



## Single-family house with brine-to-water heat pump and fresh water system for domestic water mode



### Contribution of the Austrian national project

### Summary

The Austrian Institute of Technology (AIT) developed a standardised heat pump monitoring as quality control measure.

This Best Practice Sheet presents field monitoring results of a brine-to-water heat pump for combined space heating and DHW operation in alternate mode installed in a low energy house with a specific heat load of  $34 \text{ W/m}^2$ . The system is operated monovalently, i.e. no back-up heater is installed. The system uses three single U-tube borehole heat exchangers of about 50 m as heat source. As space heating emission system a  $272 \text{ m}^2$  floor heating system at low design temperatures of  $35^\circ\text{C}/30^\circ\text{C}$  is applied. The domestic hot water (DHW) is produced instantaneously by a fresh water system connected to a 500 l DHW storage.

The brine-to-water heat pump yields a good seasonal performance factor of the generator system of an  $\text{SPF-G} = 4.3$  in space heating mode due to low supply temperatures. In DHW operation, on the other hand, the Seasonal Performance Factor with an  $\text{SPF-G} = 2.4$  is significantly lower due to the higher supply temperature of the DHW operation. However, an overall  $\text{SPF-G} = 4.0$  is reached due to a fraction of 87% space heating energy.

Compared to a condensing gas boiler with an efficiency of 97% the heat pump system can reduce the  $\text{CO}_2$ -eq.-emission by 63% and reaches an SPF based on primary energy of 3.2 and thereby a reduction of primary energy of 73% based on  $\text{CO}_2$ -eq.-emission and primary energy factors used in Austria.

### Building data

- Location: Felling, Lower Austria
- Inhabitants: 4 persons
- Year of commissioning: 2004
- Medium-weight construction, heated area  $272 \text{ m}^2$
- Design heat load (ÖN M7500):  $9.3 \text{ kW}$  ( $34 \text{ W/m}^2$ )



**Introduction**

The Austrian Institute of Technology (AIT) has developed a standardised monitoring method for heat pump systems in order to enhance the quality management of heat pump installations. The monitoring method is an instrument to prove the functionality and performance of installed heat pump systems. In the course of the IEA HPP Annex 32 project, heat pump systems were tested under real conditions in order to evaluate their performance. Therefore, nine conventional heat pumps for space heating and domestic hot water (DHW) and two compact units, which were situated in Upper- and Lower Austria as well as Styria, have been analysed. The system described in this Best Practice Sheet uses a ground-source heat pump with floor heating emission system for space heating and a fresh water system with 500 l storage in DHW operation.

**Technical concept**

The building of a specific heat load of  $34 \text{ W/m}^2$  is equipped with a brine-to-water heat pump with scroll compressor for alternate space heating and DHW. The heating capacity of the heat pump is  $11.8 \text{ kW}$  at B0/W35. The ground-source consists of 3 single U-tube boreholes with a pipe diameter of  $40 \text{ mm}$  and a length of  $58 \text{ m}$ ,  $53 \text{ m}$  and  $49 \text{ m}$ , respectively. This yields a specific heat extraction of  $58 \text{ W/m}$ . The nominal electrical power of the installed source pump is  $130 \text{ W}$ .

In space heating operation the heat pump is directly connected to a  $272 \text{ m}^2$  floor heating emission system designed for a maximum flow temperature of  $35 \text{ }^\circ\text{C}$  and a design temperature difference of  $5 \text{ K}$ . The circulation pump of the space heating system has a nominal electrical power consumption of  $55 \text{ W}$ . The low temperature design and the direct connection of the heat pump to the floor heating emission system, which has sufficient capacity, improves the seasonal performance.

In DHW operation the heat pump is switched to a  $500 \text{ l}$  DHW storage, which is connected to a fresh water system by an external heat exchanger. The installed emission pump or storage loading pump, respectively, has an electrical power of  $55 \text{ W}$ .

The system operates monovalently, i.e. no back-up heating is installed.

