Gasification process improvements

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PHYTO2ENERGY

Phytoremediation driven energy crops production on heavy metal degraded areas as local energy carrier

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 610797.

The Scientific and technological (S&T) goal of the project

To develop and validate an innovative approach combining phytoremiediation and production of biomass on heavy metal contaminanted (HMC) areas which could be used as local energy carrier.

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To demonstrate an environmentally safe way of converting the HMC biomass into energy in a small scale local installation **with special focus on gasification** as a promising technology which may become a competitive alternative for handling HMC biomass.

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Gasification

Gasification converts any carbon-containing material into synthesis gas, composed primarily of carbon monoxide and hydrogen. Gasification adds value to low or negative value feedstocks by converting them to marketable fuels and products.

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Gasification - Advantages

1. Produced gas can be burned to release energy or used for production of value-added chemicals
2. As a consequence of the reducing atmosphere, gasification prevents emissions of sulfur and nitrogen oxides, heavy metals and the potential production of chlorinated dibenzodioxins and dibenzofurans.
3. A smaller volume of gas is produced compared to the volume of flue gas from combustion because gasification is characterized by an environment containing low levels of the gasification agent.
4. Due to reducing conditions used for gasification, most of sulfur, nitrogen, chloride and fluoride in sewage sludge may be released as H_2S, NH_3, HCl and HF. The presence of these compounds is undesirable as they may be converted into the respective oxides during gas utilization. Therefore, their formation should be monitored and controlled and trapped.

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Gasification – fuel for energy application

- Producer gas (high concentration of nitrogen) is acceptable for energy application: boiler combustion, CHP and CCHP installation, indircet combustion (reburning application) etc.
- Synthesis gas (syngas; low cncentration of nitrogen) is acceptable for chemical application; hydrogen, methanol, etc.

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WP3 objectives

Objective 3) is to demonstrate an environmentally safe way of converting the HMC biomass into energy in a small scale local installation with special focus on gasification as a promising technology which may become a competitive niche alternative for handling HMC biomass.

Cost effectiveness and environmental benefits of this method will be evaluated together with technology optimization guidelines for this type of fuel.

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WP3 tasks

T.3.1 Development of a set of parameters for HMC biomass valorization for gasification

T.3.2 Development of a cost effectives and environmental benefits analysis for gasification of HMC biomass

T.3.3 Gasification tests of biomass (control, year 2, 3, 4 yield samples) with char/ash sampling, TGA+FTIR tests

T.3.4 Identification of areas for process operations improvement

T.3.5 Lab tests and analyses of biofuel feedstock for gasification (control, year 2, 3, 4 yield samples, lab tests of char/ash from gasification and its assessment as mineral fertilizer),

T.3.6 Analysis of inoculums effect on the properties of the biofuel as gasification feedstock (HM content, mineral substances content)

T.3.7 Final lab tests and analyses of biomass as biofuel feedstock according to the defined control parameters

T.3.8 Final characteristics of the biomass potential as fuel for gasification, report development

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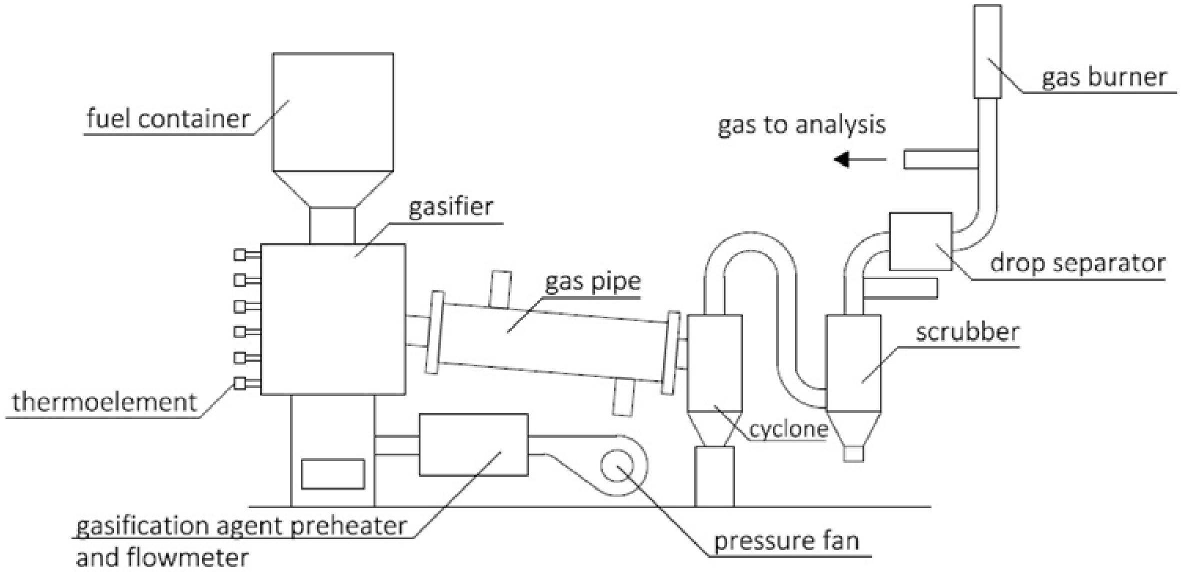
FBG installation



