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Current Trends of Increasing Efficiency of Equipment Operating on the Basis of Cogeneration with Regard to Energy Balance

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Abstract: The evaluation of the operating characteristics of the plant has a number of types depending on the parameters monitored. Part of the present paper is devoted to the creating of a model of a cogeneration unit with a full flue gas path allowing monitoring in relation to the production of pollutants. Priority is given to the contribution that the activities of the existing facilities if the integration of the new external device to an existing and functioning system for increased efficiency.

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1 Introduction

The primary solution being raised issues based on the need of mutual relations balanced way inputs to the transformation process and outputs of the process of transforming itself device both in terms of the economic, legislative and environmental indicators. Inputs represent different fuel structures. In the case of centralized heat supply, the potential of non-renewable energy sources, primarily gas and renewable energy sources, predominantly in the form of biomass, is currently being used. From the process point of view, the heat produced in the thermal installation is passed on to the hot water medium and, in the case of the central system, the heat medium passes first through the primary distribution to the heat transfer stations [1]. The application of district heating systems allows significant diversification of the fuel base. This input enables not only safe operation of the system from the standpoint of stability, but also from the point of view of impacts on the environment. Current technologies make the transformation process more efficient. These include combined heat and power generation. Depending on the parameters being monitored, there are a number of types of performance evaluation characteristics for a particular device. The presented paper deals with the issue of long-term analysis of fuel and the consequent impact of electricity and heat production efficiency. This analysis is based on monitoring deviations from the average fuel composition over a multiannual period. The next part of the paper is devoted to the analysis of flue gas properties. The flue gas analysis is performed on the basis of the realized measurement. Possibilities of utilization of waste energy potential for further energy production are evaluated. In the classification of waste energy, it is necessary to evaluate the rate of usability as a secondary potential. In many cases, the thermal potential is already dispersed and the low temperature difference does not allow its further technological resp. economic use. Cogeneration represents such facilities where the potential of so-called cogeneration waste heat is sufficient and usable by appropriate means [6].

2 Current trends in increasing cogeneration efficiency

Fossil fuels and the environmental consequences of their extensive use have shifted energy efficiency to the centre of economic and political attention at global level in recent years. Reducing energy consumption from the point of view of consumption is defined as one of the basic goals within the sustainable development of society. Nowadays, the heat supply requires some of the primary energy sources and the easiest way is to burn the right fuel, capture the heat energy, process it and then send it to the customer.

The efficiency of similar processes is high (80-100%), but exergy of the fuel is lost [4][5]. Based on the analysis presented in the previous chapter, it is possible to determine the quantitative parameters of the flue gas, which serve as input data for the solved model. The average flue gas flow after conversion to normal pressure conditions is 1180 $m^3 \cdot h^{-1}$. The average flue gas temperature entering the flue gas path is 440°C. Currently, a pipe exchanger is installed in the flue gas path. After passing the flue gas through the exchanger, their average temperature is about 160°C. The simulation solution evaluates the exchangers with a gradient of 440/80°C. The necessary theoretical flue gas temperature in the flue gas path should not fall below the temperature defined by the flue gas dew point.

Table 1 Measurement by Testo 350 S

power [%]	58	98,8
flue gas temperature [°C]	149,5	162,1
oxygen [%]	9,51	9,84
CO [ppm]	7	17
CO_2 [%]	6,51	6,32
NO [ppm]	138	122
NOx [ppm]	145	128
H_2 [ppm]	1	2
dew point[°C]	49,5	49
O_2 [%]	3	3
lambda	1,83	1,88
eta [%]	93,5	92,7

To verify the correctness of the theoretical calculations, repeated measurements were carried out at different CHP load. For the most accurate values, measurements were made at different time intervals, at different system loads and at different outdoor temperatures. Based on these measurements, it can be determined that the variance or deviation of these values has negligible values. The TESTO 350 S flue gas analyser was used for the measurement.

3 Solution design model

The design of the model represents an integration link with the existing system and its virtualization in the simulation environment in relation to the interaction with the external environment. The model consists of a cogeneration unit placed in a container, a system of exchangers and a chimney.

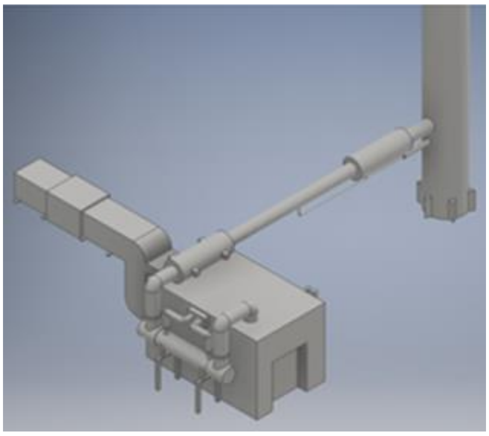

Figure 1 Model CHP 1

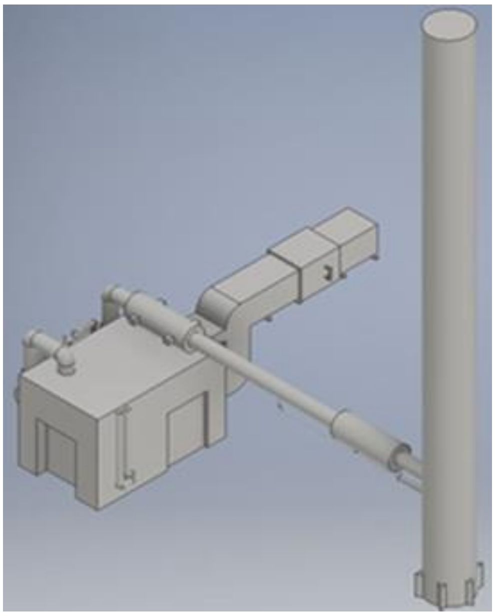

Figure 2 Model CHP 2

From the point of view of energy efficiency and the efficiency of the device itself, in the event of a shutdown or interruption of operation, the device goes into a standstill state, which results in a decrease in production, thus reducing efficiency. The capabilities of modern computer technology make it possible to avoid downtime and destructive ways of checking or measuring, integrating new devices into the system and then simulating elements. By using virtual laboratories that can simulate an identical process in the event of operation, it is possible to interfere with the operation in a non-destructive manner. These laboratories represent a computer-generated virtual environment in which a specific device model is created. In these cases, it is possible to monitor different input, output and operational quantities in the desired time increments. Various simulation tools are used to create a virtual lab, in which case the ANSYS 19 simulation tool was used [3]. Part of the submitted paper deals with the creation of a model of a cogeneration unit enabling the monitoring of flue gas routes in relation to the production of pollutants, not only to the equipment but also to the environment. The simulation allows changing input and operating conditions, installing various elements such as heat exchangers, coolers, heaters, turbochargers and other devices and tracking their impact on a particular improvement of an existing system. This makes it possible to increase the efficiency of the power plant [3].

