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NATIONAL OPEN ACCESS SCIENTIFIC CENTRE FOR FUTURE ENERGY TECHNOLOGIES

OPEN R & D LITHUANIA

# Investigation of emission of alkali radicals during combustion of single wood and straw biomass pellet under the high temperature using FES method


***M. Sadeckas, N. Striūgas, H. Wang***

WtE commissioning engineer at Steinmüller Babcock Environment GmbH

Lithuanian Energy Institute, Laboratory of Combustion Processes, Breslaujos str. 3, LT-44403 Kaunas, Lithuania

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# Lithuanian Energy Institute

**Lithuanian Energy Institute (LEI)** is internationally recognized energy-related research, development and innovation (R&D&I) competence center.

Located in KAUNAS city

# Future trends

WtE plant in Högbytorp, Stockholm, Sweden

Good experience

Process Cycle

Steinmüller Babcock Environment
SBENG
NIPPON STEEL & SUMIKIN ENGINEERING GROUP

# Future aims of WtE plants in Lithuania (on going projects)

Kauno kogeneracinė jėgainė

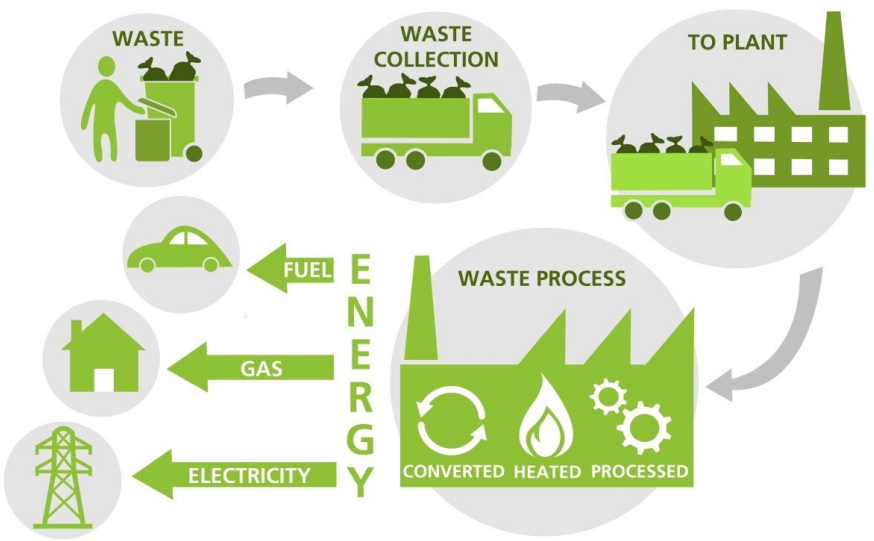
WtE plant in Kaunas city
24 MWe and 70 MWt
Fuel: waste

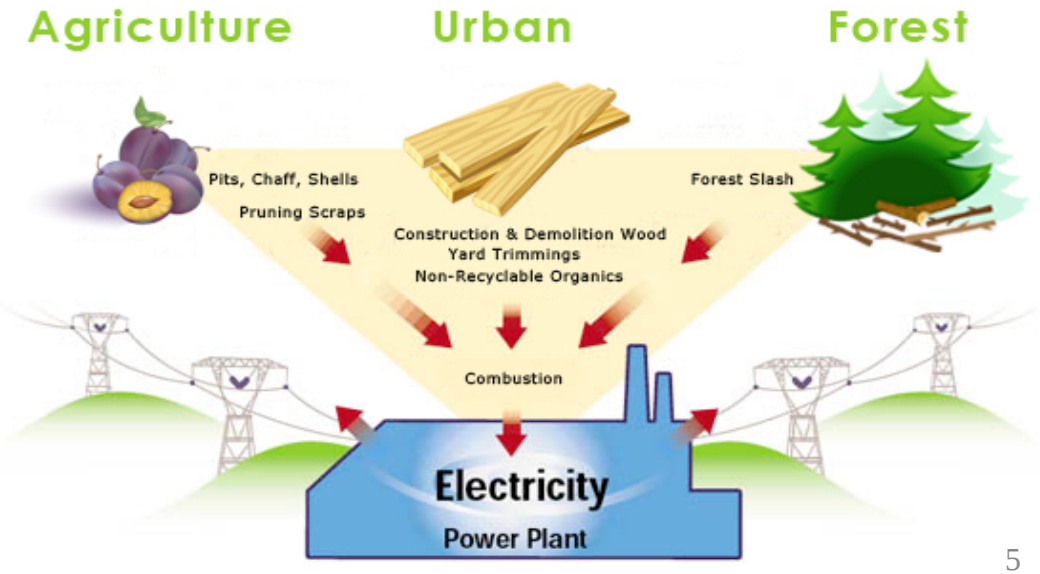
Lietuvos energija | VILNIAUS KOGENERACINĖ JĖGAINĖ

WtE plant in Vilnius city
92 MWe and 229 MWt
Fuel: waste and biomass

# Introduction

Biomass is an widely spread future fuel and is used in Lithuania in innumerable applications as a renewable energy source. As this waste comes from forest residues, agriculture organic matter, its environmental and economic feasibility have made it a competitive alternative to traditional solid fossil fuels. With the growth of the biomass usage, the quality of the feedstock for energy production becomes an issue when the feedstock variety increases.



