RESULTS FROM FIELD TRIAL WITH GAS HEAT PUMP ZEOTHERM BY VAILLANT

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Abstract: In 2012 Vaillant launched their second generation of gas heat pump “zeoTHERM” to the European market. Since 2009 several zeoTHERM gas heat pump systems have been operating and analyzed as part of a field trial organized by Germany’s “IGWP” (initiative for gas heat pumps in Germany). This report shows the results of the field trial as well as the relevant solar simulations. The total system efficiency was proven to be 35% higher than a “state of the art” heating systems with a wall hung condensing gas boiler. The Vaillant zeoTHERM heat pump system was also proven to be extremely reliable and robust. Since 2010 zeoTHERM has been manufactured in series production and has been freely available in the trade.

Key Words: gas heat pump, zeolite, solar collector, field trial

1 RESULTS FROM THE FIELD TRIAL CARRIED OUT WITH GAS HEAT PUMP ZEOTHERM BY VAILLANT

Within the scope of the “Initiative für Gaswärmepumpen” (IGWP - Initiative for Gas Heat Pumps), a field trial was conducted over 29 sites in different geographical locations across Germany. The spread of the installations has given clear and conceded results of the zeoTHERM heat pump in different environmental situations and heating systems. The zeoTHERM unit is an adsorption heat pump working with the material system zeolite (sorbent) and water (coolant).

2 ZEOLITE

Zeolite is a porous ceramic material produced synthetically. Via the composition and the porous structure it is possible to widely adjust the adsorption properties of a zeolite molecule. The zeolite used at Vaillant is highly hygroscopic.

For many decades zeolite has been used in gas separation / gas cleaning in the form of molecular filters. Since the beginning of the eighties, zeolite has replaced polyphosphates in domestic detergents, they are also used for the eco-friendly softening of water. The working agents of zeolite and water are non-toxic, non-combustible and completely ecological.

3 FUNCTIONAL PRINCIPLE OF THE GAS HEAT PUMP ZEOTHERM

The sorption process runs in two major phases: First, during desorption the water vapour is expelled from the zeolite. The heat transfer medium water is heated up to about 110°C by means of a gas condensing heat cell and flows through the adsorber/desorber. The thus produced hot vapor spreads inside the module, cools down at the bottom part of the module and condenses. The condensation energy that is released in this process phase is then discharged as useful heat.

At the end of the desorption phase the heat supply to the adsorber/desorber is interrupted; as a consequence the pressure and the temperature in the module decrease. As soon as the temperature of the evaporator/condenser falls below the temperature level of the environmental heat source, the adsorption phase starts. Now, "cold" ambient energy is transferred to the evaporator. The coolant in the bottom part of the module evaporates, the cold vapour moves upwards and is adsorbed by the zeolite. The adsorption heat released in this process is then discharged and used as useful heat too.

The evaporation of the coolant at low temperature is realised with environmental heat produced by commercially available solar panels. Considering that this installation requires an environmental output of up to 2 kW for an installation size of 10 to 15 kW, flat plate collectors of 4 sqm are sufficient to cover the heat demand.

4 STRUCTURE

At a net weight of 160 kg, the unit has a width of about 80 cm, depth of 70 cm and height of 170 cm. For ease of installation the unit can be split up for mounting and installation. The heat cell in the upper part contains the complete burner and the primary heat exchanger. All these components are Vaillant standard parts which are familiar to the installer.

The zeolite module and the appliance hydraulics are located in the lower part of the appliance (zeolite unit). This module contains the zeolite and does not require any maintenance. The extent of maintenance work for the zeoTHERM appliance is similar to the common Vaillant gas-fired condensing boilers.

It is recommended to install the zeoTHERM in a matched system (see Figure 1) with bivalent solar storage tank for domestic hot water (d.h.w.) preparation, solar station and solar thermal collectors (flat or tubular). However it can also be integrated in an existing solar thermal system.

Figure1: Complete zeoTHERM system

Thanks to choosing solar energy as environmental heat source the simultaneous operation of direct solar hot water preparation and adsorption is possible.

Due to the compact design of the collectors and the flexible solar mounting systems for both on- and in-roof installations, the zeoTHERM is easy installable and suitable for applications in both new build and retro fit.

5 FIELD TRIAL

For the IGWP field trial, 29 units were installed all over Germany (see Figures 2 and 3) and extensively surveyed and measured.