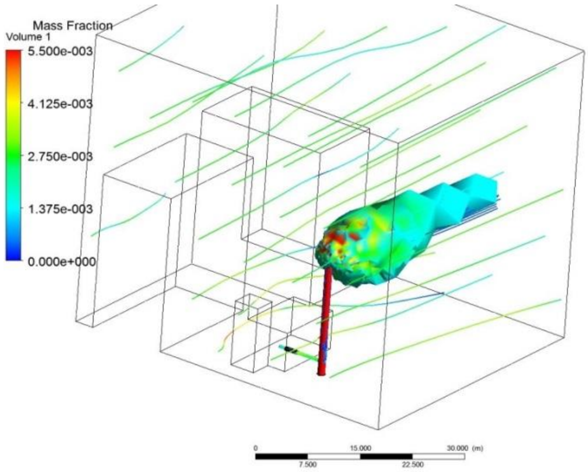

Figure 3 Solution design model - simulation results

Figure 3, 6 and 7 show a detailed view of the course and concentration of the flue gas in the flue gas route and then spread to the environment. The priority part of the contribution in the model creation was devoted to the verification of the possible installation of another heat exchanger in the flue gas path. The aim was to verify the correctness of the function, or non-destructive verification of the flue gas path or the consequences of disturbance of the further flue gas course. Analysis of input parameters was based on statistical values using external sources (SHMÚ, SPP, Ventusky) [7][8]. Different weather and season situations have been taken into account. Also extreme fluctuations in low temperatures, high temperatures and unusual weather conditions. Each of these conditions was simulated on the basis of calculations and analyses, and none of the simulations showed a flue gas disruption.

This result has led to the fact that it is possible to install an additional flue gas exchanger in the flue gas path, thus increasing the efficiency of the CHP in question [4][6]. The energy obtained by installing another low-energy heat exchanger can be used in several ways, such as pre-heating, intake air preheating and others. The inlet temperature to the proposed heat exchanger is approx. 160 °C. The final stage model is shown in Figure 3. Basically, it is a 3D model of a real object transformed and cut using a PC. The software makes it possible to create a very detailed network of points by which the user can pay more attention to certain points or areas [3]. A detailed view of the network of the model itself is shown in fig. 4. Based on the picture, it can be stated that there is a very detailed and detailed network in the vicinity of the chimney, the flue gas path and the exchanger itself for the most accurate result. Conversely, the surrounding area and neighbouring buildings work with less detailed network points.

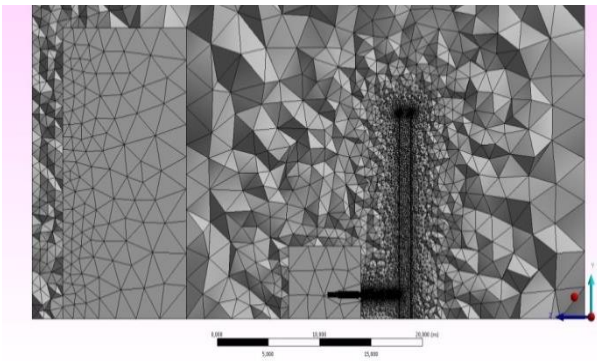

Figure 4 Detailed look on a networked model

Figure 5 View of boiler room with CHP

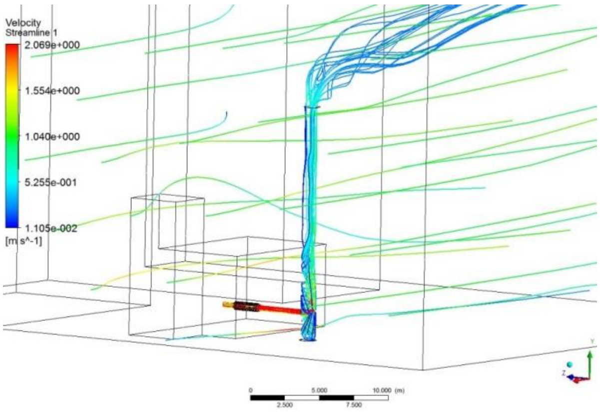

Figure 6 Solution design model - simulation results

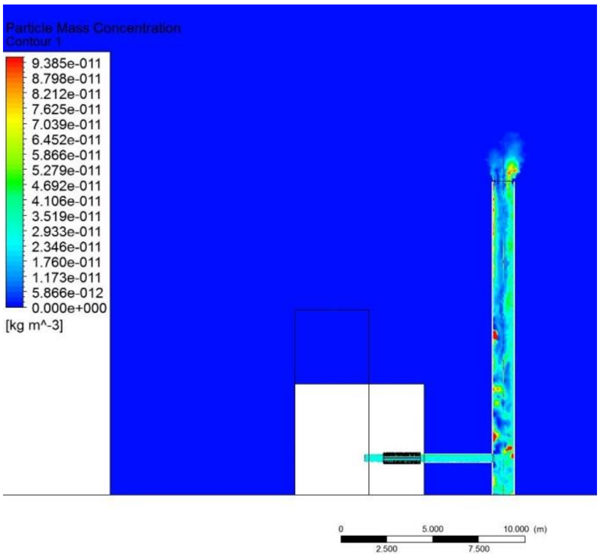

Figure 7 Solution design model - simulation results

Conclusions

Simulations and measurements show that it is possible to install an external device in the primary flue gas path for the selected system and increase the efficiency of the system. The simulations confirmed the flue gas path function and showed no signs of physical and chemical influences. The analyses were performed under different conditions and under different exterior aspects. The set of graphical and recalculation analyses pointed to the fact that even devices of such types can be improved. Waste energy can, in the case of cogeneration, cover a number of tasks such as pre-heating of the water, preheating of the intake air and the like. The measurements were supported by a correctly calibrated Testo 350S flue gas analyser. By installing such a device, the thermal efficiency in winter operation is increased by about 7.6% in the case of the CHP being monitored. The model demonstrated a detailed non-destructive analysis of the flue gas path and enabled on-line monitoring of instantaneous change settings.

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Thermal Properties of the Unusual Fast-growing Energy Crops

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Abstract : In this paper are discussed the results of experimental calorimetric measurements and organic elemental analysis of the two potencial energy crops, Chinese silvergrass (Miscanthus sinensis A.) and Elytrigia Repens. Experimental measurements have shown that the examined energy crops have a significant energy potential, which is even higher than, for example, brown coal.

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1 Introduction

Plants use CO_2 for their growth. It they absorb from the atmosphere and convert into organic compounds through photosynthesis - carbohydrates and polysaccharides. When burning biomass, the opposite process occurs and carbon dioxide is released into the atmosphere to reuse it in the photosynthesis process. It is a closed cycle in which the use of biomass for energy purposes, comparing with fossil fuels, has a neutral effect on the carbon dioxide content of the atmosphere.

