



Single-family house with heat pumps using a horizontal collector combined with an energy fence and the return temperature of the heating system as heat source of the DHW production



Fraunhofer Institut
für Solare Energiesysteme
Freiburg, Germany

Contribution of the German national project

Summary

The Fraunhofer Institute of Solar Energy systems (FhG-ISE) is carrying out an extensive field test of more than 100 heat pumps installed in low energy houses.

This Best Practice Sheet presents field monitoring results of a heat pump based heating system for a newly built detached house. The system is equipped with two separate heat pumps. The space heating heat pump uses a 100 m² horizontal ground collector which is combined with an energy fence that may be used for source regeneration. The domestic hot water unit is a heat pump with integrated storage which uses the return temperature of the heat emission system (floor heating) as energy source.

The space heating emission system is a floor heating designed to low supply temperatures, which is directly connected to the heat pump.

The source temperature reaches temperatures of 2-15°C during the year, yielding an overall Seasonal Performance Factor of the Generator system SPF-G of 3.94 due to the relatively high DHW energy share of only 20%. The fraction of used auxiliary energy is with 3% quite low.

Due to the good overall seasonal performance factor, the system reaches CO₂-eq.-emission savings of about 30% compared to a condensing gas boiler with an efficiency of 0.97. In terms of primary energy, savings of about 40% can be reached. The SPF-G based on primary energy yields a value of 1.49 compared to a condensing gas boiler of a primary energy efficiency 0.85 based on primary energy factors used in Germany.

Building data

- Location: Spechbach, Baden-Württemberg, Germany
- Inhabitants: 4 persons
- Year of construction: 2006
- Heated area: 292 m²
- Design heating load (DIN 4701): 10.8 kW (37 W/m²)



Introduction

“WP-Effizienz” (“HP-Efficiency”) is a German monitoring project run by Fraunhofer ISE in Freiburg. The aim of the project is to collect real performance data from a high number of new buildings equipped with different types of heat pumps. The data from more than 100 buildings have been collected since 2006. The project will run until 2010. The evaluation of the data allows to draw a wide range of conclusions including efficiency comparisons of different systems, the impact of different operation parameters on the performance, optimisation possibilities, typical reasons for technical failures and system breakdowns as well as explanations for other phenomena. The described building is monitored as part of the “WP-Effizienz” project.

Technical concept

The monitored system is designed for the low temperature floor emission system and consists of two separate heat pumps.

The heat pump for space heating is a ground-coupled one. A horizontal ground collector combined with the energy fence serves as heat source. An energy fence is a system of pipe work located above the ground surface. Brine can be pumped through it, if the environment (solar irradiation, wind or ambient temperature) provides additional energy gain. It can also be used for the regeneration of the ground source – the brine heated by the energy fence can be pumped through the horizontal ground collector without operation of the compressor. This may provide higher brine temperatures than in conventional horizontal ground collectors.

The domestic hot water heat pump includes an integrated storage tank. It uses the floor heating system as heat source. If the space and the DHW heating operate at the same time, the DHW heat pump uses the return of the space heating as heat source. In times with no space heating, the energy stored in the floor emission system thermal mass is used i.e. the building is cooled by the DHW operation. In such a case the circulating water, which nearly has room temperature, is cooled by the heat pump, which provides relatively high source temperatures which positively affects the performance.



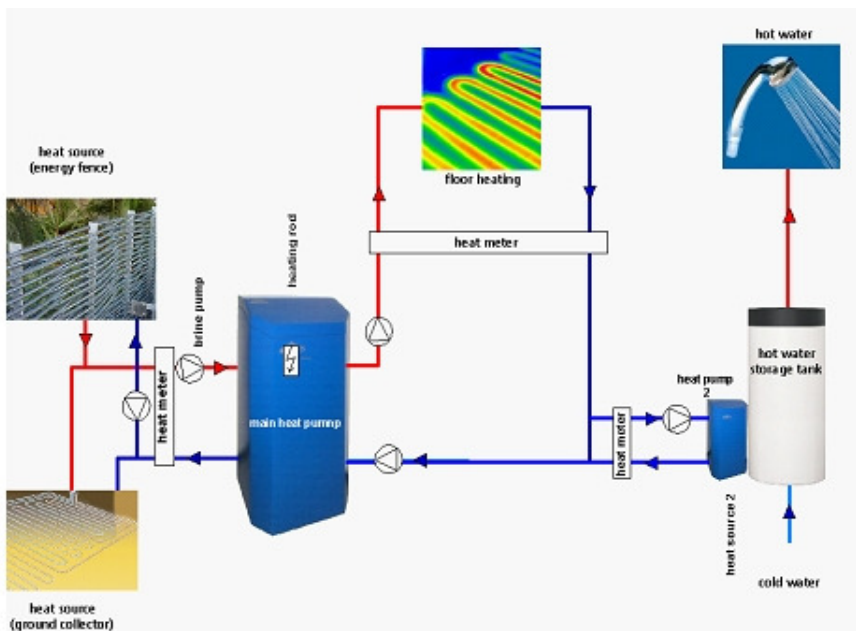
The front view of the monitored building



