LONG-TERM BEHAVIOUR AND PERFORMANCE OF RESIDENTIAL HEAT PUMPS IN DWELLINGS

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Abstract; The Swiss federal Office of Energy launched in 1994 the most comprehensive on-site trial ever made in the heating sector in Switzerland (and in the world?) so far, with 250 installations under 25kW monitored until 2003. From this sample, 150 were selected to be monitored in the long-term, while 100 are more than 10 years old. It is the longest ongoing field-test worldwide.

The goals are: to characterize SPF, reliability and costs over the whole lifetime of the heat pump system. The chosen installations are as representative as possible of average installations in the market (no prototypes, no tuning, only standard equipment).

Efficiency and reliability remain constant over the years. There is no ageing effect noticeable so far. The average cost for service and maintenance (repair) are EUR 10.00 and EUR 35.00 for 1'000 running hours.

This long-term testing will continue so that we will be able to deliver analysis over the whole lifetime of the heat pumps.

Key Words: heat pumps, performance, field test, efficiencies

1 INTRODUCTION

The project is embedded within the heat pump promotion strategy of the Swiss Federal Office of Energy. Together with the Swiss Heat Pump Association (FWS), ensuring quality is the main goal. On-site analysis is one of the key actions in order to: increase confidence in heat pumps, demonstrate performance, andshow the potential for improvement. Communication of the results, in the form of training to all professionals, is undertaken by the FWS. Understanding the long-term behaviour is especially important.

This approach has been adopted by many surrounding countries such as Germany, Austria and also the UK. The Swiss trial is the only trial which has taken detailed measurements and observations over such a long time period of 15 years. Key characteristics and aims of the trial are as follows:

- Still collecting data from over 150 heat pump installations,
- Every year, 10 new heat pump are added to the sample in order to compare the older ones with the latest ones,
- Long-term analysis of seasonal performance factor and trends over the years to detect ageing effects,
- Reliability: every problem is recorded and classified,
- Collecting costs for service and maintenance, for the first time in Switzerland and maybe in the heat pump community. These figures are very important for marketing activities,
- Determining the average seasonal performance factor which is input into the national statistics of energy for calculating energy amounts from the market's numbers.

2 SAMPLE OF INSTALLATIONS

2.1 New heat pumps 2008 - 2010

The new heat pumps added in the years 2008, 2009 and 2010 consist of 15 air/water, 12 of them also producing hot tap water; and 15 brine/water with vertical borehole heat exchangers, 13 of them also producing hot tap water. 6 air/water are installed in new build houses and 9 are retrofitted existing systems.
5 air/water are installed in new built houses and 10 retrofitted existing systems.

A sample of installations dating back to 1994 has been kept. The owners were personally contacted to ensure that the data would continue to be collected and transmitted. Some people did not wish to continue and quit.

2.2 Overview

Table 1: the whole sample

Year	Total	B/W	A/W	W/W	Hot water	Retrofit	Running years
1995	12	8	4	0	7	12	16
1996	8	5	2	1	5	4	15
1997	13	5	7	1	10	6	14
1998	9	6	3	0	6	0	13
1999	12	9	3	0	7	6	12
2000	8	5	2	1	4	4	11
2001	20	10	6	0	8	6	10
2002	23	11	12	0	16	6	9
2003	25	18	7	0	13	12	8
2004	1	1	0	0	1	1	7
2005	4	3	1	0	4	3	6
2006	0	0	0	0	0	0	5
2007	0	0	0	0	0	0	4
2008	10	6	4	0	6	3	3
2009	10	4	6	0	8	6	2
2010	10	5	5	0	8	9	1
TOTAL	165	96	62	3	103	78	

Due to heavy budget cuts at the Swiss Federal Office of Energy, there were no installations added in the years 2006 and 2007.

