New Results from the European Project COMBINE

IFBB

Integrated Generation of Solid Fuel and Biogas from Biomass

New (Old) Input Substrates

- **Roadside verges incl. Greenway verges**
- **Municipal and private green waste**
- **Leaves**
- Hedge cuttings
- Harvest residues
- Invasive plant species
- Grass from contaminated soils
- Reed / wet grassland
- Semi-natural grasslands

Input Substrate Characteristics

- Extremely variable (DM:11 – 68%)

Input Substrate Characteristics

- High in Ash (2-24% of DM)

Input Substrate Characteristics

- Containing elements detrimental for combustion (Emission, Ash slagging, Corrosion)

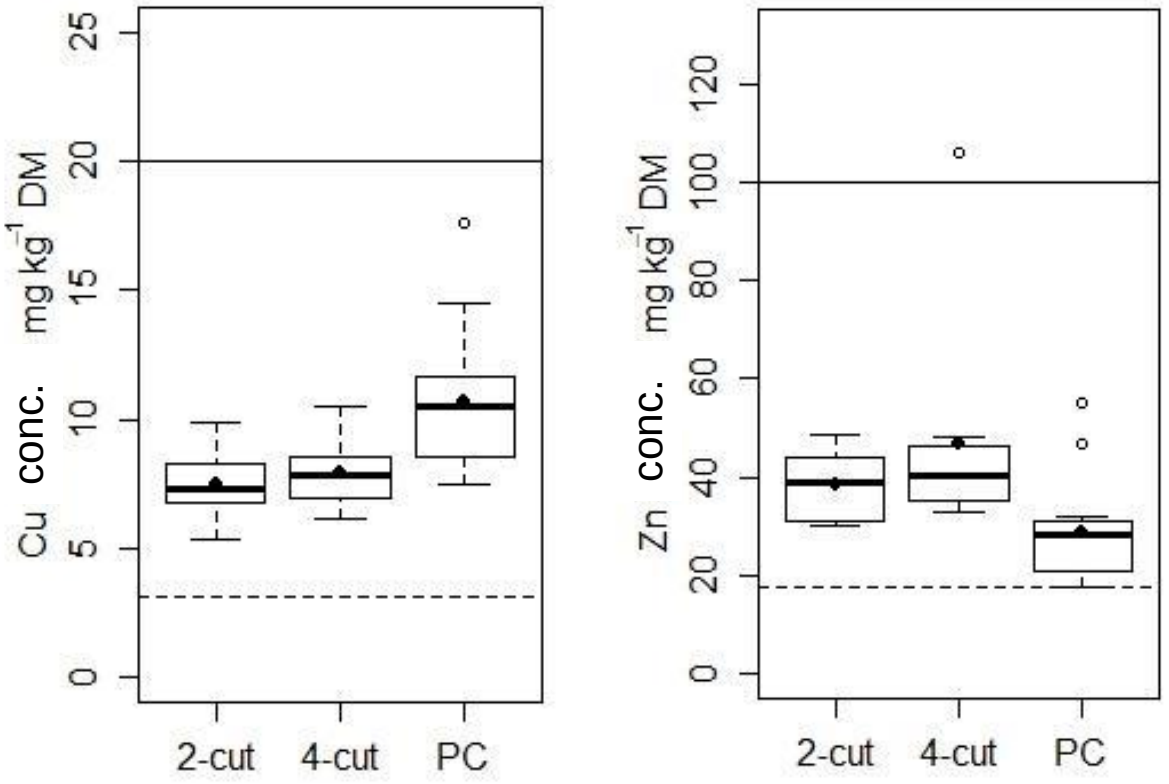
Input Substrate Characteristics

- Low biogas yields, except grass from contaminated soils and early roadside cut (36 - 360 L CH_4 per kg VS)

Input Substrate from Cities: Concentrations of "heavy metals"

For comparison: hazelnuts contain about 16 mg kg^{-1} Cu

Cd, Pb -> in 99% of samples not detectable



----- background value; Kabata-Pendias 2011, Lindström *et al.* 2013
—— limiting value DIN EN 14961-6

Input Substrate from Cities: Yield of grass from urban roadside verges

	2-cut	4-cut	mulching
2013 (t DM per Year)	4.79	2.73	2.30
2014 (t DM per Year)	6.57	3.94	4.19
Maximum height (cm)	57	32	23