The main reason of air pollution by greenhouse gases, and hence the ongoing climate changes are the burning of fossil fuels. The greenhouse gases are mainly carbon dioxide, methane, and to a lesser extent nitrous oxide. Atmospheric pollutants include sulfur dioxide SO_2 and nitrogen oxides NO_x. Energy sector is the biggest producer of anthropogenic CO_2 emissions. Therefore, the growth of energy sector should be based on the principles of sustainable development.

The most commonly used types of biomass are wood (dendromass) and wood residues (waste), straw of cereals and oilseeds, biogas, liquid biofuels and plants grown for use in the energy sector. While various solid fuels have a similar structure composition, the lower heating value varies. Steblins have more ash (8 %) than woody plants (1 %). The main combustion substances such as carbon (44 %) and hydrogen (6 %) are partially oxygenated because the plants contain 36 % chemically bound oxygen. This increases their lower heating value over fossil fuels by about 18 $MJ.kg^{-1}$ in absolute dry condition. The humidity level of the biomass has a great impact on the lower heating value. The optimal humidity level for combustion is about 15-20% for stalks and 20-30% for woody plants. A certain amount of water is necessary in the fuel because the absolutely dried organic dust is actually explosive. In combustion, biomass releases less harmful emissions into the air. It is this aspect that leads to the creation of fuels that contain only biomass [1].

2 The Fast-growing energy crops

Chinese silvergrass (Miscanthus sinensis Anderss.) comes from Southeast Asia. It is a perennial grass of high growth, the original botanical species of which reach 1.0-1.5 m height, with the fresh green colour. Some cultivated forms for decoration are much higher, they can grow to a height of 4 m. It is member of botanic family Poaceae, it is a plant of type C4, its production potential under favorable conditions is above 30 $t.ha^{-1}$, in conditions of irrigation up to 40 $t.ha^{-1}$ of dry matter. As a C4 plant, it effectively uses solar energy, water and nutrients. In our climatic conditions it is very resistant to pests and diseases. In the first year of cultivation, it is prone to freezing and in early stages of growth to the weed infestation [3] [4]. It is currently cultivated for both economic and ornamental purposes. The most well-known ornamental cultivars of this botanical species include: Adagio, Cabaret, Gracillimus, Silberfeder and Strictus [2][5].

Figure 1 Miscanthus sinensis Anderss

Elytrigia Repens is also from the family Poaceae. Elytrigia is a perennial plant with a cylindrical, hollow, sectioned, usually in the lower part of a stalk, wich growth up to 1.5 m hight. The leaves are lanceolate, bare on the back, slightly hairy on the other side. The flowers are arranged in double-row cobs, which are located on the tops of the stem, are simple with two husks - the upper and lower and three rods. The fruit is a grain grown together upper husk. Underground it is has long underground shoots. The plant blooms from June until July. The grass grows on grassy and sandy soils, alongside roads, pens, fields, gardens and vineyards.

Figure 2 Elytrigia repens

3 Experimental methods and the results of measurements

For the laboratory analyses purposes, samples of the Chinese silvergrass (M) and the Elytrigia Repens (E) were taken in four time periods at the end of each month. Samples A-M and A-E in September, 24 hours after harvest, samples B-M and B-E in October, C-M and C-E in November and samples D-M and D-E in February of the following year.

The dry matter and moisture content of the samples were determined using the Kern MLB 50-3N Electronic Moisture Analyzer from KERN & SOHN GmbH Belingen. The apparatus uses the most widely used method of thermogravimetry - halogen drying. It is equipped with a 1x400 W halogen emitter. The approximately weight of sample was 3 g weighed on analytical scales to 0.001 g. The instrument records the initial weight of the sample, then the sample is gradually dried by the halogen emitter and the built-in scales weighs the change in sample weight to constant loss. The residual weight after drying is the dry matter. Each sample was measured three times and averaged. The average dry matter and sample moisture values are shown in *Table 1*.

Table 1 Determination of humidity and dry matter of samples

	Humidity – H [%]	Dry matter – D [%]	R = H/D [x 100 %]
A-M	**56,962**	**43,038**	**132,328**
B-M	**36,065**	**63,935**	**56,445**
C-M	**30,512**	**69,488**	**43,910**
D-M	**25,166**	**74,834**	**33,654**
A-E	**47,922**	**52,078**	**91,962**
B-E	**14,049**	**85,951**	**16,351**
C-E	**10,235**	**89,765**	**11,402**
D-E	**7,212**	**94,788**	**7,772**

On the *Figure 3* is illustrated decrease in water amount, especially in the case of the Elytrigia Repens.

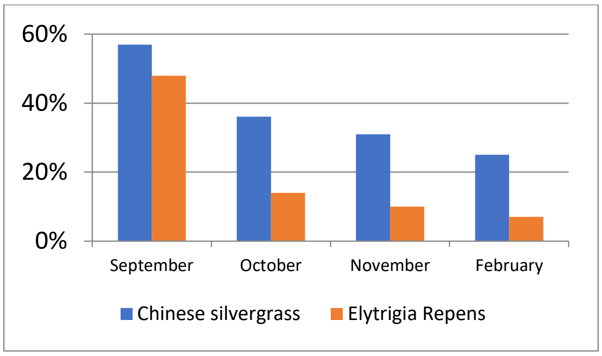

Figure 3 Water amount

The CHNS analyzer configuration operates according to the dynamic flash combustion of the sample. The sample is weighed in a tin capsule and introduced into the combustion reactor via the Thermo Scientific™ MAS™ 200R autosampler together with a proper amount of oxygen. After combustion, the resultant gases are carried by a helium flow to a layer filled with copper, then swept through a GC column that separates the combustion gases and is finally detected by a thermal conductivity detector (TCD) (*Figure 4*). For oxygen determination, the system operates in pyrolysis mode. Samples placed in silver containers are dropped into the pyrolysis chamber which is maintained at 1060 °C and contains nickel coated carbon. The oxygen in the sample combined with carbon forms CO (carbon monoxide) which is then chromatographically separated from other combustion products and finally detected by a thermal conductivity detector (*Figure 4*).

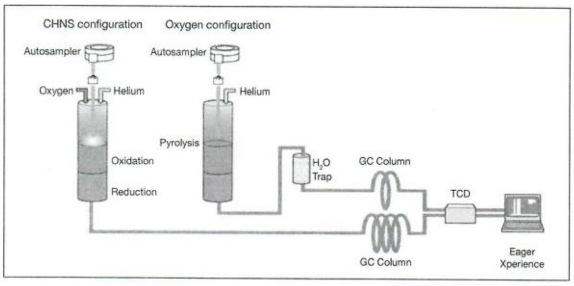

Figure 4 FLASH 2000 CHNS-O organic elemental analyzer - layout

The samples were homogenized using a rotor speed mill and a ball mill. BBOT (2,5-Bis(5-tert-butyl-benzoxazol-2-yl) thiophene was used as standard to calibrate the system in CHNS configuration, while benzois acid were used as standard in oxygen configuration. The average biogenic element values are shown in *Table 2*. On *Figure 5* is shown biogenic element content in dependents on the tracking period.