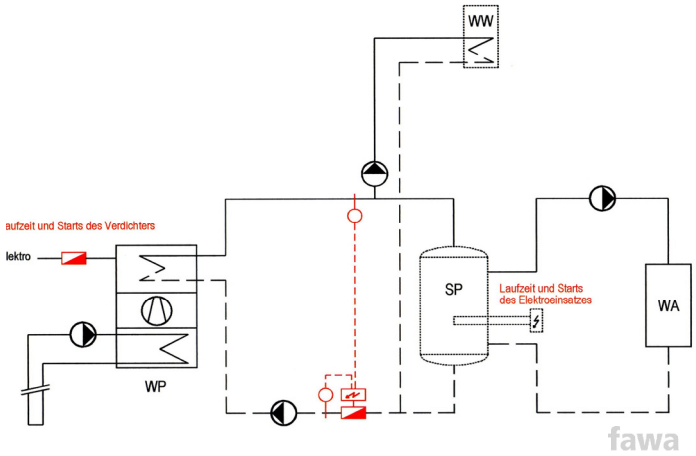
Water to water (W/W) were not added more because of the very small market share of these kind of installations.

2.3 Collecting data

For the calculation of the SPF, the following data are measured:

- Heat produced (heat pump output),
- Electricity consumption of heat pump, brine pump, fan, defrosting, circulation pump of buffer tank, operating time, numbers of starts/stops, problems, operating time of electrical supply heater.

Weekly collected data:
• heat production
• electricity conumption
• running time
• starts



Please note that the electrical supply heater was systematically and manually disconnected to avoid uncontrolled errors on the SPF. The concerned owner did not notice it! This proves that the electrical heater is necessary only in cases where the heat pump has struggled to keep the house above 10°C - due to the technical dimensioning rules, and to the national regulations.

3 ANALYSIS AND RESULTS

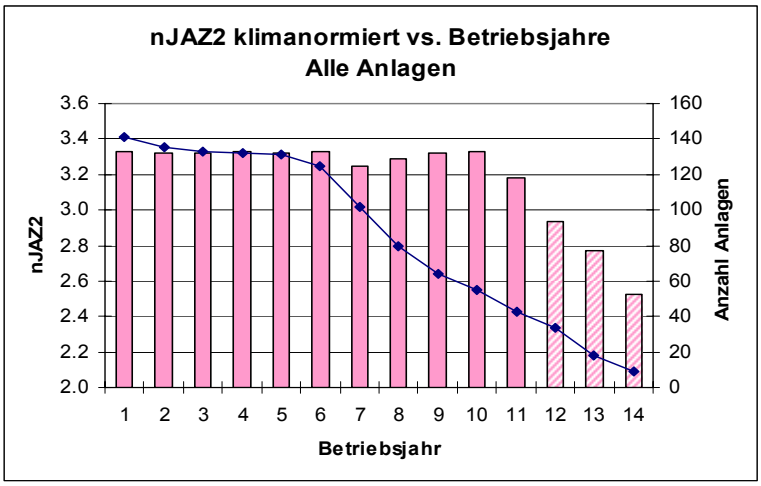
The reference year for comparison is the first year of exploitation. If the data from the first year is not usable, the reference year is the second year.

Please note that the measured SPFs are all recalculated for the same climate. This eliminates effects of climate variation and location of the heat pump.

