A COMPARISON OF DIFFERENT FUELS FOR THE GENERATION OF ELECTRICITY FOR A RESIDENCE WITH WASTE ENERGY RECOVERY GENERATOR

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ABSTRACT: The purpose of this study is to determine how to generate electricity for household needs with onsite natural gas and heat the residence with the released exit gas. In this study the issue of individual electricity generation has been experimentally investigated with a sample application. The need of heating and hot water is met by the conversion of natural gas, LPG and gasoline fuels to electricity by means of an internal combustion motor and an alternator. Full and low load operating systems operated at full load, while 1 kWh of electricity can be produced with natural gas at $0.31, it can be produced at $0.71 with LPG and $1.11 with gasoline. When the system is run with low load 1 kWh electrical energy the costs are $0.34 with natural gas $0.95 with LPG and $1.61 with gasoline. With the waste heat generated with the burning of fuels to heat the residence and obtain hot water, hot water between 38°C and 50°C was obtained.

Keywords: Natural Gas Generator, Waste heat, LPG/Natural Gas, Electricity Generation, Cogeneration

INTRODUCTION

Energy is indispensable for the daily life of individuals and industrialization, development, of countries. Due to an ever- increasing human population and energy consumption, global capacities of conventional fossil energy resources have been decreasing for more than 2 decades [1]. For this reason, energy efficiency is important issue for individuals and societies [2] . There is an important link between countries' economies, partly independence, and their energy sources. Numerous countries have stated sustainable development plans by means of energy and have developed strategies to reach these targets [3]. In the light of this issue, a great deal of developing countries have been working to improve the productivity in energy in accordance with international laws to protect the environment, the focus has been on energy types which are less harmful to the environment.

Energy types distribution used worldwide can be listed as fossil fuel 86%, nuclear 6%, hydraulic 6%, renewable energy 2%. It is known that fossil fuel source are inadequate in energy generation in Turkey. In Turkey, the demand of energy met by local production was 47.7% in 1990, 33% in 2000 and it is anticipated to be 23.6% in 2023 [4]. Even though Turkey is poor in terms of primary energy sources, the technical and commercial losses were announced as 25.64 % in 2012 [5]. The fact that ¼ of the produced energy could not be used is a serious loss for a country. For this reason, using energy sources appropriately, minimizing energy loss and increasing energy productivity is extremely important for the future of our country.

Currently natural gas is provided to necessary places for heating and hot water. For this reason natural gas is ready-to-use in residences. It is observed that the natural gas used in residences could be burned in internal combustion engines and burned by means of an alternator to generate electricity and meet the demand of heating and hot water, so consequently it is possible to increase the productivity of natural gas as a primary source of energy [6].

In this study, an internal combustion motor coupled with a generator having an alternator and using natural gas, LPG and gasoline to generate electricity onsite and the heating of a residence with waste energy has been researched. A comparison has been conducted among natural gas, LPG and gasoline fuels in terms of energy, cost and usability.

MATERIALS AND METHOD

In this experimental system of the study, natural gas, LPG and gasoline were used separately and hot water was obtained from waste heat in the exhaust. During the experiment, the amount of electricity and system parameters were recorded against time for each type of fuel. As it is difficult to determine instant readings for three types of fuel, the cumulative consumption was recorded for each type of fuel. The schematic view of the experimental system has been shown in Figure 1.