Table 2 Biogenic element content

	N [%]	C [%]	H [%]	S [%]	O [%]
A-M	**0,580**	**42,688**	**8,552**	**1,631**	**46,550**
B-M	**0,290**	**43,237**	**6,984**	**0,0**	**49,488**
C-M	**0,327**	**44,496**	**7,120**	**0,0**	**48,056**
D-M	**0,817**	**33,787**	**6,835**	**0,0**	**58,561**
A-E	**0,521**	**39,534**	**6,554**	**0,0**	**53,390**
B-E	**0,898**	**38,144**	**4,800**	**0,0**	**56,158**
C-E	**0,843**	**40,787**	**6,940**	**0,0**	**51,430**
D-E	**1,035**	**38,872**	**6,450**	**0,0**	**53,642**

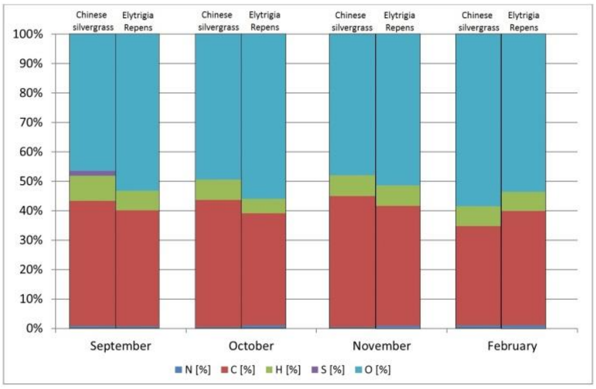

Figure 5 Biogenic element content

The higher heating value of the samples was determined calorimetrically on an IKA Calorimeter C200. The system measures the higher heating value in accordance with DIN51900 and ISO1928. The biomaterial sample was first compressed into a tablet weighing about 1 g. The sample was then placed in a calorimetric vessel along with the ignition cotton fiber attached to the ignition wire. The closed autoclave was filled with oxygen and placed in a water bath of 2 liters of distilled water equilibrated to the set temperature. After starting the measurement, the sample is burned and the calorimeter software automatically records the change in water temperature. After the measurement, the instrument evaluates the higher heating value and, after entering the hydrogen and the water contents of the sample, the lower heating value of the material. The measured higher heating values and lower heating value are in *Table 3*.

Table 3 Determination of higher heating value and lower heating value

	Average mass of sample [g]	Higher heating value Q_C [kJ.kg^{-1}]	Lower heating value Q_H [kJ.kg^{-1}]
A-M	**1,0089**	**19878**	**16546**
B-M	**1,0077**	**20168**	**17762**
C-M	**1,0210**	**20375**	**18076**
D-M	**1,0118**	**19578**	**17471**
A-E	**1,0290**	**19136**	**16535**
B-E	**1,0247**	**19445**	**18054**
C-E	**1,0480**	**19424**	**17659**
D-E	**1,0048**	**19653**	**18069**

On ***Figure 6*** and ***Figure 7*** is illustrated higher heating value and lower heating value of the Chinese silvergrass and the Elytrigia Repens for each period.

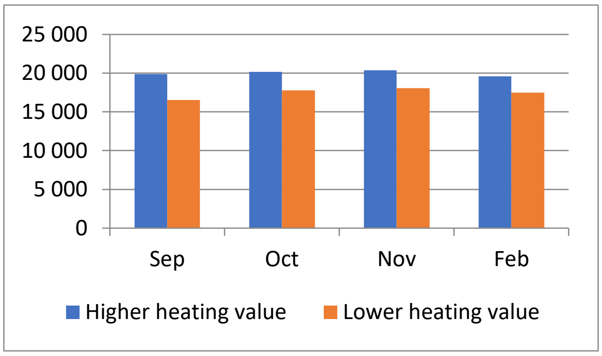

Figure 6 Graphical dependence of higher heating value and lower heating value of the Chinese silvergrass

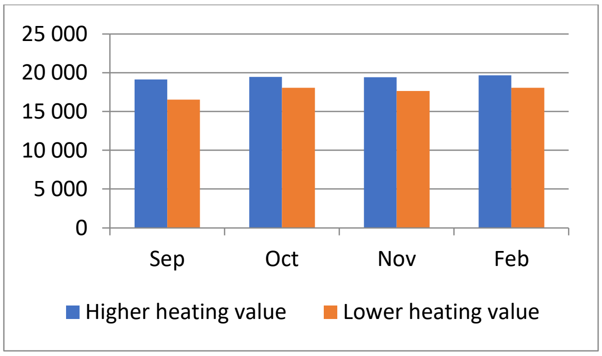

Figure 7 Graphical dependence of higher heating value and lower heating value of the Elytrigia Repens

4 Discussion

The results of the moisture and dry matter determination in the analyzed samples are show a rapid decrease in the water content of the plants after the end of the growing season. The graphical dependence (***Figure 3***) expresses a rapid decrease in water amount, especially in the case of the Elytrigia (sample E), despite the fact that the plants remained in the soil after the end of growth during the autumn and winter.

The elemental analysis of the biogenic elements of the Elytrigia samples shows a practically unchanged carbon and hydrogen amount during the tracking period. On the other hand, silvergrass (sample D-M) has a sharp decrease of the carbon amount in favor of oxygen amount at the end of the winter season, while the content of nitrogen and hydrogen has not changed (***Figure 5***). We believe that this may have caused the beginning of decomposition processes in the case of a silvergrass, savoir, oxidation reactions in saccharides of bound carbon.

The water amount significantly reduces the higher heating value of energy crops. As a result, the dry matter amount is reduced and and heat consumption to evaporate the water. This is also illustrated by the graphical dependence (***Figure 6*** and ***Figure 7***) of higher heating value and lower heating value of the individual samples examined from harvest time. While the lower heating value difference is negligible for the lower heating value, the higher heating value there is a significant difference (ΔQ_H ~ 1,0 – 1,5 MJ.kg^{-1}) between September crop samples (samples A-M and A-E) and samples of other periods, due to the high moisture amount of biomass.

On the basis of experimental results, it can be concluded that the examined energy crops have a significant energy potential, which is even higher than, for example, brown coal (Q_H ~ 15,0 MJ.kg^{-1}).

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Analysis of Wood Chips Combustion with Waste Oil Additives

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Abstract : The timeliness of low-emission combustion research is caused by need to predict and reduce pollutant emissions qualitatively. Due to incomplete combustion of wood, wood chips, pellets, huge amounts of carbon monoxide and particulate matter are produced. The main idea of the analysis was to compare the combustion of "pure" wood chips and wood chips with sunflower oil in the conditions of ordinary households. The results of the experiment confirmed that flame temperature increases with adding of waste sunflower oil to the wood chips. That results the growth of combustion efficiency and reduction of CO emissions to about 60 %.

