Zukunft Bau

SUMMARY

Title

Development of novel approaches of in-house heat recovery from domestic waste water using modern heat pump technology to increase energy efficiency in buildings

Occasion

About 12 % of the delivered energy consumption in buildings is used for domestic hot water. This amount of energy is mostly unused discharged in the sewage system. In the recovery of this heat directly inside the building lies a large, widely untapped potential for developing energy-efficient building facilities.

Content

The research work build on the in spring 2012 completed - also funded by the research program “Zukunft Bau” of the Federal Institute for Research on Building, Urban Affairs and Spatial Development - research project "Decentralised heat recovery of domestic waste water" (SF-10.08.18.7-10.4). Objectives of the current project are the continuation of the metrological potential analysis in four buildings of the previous project (2 student residences, 1 hotel, 1 hospital), the extension of the metrological potential analysis by including two other multi-family houses in the analysis, the generation of representative time-variation curves of the energy source waste water on the basis of long-term measurements and analyses of the relevant influencing variables of the energy potential as well as the design, simulation and evaluation of decentralised waste water heat pump systems.
The results of the potential analysis show a daily water consumption for residential use of 113 - 128 liters per person and working day (Monday to Friday) and of 103 - 145 liters per person and weekend day and a daily room or bed water consumption of 157 - 197 liters per room and day (hotel) and of 182 - 327 liters per bed and day (hospital). All time-variation curves (cp. fig. 1 to 6) illustrate a well distinct drinking water peak during the morning hours. The average in-house waste water temperatures of 21 to 26 °C show - in comparison to renewable energy sources - the high source-temperature level. The highest hourly values of the waste water temperature of more than 28 °C occur during the drinking water consumption peaks whereby a possible decentralised energetic use is supported. The analysis of the influence of a fluctuating cold water temperature to the waste water temperature level results in a high correlation of the two temperatures. The regression analysis shows that an increase or a decrease of the cold water temperature of 1 K effects an increase or a decrease of the average waste water temperature from 0.3 to 0.38 K for the residential buildings and from 0.47 to 0.51 K for the hotel and the hospital. A seasonal variation of the quantity of sewage cannot be found. In order to find out the daily shower behavior a survey was conducted in the two student residences. As a result, the residents use the showers

mainly in the morning, whereby the morning peak in the time variation curves can be explained.