# The main problem and the relevance of research work

Poor quality biomass growth in the district heating sector, WtE and biomass power plants

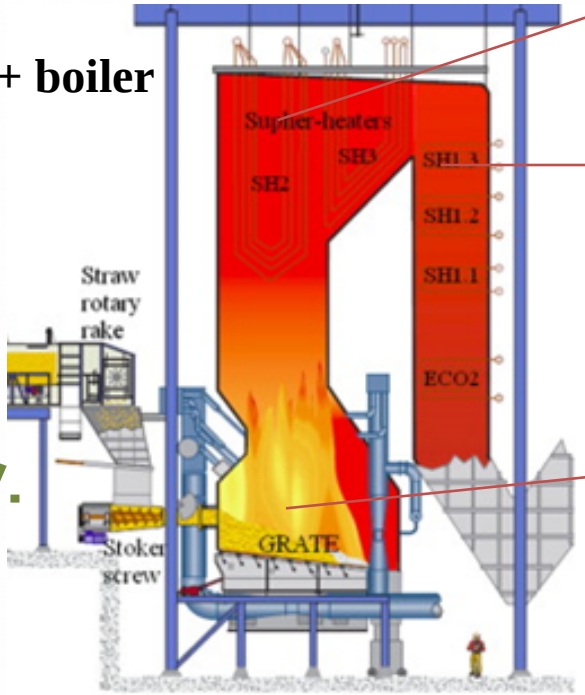
Alkali-induced slagging formation on the heating surface and impact on the durability of the structural components of the boiler