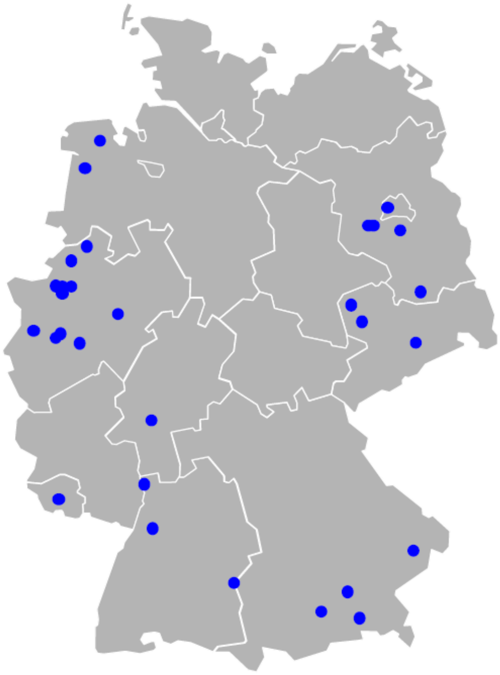

Figure 2: 29 field trial appliances and 4 laboratory appliances of the zeoTHERM (Vaillant) in Germany

Figure 3: Field trial in Odenthal (Remscheid)

The 29 sites monitored as part of this trial confirmed that the zeoTHERM system is 35% more efficient when compared to a condensing gas boiler connected to an under floor heating system. The considered efficiency is defined as usable energy in relation to the gas consumption (see Figure 4).

In locations with high levels of solar radiation the performance of the zeoTHERM heatpump system greatly improves. When installed in high efficient properties with low heating loads even higher levels of efficiency can be expected. The high efficiencies at low heating loads are caused by covering the heat demand by mere heat pump operation. Increasing heating loads involve increasing part of direct heating mode which reduces the efficiency.

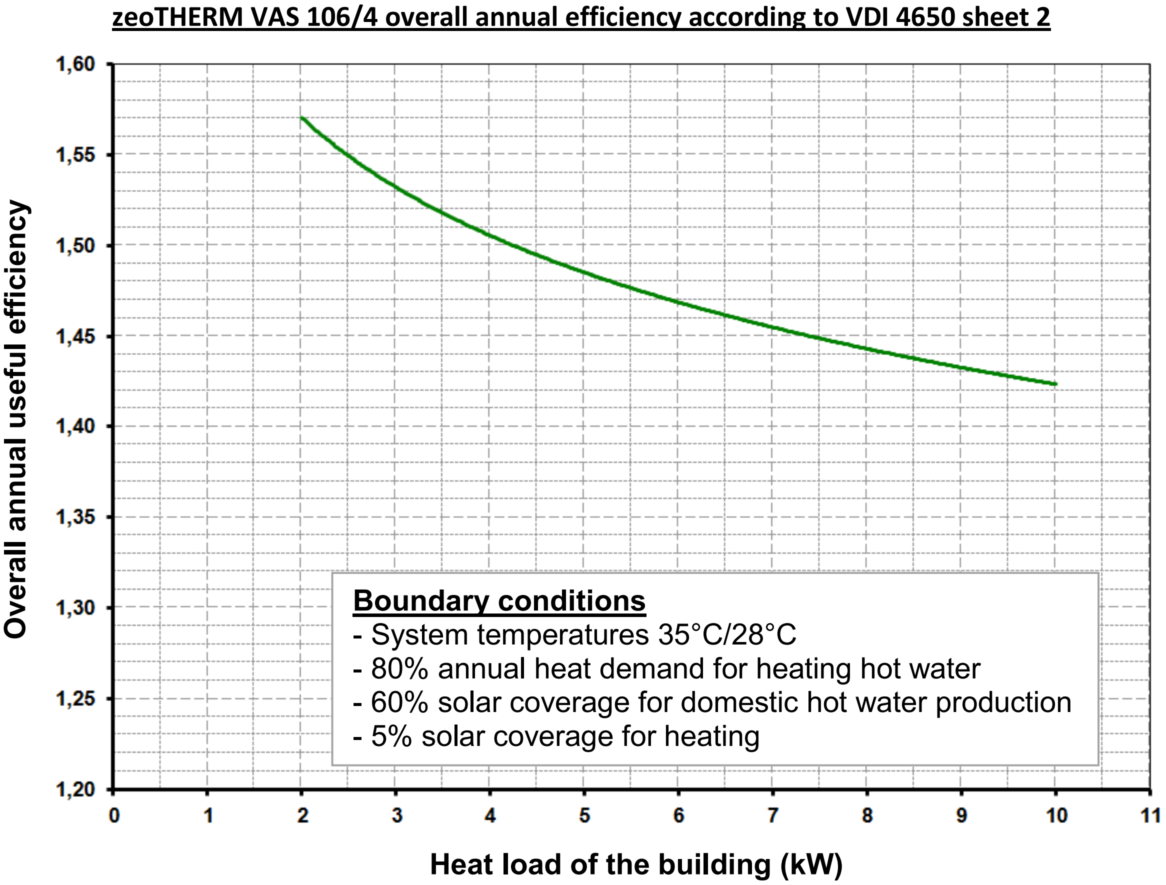

Figure 4: Annual efficiency according to the VDI 4650 sheet 2

From 2011, the zeoTHERM units have been equipped with an integrated solar direct heating function. This allows the zeoTHERM heat pump to link to solar thermal systems, directly transferring solar energy to both domestic hot water and direct solar heating. In this type of system, the zeoTHERM heatpump can make use of the solar energy across the massive temperature range of 3°C to 130°C (see Figure 5).

