PRODUCTION OF DOMESTIC HOT WATER IN A SUSTAINABLE WAY BY USING A COMBINED SOLAR - TLUD SYSTEM

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ABSTRACT

Fossil fuels are an exhaustible resource on Earth, and their use pollutes the environment massively. The population of the planet has grown a lot, and for the production of domestic hot water, to ensure a decent standard of living, it is necessary to consume increasing quantities of fossil fuels. The very high level of greenhouse gases released into the atmosphere leads to an increase in average of annual temperature and climate change. Climate change is manifested by the melting of the ice caps, which has the consequence of increasing the level of the seas and oceans. Climate change also leads to extreme weather events such as floods, heat waves or the appearance of arid areas.

Risks to human health have increased through deaths caused by heat or by changing the way some diseases are spread. Risks also exist for flora and wildlife due to rapid climate change.Many species of animals migrate, and other species of animals and plants are likely to disappear.

Climate change also leads to costs for society and the economy due to damage to property and infrastructure, which have been more than 90 billion euros in the last 30 years, just because of the floods.

In order to reduce the effects of environmental pollution, ecological energy production solutions need to be expanded.

The article presents the creation of an experimental stand of a Solar - TLUD stove combined system for the production of domestic hot water in a sustainable way. TLUD is the acronym for "Top-Lit UpDraft". The advantage of the combined heat system is that it can provide thermal energy both during the day and at night. If the atmospheric conditions are unfavorable (clouds, fog) and do not allow the water to be heated only with the solar panel, TLUD gas stove can be used to supplement the energy. The TLUD stove has low Carbon Monoxide (CO) and Particulate Matter (PM) emissions. After gasification, about 10% of the carbon contained in the biomass is thermally stabilized and can be used as a "biochar" in agriculture or it can be burnt completely, resulting in very little ash.

The stand is composed of a solar thermal panel, a TLUD stove, a boiler for hot water storage and an automation system with circulation pumps and temperature sensors. To record the experimental results, a data acquisition board was used, with which data were recorded from a series of temperature and flow transducers located in the installation.

Experimental results include diagrams for temperature variation, available energy and heat accumulated in the boiler.

Keywords: *combined thermal system, TLUD stove, domestic hot water, solar thermal panel, data aquisition system*

INTRODUCTION

For reduction of the very high level of greenhouse gases released into the atmosphere which leads to an increase in average of annual temperature and climate change, the production of energy from renewable sources must be expanded [1], [2].

Putting into use the systems for production of domestic hot water requires testing of constructive solutions adopted, in order to be able to optimize them in terms of efficiency. Thus, for conducting research in the field of combined thermal systems, it was necessary to create an experimental stand equipped with sensors and a system for recording numerical data [3].

The article presents the creation of an experimental stand of a Solar - TLUD stove combined system for the production of domestic hot water in a sustainable way. TLUD is the acronym for "Top-Lit UpDraft". The advantage of the combined heat system is that it can provide thermal energy both during the day and at night. If the atmospheric conditions are unfavorable (clouds, fog) and do not allow the water to be heated only with the solar panel, TLUD gas stove can be used to supplement the energy. The TLUD stove has low Carbon Monoxide (CO) and Particulate Matter (PM) emissions [4], [5]. After gasification, about 10% of the carbon contained in the biomass is thermally stabilized and can be used as a "biochar" in agriculture or it can be burnt completely, resulting in very little ash.

The stand is composed of a solar thermal panel with 4 evacuated tubes, a TLUD stove designed for a power of 3 kW, a boiler for hot water storage and an automation system with circulation pumps and temperature sensors. To record the experimental results, a data acquisition board was used, with which data were recorded from a series of temperature and flow transducers located in the installation.

METHODOLOGY

The scheme of the installation, presented in figure 1, includes the equipments and hydraulic installation from the componence of the combined thermal system, as well as the sensors necessary for the controlled operation, as well as the computer system of data acquisition and recording of the evolution data of the thermal parameters of interest.

The functional scheme of the combined thermal system has as central element a boiler with dual coil (SER1 and SER2), equipped with the necessary elements for pressure control (safety valve SV and manometer M). The boiler facilitates the heating of domestic water from two renewable energy sources (solar thermal energy and thermal energy from plant biomass) and with electric energy, the boiler being equipped from construction and with electrical resistance.

Solar thermal energy is captured using a mini solar thermal panel (SC), whose characteristics are shown in Figure 2, equipped with a solar station [6]. The solar station provides the heat transfer from solar panel by circulation of the transfer fluid, using a circulation pump (P1), supervised by a safety valve (SV1) and a manometer (M1). Pump P1 sends the hot fluid into a coil (SER1) of the dual coil boiler (B) to transfer the captured solar heat.