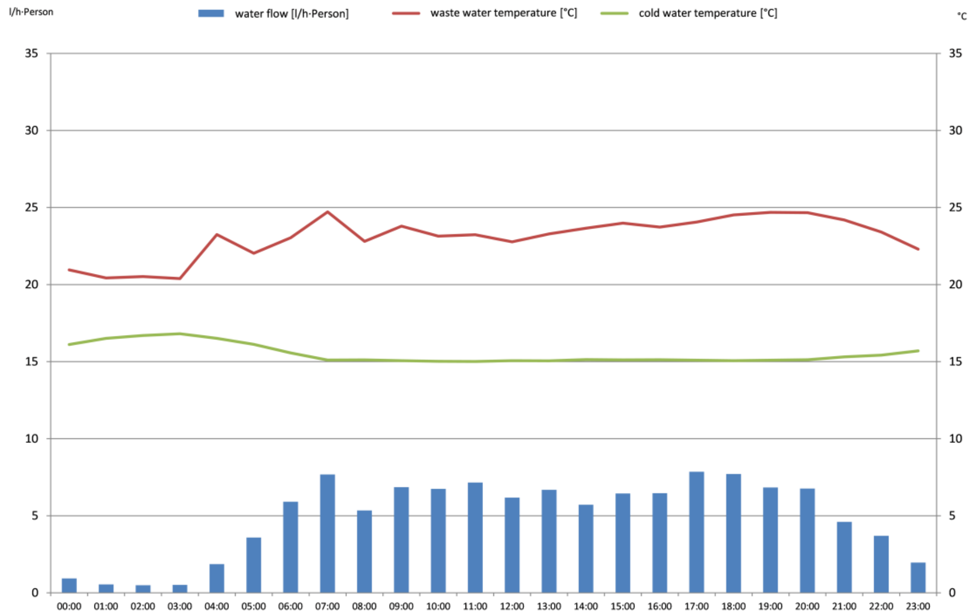

Figure 1: Time-variation curve multi-family house in Düren (DNW), workdays

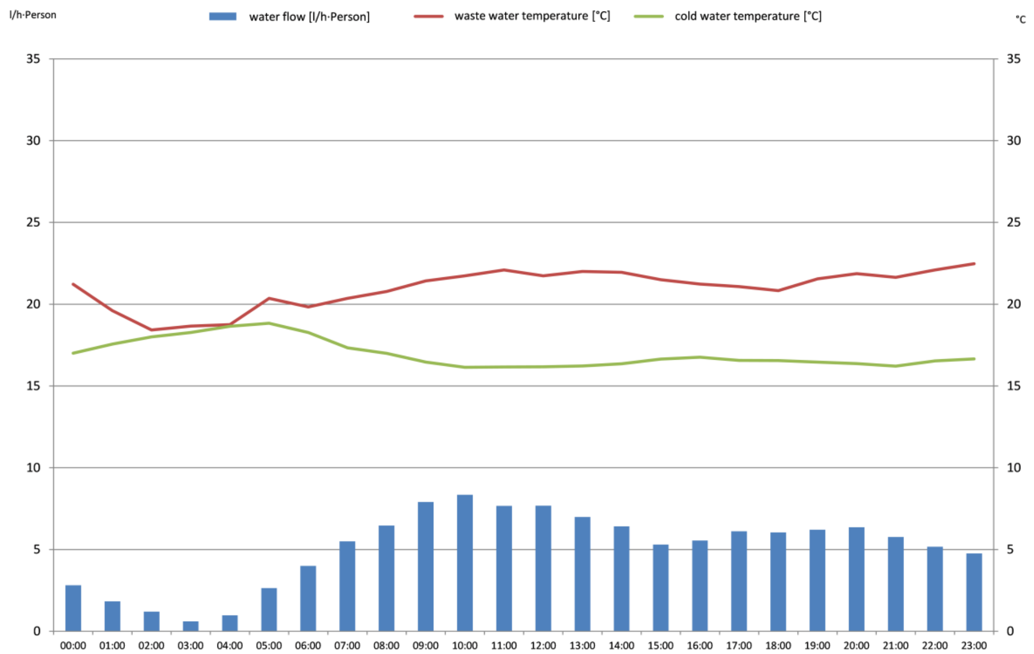

Figure 2: Time-variation curve multi-family house in Pforzheim (PFG), workdays

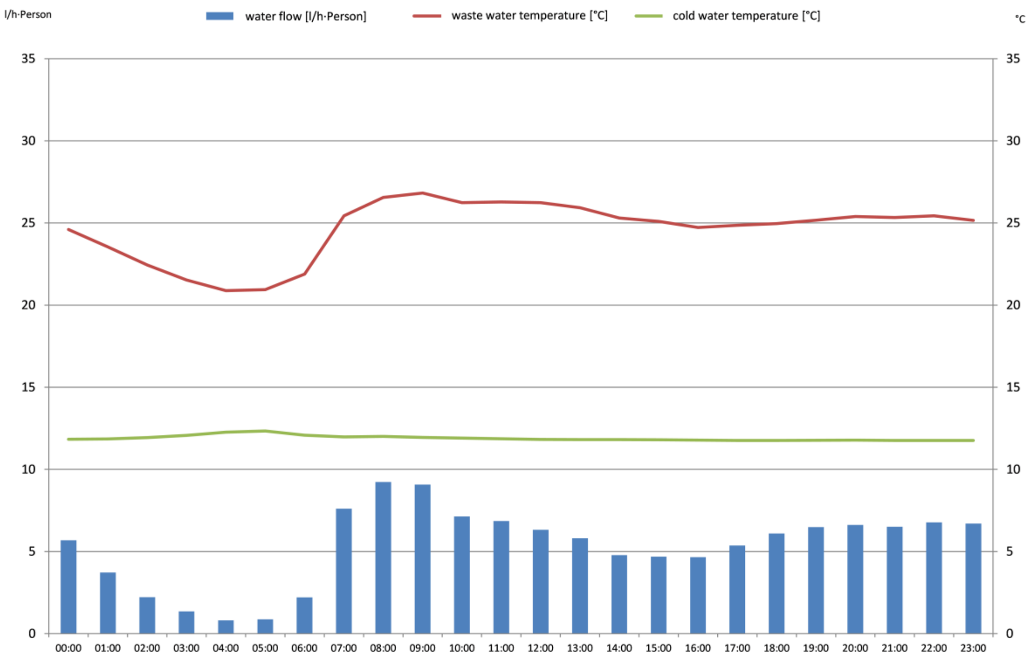

Figure 3: Time-variation curve Otto Petersen Haus (OPH), workdays

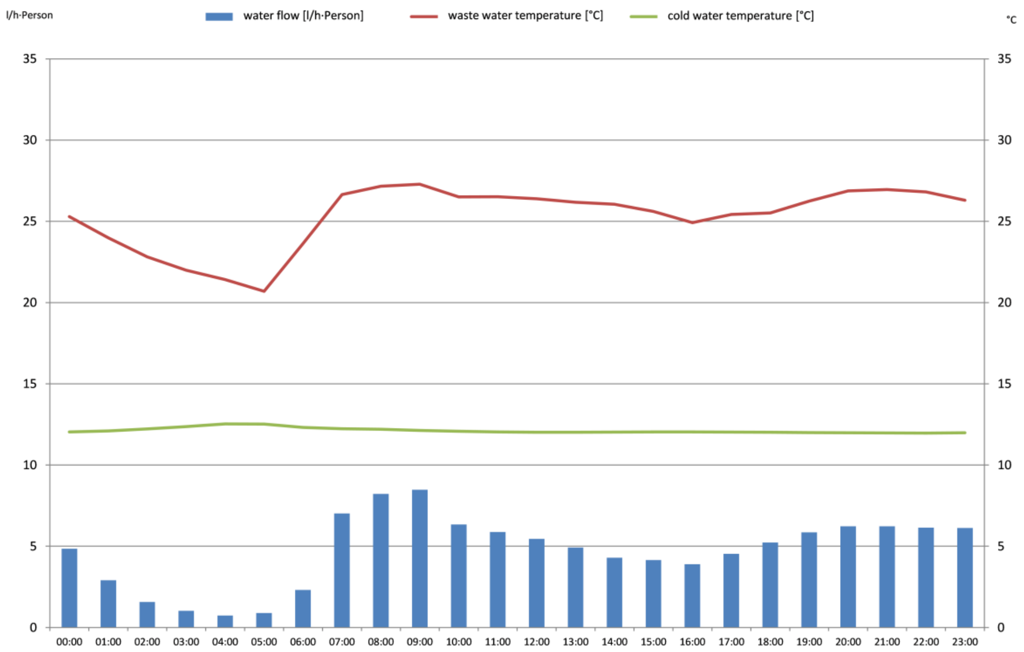

Figure 4: Time-variation curve Theodore von Kármán Haus (TKH), workdays

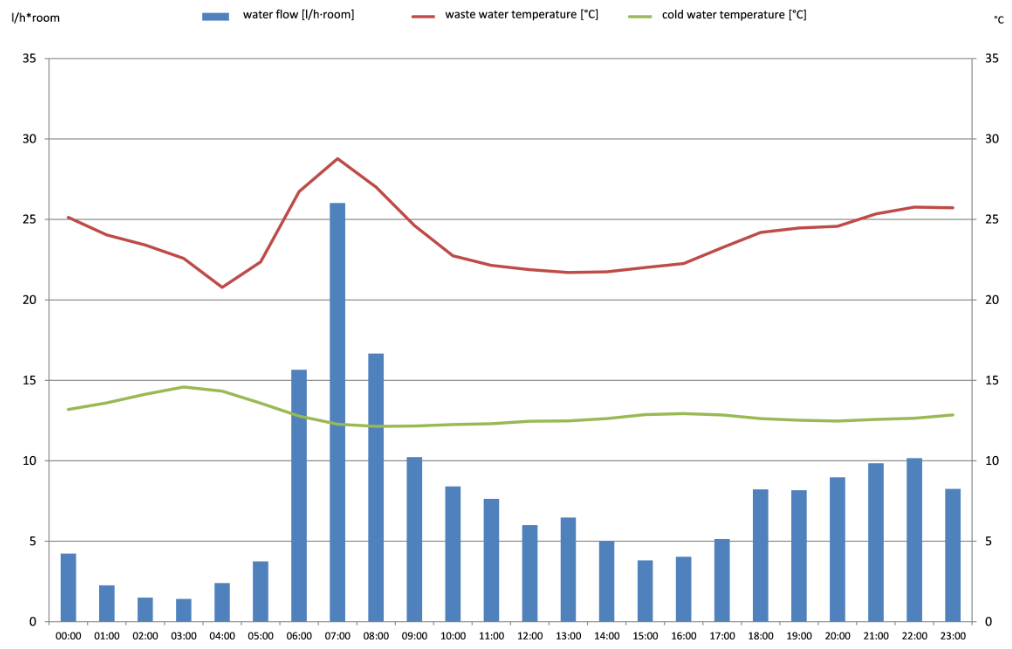

Figure 5: Time-variation curve Business-Hotel, Tuesday - Friday

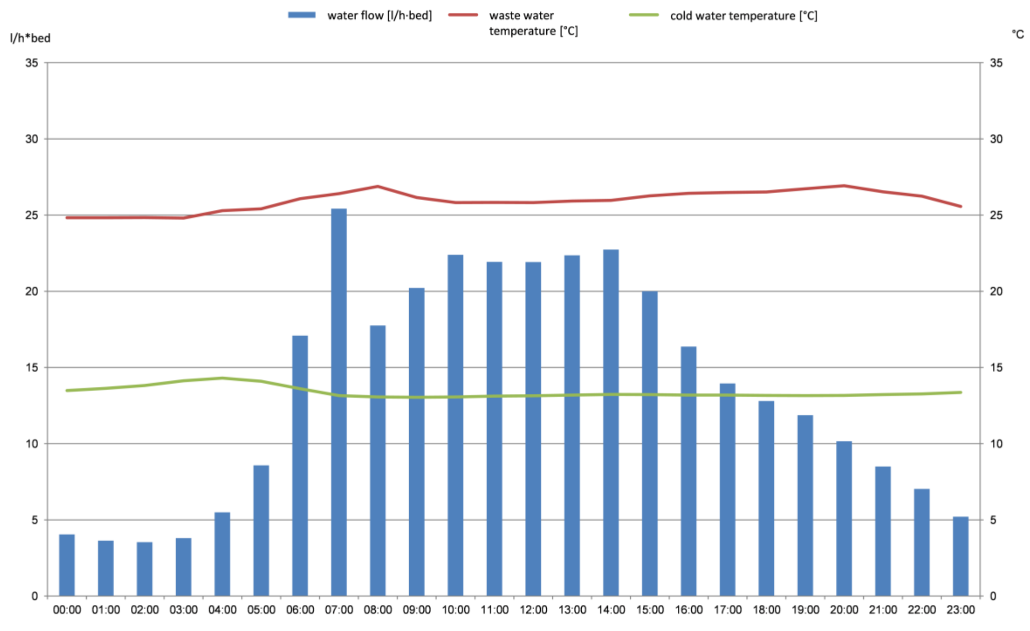

Figure 6: Time-variation curve Luisenhospital (LUI), workdays