The heat pump

Current market situation

All components of the system as well as the system itself are being produced and are available on the market.



Sketch and measurement concept of the monitored heating and DHW system

Technical data of the unit	
Space heating unit:	ground-coupled heat pump
Energy emission system:	low temperature floor system
Energy sources:	horizontal ground collector (100 m ²) combined with energy fence
	292 m ² floor heating emission system
Thermal output / COP(space heating):	
B0/W35:	11.2 kW / 4.6
Refrigerant:	R407C
Defrosting agent:	33% ethylene glycole
Domestic water unit:	heat pump integrated in the storage

Field monitoring

The building is monitored within the scope of the “WP-Effizienz” project since November 2007 and will at least be monitored until the end of 2010. The monitoring period covers the complete year of 2008.

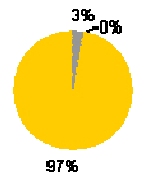
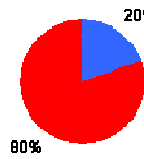
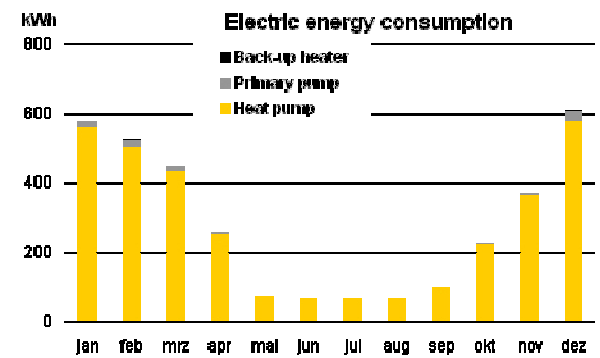
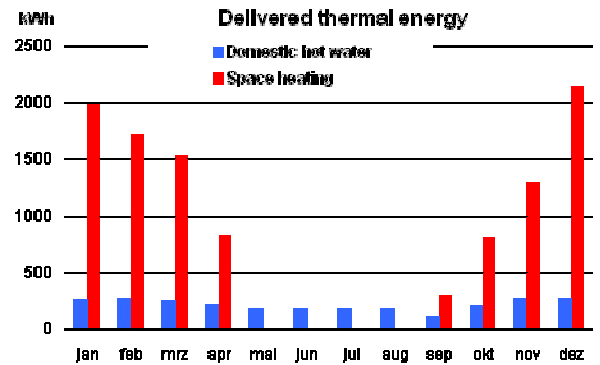
The temperatures, flows, powers and energies in the brine circuit as well as space heating and domestic water heating circuits are recorded once per minute. The consumption of the electrical energy by all system components is stored as well. The collected data are transmitted to Fraunhofer ISE where automatic data quality control and further processing including data filtration, computation of sums, averages and other factors concerning day, month and year are performed.

The thermal energy delivered by the heating system in 2008 was 13256.8 kWh. The amount of energy used for space heating was 80% corresponding to 10592.7 kWh or 36.2 kWh/(m²a) which is a normal value. The corresponding electrical energy consumed was 3357.3 kWh of which 97% was consumed by the heat pumps. The additional electrical consumption of the back-up heater is with 9.2 kWh negligible.

This energy consumption yields an overall Seasonal Performance Factor of the generation system SPF-G of 3.94.

