ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

Department of Fluid Dynamics and Power Engineering

Czech Technical University in Prague (CTU), Czech Republic

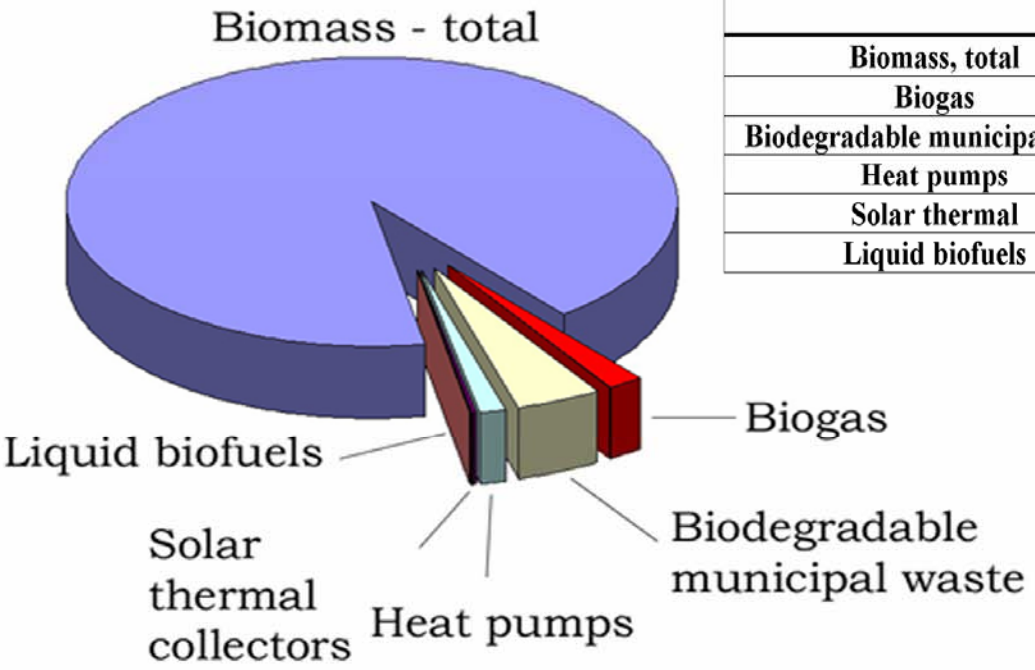
# Combustion of Agricultural Biofuels in Fluidized Bed Boilers

Prof.Ing. František Hrdlička,PhD.

Ing.Jan Hrdlička,PhD.