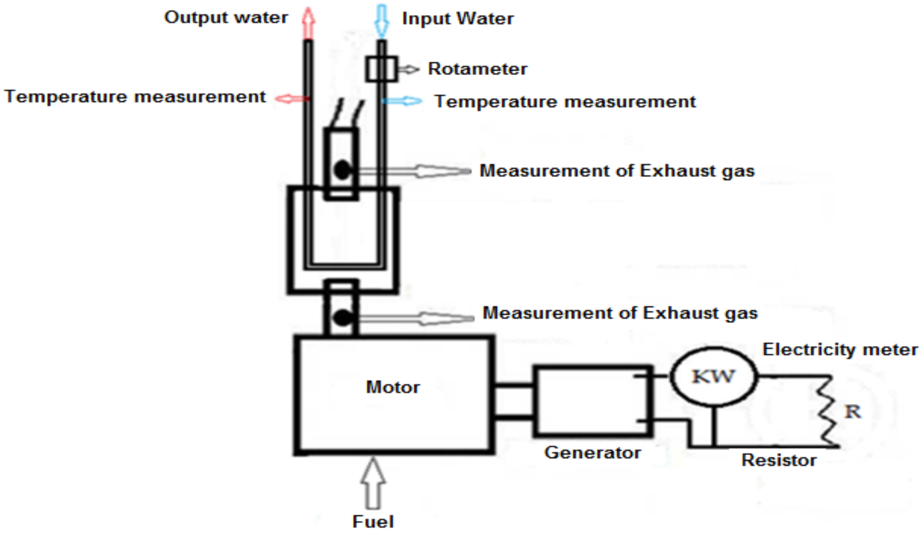


Figure 1. The view of the experimental system

During the experiment, some alterations were implemented in the fuel system and exhaust of the generator to measure the amount of benefit from the waste heat of each fuel. The alterations are a LPG tank on the generator resistant to a pressure 30 bars and decrease of gas pressure to a useable level and installation of a regulator (evaporator) to convert LPG to gas. Multivalve on the tank and regulator open and close with electricity, so electricity was provided with an accumulator and adapter. Due to the high pressure between the LPG tank and the regulator, some connections were established with standardized copper pipes. To install an atomizing nozzle, a screw thread was cut. A gas regulator valve was installed on the standard rubber pipe, one end on the carburettor, the other end on the fuel atomizing nozzle.

Due to the fact that the internal combustion engine is air cooled, the need of hot water for the conversion of LPG from liquid to gas form in the vaporizer, was eliminated with exhaust heat. Consequently the copper pipe under high pressure, as shown in figure 2 which was in contact with the exhaust caused the LPG to convert from liquid to gas form. Liquid LPG which has a pressure of 4 bars in the tank, owing to its high pressure contacted with exhaust heat via the copper pipe in the high pressure line and was converted into gas form. After the pressure decreased to a usable level, the motor was run by atomizing the LPG to the carburettor from the atomizing nozzle in the low pressure line where the gas regulator valve was located. LPG connections of the system is shown in Figure 5.

The experimental system was run with natural gas used at residences with 21 mbar pressure, and natural gas was connected to the system with a standardized flex hose. The gas regulator valve and fuel atomizing nozzle used for LPG, were also used for natural gas.

Figure 2. Water connection to the heat exchanger and preheating of the LPG on the exhaust

The dimensions of the schematic view of the exhaust shown in Figure 3 are A length of 220mm, B height of 200 mm and C depth of 120 mm. The copper pipe used as heat exchanger has a length of 5650 mm, 6.350 mm of external diameter, 4.826 mm of internal diameter and a wall thickness of 0.76 mm. In order to prevent the accumulation of particles as a result of burning and because of the exhaust structure on the heat exchanger, vanes were not used on the copper pipe. For this reason the copper pipe was designed as a spiral heat exchanger and was installed as 18 pass in the exhaust. Water entered the heat exchanger as reverse bias and the flow rate was measured with a rotameter. The heat of input and output water was measured K type thermocouple. The design phases of the exhaust in the experimental system is shown in Figure 4.

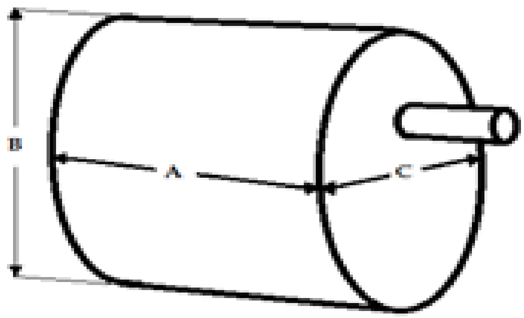


Figure 3. Schematic view of the exhaust in the experimental system.

