Best practice

IEA HPP Annex 32

Economical heating and cooling systems for low energy houses

Passive house with ground-coupled heat pump compact unit and ventilation heat recovery

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 brine-to-water heat pump compact unit with ventilation heat recovery for the operation modes space heating, DHW, space cooling and ventilation in one unit. The 3.3 kW compact unit is installed in a passive house and connected to a 350 m^2 horizontal ground collector as heat source. The space heating energy is emitted to the room by an 80 m^2 low temperature wall heating system with a design temperature of 35 °C/30 °C.
The seasonal performance factor of the generator SPF-G reaches an overall SPF-G of 4.3. In space heating operation, the SPF-G reaches a good value of 4.7. In DHW operation, the seasonal performance factor is with an SPF-G of 3.6 significantly higher than SPF-values commonly reached with conventional brine-to-water heat pumps. The larger SPF-G value may be due to higher ground temperature caused by the passive cooling operation. The passive cooling operation by direct coupling of the horizontal ground source collector to the wall heating distribution system reaches an SPF-G of 4.7.
Compared to a condensing gas boiler of high efficiency the heat pump system can reduce the CO_2-eq.-emission by 61% and reaches an SPF based on primary energy of 3.4 and thereby a reduction of primary energy of 71%. These values are based on efficiencies, primary energy and CO_2-eq.-emission factors used in Austria.

Building data

- Location: Hitzendorf, Styria, Austria
- Detached single family passive house, 4 inhabitants
- Year of commissioning: 2006
- Medium-weight construction, heated area 180 m^2
- Design heat load (EN 12831): 3.8 kW (21.1 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 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 efficiency. Therefore, nine conventional heat pump systems and two compact units, which were situated in Upper-, Lower Austria and Styria, had been analysed. In the case of two ground-source heat pump compact units with ventilation heat recovery installed in passive houses an extended monitoring has been performed, which includes also the DHW storage and the space heating circulation pump. Results are used to prove the functionality and performance of the system, since they have been recently introduced into the market.

The front view of the passive house

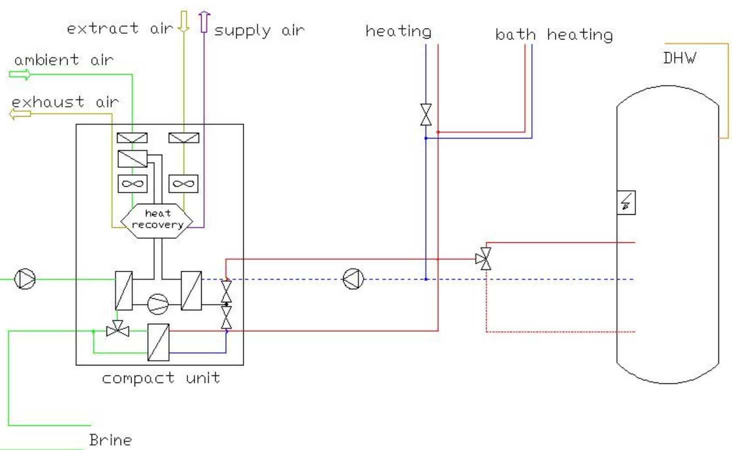
Technical concept

The building is designed according to the passive house standard which has the main requirements of maximum space heating energy need of 15 kWh/(m^2a) and an approved air-tightness of the building envelope n_{50} of max. 0.6 h^{-1}.
The building is equipped with a highly integrated so-called heat pump compact unit with ventilation heat recovery which covers the building functions space heating (SH), domestic hot water (DHW), space cooling (SC) and ventilation (V) with one unit. Contrary to common heat pump compact unit designs for passive houses, where the heat emission is provided by the ventilation system, i.e. the system is equipped with air heating and uses solely exhaust air as heat source. This system concept uses a ground source and a hydraulic emission system, which enables higher capacities and lower supply temperatures. The nominal heating capacity of the heat pump is 3.3 kW at B0/W35 and the design temperatures of the floor heating 35 °C/30 °C. The source system consists of a 350 m horizontal ground collector, which also provides passive space cooling in summertime. For the emission of cooling power to the room, the system uses the same emission system as for space heating, in this case an 80 m^2 wall heating.
Moreover, a 300 l domestic hot water storage is integrated in the casing, which is charged by a desuperheater. The heat pump includes a condensate subcooling used for preheating the outdoor air.
The system is normally operated monovalently, i.e. the installed direct electrical back-up heating is usually deactivated.