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1 Introduction

In 2009 28 EU countries had started a sharp transition to renewable energy in the production of electricity and heat. Huge part of a new "green" energy in fact is about a return to wood combustion [1].

Most of the wood is harvested locally and there are serious concerns raises among the ecologists whether every tree cut and burned is really replaced by a new one.

Plants are able to receive solar energy and store it. During photosynthesis, carbon dioxide CO_2 and water are transformed into organic matter and retained in wood as energy. Then during combustion, this energy is released and used as heat. The CO_2 intake of wood growth is as great as the amount of CO_2 released when it is burned [2]. It is mean that wood is neutral in terms of CO_2 content and thus does not burden the environment comparing with fossil fuels.

Higher heating value is a parameter that defines the energy amount of wood. It depends on moisture content. The higher heating value of net dry matter ranges from 4,86 to 5,55 kWh/kg at 0% humidity, but is unattainable. At a normal humidity level of 20%, what can be achieved storing in air for about 1,5 - 2 years, the wood, depending on the type, achieves a calorific value of about 3,89 kWh/kg [3]. Beech wood, oak wood, hornbeam wood and acacia wood are the most used from among broadleaved species. And from among coniferous species are more often used pine-wood or spruce wood.

In many households, wet wood combustion occurs for a many reasons. Such king of wood has negative properties not only in terms of consumption but also operating parameters, respectively emissions [1].

2 Experimental methods and equipment

One of ways to increase combustion efficiency is to use additives. Used cooking sunflower oil has been selected as an additive owing of its availability, respectively necessity of its utilization.

The analyzed wood chip is a mixture of broadleaved and coniferous species of trees which commonly used for energy purposes in households and industry in the region. Chips are prepared at chippers Klocner with an output about 20 stacked cubic meters per hour. Used wood chip is a mixture of broadleaved (20%) and coniferous (80%) species of trees.

Based on the analysis of the consumption of sunflower oil and energy in households, to maintain a constant fuel / admixture ratio, it was established that such ratio should be 97% / 3%.

Before combustion samples of the wood chip was prepared to determine higher heating value. Higher heating value was determined in terms of technical standards STN ISO 1928 „Solid fuels. Determination of combustion heat by calorimetric method in pressure vessel and calculation of heating value“ [5]. The results of measurements are shown at Table 1.

Table 1 Determination of higher heating value of preparing fuel

Sample	Number of measurements	Average higher heating value, [MJ/kg]
Wood chips	5	19,7846
Wood chips with sunflower oil	5	21,3278

According to the measurement results of Higher heating value determination wood chip with sunflower oil (97/3) produce by 8% more heat compared to a "clean" wood chips.

In this experiment, a wood chip boiler with a heat output of 42 kW with a steep grate and an exhaust gas analyzer Testo 360s were used.

Fuel to the boiler was supplied automatically from the stock. 37 kg of wood chips were consumed during the combustion, including the cold start, warm start, high running and burn-out phases. The measurements were done over a phase of high running.

For each measurement for high running phase 28 kg of wood chips was consumed. The prepared wood chips were combust in about one hour of high running phase.

3 The results of measurements

3.1 Original biomass

Experimental measurements were performed in accordance with the standard STN EN 13 229 “Inset appliances including open fires fired by solid fuels. Requirements and test methods” [6].

Table 2 shows the exhaust gas measurement results of wood chip combustion without additive over a phase of high running.

Table 2 Exhaust gas measurement results, original wood chips

No. sample	Sample temperature, °C	CO, ppm	NO, ppm	CO_2, %	O_2, %
1	104,1	1628	96	7,9	14,3
2	110,3	1883	51	7,7	14,6
3	93,5	1479	84	8,9	13,4
4	92,2	962	117	9,7	12,5
5	92,6	540	138	10,9	11,7
6	92,7	520	135	11	11,4
7	91,6	1220	108	10,4	12
8	91,2	1334	106	10,5	11,9
9	91,3	923	136	10,8	11,6
10	91,4	462	132	11	11,5
11	92,7	634	138	11,4	11,1
12	94,3	391	163	12,4	10,4
13	96,2	312	172	12,7	10,1
14	96,9	636	133	10,8	11,7
15	85	1257	118	9,7	12,6
16	81,5	943	120	10,2	12,2
17	79	663	128	10,6	11,9
18	79,8	508	150	11,8	10,8
19	82,6	936	110	9,4	13,1
20	81,7	700	134	10,5	12
21	78,2	1582	113	9,4	12,9
22	82,8	1144	110	9,3	13
23	76,2	1275	112	9,5	12,8
24	79,8	858	122	10,1	12,3
25	85,4	382	133	10,9	11,7
26	83,1	353	162	12	10,6
27	78,5	579	127	10,3	12,2
28	82,6	917	124	10	12,4
29	77,6	747	132	10,1	12,3
30	77,3	636	124	10,4	12,1
31	81,8	712	124	10,2	12,4
32	76,9	653	124	10,5	12,1
33	79,9	250	151	12,3	10,5
34	79,9	694	124	10,1	12,3
35	79,6	1305	98	8,9	13,3
36	80,2	528	139	10,6	11,9
37	80,2	420	133	10,4	12,1
38	81,2	496	127	10,2	12,3
39	79,9	475	137	10,9	11,4
40	80,2	279	141	11,1	11,5
41	78,1	1583	88	8,1	14,1
42	78	1646	90	8,3	13,9
43	77,9	1247	102	8,9	13,5
44	78,9	686	116	9,6	12,8
45	78,3	770	110	9,3	13,1
46	79,3	668	119	10,1	12,4
47	79,4	602	106	9,3	13,2
48	79,8	536	119	10	12,5
49	79,7	679	122	9,7	12,7
50	79,8	1009	106	9,1	13,2
51	79,1	993	99	8,6	13,8
51	79	1020	98	8,8	13,6
53	79,3	640	126	10,1	12,1
54	78,8	793	110	8,9	13,4
55	79,2	830	95	8,9	13,6
56	79	957	104	8,9	13,5
57	79,4	623	107	9	13,3
58	79	455	107	8,9	13,4
59	79,5	739	106	9,1	13,2

60	79,5	433	129	10,3	12,1
61	80,9	628	112	9,4	13
62	80,7	1110	102	8,5	13,8

3.2 Oil-biomass mixtures

The wood chip was treated with sunflower oil, which was soaked into the mass. Prepared fuel was burned as well as in the first case. Table 3 shows the exhaust gas measurement results of wood chip combustion with the sunflower oil.

