Modeling and Analysis of µCHP System for Domestic Use

Angel Marinov[1], Vencislav Valchev[2], Georgi Nikolov[3]

Abstract – **Combine heat and power (CHP) is a well known technique that maximizes the utilization of primary fuel sources, by recovering losses and rejected energy. The modern technology allows instantaneous generation of heat and power to be scaled into so called micro CHP systems. These units are applicable to single or blocks of households. Most µCHP systems run on fuels with low CO2 emissions – mostly biomass and thus have a status of renewable energy generation. This paper presents a study of µCHP systems concentrating on their usefulness both on social and consumer level. The study provides environmental, economical and parametric analysis on the µCHP systems. A dedicated model on which the analysis is conducted is developed and presented in the paper.**

Keywords– **Biomass, Combined Heat and Power, Efficiency, Micro-generation, Renewable energy.**

I. Introduction

Domestic energy consumption takes more than 26% of the total energy consumption in the European Union. More than 60% of that power is used to generate space heating. Domestic heating can be either supplied by a centralized source (heating power plant, gas, electricity) or generated locally by various decentralized means (solar thermal, burning of fossil fuels or solid biomass). Both types of power generation have their advantages and disadvantages. [1]

Decentralized heating attracts users by: breaking their dependence from monopolized central energy structures; allowing them to choose and fine tune power generation based on their specific energy demand; provide economical benefits over years. Decentralized heating systems have also significant social advantages such as: reducing fuel poverty; allowing the use of fast growing solid biomass with low CO_2 emissions; increasing the power generation without the need of improving the distribution system.

Technological development has reduced the size of decentralized heating units, increased their efficiency and allowed the use of various fuels. It is only reasonable to improve and further develop them by introducing large scale generation techniques to the small scale decentralized units. One such solution is the development of micro systems for combined heat and power (µCHP). Thattype of systems utilize the simultaneous generation of heat and power, where heat is the main energy product and power is a byproduct. µCHP allows better fuel utilization, greater economical benefits to users as well generation based on low carbon solid biomass such as: pallets derived from wood and agricultural waste; energy crops. In this wayµCHP systems can be consider renewable energy generation, which allows the use of subsidies as well as better feed-in tariffs where grid injection is available.[3]

The paper presents a study on the use and efficiency of µCHP. A major point in the study is the usefulness of the system to the end consumer. As various parameters are involved, the study is conducted using a MATLAB – Simulink model.

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II. Modelling a Micro CHP System

A. Modelling parameters

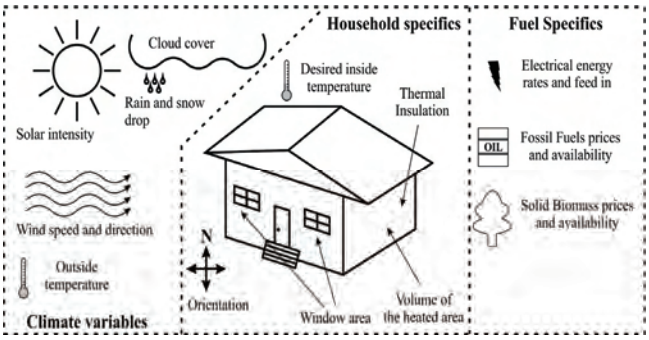

Fig. 1. Variables affecting heat energy generation

In order to evaluate the properties of a µCHP a correct determination of the required energy generation for a household and respectively its price is needed. This involves a wide range of parameters. Those parameters are depicted on figure 1. They can be briefly summarized into three groups, as follows:

Climate variables–this set of parameters involves all climate changes and properties specific to the region that can affect the thermal generation. Such as: solar intensity; cloud cover; rain and snow drop; wind speed and direction; outside temperature. Those parameters have major effect on the level at which the inside heat will be dissipated and lost.[2,4]

Household specifics– this set of parameters covers all variables and constants specific to the house construction and position. The major effect here is the volume that requires to be heated, the insulation that will prevent the thermal energy to “escape” and the required inside temperature.[2,4]

Fuel specifics–shows the availability and prices of the fuels specific to the area. Those parameters describe not only the properties of the fuel on which the system will run but also the rates and tariffs of the electrical energy, since they will be used as a basis when the system injects power. [2,4]

B. MATLAB – Simulink model

The study presented in the current paper, describing the usefulness and efficiency of the µCHP is determined by the a dedicated MATLAB Simulink model. The model structure and block diagram is presented on figure 2. The model has a basic and simple composition and only partly covers the above mentioned parameters.

It can be divided into several functional blocks:

• Simulation of the electrical consumption and system – describes the energy consumption of the household, based on a statistical evaluation. It shows the electrical energy needs in order to describe how they can be addressed by the µCHP system.

