Best practice

IEA HPP Annex 32

Economical heating and cooling systems for low energy houses

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

AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY

Contribution of the Austrian national project

Summary

The Austrian Institute of Technology developed a standardised heat pump monitoring as quality control measure.
This Best Practice Sheet presents field monitoring results of a ground water-to-water heat pump for combined space heating and DHW operation.
As space heating emission system a 241 m^2 floor heating system at low design temperatures 35 °C/30 °C is applied. The space heating includes a buffer storage.
The domestic hot water (DHW) is produced alternately by switching the heat pump to the 500 l DHW storage, which is connected to a fresh water system.
In heating mode, the water-to-water heat pump reaches a high seasonal performance factor of the generator SPF-G of 4.5. In DHW operation, the performance is with SPF-G of 3.1 also higher than for other sources despite a high measured average DHW temperature of 54 °C. The energy weighted overall performance factor yields a SPF-G of 4.2 due to a fraction of 85% space heating energy.
Compared to a condensing gas boiler with high efficiency the heat pump system can reduce the CO_2-eq.-emissions by 66% and reaches an SPF based on primary energy of 3.3 and thereby a reduction of primary energy of 75%, if primary energy and CO_2-eq.-emission factors used in Austria are taken for the calculation.

Building data

- Location: St. Peter/Au, Lower Austria
- Inhabitants: 6 persons
- Year of commissioning: 2004
- Medium-weight construction, heated area 264 m^2
- Design heat load (ÖN M7500): 16.2 kW (61 W/m^2)

International Energy Agency
Heat Pump Programme

Introduction

The Austrian Institute of Technology (AIT) has developed a standardised monitoring method for heat pump systems in order to enhance the quality management in 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 efficiency. Therefore, nine conventional heat pump systems and two compact units, which were situated in Upper-, Lower Austria and Styria, had been analysed. The system described in this Best Practice Sheet uses a ground water-source heat pump with floor heating emission system for space heating and a fresh water system with 500 l storage for DHW operation.

The front view of the described building

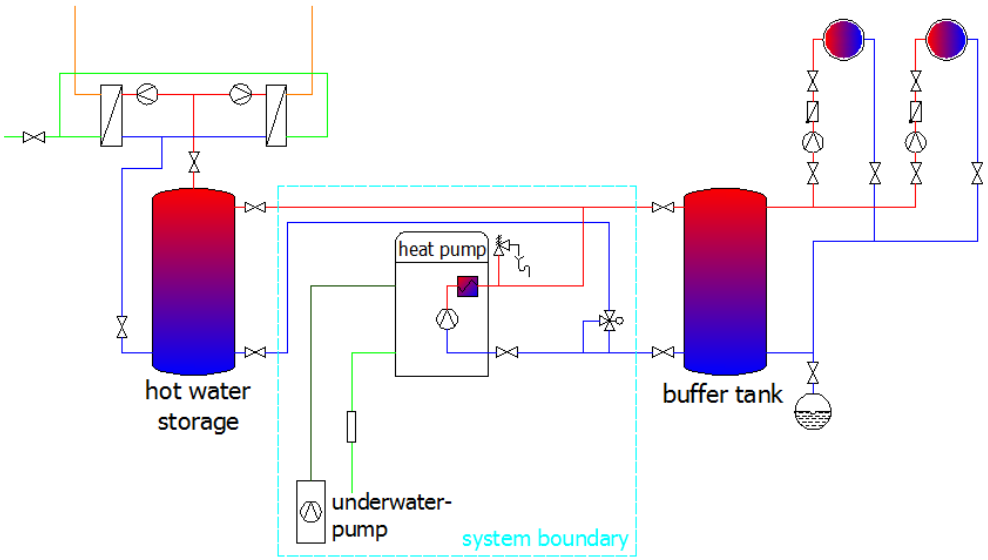
Technical concept

The building of a calculated specific heat load of 61 W/m^2 is equipped with a ground water-to-water heat pump with scroll compressor for alternate space heating and DHW.
The heating capacity of the heat pump is 19.4 kW at W10/W35, i.e. the system design is monovalent and no back-up heating is installed.
The ground water source is connected directly by an extraction well and an injection well. The source pump has a nominal electrical power consumption of 370 W and the installed circulation pump of the space heating distribution system has a nominal power of 90 W. The design source temperature was set to constantly 10 °C and yields ideal temperature conditions for the heat pump operation. On the other hand, the auxiliary energy to connect the source is with 370 W higher and the costs for the connection of the source are more elevated compared to other heat sources.
For space heating operation the heat pump is connected to a 241 m^2 floor heating emission system by a buffer storage tank, since several distribution cycles are connected to the heat pump. The design supply temperature of the distributions cycles is 35 °C.
In DHW operation the heat pump is switched to a 500 l DHW storage which is connected to a fresh water system by external heat exchangers. The design DHW temperature was set to 48 °C.