The ventilation compact unit with ground-source heat pump

Market status

The heat pump compact unit is available on the market.



Sketch of the ground-coupled heat pump compact unit with ventilation heat recovery

Technical data of the unit

Heat pump unit: brine-to-water heat pump compact unit with ventilation heat recovery
Ground-source system: 350 m pipe in the working space of the building
Capacity of the source: 2.5 kW (7.2 W/m)
Thermal output/COP:
B0/W35: 3.3 kW / 4.5
Wall heating emission system: 80 m^2
Design temperatures 35 °C/30 °C
DHW system:
Design temp.: 52 °C
DHW storage: 300 l
Ventilation system:
Volume flow: 160 m^3/h
Heat recovery efficiency: 85%
Nom. Fan power: 2x35 W

Field monitoring

The evaluation was made based on three system boundaries including the generation system which comprises the heat pump and eventually installed back-up heaters as well as the source system. Thus, in- and outlet temperatures and mass flows of the heat pump source and sink side are monitored in a 1 s interval 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 of Oct. 2008 - Sept. 2009.

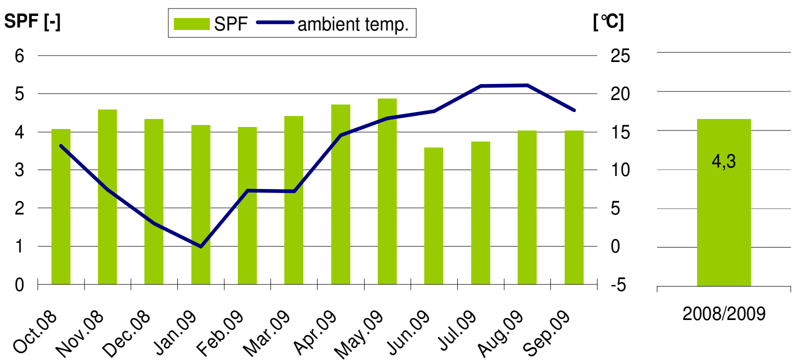
The total energy consumption in the monitored period is 12700 kWh. 49% of the energy or 6302 kWh (35 kWh/(m^2a)) is consumed for space heating operation which is consistent to the low energy building better than the legal requirement of the period, however, the passive house consumption is not reached. The annual DHW consumption is 3511 kWh and thereby 50% of the total consumption, which underlines the low space heating energy consumption. The corresponding overall electrical energy consumed is 3403 kWh.

The seasonal performance factor of the heat pump operation SPF_1, without auxiliary drives, was evaluated to 4.8 for the measured period. The SPF_2 for the generator incl. auxiliaries was split-up into the SPF_2 for space heating and the SPF_2 for domestic hot water. The space heating operation yields a very good generator SPF of 4.7, while the performance in DHW operation is with an SPF of 3.6 lower, but also high for the DHW operation. The high seasonal performance factor for DHW can be explained by the high heat source temperature during summer, generated by the passive cooling operation. The overall SPF of 4.3 for space heating and DHW is due to the higher energy fraction in the space heating mode. The performance of the space cooling yields a performance factor of 4.7.

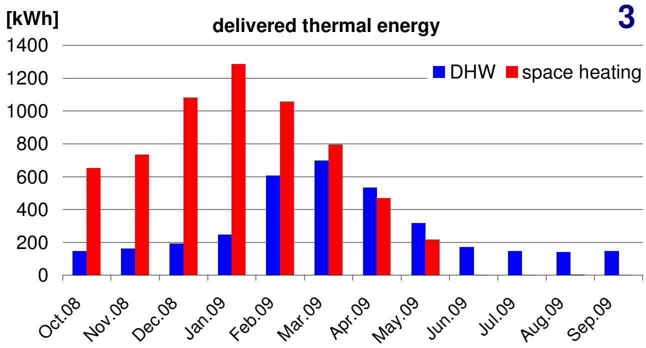
Concerning the evolution of the seasonal performance factor, the highest values are registered in April and May, when ground temperatures are high and supply temperatures of the space heating are low. The lowest value is reached in June with DHW-only operation, while in the following summer month the space cooling operation augments the SPF a bit.