Table 3 Exhaust gas measurement results, oil-biomass mixtures

No. sample	**Sample temperature, °C**	**CO ppm**	**NO ppm**	**CO_2 %**	**O_2 %**
1	59,8	1336	32	5,7	16,3
2	60,2	1154	29	6,2	15,7
3	61,8	837	84	7,6	14,4
4	62,8	893	74	7,4	14,7
5	63,8	882	65	6,8	15,3
6	65,6	1272	142	10,1	12,3
7	67,3	614	129	9,3	12,9
8	68,6	643	98	8,3	13,9
9	69,7	881	86	8,5	13,7
10	71,8	594	128	9,9	12,3
11	71,4	357	147	11,1	11,2
12	70,6	433	150	11,1	11
13	70	161	180	12,9	9,7
14	71,3	221	176	12,5	10,2
15	71	395	141	10,6	11,7
16	72,8	573	131	10	12
17	72,5	481	135	10,4	11,9
18	73,2	236	162	11,8	10,6
19	74,3	188	195	14,9	7,8
20	73,9	137	194	14,9	7,6
21	76,7	167	197	14,9	7,7
22	77,4	184	198	14,9	7,4
23	76	265	166	12,8	9,6
24	80,7	102	187	14,1	8,3
25	78,1	106	198	14,7	7,8
26	78,8	145	183	14	8,5
27	82,6	118	210	16,5	6,3
28	83,6	104	191	15,5	7,1
29	83,6	151	164	12,7	9,8
30	83,3	360	149	11,9	10,3
31	83,6	224	163	12,5	9,9
32	84,7	112	176	13,6	8,9
33	85,6	95	191	13,9	8,4
34	85,6	106	187	14	8,5
35	86	93	177	13,7	8,8
36	84,3	292	138	10,8	11,5
37	85,1	147	162	12,6	9,8
38	85,2	99	158	12,6	9,7
39	85,8	85	170	13,5	9
40	86,5	102	194	15,3	7,4
41	86,6	88	178	14,5	8,1
42	85,7	209	152	11,6	10,8
43	84,3	332	144	11	11,3
44	84,6	236	148	11,1	11,1
45	85,3	172	160	12	10,4
46	86,7	76	190	14,1	8,5
47	87,6	91	206	15,8	6,9
48	86,8	105	167	13,1	9,5
49	85,7	266	130	10,7	11,6
50	85,9	156	141	11,2	10,9
51	86,1	120	157	12,4	9,9
51	85,8	199	145	11,1	11,2
53	86,9	104	181	14,1	8,5
54	87,4	69	187	14,5	7,8
55	86,4	91	141	11,7	10,6
56	86,2	127	148	11,3	11
57	86,7	72	170	12,9	9,6
58	86,9	87	167	12,8	9,6
59	87,5	86	185	14,6	7,7
60	87,6	88	180	14,1	8,4
61	87,1	84	152	12,1	10,6
62	98,4	71	168	12,2	10

4 Results and discussion

Comparing the measurement results of the combustion of original wood chips and wood chips with the sunflower oil, a significant increase in the flame temperature in the combustion chamber was observed (Figure 1).

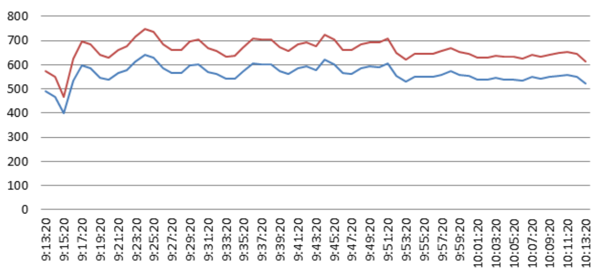

Figure 1 The temperature of the fire in the combustion chamber

Such an increase caused by the fact that when the oil is added to the biomass, the calorific value of the mixture increased by 8% what leads to the increasing of the flame temperature in the boiler.

Subsequently, the production of carbon monoxide (CO) and nitric oxide (NO) in this two cases were compared. According to the Figure 2 and Figure 3, adding sunflower oil to chip leads to the CO emissions reduction by almost 60%.

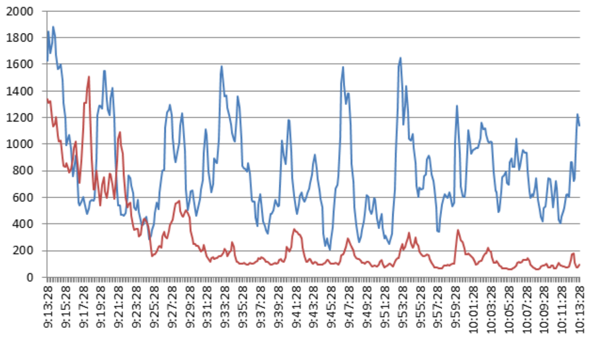

Figure 2 CO amount in the exhaust gas, ppm

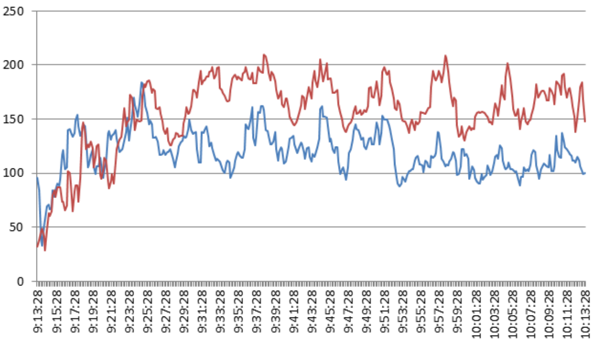

Figure 3 NO amount in the exhaust gas, ppm

According to the O_2 concentration, which reduced by 18% (Figure 4), is obvious, that combustion of the fuel mixture is more complete comparing with original wood chips combustion.

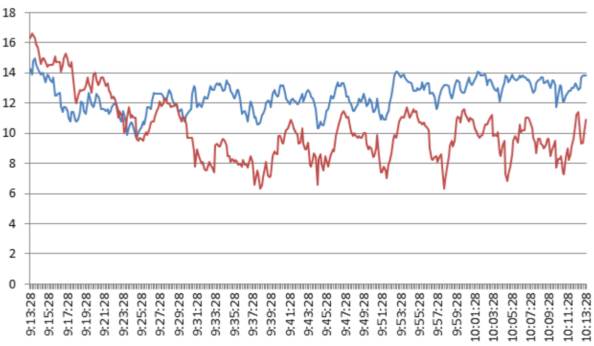

Figure 4 Oxygen concentration, %

NO concentration increased by 30%. The reason for concentration increasing is the temperature growth according to the Arrhenius thermal NO_x production formulation.

5 Conclusions

The main idea of the analysis was to compare the combustion of original wood chips and mix of wood chips with sunflower oil. During the analysis, the ratio of wood chip and sunflower oil was selected as 97% / 3%.

Based on the analysis of the combustion results, the next following can be determined:

1) Adding a small amount of oil to the wood chip mixture results a significant increase in the fuel mixture calorific value. Adding 3% of the oil increase calorific value by approx. 8%.