The "Waterkotte" heat pump unit

Market status

All system components are available on the market.



Sketch of the hydronic integration of the space heating and DHW system and system boundary for the performance evaluation

Technical data of the unit

Heat pump unit:	**ground water-to-water heat pump for alternate SH and DHW operation**
Thermal output / COP:	
W10/W35:	**19.4 kW / 5.9**
W10/W50:	**18.1 kW / 4**
Refrigerant:	**R407C (2.65 kg)**
Floor heating emission system:	**241 m^2**
Design temperatures:	**35 °C/30 °C**
Electrical power consumption:	
Source pump:	**370 W**
Sink pump:	**90 W**
DHW operation:	**Fresh water system**
DHW temperature:	**48 °C (design)**
DHW storage:	**500 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.

The monitoring period covers year-round monitoring data of Nov. 2007 to Oct. 2008.

The total heat energy produced by the heat pumps in the monitored period was 19250 kWh. 85% of the heat or 16273 kWh (62 kWh/(m^{2}a)) is consumed for space heating operation which is higher than the consumption of a low energy building, but better than the legal requirement of the period.

The annual DHW consumption is with 2977 kWh or 15% of the overall heat consumption rather low for a low energy house and regarding the fact, that the house is inhabited by 6 persons.

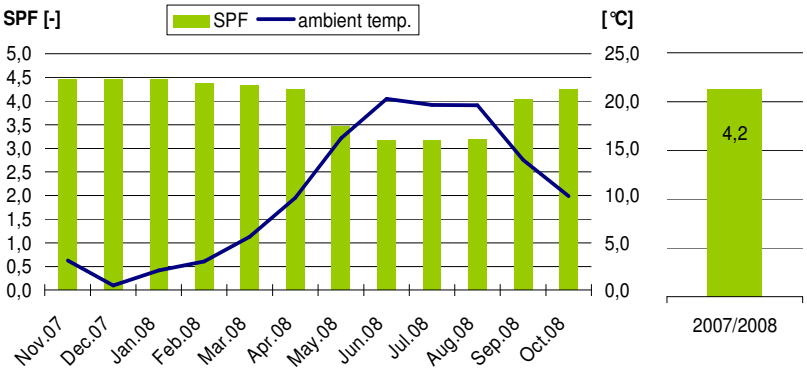
The total electrical energy consumption is 4532 kWh, which can be split up to 3584 kWh for the space heating operation and 948 kWh for the DHW operation.

The space heating operation yields a good Seasonal Performance Factor of the generation system (SPF-G) of 4.5, even though the average measured sink temperature of the period is with 36.9 °C rather high. However, the average and stable source temperature of 13.8 °C explains the high performance. The measured range of source temperatures of the heat pump is between 13.1 °C and 16.3 °C.

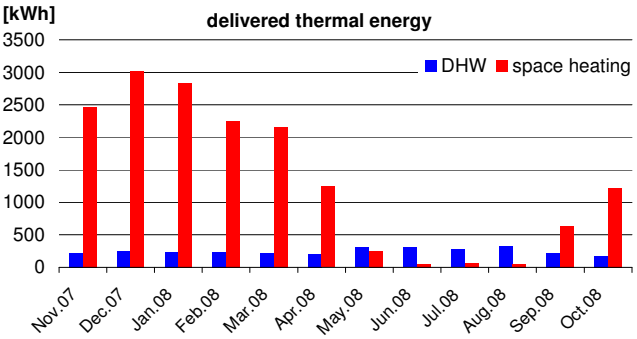
The DHW operation is with an SPF-G of 3.1 also good and on average higher than for other heat sources. This is mainly due to the stable and high source temperatures also in wintertime in comparison to the average for other heat sources. Therefore, the SPF-G is above 3 despite the rather high measured DHW temperatures of 54 °C.

