Nolde & Partner
innovative Wasserkonzepte

Water and Energy Recycling in a Residential Passive House

Dipl.-Ing. Erwin Nolde
Nolde & Partner Innovative Water Concepts, 10405 Berlin, Germany. Email: erwin.nolde@t-online.de

INTRODUCTION

- Water and energy are closely linked. Saving water also results in energy saving as the water sector is considered to be the largest municipal energy consumer.
- A city like Berlin (3.5 million inhabitants) requires for its water sector alone as much electrical energy as the electrical household demand for a city with 280,000 inhabitants [1]. Other cities comparably need more energy for the water sector.
- In a passive house, hot water considerably needs more energy than space heating and most of it is lost in the sewer.
- The energy potential of warm wastewater has not been yet exploited as a resource for residential construction. Former projects suffered from low efficiency and high maintenance.

The results presented here are based on a more than 1.5 year ongoing advanced research and monitoring programme.

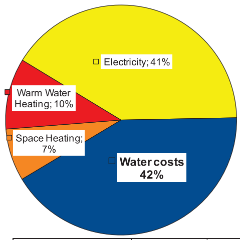

Figure 1: Running costs without water and energy recycling.

	specific demand		yearly demand	unit	price		yearly costs
Space Heating	15	kWh/m²/a	69.000	kWh/a	0,07 €	/kWh (Gas)	4.830,00 €
Warm Water Heating	760	kWh/P/a	93.480	kWh/a	0,07 €	/kWh (Gas)	6.543,60 €
Electricity	875	kWh/P/a	107.625	kWh/a	0,25 €	/kWh	26.906,25 €
Water	122	L/P/d	5.477	m³/a	5,00 €	/m³	27.385,95 €
						total	65.665,80 €

Photo 1: Multi-storey passive house at Arnimplatz, Berlin-Prenzlauer Berg built for 123 persons (41 dwellings) and covering an area of 4,600 m².

OVERVIEW OF APPROACH

A greywater recycling system combined with heat recovery from greywater was launched in March 2012 in a multi-storey passive house in Berlin, Germany and is running since then problem-free and at very low maintenance.

Greywater from showers and bathtubs undergoes an advanced physical-biological treatment followed by UV disinfection without the use of chemicals.

The heat energy recovered from greywater is used to pre-heat the cold water for the building's combined heat and power plant (CHP).

For a standard passive house, which has a heat demand for space heating of <15 kWh/m²/a, more energy is needed for hot water generation than for space heating. A total of 41 flats with 123 tenants occupying an area of 4,600 m² and 4 commercial units (600 m²) are connected to the greywater/heat recovery system. About 3,000 litres of low load greywater are treated daily to produce high quality service water which is reused for toilet flushing.

The filtered greywater enters the heat exchanger, where heat is withdrawn by a 20-watt circulating pump before it undergoes biological treatment in a Moving Bed Biofilm Reactor (MBBR) followed by UV disinfection (Fig. 2).

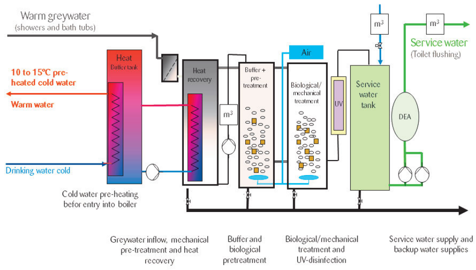

Figure 2: Schematic diagram of the greywater recycling system coupled to heat recovery.

Photo 2: Greywater recycling combined with heat recovery. The combined system is placed in the basement where the building's heating system is also found, occupying an area of 9 m² (approx. 0.1 m²/person).

RESULTS AND DISCUSSION

The water quality of the treatment plant is far better than the hygienic requirements of the EU guidelines for bathing water, further BOD_7 is always less than 3 mg/l and turbidity < 1-2 NTU. Treatment is without the addition of chemicals and at very low maintenance.

The average greywater temperature is 31 °C. During winter, when drinking water temperatures are relatively low (approx. 8.5 °C), it was possible to withdraw over 15 KWh of thermal energy per m³ of greywater without the use of a heat pump. The circulation pump and self-cleaning process of the heat exchanger need about 0.25 kWh/m³. During the first year of operation heat recovery with very low maintenance heat exchangers achieved a coefficient of performance (COP) of 60 in winter and 40 in summer.

Dependent on the amount of generated greywater and freshwater demand more than 40 kWh/d of thermal energy can often be recovered from the system (orange line) compared to the electric energy demand for the entire system, which is about 4 kWh/d (yellow line) (Fig. 4). Comparing the primary energy gains, this decentralised approach achieves a relatively higher degree of efficiency than centralised systems, where only about 1.5 °C can be withdrawn from municipal wastewater using heat pumps.