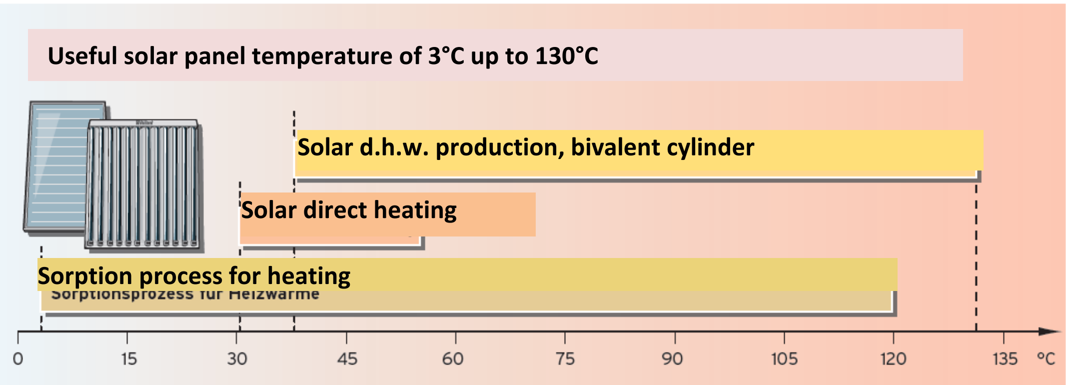

Figure 5: Useful solar collector temperature

6 SOLAR DIRECT HEATING

The zeoTHERM system can transfer solar energy into the system without the need for buffer storage. As a result of this the system operates without any buffer losses and it is possible to realize direct solar heating with only 7 sqm flat plate collector surface.