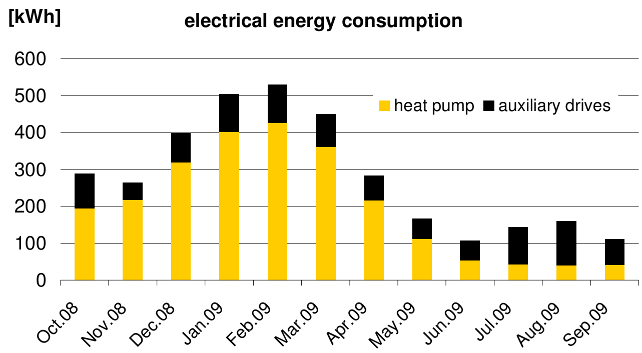
By considering all auxiliary drives the SPF_3 reaches a value of 3.7.

The average outlet temperature during heat pump operation is 35.4 °C at an average source temperature of 6.6 °C.

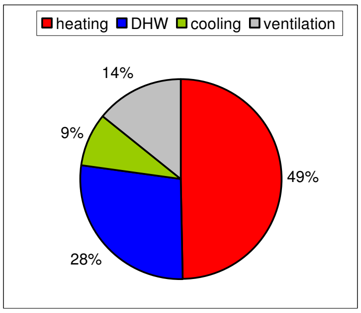


Seasonal performance factor (monthly profile and total value for monitoring period) and ambient temperature





Energy delivered and consumed in 2008/2009



Space Heating:	6302 kWh	Ventilation:	1804 kWh
Hot water:	3511 kWh	Cooling:	1083 kWh
Total Output:	**12700 kWh**	**Energy Input:**	**3403 kWh**

Energy delivered and consumed in 2008/2009

Performance indicators

Seasonal performance factors

Overall SPF space heating/DHW:	**4.3**
SPF heating unit:	**4.7**
SPF domestic water unit:	**3.6**
SPF space cooling	**4.7**

Operation time:

Heating period:	**324 d**
DHW period:	**year-round**
Operation SH	**1533 h**
Operation DHW	**848 h**

Performance and optimisation potentials

The seasonal performance factor in the space heating mode is with 4.7 in the upper range of measured SPF-G. The DHW SPF-G is with 3.6 high, as well, leading to a good overall SPF value of 4.3.

In passive cooling mode, only auxiliary energy is used, since only the pumps are running without a heat pump operation. Therefore, the SPF in the passive cooling mode is with 4.7 rather low. For systems with ground-coupled borehole heat exchangers performance factors around 8 have been measured in residential buildings which still yield potentials for an improvement.

Reasons for the lower seasonal performance can be on the one hand a low amount of energy extracted from the house in the cooling mode, which is due to the fact, that the auxiliary energy consumption is almost constant and not affected by the extracted cooling power.

On the other hand, horizontal ground collectors may have higher ground temperatures in summer due to the higher impact of the outdoor air temperature. Ground temperatures may even be too high to operate the system in the cooling mode.

Moreover, the efficiency of the auxiliary components themselves and thereby the auxiliary consumption could have an impact. Performance factors can be significantly increased by the use of efficient pumps.

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***:	1259 kg
Primary energy factor:	1.26 kWh$_{prim.}$/kWh$_{el.}$
Primary energy***:	4288 kWh$_{prim.}$
SPF based on primary energy:	3.41

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***:	3234 kg
Primary energy factor:	1.14 kWh$_{prim.}$/kWh$_{th.}$
Primary energy***:	14926 kWh$_{prim.}$
Primary energy efficiency****:	0.85

* values based on GEMIS Österreich 4.5
**values based on FANINGER, 2007
*** values based on produced thermal energy from 10/08 until 09/09
****value based on 97% efficiency according to SIMADER, 2007

Conclusion

The presented data confirms that a ground-coupled compact unit reaches a high generator seasonal performance factor of 4.3 due to low flow temperature design of 35 °C in monovalent operation.

The calculated results of CO_2-eq.-emissions and primary energy consumption presented above prove significant reduction potentials of 61% and 71% respectively compared to a condensing gas boiler with an efficiency of 97% and factors used in Austria

Imprint

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Literature

Andreas Zottl, Heinrich Huber and Christian Köfinger
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Field test of 11 heat pump systems,
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