The DHW temperature was set to  $48 \text{ }^\circ\text{C}$ , but the measured average temperature was  $51.6 \text{ }^\circ\text{C}$ . The advantages of a fresh water system are a hygienic DHW production, which avoids legionella, no separate DHW storage is necessary and there are no problems with calcinations of the components, e.g. heat exchangers.

**Market status**

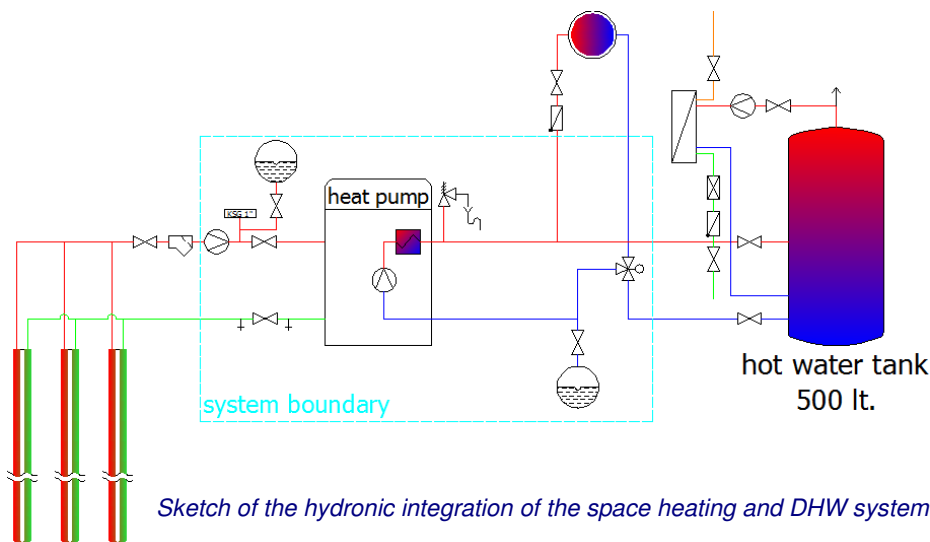
The system is available on the market.



The front view of the monitored building



The heat pump unit



Sketch of the hydronic integration of the space heating and DHW system

**Technical data of the system**

Heat pump unit:	brine-to-water heat pump with 3 single U-tube borehole heat exchangers of $\approx 50 \text{ m}$
Operation mode:	alternate SH/DHW
Capacity of the source:	$9.3 \text{ kW}$ ( $58 \text{ W/m}$ )
Refrigerant:	R407C (2.35 kg)
Thermal output / COP (heating unit)	
B0/W35:	$11.8 \text{ kW}$ / 4.6
B0/W50:	$11.1 \text{ kW}$ / 3.1
Floor heating system:	$272 \text{ m}^2$
Design temperatures:	
Space heating	$35 \text{ }^\circ\text{C}/30 \text{ }^\circ\text{C}$
DHW	$48 \text{ }^\circ\text{C}$
Electrical consumption:	
Source pump:	$130 \text{ W}$
Sink pump:	$55 \text{ W}$
DHW:	Fresh water system
DHW storage:	$500 \text{ l}$



## Field monitoring

The system boundary includes the generation system comprising the heat pump and eventually installed back-up heaters as well as the source system. Inlet and outlet temperatures as well as mass flows of the heat pump source and sink side are monitored in an interval of 1 s and stored as 15 min average values. The electrical energy consumed by the heat pump compressor, the compressor on-/ off cycles and the operating hours are registered every 15 min to characterise the performance.

The monitoring period covers year-round monitoring data from 01. February 2008 to 01. February 2009.