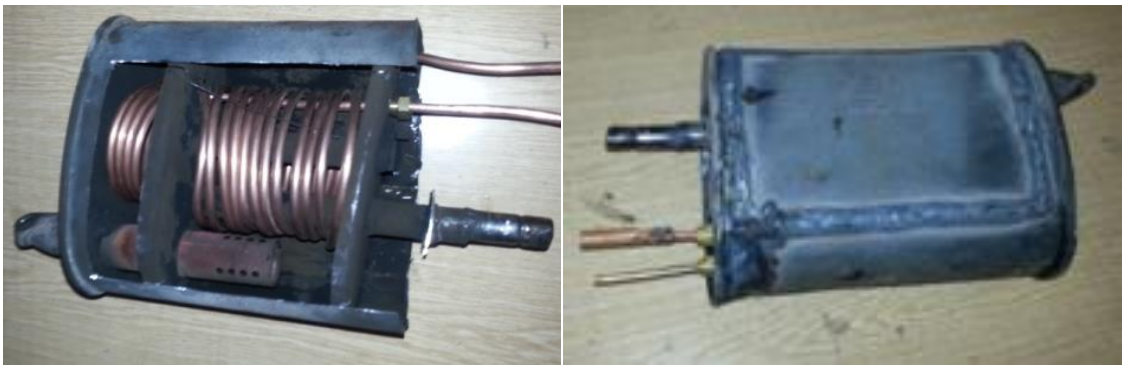


Figure 4. Design phases of the exhaust and heat exchanger

As shown in Figure 5 in this study an 4-stroke air cooled single cylinder, with a maximum output of 6.5/3000 HP/rpm internal combustion motor was used. The generator coupled with the motor was an alternator with a maximum 230 V output voltage, 50 Hz output frequency and a nominal output power of 2.5 kWh.

The electrical output power generated by the system was measured by an electricity meter. Exhaust heat and power measurement were conducted when the generator reached a specific load capacity and steady state conditions. Meanwhile, to determine the duration of the system coming to regime, results were constantly recorded. For the maximum output power of the system rheostats of 2.8 kWh power were used.

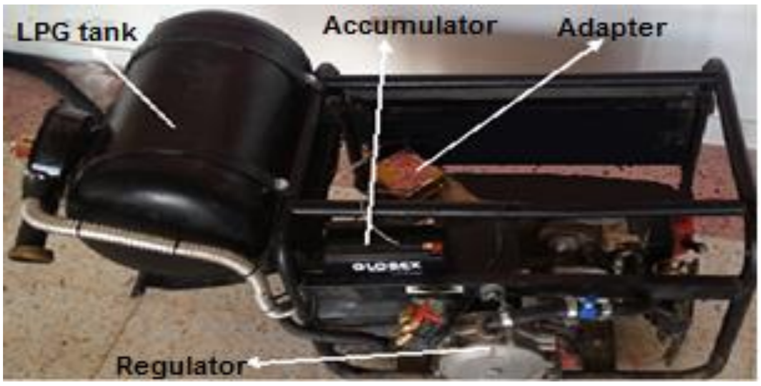


Figure 5. The generator and LPG connections used in the experimental study

RESEARCH FINDINGS

It has been observed that the system reached the regime 10 minutes after the start. After the system reached the regime, it was run full and low load for each fuel and results were obtained for each load. The system which was run with two loads, when run with full load could produce 1 kWh electricity with natural gas at $0.31, LPG $0.71 and gasoline at $1.11. The full load system run values are shown in a graphic in Figure 6. According to the readings, in full load natural gas is 1.25 times cheaper than LPG and 2.5 times cheaper than gasoline.