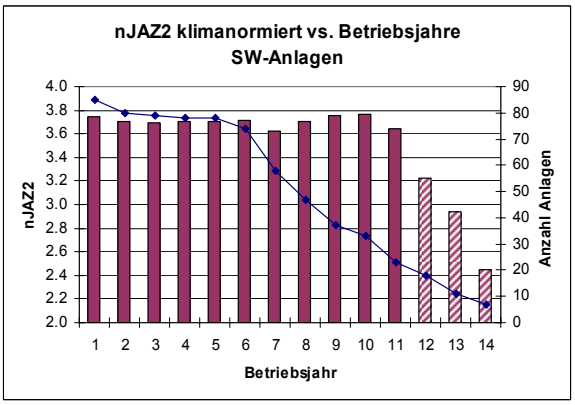
3.1 Ageing or trends in SPFover time

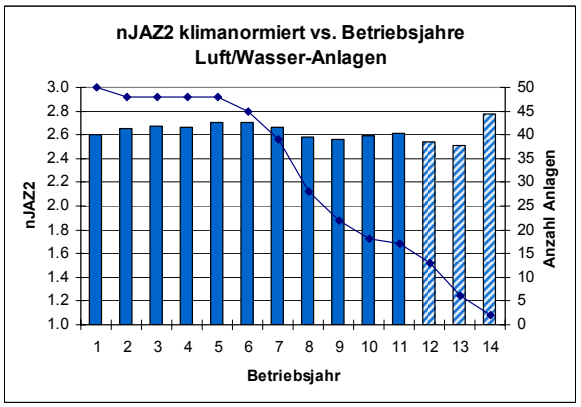
The seasonal performance factor also includes the heat losses of the heat buffer tank (when installed) and its pump. The complete energy consumption for the heat source (brine pump, fan, defrosting energy) is also taken in account.

In the next step, the measured SPFs are recalculated to eliminate the influence of the local climate. All installations are then normalised as if they were in the same location with an average outside air temperature of +3 °C during the heating period. This is the “nJAZ2”



Horizontal-axis: number of running years
Left scale: Seasonal performance factor (“JAZ2”)
Right scale: number of installation with this running time





Brine/Water **Air/Water**

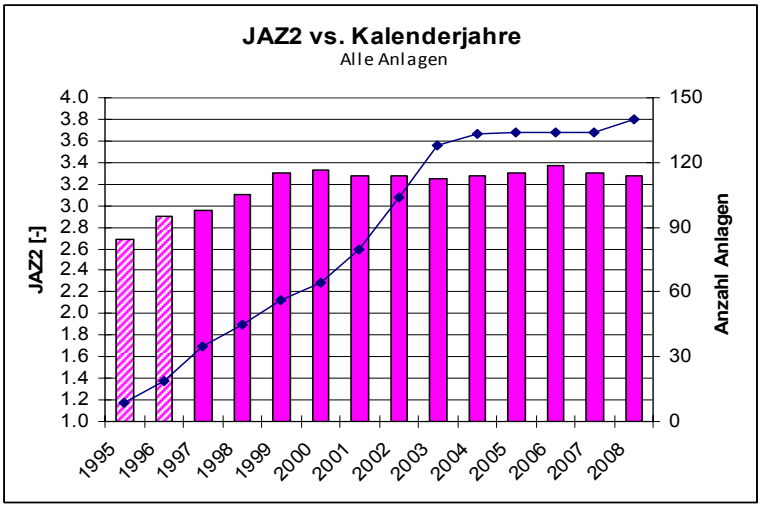
Horizontal-axis: number of running years
Left scale: Seasonal performance factor (“JAZ2”)
Right scale: number of installation with this amount of running years

In all installations, the SPF is relatively constant during the first 11 years. The last 3 years cannot now be interpreted meaningfully because the sample is too small. The installations with 12, 13 or 14 years running time show the poorest performance because they date back to the 90s.

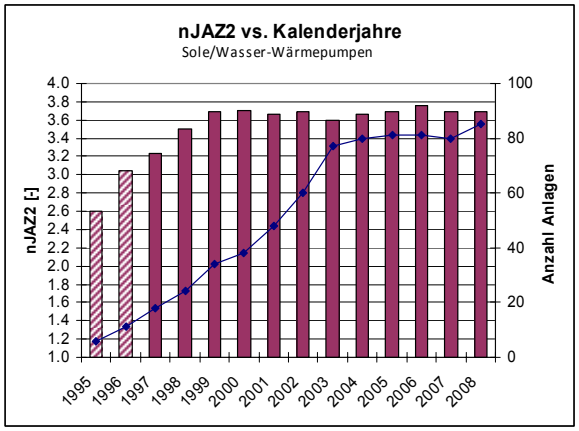
The variation over time is attributable primarily to the accuracy of the on-site measurement, rather than to any change in efficiency - SPF.

