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Renewable energy sources to supply home power plants

***Abstract**. The possibility of use the micro combined heat and power systems with the Stirling engine fed by biomass occurring in lubelskie province is aim of the paper. The consider of micro-cogeneration unit with the Stirling engine is made investigations to prepare experimental system model. The concerning method of biomass in micro combined heat and power system in agricultural farms in the following years.*

Streszczenie.** Przedmiotem artykułu jest przedstawienie możliwości wytwarzania energii elektrycznej i ciepła za pomocą silnika Stirlinga zasilanego biomasą występującą w województwie lubelskim. Rozważania nad układem mikrokogeneracyjnym wykorzystujący silnik Stirlinga są prowadzone w celu przygotowania modelu doświadczalnego. **(Odnawialne źródła energii w elektrociepłowniach domowych)

Keywords: Micro-cogeneration, renewable energy sources, Stirling engine.
Słowa kluczowe: Mikrokogeneracja, odnawialne źródła energii, silnik Stirlinga.

Introduction

Renewable sources of energy appear promising in reducing emissions and slowing down world's energy consumption. New technologies offer the promise of clean, abundant energy gathered from self-renewing resources such as the sun, wind, earth and plants. The article will review the possibilities of biomass application in microcogeneration devices and let specify the profitability of microCHPH application (Eng. Micro Combined Heat and Power for the Home) with Stirling engine in agricultural farms.

Micro combined heat and power plants are promising, innovative and commercial solution to produce both, heat and electric power in decentralised power plants. Using biomass as a fuel for these power plants confers advantages in terms of clean energy.

The exploitation of renewable sources of energy in cogeneration is crucial issue, in accordance with the present tendencies of stable development in power industry.

The reduced resources of primary energy, dangers caused by greenhouse gases emission, low efficiency of transmission heat energy systems, requirements of high quality of electric energy by advanced industrial and computer technologies [7]. They require searching other ways of producing, transmission and the using of electric and heat energy. One of the solution is the idea of generating electric energy and heat directly in a flat, especially in a detached house called "Power plant for Home or Micro Combined Heat and Power for the Home".

The high efficiency (about 90%) of domestic microCHPH ensures the less exploitation of natural gas resources and at the same time it places in the tendencies of stable development. The basic source of renewable energy in Poland is biomass in solid form, biogas and biofuels.

Producing heat from biomass is practised in our climate from old times and it is taken control, however the heat conversion in electric energy is developed in big power stations and in heat and power stations.

In domestic micro heat and power stations (microCHPH) using biomass to convert the heat in mechanical energy the most predisposed is engine with external consuming like Stirling engine because: it is quiet and can be put in a flat and can be powered by any renewable fuel (biogas, liquid biofuels, wood, straw, briquettes), as well as non renewable (natural gas, oil derivatives fuel, coal or peat) [3].

The experimental research carried out concerning the biomass application by microCHPH system application it is the problem that has not been taken up in Poland yet.

Methodology

Searching of new solutions for electric power warranty and heating small objects caused the technologies development connected with associated production of heat and electric energy on the basis of sources of small power with renewable sources usage [1].

Combined Heat and Power (CHP) is the simultaneous production of heat and power from primary fuel (gas, oil, coal). In any electricity generating plant using a thermal process, both heat and power are produced. Combined Heat and Power is industrial processes or to heat buildings and generally produces electrical power near the point of demand, substantially avoiding the electrical distribution losses.

The idea of microCHPH system operation consists in simultaneously production of two or more types of usable energy from one source of primary energy and using waste heat from devices producing electric energy. The diagram presents the way this system works in picture 1.

The electricity and the teat are produced at the location they will be consumed, thus avoiding the electrical and thermal distribution losses associated with centralized plant. Equally importantly, the heat will be produced at the time it is required by the individual household, unlike large scale communal CHP schemes which are unable to respond to the thermal demands of individual homes [2].