IFBB

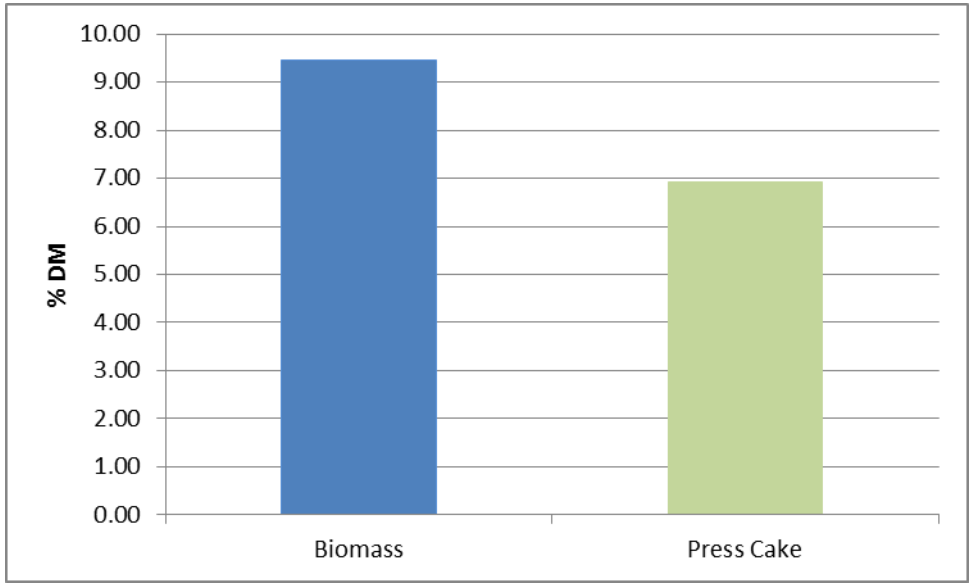
Cleaning Efficiency

- Percentage of element that is washed from the silage into the press fluid:

