1 PREMISE

As known, the calculation of the design heat demand of a building (power) provides the winter peak value on which to size the heating system.
In an installation with boiler only, the result of this calculation actually provides sufficient criteria for selecting the boiler.
In the case of absorption heat pumps, correct sizing cannot disregard a more comprehensive system analysis, also involving emission devices, and above all their behaviour at the operating temperatures of heat pumps.
In fact it is essential, for efficient system operation, that the temperatures of terminals are adequate to the specific operative limits of heat pumps, summarised in Table 1.1 *p. 1* below, in particular for return temperatures.

Table 1.1 *GAHP heating temperature limits*

			GAHP A	GAHP-AR	GAHP GS/WS	AY00-120
Heating mode						
Hot water delivery temperature	maximum for heating	°C	65	-	65	-
	maximum	°C	-	60	-	80
Hot water return temperature	maximum for heating	°C	55	-	55	-
	maximum	°C	-	50	-	70

After successfully passing this indispensable check, one should consider a more advanced sizing approach than the mere winter peak power calculation, aimed at optimising the return on the investment.
This approach involves covering with absorption heat pumps only a part of the nominal heating requirements of the building (the so-called “base load”), with integration boilers in charge of covering the remaining share (“peak load”); the limited number of hours per year of operation at peak load in fact, makes the total contribution of the peak negligible in terms of seasonal energy (and therefore in economic terms).
It should be emphasised that absorption heat pumps maintain uninterrupted operation even at extremely low outdoor temperatures. Therefore, the role of supplementary boilers is not that of backup units (as in a "bivalent" system typical of electric heat pumps, i.e. with replacement of the heat pumps below a certain outdoor temperature), but is indeed to integrate the power supplied by the heat pumps, which does not cover the peak load due to a technical-economic design choice.
This different sizing criterion is reflected in the choice of the best compromise between base load and peak load, i.e. the number of heat pumps to be installed in view of the building’s design load.
The assessment is complex and involves a number of parameters, the two main ones being:

- trend of the actual thermal load in the heating season, which in its turn depends on the geographical position of the building to be heated and on its utilisation profile;
- operating temperature of the systems, also in relation to the features of the heat pump model that is intended to be used.

To be able to give some useful indications of a general nature, below is an analysis based on the calculation models provided by European Directive 2009/125/EC and related ErP Regulations (Energy Related Products, 811/2013 in particular), as well as by the European product regulations EN 12309:2014.
The graphs in the following Paragraphs are always in percentage terms with respect to the design power for the building in question (to be determined based on applicable regulations) and therefore are generally valid.
Sizing cases that are placed in intermediate positions between those proposed will be evaluated through appropriate interpolations.

It is essential to emphasize once again that the proposed sizing criteria is geared to the best economic return on investment in the presence of systems consisting of heat pumps and boilers. However, proper sizing can not ignore a more complete evaluation of the system, which also involves the emission devices, and especially the behavior of the same at the operating temperatures of the heat pumps.

1.1 THE REGULATION 811/2013

Regulation 811/2013 sets forth:

- three climatic zones (warm climate, medium climate and cold climate);
- a building model of reference;
- a typical profile of seasonal temperature trends, in terms of bins. The bins represent the number of hours/year for which the system is intended to operate at a given outdoor temperature.

The three climatic zones are identified by the following conditions of reference:

- Athens for the hot climate (design outdoor temperature 2°C);
- Strasbourg for the medium climate (design outdoor temperature -10°C);
- Helsinki for the cold climate (design outdoor temperature -22°C).

1.2 THE STANDARD EN 12309

For the three climate zones described in Paragraph 1.1 *p. 1*, the system operating temperatures are defined within the product standard EN 12309:2014 according to the distribution system type (underfloor heating, fancoil, radiators,...).
In particular, the standard defines four temperature profiles, each of which may be fixed delivery or variable delivery according to a weather curve as a function of the outdoor temperature (hence of the climate zone)
The four temperature profiles are as follows:

- low temperature, corresponding to a nominal delivery temperature of 35°C;
- medium temperature, corresponding to a nominal delivery temperature of 45°C;
- high temperature, corresponding to a nominal delivery temperature of 55°C;
- high temperature, corresponding to a nominal delivery temperature of 65°C.

Pay attention to the terminological misalignment between the definitions in standard EN 12309 and

Regulation 811/2013

The profile corresponding to 55°C delivery temperature is defined "high temperature" in EN 12309 (as per the list above), while it is defined "medium temperature" in Regulation 811/2013.