System monitoring also showed that the amount of greywater (black line), originating in this case only from showers and bathtubs, is not sufficient to cover the demand for toilet flushing (green line). It is therefore recommended to include additional greywater sources (e.g. laundry, kitchen), which can be recycled successfully [2] to increase the amount of greywater and improve the system's efficiency.

The additional investment costs for the combined recycling system of 10 €/m² of floor space (excluding second pipe network), compared to the real estate costs (3,500 - 4,000 €/m²), are very low (< 0.3%). The total electrical demand for heat recovery, greywater treatment and service water distribution is less than 1.5 kWh/m³. The annual savings on water and energy were 5,000 € and 1,000 €, respectively. Energy recycling shows best performance during the cold winter months, when thermal solar plants are not productive.

The yearly energy recovered by this plant is equivalent to the energy delivered by a thermal solar energy system of 35 m².

The yearly total electric energy demand for greywater recycling and heat recovery of 1,800 kWh can be covered by 18 m² of the building's 145 m² installed PV-Modules.

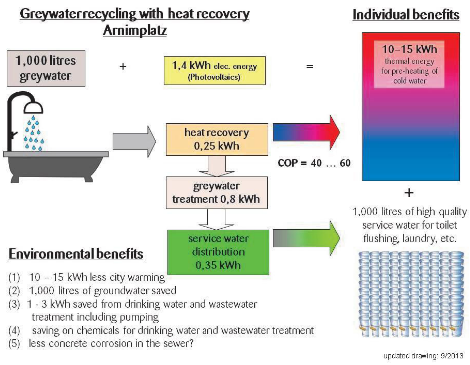

Figure 3: Individual and environmental benefits of greywater recycling combined with heat recovery based on an inflow of 1,000 Litres of raw greywater.

Remarks to Fig. 3:

Centralised heat recovery systems, built in a sewer and operated by heat pumps are working with comparably low COP between 3 and 4. Heat pumps are able to produce warmer water than the above described system, which only preheats the cold water up to approx. 25 °C before it enters the boiler. But both systems have to run as bivalent systems to ensure the security of supply.

Only the decentralised system shows a high resource efficiency with COP between 40 and 60 and can be easily operated by photovoltaics.

If centralised heat recovery systems are connected to the national grid, primary energy savings can be achieved if electricity is produced with a high percentage of renewable energy. If not, primary energy savings by heat pumps are only marginal.

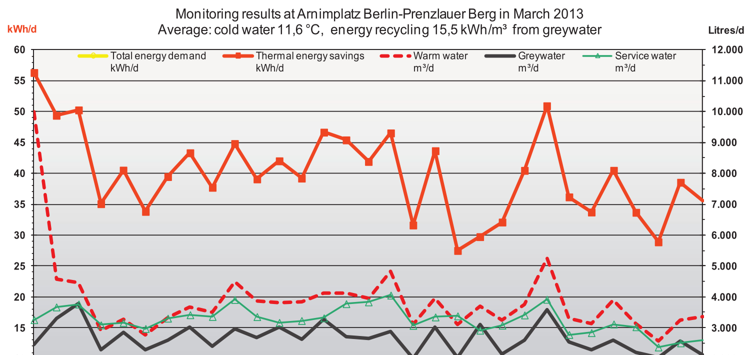

Figure 4: Monitoring results of water and energy input and output from the combined recycling plant during March 2013.

Web page:
http://www.nolde-partner.de/node/32

CONCLUSIONS

- ☑ Greywater is a renewable and safe resource for non potable water and energy.
- ☑ Higher water and energy savings as shown in this project are possible .
- ☑ Total system costs including dual pipe network are less than 0.6% of the total apartment costs.
- ☑ More than a tenfold higher water and energy efficiency, compared to central systems, can be achieved with a decentralised approach by operating greywater recycling plants in combination with heat recovery.
- ☑ **Today no new building should be designed without a dual pipe network for water and energy recycling!!**

LITERATURE

[1] BWB : Nachhaltigkeitsbericht 2012 der Berliner Wasserbetriebe, S. 24. http://www.bwb.de/content/language1/html/7198.php

[2] Berlin Senate for Urban Development (2008) Block 6: Integrated water concept - ecological integrated concept. Berlin, Germany. http://www.stadtentwicklung.berlin.de/bauen/oekologisches_bauen/download/modellvorhaben/flyer_block6_engl.pdf

Acknowledgments: I would like to thank the DBU, who supported this project (AZ 28201), Dr. Paul Grunow (owner) and Uwe Heinhaus (architect) for their trust in our new technology. Many thanks also to Rudi Büttner from Lokus GmbH for the perfect installation work and last but not least to my employees Nils Freudenberg and Holger Sack.

Nolde & Partner innovative Wasserkonzepte | Lokus GmbH | **Projekt: Arnimplatz** Bauherr: Dr. Grunow Inbetriebnahme: März 2012 | heinhaus architekten | DBU Deutsche Bundesstiftung Umwelt