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Many possibilities of process improvements…

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Process improvements – change the gasification agent

Table 4 A summary of the performance of using the steam as a gasifying agent

Gasifying agent	Air	Air-steam
Maximum steam feed rate [kg/h]	0	2.6
Volume flow rate of air [Nm^3/h]	14.13	14.13
Reactor temperature [°C]	920	920
Fuel consumption [kg/h]	14	14
Producer gas flow rate [Nm^3/h]	31	32
H_2 [%]	11	19
CO [%]	14	12
CO_2 [%]	12	13.5
CH_4 [%]	2.6	3.3
HHV [kJ/Nm^3]	4,300	5,200
Cold gas efficiency, CGE [%]	69.4	82.8
Equivalent ratio, ER	0.45	0.45
The effectiveness of heat exchanger, $\varepsilon = 0.92$		

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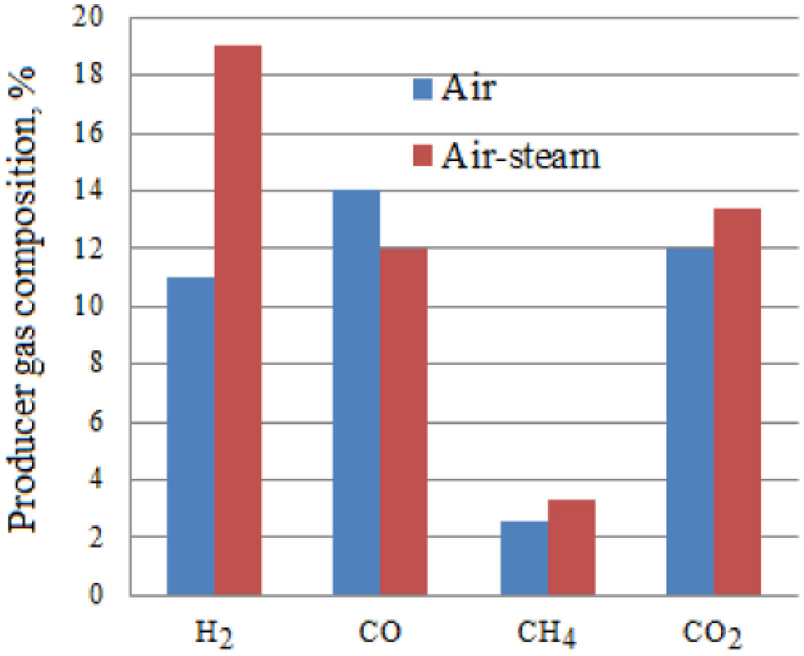
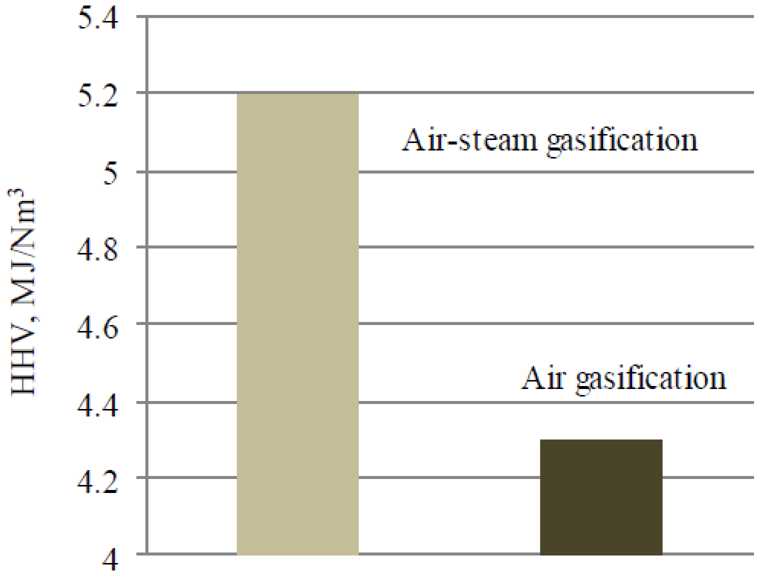
Process improvements – change the gasification agent