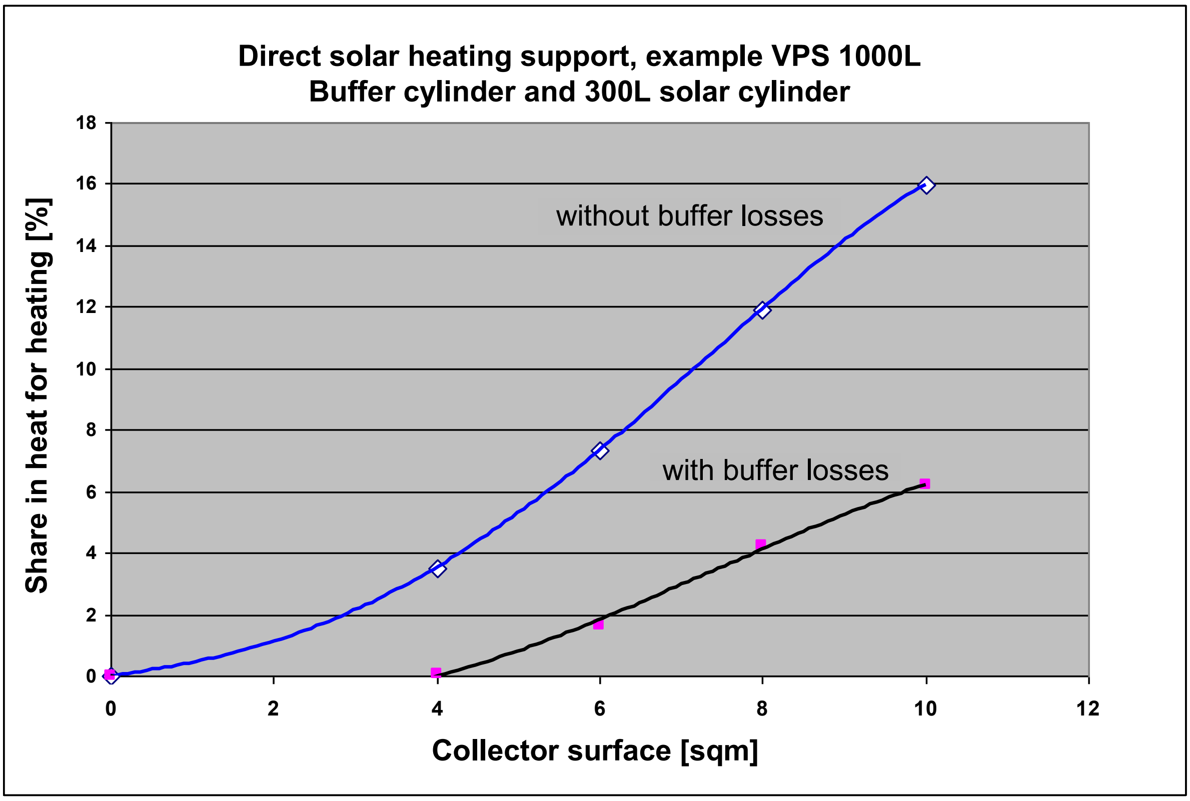

Figure 6: Simulation results [Vaillant]

In Figure 7, we present the time-wise fractions of the condensing DHO (Direct Heating Operation) (incl. production of d.h.w.), of heat pump operation HP and of solar direct heating SDH for the period 20th to 24th October 2011 found with 10 field test appliances positioned all over Germany.

On the average, SDH (solar direct heating) covered the heat demand for 24% of the heating time. The ambient air temperature for monitored period was from 3-10°C with slightly cloudy skies. Even in the winter months January to March 2012, SDH could be recorded during a time slice of 10% on the average. Thus, thanks to SDH, the system efficiency increased by about 10%.

The results from a simulation as well show a solar fraction for heating of 11% and of 60% for d.h.w. production for the installation recommended by Vaillant: equipped with a solar cylinder 300 L for a 3 - 4 person household and an aperture surface of 7.05 sqm. These results prove that the system has been matched such that the production of domestic hot water is not impaired by solar direct heating function. With a higher demand in hot water, such a cannibalization, often discussed among experts, could easily be compensated by an additional solar panel.

