# EVALUATION OF THE FIRST MICRO COMBINED HEAT AND POWER FOR SOCIAL HOUSING IN BELGIUM

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*Abstract:* - The application of Combined Heat and Power (CHP) is a possible means to save on primary energy consumption and to meat partly the goals of $CO_2$-reduction. The heat released by electricity production is also used in those systems what can lead to a higher total efficiency compared to separated production of heat and power. So far in Flanders only a number of large and medium scaled CHP-projects were realised (for reciprocating engines a total of 139.5 $MW_e$ in 2002). Because of technical evolutions smaller systems called micro-CHP with a power of 2 till 10 $kW_e$ are sold on the market.
In this social housing project in Herenthout (Belgium) for the first time in Belgium a gas fuelled micro-CHP is installed in a collectively heated building block of 12 dwellings. The produced electricity is used for the electricity demand of the dwellings. The produced heat is used for room heating and for domestic hot water production. The micro-CHP is a part of a global project concerning energy efficient and sustainable building in social housing.
The project is partially financed by the Flemish Government and is closely monitored and evaluated during two years by the research institute VITO.

*Key-Words:* CHP, monitoring, evaluation, rational use of energy, emission reduction, combined heat and power

## 1 INTRODUCTION

The concept of combined heat and power (CHP) or cogeneration has been known for a long time [1]. Because of the growing environmental awareness and the ratification of the Kyoto Protocol, combined heat and power can play an important role to the reduction of energy use and the $CO_2$-emissions [2]. In the Energy Performance of Buildings Directive of the EU CHP is seen as a technology to fulfil the energy requirements of buildings. At the moment, new small scaled combined heat and power systems are emerging on the market especially for individual houses and small building blocks. Small scaled combined heat and power is however quit expensive and not enough diffuse in Europe. Economic analysis shows that even well known gas engines have a small internal rate of return (less than 5%) and this only occurs in favourable economic circumstances [1]. Installation costs should be reduced by 50% before CHP systems become interesting for residential use [1]. The Flemish Government has different support mechanisms for CHP. The first mechanism is the Program of the Energy Demonstration Projects. It is a Program for promoting the rational use of energy (inclusive CHP) and the use of renewable energy by funding the first elaborated project in a sector. The funding has an upper limit of 50% of the (extra) investment cost for the project [3]. The second mechanisms for supporting CHP in Flanders are the CHP certificates. Electricity suppliers are obliged to deliver part of the supplied electricity with CHP. If the obliged part can not be proven, the supplier has to pay a penalty. Electricity suppliers can meet the target by investigating in own CHP projects or by purchasing CHP certificates on the market [4].

## 2 PROJECT

The project consists of the construction of 19 new energy efficient dwellings in the municipality of Herenthout. The owner is the social housing company Zonnige Kempen in Westerlo.

Nineteen dwellings are divided over two building blocks with respectively 12 and 7 dwellings. The aim is to reduce the energy consumption for room heating and for hot sanitary water. At first the heat demand for room heating are diminished by reduction of the transmission and ventilation losses. Applying extra insulation compared to the level for new dwellings imposed by the Flemish Government reduces the transmission losses. The ventilation losses are reduced by applying mechanical ventilation with heat recovery. The rest heat of the extraction air is used for heating the fresh pulsation air. The remaining heat demand for room heating is covered by energy efficient thermal technologies: micro-CHP and condensing boilers. Applying thermal solar collectors reduces the energy consumption for hot sanitary water production. The described installation is placed in the building block 1 existing of 12 dwellings [5].
Fig. 1 shows a picture of building block 1 with the solar collector system on the roof.

Fig. 1: Picture of the building block 1

## 3 MICRO-CHP

Fig. 2 shows a principal scheme of the thermal installation. The installation is built up with a condensing boiler (100 $kW_{th}$), a micro CHP (5.5 $kW_e$ and 12.5 $kW_{th}$ [6]) and a flat plate solar collector system (18.5 m³). The micro CHP is placed in the return pipe of the thermal installation. return water is pumped through the micro CHP for cooling the power generator, the engine and the flue gasses. The heated water is injected again in the return pipe. The installation water is after heated by the condenser and the heat exchanger of the condensing boiler used for room heating and for after heating of the hot sanitary water. Solar collectors are used for preheating the hot sanitary water. The electricity produced by the micro CHP is delivered to the power grid of the two building blocks and used by the tenants.

