PROFITABILITY OF GAS MICROCOGENERATION USE IN BUILDINGS WITH CALCULATED ENERGY PERFORMANCE

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Abstract: Various aspects of high-efficiency gas microcogeneration application in buildings with varying demand for heat and power were presented. Recent changes the European and national legislation were described concerning the methodology of defining energy characteristics. For chosen referential objects a profitability of applying the MCHP XRGI gas microcogeneration by determining the time of the return on investment was defined.

Keywords: gas microcogeneration, energy performance of buildings, time of return on investment.

1 Introduction

When taking into consideration the requirements of energy performance of buildings resulting from the EU Directive 2010/31/ [3] of 19 May 2010 on energy performance of buildings and the subsequent amendment to the Construction Law [6], including the so-called second methodology of determining energy performance of buildings [4] they can be described as exhausting, but at the same time allow drafting acorrect energy characterization of a building, resulting in obtaining a proper energy performance certificate. For efficient use of primary energy for newly-designed as well as modernized energy supply systems in buildings, it is necessary to rely not only on the energy performance of the building in question. It is essential also to show that the technology applied is economically sound.

2 Methodology for calculation of energy performance of buildings

Directive of the European Parliament and of the Council on the energy performance of buildings states, that methodology for calculating energy performance should not only be based on the season in which the heating is required, but also cover the annual energy performance of the building. This methodology should take into account existing European standards [3]. Member States should set minimum requirements for the energy performance of buildings and building elements.

For the purpose of optimizing energy use of technical systems of the building, system requirements in respect of the overall energy performance, the proper installation, and the appropriate dimensioning, adjustment and control of the technical systems installed in already-existing buildings shall be set.

System requirements were set for installation, replacement and upgrading of technical building systems and shall be applied insofar as they are technically, economically and functionally feasible.

The system requirements shall cover at least the following:

(a) heating systems;
(b) hot water supply systems;
(c) air-conditioning systems;
(d) large ventilation systems;
or a combination of the above.

2.1 Energy performance certificates

The energy performance of a building shall be determined on the basis of the calculated or actual annual energy that is consumed in order to meet the different needs associated with its typical use and shall reflect the heating energy needs and cooling energy needs (energy needed to avoid overheating) to maintain the envisaged temperature conditions of the building, and domestic hot water needs.

The energy performance of a building shall be expressed in a transparent manner and shall include an energy performance indicator and a numeric indicator of primary energy use, based on primary energy factors per energy carrier.

The methodology shall be laid down taking into consideration at least the following aspects:

(a) the following actual thermal characteristics of the building including its internal partitions:
(i) thermal capacity;
(ii) insulation;
(iii) passive heating;
(iv) cooling elements; and
(v) thermal bridges;
(b) heating installation and hot water supply, including their insulation characteristics;
(c) air-conditioning installations;
(d) natural and mechanical ventilation which may include air-tightness;
(e) built-in lighting installation (mainly in the non-residential sector);
(f) the design, positioning and orientation of the building, including outdoor climate;
(g) passive solar systems and solar protection;
(h) indoor climatic conditions, including the designed indoor climate;
(i) internal loads.

For the purpose of the calculation, buildings should be adequately classified into the following categories:

(a) single-family houses of different types;
(b) apartment blocks;
(c) offices;
(d) educational buildings;
(e) hospitals;
(f) hotels and restaurants;
(g) sports facilities;
(h) wholesale and retail trade service buildings;
(i) other types of energy-consuming buildings.

In Poland energy performance is provided based on the regulation concerning the methodology of calculating energy performance of both the housing unit of the building and the part of the building constituting the self-contained technical-functional whole, and the method of issuing and template of energy performance certificates [4].

The regulation in question is defining: the methodology of calculating energy performance, the method of issuing energy performance certificates, and template of energy performance certificates. This regulation is also providing definitions of: heating system, built–in illumination installation system, simple technical system, complex system, non-renewable primary energy, renewable primary energy, final energy, additional final energy.

This regulation also gives definitions of functional energy for heating of the building, cooling of the building, for warming the water, and emission of pollutant into the atmosphere mentioned in act on the management system of emissions of greenhouse gases and other substances [2].