# Renewables in heat production

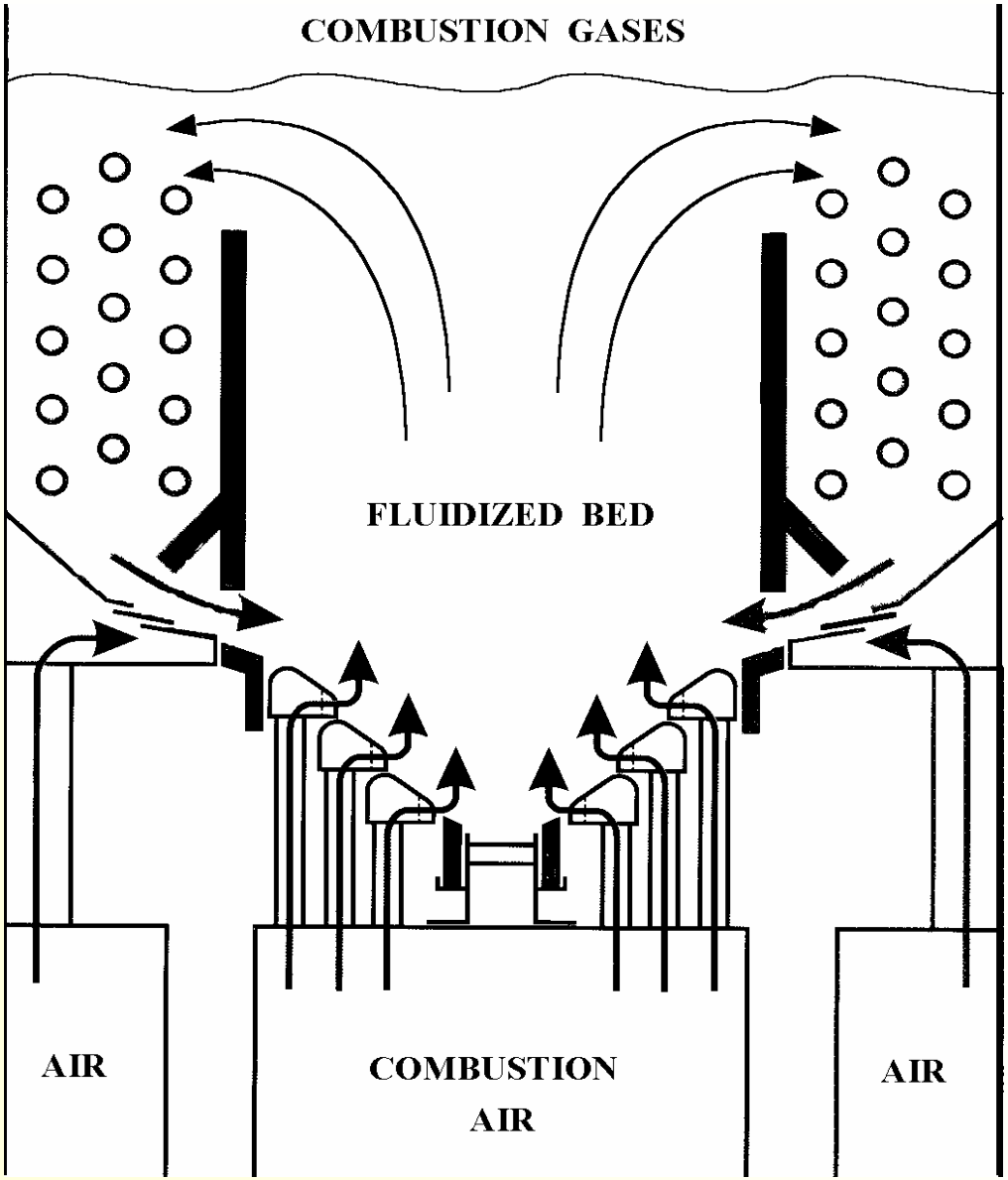
## RES SHARE IN HEAT PRODUCTION FROM RES, CR 2006