Element	Mass flow
Ash	51 %
N	30 %
S	42 %
K	77 %
Mg	53 %
Ca	30 %
Cl	87 %

Press cake

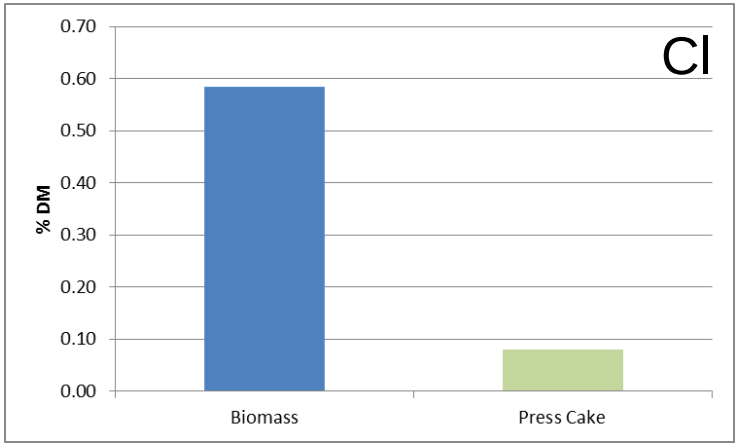
- Lower ash concentration

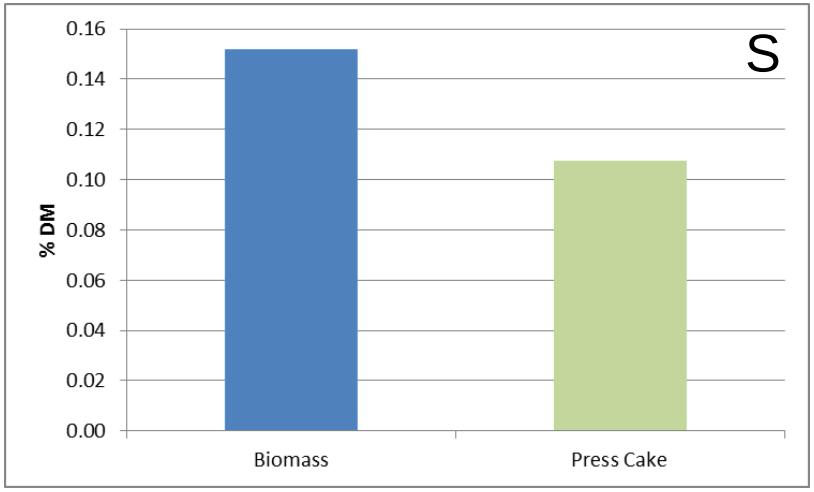


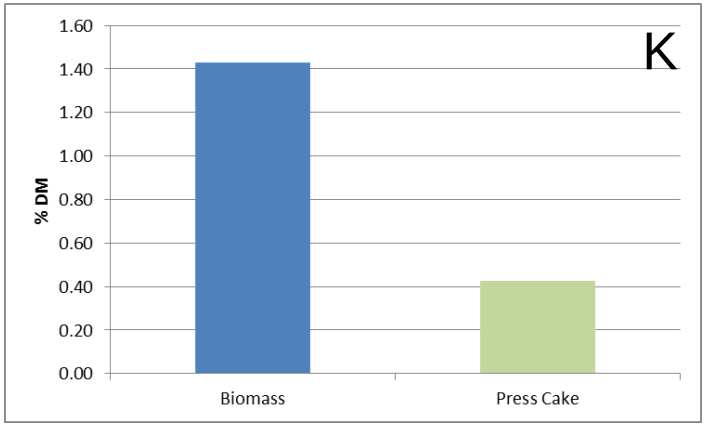
- Further reduction needed: Pre-washing step!!!

Press cake

- Contains less detrimental elements







Press Cake

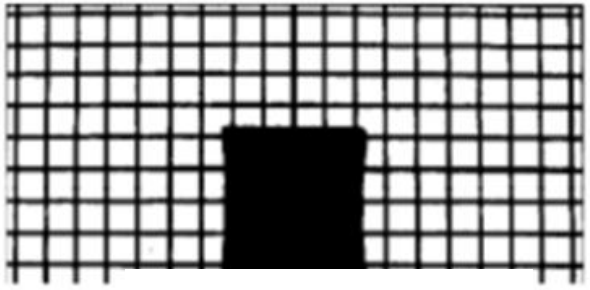
- Increased heating value

(17.57 -17.85 MJ per kg DM HHV)

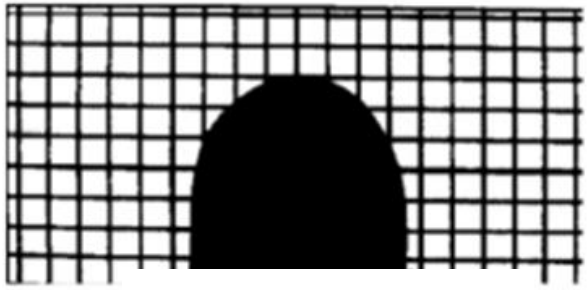
- Increased ash melting temperature

Silage: 1062°C

PC: 1105°C

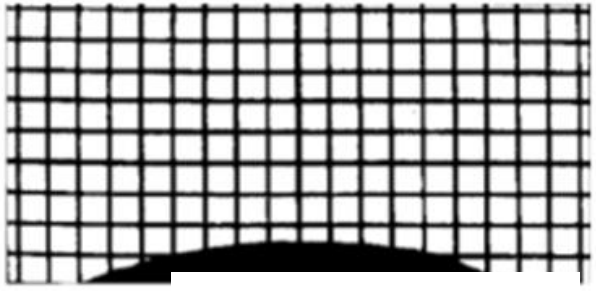


Softening



Spherical

Hemispherical



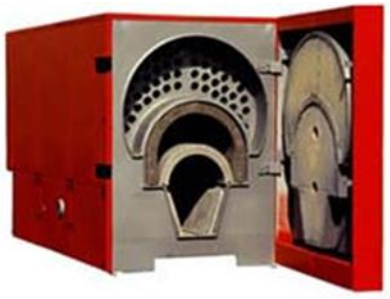
Flowing

Press Cake

- After drying and compaction → storable and transportable

Combustion Test I

- Ökotherm 120 kW (C1L)
- Stoke fired, cooled combustion cavity, automated λ- control, no dust filter applied
- PM: 37 – 53 mg /m³
- NO_x: 353 – 405 mg /m³
- SO_2: 41 – 58 mg /m³
- CO: 38 – 75 mg /m³