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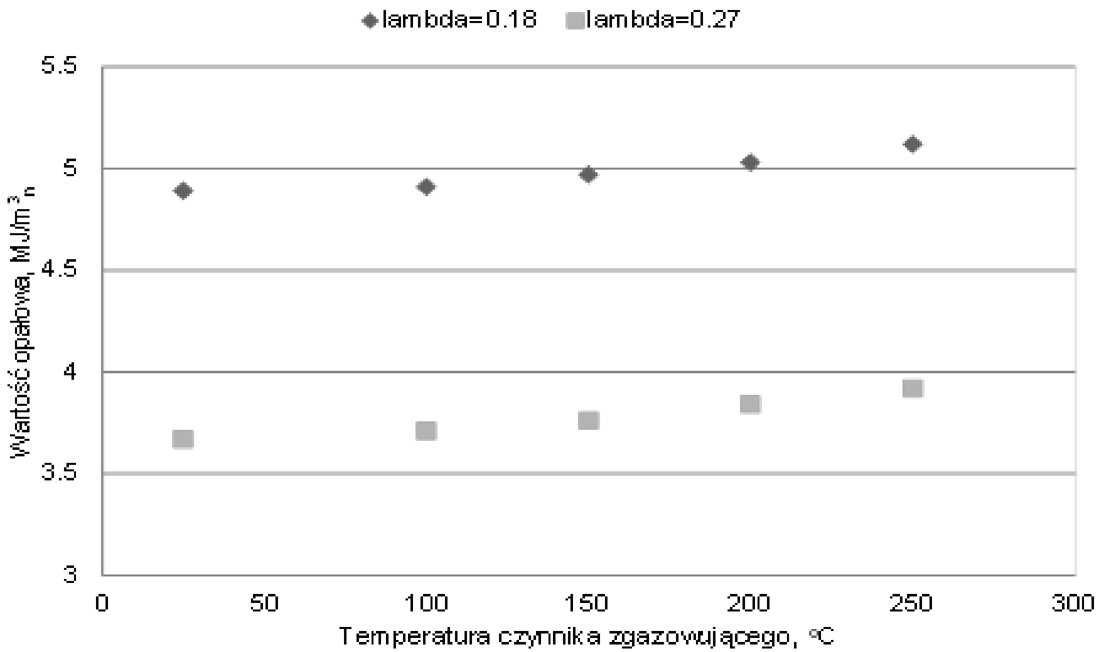
Process improvements – increment of the gasification agent temperature



Werle S., *Impact of feedstock properties and operating conditions on sewage sludge gasification in a fixed bed gasifier*, Waste Management and Research, 2014, 32, 954-960; doi:10.1177/0734242X14535654

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Improvements - Reactor change

Fixed bed gasifiers are generally rather inexpensive and simple. They have high overall carbon conversion, high residence time of solids and low gas velocity, but have limited scalability – proper to small installations.

Aalto University School of Engineering
Department of Energy Technology
Individual Assignment in Environment Friendly Energy Processes

Biomass Gasification

Mikko Kouhia*

11th April 2011

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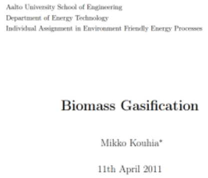
Improvements - Reactor change

Fluidized bed technology is considered as the preferred technology in nearly all medium-to-large scale biomass gasification plants for power production. It can handle high throughput, it has good up-scaling potential and it can tolerate big variations in biomass quality and particle size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Fuel improvements