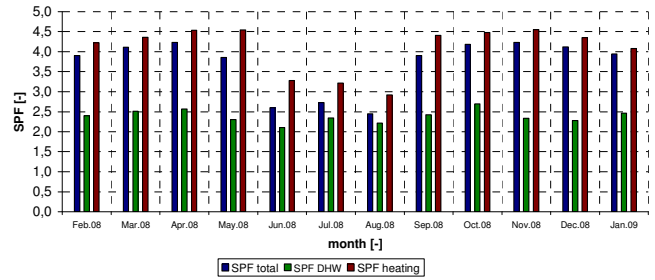
The total heat energy produced by the heat pump in the monitored period was 15191 kWh. 13624 kWh (50 kWh/(m<sup>2</sup>a), 90 % of the heat), is produced in space heating mode which is consistent to the low energy building and better than the legal requirement of the period. The annual DHW consumption is with 1567 kWh quite low. The corresponding consumed electrical energy is 3168 kWh in space heating mode and 659 kWh in DHW mode yielding a total consumption of 3827 kWh. Thus, the fraction of DHW energy is only roughly 10% of the space heating energy consumption, which is on the one hand due to the large area of the building. On the other hand, the DHW energy consumption of 400 kWh/(pers.·a) is relatively low.

The space heating operation yields a good Seasonal Performance Factor of the Generator system (SPF-G) of 4.3, while the performance in DHW operation is with an SPF of 2.4 significantly lower due to the higher measured supply temperature of 52 °C. The overall SPF of the system is 4.0 due to the high fraction of space heating energy.

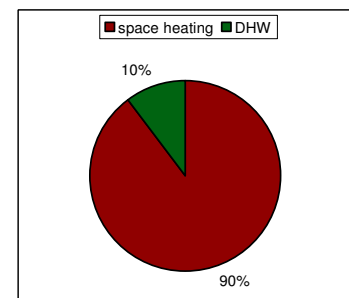
The space heating energy depicted in summertime is due to an error in the three way valve, which automatically switches to space heating operation. Therefore, at the start of the DHW operation, the three-way-valve has to switch first, which leads to a small fraction of space heating energy even in the summertime, i.e. in the months from June to August, where only DHW is needed. Due to the higher DHW temperatures, the SPF for this energy produced for space heating leads to a lower SPF.

Source temperatures were evaluated to 6.3 °C in winter and to 14 °C in summer. This leads to an annual average temperature of 8.5 °C.

Due to the measurement concept the auxiliary energy consumption could not be evaluated separately.

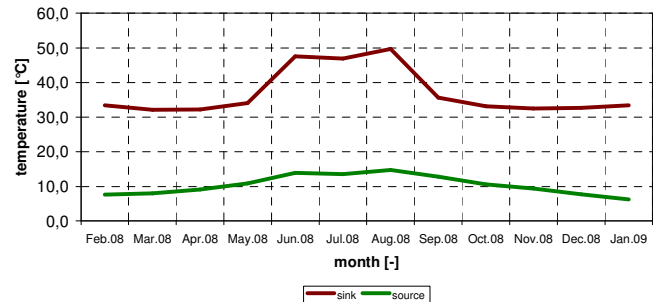


Seasonal performance factor Generator 2008/2009

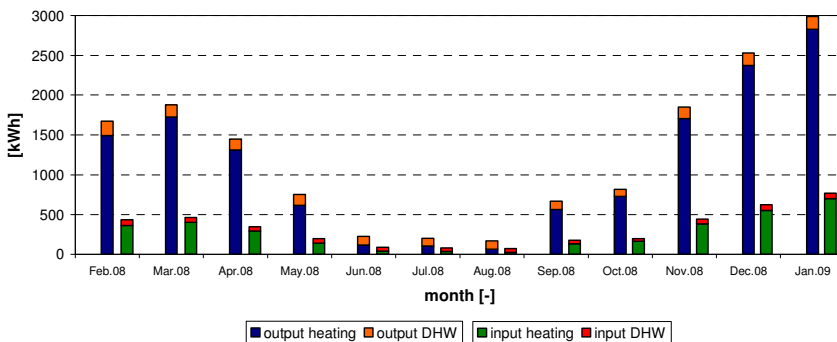


Space Heating:	13624,0 kWh
Hot water:	1567,0 kWh
<b>Total:</b>	<b>15191,0 kWh</b>
Total energy Input: 3827,0 kWh	

Fractions of energy use 2008/2009



Monthly average source and sink temperature



Monthly energy input and output in the monitoring period

### Performance indicators

#### Seasonal performance factors

Overall SPF-G:	4.0
SPF-G space heating:	4.3
SPF-G domestic hot water:	2.4

#### Operation time:

Heating period:	229 d
DHW period:	year-round
Total operation time	1373 h
DHW operation time	600 h



## System performance and optimisation

Due to the low temperature design the space heating performance is with 4.3 quite good, but the DHW operation is with 2.4 rather on the lower end. However, the overall seasonal performance is with 4.0 in the typical range of the generator seasonal performance factors of systems measured in other field tests.