2 MEDIUM CLIMATE

Table 2.1 *p. 2* shows the main data obtained from the aforementioned standards, with regards to medium climate (reference Strasbourg, design temperature -10°C).

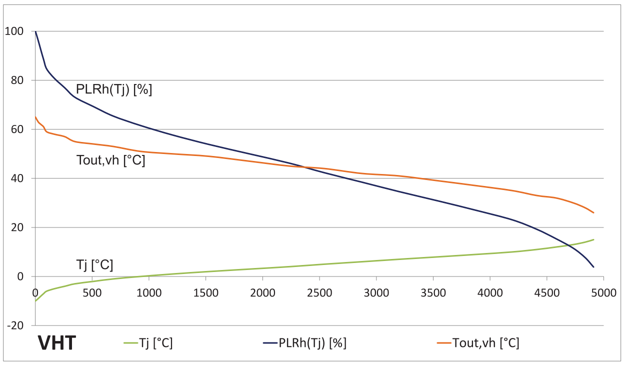
Table 2.1 *Table of medium climate ErP profiles*

Tj [°C]	Hj [h/y]	ΣHj	PLRh(Tj) [%]	Tout,vh [°C]	Tout,h [°C]	Tout,m [°C]	Tout,l [°C]
-10	1	1	100	65	55	45	35
-9	25	26	96	63	54	44	34
-8	23	49	92	62	53	43	34
-7	24	73	88	61	52	43	34
-6	27	100	85	59	50	42	33
-5	68	168	81	58	49	41	33
-4	91	259	77	57	48	41	32
-3	89	348	73	55	47	40	32
-2	165	513	69	54	46	39	31
-1	173	686	65	53	45	39	31
0	240	926	62	51	44	38	30
1	280	1206	58	50	43	37	30
2	320	1526	54	49	42	37	30
3	357	1883	50	47	40	36	29
4	356	2239	46	45	39	35	28
5	303	2542	42	44	38	34	28
6	330	2872	38	42	37	33	27
7	326	3198	35	41	36	33	27
8	348	3546	31	39	34	32	26
9	335	3881	27	37	33	31	25
10	315	4196	23	35	32	30	25
11	215	4411	19	33	31	29	24
12	169	4580	15	32	30	28	24
13	151	4731	12	30	28	27	23
14	105	4836	8	28	27	26	22
15	74	4910	4	26	26	25	22

Tj [°C] = bin outdoor temperature
Hj [h/y] = annual hours of operating at outdoor temperature Tj
ΣHj = cumulative annual hours of operating at temperature equal to or lower than Tj
PLRh(Tj) [%] = system partial load factor at outdoor temperature Tj
Tout,vh [°C] = temperature profile for operating at very high temperature
Tout,h [°C] = temperature profile for operating at high temperature
Tout,m [°C] = temperature profile for operating at medium temperature
Tout,l [°C] = temperature profile for operation at low temperature

The graphs for each temperature profile let one appreciate at a glance the relationship between outdoor temperature, load profile (represented by the power percentage with respect to the nominal design power) and system water flow temperature in relation to the cumulative number of hours of operation of the heating system at a given outdoor temperature Tj, for the climate zone considered.
The choice of this reference axis makes it possible to quickly extract useful information for sizing, as detailed in Paragraph 5 *p. 9*.
For the "very high temperature" profile (VHT) see Figure 2.1 *p. 2*.

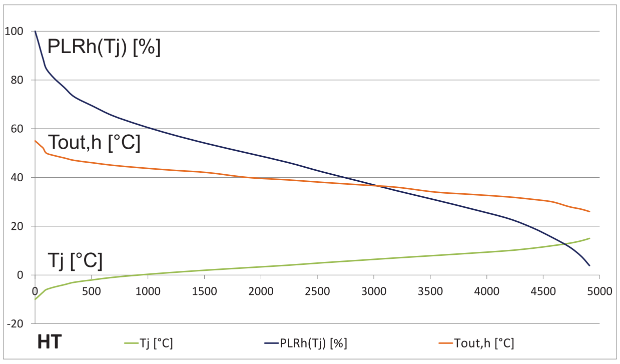
Figure 2.1 *Graph of VHT medium climate ErP profiles*



Tj [°C] bin outdoor temperature
PLRh(Tj) [%] plant partial load ratio at outdoor temperature Tj
Tout,vh [°C] temperature profile for operation at very high temperature

For the "high temperature" profile (HT) see Figure 2.2 *p. 3*.