Properties	Unit	Wood	Torrefied biomass	Wood pellets	Pellets
Moisture content	%	35	3	7-1	1-5
LHV (dry)	MJ/kg	17.7	20.4	17.7	20.4-22.7
Mass density	kg/m^3	550	230	500-650	750-850
Pellets strength	-	-	-	Good	Very good
Dust formation	-	Moderate	High	Limited	Limited
Hygroscopic nature	-	Water uptake	Hydrophobic	Swelling/water uptake	Poor swelling (hydrophobic)
Biological degradation	-	Possible	Impossible	Possible	Impossible

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Fuel improvements

- **1. Palletisation - the contact of gasification air with the feedstock in the reactor is better; reactions are more effective. Cost is higher**


2. Pelletisation with catalyst (10%mass); milled

Halloysite is a 1:1 alumino silicate clay mineral with the empirical formula $Al_2Si_2O_5(OH)_4$ with Fe additives. Its main constituents are aluminium (20.90%), silicon (21.76%) and hydrogen (1.56%).

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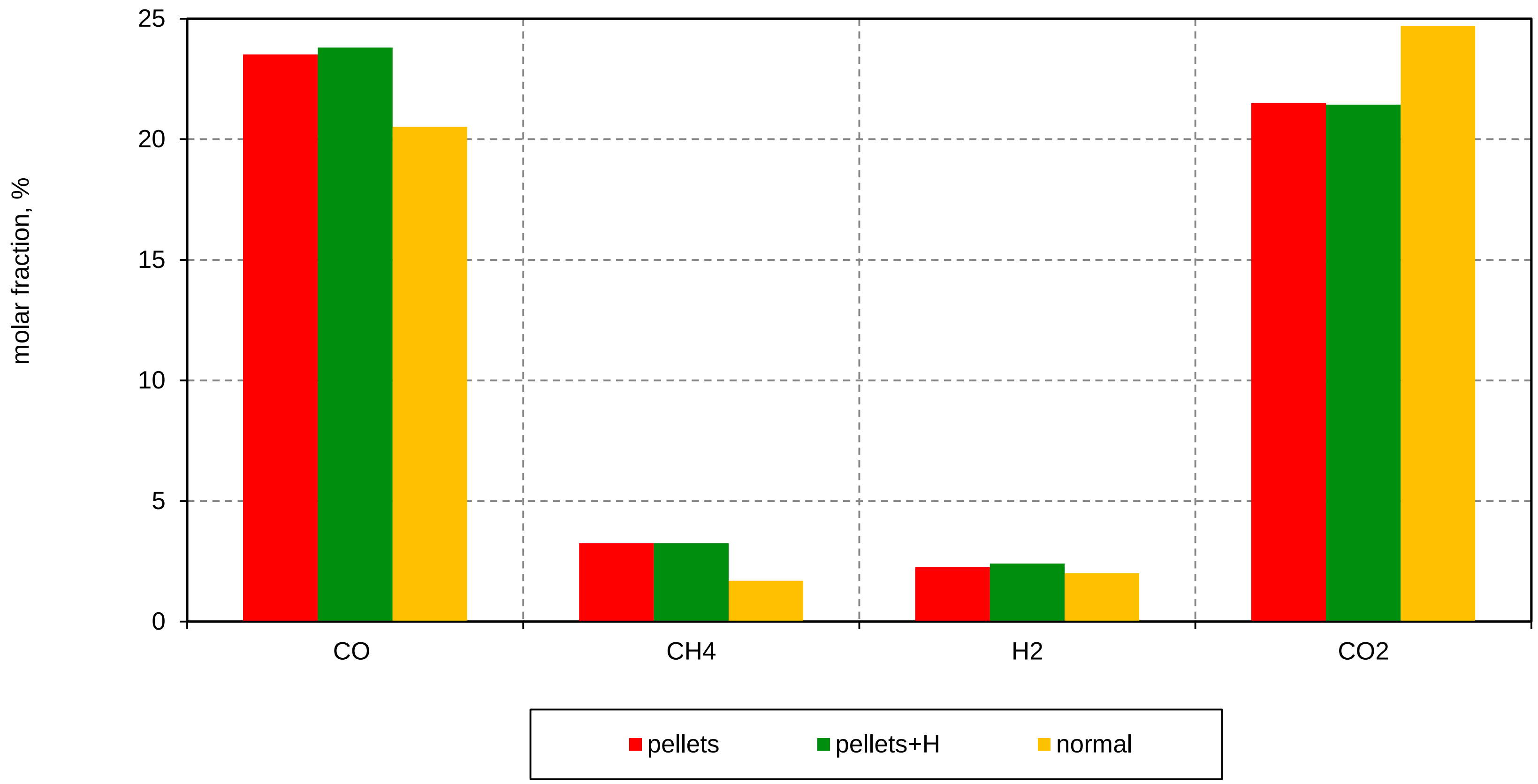
Gas composition