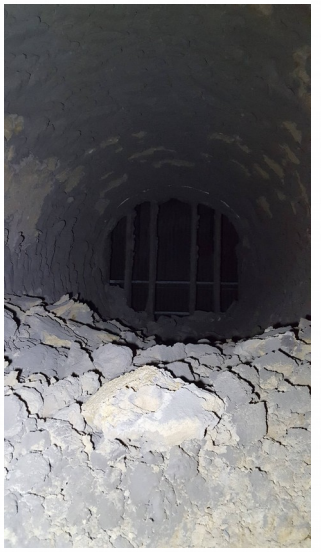
**Furnace + boiler**

**Biomass storage**

**Biomass feeding system**

K, Na, Ca



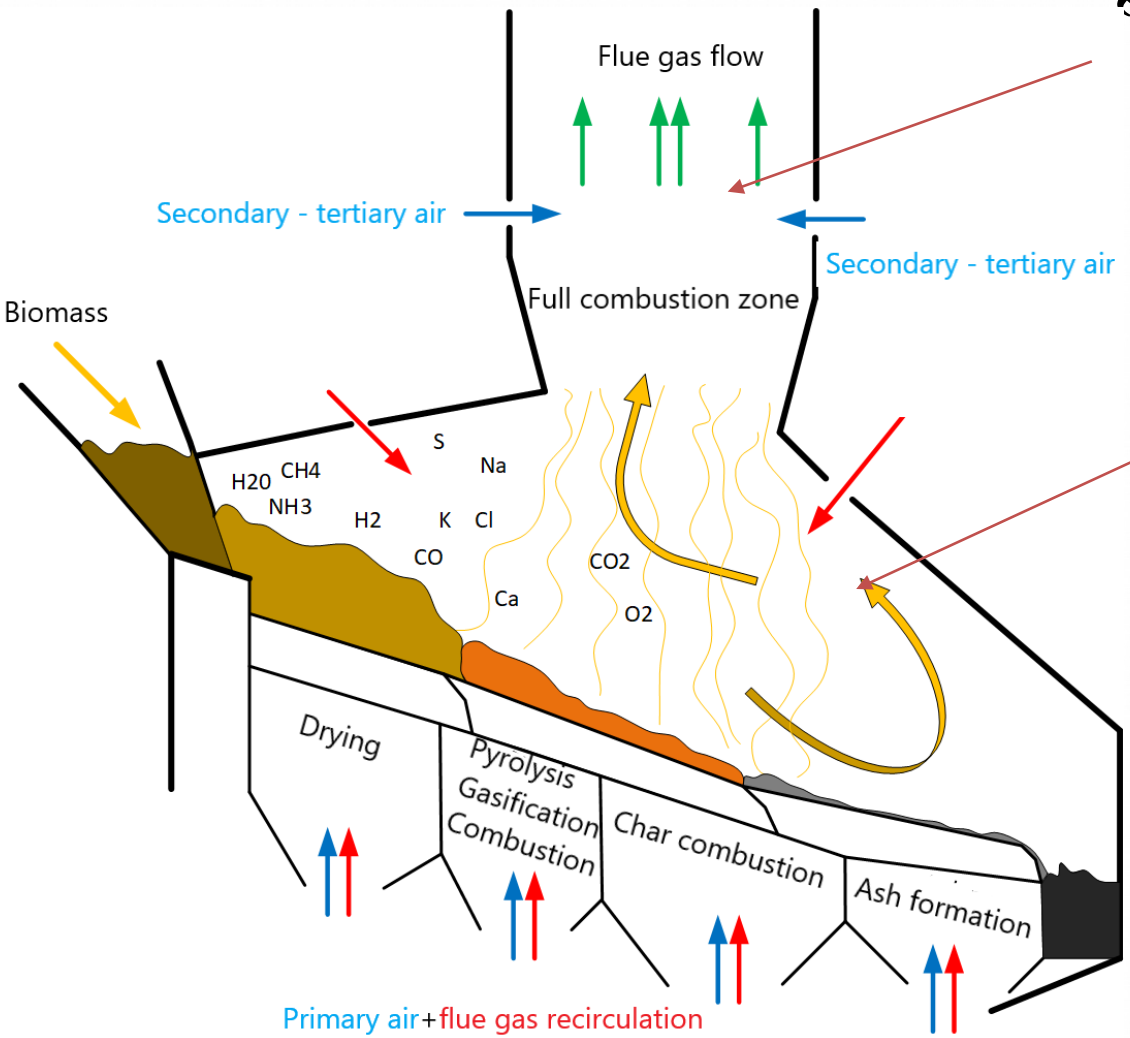



$OH^-$, $CH^-$, $C^-_2$, $CO^-_2$ $Na^+$,$Ca^{2+}$, $K^+$, $Cl^-$

# The aim

- To investigate the regularities of chemiluminescence phenomena occurring during the biomass pellet combustion process.
- In this work,  chemiluminescence detection is apply to measure the emission intensity of Na, K and Ca during the combustion of wood and straw pellets doped with different concentrations of selected elements.