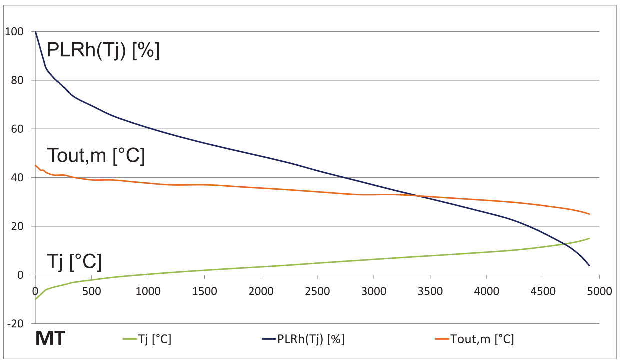
Figure 2.2 *Graph of HT medium climate ErP profiles*



Tj [°C] bin outdoor temperature
PLRh(Tj) [%] plant partial load ratio at outdoor temperature Tj
Tout,h [°C] temperature profile for high temperature operation

For the "medium temperature" profile (MT) see Figure 2.3 *p. 3*.

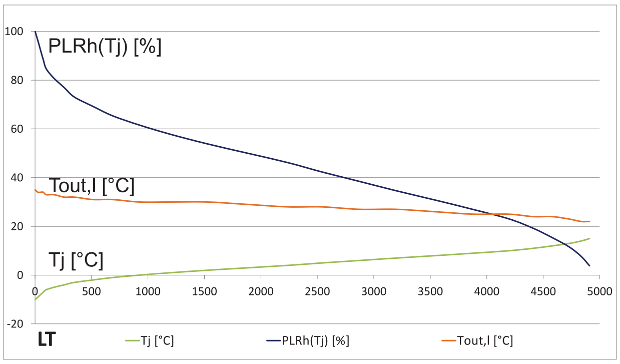
Figure 2.3 *Graph of MT medium climate ErP profiles*



Tj [°C] bin outdoor temperature
PLRh(Tj) [%] plant partial load ratio at outdoor temperature Tj
Tout,m [°C] temperature profile for medium temperature operation

For the "low temperature" profile (LT) see Figure 2.4 *p. 3*.

Figure 2.4 *Graph of LT medium climate ErP profiles*



Tj [°C] bin outdoor temperature
PLRh(Tj) [%] plant partial load ratio at outdoor temperature Tj
Tout,h [°C] temperature profile for low temperature operation

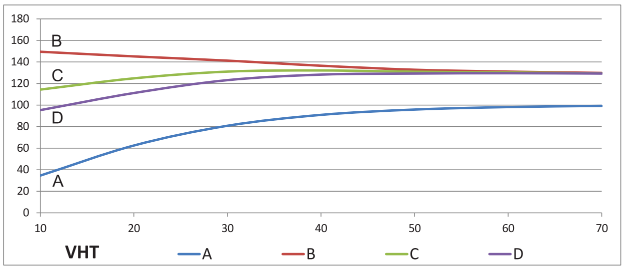
For each of the profiles it is possible to determine, on the basis of the power share covered with GAHP with respect to the design power (both referred to design conditions for the climate zone and chosen temperature profile):

- The percentage of energy produced with GAHP;
- The average seasonal efficiency (SGUE) of the GAHP units alone;
- The average seasonal efficiency (SGUE) of the GAHP hybrid system and supplementary condensing boilers;
- The average seasonal efficiency (SGUE) of the hybrid system GAHP and existing supplementary boilers (assumed with 80% efficiency).

The following Figures show these data for the medium climate zone and for each of the temperature profiles.

For the "very high temperature" profile (VHT) see Figure 2.5 *p. 3*.

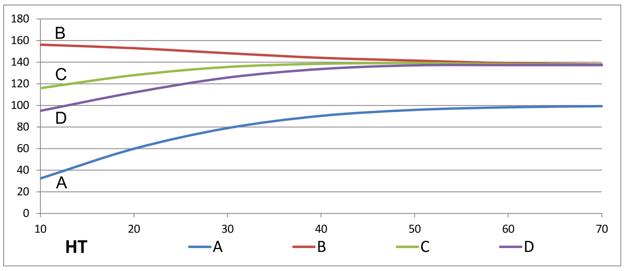
Figure 2.5 *Graph of VHT medium climate ErP energy performance*



In abscissa the power percentage with GAHP compared to the design power (both calculated at conditions A-10W65)
A percentage of energy produced with GAHP
B SGUE (seasonal GUE) GAHP only
C SGUE (seasonal GUE) GAHP and condening boilers
D SGUE (seasonal GUE) GAHP and existing boilers (assumed with 80% efficiency)

For the "high temperature" profile (HT) see Figure 2.6 *p. 3*.