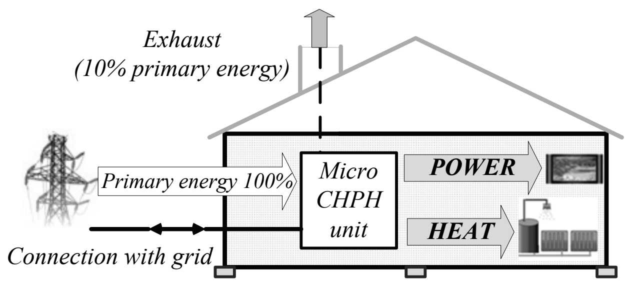

Fig. 1. The system of microCHPH

In fact, microCHPH works very much like the gas boiler in a central heating system and heats the home in just the same way. However, at the same time it generates electricity, most of which is used in that home. The remainder is exported to the grid. It is not usually practical to provide all of the homes electricity from the microCHPH unit all the time. Instead, peak electrical needs are met by importing some power from the grid. Although the home may produce the same total amount of electricity over the course of a year as it consumes. It will import at some time and export at others [5].

Among the latest solutions the small power systems (microCHPH) are proposed below 10 kW heat power and electric power 1 – 5 kW dedicated to separate household. The idea of operation such „micro heat and power station at home" consists in placing the source of electric energy as well as heat energy inside the powered building, which eliminates the total loss of heat and transmission costs.

In micro CHP system the primary energy embodied in natural or liquid gas, fuel oil, biomass and others is transformed into electric and heating energy. Efficiency of the system is around 90%. Electric energy is produced in a turbine of 10-45% efficiency. The heat, which is a result of fuel combustion, is recovered in a heat exchanging system and constitutes 45-80 % of primary energy. It heats mains water and water in the central heating.

The division of the energy into heat and electricity depends on the climatic and geographical conditions. It means that during the period when we do not need the energy for heating a house (summer time), the system is aimed at producing the electricity, whereas during the period when the need for heat increases, the percentage of thermal energy in the system outweighs electricity. Therefore there is possibility of selling out the electricity excess to electrical system or switching off some parts of the system and purchasing electrical energy from the circuit.

Stirling engine

The Stirling engine was invented in 1815 by a Scottish clergyman, Robert Stirling and patented the following year. It was first put to use a quarry pump in 1818. One of the distinguishing features of the engine was that it simply heats and cools the working gas, initially air unlike the steam engine [10].

Stirling engines are external combustion engines, which allow continuous, controlled combustion resulting in very low emissions and high combustion efficiency (Fig.2).

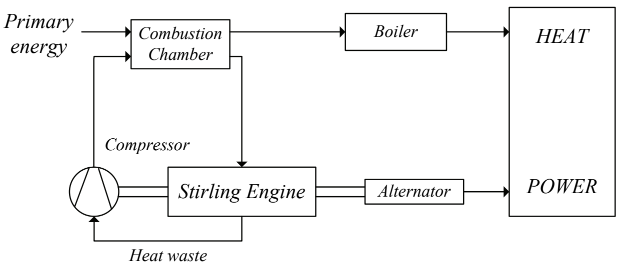

Fig. 2. The Stirling engine scheme

The systems associated with internal combustion gas engines are usually shaped as modules consisting of an engine, a generator, the heat exchanger system, the fumes discharge system and noise softening system.

The Stirling engine transforms heat into mechanical energy without the combustion process. The heat is provided to labor factor, gas, while heating the external wall of a heater. As a result of heat being provided from the outside, it is possible to drive the engine with primary energy from an unspecified source: petroleum derivatives, coal, wood, different types of gas fuels, biomass and even the solar power. The Stirling engine is a perfect drive for generators in cogeneration systems supplying small facilities [3].

