



Retrofitted single-family house with air-to-water heat pumps for radiator space heating emission system and domestic water operation



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 an air-to-water heat pump for space heating. The heat pump is installed in a house with a measured specific heat load in the range of 70 W/m^2 . The building was renovated in the year 2007 and therefore, the existing space heating emission system with radiators is used. The average temperature at the heat pump outlet is with 34°C very low for a radiator emission system. The space heating system contains a 400 l storage installed in the supply line of the emission system.

The DHW is produced by a second, already existing 20-year-old air-to-water heat pump and stored in DHW storage.

Despite the system configuration of an air-to-water heat pump coupled to a radiator emission system the heat pump reaches a high seasonal performance factor of the generator of an SPF-G of 3.2 in space heating mode. The DHW is produced at an SPF-G of 2.6 yielding an overall SPF-G of 3.1.

Compared to a condensing gas boiler with an efficiency of 97% the heat pump system can reduce the CO_2 -eq.-emissions by 52% and reaches as primary energy performance of $2.5 \text{ kWh}_{\text{th}}/\text{kWh}_{\text{pe}}$ and thereby a reduction of primary energy of 64% based on CO_2 -eq.-emission and primary energy factors used in Austria.

Building data

- Location: Klein Meiseldorf, Austria
- Inhabitants: 5 persons
- Year of construction: 2007
- Medium-weight construction, heated area 500 m^2
- Design heat load (ÖN B8135): 23 kW (46 W/m^2)



Background

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 condition 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 analyzed. The system described in this best practice sheet uses an air-source two-compressor heat pump system with radiator emission system for space heating and a separate air-to-water heat pump for DHW production.

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Technical concept

The building is equipped with an air-to water heat pump for space heating and a separate air-to-water heat pump for the domestic water production. The space heating heat pump incorporates two scroll compressors in parallel. The system operates monovalently, i.e. no back-up heating is installed.

The compact air-to-water heat pump is installed outside and operates with two parallel connected scroll compressors for having 2 capacity steps in order to match the heating capacity to the heat load.

The space heating emission system consists of radiators. A 400 l buffer storage is integrated in the supply line of the emission system. By the integration of the storage, the lowest return temperature is returned back to the heat pump unit during the heat pump is in operation. Thereby, the capacity of the rather quick reacting radiator system is increased, a cyclic operation can be reduced and the heat pump works with lower supply temperatures.

The existing radiator system was designed to low temperatures of 55 °C/45 °C, i.e. the radiator area is relatively high compared to common designs in boiler systems to 70 °C/55 °C. Due to the renovation of the building the heat load decreased and therefore the existing radiator system can be operated at even lower supply temperatures.

The DHW is produced independently of the space heating operation by a second already existing 20-year-old air-to-water heat pump, which was already existing before the retrofitting of the building, and stored in a DHW storage.



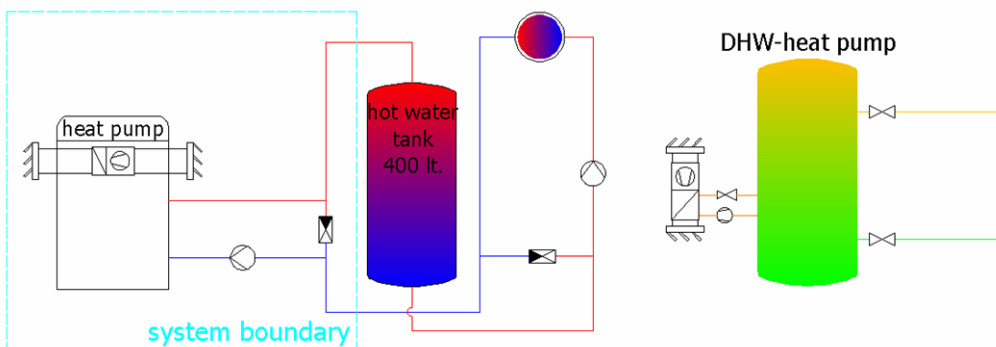
The front view of the monitored building



The "Alpha Innotec" heat pump unit

Market status

The heat pump is available on the market.