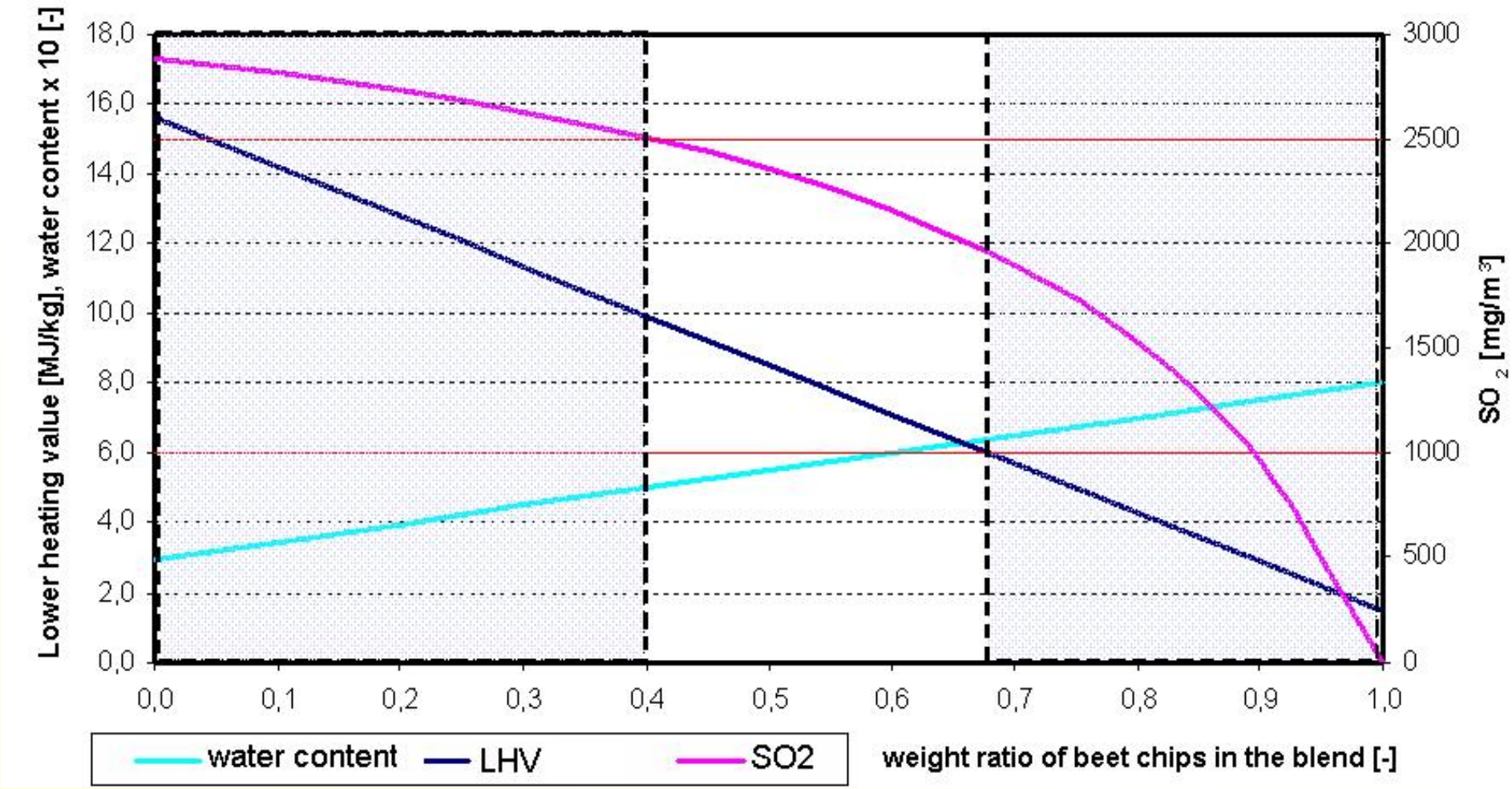

| | Share in heat from RES (%) | Gross production (PJ) |
|---|---|---|
| Biomass, total | 91,19 | 41,76 |
| Biogas | 2,01 | 0,92 |
| Biodegradable municipal waste | 4,17 | 1,91 |
| Heat pumps | 1,48 | 0,68 |
| Solar thermal | 0,28 | 0,13 |
| Liquid biofuels | 0,00 | 0,0001 |

Total heat consumption is 381 PJ/yr , including centralized heat sources (CZT) 209 PJ/yr and decentralized heat sources (DZT) 172 PJ/yr

