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ENERGY COSTS SAVINGS BY USE OF MICRO-CHP UNITS IN DOMESTIC HOUSEHOLDS

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Abstract

Prices of thermal and electric energy delivered to households are constantly increasing, and it will probably not change over the next few years. Due to this fact, people had been forced to find different ways to reduce costs of buying energy. The paper contains description of the most popular systems which are already in use from many years and some innovative systems which are implemented now, or which may be probably installed in nearly future – for example: internal combustion engines, Stirling engines, proton exchange membrane fuel cells, gas turbines, engines with Rankine cycle, etc. Each of mentioned above appliances is necessary to create CHP system which advantages and disadvantages are also described. In this publication, the most promising units have been compared to show their performance, flexibility, profitability and range of using ability. In this paper, approximate money and energy savings that may occur by using modern solutions compared to traditional systems are also shown. As always, during design and development of this kind of devices, there are a lot of problems related to various issues. Main problems and potential solutions have been also presented in this article. In summary further research, directions are suggested due to improve performance of this kind of systems.

Keywords: *micro cogeneration, CHP issues, Stirling engines, cost savings, primary energy savings*

1. Introduction

After analysing some statistics form the past it can be seen that price of electricity in Poland has increasing trend. For example for households cost of electric energy raised over 41 times from 0.0248e/kWh in 1990 to 1.02e in 2009 as shown on Fig 1 [1].

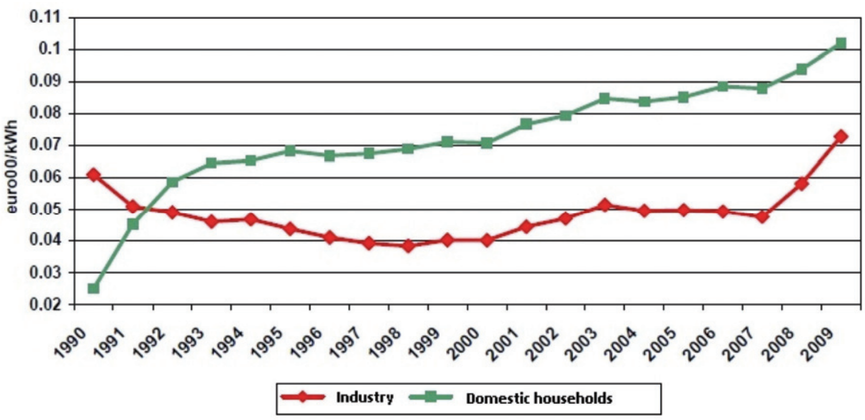

Fig. 1. Prices of electricity in Poland over last two decades

Furthermore, bad news is that probably growing trend will not stop in future. Energy Market Agency provide information that price of electricity may increase twice from now up to 2030. Predicted prices are shown in Tab. 1 [2].

Tab. 1. Predicted prices of electricity in Poland in nearly future

Year	PLN/MWh
2013	237.9
2014	246.2
2015	258.3
2016	274.4
2017	289.8
2018	305.7
2019	324.4
2020	341.6
2021	347.9
2022	351.8
2023	355.2
2024	358.1
2025	359.6
2026	369.5
2027	376.2
2028	376.5
2029	375.7
2030	379.3

2. Definition of Combined Heat and Power

In this case, there is a need to find ways to avoid spending larger amount of money for buying energy from the market. During last few years, there became a lot of inventions contributing saving costs. Some of the most popular are:

1) Renewable energy sources:
   - Wind power,
   - Hydropower,
   - Solar energy,
   - Geothermal energy,
   - Biomass,
   - Biofuel,
2) High efficiency condensing boilers,
3) CHP Systems,
4) Better insulation and windows,
5) Rational management of electricity use.

All of mentioned above ideas have their pros and cons. Renewable energy sources give “green” and “free” energy but for domestic households are still too expensive and take up too much space. Condensing boiler is good solution, and can provide reduction of costs spent for thermal energy from 10-20% compared to traditional old boilers [3, 4]. Modern polystyrene insulation and plastic windows are well known and already in use. In comparison to other units, CHP Systems connected with intelligent control and electricity use managements looks promising and latest trends is to develop and test this devices.

Idea of Combined Heat and Power System (CHP) is to convert primary energy stored in fuel to thermal and electric energy simultaneously [5], what increase overall efficiency of this unit up to 97.2%. Principle of operation is shown in Fig. 3 [7].