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Fe content also made contribution to the gas and hydrogen yields by promoting the gasification process. According to Nordgreen et al.[21], the metallic iron obtained by reducing the iron oxides (FeO, Fe2O4 and Fe3O4) as tar breakdown catalysts was utilized in the atmospheric fluidized bed gasification process of biomass, the amount of permanent gases was increased and the tar content was declined significantly compared with non-catalytic gasification process of biomass

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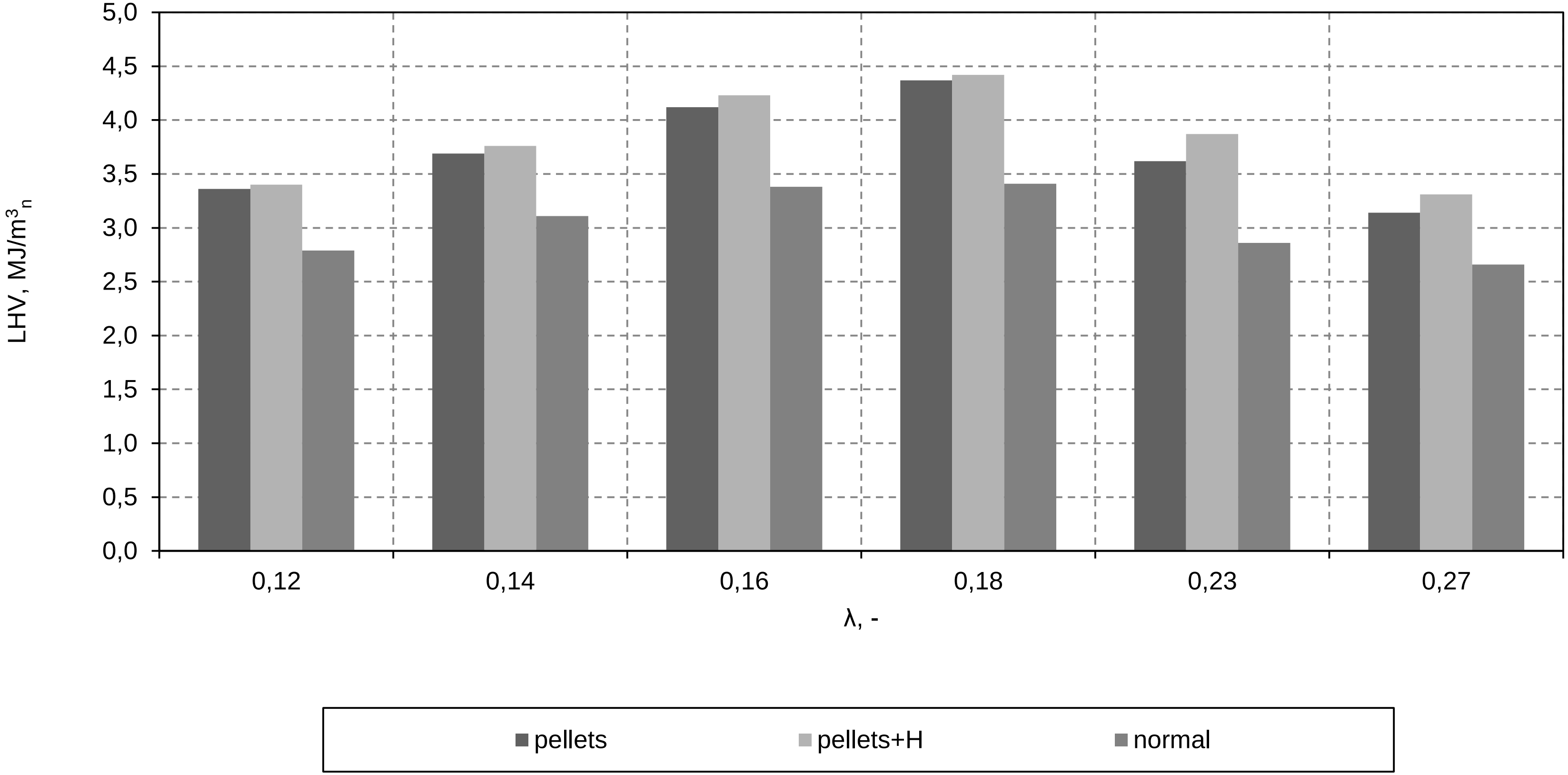
Gas LHV



