# ENERGY EFFICIENT BUILDINGS AND RENEWABLE SUPPLY WITHIN THE GERMAN POLYCITY PROJECT

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**ABSTRACT**
The paper presents results from the implementation of energy efficient buildings, renewable energy supply systems and energy management in the area of the German Scharnhauser Park project. About 80% of the heating energy demand and 50% of the electricity consumption of the whole area is supplied by a wood fired co-generation plant with 1 MW electrical power and 6.3 MW thermal power. In summer the heat from the network is used for decentral absorption cooling in one of the office buildings.

**KEYWORDS**
Energy efficient buildings, communal energy management, renewable energy supply

**INTRODUCTION**
The **POLYCITY** project deals with the implementation of energy efficient buildings in city quarters, which are supplied with efficient district heating and cooling networks, partly powered by renewable energy sources. The German project is located in the town of Ostfildern at the southern border of the city of Stuttgart and the neighbourhood investigated is Scharnhauser Park. The area is a former military ground and has been developed since 1992. The area has 150 hectares and includes public spaces, 90.000 m² of commercial area and several housing types such as multifamily apartment blocks, row houses, public buildings and some single family homes.

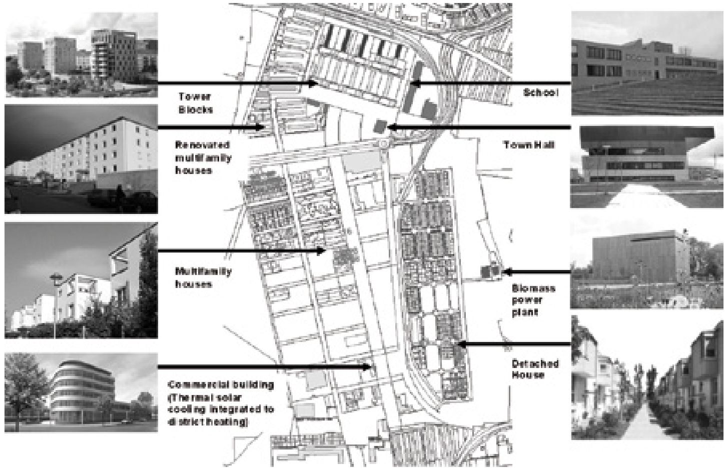


*Figure 1: Design and building types in Scharnhauser Park*

**BUILDING ENERGY EFFICIENCY**

When the site was developed, energy standards for buildings were established by the town of Ostfildern in 1995, which demanded 25% lower end energy demand values than the existing national standard at that time (WSVO 1995). The building standard WSVO 1995 required maximum heating end energy demand values of 70 – 100 kWh/m²a, depending on the ratio of surface to volume (from 0.5 up to 1.05 or higher). In the energy saving legislation **EnEV 2002**, the supply technology of the building with different conversion efficiencies and primary energy balances was included. From now on, there was only a primary energy demand limit so that buildings supplied by renewable energy (as in the Scharnhauser Park district) could be constructed with lower building standards.

This standard was in place, when the **POLYCITY** project was prepared. To obtain financial support for building investment measures, the **POLCITY** project demanded about 40% lower end energy values than the average EnEV 2002 value of about 90 kWh/m²a, i.e. 56 kWh/m² a for residential buildings and 50 kWh/m² a for office buildings.

In 2007 a certification system was introduced for buildings. In 2009 the dependence on surface to volume ratio was abandoned even for residential buildings. The calculated demand must now be lower than that of a reference building of the same geometry which is approximately between 50 – 80 kWh/m² a.

The targets set in the **POLYCITY** project for electricity consumption are 28 kWh/m²a in residential buildings and 35 kWh/m²a in office buildings. Under German climatic conditions residential buildings are not supposed to have active cooling systems, for office



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buildings the **POLYCITY** target was 30 kWh/m²a cooling end energy.

In summary the requirements set by the project in 2003 were high enough to comply with today's legislation.

Only a small fraction of residential buildings in the Scharnhauser Park received additional funding (13.216 m² out of a total residential area of 178.000 m²). Three four-storey multi-family apartment buildings of 5540 m² with a total of 42 apartments received 28 €/m² funding for energy measures, which corresponds to less than 3% of the total construction costs of 1065 €/m². A total of 10 single family houses also received 3% funding with total construction costs of 896 €/m².

All buildings were planned and constructed by the housing society Siedlungswerk Stuttgart GmbH during 2005 – 2010. The residential building measures supported include higher insulation standards (6 cm more wall insulation and 4 cm more roof insulation and improved low e-coated double window glazings with plastic spacers), low temperature heat distribution systems to reduce the district heating return temperatures (floor heating system) and mechanical exhaust ventilation for good indoor air quality control.

