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Source Temperatures for Heat Pump Water Heaters.

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This note is made to propose source (input) temperatures for heat pump water heaters for efficiency calculations for EU-Ecodesign regulation of water heaters. It is a comment to the working documents of June 24, 2010 for Ecodesign regulation and June 23, 2010 for labelling of water heaters, in the following referred to as WD..

Air Source Heat Pumps

For heat pumps with air as heat source is proposed in the WD an outdoor air temperature of 10'C for the average climate zone. It is proposed that tests are carried out with this outdoor air source temperature, rather than with a series of different outdoor air temperatures to test the different efficiencies of the heat pump at different source temperatures. 10'C is the average temperature in the average climate zone. Unfortunately a test with 10'C source temperature does not give the average annual efficiency of a heat pump. In fact it gives a too high efficiency thereby over-evaluating this kind of heat pumps in the efficiency rating. There are three reasons for this:

- A heat pump will have lower efficiency at lower temperatures and higher at higher temperatures; but the lower efficiencies will weight higher that the higher temperatures in the annual average
- At low temperatures icing in the air source heat exchangers require de-icing, a procedure that require heating, typically electric heating.
- At the lowest temperatures air source heat pumps have to use electric resistance heating for back-up

A theoretical example:
A heat pump has the following COP (Coefficient of performance) when producing hot water:
COP = 3 with 10'C air temperature,
COP = 2 with 0'C air temperature,
COP = 4 with 20'C air temperature

If this heat pump always works with 10'C air temperature, it will require **1/3= 0.33 kWh electricity for each kWh of hot water** produced (regarding tank loss & auxiliary energy are not taken into account in this example)
If the same heat pump works half of the year with 0'C air temperature and half of the year with 20'C air temperature, it will require ‘1/2 = 0,5 kWh of electricity to produce 1 kWh in the cold period and ‘1/4 = 0,25 kWh in the hot period. In average it will require ½ *(0.5 + 0. 25 kWh) = **0. 38 kWh electricity for each kWh of hot**

water. This is 13% more than with constant temperature, and same average temperature**.**

A Practical example:

An air source Heat Pump (Mitsubushi LTD-SRK) has measured COP = 4.2 at +7'C and COP=2.9 at -7'C. In the following is assumed linear relations between air source temperatures and COPs, which is a relatively good approximation, except for low temperatures, where electricity for de-icing and electric backup are needed.

This heat pump will have a COP = 4,51 at the average temperature of Strasbourg (10.3'C). Strasbourg is a good example of a climate that is the average of the average climate zone in EU.

In practice the COP of the heat pump will vary over the year. Based on a linear relation between COP and temperature, the COP will vary as in the following table with temperature "bins" for Strasbourg:

Tout	Hours/year	COP
-10	1	2,62
-9	27	2,71
-8	24	2,81
-7	21	2,9
-6	29	2,99
-5	73	3,09
-4	87	3,18
-3	89	3,27
-2	177	3,36
-1	171	3,46
0	230	3,55
1	284	3,64
2	321	3,74
3	358	3,83
4	361	3,92
5	320	4,01
6	343	4,11
7	353	4,2
8	377	4,29
9	404	4,39
10	430	4,48
11	362	4,57
12	399	4,66
13	399	4,76
14	384	4,85
15	407	4,94
16	343	5,04
17	322	5,13
18	263	5,22
19	271	5,31
20	249	5,41
21	208	5,5
22	154	5,59
23	124	5,69
24	100	5,78
25	86	5,87

26	63	5,96
27	48	6,06
28	45	6,15
29	25	6,24
30	21	6,34
31	7	6,43

The average of COP weighted with the length (in hours) of each bin is a COP = 4,39 (3% lower than COP of the average temperature). This is equal to the COP at 9'C air temperature. That does not include effects of de-icing or electric back up.
Source for heat pump data: Data for heat pump COP's are from Råd&Røn heat pump testing 2007, available from www.radron.se

The same calculation have been carried out for other heat pumps, with the following differences between average outdoor temperature and the temperature corresponding to the average COP (also with COP data from Råd&Røn):

Heat pump	Temperature difference
Sirius S2-7 Luft:	1,2'C
Atria optimum 8:	1.0'C
Mitsubushi LTD-SRK:,	1.1 'C
Sanyo CRV93EHN:	0.9'C
Queen5*	1.1'C

*Danish heat pump, water source, data from manufacturer,
http://www.jordvarme.dk/47_queen%20combi.htm

Proposal for air source heat pumps
To account for the lower average efficiency of air source heat pumps annual variation of temperatures is proposed one of the following two options:

1) Require measurements at 4 air temperatures, as proposed for heat pumps for space heating (5 temperatures for colder climate), or
2) Reduce the outdoor air temperature from the proposed 10'C for the average climate to 8'C to include the effects of the lower average COP, as well as for the effects of energy demands for de-icing and for electricity back-up. For colder climate the effects of these factors are larger, and thus it is proposed to reduce the outdoor air temperature to 2'C for measurements to specify energy consumption in the colder climate zone.

Water Source Heat Pumps
For water source heat pumps is proposed in the WD a water source temperature of 11.5'C. Water source heat pumps are expected to use ground water as the main source of water. Ground water temperatures are very close to the annual average temperatures, which for the average climate zone of EU is 10'C. Therefore **it is proposed to change the water source temperature to 10'C** in efficiency tests for Ecodesign.

In reality water source heat pumps will be used in a number of applications, where the water source can also be surface water (resulting in a lower average COP) and waste water (resulting in higher COPs); but for the labelling the most common application of ground water is the most relevant.

Waste water sourced heat pumps
Water heaters that are specifically made to utilise the heat in waste-water from the hot water usage, should be able to include this in the measurements of efficiency, if the heat recovery equipment (heat exchanger) is included in the water heater.