The way the Stirling engine works with consists of: two pistons (cold and warm), regeneration heat exchanger and heat exchanger between a labor factor and external sources. Fuel is burned continuously outside the engine to maintain one end of the cylinder at high temperature while the opposite end is cooled by circulating water around it. The burner (furnace) which provides the heat to the whole process, can operate using different types of fuel (petrol, alcohol, natural gas, biogas, butane or peat). The external burning makes the process easier to control as well as cleaner and more efficient. One of the most important elements of the process is a regenerator which overtakes the heat from a labor factor while it flows from a heated to cooled area. Power is derived from the pressure fluctuations acting on the working prison, as a fixed volume of working gas. The working gas is moved by the displacer, which is 90° in advance of the working piston. The sinusoidal waveform of the power output results in low vibration and noise levels. The heat from the gas burner is transferred to the central heating flow to the radiators through the Stirling cycle in the engine, rather than directly through the conventional heat exchanger which would be found in a gas boiler [8].

The PV (Pressure/Volume) diagram above shows the theoretical thermal cycle of Stirling engine. At point 1. the working gas is at its maximum volume and minimum temperature and is contained within the cold end of the cylinder. A displacer shuttles the gas into the hot end of the cylinder without doing work and without any temperature increase. In reality of course work has to be done to compress the cold gas into the hot end space and inevitably the temperature does rise before reaching point 2. At point 2, heat is added to the gas and both temperature and pressure rise towards point 3.

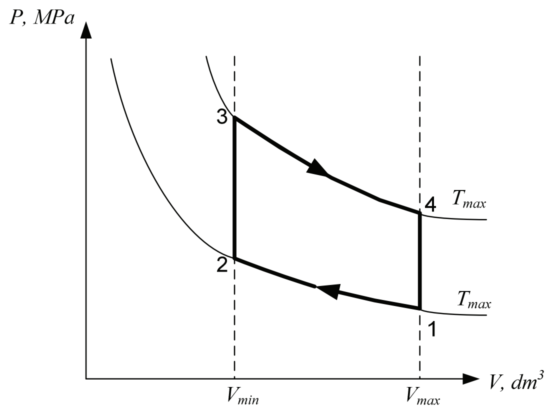

Fig.3. The PV (Pressure/Volume) diagram

From point 3 to point 4, the hot gas expands, exerting a force on the working piston. It is this stage which produces useful power from the engine and is known as the power stroke. At point 4 the gas is at its maximum volume and is then shuttled back to the cold end where it is cooled, ready to commence the next cycle [5].

Comparison

The table presents the numerous references to headline and rule of economics. This comparison provides explanation of the economic value of microCHPH units. On the assumption that the total efficiency of the microCHPH unit and the alternative gas boiler it displaces is the same. It follows that electricity is produced at the expense of additional gas input. There are presented such micro-CHPH systems: WhisperGen and MicroGen.

Table 1. Simplified economics for microCHPH systems [5]

Item	Unit	Gas boiler	Whispergen microCHPH	Microgen microCHPH
Total thermal demand	kWh	21000	21000	21000
Total efficiency	%	88	88	88
Electrical efficiency	%	-1.5	11	15
Thermal efficiency	%	88	77	73
Total gas	kWh	23864	26994	28367
Total CO2 (gas)	kg	4630	5237	5503
Electric generation	kWh	-358	2755	3963
Utilisation	kWh	-358	1929	2774
Electic import	kWh	4858	2571	1726
Total CO2 (electricity)	kg	2759	1461	980
Electic export	kWh	-	827	1189
Total energy bill	£	1321	1163	1110
Annual saving	£	-	158	211
Total benefit	£	-	434	608
Total CO2	kg CO2	7389	6228	5808
Annual saving (CO2)	kg CO2	-	1161	1581

All the systems are driven by the Stirling engine at power of 1 kW fed by natural gas or LPG. The overall efficiency of the device reaches 88%. WhisperGen offers also a system of 1kW electric energy, whereas the source of the heat ranges from 7.5kW to 14 kW. The electric efficiency is of 11%, the thermal efficiency – 77% [9]. The Microgen unit was developed by BG Group from US and offers system of 1 kW electric energy and 6kW thermal output.

