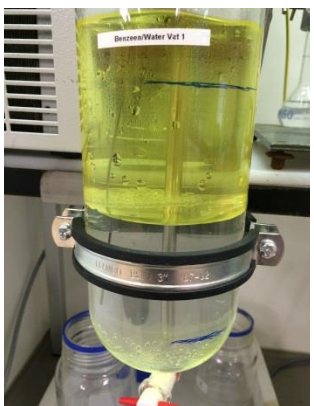
bioSNG PROCESS with BTX removal



Gasifier: Fluidized Bed Gasifier operating at temperature below 1000°C
BTX: Benzene, Toluene, Xylene (~90%/9%/1% in case of fluidized bed gasification at ~800°C)

BTX SCRUBBER

- Removes BTX (Benzene, Toluene, Xylenes)
- Scrubbing process
- Produces liquid BTX for further use



BTX scrubber, 2 nm^3/h

CONCLUDING REMARKS

- Biomass gasification has many options to make renewable energy
- And it can make money

- Main challenges:
  - Feeding
  - Tar
  - Non-conventional gas cleaning
- Fortunately, these challenges all have good solutions

- *Main challenges remaining are … non-technical*

CHEMICAL INDUSTRY as role model, but…

What do you get if you ask an experienced EPC in petro-chemistry to design a bioSNG plant?

What do you get if you ask an experienced car manufacturer to build a human-powered two-wheel car? Also called a bicycle.

It certainly works, but may not be the best choice

MORE INFORMATION

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