2) The efficiency of the combustion process can be increased by adding waste additives, like the sunflower oil in the wood chip mixture.

When the sunflower oil was added to the wood chips, the CO emission reduced by about 60% (the CO content was approx. 150-350 ppm). The NO concentration is increased by 30%. In the shown combustion conditions, the NOx content was around 160-180 ppm with a short (less than 1 min) exceedance of 140-210 ppm levels.

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Case Study of Smart-based Cooling System Application

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Abstract : Cooling buildings is now as important as heating. It helps to maintain appropriate and healthy conditions for work and life. There are several cooling systems and each is suitable for other conditions. Smart control systems are also an important part of the system, which increases the optimatization and efficiency of technological equipment, thus also cooling devices.

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1 Introduction

In the early 1980s, the phrase smart building was created. Defining the notion of smart building is not entirely unambiguous but can generally be defined as a building that provides a quality indoor environment with minimal resource consumption and minimal environmental impact. To be quality-conscious, the building's internal environment must meet 3 basic requirements: health, comfort and safety. It follows from the definition that for an intelligent building not necessarily to contain a complex control system and electronics, so we distinguish the intelligence of the building as active, passive and latent [1]. An intelligent building with a high-quality indoor environment with minimal energy requirements and environmental impact can only be created by combining active, passive and latent intelligence components. Elements of passive and latent intelligence (materials used, building orientation, layout, etc.) affect the building's energy requirements and the environment. Therefore, an inappropriately designed building with excellent technical facilities and control will exhibit worse characteristics than an optimally designed building with simple technical equipment and control system. Smart systems in smart buildings can be applied to any electronic device. Smart systems are most often used to:

- heating/cooling controls
- energy monitoring
- control of blinds
- smoke detectors, motion detectors, etc.
- control cameras, speakers, etc.
- lighting

The most important task in buildings is to ensure the heating/cooling of building. An intelligent building ensures indoor thermal comfort and not only heating, but also building cooling is an important way to maintain comfort. There are currently several cooling options and it is important to select the best cooling option for a building. Cooling can be provided by air conditioning, ceiling cooling or floor convectors.

2 Internal thermal comfort

It is not possible to set thermal comfort the same for every person, because all people are different, and everyone perceives thermal comfort differently. Several factors such as season, weather clothing and human activity, affect the thermal comfort. Achieved thermal comfort means that person in the room does not overheat but does not feel the cool in the room. The human body does not have the same temperature throughout its surface, so proper room temperature balance is needed. Thermal comfort means that temperature ratios are achieved, where the person does not feel overheat or cool – feels comfortable [2]. Thermal balance is needed to ensure thermal comfort. It is a state where the amount of heat a person produces is scattered around [3]. Six main factors affect thermal comfort:

- ambient air temperature
- radiation temperature
- air humidity

- air velocity
- value of metabolism
- clothes

In addition to these major factors, others such as acclimatization, figure of man, subcutaneous fat, sex, age, etc., may be considered. These factors indicate that thermal comfort is a very subjective state and thermal comfort can only be determined for a person. Two seven-point scales are most commonly used to determine thermal comfort:

1) Bedford scale
2) ASHRAE scale

The Bedford scale is focused on the feeling of thermal comfort and the ASHRAE scale describes the assessment of human satisfaction [4]. The scales are compared in Tab. 1.

Table 1 Bedford and ASHRAE scale

Bedford	Much too cool	Too cool	Comfortable cool	Comfortable	Comfortable warm	Too warm	Much too warm
	-3	-2	-1	0	1	2	3
ASHRAE	Cold	Cool	Slightly cool	Neutral	Slightly warm	Warm	Hot

Smart technology also helps to create warmth in the room. Smart systems monitor and control temperature, air humidity and airflow speed and can maintain and, as needed, change those parameters, that depend on thermal comfort. Smart systems are easy to use and can adapt to changing conditions. These options contribute to faster achievement and a more sustainable state of thermal comfort.

3 Experimental evaluation of smart technology application

The bulding consists of research laboratories, classes and offices. The building can be considered as one complex large laboratory. The laboratory is a multivalent system equipped with a condensing boiler and equipment that extracts heat from renewable energy sources photovoltaic panels, solar panel, bivalent air-water heat pump, recovery unit and wood chip boiler. As a building management system, the DESIGO system from Siemens was selectecd as part of the VUKONZE project. This system allows us to control all heating devices, pumps, valves and solar collectors installed on the flat collector swivel system design. Individual devices can be controlled manualy or left to control the system automatically. The system also records temperature, humidity and pressure thanks to a number of sensors. The historical data processing module provides evaluation and analysis of historical data as well as current data. An important function of the buildingmanagement system is the automatic reporting of alarms in tne event of failures that may arise in process equipment or in the automation system itself. The system allows us to create time programs that take care of device management. Turning on/off heating or cooling according to the time is an effective way of managing, that helps to save energy and prolongs the life of the technology. During vacations or longer time when the building is empty, the system can be completely shut down and automatically restarted before entering the building.

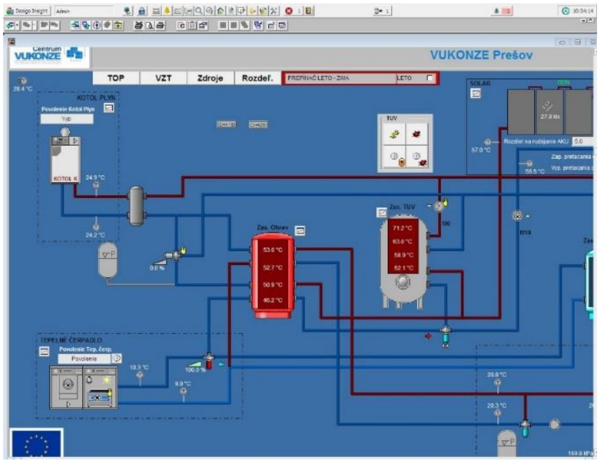

Figure 1 DESIGO program

The study focuses on applying a cooling system to a renewable energy laboratory. In the laboratory, there are two heat water tanks (800 l and 950 l), 5 computers and 3 people as the heat source. A reversible heat pump is used to produce cold, and produced cold accumulates in a tank (800 l), which is also located in the laboratory. Figure 2. shows a reversible heat pump.

Figure 2 Reversible heat pump

Laboratory cooling is provided by floor convectors located under the windows. In the laboratory, floor convectors are the best choice for cooling, as there are plenty of equipment, wiring and with large windows in the laboratory. They do not require a lot of space and thanks to the placement under the windows, the cool air flowing from the convectors is mixed with warm air, which heats the sunlight. The convectors in the laboratory are shown in Figure 3. Convectors automatically turn on according to the set shedule. They cool the laboratory to the required temperature they maintain during the day. For better control it is possible to set the convectors to the reyuired power or the system can independently control the power and change it as needed.