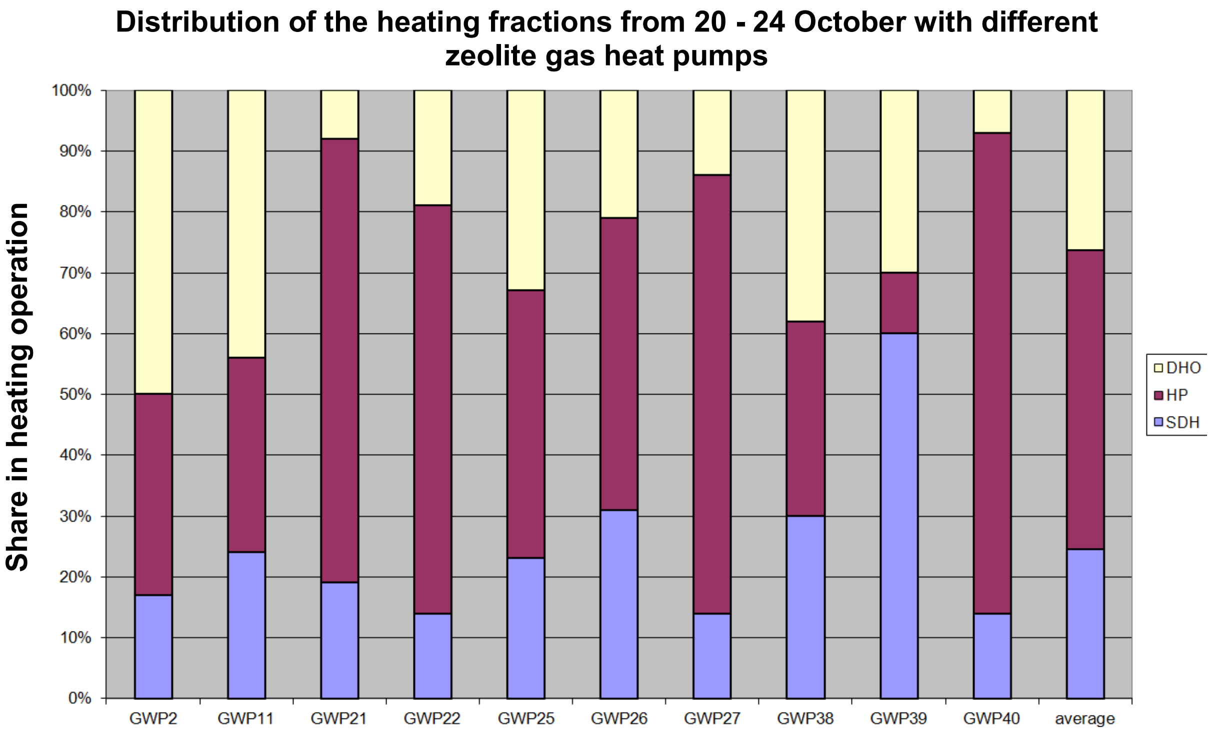

Figure 7: Time-wise fractions of different heating operations

7 PANEL TYPE

As part of this field trial we also compared the differences between the flat plate and evacuated tube solar systems. For these analyses, 4 installations were equipped with evacuated tube collectors (3 x 6 sqm, 1 x 5 sqm). When comparing the systems (Figures 8 and 9), you can see that the evacuated tube collector provides significantly higher temperatures, especially in diffused sun light. Thus, the system equipped with the evacuated tubes offers an average temperature increase of 12.5°C compared to the ambient temperature and with diffused sun light while the flat plate collector installed in the vicinity only supplied an increase of 5°C. With strong solar radiation the temperature ranges are similar.

Simulation confirmed the aforesaid results according to which the evacuated tube collector supplies temperatures that are about 5.3 K higher on the annual average than the flat plate collector temperatures. These higher source temperatures support the operation of installations with higher heating temperatures (55°C/45°C, radiators). Therefore, it is recommended to equip such systems with evacuated tube collectors.

As described in VDI4650 sheet 2, the average temperature difference between the collector temperature and the ambient temperature is determined by

$$T_{koll,in} - T_U = \Delta T_R \cdot \left[1 - e^{-\left(\frac{A}{A_R}\right)} \right] \qquad (1)$$

whereby
A aperture surface of the collector in m^2
ΔT_R reference temperature difference
A_R reference collector surface
with the parameters for flat plate collectors given in Table 1. For the evacuated tube collectors, derived from simulation and field tests, the results are also given in Table 1.