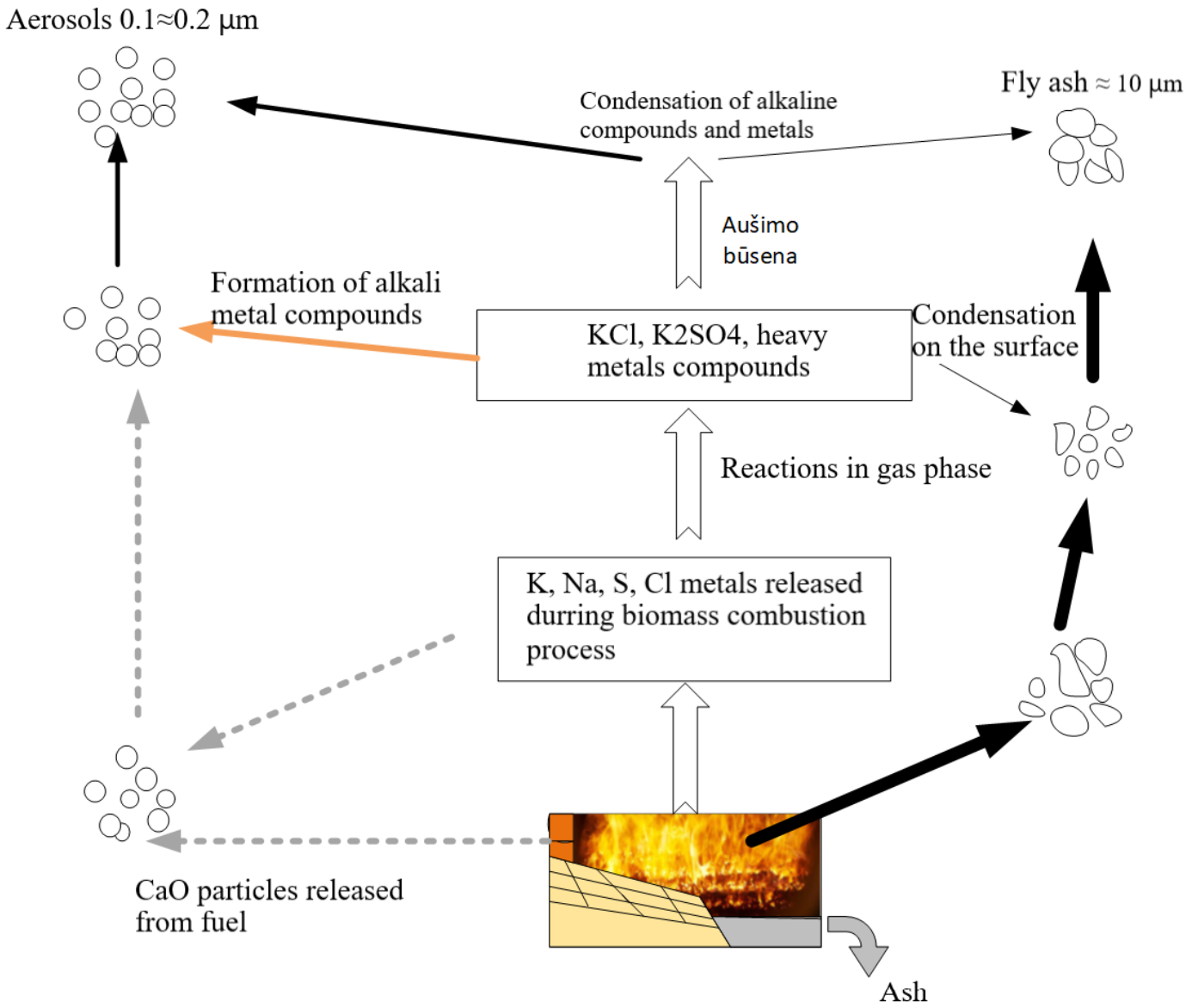
# Stage of biomass combustion




**Different combustion temperature zones**
**600 – 1200 °C**

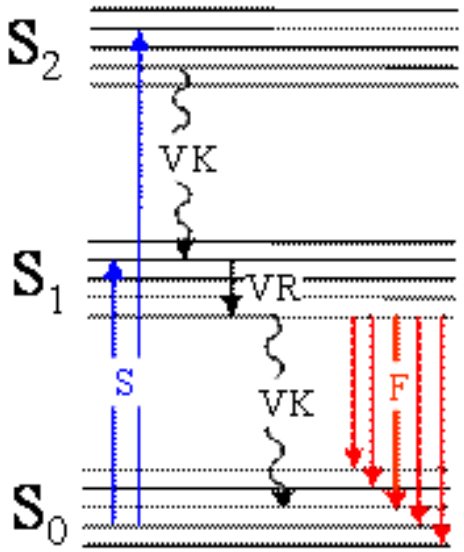
- Drying
- Pyrolysis/gasification
- Combustion
- Ash formation

# Schematic of the formation processes of the main ash-related issues



# Method of chemiluminescence

- The phenomenon of emission or luminescence is characterized by quantum leaps. Each molecule has a series of filled and empty electronic levels. The absorption of light quantum gives the molecule extra energy, which results in an electron leap from an energetically lowered orbital to a higher, non-filled molecular electronic orbital. This state of the molecule is unbalanced and unstable, so the molecule emits a light quantum of longer wavelength, "returning to the main" equilibrium state.



# Spectroscopy equipment

- Using the spectroscopy method, flame monitoring is carried out and the radiating element ions in a certain wavelength range are captured using the ICCD camera Andor iStar DH734-18U-E3 spectroscopic system.
- Interference filters are used to help recording the intensity of radiation of different radicals with ICCD camera

| Filter | K | Na | Ca |
|---|---|---|---|
| Wavelenght, nm | 770 ± 2 nm | 590 ± 2 nm | 620 ± 2 nm |