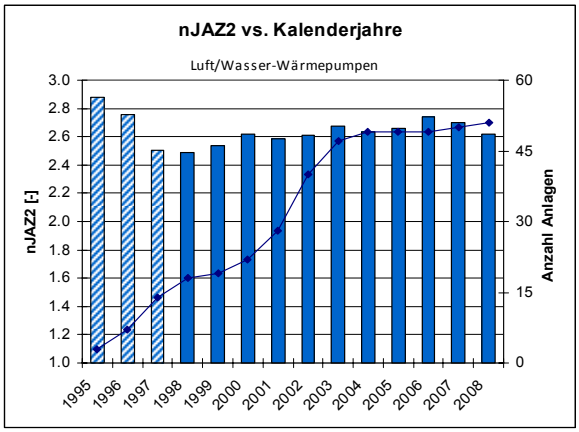
3.2 Trends in SPF over time

Graphing the value of the SPF every year is interesting, as it shows the efficiency improvements over time. The figures show the increase in COP and also SPF over the years since the trial began.



Horizontal-axis: year of installation
Left scale: Seasonal performance factor ("JAZ2")
Right scale: number of installation in the whole sample



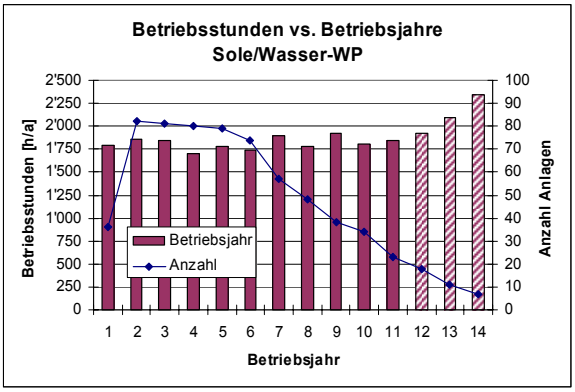


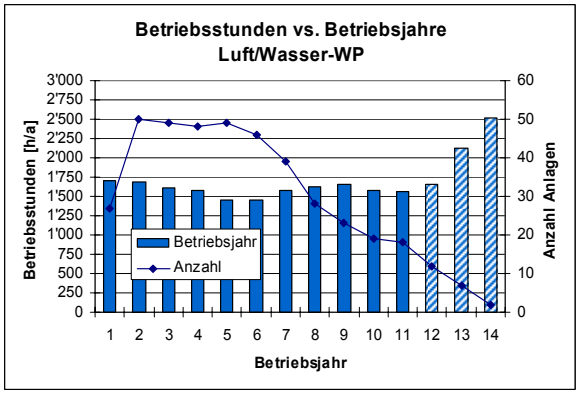
Brine/Water **Air/Water**

Horizontal-axis: year of installation
Left scale: Seasonal performance factor ("JAZ2")
Right scale: number of installation in the whole sample

The figures show the improvements achieved during the 90s, due mainly to the introduction of the quality label by the Swiss heat pump promotion group and the Swiss Federal Office of Energy. Then, efficiency was no longer the priority, with a focus shifting to other characteristics: new refrigerants, design, price….

3.3 Running hours over a heating period





Brine/Water **Air/Water**

Horizontal-axis: number of running years
Left scale: Seasonal performance factor ("JAZ2")
Right scale: number of installation in the whole sample

The running time over the heating season is especially important for brine/water heat pumps with borehole heat exchanger. The average for dimensioning installation is 2'000 hours for heating and 2'300 hours for heating and hot water production in the lowlands in Switzerland.

The figure shows that the effective running time is lower, between 1750 and 2'000 hours a year. For brine/water heat pumps, the effective running time must not exceed the theoretical one, in order to avoid the cooling down of the earthprobe.

For air/water, the running time gives an indication of the dimensioning. An oversized heat pump will run much less than 2'000 hours a year.