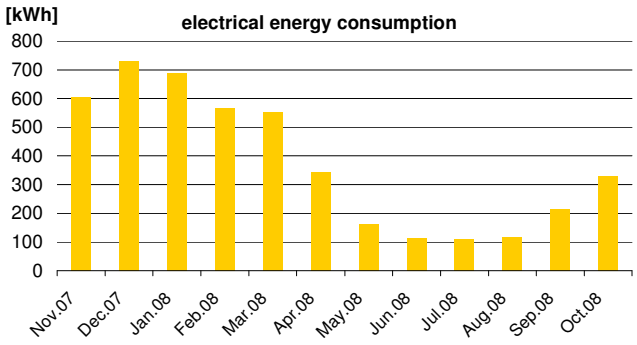
The overall performance of the system is SPF-G = 4.2 as energy weighted average of the two operation modes.

An evaluation of the source energy would have been interesting, since ground water source heat pumps have normally higher auxiliary expense on the source side. However, due to the measurement concept the fraction of auxiliary energy could not be evaluated separately, but only the total electricity consumption.

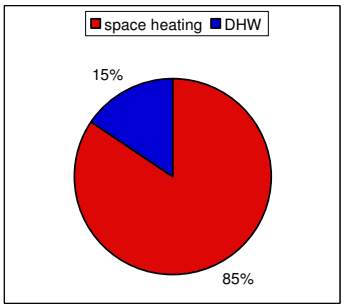


Seasonal performance factor (monthly profile and total value for monitoring period) and ambient temperature (monthly average)





Energy delivered and consumed in 2007/2008



Space Heating:	16273,0 kWh
Hot water:	2977,0 kWh
Total:	**19250,0 kWh**
Total energy Input:	4532,0 kWh

Energy delivered and consumed in 2007/2008

Performance indicators

Seasonal performance factors

Overall SPF space heating and DHW:	**4.2**
SPF heating unit:	**4.5**
SPF domestic water unit:	**3.1**

Operation time:

Heating period:	**215 d**
DHW period:	**year-round**

System performance and optimisation

The overall seasonal performance factor of 4.2 is good and reflects the excellent source temperatures of ground water source systems. A space heating performance factor of 4.5 is in the range of the best indirect ground-coupled systems which have a design temperature of the emission system below 30 °C. Direct expansion systems and systems with CO_2 borehole heat exchanger reached seasonal performance factors above 5 in field tests. A DHW performance factor above 3 is also good, in particular for the high measured DHW temperatures of 54 °C.

The building includes 2 flats, and therefore the buffer storage tank is integrated in the heating distribution system, which on the one hand has the advantage of decoupling the generation and the heating needs, but on the other hand causes heat losses, which, however, are low due to the low temperature level.

Due to the instantaneous water heater principle and the large DHW storage of 500 l it is normally possible to set a low temperature for DHW operation, and consequently, the design DHW temperature has been set to 48 °C. However, during the measurement the average temperature in the DHW storage was evaluated to 54 °C. Furthermore, the instantaneous water heating principle avoids legionella problems and thereby the need to heat the storage volume to high temperatures.

Concluding, the performance of the heat pump is good and has no significant optimisation potentials.

Economy, Ecology and Costs

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

CO_2-eq.-emission factor:	370 g/kWh$_{el.}$
CO_2-eq.-emission***:	1676.8 kg
Primary energy factor:	1.26 kWh$_{prim.}$/kWh$_{el.}$
Primary energy:	5710.3 kWh$_{prim}$
SPF based on primary energy:	3.33

Comparative environmental impact of a condensing gas boiler based on thermal energy produced**:

CO_2-eq.-emission factor:	247 g/kWh$_{th.}$
CO_2-eq.-emission***:	4901.8 kg
Primary energy factor:	1.14 kWh$_{prim.}$/kWh$_{th.}$
Primary energy:	22623.8 kWh$_{prim.}$
Efficiency****:	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 confirms the good performance of water-to-water heat pumps with low temperature emission system and the excellent source temperature.

The calculated results of environmental impact CO_2-eq.-emissions and primary energy consumption presented above prove that the described heat pump contributes to significant savings even compared to best of commonly installed boiler systems, a condensing gas boiler.

Imprint

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Literature

Andreas Zottl, Heinrich Huber and Christian Köfinger
Task 3 – Field test of integrated heat pump systems –
Field test of 11 heat pump systems
Report Task 3 IEA HPP Annex 32,
Austrian Institute of Technology, Vienna, July 2010

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