Figure 3 Floor convectors

In Figures 4. thermal images of floor convectors operating under different conditions are shown. Images 1-3., the thermo images of convectors in which water flows at 15°C, but operate at different power levels. The convectors in thermal image 1 operate at 33% of total power, image 2 at 66% of total power and image 3 at 100% of total power. In Images 4 and 5, 12°C water was injected into the convectors. The power of the convectors was 66% in image 4 and 100% in image 5. In image 6, water with a temperature of 10°C was in the convectors and convectors worked at 100% of total power. At 15°C water in convectors, the air temperature exiting the convectors did not reach below 20°C in either case. At 33% of the convector output, the lowest outgoing temperature 21,2°C. At 66% and 100% of total power, the exiting air temperature was lower about 1°C, but the difference between these outputs was minimal. The temperature was at 66% of total power 20,3°C and 20,1°C at 100% of total power. If 12°C water passed through the convectors, cooling was more pronounced and at 66% and 100%, the cooled air temperature was around 19°C. In the case of 66% total power, this was 19,3°C and at 100% of total power 18,9°C. As in the first case at 15°C water and 66% and 100% of total power, the temperature change is small and convector power above 66% no longer has a significant effect on temperature. In image 6, where 10°C water flows in the convectors, the temperature of the cooled air is cooled down to 16,5°C. It is a significant differencee from 12°C where the difference at 100% of total power is up to 2,4°C. Cooling is flexible and the desired temperature is always chosen by the user. At a water temperature of 10°C, the water in the tank must be cooled down to about 7°C, so the heat pump has to work for a longer time to cool the water , so it has a higher electricity consumption. At higher water temperatures, e.g. 12°C or 15°C, the punp would run in shortter cycles and thus lower electricity consumption. According to the weather, it is therefore possible to control the value of cooling and to approach as close as possible to the state of internal thermal comfort.

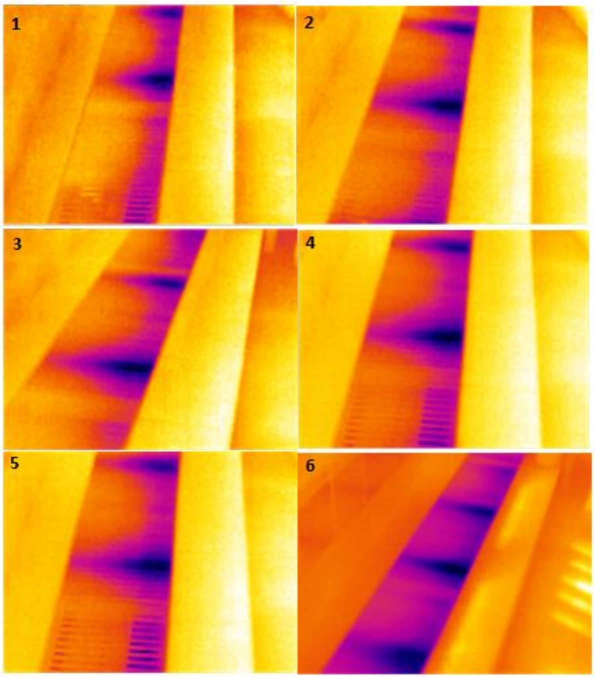

Figure 4 Floor convectors – thermal images under different conditions

Convectors are spun and cold air is blown up around in the windows. Cold and warm air is stirred and the required laboratory temperature is reached. On thermal image it is possible to see on the floor the area where sunlight falls between the blinds. Much of the heat from these rays accululates in the blinds and the heat remains in the room. The location of the convectors under the windows is therefore very convenient and by blowing cold air into the blinds and windows we cool the hottest places in the room.

After entering the required temperature for the laboratory, the control system turns on the heat pump that produces the cold that accumulates in the tank. The circulating pump blows cold water into the floor convectors. The cool air mixes with the warm air rising around the windows and cools the laboratory. Thanks to the temperature sensors, the control system regulates the performance of the three-way mixing valve and the amount of cold water circulating in the system, which keeps the room temperature constant without significant fluctuations.

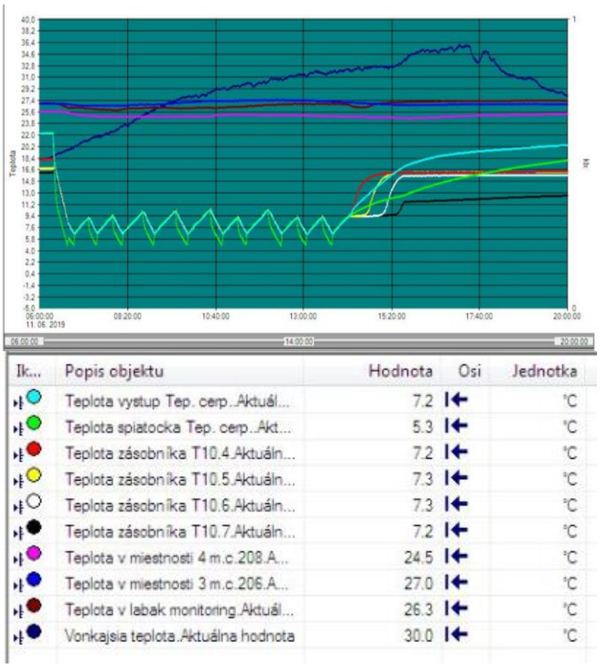

Figure 5 Temperatures

The figure 5 shows the monitores temperatures of the heat pump inlet and return, the temperatures in the different cold water storage levels, the room temperatures, the laboratory temperature and the outside temperature. The control system has a set schedule to activate a heat pump every morning before people arrive to work, which starts to cool the water in the tank. The pump cools the incoming water to 4,8°C and then shuts off, then if the water in the system rises more than 9°C the pump is switched on again and the circulating water is cooled to the desired temperature. The heat pump cyclically cools the water until the end of the set schedule until 14:00. The heat pump will perform 10 cycles in one day and will not allow the water temperature to rise above 10°C. The water in the cold cold water tank during the day when the heat pump is operating reaches from 7°C to 10°C. When the water has cooled down, the water temperature in the tank gradually increases but does not exceed the desired room temperature. From the graph, it can be seen that when the water has cooled down, the water temperature at the top of the tank begins to rise and the water temperature gradually increases from top to bottom. The air temperature in the laboratory is maintained at the desired value during the day and the control system does not allow for bigger variations.

4 Conclusions

Smart technologies are increasingly part of new but also older buildings, where they simplify and automate the management of technical systems. Increase comfort, thermal comfort and reduce the cost of operating technology equipment. The study focuses on applying a smart-based cooling system. The smart system used controls and optimizes the entire cooling process and adapts to changing conditions. Floor convectors are one of the cooling options and are the most suitable solution in our laboratory.

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