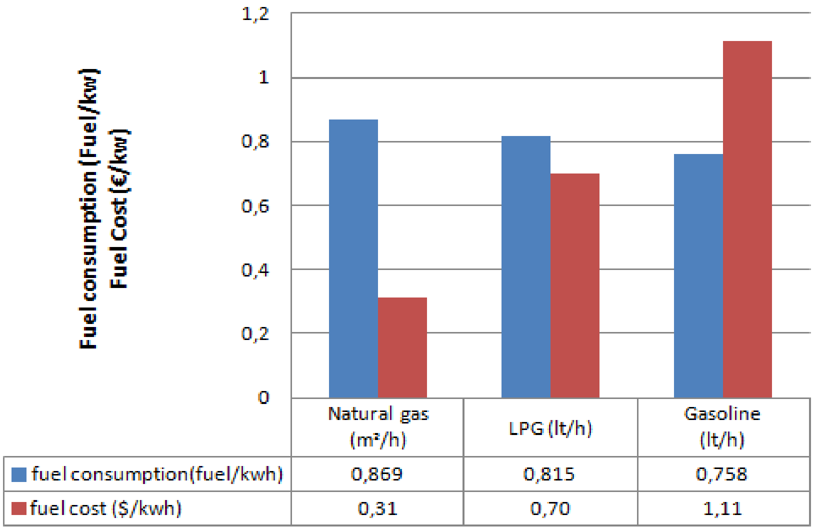


Figure 6. System run at full load for 1kWh electricity generation

It can be seen in the graphic in figure 7 that natural gas is superior to other types of fuel in terms of cost as well as it is in full load run. When running with low load, the system could produce 1 kWh electricity with natural gas at $0.34, LPG $0.95 and gasoline at $1.61. According to the readings, in full load natural gas is 1.8 times advantageous than LPG and 3.7 times more advantageous than gasoline.

Gasoline sale unit rate: □4.30 = $1.47 Feul/liter [7].
LPG sale unit rate: □2.54 = $0.86 fuel/liter [8].
Natural gas sale unit rate: □0,099 = $0.033 fuel//kWh [9].

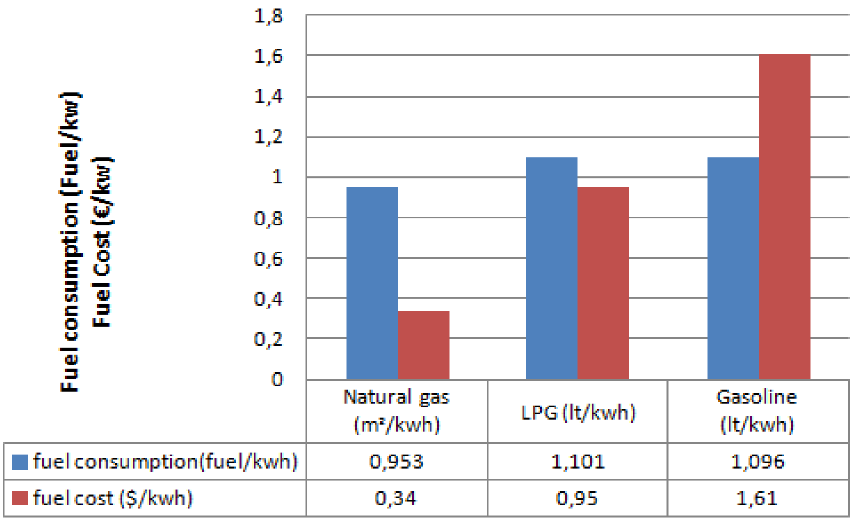


Figure 7. System run at low load for 1kWh electricity generation

It has been observed from the results of the experiments that in both loads natural gas is more advantageous; however running the system at low load was more costly for three types of fuel. As shown in Figure 8 when the system is run at low load, fuel cost increases for natural gas, LPG, gasoline respectively by %7, %34 and % 44. Therefore in terms of system cost, the best results were obtained with full load and natural gas.