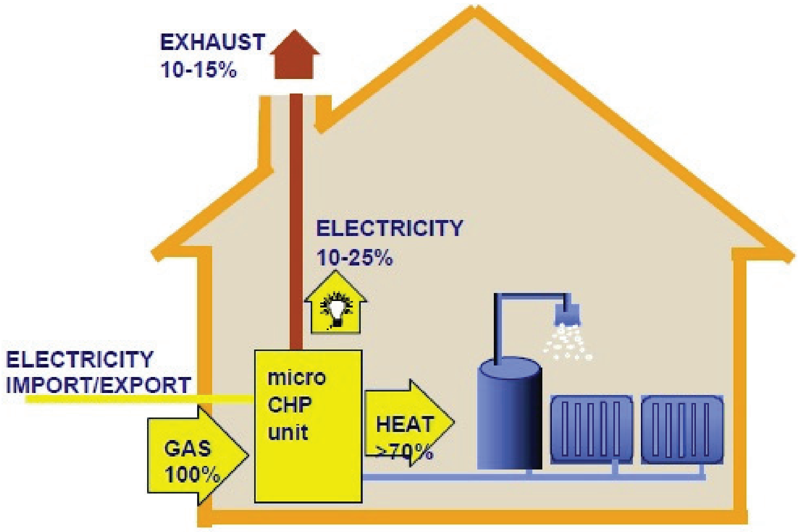

Fig. 3. Principle of operation of CHP systems

According to maximum power generation, there are three types of cogeneration [8-10]:

- micro cogeneration known also as „m-CHP" – power less than 10-15 kW used usually in domestic households,
- mini cogeneration – power from 15 kW-100 kW,
- cogeneration – power over 100 kW,

Depending on prime mover on/at, the market are available different units based on [11, 12]:

- Internal combustion engines (ICE),
- Stirling engines,
- Gas turbines,
- Fuel cells (PEMFC),
- Rankine cycle systems.

3. State of the art of micro cogeneration technologies

First units have been already installed, and they are successfully working since few years. This technology spreads very fast mostly in western and northern Europe (Denmark, Great Britain, Germany, Netherlands, etc.). However this systems are still underdeveloped and there is requirement to improve them due to some problems existence. Main obstacles to install micro-CHP units in domestic households in Poland are [10, 13, 14]:

- High production costs,
- Noise,
- Pollutants emission,
- Efficiency lower than expected,
- Insufficient electricity production relatively to thermal energy production,
- Uncertain prices of energy in future,
- Reluctance of energy suppliers to cooperate with customers,
- Lack of incentive legislation rules and discounts,
- Warm climate.

Nevertheless, there is a big potential of micro cogeneration to reduce costs for energy. Electricity in Poland is relatively much more expensive than gas, so main target is to decrease bills for current by producing electric energy in CHP.

Review of literature shows that there are few investigations about analyses of micro-CHP systems in residential applications [15-17]. Based on some publications, it is possible to obtain such important parameters as: Investment costs, primary energy savings (PES) and payback time (PBT). All of those values are collected and showed in Tab. 2-4.

Tab. 2. Investment costs of m-chp systems based on different prime movers

Prime mover	Electric power [kW]	Thermal Power [kW]	Investment Cost [€]
Condensing boiler	0	20	1500-3000
ICE	1	3.25	5600
Stirling Engine	1	12	6000
Fuel Cell	3	5	9000-24000
Rankin Cycle	5-10	50-100	2500-3000*
Gas Turbine	20	43	3360**

* – Price in euro per kW
** – Price in euro per kW assuming exchange rate of 1.2 £/€.

Tab. 3. Primary energy savings of different systems

Prime mover	PES [%]
Condensing boiler	0
ICE	18-23
Stirling Engine	20-36
Fuel Cell	12-20
Rankin Cycle	23
Gas turbine	<25%

Tab. 4. Approximate payback periods for different CHP

Prime mover	PBT [years]
Condensing boiler	0
ICE	3-6
Stirling Engine	4-8
Fuel Cell	16-17
Rankin Cycle	6-8
Gas Turbine	10

Data mentioned in Tab. 2-4 are only demonstrative examples of different systems investigated in literature. Almost all of them refers to various conditions in investigations, but they show general situation on European markets today. It is important to understand that these information may differ when you try to refer them to one individual case. Generally, CHP systems based on ICE are one of the cheapest solutions available on the market. It is due to years of experience with reciprocating engines and mass production of these machines. All the rest are relatively new devices, which enter to the market so they are much more expensive now. At present day, m-CHPs reach about 15-30% of primary energy saving what can generate significant costs savings. With payback time of less than 10 years (what is possible for some applications in specific conditions) and life of device estimated to 20 years (or more) it is possible to gain much profits. All of these calculations are only theoretical and includes some assumptions. Main criterion in order to above statements were true is that these applications need some subsidy from government. For example, in Netherlands, grants in the amount of 4000 euro were given to every micro-CHP device purchased in 2010 [16]. In Denmark, respectively dotation is in amount of 5000 euro [18]. Without donations payback period increase 2-3 times what cause this technology economically infeasible. Moreover, most of investigations exclude breakdowns, maintenance costs, potential energy costs changes etc.