# **SUCCESSFUL EXAMPLE** – co-firing of sugar beet and coal in 2MW BFBC boiler with internal bed material circulation



# **Co-firing of sugar beet chips and coal** – experimental data




- significant $SO_2$ reduction
- works well up to 1:1 coal:chips ratio

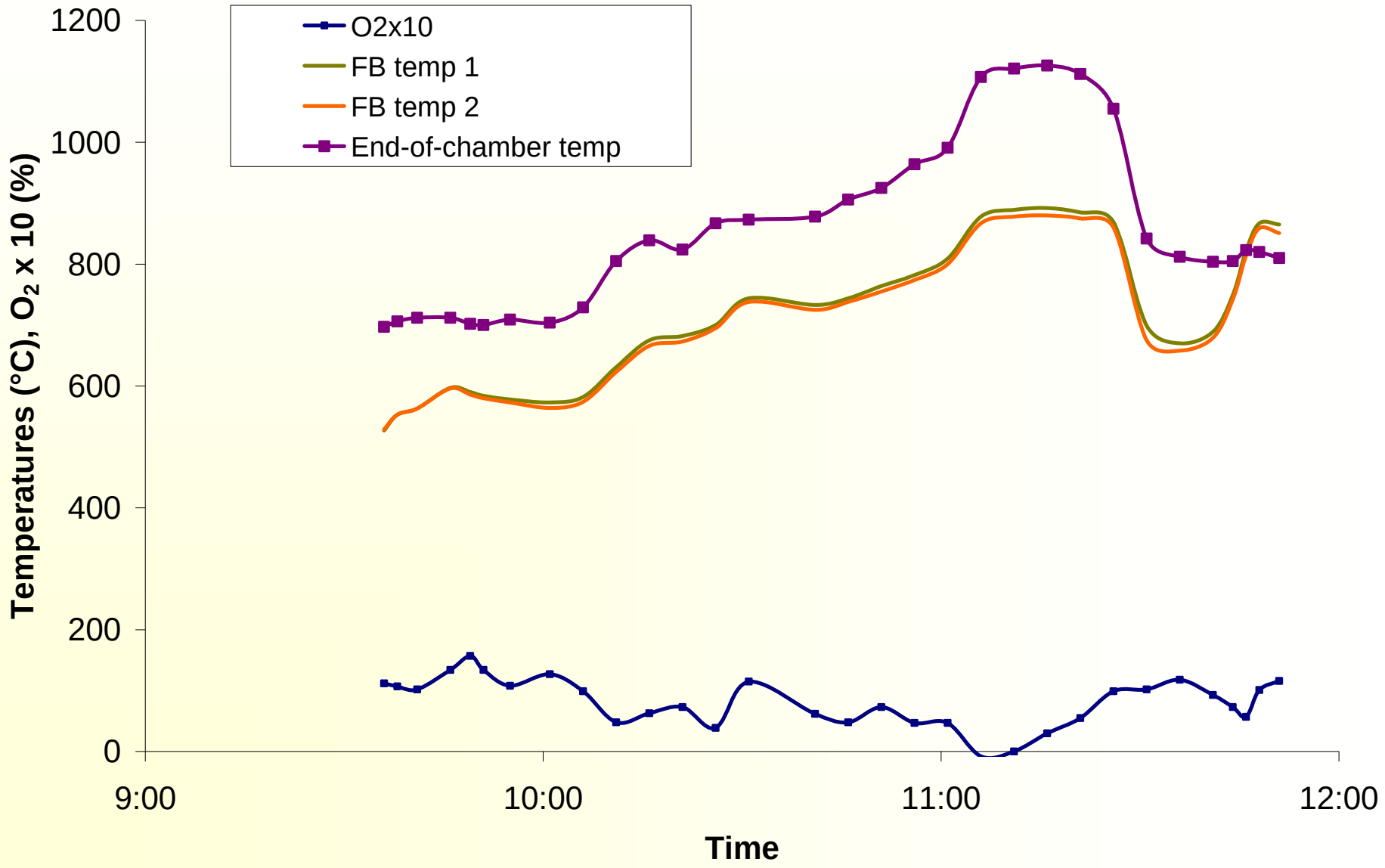
# Analysis of sugar beet chips

| | |
|---|---|
| **Water content** | Wr = 79,7 % |
| **Ash content** | Ar = 1,21 % |
| **Combustibles** | hr = 19,09 % |
| **LHV** | Qs = 3,41 MJ/kg |