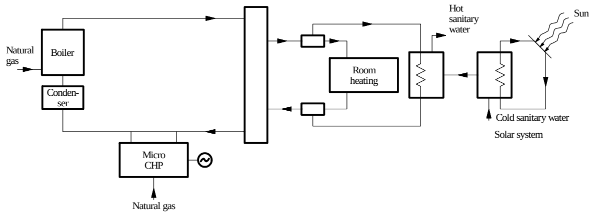


Fig. 2: Principal scheme of the thermal installation

Fig. 3 shows a picture of the CHP integrated in the heating system and Fig. 4 shows the CHP without sound insulation.

Fig. 3: Picture of the CHP integrated in the heating system

Fig. 4: Picture of the CHP without sound insulation

## 4 MEASUREMENTS

The project was monitored and evaluated by VITO. During a period of two years the energy flows of the project were measured. Table 1 gives an overview of the measurements [5].

Table 1: Overview of the measurements

| System | Parameter | Meter |
|---|---|---|
| micro CHP | natural gas consumption | gas meter |
| micro CHP | produced electricity | electricity meter |
| micro CHP | produced heat | heat meter |
| micro CHP | water temperature inlet | temperature meter |
| micro CHP | water temperature outlet | temperature meter |
| condensing boiler | natural gas consumption | gas meter |
| condensing boiler | produced heat collector | heat meter |
| solar collector | solar radiation | solar meter |
| solar collector | produced heat primary | heat meter |
| solar collector | heat delivered to sanitary water | heat meter |

Each parameter was measured every 15 minutes. The measured data are stored in a data logging system.

Fig. 5 shows an overview of the meters in the installation.

## 5 EVALUATION

In the first measurement period the results of the CHP were very poor. In this first year the total electricity production was only 4,899 kWh/year. After an hydraulic adaptation and some important changes in offset values in the control system of the CHP and the boiler the results were a lot better [5]. All further conclusions are based on the second measuring period from March 2002 till February 2003.

Fig. 6 shows an overview on monthly base of the electricity production and the electricity consumption of the CHP. The installation produced most of the electricity in the month January 2003, namely 3,590 kWh. Over the second measuring period the CHP ran about 3,645 hours/year and produced 18,700 kWh/year. The consumption of the installation was 146 kWh/year what results in a net electricity production of 18,554 kWh/year over the second measuring period [5].

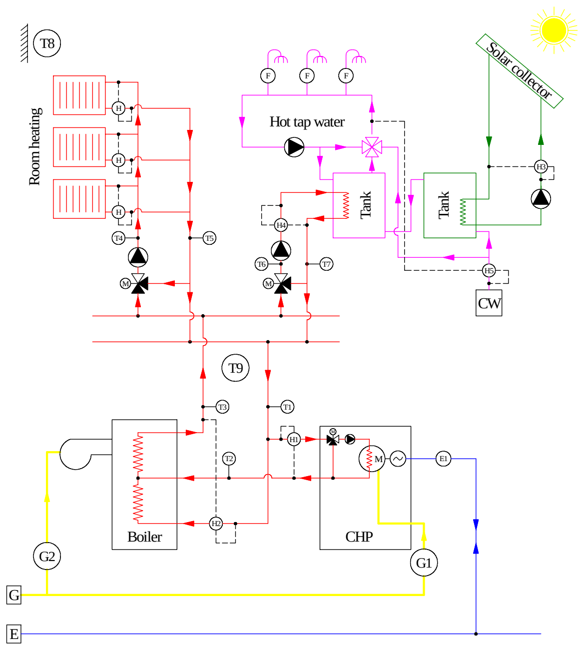


Fig. 5: Overview of the meters in the installation

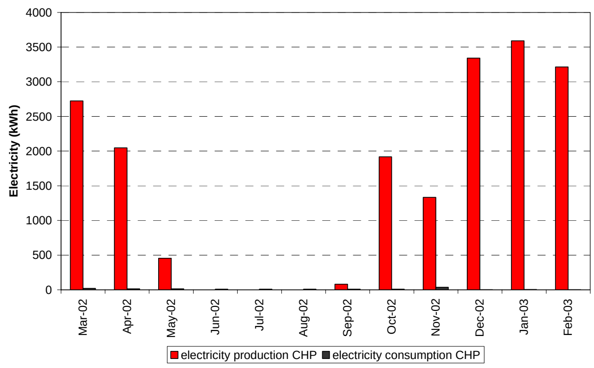


Fig. 6: Electricity production and electricity consumption of the CHP

The total useful heat production of the CHP over the second measuring period was 45,014 kWh/year or 162.1 GJ/year. The consumption of natural gas amounts to 8,201 $m^3$/year or 276.5 GJ/year (lower caloric value). The overall electrical efficiency is thus 24.3% and the useful thermal efficiency amounts to 58.6%. This leads to a total efficiency of the CHP of 83.0% [5].