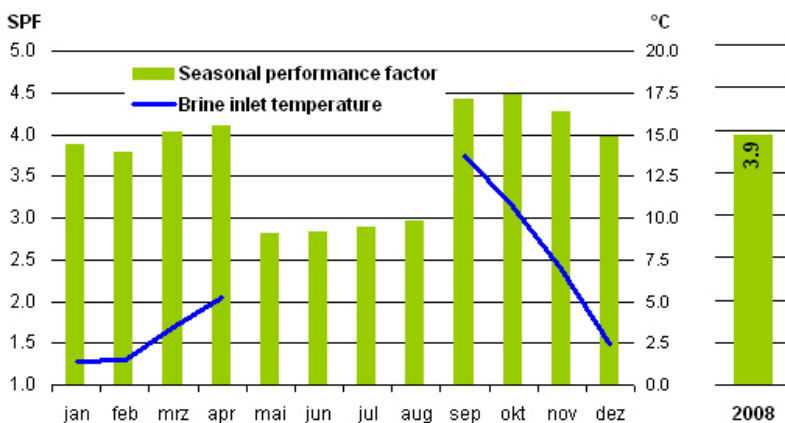
The yearly profile of the overall SPF-G and the brine inlet temperature are presented in the graph below. Times of lower system performance correspond to months, in which no or very little energy for space heating was needed. During these months only the domestic hot water heat pump was used. As no space heating took place, the heat pump worked with lower source temperature (room temperature) which negatively affected the performance of the heat pump. About 77% of the source energy for the domestic water unit was delivered without simultaneous space heating operation.

The energy fence provides extra energy for the brine circuit of the space heating unit which supports the regeneration of the ground source and increases the temperature of the brine. This results in an increased performance of the whole system. The SPF profile presented below confirms this tendency.



2008 Total		2008 Gesamt	
Space heating:	10592.7	Heat pump:	3256.8 kWh
Hotwater:	2664.1 kWh	Primary pump:	100.5 kWh
Total:	13256.8 kWh	Total:	3357.3 kWh
		Back-up heater:	9.2 kWh

Delivered and consumed energy in 2008



Seasonal performance factor (monthly profile and total value for 2008) and temperature of brine inlet

Performance indicators

Seasonal performance factors

SPF heat pump (without backup heater):	3.9
SPF heat pump (with backup heater):	3.9
Minimal SPF (Mai 2008):	2.8
Maximal SPF (October 2008):	4.5

Operation times

Heat pump space heating:	1060 h
Heat pump for DHW:	2353 h



Economy, Ecology and Costs

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

CO ₂ -eq. emission factor:	650 g/kWh _{el.}
CO ₂ -eq. emission***:	2182 kg
Primary energy factor:	2.65 kWh _{prim.} /kWh _{el.}
Primary energy:	8897 kWh _{prim.}
SPF based on primary energy:	1.49

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

CO ₂ -eq. emission factor:	252 g/kWh _{th.}
CO ₂ -eq. emission***:	3341 kg
Primary energy factor:	1.15 kWh _{prim.} /kWh _{th.}
Primary energy***:	15245 kWh _{prim.}
Primary energy efficiency:	0.85

*values based on thesis made by Fraunhofer ISE, considering the whole process chain and the supply energy effort

**values based on GEMIS 4.5

***values based on thermal energy produced in 2008

Conclusion

The presented data confirms that a ground-coupled heat pump which delivers thermal energy for a floor emission system, can achieve high performance. A relatively high source temperature combined with a low temperature in the heating circuit results in a high Seasonal Performance Factor. This does not only lead to savings as far as operating costs are concerned but also with respect to the environment. The computed results of CO₂ emissions and primary energy factors presented above prove that the monitored heat pump has less environmental impact than an alternative solution such as a condensing gas boiler.

Imprint

Field monitoring

Fraunhofer Institute for Solar Energy systems
Thermal Systems and Buildings Department
Heidenhofstraße 2
79110 Freiburg, Germany
Phone: +49 (0) 761/ 4588-5529
Fax +49 (0) 761/ 4588-9529
E-mail: marek.miara@ise.fraunhofer.de
Web: <http://www.ise.fraunhofer.de>

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Literature

Website of the "WP-Effizienz" project

<http://wp-effizienz.ise.fraunhofer.de>

Marek Miara, Christel Russ, Rainer Becker

Wärmepumpen im Feldtest
KI Luft Kälte Klimatechnik, September 2007, p. 24-27
Outline of project, in German, download at www.annex32.net

Marek Miara

HP-Efficiency
Presentation Annex 32 Workshop, 9th IEA HP Conference,
19.-22. May 2008, Zurich, download at www.annex32.net

Marek Miara

Richtig geplant, wirklich gespart
Interim results WP-Effizienz IKZ Haustechnik Heft 3/2009
(In German), download on www.annex32.net

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>