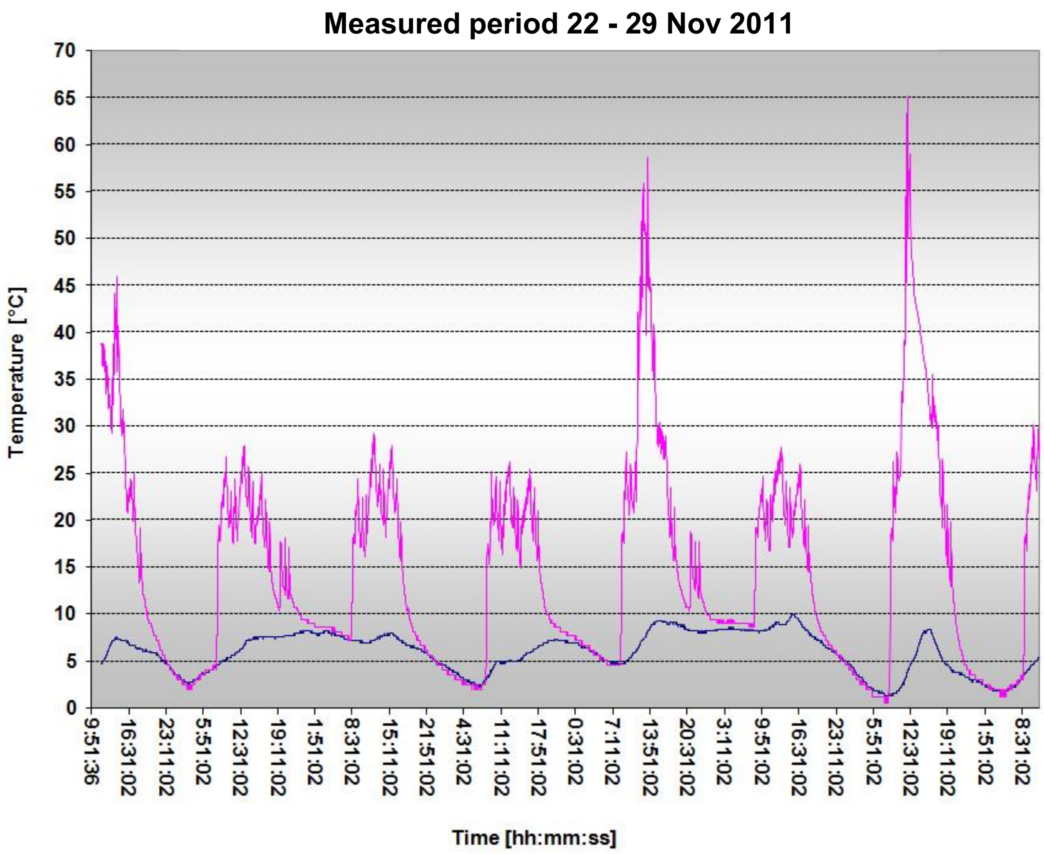

Figure 8: Tube collector (pink) temperature and ambient (blue) temperature

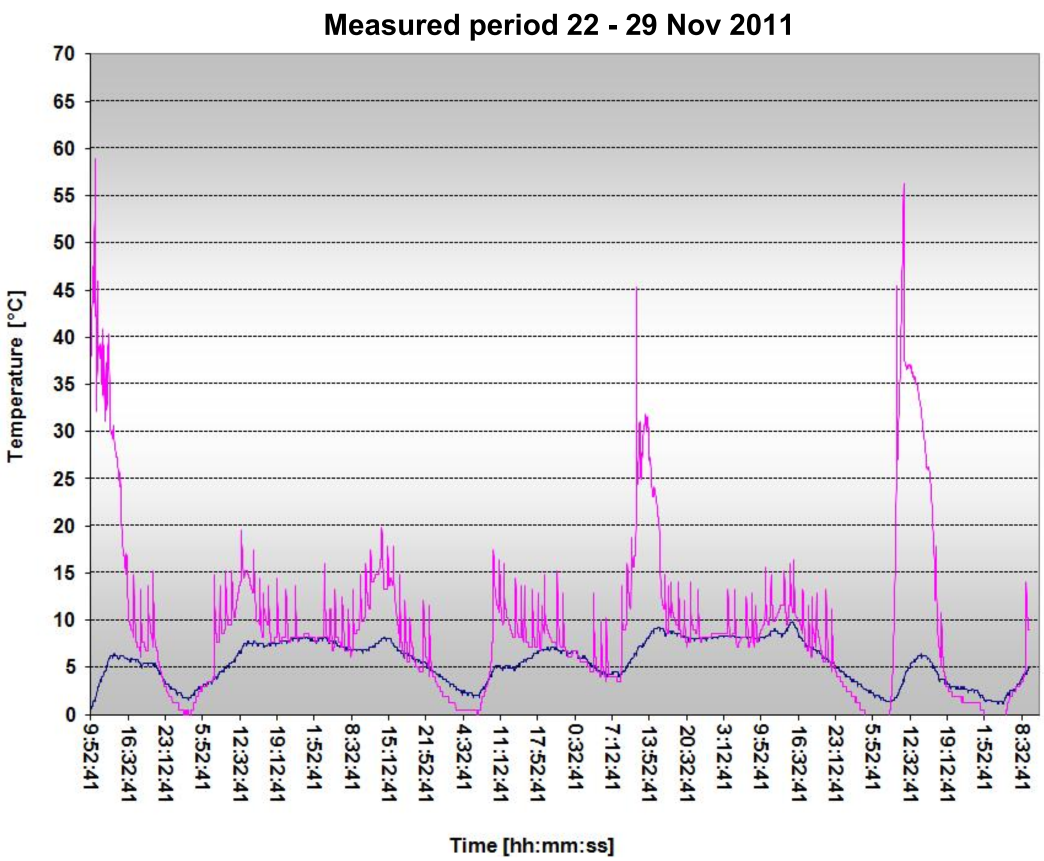

Figure 9: Flat plate collector (pink) temperature and ambient (blue) temperature

Table 1: Parameters ΔT_R and A_R

Collector type	ΔT_R	A_R
	[K]	[m^2]
Flat plate collector	8.2	6.9
Evacuated tube collector	16	6.9

The difference between collector temperature and ambient temperature for flat plate and evacuated tube collectors is shown in Figure 10 depending on the collector aperture surface.