# Biomass pretreatment procedure

Raw biomass

Milled biomass

Washing $HNO_3$/pH=2 /1h/60˚C

Filtering-drying at 105˚C

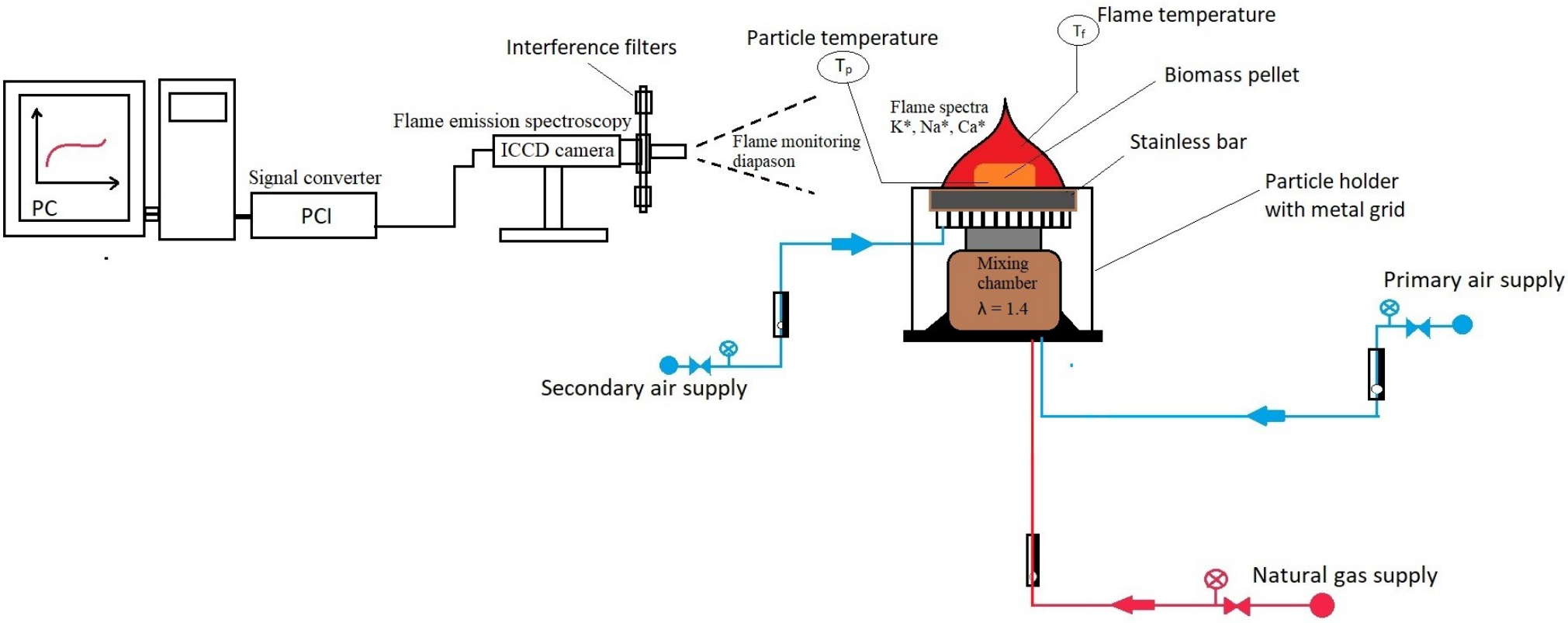
Doping with K, Na, Ca salts

Filtering-drying at 105˚C and pelletizing

| Parameter | Wood pellet | Straw pellet |
|---|---|---|
| Moisture, wt.% | 5.8 | 8.28 |
| HHV, MJ/kg | 17.49 | 16.56 |
| LHV, MJ/kg | 16.25 | 15.33 |
| Ash, wt.% | 0.2 | 4.9 |
| C, wt.% | 49.59 | 45.84 |
| H, wt.% | 5.36 | 5.16 |
| O, wt.% | 45.05 | 47.67 |
| N, wt.% | 0.01 | 1.12 |
| S, wt.% | 0.01 | 0.21 |
| **K, mg/kg** | **339** | **16481** |
| **Na, mg/kg** | **45** | **45.1** |
| **Ca, mg/kg** | **705** | **2638** |
| Diameter, mm | 13 | 13 |
| Length, mm | 10 | 10 |

| Parameter | K, mg/kg | Na, mg/kg | Ca, mg/kg |
|---|---|---|---|
| **Wood** | | | |
| washed | n.d. | n.d. | 314 |
| washed + doped 0.5% | 4840 | 5845 | 5248 |
| washed + doped 2% | 18984 | 27584 | 17576 |
| washed + doped 5% | 56224 | 49378 | 42360 |
| **Straw** | | | |
| washed | 1054 | n.d. | 1079 |
| washed + doped 0.5% | 5534 | 5411 | 5709 |
| washed + doped 2% | 21356 | 21450 | 19500 |
| washed + doped 5% | 53458 | 48965 | 48562 |