The evaluated source temperatures are with an average value of 8.5 °C and a minimum of 6.3 °C quite high. This is a further reason for the good seasonal performance. Additionally, the source system could have been dimensioned smaller. Nevertheless, water as source fluid should be considered, a feasible fluid, if a temperature above 0 °C can be guaranteed. Water as source fluid has the advantages of a higher specific heat capacity and a lower viscosity, which lowers the hydraulic resistance and the auxiliary energy of the source system.

Due to the instantaneous water heater principle, the good heat transfer by an external plate heat exchanger and the large DHW storage of 500 l makes it possible to set a lower temperature for DHW. Moreover, the instantaneous water heater principle of the fresh water system avoids problems with legionella.

No operational problems occurred during the field monitoring. The house owners were satisfied with the good seasonal performance.

## Economy, Ecology and Costs

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Environmental impact of the heat pump based on produced thermal energy\*:

CO <sub>2eq</sub> emission factor:	370 g/kWh <sub>el</sub> .
CO <sub>2eq</sub> emission***:	1415.9 kg
Primary energy factor:	1.26 kWh <sub>prim</sub> /kWh <sub>el</sub> .
Primary energy***:	4822.0 kWh <sub>prim</sub> .
SPF based on primary energy:	3.15

Comparison to thermal energy of condensing gas boiler\*\*:

CO <sub>2eq</sub> emission factor:	247 g/kWh <sub>th</sub> .
CO <sub>2eq</sub> emission***:	3868.2 kg
Primary energy factor**:	1.14 kWh <sub>prim</sub> /kWh <sub>th</sub> .
Primary energy***:	17853.3 kWh <sub>prim</sub> .
Annual efficiency****:	0.97
Primary energy efficiency:	0.85

\* values based on GEMIS Österreich 4.5

\*\* values based on FANINGER (2007)

\*\*\* values based on produced thermal energy from 02/08 until 01/09

\*\*\*\*value based on SIMADER (2007)

## Conclusion

The presented data confirm that brine-to-water heat pumps can be operated monovalently with a high overall performance factor of 4.0 for space heating and DHW due to the low flow temperature design of 35 °C.

The calculated results of CO<sub>2</sub>-emissions and primary energy consumption approve that the described heat pump yields impressive savings of 63% CO<sub>2</sub>-emissions and 73 % primary energy even compared to the best fossil fuel heat generator of a condensing gas boiler with 97% efficiency based on factors used in Austria

## Imprint

### System design

Schnauer Energie Solar und  
Umwelttechnik GmbH & Co KG  
Hafenstraße 57  
3500 Krems

### Field monitoring

Austrian Institute of Technology (AIT)  
Energy Department  
Sustainable Thermal Energy Systems  
Giefinggasse 2  
1210 Vienna, Austria  
Phone: +43-(0)50550-6309  
Fax +43-(0)50550-6613  
E-mail: [andreas.zottl@ait.ac.at](mailto:andreas.zottl@ait.ac.at)  
Web: <http://www.ait.ac.at>

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## Literature

### Andreas Zottl, Heinrich Huber and Christian Köfinger

Task 3 – Field test of integrated heat pumps systems -  
Field test of 10 heat pump systems  
Report Task 3 IEA HPP Annex 32, N 161, Austrian Institute  
of Technology, Vienna, Sept. 2009

## IEA HPP Annex 32

IEA HPP Annex 32 is a corporate research project on technical building systems with heat pumps for the application in low energy houses.

The project is accomplished in the Heat Pump Programme (HPP) of the International Energy Agency (IEA).

Internet: <http://www.annex32.net>