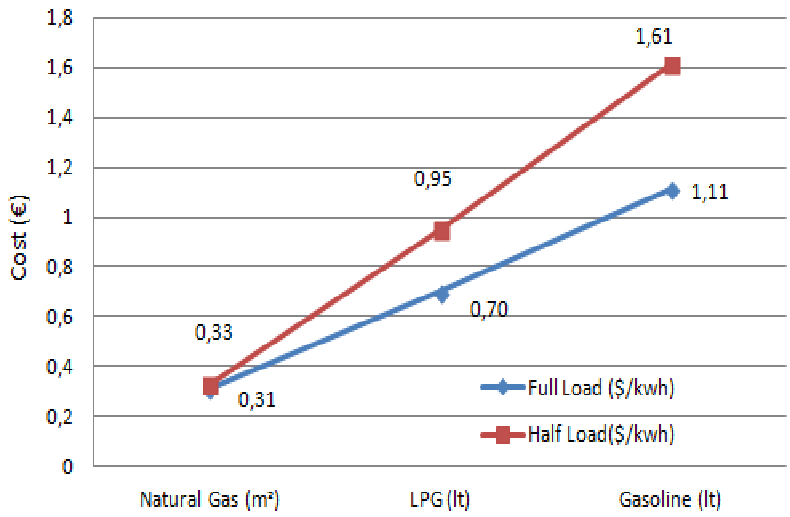
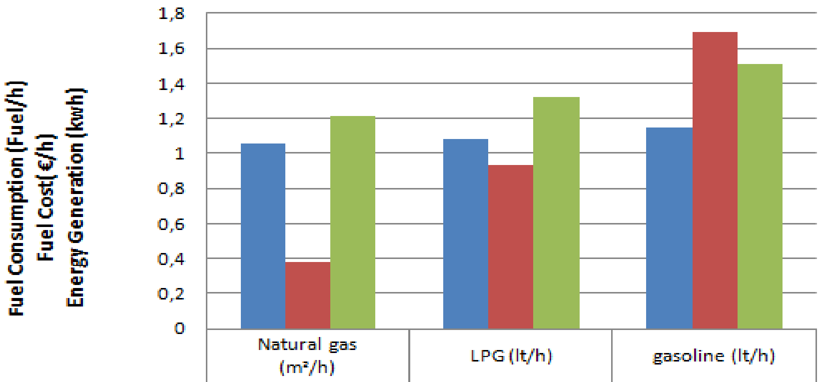


Figure 8. Comparison of system run with full and low load

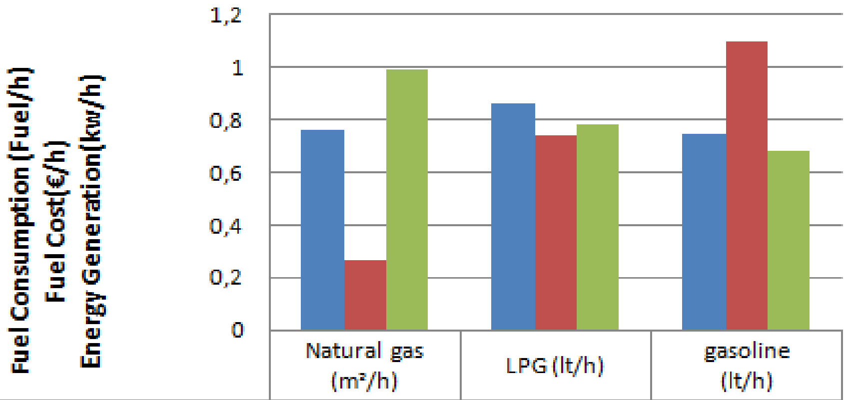
In the second phase of the study, in order to compare consumption, cost and energy generation of the fuel in the system, the experiments were conducted in two different types; such as full and low load. Data obtained as a result of one hour operation in full load are shown in details in Figure 9. A one-hour system run, revealed that the highest energy production was with gasoline as 1.51 kWh, secondly LPG as 1.32 kWh and the lowest with natural gas as 1.21 kWh. Natural gas as fuel performance could generate 9% less electricity than LPG and 24.7 % less than gasoline. In the first phase of one-hour system run, it has been established that the lowest cost was with natural gas, the highest gasoline.



	Natural gas (m³/h)	LPG (lt/h)	gasoline (lt/h)
fuel consumption(fuel/h)	1,06	1,08	1,15
fuel cost($/h)	0,38	0,93	1,69
Energy generation(Kwh)	1,21	1,32	1,51

Figure 9. Full load system run in one hour

In the second phase of the hourly system run, the system was tested in low load. The results of the one-hour system run have been shown in details in Figure 10. The highest energy generation in a one-hour run was with natural gas 0.99 kWh, 0.78 kWh with LPG and lowest with gasoline as 0.68 kWh. According to the data, the lowest fuel cost was natural gas and the highest gasoline. In contrast with the full load run, in terms of fuel performance, natural gas generated 26.9% more electricity energy than LPG and 45.5 % more than gasoline.