A possible concept for using the waste water heat lies in the domestic water heating by bivalent designed heat systems (cp. fig. 7) that are powered by a waste water heat pump as well by a conventional second generator (a gas boiler for instance). The bivalent system enables a preheating of the drinking water by the heat pump and a heating up to the hygienic minimum temperature of 60 °C by the second generator. The simulation results for these bivalent designed domestic water heating systems show for the four considered residential buildings - on basis of further assumptions - with an average biofilm thickness of 1 mm at the sewage-sided heat exchanger in a waste water storage and with a preheating temperature of 45 °C performance factors of the heat pump of 4.6 to 5.5, that corresponds to energy cost savings from 18.8 to 22.6 € per person and year and to a reduction of CO2 emissions from 37.9 to 47.1 kg per person and year. With these energy cost savings the investment in decentralised waste water heat pump systems is for the considered buildings profitable. An increase of the mean biofilm thickness on the sewage-sided heat exchanger leads due to the insulating effect to a deterioration of the efficiency of the used heat pump. Using the example of one of the student residences the performance factor is reduced from 5.5 to 3.5 (heating coverage 48%) with an increase of the biofilm from 1 to 5 mm. With an average biofilm thickness of 3 mm or greater an uneconomical operation of the heat pump system is expected.

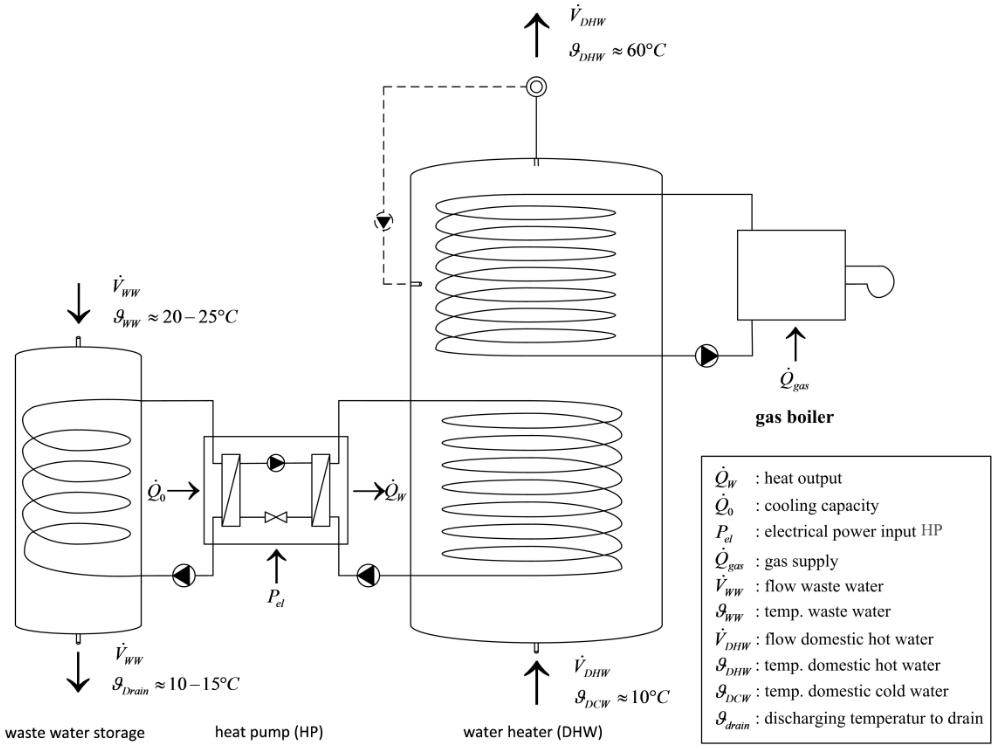

Figure 7: In-house waste water heat pump system

Conclusion

Within the building, domestic waste water provides a high energetic potential that can be efficiently used with heat pump technology. The high performance factors of waste water heat pumps show that, firstly, the waste water heat recovery system can be used efficiently in terms of energy policy as well as economical profitably with containable payback periods and, secondly, a significant contribution to the reduction of CO2 emissions of buildings is possible. Only the biofilm layer impedes the energy recovery und requires further analysis. Furthermore, a practical low-maintenance cleaning method for clearing the heat exchanger is required.

Key data

In-house heat recovery of domestic waste water for increasing the energy efficiency of builings

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