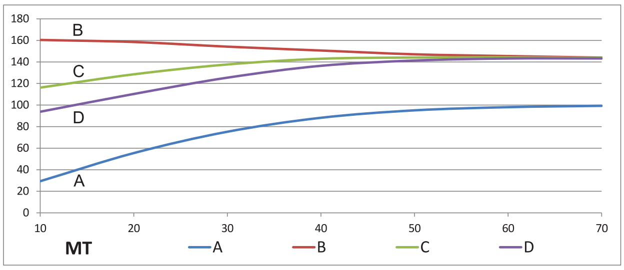
Figure 2.6 *Graph of HT medium climate ErP energy performance*



In abscissa the power percentage with GAHP compared to the design power (both calculated at conditions A-10W55)
A percentage of energy produced with GAHP
B SGUE (seasonal GUE) GAHP only
C SGUE (seasonal GUE) GAHP and condening boilers
D SGUE (seasonal GUE) GAHP and existing boilers (assumed with 80% efficiency)

For the "medium temperature" profile (MT) see Figure 2.7 *p. 4*.

Figure 2.7 *Graph of MT medium climate ErP energy performance*

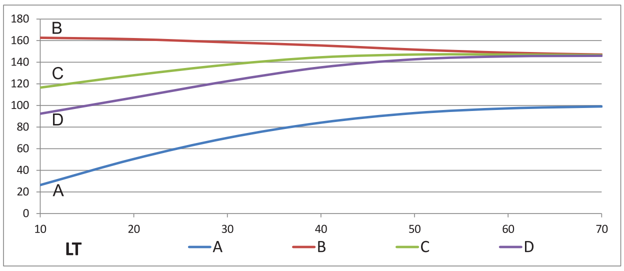


In abscissa the power percentage with GAHP compared to the design power (both calculated at conditions A-10W45)

A percentage of energy produced with GAHP
B SGUE (seasonal GUE) GAHP only
C SGUE (seasonal GUE) GAHP and condening boilers
D SGUE (seasonal GUE) GAHP and existing boilers (assumed with 80% efficiency)

For the "low temperature" profile (LT) see Figure 2.8 *p. 4*.

Figure 2.8 *Graph of LT medium climate ErP energy performance*



In abscissa the power percentage with GAHP compared to the design power (both calculated at conditions A-10W35)

A percentage of energy produced with GAHP
B SGUE (seasonal GUE) GAHP only
C SGUE (seasonal GUE) GAHP and condening boilers
D SGUE (seasonal GUE) GAHP and existing boilers (assumed with 80% efficiency)

3 HOT CLIMATE

Table 3.1 *p. 4* shows the main data obtained from the aforementioned standards, with regards to hot climate (reference Athens, design temperature +2°C).

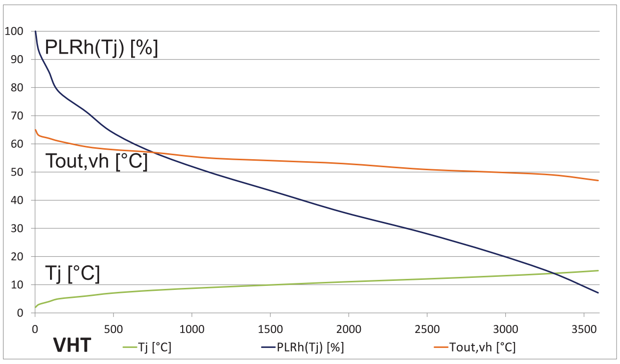
Table 3.1 *Table of hot climate ErP profiles*

Tj [°C]	Hj [h/y]	ΣHj	PLRh(Tj) [%]	Tout,vh [°C]	Tout,h [°C]	Tout,m [°C]	Tout,l [°C]
2	3	3	100	65	55	45	35
3	22	25	93	62	53	43	34
4	63	88	86	60	51	42	33
5	63	151	79	57	49	41	32
6	175	326	71	55	47	40	31
7	162	488	64	53	46	39	31
8	259	747	57	50	43	37	30
9	360	1107	50	47	41	35	29
10	428	1535	43	44	38	34	28
11	430	1965	36	41	36	32	27
12	503	2468	29	39	34	31	26
13	444	2912	21	36	31	29	25
14	384	3296	14	33	29	27	24
15	294	3590	7	30	26	26	23