National regulation shows two methods of evaluation of energy performances:

- calculation method (newly-designed and existing buildings) - method based on the standard use and on climatic data from the database of the nearest meteorological station,
- consumption method (existing buildings, in use for at least 3 years) - the method based on the actual consumed quantity of energy or energy carrier [4, 6].

The regulation has already been amended in order to eliminate the simplified method of determining energy performance of residential buildings.

Types of buildings, for which energy characteristics are provied:

- residential buildings,
- apartment blocks,
- public buildings,
- individual recreation buildings,
- farm buildings,
- production buildings,
- storage buildings.

3 MCHP XRGI technology of gas microcogeneration

Microcogeneration system MCHP XRGI offers an economically viable solution to lower energy costs in an environmentally-friendly way. Using the principle of combined heat and power generation, the XRGI system achieves an extremely high level of efficiency (up to 96%) with the primary energy input, and thus helps protect the environment and lower energy costs. The special feature of this tried-and-tested method is that it allows the heat produced during electricity generation to be used rather than releasing it to the atmosphere with harmful consequences for the climate. This is why combined heat and power (CHP) generation is seen as the sustainable energy production of the future: it actively contributes to protecting the environment. That is also reason why this technology has been welcomed by environmental associations and supported by many of European governments. Cogeneration occupies a special place among the environmentally-friendly methods of energy production. Unlike solar and wind power, cogeneration does not depend on the weather. Combined heat and power units save resources in all weather conditions and provide reliable supply of electricity and heat. The XRGI system consist of main components shown in Figure 1 [1]:

Fig. 1. MCHP XRGI unit– (left to right: power unit, Q-heat distributor, iQ-control panel, storage tank)
Source: [1]

Power unit has the following functions: heat generation, electricity generation, safety and output regulation. The Q-Heat Distributor allows for regulation of engine water temperature, connection of XRGI system to storage tank and central heating system, the use of highly efficient pumps with controlled output based on current needs, creation of storage strategies based on current needs, service notification and error messages.

The iQ-Control Panel has the following functions: integration into electrical network, electrical safety features, control of the XRGI system, status and output display, remote data transmission.

The storage tank with external Storage Control ensures that the XRGI system saves engine heat until it is required. The storage tank retains surplus heat for times when heat consumption is high. The XRGI system thus operates for longer periods of time, making it more efficient. Installation of a storage tank is essential for the XRGI system to operate properly.

Figure. 2 shows a basic chart of heat and electricity production with the use of MCHP XRGI and an additional (for example already-existing) boiler.