In the office building project of the company Electror GmbH also low temperature heat and cooling distribution systems were chosen (concrete core activation) to improve the performance of the absorption chiller for cooling and to reduce peak power demand. The foundation piles were activated with plastic tubes to extract heat from the ground during winter and to reject heat loads from the ventilation system during summer.

To reduce the electricity consumption for lighting, a centrally controlled corridor dimming strategy was chosen combined with highly efficient individual work space lamps, which are dimmed according to daylight availability.

A newly constructed public building of the municipality of Ostfildern was designed for near passive standard. Only triple glazing was not used, as the building is used as a youth centre and therefore there is a high risk of damage to the expensive glazing.

**RESULTS BUILDING ENERGY EFFICIENCY**

Multi-family apartment blocks dominate the heating energy delivered by the biomass co-generation plant with 54% of total energy delivered.

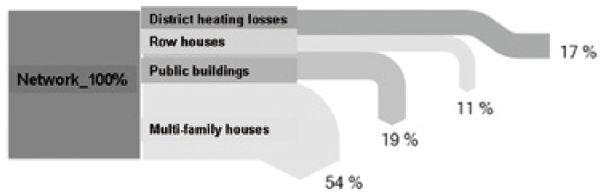


*Figure 2: Distribution of heating energy delivered by the biomass co-generation plant*

The monitoring results from the multi-family apartment buildings supported by the project can now be compared with the values obtained from standard multi-family constructions in the same district.
The measured consumption of all multi-family houses is in general slightly lower than for the average row houses (between 56 and 68 kWh/m²a for the years 2005 and 2009 compared to 62 to 69 kWh/m²a for the row houses). Some errors are unavoidable, as the gross surface areas for all buildings was determined using only basic geoinformation system data (ground floor area and building height). Also some metering information included several buildings and was equally distributed to the building surfaces.

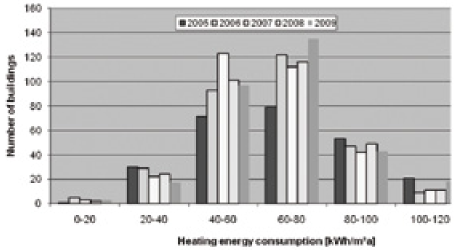


*Figure 3: Distribution of heating energy consumption measured for all multi-family houses*

The Siedlungswerk apartment building fulfils the set requirements for heating energy demand well. Only in the first year of occupation the measured consumption was higher than specified. It has to be noted that the consumption of individual apartments fluctuates very strongly.

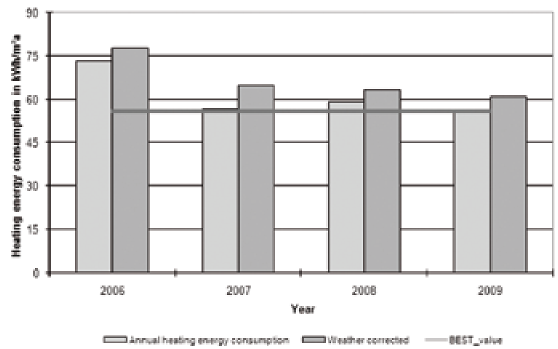


*Figure 4: Measured heating energy consumption per brut surface area of the multi-family apartment building of the Siedlungswerk GmbH.*



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*Figure 5: Photograph of multi-family building with detailed monitoring results.*

The row houses analysed did not receive funding from the POLYCITY project and were constructed by different housing societies or investors. Despite rather similar building type and construction age, the consumption fluctuates strongly.

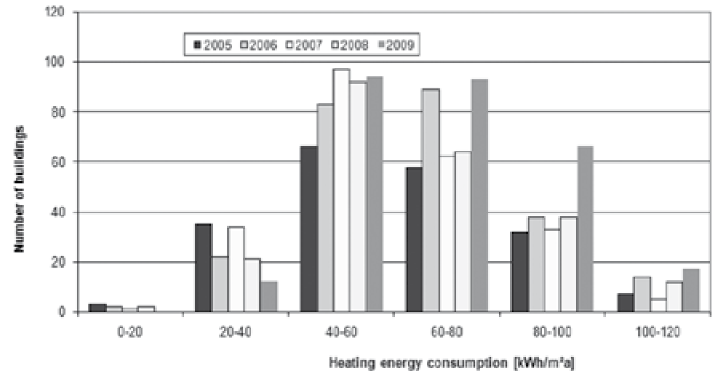


*Figure 6: distribution of heating energy consumption for all row houses.*

To evaluate the influence of user behaviour, row houses with a very similar construction type were compared. The calculated demand is thus very similar. However, monitoring results show strong fluctuations of consumption within the same type, demonstrating again the rather high user influence.