Tj [°C] = bin outdoor temperature
Hj [h/y] = annual hours of operating at outdoor temperature Tj
ΣHj = cumulative annual hours of operating at temperature equal to or lower than Tj
PLRh(Tj) [%] = system partial load factor at outdoor temperature Tj
Tout,vh [°C] = temperature profile for operating at very high temperature
Tout,h [°C] = temperature profile for operating at high temperature
Tout,m [°C] = temperature profile for operating at medium temperature
Tout,l [°C] = temperature profile for operation at low temperature

The graphs for each temperature profile let one appreciate at a glance the relationship between outdoor temperature, load profile (represented by the power percentage with respect to the nominal design power) and system water flow temperature in relation to the cumulative number of hours of operation of the heating system at a given outdoor temperature Tj, for the climate zone considered.
The choice of this reference axis makes it possible to quickly extract useful information for sizing, as detailed in Paragraph 5 *p. 9*.
For the "very high temperature" profile (VHT) see Figure 3.1 *p. 5*.

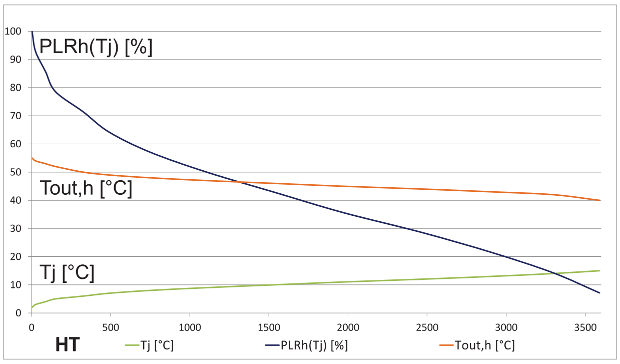
Figure 3.1 *Graph of VHT hot climate ErP profiles*



Tj [°C] bin outdoor temperature
PLRh(Tj) [%] plant partial load ratio at outdoor temperature Tj
Tout,vh [°C] temperature profile for operation at very high temperature

For the "high temperature" profile (HT) see Figure 3.2 *p. 5.*

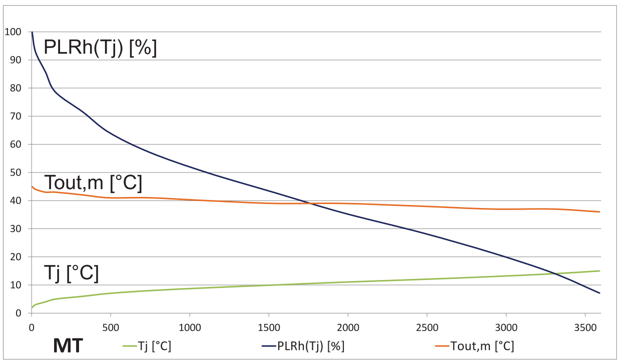
Figure 3.2 *Graph of HT hot climate ErP profiles*



Tj [°C] bin outdoor temperature
PLRh(Tj) [%] plant partial load ratio at outdoor temperature Tj
Tout,h [°C] temperature profile for high temperature operation

For the "medium temperature" profile (MT) see Figure 3.3 *p. 5.*

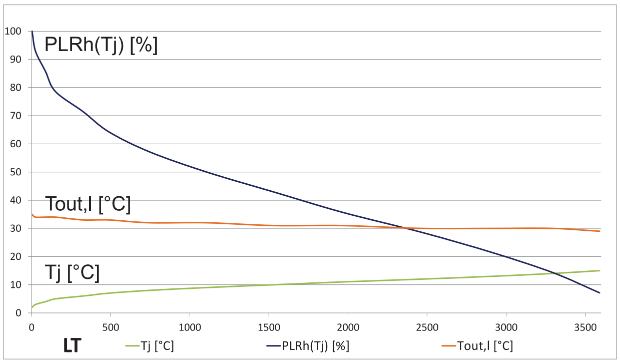
Figure 3.3 *Graph of MT hot climate ErP profiles*



Tj [°C] bin outdoor temperature
PLRh(Tj) [%] plant partial load ratio at outdoor temperature Tj
Tout,m [°C] temperature profile for medium temperature operation