The temperature is visually monitored with a temperature gauge (T) and the fluid flow is measured with a rotameter (R). The temperatures of the fluid at the exit of the solar thermal panel (SC) and, respectively, in the output area of the SER1 coil, are measured and taken through thermal sensors (TS1 and TS2).

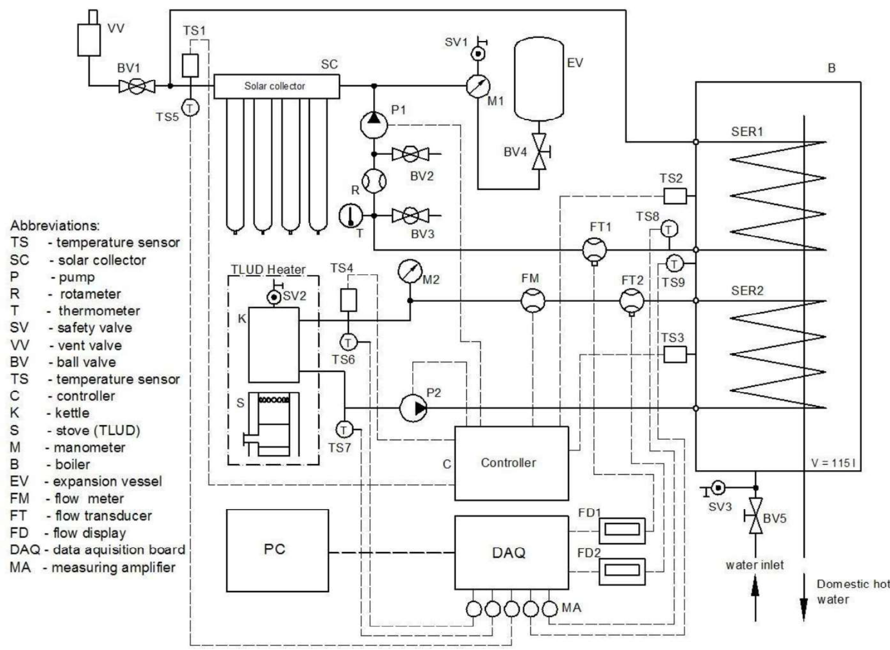

Figure 1. *Scheme of the combined thermal system*

The flow rate of the circulation pump P1 with PWM control is adjusted, via a controller, depending on the temperature difference between the sensors TS1 and TS2.

Features	
- Model	WT-S58
- Number of tubes:	4
- Gross absorber area	0.86 m^2
- Net absorber area	0.32 m^2
- Width	460 mm
- Height	157 mm
- Length	570 mm
- Weight	9 kg

Figure 2. *Features of solar thermal panel*

The thermal energy produced by a gasifier stove (S) (TLUD) - Figure 3, which burns and gasify some pellets from biomass [7], is taken over by a kettle (K) with water, which can operate under pressure assisted by a pressure safety valve (SV2). The temperature of the liquid in the kettle is measured by a thermal sensor (TS4). The captured heat is taken by the water conveyed by the circulation pump (P2), through pipe coil (SER2), the flow being measured with a flow meter (FM). Fluid temperatures at the outlet of the kettle and at the exit of the SER2 pipe coil, respectively, are measured by means of temperature sensors (TS4 and TS3). The controller of the combined system controls the flow rate of the pump P2 (figure 4) depending on the temperature difference between the temperature sensors TS3 and TS4.