# Experimental setup



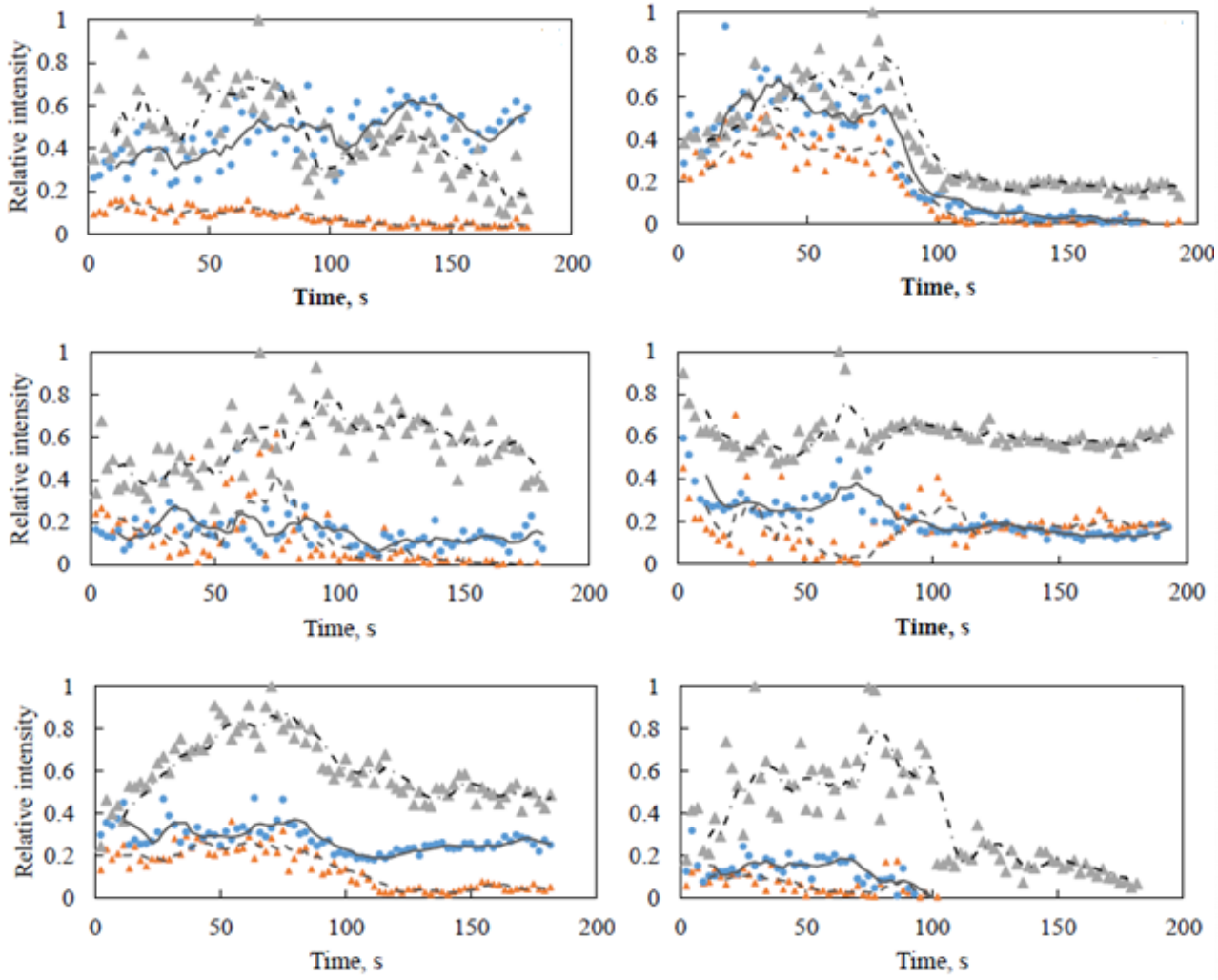

1 pav. Principal scheme of laboratory stand

# K*, Ca* and Na* intensities of the pellets doped with 0.5%, 2% and 5% of selected minerals during combustion process

K

Ca

Na



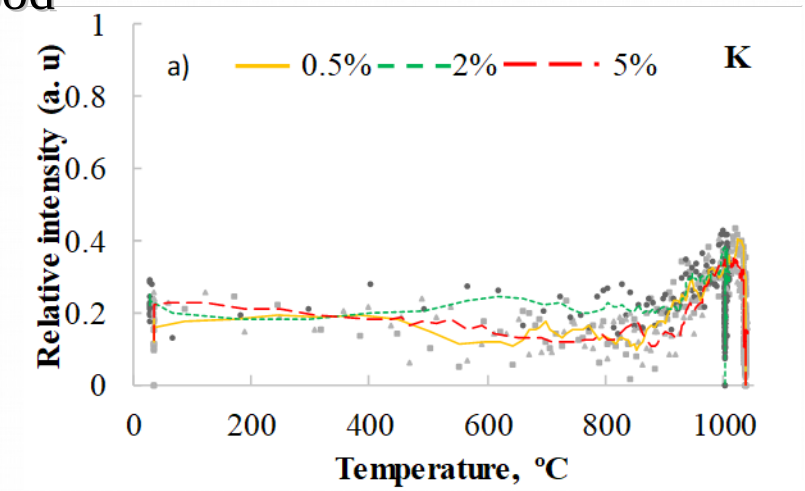
# Relative intensities dependence on the internal pellet temperature in surrounding gas flame 1100-1200 °C temperature