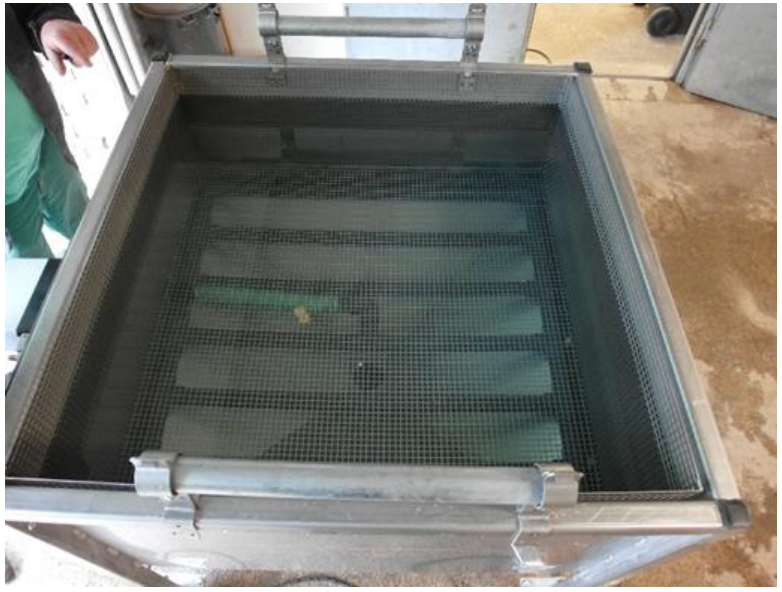
Combustion Test II

- Hand-fed „Fröling FH 25“ (1986) 22-29 kW
- Not a state of the art boiler → high CO and PM emissions

Parameter	Wood	IFBB
Ash [%]	1.3	5.4
PM [mg / m³]	110.7	133.1
CO [mg / m³]	5355	3599
NO_x [mg / m³]	75	182.7
SO_2 [mg / m³]	3	0

Wood vs. IFBB

Developing a new washing step

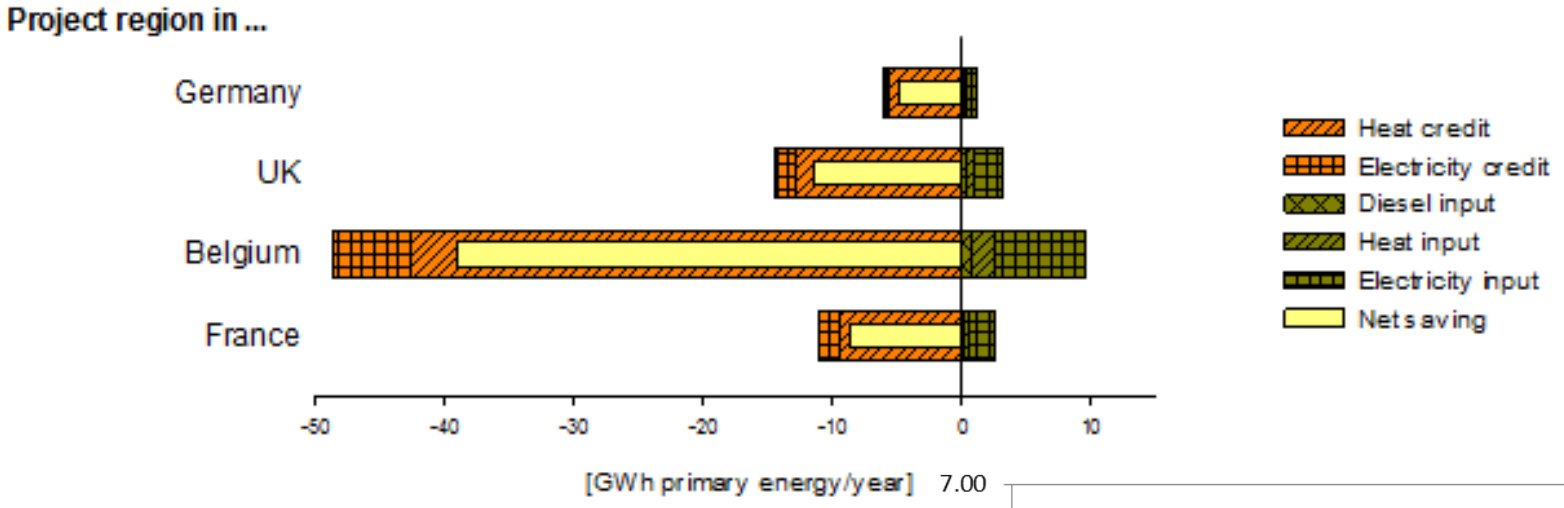


Washing leaf litter

Results on ash content, contamination with PAHs and heavy metals, mineral concentration etc. will follow.

Thank you very much for your attention!

Regional Net-Energy-Saving-Balance



- Large differences between the regions caused through diferent biomass potentials