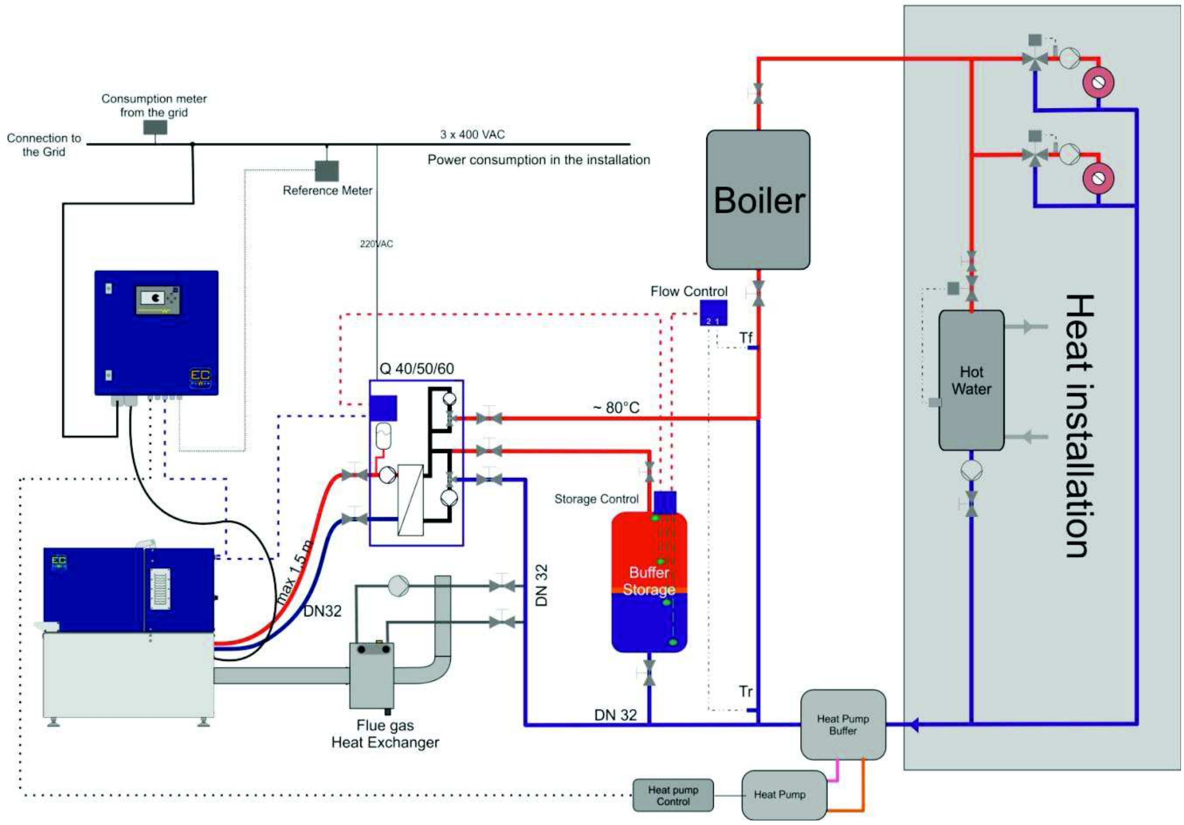

Fig. 2. Chart of heat and electricity production with the use of MCHP XRGI unit
Source: [1]

Technical parameters of the MCHP series of microcogenerators are shown in Table 1. Some of these units' parameters are very important. For example: low sound pressure level (only 49 dB), service intervals (10000 operating hours for units 6 and 9, and 6000 to 8000 operating hours for units 15 and 20), very high total efficiency (102-106% with condensation), small size allowing installation in the existing boiler rooms, high durability and reliability.

Table 1. Technical parameters of the MCHP XRGI series of gas microcogenerators

Cogeneration units XRGI 6 - 9 - 15 - 20				
	XRGI 6	XRGI 9	XRGI 15	XRGI 20
Electrical output (modulated)	2,5 - 6,0 kW	4,0 - 9,0 kW	6,0 - 15,2 kW	10,0 - 20,0 kW
Thermal output	8,5 - 13,5 kW	14,0 - 20,0 kW	17,0 - 30,0 kW	25,0 - 40,0 kW
Total efficiency (including optional condenser)	102%	104%	102%	106%
Gas engine	Layout-series			
Number of cylinders	3	3	4	4
Displacement [ccm]	952	952	2237	2237
Fuel	Natural gas, LPG			
Cooling	Water			
CO emission	<150 mg/m^3	<50 mg/m^3	46/89$^{*)}$ mg/m^3	25/49$^{*)}$ mg/m^3

NO_X emission	<350 mg/m^3	<100 mg/m^3	49/314$^{*)}$ mg/m^3	26/84$^{*)}$ mg/m^3
Generator	Asynchronous, three-phase, cos φ- 0,8			
Voltage	400 V	400 V	400 V	400 V
Nominal / maximum current	12/12 A	20/20 A	27/27 A	40/40 A
Service interwal	10 000 h	10 000 h	8 500 h	6 000 h
Flow temperature	80 - 85 ºC			
Return temperature	5 - 75 ºC			
Sound presure	< 49 dB(A), from 1 m distance			

$^{*)}$ At partial/full load
Source: [1]

3.1 Principles of adjusting the power of the cogeneration system to the needs of the facility.

The microcogeneration system should be properly adjusted to the needs of the facility for electricity and heat and their changes during the year. Correct choice of cogeneration unit or units ensures their continuous operation up to 24 hours a day throughout the year. Owing to such use, the highest operating savings and the shortest investment return periods are achieved. In order for the cogeneration system to work for the maximum number of hours per year, it is necessary to select cogeneration based on the electrical and thermal power values that are constant throughout the year. Basing on the smallest basic power consumption means that these values will be constant throughout the year, and that at this level there will be a constant delivery of both streams of energy produced by the co-generator.