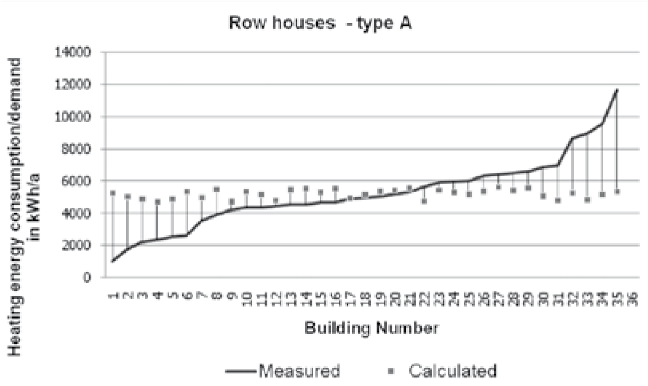


*Figure 7: Measured heating energy consumption compared to calculated demand for similar row house types.*

If user related building parameters are statistically varied (air change rates, heating set-point temperatures, night shut-off times of heating system), the measured consumption curves can be approximated quite well.

**RESULTS FROM ENERGY SUPPLY SYSTEMS**

The biomass ORC cogeneration plant performance was analysed in detail over the years. Furthermore the decentral absorption cooling system implemented in the office building of the company Elektror was analysed.

The following table shows the design specifications of the biomass furnace:

| Aggregate | Description | Value | Unit | Reference |
|---|---|---|---|---|
| Biomass furnace | thermal power (max) | 8 000 | kW | Manufacturer |
| Wood storage | capacity | 1 400 | $m^3$ | Manufacturer |
| Fuel consumption | design point | 200 | $m^3/d$ | Manufacturer |
| Auxiliary power furnace | electric | 25 | kWh/MWh | Manufacturer |
| Annual wood consumption | average | 43 000 | t/a | SWE |
| Fossil fuel saving | | 38 000 | MWh/a | SWE |
| $CO_2$-reduction | | 7 000 | t/a | SWE |

*Table 1: Design specifications of the biomass furnace*



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The district heating system is now supplied up to 80% from condenser heat from the electricity producing ORC turbine.

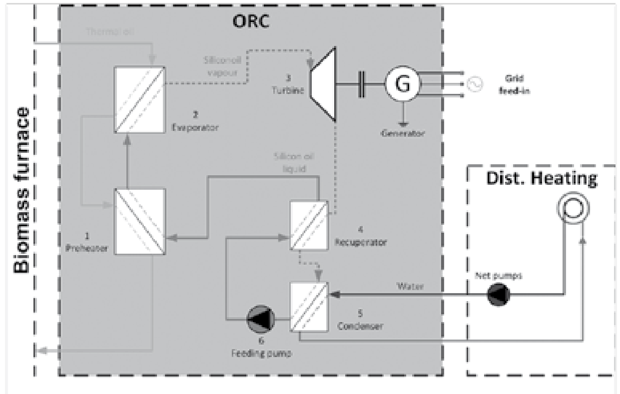


*Figure 8: ORC-scheme including district heating*

During normal operation, the biomass supplies 80% of the total heating energy demand. Only in 2009 there was a long plant shutdown due to a fire incidence. Since then the plant has been running at a reduced maximum power level.

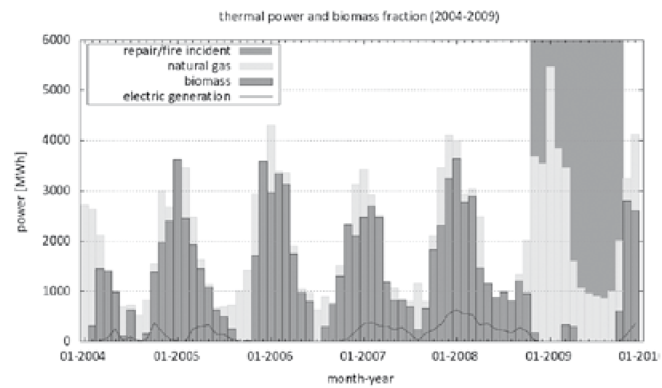


*Figure 9: Monthly demand and biomass coverage*

Over a period of six years all auxiliary supply of the biomass plant has been monitored. For the conversion of biomass to district heat 43 kWh electric energy for the combustion process per MWh thermal are necessary. Including the heat from gas boilers the specific value goes down to 26 kWh/MWh. This clearly shows that biomass combustion is more demanding compared to gas combustion.
As the ORC module had few operation hours and often runs in partial load conditions, the consumption of electricity of the whole plant itself including the combustion process is high. In total the electricity consumption of the plant itself compared to the electric energy fed to the grid was 28% in 2007 (939 MWh out of 3327 MWh electricity feed in) and 30% in 2008 (1044 MWh out of 3527 MWh).
The electric efficiency of the ORC module was expected to be around 17%. So far, the annual efficiency did not exceed 12% and maximum values of 14.5% were reached.