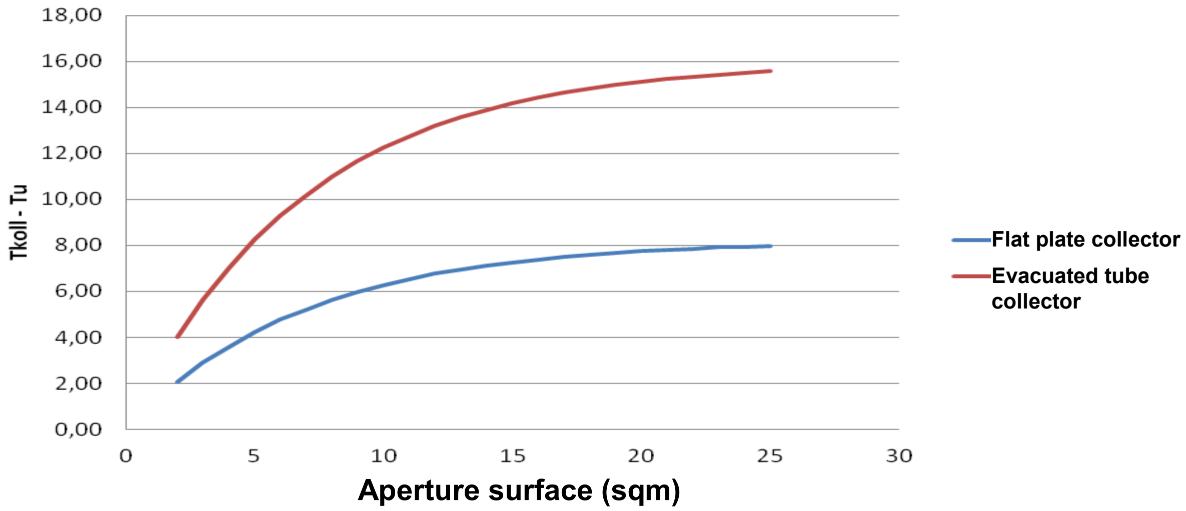

Figure 10: Difference between collector and ambient temperature with different collector types

The solar coverage has a similar characteristic curve. Here, the influence of the aperture surface increases with the square.

Thus, the following relation results for the solar coverage from simulations:

$$\eta_{sol,Hz} = \frac{\Delta\eta_R}{Qn} \cdot \left[1 - e^{-\left(\frac{A^2}{A_R{}^2}\right)}\right] \quad (2)$$

whereby

A aperture surface of the collector in m^2

$\Delta\eta_R$ reference fraction

$A_R{}^2$ square of the reference collector surface

Qn appliance output.

The parameters are given in Table 2 and the coverage for solar direct heating with evacuated tube collectors and flat plate collectors combined with a gas heat pump unit of 10 kW in Figure 11.

Table 2: Parameters $\Delta\eta_R$ and A_R^2

Collector type	$\Delta\eta_R$	A_R^2
	[kW]	[m^4]
Flat plate collector	2.3	80
Evacuated tube collector	2.3	65

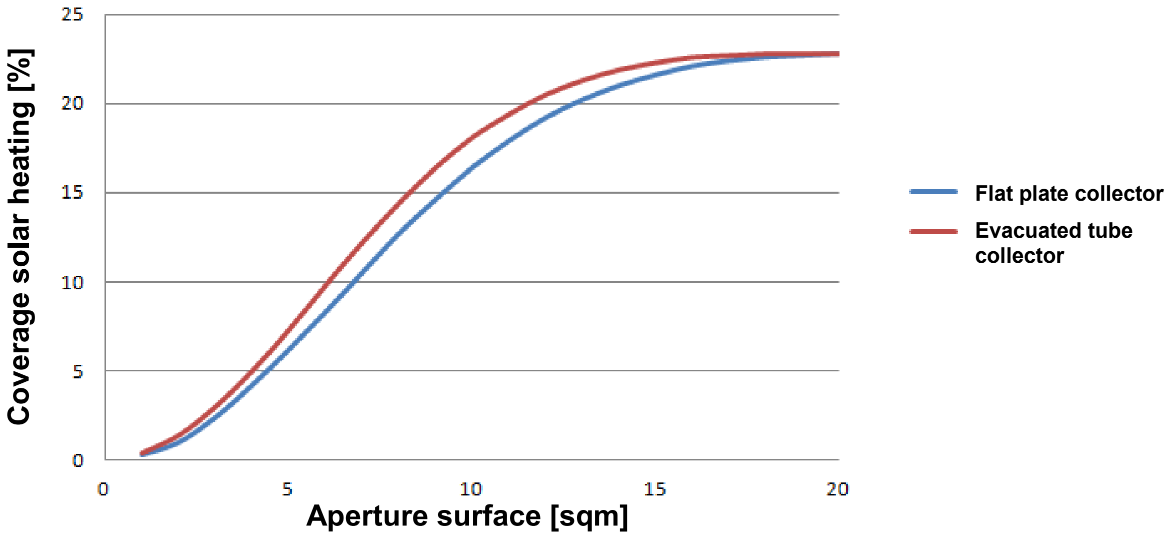

Figure 11: Solar heating coverage

8 COMPARISON OF CONSUMPTION

A comparison of consumption in case of changing from a condensing underfloor heating system to the zeoTHERM system without solar direct heating proved a reduction of about 30% in gas consumption. This is in compliance with the previously given results.

Yet, for a radiator system “Non-condensing boiler with solar d.h.w. production" changed to a zeoTHERM system (aperture surface of 5 sqm) the gas consumption was reduced by 30% compared to the previous year.

A third system of GASAG showed 19% savings in case of a change from a condensing underfloor heating system to a zeoTHERM system without solar direct heating.

8.1 Comparison of theory (VDI 4650 sheet 2) and practice

When comparing the annual useful efficiencies of the field trial systems with the expected useful efficiencies according to VDI 4650 sheet 2 for a heating system 35°C/28°C, we state a difference below 10% despite not yet ideal conditions for many field trial systems (see Figure 12). The aforesaid results elaborated by Gas und Wärmeinstitut (Essen) prove that the VDI guideline properly describes the zeolite system.