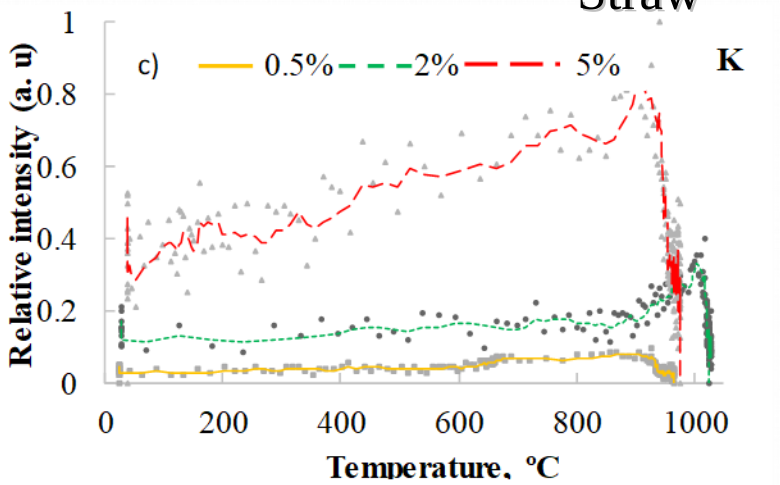
Wood

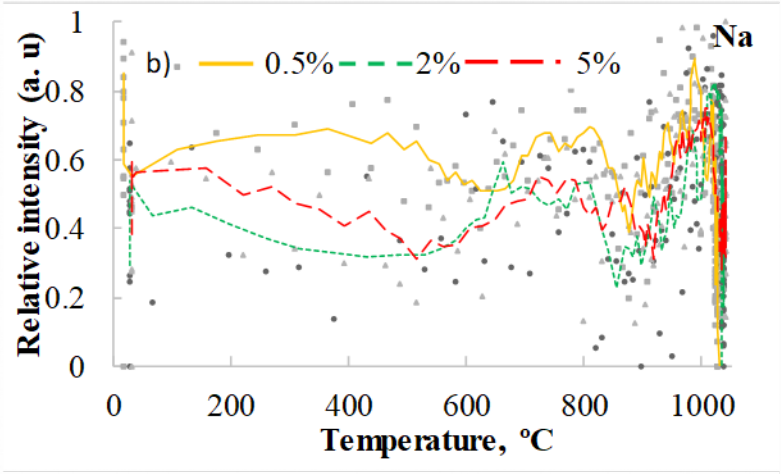
Straw

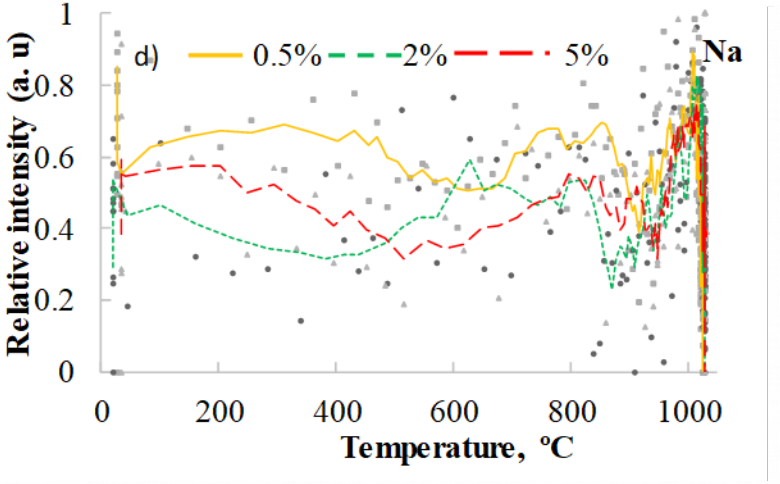
K

Na

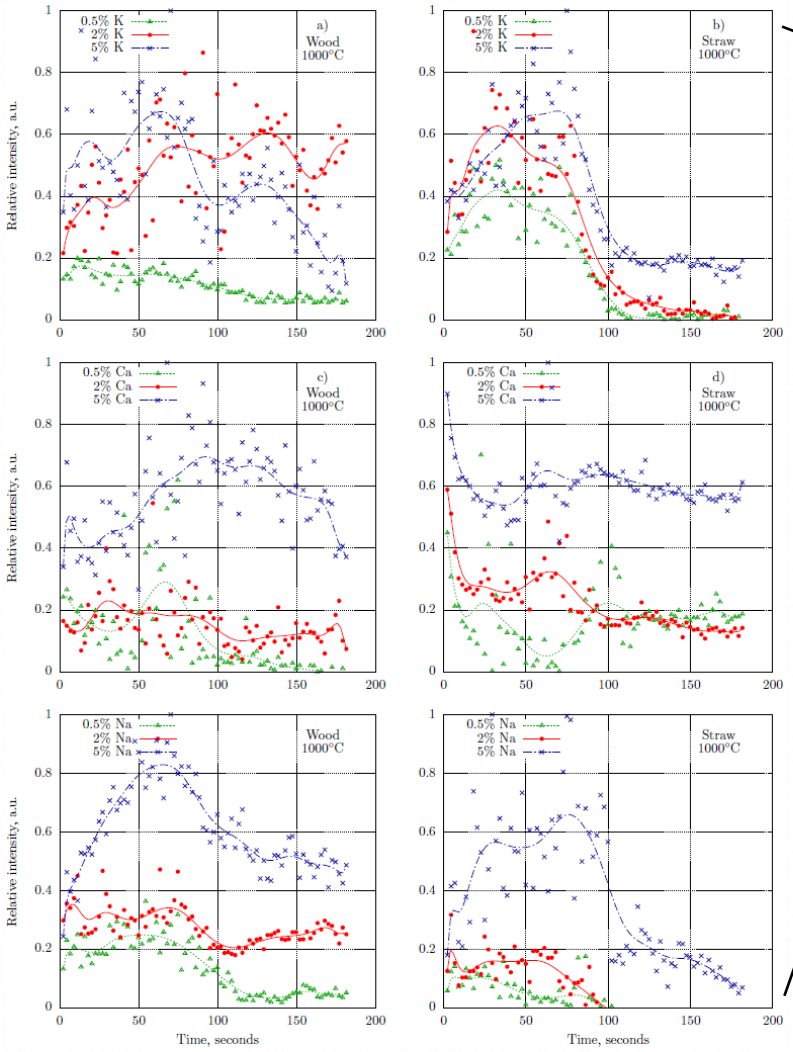


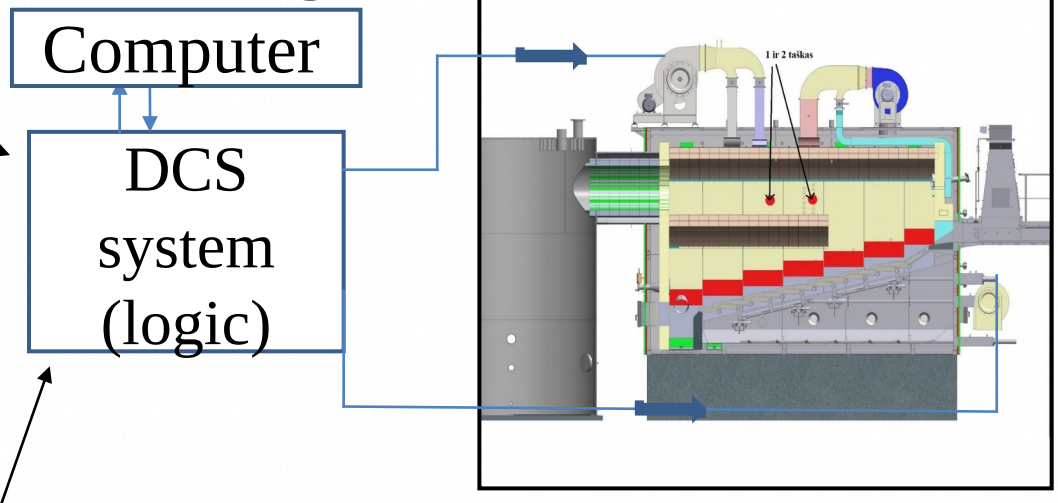



# Application in real working conditions




The obtained data can be used to develop smart furnace controlling systems. Also to improve and automate existing furnace control systems (updated old system)