The total amount of electricity produced annually from the microCHPH unit after parasitic have been taken into account. For the gas boiler an additional 1.5% of the thermal demand has been added to allow for electrical loads. The electric generation and total utilisation (avoided import) in conventional gas boiler 358 kWh below zero but the microCHPH units are more than 1900 kWh (utilisation) and above 2700 kWh (electric generation). Customers who have conventional boiler must import of energy about 4800 kWh, but they can't export of energy. The total electric export of microCHPH units ranges from 827 – 1189 kWh (Fig. 4).

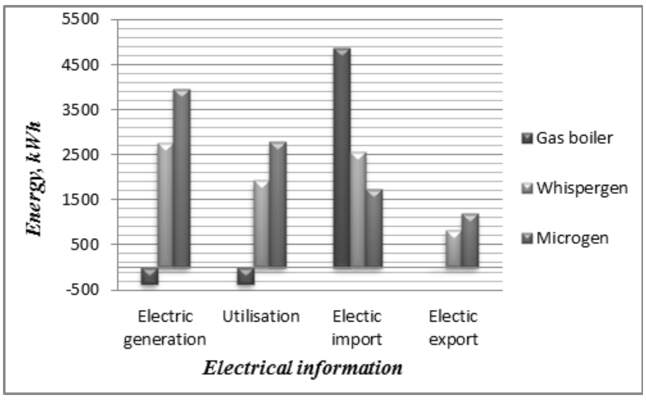

Fig.4. The comparison of a energy

The total CO2 (gas) are the amount of gas consumed multiplied by the specific CO2 resulting in the total carbon dioxide emissions resulting from the gas fuel input and reaches from 4630 kg (gas boiler) to 5503 kg (microCHPH). The total CO2 (electricity) are the amount of electricity consumed net of generation multiplied by specific CO2 (reaches 2759 kg – gas boiler and from 1461 kg to 980 kg – microCHPH) . All electricity generated is considered to be of value in displacing centrally generated electricity. Any export will be consumed by neighbours so having an equal carbon value even if not an equal economic value. The total annual carbon emissions for the entire energy consumption of the same house with gas boiler (7389 kg CO2) and centrally generated electricity compared with a microCHPH (ranges from 5808 – 6228 kg CO2) equipped home with reduced grid electricity supply (Fig. 5).

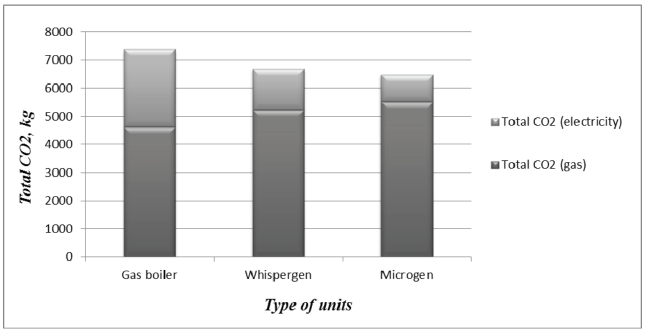

Fig.5. The comparison of a total CO2

Economy aspects

The technologies of associated production applied are profitable not only from economic but also ecological point of view [4]. It can be applied where at the same time there is a demand for heat and electric energy, whereas investing in the big system of heat and power station is not possible or even unprofitable. Hence the small associated systems are installed in the places where for many hours during a year there is a significant demand for heating heat and electric energy.

The application of microgeneration gives great opportunities because apart from big professional and industrial heat and power stations in the world, the small associated systems (50KW ÷ 3 MW) are more and more popular. They let apply associated production in small devices, where there is a small demand for heat and electric power in single objects (school, hospital) or objects groups (small housing estate). The small associated systems are mostly powered by gas, sometimes by oil fuel so their application does the structure of fuels usage in energetic systems of particular countries good. There are more advantages: it is easy to acquire and transport the fuel that has big calorific value fuel, the simplicity of conducting the using up process, the lack of solid waste and lowered the emission of harmful substances into the environment.