**DECENTRAL ABSORPTION COOLING**
The Elektror company office building with an office surface area of 3280 m² is heated and cooled using heat from the biomass ORC cogeneration plant. Winter heating energy is supplied to thermally activated ceilings and in addition to convectors at the air outlets. Cooling is only provided to the concrete core ceiling. The installed absorption chiller with 105 kW cooling power is directly connected to the district heating network and provides about 2/3 of the total cooling energy demand of the building (180 MWh).

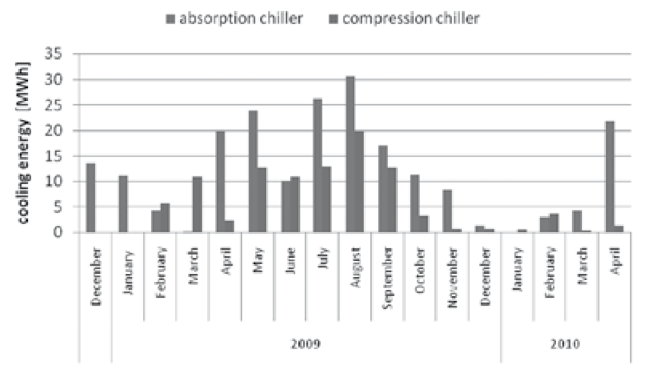


*Figure 10: cooling energy provided to the office building by absorption and compression chillers.*

The coefficient of performance of the chiller was between 0.6 and 0.7 during summer months and thus corresponds to expectations. The performance drop during autumn and winter months can be attributed to frequent switch-on and off under part load



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conditions and needs to be optimised during the next months. The annual heating energy required for the absorption chiller is similar to the winter heating energy demand and thus helps to increase operation hours of the ORC plant in summer (heating in 2009: 371 MWh, heat for cooling 320 MWh)

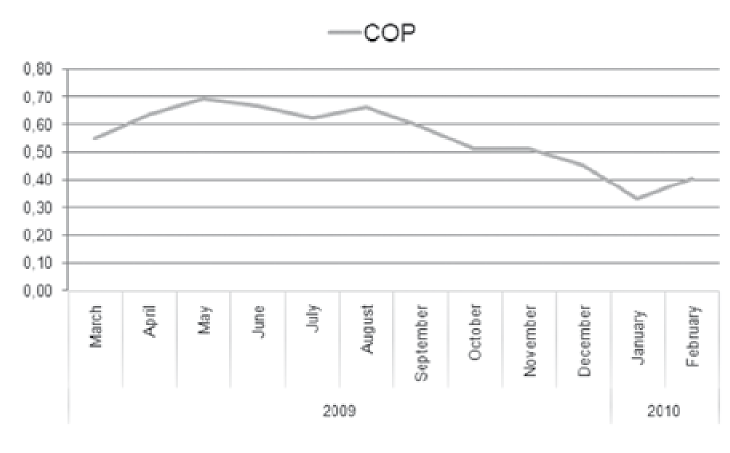


*Figure 11: Coefficient of performance of the absorption chiller in the Elektror office building.*

**CONCLUSIONS**
Monitoring of the city quarter Scharnhauser Park in Ostfildern showed that low energy building standards can be reached on a city scale. The user behaviour leads to a large fluctuation of consumption values, although building age and standard are rather comparable. The monitored multi-family houses had about 10-20% lower energy consumption values than the standard constructions in the area.
The area is supplied with a very high renewable energy fraction of 80% of the heat and 50% of the electricity consumption. The electricity consumption of the ORC power plant itself is rather high, as full load conditions are rarely reached. The situation will be improved with increasing population and with additional heat use in summer, for example from thermal cooling plants in office buildings. A first project was implemented and monitored in one of the offices of the commercial district. The heating energy required for cooling was comparable to the winter heating energy of the building and extends the power plant full load operation during summer approximately 50 hours.

**ACKNOWLEDGEMENT**
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