4 Reference facilities

By using the EU directive and the Polish regulation guidelines, energy demands for selected groups of buildings can be determined in accordance with the applicable methodology. In order to analyze the utility of gas microcogeneration in buildings with various levels of demand for heat and electricity, the following reference objects were defined:
a) 180 m^2 residential building,
b) 330 m^2 residential building,
c) 330 m^2 residential building with a seasonal swimming pool of 30 m^2,
d) 330 m^2 residential building with a 30 m^2 of year-round swimming pool,
e) guest house of 380 m^2,
f) terraced houses: 20 x 180 m^2,
g) terraced houses: 40 x 180 m^2,
h) hotel with an area of 1000 m^2,
i) hotel with an area of 1000 m^2, including 80 m^2 of a year-round swimming pool,
j) hotel with an area of 2000 m^2,
k)hotel with an area of2000 m^2, including 80 m^2 of a year-round swimming pool,
l) hotel with an area of 4000 m^2,
m) hotel with an area of 4000 m^2, including 120 m^2 of a year-round swimming pool,
n) 3000 m^2 public swimming pool complex with 312 m^2 of a year-round swimming pool,
o) 2000 m^2 production plant with a continuous demand for 70 kW of thermal energy of,
p) 2000 m^2 production plant with a continuous demand for 140 kW of thermal energy,

Table 2 shows the comparison of operating savings and investment return periods (without subsidization, with funding for investment and with subsidy for generated energy) for all of the analyzed facilities [5].

Table 2. Comparison of operational costs, investment return periods and reduction of CO_2 for referential models considering use of the MCHP XRGI. Red is for return of investment in time longer than 10 years, yellow for 5-10, and green for less than 5 years.

Referential model	Code in prosument classification	Implemented microcogeneration unit	Operaational savings PLN/year	Simple investment return time, [years]			
				Without subsidy	With 30% subsidy	With surcharge of 0,10 zł/kWh	With 30% subsidy and surcharge of 0,10 zł/kWh
180 m² residential building,	PME 1	1 × MCHP XRGI 6	700,-	168,5	118,0	119,2	83,5
330 m² residential building,	PME 1	1 × MCHP XRGI 6	1.745,-	67,6	47,3	47,8	33,5
330 m² residential building with a seasonal swimming pool of 30 m²,	PME 1	1 × MCHP XRGI 6	2.689,-	43,9	30,7	31,0	21,7
330 m² residential building with 30 m² of year-round swimming pool,	PME 1	1 × MCHP XRGI 6	4.324,-	27,3	19,1	19,3	13,5
Guest house of 380 m²,	AG 1	1 × MCHP XRGI 6	4.967,-	23,8	16,6	16,7	11,6
Terraced houses: 20x180m²,	PME 2	1 × MCHP XRGI 9	14.155,-	9,2	6,5	6,6	4,6
Terraced houses: 40x180m²,	PME 2	1 × MCHP XRGI 20	33.214,-	5,7	4,8	4,1	3,4
Hotel with an area of 1000 m²	AG 1	1 × MCHP XRGI 6	8.420,-	14,0	9,8	9,9	6,9
Hotel with area of 1000 m² including 80 m² of a year-round swimming pool	AG 1	1 × MCHP XRGI 15	25.590,-	6,3	4,4	4,5	3,1
Hotel with an area of 2000 m²,	AG 1	1 × MCHP XRGI 9	17.552,-	7,4	5,2	5,4	3,6
Hotel with an area of 2000 m², including 80 m² of a year-round swimming pool	AG 1	1 × MCHP XRGI 20	39.801,-	4,8	3,3	3,4	2,3
Hotel with an area of 4000 m²	AG 1	1 × MCHP XRGI 20	42.414,-	4,5	3,1	3,2	2,2
Hotel with area of 4000 m², including 120 m² of a year-round swimming pool	AG 1	2 × MCHP XRGI 20	74.338,-	5,0	3,5	3,5	2,4
3000 m² public swimming pool complex, with 312 m² of a year-round swimming	PISE 3	3 × MCHP XRGI 20	142.655,-	4,0	2,8	2,9	2,0