• House – presented by its volume, thermal insulation and window area.

• µCHP system – presented by a burner, organic rankine cycle block (as for this specific system composition), a thermostat, a generator and a convertor part. The µCHP is controlled using hysteresis which activates and deactivates the system based on the outside temperature and the desired indoor temperature. The rate of witch heat and power are

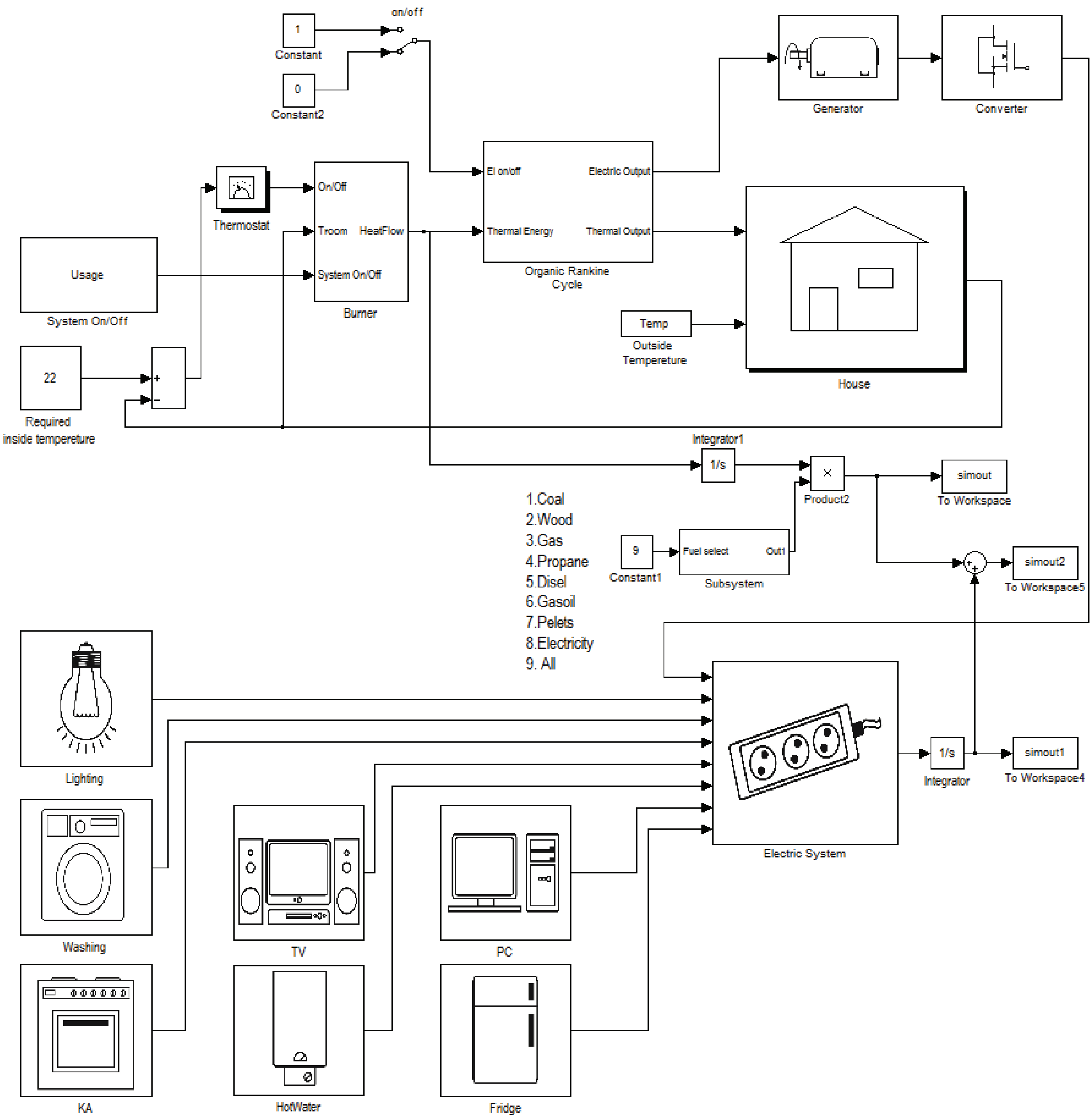

Fig. 2. Model of a µCHP for domestic use

generated is 80% heat, 20% power.

• Fuel section system – allows a broad range of fuels and their properties to be loaded in the model, so an optimal fuel for a given case can be selected.

The model was confirmed and verified by running it and comparing it with existing data on commercial conventional heating and µCHP systems.