3.4 Reliability

The reliability is defined as follows: 100% reliability is when the heat pump always runs when it should be running. A problem is defined as when the heat pump stops when it should be running.
The dataset gathered over 14 years is huge but had to be carefully checked to ensure the quality.

Over all installations, the cumulated running time amounts to 2'127'783 hours, while the amount of time with problems occuring during heating time is 6'952 hours. The reliability is 99.67%. This is very high. It means that over an operational lifespan of 25 years, the average down time is one week.

There are very small differences in results between new build and retrofit (99.78% and 99.56%) and between brine/water and air/water (99.28% and 99.88%).

The following facts are of interest:

- Air/water do not have more problems ocurring than brine/water,
- Retrofit do not have more problems than new built.

The average reliability of above 99.5% shows the high quality standards reached by heat pumps so far.

3.5 Costs for maintenance and repair

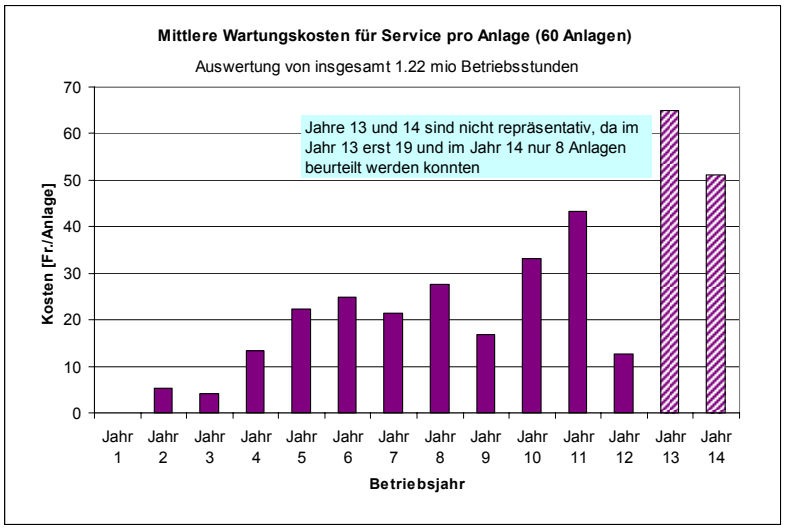
The costs for maintenance and repairs are defined as follows:

Maintenance	Controlling and adjusting the installation, changing normally used components, controlling refrigerant leaks, cleaning filters.
Repair:	Repair or replacement of components before the end of a normal lifetime.

The question is how much does maintenance and repair cost in relation to the costs of energy consumption. The key point is to check if the bigger investment (compared with oil or gas furnace) is compensated through lower operating costs.

The costs of 60 installations were carefully collected and checked during an interview with the owners. The repartition is: 31 brine/water with earthprobes, 3 horizontal collectors, 1 energy piles, 21 air/water, 4 water/water.

Average annual costs for maintenance and repair over 1.22 million hours operation



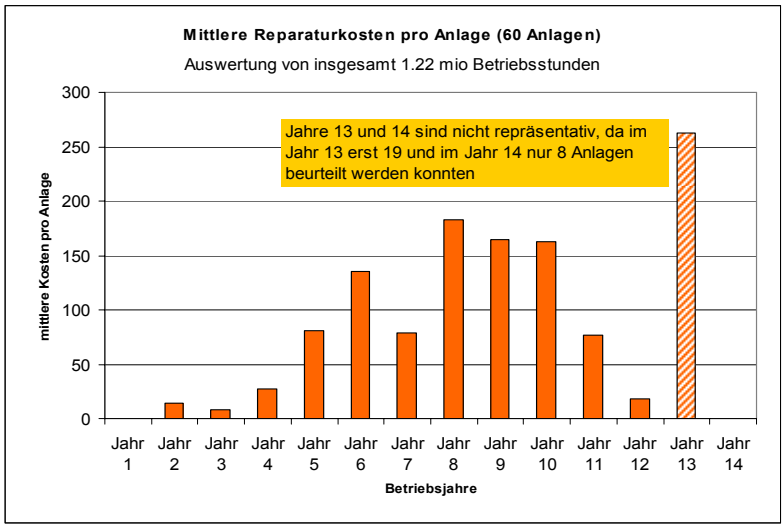
Horizontal-axis: year of observation
Vertical axis: average costs per installation in Swiss Francs CHF

The costs for maintenance and repair are extremely low at EUR 20.00 per annum. The first few years after installation, the costs are – as would be expected - close to zero (the typical warranty duration is 2 years), and then grow to about EUR 20.00.