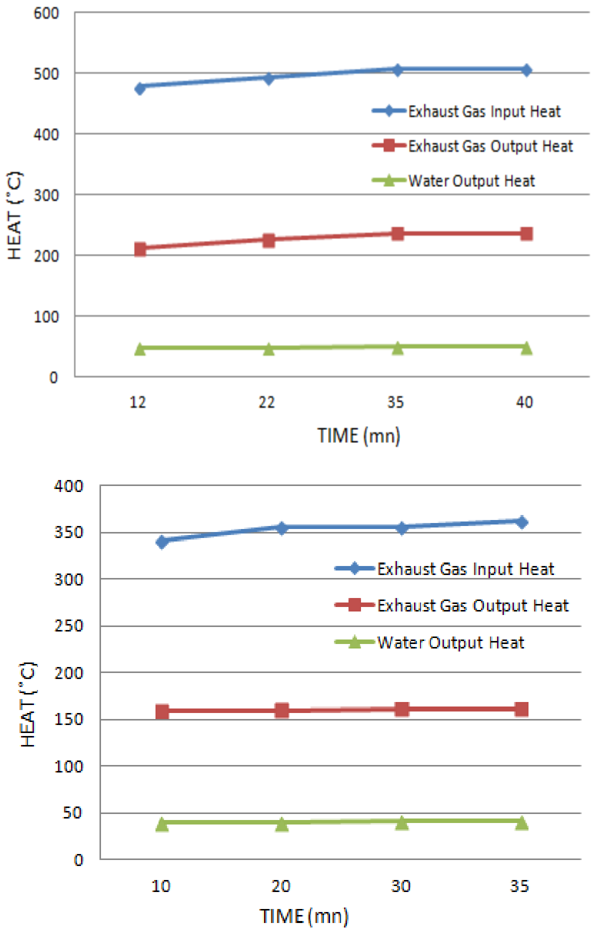


	Natural gas (m³/h)	LPG (lt/h)	gasoline (lt/h)
fuel consumption(fuel/h)	0,76	0,86	0,75
fuel cost($/h)	0,27	0,74	1,10
Energy generation(Kwh)	0,99	0,78	0,68

Figure 10. System run at low load in one hour

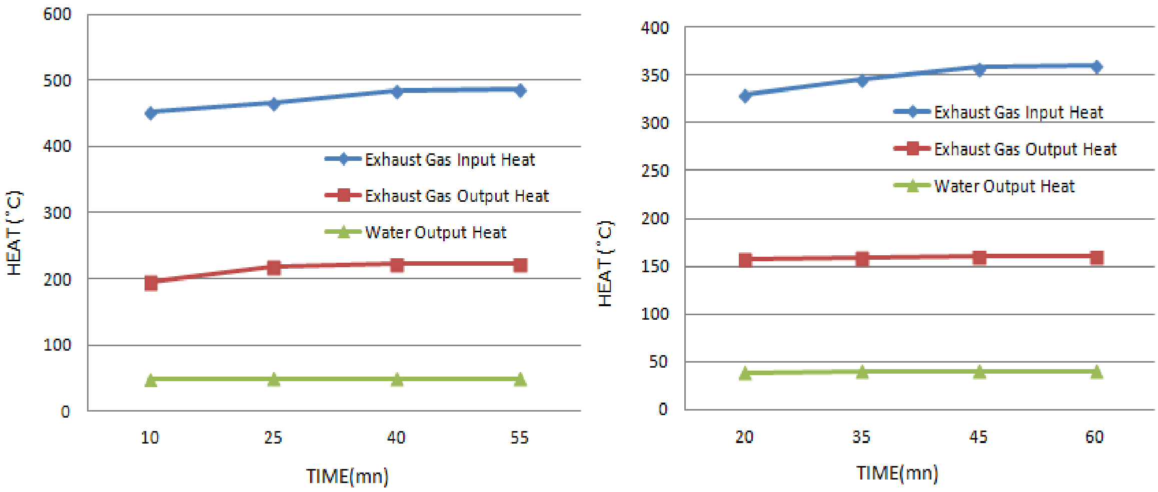
In the experiments to determine electricity generation and consumption of fuel, another aspect was to measure exhaust gas heat and by means of a heat exchanger in exhaust, production of hot water from waste heat. The experiments were conducted at low and full load for all the three types of fuel. When the system was run at full load, the input temperature of the exhaust gas was between 450°C and