The total heat demand of the dwellings over the second measuring period was 102,279 kWh/year (368.2 GJ/year) of which 20% or 20,426 kWh/year (73.5 GJ/year) for hot sanitary water and 80% or 81,853 kWh/year (294.7 GJ/year) for room heating [5].

44 % of the total heat demand was produced by the CHP, 56% was produced by the condensing boiler and the solar collector. The CHP delivered most part of the heat demand during the month April 2003. During the summer (June, July and August 2002) the heat demand was only fulfilled by the condensing boiler and the solar collector [5].

## 6 REDUCTION OF THE PRIMARY ENERGY CONSUMPTION

For the calculations of the reduction of the primary energy consumption this CHP is compared to separated energy production with an electricity plant and a gas fuelled boiler. The following assumptions are made:

- the heat delivered by the CHP is in the reference delivered by a gas fuelled boiler with an efficiency of 85%;
- the net electricity production of the CHP is in the reference produced by an electricity plant (mix coal / steam and gas) with an average efficiency of 44%.

The primary energy consumption of the CHP was 276.5 GJ/year. In the reference situation the primary energy consumption amounts to 342.4 GJ/year of which 190.6 GJ/year by the reference boiler and 151.8 GJ/year by the electricity plant. This means that the reduction of the primary energy consumption amounts to 65.9 GJ/year or 19% compared to the reference situation [5].

## 6 REDUCTION OF THE CO2-EMISSION

For the calculation of the $CO_2$-emission the following assumptions next to the assumptions made for the calculation of the primary energy are made:

- the $CO_2$-emission factor of natural gas amounts to 55 gr $CO_2$/MJ;
- the $CO_2$-emission factor for the electricity production amounts to 624 gr $CO_2$ / $kWh_e$.

The $CO_2$-emission of the CHP was 15.2 tons/year. In the reference situation the $CO_2$-emission would be 22.1 tons/year of which 10.5 tons/year by the reference boiler and 11.6 tons/year by the reference electricity plant. This means that the $CO_2$-emission is reduced by 6.9 tons/year or 31% compared to the reference situation [5].

## 7 ECONOMICS

Table 2 shows the economic analysis of the micro-CHP. The investment cost amounts to 12,169 euro, the maintenance cost was 241 euro/year and the net energy saving is 1,773 euro/year. The pay back period of the investment is thus 7.9 years. If the funding of the project is included in the economic evaluation the pay back time of the project is 3.1 years [5].

Table 2: The economic analysis of the micro-CHP

| | |
|---|---|
| investment cost (€) | 12,169 |
| maintenance cost (€/year) | 241 |
| energy billing CHP (natural gas) (€/year) | 1,879 |
| reduction electricity billing (€/year) | 2,356 |
| reduction billing boiler (€/year) | 1,296 |
| total energy cost reduction (€/year) | 1,773 |
| Pay back time without funding (year) | 7.9 |
| Pay back time with funding (year) | 3.1 |

# 8 CONCLUSIONS

Micro CHP is an interesting alternative for reducing the energy consumption and the CO2-emissions in social housing projects. In this project a small CHP system with an electrical power of 5.5 $kW_e$ was integrated in a heating system existing of a condensing boiler and a solar collector in a social housing project with 12 dwellings. During the second period the CHP consumed 8,201 $m^3$/year natural gas and produced 18,700 kWh/year electricity and 162.1 GJ/year heat. Over the second period the average electrical efficiency amounts to 24.3% and the thermal efficiency was 58.6% what leads to a total efficiency of 83.0%.

The total heat demand of the dwellings over the second measuring period was 368.2 GJ/year of which 44 % was produced by the CHP, 56% was produced by the condensing boiler and the solar collector.

The primary energy consumption of the CHP was 276.5 GJ/year. In the reference situation the primary energy consumption amounts to 342.4 GJ/year of which 190.6 GJ/year by the reference boiler and 151.8 GJ/year by the electricity plant. This means that the reduction of the primary energy consumption amounts to 65.9 GJ/year or 19% compared to the reference situation.

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