# **Co-firing of sugar beet chips and coal** – experimental data

| | | coal | coal : chips ratio | |
|---|---|---|---|---|
| | | | 3 : 1 | 1 : 1 |
| **Power output** | **kW** | **1150** | **1100** | **1200** |
| **$O_2$** | **%** | **10,1** | **9,2** | **8,6** |
| **CO at $O_2$=6 %** | **mg/m$^3$** | **24** | **111** | **196** |
| **Excess air ratio** | **-** | **1,95** | **1,78** | **1,70** |
| **$NO_x$ at $O_2$=6%** | **mg/m$^3$** | **658** | **616** | **570** |
| **Bed temperature** | **°C** | **860** | **835** | **845** |

# **Unsuccessful example –** combustion of dry grain stillage in 1,5 MW coal BFBC boiler



# Agricultural biofuels – ash melting problem

# Important properties influencing FB operation

- ash and water content
- volatiles content
- ash melting temperatures
- elementary composition

# Properties of several biofuels of agricultural origin

| Fuel | A (wt.%) | W (wt.%) | $V^{daf}$ (wt.%) | HHV (kJ/kg) | LHV (kJ/kg) |
|---|---|---|---|---|---|
| sorrel | 4,95 | 9,32 | 80,3 | 17 520 | 15 951 |
| lucerne | 7,13 | 8,09 | 79,4 | 17 149 | 15 619 |
| sorrel + phalaris 1:1 | 4,99 | 9,20 | 79,2 | 16 740 | 15 214 |
| grain residues – rye | 3,59 | 9,06 | 78,4 | 17 142 | 15 525 |
| grain waste | 6,15 | 10,47 | 85,2 | 16 267 | 14 558 |
| sorrel + sawdust 1:1 | 2,90 | 7,87 | 77,0 | 16 310 | 14 729 |
| hay | 9,01 | 9,48 | 80,0 | 15 690 | 14 097 |

| Fuel | C | H | O | N | S | Cl | F |
|---|---|---|---|---|---|---|---|
| sorrel | 43,40 | 6,07 | 35,20 | 0,94 | 0,09 | 0,030 | ---- |
| lucerne | 43,37 | 6,03 | 32,13 | 2,94 | 0,17 | 0,140 | ---- |
| sorrel + phalaris 1:1 | 43,28 | 5,89 | 35,86 | 0,44 | 0,09 | 0,140 | 0,110 |
| grain residues – rye | 42,35 | 6,32 | 36,28 | 2,05 | 0,29 | 0,060 | ---- |
| grain waste | 42,23 | 6,58 | 30,24 | 3,08 | 0,24 | 0,270 | 0,740 |
| sorrel + sawdust 1:1 | 45,10 | 6,29 | 37,31 | 0,24 | 0,07 | 0,100 | 0,120 |
| hay | 41,20 | 6,16 | 31,63 | 1,63 | 0,15 | 0,147 | 0,600 |