Currently the applied solutions concerning powering individual consumers in electric energy and heat base on the exploitation of expensive transmission chain and distribution these media belonging to big energetic companies. Such solutions force consumers high prices of energy connected with its transmission, production and must consider the loss of energy caused by a distance of individual consumer from producing centre. The production of electric energy and heat in an associated way directly by final consumer eliminates the cost of transmission, reduces the cost of energy towards the cost of its production, increases the certainty of powering and usage elasticity and enables to apply the fuels from renewable sources which often are near the powered object.

Increasing requirements of environment protection and resulting from them careful selection of the energy source type cause that more and more people become interested in new technologies which application for a large scale in energetic companies is economically unfounded. At the same time in the countries politics new energetic priorities were accepted promoting effective energy usage with the exploitation of renewable sources and high standards concerning pollution emission.

The example of solutions used in other European countries can be report from English literature where it is written that the installation of microcogeneration units is possible in about 40 million of British houses which mostly have heating based on systems using gas. The exchange of one heating system with standard boiler for microCHPH system with an opportunity of production 1 kW of electric energy will cause the reduction of dioxide carbon emission about 1,7 tonnes per year. Potentially microCHPH units application in Great Britain could decrease the emission of dioxide carbon about 9 - 12 million tonnes per year. Hence promoting the solutions proposed in the project is also well-founded in Poland where there are similar regulations and it aspires to comply with the international standards and UE guidelines.

Discussion and conclusions

The article verify the new method of renewable energy sources, the possibilities of different forms of biomass application in microcogenertion devices and let specify the profitability of microCHPH in agricultural farms. Methodology of combined heat and power production is intended to prepare experimental system model.

It is an important scientific issue to conduct research regarding combined heat and power systems with the use of microcogeration unit with the Stirling engine fed by biomass, which can operate while burning different forms of primary energy. The analysis of microCHPH system fed by biomass in individual households has never been investigated on a larger scale before in Poland, which proves its innovation.

In EU politics new energy priorities have been applied which emphasize the use of energy from renewable sources and underscore high restrictions regarding the emission of pollution. When EU curtailments are taken into consideration, the projects involving the use of biomass in microcogeneration seem to be even more crucial. This will enable the development of biomass production for power engineering purposes. Promoting the solutions included in the project aims at fulfilling international and EU standards.

The subject becomes part of strategy accepted by Poland. It is in accordance with UE guidelines and with Regional Strategy of lubelskie voivodeship Innovation and with the voivodeship programme of development alternative sources of energy for lubelskie voivodeship realised which makes conditions to use renewable energies on the level up to 7,5% in 2010 and 14% in 2020, accepted in 2004.

The application of the solution proposed can bring tangible benefits for natural environment by: the reliability increase the powering of objects, waste usage (biomass), better development of refuse dump (biogas), better usage of renewable sources of primary energy, decreasing the emission of greenhouse gases.

The potential consumers of devices to producing electric energy for households from renewable sources are small households especially from rural areas with poor infrastructure connected with support in media, for example, gas or heat, and possessing the potential sources of fuels from renewable sources, for example, biomass. The application of technology proposed concerning obtaining the electric and heat energy in separate households can cause the reduction of households maintenance costs, and the increase of life quality of members of local communities.

Prospective users of devices producing the electric energy from renewable sources for individual households are agricultural farms and small possessions situated in countryside areas, where infrastructure concerning gas and heat supply is poorly developed but where there can be found renewable sources of energy.

The measuring station will undergo exploitation tests. The device efficiency will be specified as well as regulations of usage will be set when using the primary energy from renewable sources. The results will indicate the range of microcogeneration systems implementation in individual households and apartments. The experimental research will allow denoting profitability of biomass usage in domestic microcogeneration in lubelskie province.

Information gathered, results and experiments will be useful for further research regarding associated heat and electricity production.

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