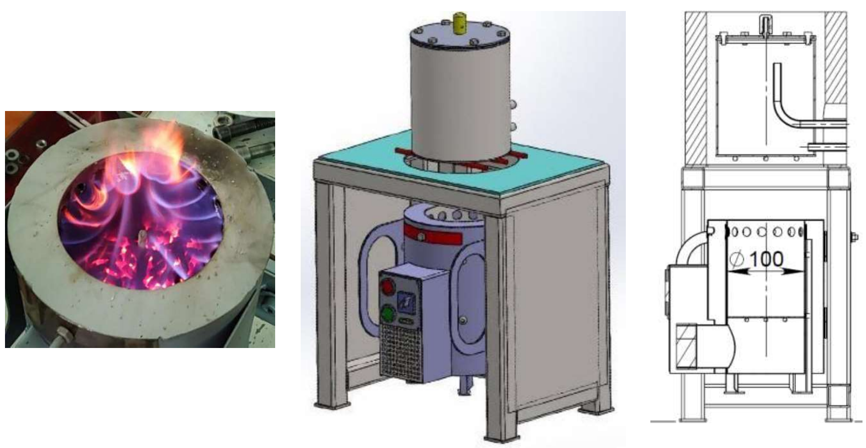

Figure 3. *Gasifier fire and the 3D CAD of the TLUD water heater*

The computer subsystem for the acquisition of experimental data

For the acquisition of the experimental data regarding the evolution of the parameters of interest, a data acquisition system has been created which is composed mainly of the following hardware components: data acquisition board, signal amplifiers for Pt 1000 temperature sensors with 4 ... 20 mA current output, elements for transforming current type values (I) into voltage type values (U), including numeric display for the parameters of interest (temperature and flow), as well as the original virtual instrument application, installed on a laptop computer, through which the recording and processing of experimental data describing the evolution of the parameters of interest is made (figure 5). To record the evolution of the temperature, 5 temperature sensors were used in addition to the 4 used by the temperature controller of the combined thermal system. The 5 points in which the evolution of temperature was recorded were: TS5 - temperature at the exit of the solar collector, TS6 - temperature at the exit of the serpentine SER2 from boiler, TS7 - temperature at the exit from the kettle heated by the TLUD stove, TS8 - temperature at the exit of the pipe coil SER1, from boiler and TS9 - water temperature in the boiler.

The flows through the 2 heat transfer coils in the boiler were measured with 2 low-cost YF-S201 type transducers (figure 6) with pulse output signal. The measuring range of the flowmeters is 1 ... 30 l / min, and the maximum working temperature is 80°C. The signal from the two flow transducers was processed by means of two digital indicators with frequency type input and analog output 0...10 V.

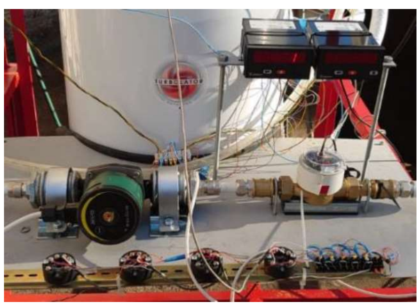

Figure 4. *Circulation pump and the measurement equipments*

Figure 5. *Laptop with data aquisition software, DAQ and power supply*

Figure 6. *Flow transducer YF-S201*

Theoretical considerations

The amount of solar heat (Q_s) for heating boiler water volume of 115 l is given by:

$$Q_S = m_w \cdot c_w \cdot \Delta t \qquad (1)$$

- m_w - mass of water in kg corresponding to a volume of 15 l(m_w= 115kg);
- c_w=specific heat of water ($c_w = 4{,}186 \cdot 10^3$ J/kg·°C);
- Δt =temperature difference in°C (Δt = 40°C).

$$Q_S = 115 \cdot 4186 \cdot 40 = 19{,}2556 \cdot 10^6 \text{J}$$

The amount of solar heat yield by the solar collector:

$$Q_S = S_{col} \cdot \eta_{col} \cdot G_{\beta med} \qquad (2)$$

- Scol- surface of the solar collector (Scol=0,86 m2);
- η_{col} –collector efficiency (η_{col} = 83 %);
- $G_{\text{®} med}$ -average global irradiation on collector; $G_{\text{®} med}$ = 12,6 MJ/m^2 per day

$$Q_S = 0.86 \cdot 0.83 \cdot 12{,}6 = 13{,}3 \text{ MJ}$$

Direct normal irradiation at location where the experimental installation was placed is in accordance with [8] de 3,5 kWh /m^{2}per day (figure 7). The solar collector with 4 evacuated tubes and heat absorbtion area of 0.86 m^2 can produce a daily energy of 3010 Wh.

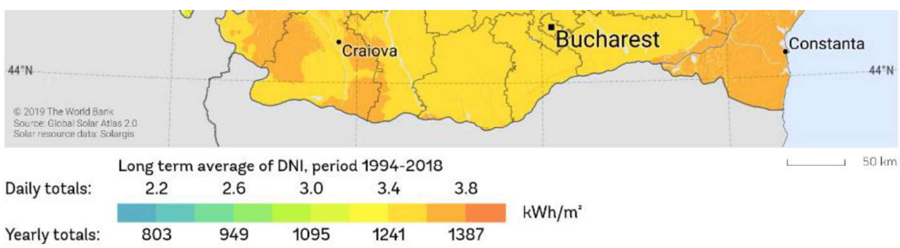

Figure 7. *Direct solar irradiation map*

It turns out that it still needs a heat input of 5.9556 MJ to raise the water temperature in the boiler to a Δt = 40°C. The difference in heat can be covered by the TLUD stove in a time interval which can be determined as follows:

$$t = \frac{Q_T}{P_{TLUD}} = \frac{5955600}{3000} = 1985\, s \quad \text{(33 min.)}$$

- P_{TLUD} – power of the TLUD stove (3 kW = 3000 J/s).