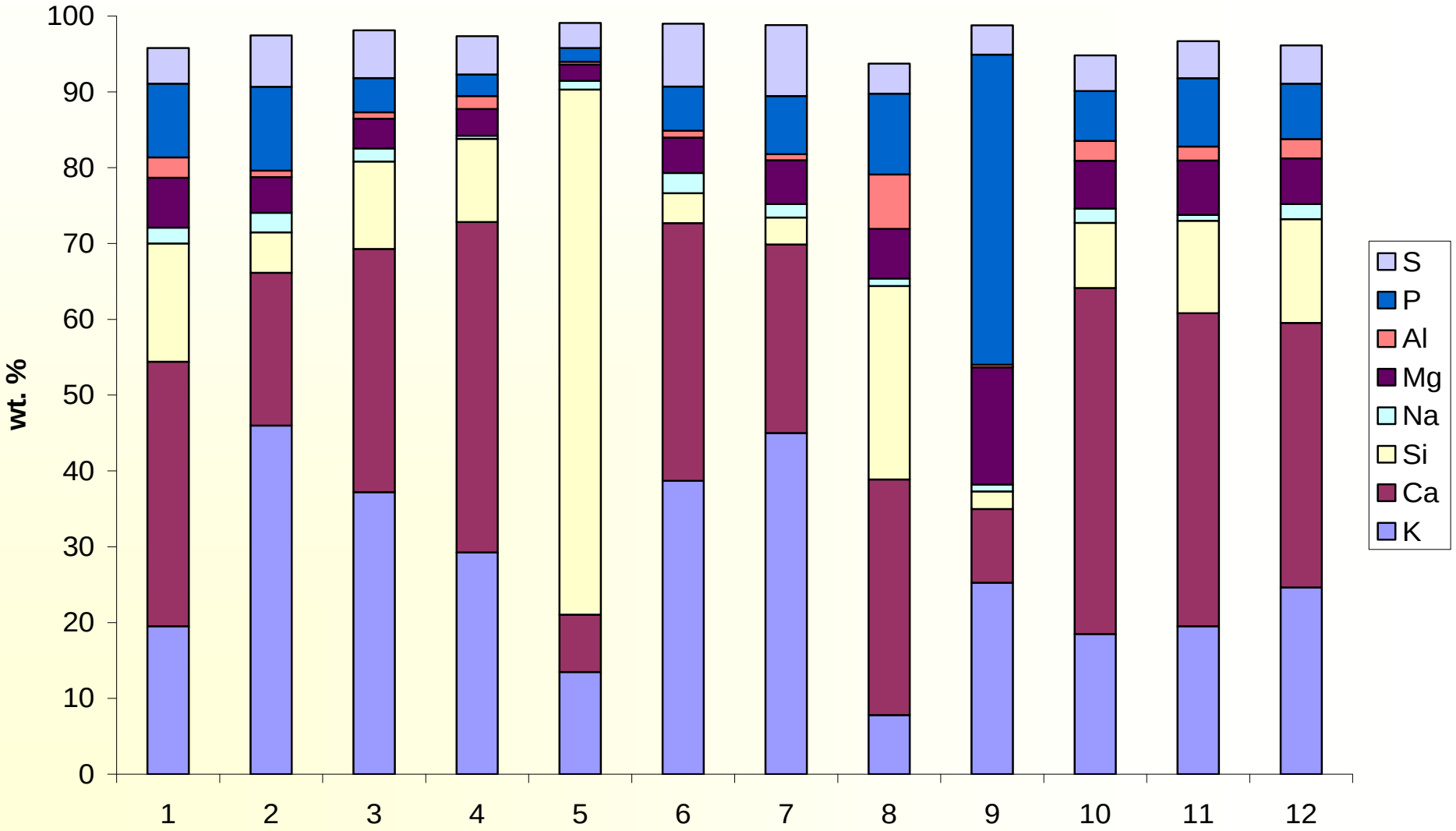
# Ash properties

| Fuel | Softening point °C | Melting point °C |
|---|---|---|
| sorrel | **1255** | **1280** |
| lucerne | 1500 | >1500 |
| sorrel + phalaris 1:1 | **860** | **905** |
| sorrel + sawdust 1:1 | 875 | 920 |
| grain residues – rye | 1120 | 1135 |
| hay | 1080 | 1170 |
| grain waste | 1080 | 1140 |

# Ash properties in pictures – furnace and heat exchanger input after 1 month operation

# Ash properties in pictures – ash from the bottom of the furnace

# **SORREL** – an example of influence of various locations on ash composition in a biofuel



# Conclusions

- necessity of modification of the density or granulation of the inert bed component
- good knowledge of composition of the energetic crops
- feeding of energetic crops through secondary air

**Thank you for your attention!**