For the "low temperature" profile (LT) see Figure 3.4 *p. 5.*

Figure 3.4 *Graph of LT hot climate ErP profiles*



Tj [°C] bin outdoor temperature
PLRh(Tj) [%] plant partial load ratio at outdoor temperature Tj
Tout,h [°C] temperature profile for low temperature operation

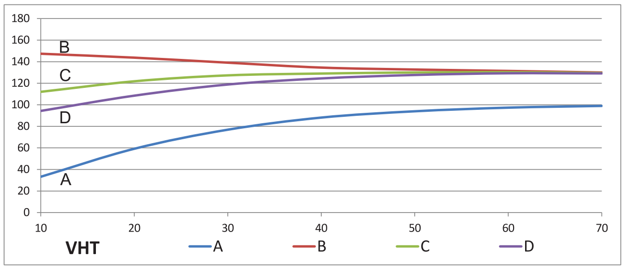
For each of the profiles it is possible to determine, on the basis of the power share covered with GAHP with respect to the design power (both referred to design conditions for the climate zone and chosen temperature profile):

- The percentage of energy produced with GAHP;
- The average seasonal efficiency (SGUE) of the GAHP units alone;
- The average seasonal efficiency (SGUE) of the GAHP hybrid system and supplementary condensing boilers;
- The average seasonal efficiency (SGUE) of the hybrid system GAHP and existing supplementary boilers (assumed with 80% efficiency).

The following Figures show these data for the medium climate zone and for each of the temperature profiles.

For the "very high temperature" profile (VHT) see Figure 3.5 *p. 5.*

Figure 3.5 *Graph of VHT hot climate ErP energy performance*

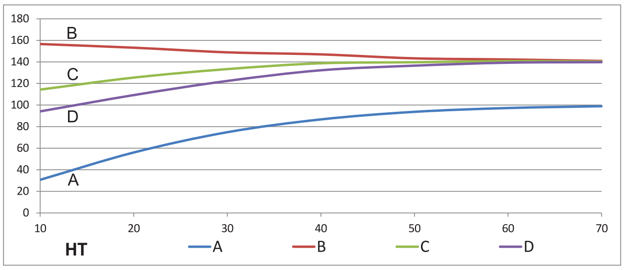


In abscissa the power percentage with GAHP compared to the design power (both calculated at conditions A2W65)

A percentage of energy produced with GAHP
B SGUE (seasonal GUE) GAHP only
C SGUE (seasonal GUE) GAHP and condening boilers
D SGUE (seasonal GUE) GAHP and existing boilers (assumed with 80% efficiency)

For the "high temperature" profile (HT) see Figure 3.6 *p. 6.*

Figure 3.6 *Graph of HT hot climate ErP energy performance*

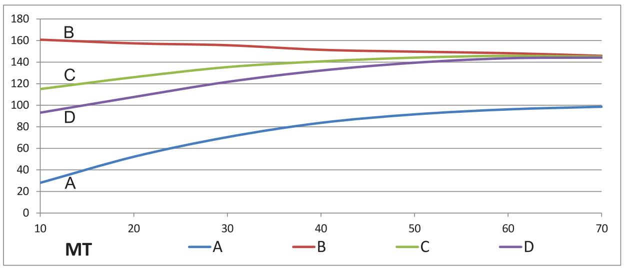


In abscissa the power percentage with GAHP compared to the design power (both calculated at conditions A2W55)

A percentage of energy produced with GAHP
B SGUE (seasonal GUE) GAHP only
C SGUE (seasonal GUE) GAHP and condening boilers
D SGUE (seasonal GUE) GAHP and existing boilers (assumed with 80% efficiency)

For the "medium temperature" profile (MT) see Figure 3.7 *p. 6.*

Figure 3.7 *Graph of MT hot climate ErP energy performance*

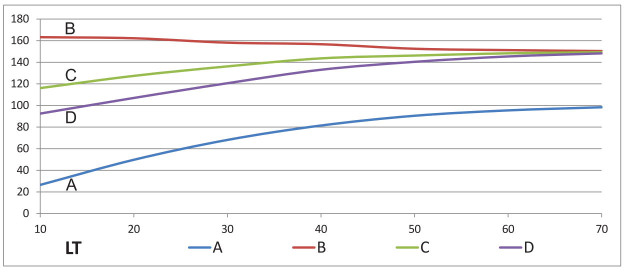


In abscissa the power percentage with GAHP compared to the design power (both calculated at conditions A2W45)