The most promising systems (ICE, SE) have small electric to thermal power ratio – from ~1:7 for Stirling engines to ~1:3 for internal combustion engines. It shows that micro cogeneration units can be installed only in buildings with high thermal energy demand. Target customers are big detached houses, smaller but not well-insulated houses, hospitals, swimming pools, sport objects, and other public buildings. Summarizing, everywhere where CHP's can work as long as it is possible. To realize how payback time can potentially change with a change of operating hours chart is presented on Fig. 2. [6] This is only an example, investigated for Italy and assuming full electric load and financial support in amount of 4200 euro. SPB is Simple Payback Period in years, and "n" is amount of operating hours in one year. Ecowill, Ecopower, Dachs an Aisin are ICE systems, Solo is technology based on Stirling engine. Investigation results are very optimistic, because 3-4 years of payback time is reached with 4000 operating hours. For domestic household it is rather impossible to achieve, especially in Italy where climate is warm.

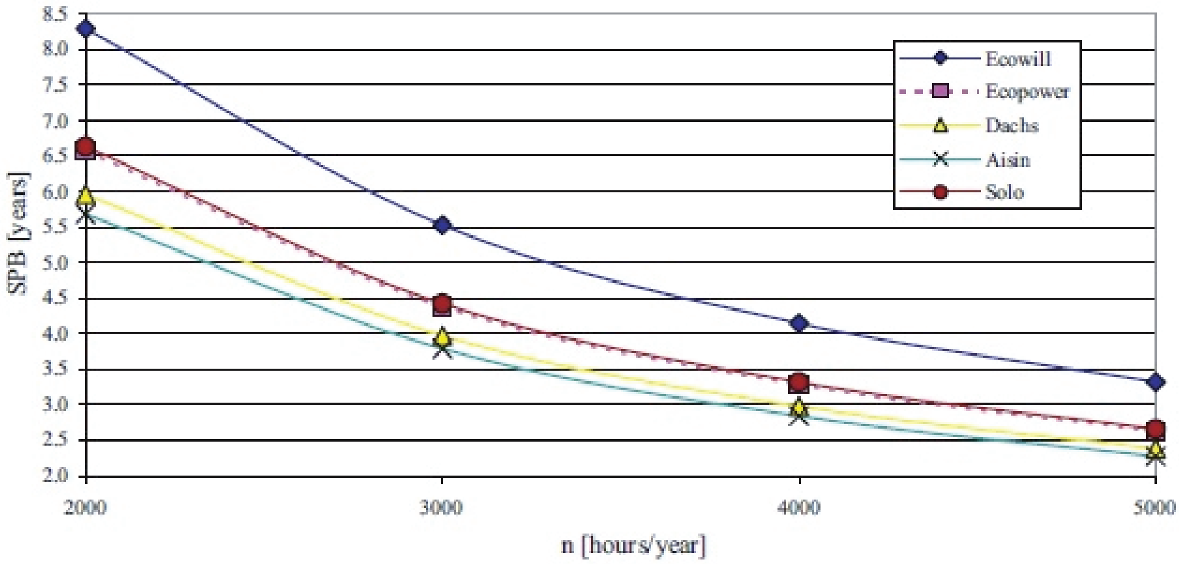

Fig. 2. CHP Investment cost depending on yearly operating hours

4. Conclusions

In this paper, newest Combined Heat and Power technologies are presented. Main features like power, investment costs, primary energy savings, and time of investment costs return are collected in Tab. 2-4. Afterwards, main advantages and obstacles are discussed. Summarizing, micro cogeneration is very interesting and promising new technology. Despite its cons, thousands of units are already working all over the world. In Poland this technology is quite new, but now some investigations in companies producing heating devices are under development (for example Viessmann Vitotwin 300-W [19]). It means that there is possibility to introduce them to the market in future. However, a lot of researches must be done to improve weak points of units. In our country there is problem with lawn regulations – now there are no favourable legislation supporting CHP units installation (government subsidies like in Denmark, Netherland or Japan). There is also uncertainty of behavior of power grid – mass installations of devices which produce and give power to the grid may cause unstable of the grid or cause breaks in electricity delivery. A positive side of cogeneration is that it can be probably connected with other renewable energy sources like solar plants or wind farms in the future, what should result in increased overall efficiency and lower bills.

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