III. Main Simulation Parameters

The simulation used to analyze the µCHP and the results presented in this paper are based on:

A house with the following parameters: area equal to $100m^2$; height 2.80m; window area $300m^2$;

The weather conditions that are used are for the area of the Technical University of Varna, where a weather station is operational and day to day data is available. Mean temperatures for each day of 2010 are used.

Fuel prices and energy values are provided by a local supplier. Fuel data used in the simulations is presented in Table I.

TABLE I
FUEL PRICES AND ENERGY VALUES

Fuel Type	Price	Energy Value[
Coal	75 EUR/t	3,72 kWh/kg
Wood	72,64 EUR/t	3,14 kWh/kg
Electricity	0,86 EUR/kWh	1,00 kWh
Nature gas	402 EUR/ 1000 nm3	9,01 kWh/m3
Butane	1050,8 EUR/t	12,80 kWh/kg
Diesel	1028,7 EUR/t	11,63 kWh/kg
Gasoil	950,15 EUR/t	10,98 kWh/kg
Pellets	190,02 EUR/t	4,88 kWh/kg

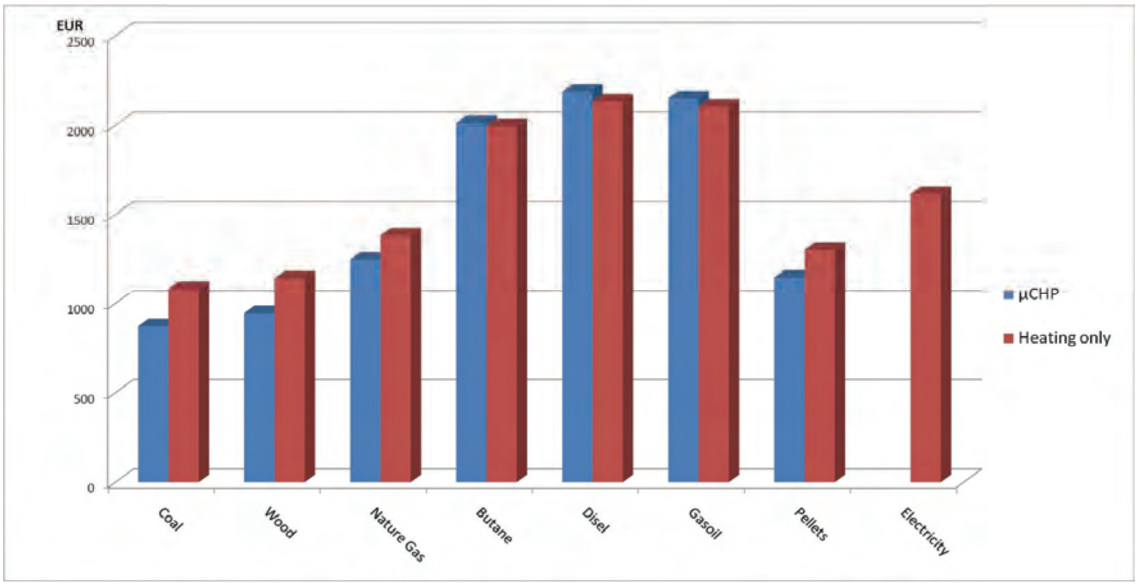

Fig. 3. Comparison between energy expenses of heating only system and µCHP

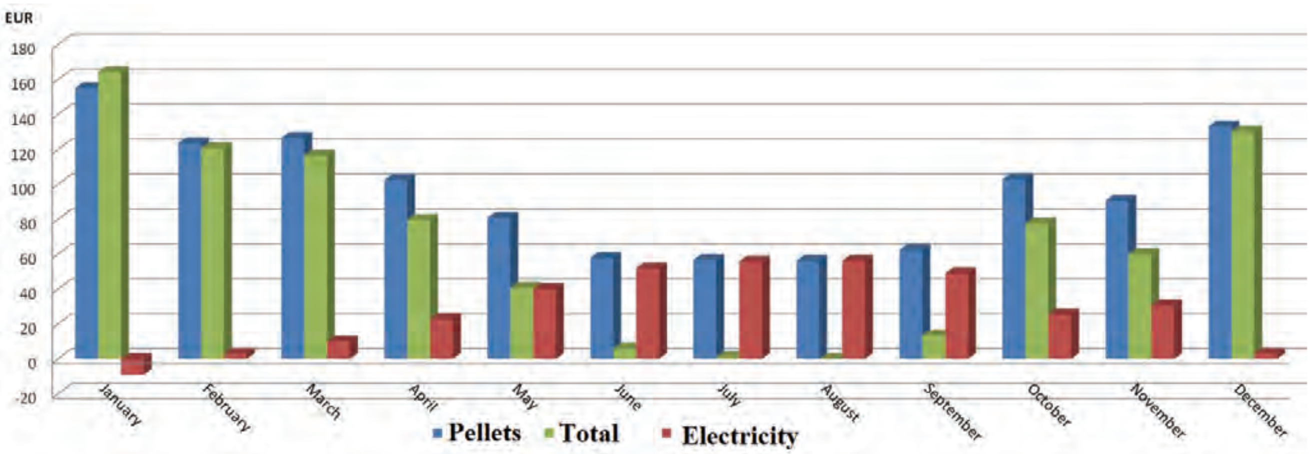

Fig. 4. Energy expenses of µCHP running on pellets

IV. Simulation Results

General simulation results are present at figures 3, 4, 5, 6 and 7

The simulation results show that the µCHP system has better economical efficiency then conventional heating systems – especially with the more inexpensive fuel types – coal, wood, and pellets (fig. 3). The total expenses when using µCHP show 13 to 20% less energy expenses compared to conventional heating systems (fig.5) and 28 to 46% less energy expenses compared to heating using electrical energy (fig. 6).

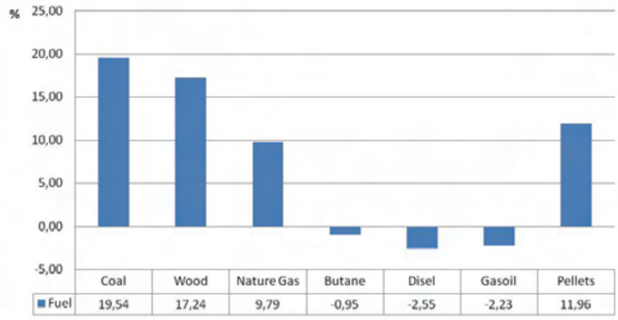

Fig. 5. Economical efficiency of µCHP systems relative conventional heating systems

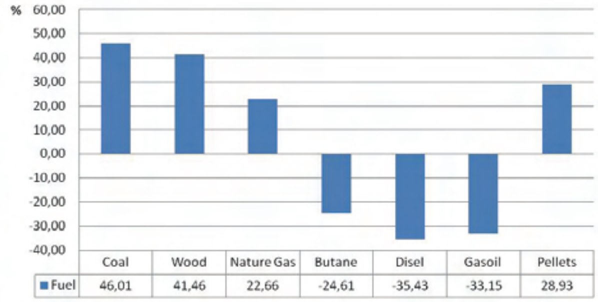