A percentage of energy produced with GAHP
B SGUE (seasonal GUE) GAHP only
C SGUE (seasonal GUE) GAHP and condening boilers
D SGUE (seasonal GUE) GAHP and existing boilers (assumed with 80% efficiency)

For the "low temperature" profile (LT) see Figure 3.8 *p. 6.*

Figure 3.8 *Graph of LT hot climate ErP energy performance*



In abscissa the power percentage with GAHP compared to the design power (both calculated at conditions A2W35)

A percentage of energy produced with GAHP
B SGUE (seasonal GUE) GAHP only
C SGUE (seasonal GUE) GAHP and condening boilers
D SGUE (seasonal GUE) GAHP and existing boilers (assumed with 80% efficiency)

4 COLD CLIMATE

Table 4.1 *p. 7* shows the main data obtained from the aforementioned standards, with regards to cold climate (reference Helsinki, design temperature -22°C).

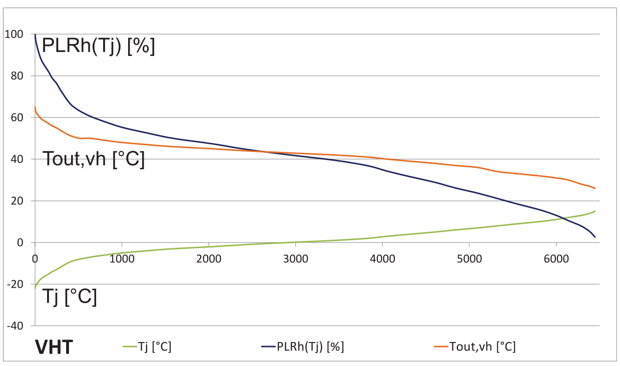
Table 4.1 *Table of cold climate ErP profiles*

Tj [°C]	Hj [h/y]	ΣHj	PLRh(Tj) [%]	Tout,vh [°C]	Tout,h [°C]	Tout,m [°C]	Tout,l [°C]
-22	1	1	100	65	55	45	35
-21	6	7	97	63	54	44	34
-20	13	20	95	62	53	43	34
-19	17	37	92	61	52	43	33
-18	19	56	89	60	51	42	33
-17	26	82	87	59	50	42	32
-16	39	121	84	58	49	41	32
-15	41	162	82	57	49	41	32
-14	35	197	79	56	48	40	31
-13	52	249	76	55	47	40	31
-12	37	286	74	54	47	39	31
-11	41	327	71	53	46	39	31
-10	43	370	68	52	45	39	30
-9	54	424	66	51	45	38	30
-8	90	514	63	50	44	38	30
-7	125	639	61	50	44	38	30
-6	169	808	58	49	43	37	29
-5	195	1003	55	48	42	36	29
-4	278	1281	53	47	41	36	29
-3	306	1587	50	46	40	35	28
-2	454	2041	47	45	40	35	28
-1	385	2426	45	44	39	34	28
0	490	2916	42	43	38	34	27
1	533	3449	39	42	37	33	27
2	380	3829	37	41	37	33	27
3	228	4057	34	40	36	32	26
4	261	4318	32	39	35	31	26
5	279	4597	29	38	34	31	25
6	229	4826	26	37	33	30	25
7	269	5095	24	36	32	30	25
8	233	5328	21	34	31	29	24
9	230	5558	18	33	30	28	24
10	243	5801	16	32	29	27	24
11	191	5992	13	31	28	26	24
12	146	6138	11	30	28	26	24
13	150	6288	8	28	27	25	23
14	97	6385	5	27	26	24	23
15	61	6446	3	26	25	23	23

Tj [°C] = bin outdoor temperature
Hj [h/y] = annual hours of operating at outdoor temperature Tj
ΣHj = cumulative annual hours of operating at temperature equal to or lower than Tj
PLRh(Tj) [%] = system partial load factor at outdoor temperature Tj
Tout,vh [°C] = temperature profile for operating at very high temperature
Tout,h [°C] = temperature profile for operating at high temperature
Tout,m [°C] = temperature profile for medium temperature operating
Tout,l [°C] = temperature profile for operation at low temperature

The graphs for each temperature profile let one appreciate at a glance the relationship between outdoor temperature, load profile (represented by the power percentage with respect to the nominal design power) and system water flow temperature in relation to the cumulative number of hours of operation of the heating system at a given outdoor temperature Tj, for the climate zone considered.
The choice of this reference axis makes it possible to quickly extract useful information for sizing, as detailed in Paragraph 5 *p. 9*.
For the "very high temperature" profile (VHT) see Figure 4.1 *p. 7*.