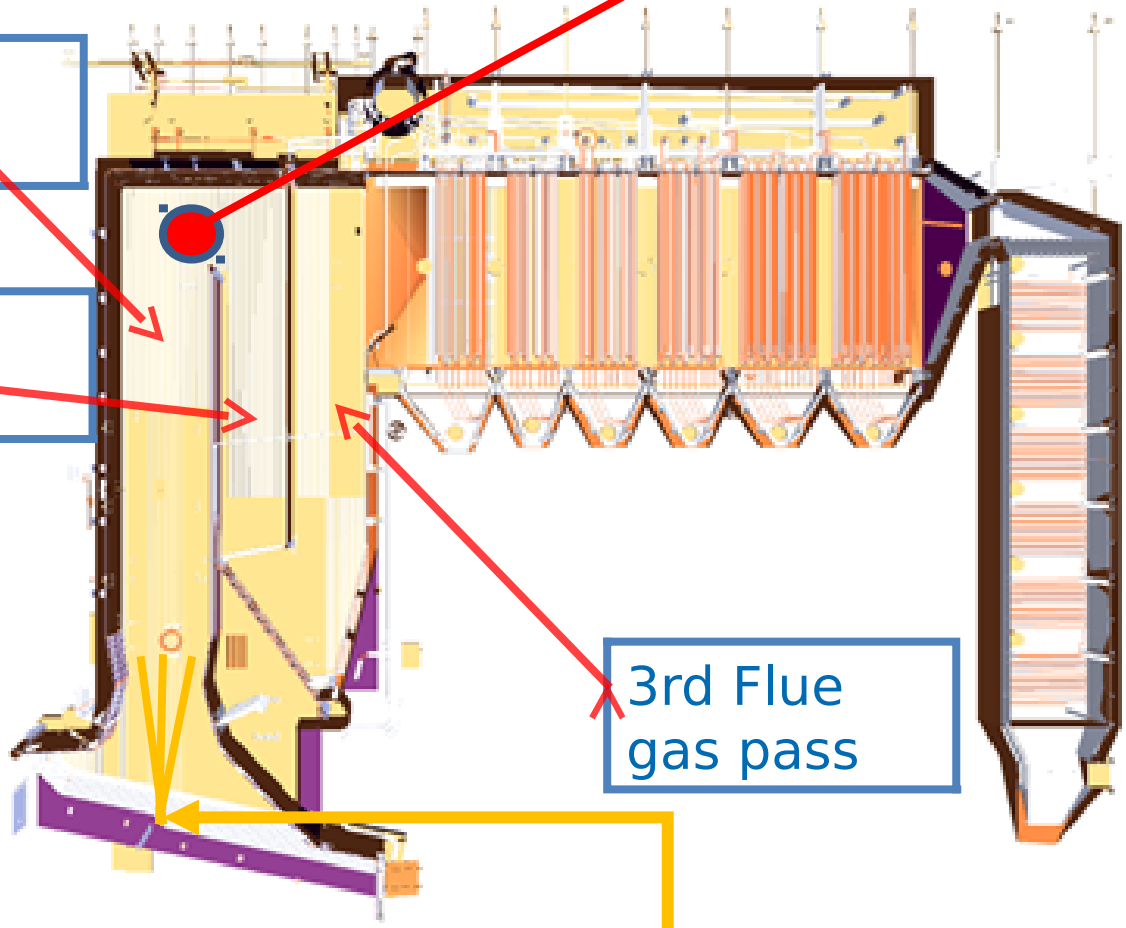
# Scope of biomass combustion boiler
# Possible K*, Na* measuring points

Higher temperature zones

1st Flue gas pass

2nd Flue gas pass

3rd Flue gas pass



# Conclusions

- The K*, Ca* and Na* emission profiles can be correlated with the combustion period. Comparison of the release intensities of inorganic content shows that the combustion temperature has the most important effect. The experimental results show that the emission intensity of K* and Na* was noticeable bright in higher temperature zones from 900 °C to 1200 °C
- Calcium keeps stable and does not evaporate under given conditions and shows extra stability during wood and straw combustion.
- It can be concluded, that chemiluminescence method can be used for monitoring the release of alkali species (mainly potassium) as indicator in biomass furnaces at high temperature zones. This method can be used in conjunction with other boiler auxilary systems to reduce emissions or prevent ash-slagging occurrence.

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# Thank you for your time!

**Marius Sadeckas**

Marius.Sadeckas@lei.lt