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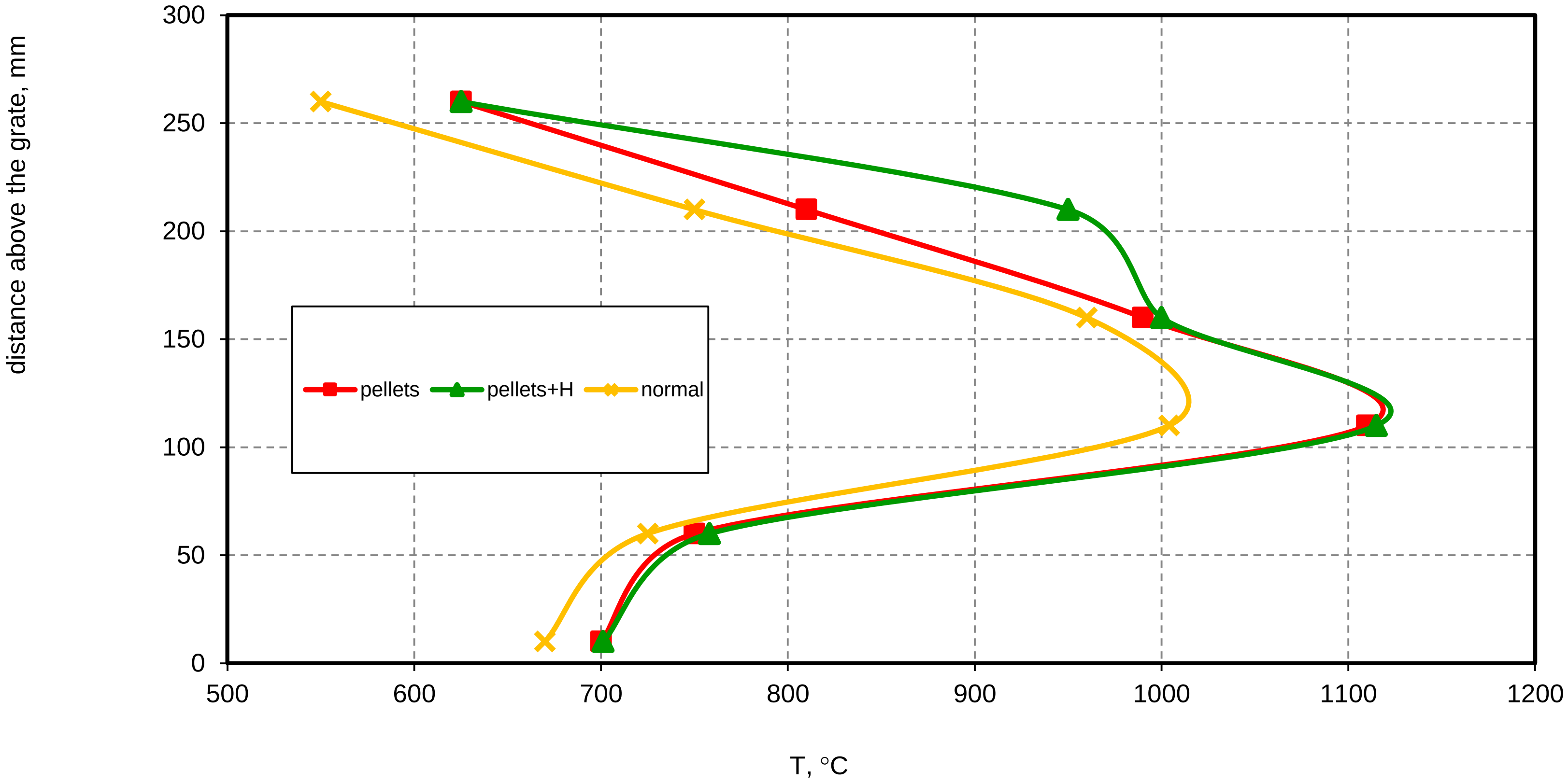
Temperature distribution in the reactor