pool							
2000 m² production plant with a continuous demand for 70kW of thermal energy,	AG 4	2 × MCHP XRGI 20	95.096,-	3,9	2,7	2,8	1,9
2000 m² production plant with a continuous demand for 140 kW of thermal energy	AG 4	4 × MCHP XRGI 20	187.827,-	4,0	2,8	2,9	2,0

For residential buildings, guest houses or hotels, where there is no swimming pool, the only heat demand in the summer is the warming of water for domestic use. In the case of residential buildings, even where there is a swimming pool, operating savings are not able to provide return at a rate justifying the investment. For guest houses and hotels with fewer than 80 guests (hotel 2000 m^2), investment return periods are longer than 7 years. The situation will improve considerably if the hotel (even a small one) has a swimming pool. At this point, the time of return on investment is clearly reduced.

In the case of the terraced houses, significant savings are only visible in housing communities of ca 40 houses. Investment return time without subsidy is ca 5.7 years, and when a 30% subsidy can be included, this period is reduced to 4.8 years.

On the other hand, hotels with a number of guests around 140 (hotel 4000 m^2) reach an investment return time of 4.5 years, even if there is no swimming pool and even if no subsidy is provided for equipment and installations. Very significant operational savings and short investment return times are found as well for the public swimming pools and production facilities with constant year-round demand for thermal energy.

The following reference facilities show simple return on investment (total cost of equipment, project and installation) to be less than 5 years without any additional funding:

- hotel 2000 m^2 with a year-round swimming pool of 80 m^2,
- hotel 4000 m^2,
- hotel 4000 m^2 with a year-round swimming pool of 120 m^2,
- 3000 m^2 urban swimming pool, with 312 m^2 of a year-round swimming pool,
- 2000 m^2 production plant with a continuous demand for 70 kW of thermal energy,
- 2000 m^2 production plant with a continuous demand for 140 kW of thermal energy.

By comparing the changes in the return times of investment outlays for different levels of co-financing, it can be stated that direct subsidies to micro-cogeneration plants are able to expand the segment of economically-justified customers, for it to encompass the housing communities and small hotels (with or without a swimming pool).

Conclusion

High-performance gas cogeneration is a cost-effective technology for achieving cost savings in buildings with varying electrical and heat demands. It is important, however, that the energy performance of the building should be analyzed, which would then allow for selection of the technologies, which are the best from the purely technological, as well as economic and environmental point of view. Any given technology is not economically justified for use everywhere, as shown by the analysis of reference facilities. Application of economic instruments may extend the scope of use of MCHP XRGI technology, but this is conditional upon the introduction of comprehensive solutions through national legislation.

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OPŁACALNOŚĆ STOSOWANIA MIKROKOGENERACJI GAZOWEJ DLA BUDYNKÓW Z PRZYGOTOWANĄ CHARAKTERYSTYKĄ ENERGETYCZNĄ

Streszczenie: W artykule przedstawione zostały uwarunkowania dotyczące zastosowania wysokosprawnej mikrokogeneracji gazowej w obiektach o zróżnicowanym zapotrzebowaniu na energię elektryczną i ciepło. Opisano zmiany w prawodawstwie europejskim i krajowym dotyczące metodologii wyznaczania charakterystyki energetycznej. Dla wybranych obiektów referencyjnych wyznaczono opłacalność zastosowania mikrokogeneracji gazowej MCHP XRGI poprzez określenie czasu zwrotu nakładów inwestycyjnych.

Słowa kluczowe: Mikrokogeneracja gazowa, charakterystyka energetyczna, czas zwrotu nakładów inwestycyjnych