



Single-family home with ground-coupled heat pump



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 a large field test of more than 100 heat pumps installed in low energy houses.

This Best Practice Sheet presents field monitoring results of a ground-coupled heat pump providing thermal energy for a newly built detached house.

One borehole of 130 m with double U-Tube heat exchanger is used as heat source. The space heating emission system is a floor heating designed to a supply temperature of 38 °C, which is connected to the heat pump by a heating buffer storage. DHW is produced alternately by switching the heat pump from the space heating operation to a DHW storage.

The source temperature reaches very high temperatures of 9 °C-15 °C during the year, yielding an overall Seasonal Performance Factor of the Generator system SPF-G of 4.11 despite the relatively high DHW energy share of 24%. The fraction of auxiliary energy is with 8% slightly higher than the average.

Due to the good overall seasonal performance factor, the system reaches CO₂-eq. emission savings of about 37% compared to a condensing gas boiler with an efficiency of 1.0. In terms of primary energy, savings of about 44% can be reached. The SPF-G based on primary energy yields a value

Building data

- Location: Neuffen, Baden-Württemberg, Germany
- Inhabitants: 5 persons
- Year of construction: 2006
- Heated area: 150 m²
- Design heating load (DIN 4701): 7.5 kW (50 W/m²)



Introduction

“WP-Effizienz” (“Heat pump 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 large 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 potentials, 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 a low temperature floor emission system with buffer tank. A separate circuit for domestic water heating is equipped with a storage tank. The heat pump operate alternately in SH or the DHW mode and is switched between the modes.

The source energy for the heat pump is delivered by a borehole heat exchanger with a total length of 130 m. The electrical back-up heater is supposed to support the heat pump when peak heating load occurs.

The low heating circuit temperature with a design temperature of 38 °C combined with the relatively constant and high source temperature (9 °C -15 °C) provide good thermodynamic operating conditions for the heat pump. This leads to a high efficiency of the whole system.

Performance is positively influenced by the fact that the concept of the heat distribution and the emission system is not too complex. The use of a limited amount of control equipment reduces the risk of failures, operation strategy errors and electrical energy consumption.

Another factor contributing to the generally high performance factors is the careful installation of the system. Well-designed and executed piping reduces the loss of pressure and energy which positively affects the general efficiency of the heating system.

Current market situation

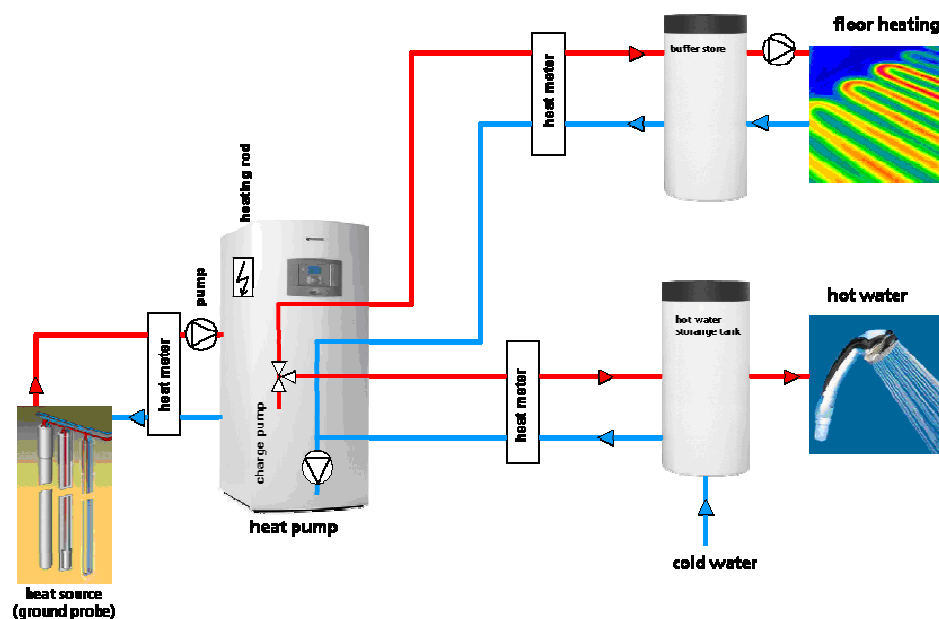
The monitored system is available on the market.



The front view of the monitored building



The heat pump and the measurement equipment



System sketch of the monitored system

Technical data of the unit

Heat pump:	ground-coupled heat pump for alternate SH and DHW operation
Refrigerant:	R407C
Energy source:	1 borehole of 130 m
Defrosting agent:	22% ethylene glycol
Heating capacity / COP:	
B0/W35:	7.3 kW / 4.1
B0/W50:	7.0 kW / 3.0
Emission system:	low temperature floor heating
Design temperature:	
SH	38 °C



Field monitoring

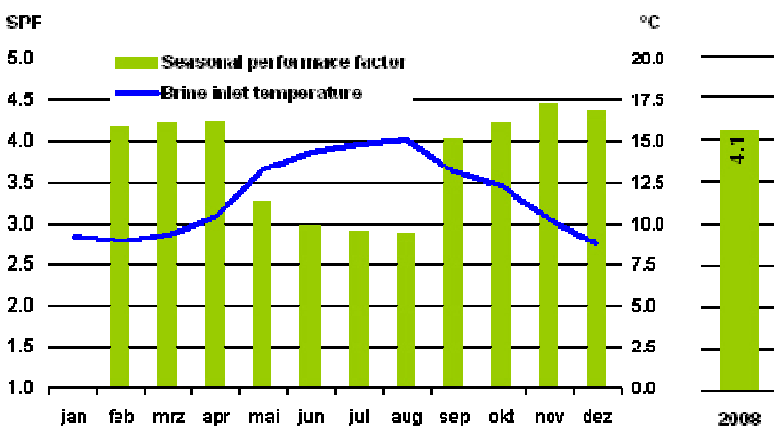
The building is monitored within the scope of the “WP-Effizienz” project since November 2007 and will at least be monitored until the end of 2010. The monitoring period covers the complete year of 2008.