Fig. 6. Economical efficiency of µCHP systems relative to electrical energy

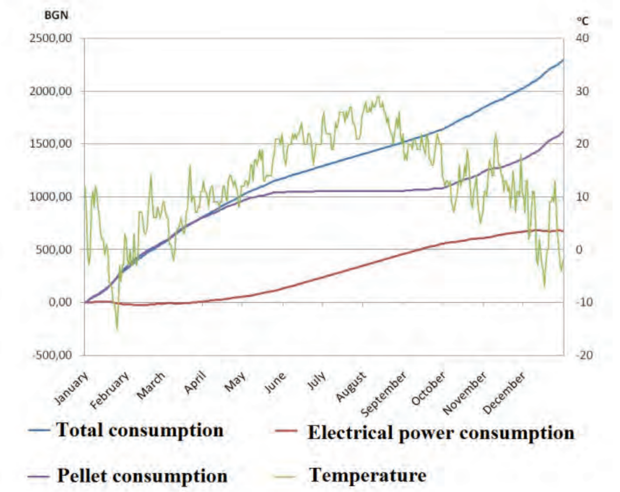

Fig. 7. Electrical and fuel energy expenses relative to the outside temperature

Wood and coal show the best financial values but also have some disadvantages, considering that both types cannot be described as renewable energy fuel. Pellets on the other hand can be produced form agricultural and wood waste, have less CO_2 emissions and produce less disposable waste (such as ash and sludge). That's why pallets where chosen to further the simulation.

Spanning the simulation for 1 year period shows that using µCHPcan, during the "cold" months eliminate or majorly reduce the electrical energy bill by generating electricity and consuming it on spot or feeding it in the electrical grid (fig. 4 and fig, 7).

V. Conclusions

Using the values and graphs generated by the model one can determine the general efficiency for a µCHP as well as the parameters that affect it. The presented results show that in this given case the reduced expenses, compared to a conventional heating system are not enough to cover the higher investment on a µCHP system – only 20% better performance.

It is clear however that the economical efficiency on the system depends on the number of cold days and the price of the electrical energy. Thus the performance of µCHP for this general case can be explained with the smaller number of cold days in Varna and the relatively inexpensive price of the electrical energy. Further investigation is considered where the µCHP will be simulated for different EU countries, various climatic and economic factors will be involved.

Acknowledgement

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