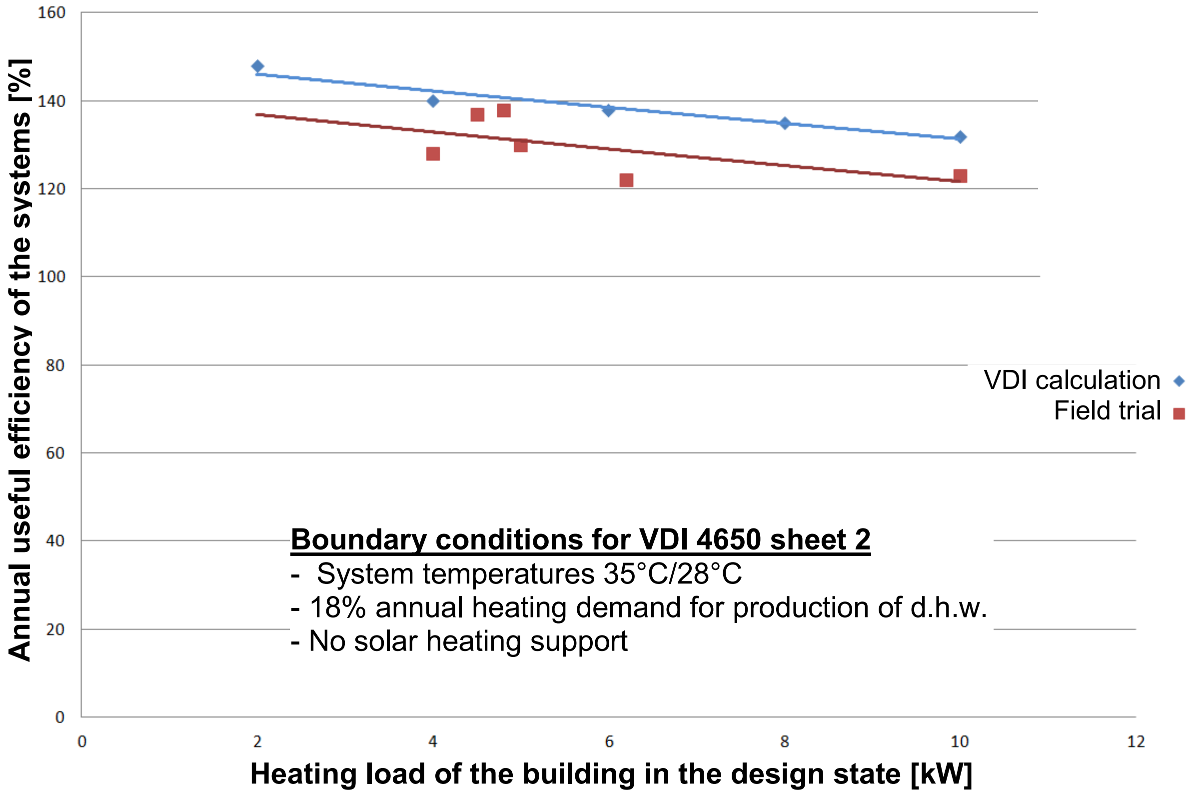

Figure 12: Comparison of field trial data (w/o solar heating support) and of the expected values (VDI 4650 sheet 2, w/o solar heating support) [Source GWI Essen]

8.2 Comparison zeoTHERM system with a condensing boiler with solar heating support

An additional simulation compares the zeolite system to a system equipped with a condensing unit with solar heating support. To achieve the same system efficiencies as with a zeolite system, the condensing system must be equipped with a 1400 L buffer cylinder and a collector aperture surface of about 25 sqm. Thus, it would be possible to replace a condensing boiler system (with a collector surface of 25 sqm) by a zeolite system offering a collector surface of only 7 sqm. The collector surface relation would be 1:3.5.

9 SUMMARY

We can state here that the Vaillant zeolite heat pumps are able to provide an increase in efficiency of about 35% compared to a condensing boiler system. Here, the following parameters turn out to be positive

- low heat demand
- low heating temperatures
- high solar radiation on the collectors
- evacuated tube collectors for higher heating temperatures
- the d.h.w. cylinder must not be bigger than required for the hot water demand.

In the field the systems proved to be extremely reliable and robust. Costumer expectations were completely met and in some cases exceeded. Sheet 2 of VDI 4650 describes the Vaillant zeolite system with proper accuracy. In view of the efficiency increase with the reduction of the heat demand, insulating the building after the installation of the unit still makes sense. This would not result in overdimensioning of the unit as only the heat pump fraction would increase.

Part of

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