507°C.Water entering the heat exchanger in this heat range with 23°C and a flow rate of 0.015 kg/s, exits with a temperature of 45°C and 50°C. As a result, the output temperature of exhaust was between the range of 190°C and 237°C. When the system run at low load the input temperature of exhaust gas was between a range of 320°C and 362°C and the output temperature between 158°C and 161°C. Water entering the heat exchanger in this heat range with 23°C and a flow rate of 0.015 kg/s, exits with a temperature of 38°C and 41°C. In this experiment the results for all three fuel types were quite close to each other. The results reveal that exhaust gas installed in such a system could meet the demand of heating and hot water in residences. The values about natural gas, LPG and gasoline in exhaust gas and heat exchanger are shown in graphics from Figure 11 to 13



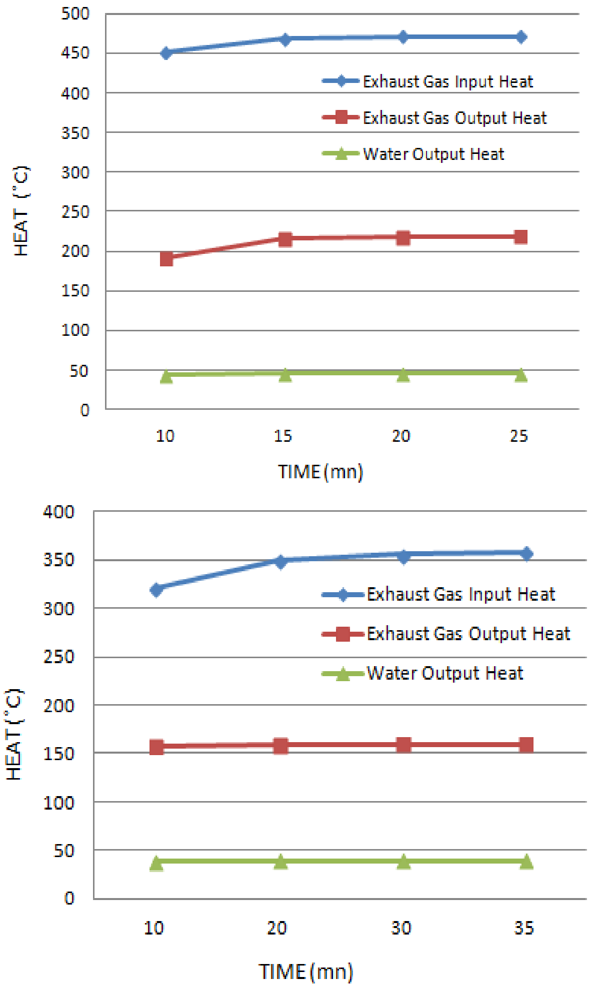
a) Full load b) Low load

Figure 11. Values obtained from exhaust gas and heat exchanger for natural gas in full and low load



a) Full load b) Low load

Figure 12. Values obtained from exhaust gas and heat exchanger for LPG in full and low load



a) Full load b) Low load

Figure 13. Values obtained from exhaust gas and heat exchanger for gasoline in full and low load

CONCLUSION

In this study electricity generation onsite, which could be a model for small scale cogeneration has been researched. This study could minimize the loss of electricity during transportation and energy transportation costs [10]. This implementation will also benefit to the transformation of waste heat to usable energy, which has an important role in using energy more productively.

It is anticipated that with such a system installed in residences and with more productive devices and better designed and insulated exhaust and heat exchanger, the need of heating and hot water could be met with waste heat. It is highly probable that there will be a surplus to requirement. If the surplus energy is included to the mains electricity, both the country's economy and the household will benefit [11]. This benefit can be regarded to meet the demand of energy (electricity, hot water) with less cost and as income by selling the surplus energy to the current system. The contribution to the country could be listed as less polluted environment, keep national funds in the country and more production.

As a result natural gas is used in more than 70 cities, and it is planned to spread this usage to the whole country [12]. It is known that the vast majority of residences have started to use natural gas where available. Therefore, it seems possible to use natural gas which is cheaper, environmentally friendly, free of storage problems compared with other fuel types more productively and more efficiently.

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