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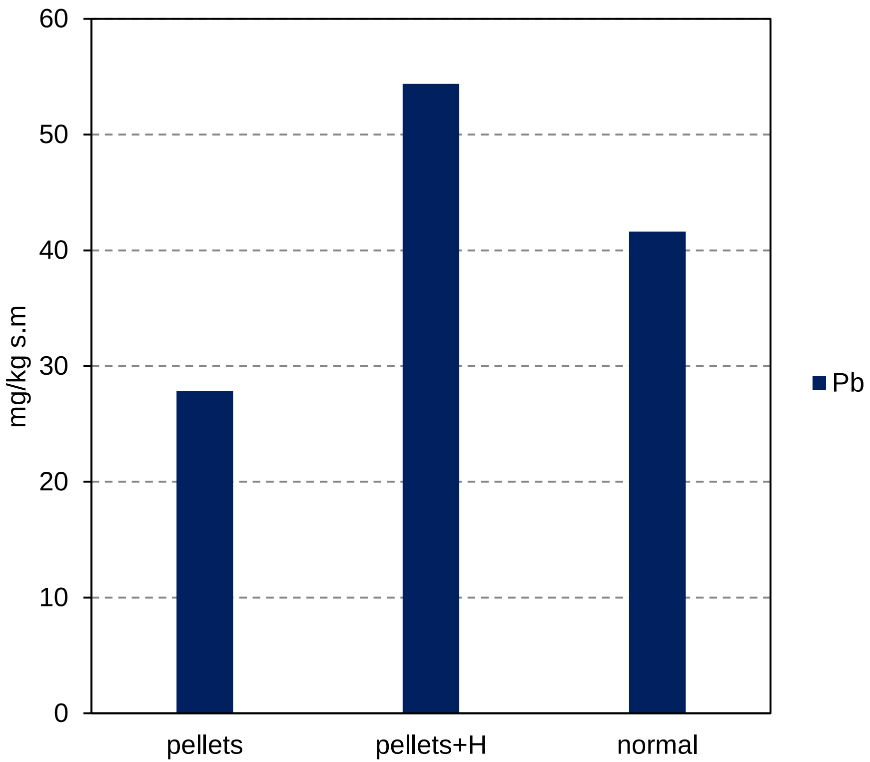
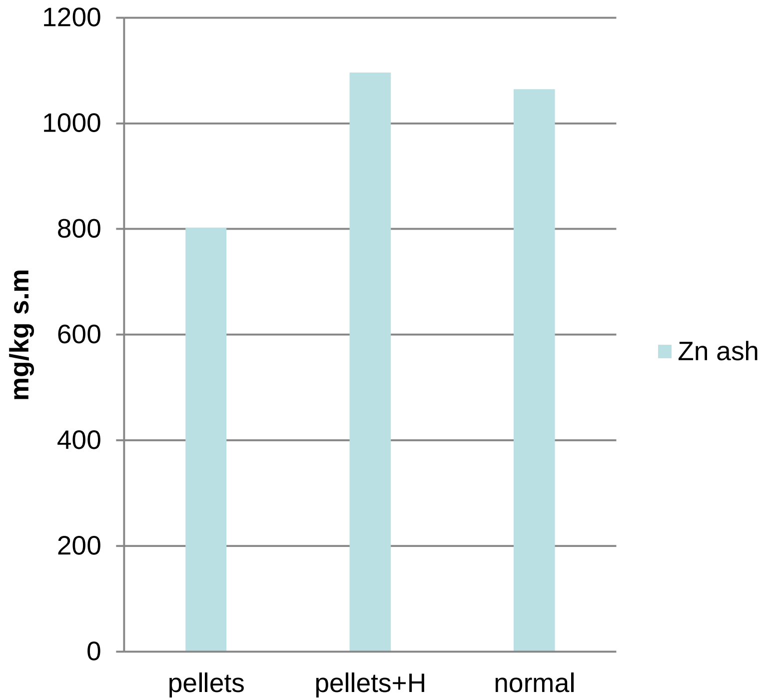
Pb/Zn





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Conlusions

- Pelletizing of input material were identified as areas for gasification process improvement which may have an impact on the quality of the produced gasification gas.
- Pelletizing is cheap and easy method to improve the gasification process
- Pelletizing with catalyst can by also profitable

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Thank you for your attention

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