Hydronic sketch of the space heating and DHW system of the investigated heat pumps and system boundary for the performance evaluation

Technical data of the unit

Heating unit:	air-to-water heat pump with two parallel scroll compressors
Thermal output / COP (heating unit):	
A7/W35:	36 kW / 4.2
A2/W35:	33 kW / 3.8
A-7/W35:	27.6 kW / 3.1
Refrigerant:	R404A, charge 12.2 kg
Buffer storage:	400 l installed in supply line
DHW-unit:	separate 20 year-old air-to-water heat pump



Field monitoring

In the AIT standard monitoring of heat pumps 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 temperature 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.

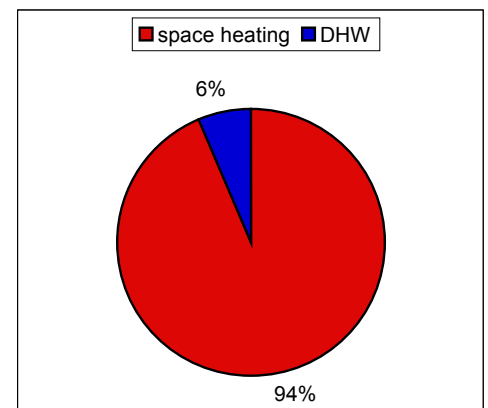
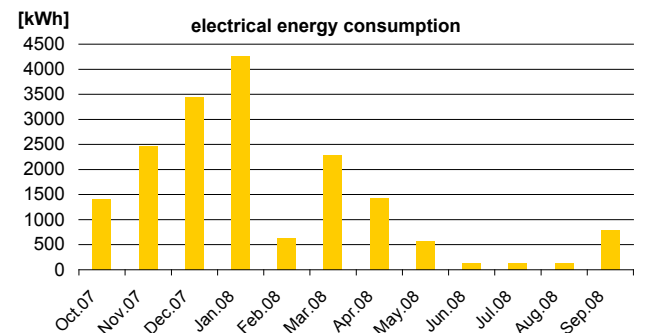
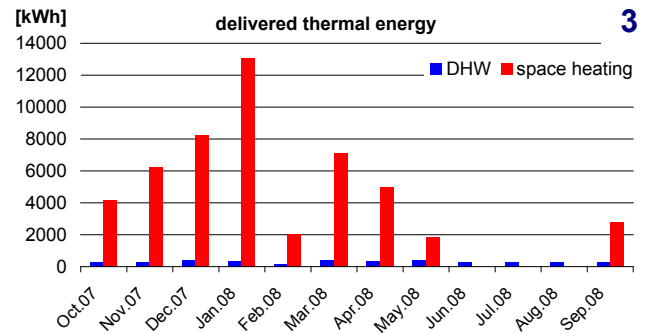
The monitoring period covers year-round monitoring data of Oct. 2007 until Sept. 2008. However, due to a failure of the recording system, no measurements could be evaluated between 29.1.-19.2.2008.

The total heat energy produced by the heat pumps in the monitored period was 54008 kWh. 94% of the heat or 50511 kWh (100 kWh/m²) are consumed for space heating operation which is consistent with the standard building based on the legal requirement of the period. The DHW consumption is with 3497 kWh or 700 kWh/persons in a common range, as well. The DHW share, however, is with 6% low, which is due to the size of the building and the therefore high specific heat load.

The corresponding electrical energy consumed is 17698 kWh. The overall Seasonal Performance Factor of the generator system (SPF-G) of the complete system is 3.1, resulting in a SPF-G in SH-mode of 3.2 and SPF-G in the DHW-mode of 2.6. Due to the energy fractions the low-temperature space heating operation is determining the overall performance.

While the SPF-G in the DHW mode is in the common range and benefits from higher outdoor air temperatures during the summer months, the SPF of the space heating operation is above the average of outdoor-air heat pumps with radiator emission systems. Due to the renovation of the building the heat load decreased and therefore the existing radiator system can be operated with lower supply temperatures, resulting in a low average outlet temperature of only 34.3 °C, which is similar to the common design of a floor heating system. Therefore, the seasonal performance factor also reaches a value similar to a floor heating system.