In the table 1 is shown the annual energy yield per square metre for different renewable energy sources [9]. The annual energy yield for solar thermal collectors is much higher than for other renewable energy sources.

Table 1

	Solar thermal	**Photovoltaics**	**Biomass / bioethanol**
Average annual yield	150 $kWh_{thermal}/ m^2$	59.5 $kWh_{electric}/ m^2$	3,5 $kWh_{thermal}/ m^2$

RESULTS

The main parameters, of interest, are the temperatures, which influence the thermal process, namely: the ambient temperature, the temperature of the water from the thermal kettle, the water temperature from the solar panel and the water temperature from the boiler.

Testing conditions

- filling the boiler with a volume of water Vb = 115 l;
- filling the kettle with a volume of water Vc = 8 l;
- enviroment temperature: $T_{env} = 8^0C$;
- atmospheric pressure: P_{atm} = 1,013 bar;
- feeding the TLUD stove with biomass pellets (0.5 kg);
- filling and venting the solar heat agent circuit and venting the heat agent circuit from the TLUD stove.

During the experiments, a series of numerical and graphic recordings were made using the data acquisition system. Figure 8 shows the panel with thermometers from the virtual instrument application made in the LabView environment.

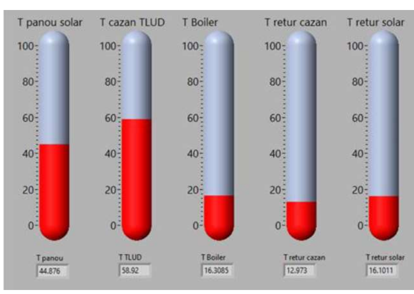

Figure 8. *Panel with temperature indicators*

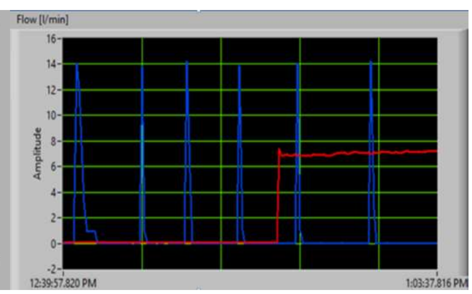

Figure 9. *Thermal agent flow in solar circuit (blue) and in the TLUD heater circuit (red)*

In figure 9 we can see, with blue plot, the starts of the pump in the solar circuit when touching ⊗T set at the controller of the installation. The recordings being made in a winter day and the water temperature from the boiler being still low, the solar collector with small surface cannot sustain the operating temperature for a long time.

In figure 10 is shown an interval of variation of the temperatures in the installation.

The plots of temperatures by the colors are: plot 0 red – temperature at the solar collector; plot 1 white – temperature from TLUD kettle; plot 2 green – temperature from boiler; plot 3 blue – temperature at inlet of the kettle; plot 4 yellow – temperature at inlet of solar collector.

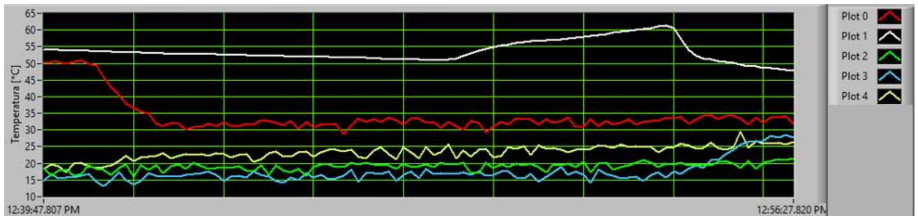

Figure 10. *Interval of variation of the temperatures in the installation*

CONCLUSION

The realized installation allows the recording of the parameters for the functional characterization of a combined solar thermal - TLUD system.

For a shorter duration of heating of the water in the boiler, to the desired temperature, the power of the heat sources (the biomass-based thermal generator and the solar thermal panel) must be increased.

Experimental testing of the thermal subsystem based on biomass, has highlighted its good functional behavior, from a conceptual point of view.

Restarting the TLUD stove after evacuating the ash and refueling it with pellets, it takes some time and it is necessary to increase the operating autonomy by increasing the enclosure of biomass loading.

By the experimental testing of the thermal subsystem based on a solar thermal panel, in tandem with the solar station, which includes the circulation pump, as well as the operating controller, the good functioning of the model was confirmed, as long as the solar radiation is available.

For a marketable system, it is necessary to properly dimension the powers for both thermal subsystems, depending on the size of the boiler, in order to ensure optimum duration for obtaining the domestic hot water.

The large-scale use of these production systems for domestic hot water from renewable resources can help reduce pollution.

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