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 levels are performed.

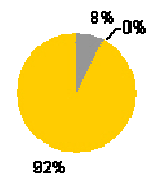
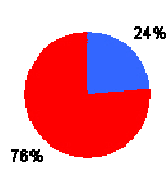
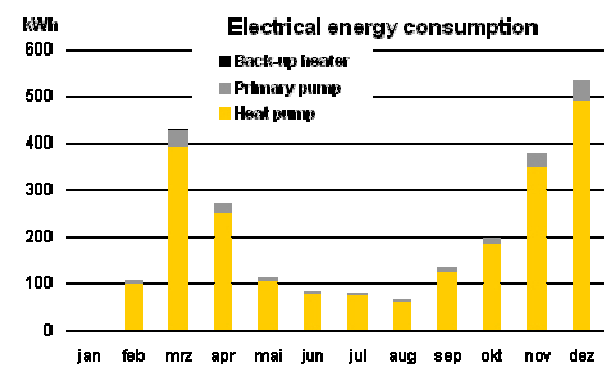
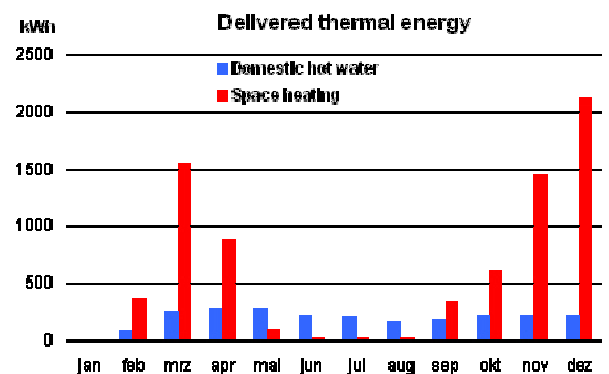
The thermal energy delivered by the heat pump in 2008 was 9790.1 kWh. The amount of energy needed for space heating was 76% or 7467.0 kWh ($50 \text{ kWh/m}^2\text{a}$) which is below the standard value and at the upper limit of a low energy house. The corresponding electrical energy consumed was 2380.8 kWh (fraction of energy consumed by the heat pump 89%).

Consumption of electrical backup heater is negligible.

The energy amounts given above determine an overall Seasonal Performance Factor of the Generator system SPF-G of 4.11. A yearly profile of the performance factor and the brine inlet temperature is presented in the graph below. Times of lower system performance corresponds to months, in which no or very little energy for space heating was needed. The increase of the average brine inlet temperature which can be observed during these months does not compensate the increase of the average temperature of hot water delivered by the heat pump ($\approx 35 \text{ }^\circ\text{C}$ for space heating and $52 \text{ }^\circ\text{C}$ for domestic water heating). Because when the average difference between the source and the output temperature is higher in summer, the performance factor drops. An increase of performance correlating with an increase of the brine inlet temperature can be observed when a high demand of energy for space heating (from February to April) was recorded. The amount of the non-productive electrical energy consumption (energy used by the heat pump for controlling without any compressor activity) is much higher in summer which also contributes to the observed decrease of system efficiency.



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



2008 Total		2008 Total	
Space heating:	7467.0 kWh	Heat pump:	2185.4 kWh
Hot water:	2323.1 kWh	Primary pump:	185.4 kWh
Total:	9790.1 kWh	Total:	2380.8 kWh
		Back-up heater:	2.2 kWh

Delivered and consumed energy in 2008

Performance indicators	
Seasonal performance factors	
SPF heat pump (excl. backup heater):	4.1
SPF heat pump (incl. backup heater):	4.1
Minimal SPF (August 2008):	2.9
Maximal SPF (November 2008):	4.4
Operation times	
Heat pump total:	1147 h
Heat pump space heating:	832 h
Heat pump for DHW:	314 h

Economy, Ecology and Costs

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

CO ₂ -eq. emission factor:	650 g/kWh _{el} .
CO ₂ -eq. emission***:	1549 kg
Primary energy emission factor:	2.65 kWh _{prim.} /kWh _{th} .
Primary energy:	6315 kWh _{prim.}
SPF based on primary energy:	1.55

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***:	2467 kg
Primary energy emission factor:	1.15 kWh _{prim.} /kWh _{th} .
Primary energy:	11258 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 produced thermal energy in 2008

**** based on a boiler efficiency of 0.97

Conclusion

The presented data confirms that a ground-coupled heat pump with a floor emission system can achieve high performance. This does not only lead to savings concerning operating costs, but also with respect to the environment. The computed results of CO₂-eq. emissions and primary energy presented above prove that the described heat pump affects the environment significantly less than an alternative solution such as a condensing gas boiler.

Imprint

Field monitoring

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Literature

Website of the “WP-Effizienz” project

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

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

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

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Richtig geplant, wirklich gespart
Interim results WP-Effizienz IKZ Haustechnik Heft 3/2009
(In German), download at 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>