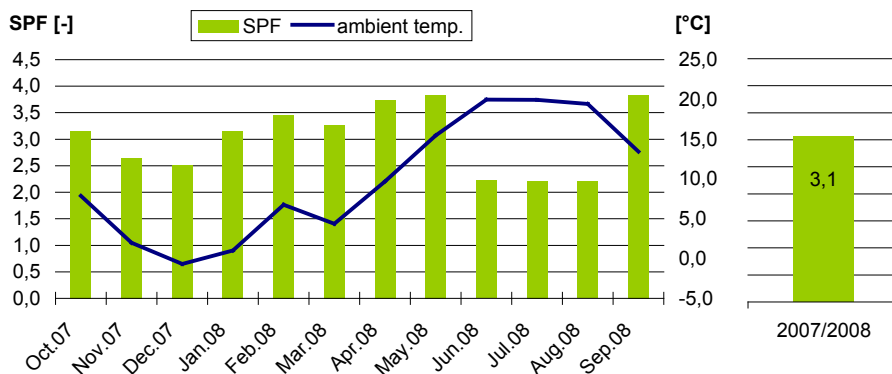
Furthermore the house owners accepted a rather low indoor temperature of 18.4 °C during heating season.



Space Heating:	50511,0 kWh
Hot water:	3497,0 kWh
Total:	54008,0 kWh

Total energy Input: 17698,0 kWh

Energy delivered and consumed in 2007/2008



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

Performance indicators

Seasonal performance factors

Overall SPF-G of the system:	3.1
SPF-G heating unit:	3.2
SPF-G domestic water unit:	2.6

Operation time:

Heating period:	226 d
DHW period:	year-round



System performance and optimisation

Due to the renovation of the building the heat load decreased and therefore, the existing radiator system can be operated with very low supply temperatures similar to a floor heating system which is favourable for a good performance factor of air-to-water heat pumps. For the radiator system a heating buffer tank is installed, since the heating system has little inertia functioning as thermal capacity. Moreover, the air-to-water heat pumps need the heating buffer tanks in the defrost operation with reversible refrigeration cycles, since otherwise the heat pump would extract heat directly from the building during defrosting.

In this system configuration a heat pump with 2 scroll compressors is used to have 2 capacity steps in order to match the heating capacity of the heat pump to the heat load of the building. Especially air-to-water heat pumps have increasing heating capacity with increasing outside air temperatures. The heat pump capacity increases opposite to the heat load of the building. Therefore, a capacity control contributes to the good performance of the heat pump.

Due to the realised low temperature level and the capacity control, the heat pump reaches a good seasonal performance in the retrofitted building in the same range as in new buildings.

Thus, the good performance documented in this Best Practice Sheet confirms the feasibility of retrofitting projects with outdoor air source heat pumps if supply temperatures can be lowered to an adequate range of an annual average around 35°C.

Economy, Ecology and Costs

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

CO _{2eq} emission factor:	370 g/kWh _{el.}
CO _{2eq} emission***:	6548.3 kg
Primary energy factor:	1.26 kWh _{prim.} /kWh _{el.}
Primary energy:	22299.5 kWh _{prim.}
SPF based on primary energy:	2.46

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

CO _{2eq} emission factor:	247 g/kWh _{th.}
CO _{2eq} emission***:	13752.5 kg
Primary energy factor:	1.14 kWh _{prim.} /kWh _{th.}
Primary energy:	63473.3 kWh _{prim.}
Efficiency boiler ****:	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 10/07 until 09/08

****value based on SIMADER, 2007

Conclusion

The presented data confirm that an air-to-water heat pump system can be operated monovalently to cover the entire space heating of the house. Due to low temperature design of the radiator heating system after building renovation the SPF of 3.2 in space heating mode is good and similar to new buildings.

The calculated results of CO₂-emissions and primary energy consumption confirm significant saving potentials compared to a condensing gas boiler.

Imprint

System design

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Field monitoring

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Literature

Andreas Zottl, Heinrich Huber and Christian Köfinger

Field test of integrated heat pumps systems – Field test of 10 heat pump systems
IEA HPP Annex 32 country report Austria Task 3, 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>