Years 13 and 14 must be carefully interpreted: the amount of data is limited.

Costs for repairs are shown below.

Average yearly costs for repairs over 1.22 million hours operation



Horizontal-axis: year of observation
Vertical axis: average costs in Swiss Francs CHF

The years with high costs are due to change of expensive component such as the compressor and evaporator, or a result of fire damages (one case because of propane). The other costs are due to smaller repairs such as controls and tuning, and change of smaller components (expansion valve, temperature probe). The average cost of repair is about EUR 70.00 per annum. This is very low and also has almost no influence on the total annual costs.

The average annual cost for maintenance and repair over 14 years and 60 installations is EUR 90.00, which in comparison to annual energy costs and capital costs, is negligible.

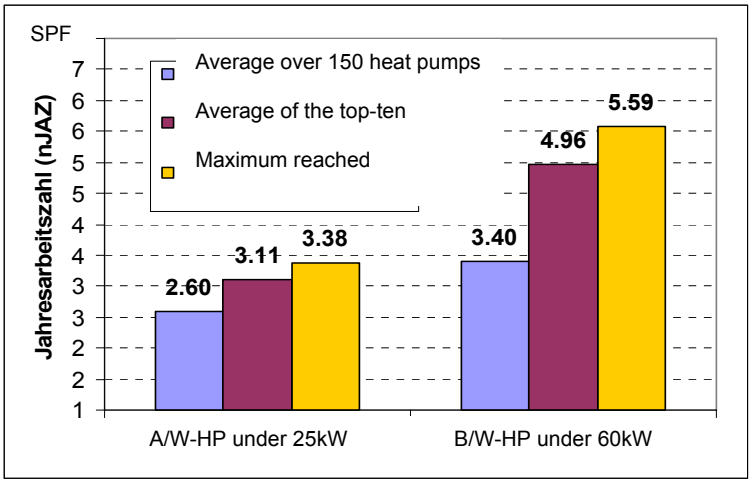
Most of the time, the repairs are due to minor problems, not to serious damage or problems occurring. And most of these issues are solved by installers or manufacturers at low cost, who adopt a wider interpretation of the warranty to cover the problems. This effort is to be emphasised: customer satisfaction is now acknowledged as a central success factor. This was not always the case in Switzerland.

The comparison with furnaces is difficult because there is no systematic and neutral survey about theses costs. However, almost every owner of furnace pays a yearly amount for servicing, which control of the burner, of the furnace and a quick check of the installation (pressure in heat distribution, circulating pumps, temperatures, parameters of control). The costs are between EUR 200 and EUR 500.

3.6 Best practice

Another part of the project was to identify what the best possible SPF can be by now. The figure below gives the results.

Average SPF over 150 heat pumps, average SPF of the top-ten and maximum SPF



The potential is obvious. The top-ten of today can and should be the average of tomorrow! The best ones have nothing special: as already mentioned, there are only serial products in the sample, no prototypes or tuned ones.

The key criteria to achieve better SPF are: hydronic integration, dimensioning of the heat pump and especially of the heat source and optimal adjusting of the parameters of function and choice of a good heat pump according to EN14511.

3.7 National and international collaboration

The project is done in collaboration with the Swiss heat pump promotion group, first to get 10 new installations every year, and then to disseminate the results of the on-site observations and analysis. A part of the national project is integrated into Annex 37 of the IEA-HPP.

4 REFERENCES

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