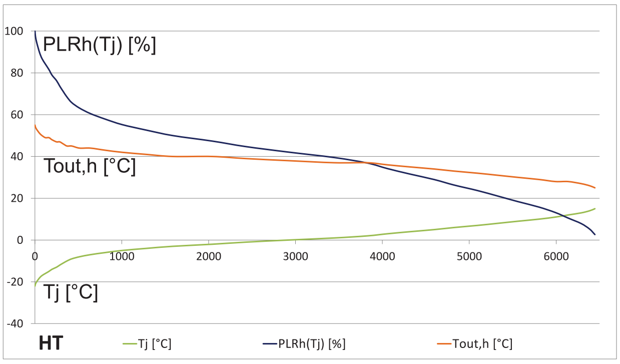
Figure 4.1 *Graph of VHT cold climate ErP profiles*



Tj [°C] bin outdoor temperature
PLRh(Tj) [%] plant partial load ratio at outdoor temperature Tj
Tout,vh [°C] temperature profile for operation at very high temperature

For the "high temperature" profile (HT) see Figure 4.2 *p. 8*.

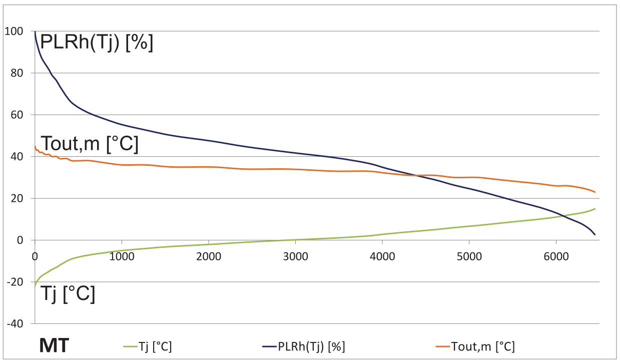
Figure 4.2 *Graph of HT cold climate ErP profiles*



Tj [°C] bin outdoor temperature
PLRh(Tj) [%] plant partial load ratio at outdoor temperature Tj
Tout,h [°C] temperature profile for high temperature operation

For the "medium temperature" profile (MT) see Figure 4.3 *p. 8*.

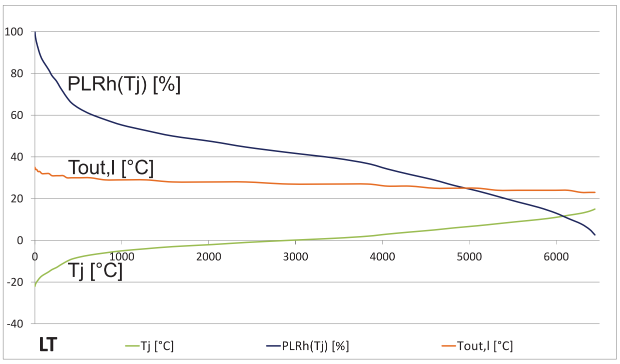
Figure 4.3 *Graph of MT cold climate ErP profiles*



Tj [°C] bin outdoor temperature
PLRh(Tj) [%] plant partial load ratio at outdoor temperature Tj
Tout,m [°C] temperature profile for medium temperature operation

For the "low temperature" profile (LT) see Figure 4.4 *p. 8*.

Figure 4.4 *Graph of LT cold climate ErP profiles*



Tj [°C] bin outdoor temperature
PLRh(Tj) [%] plant partial load ratio at outdoor temperature Tj
Tout,h [°C] temperature profile for low temperature operation

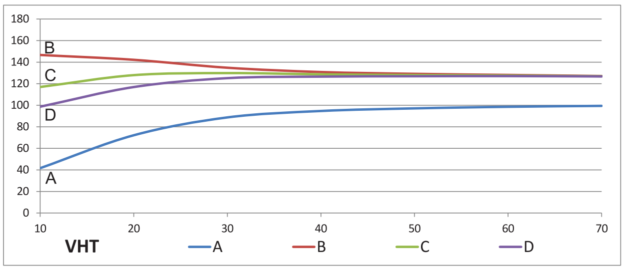
For each of the profiles it is possible to determine, on the basis of the power share covered with GAHP with respect to the design power (both referred to design conditions for the climate zone and chosen temperature profile):

- The percentage of energy produced with GAHP;
- The average seasonal efficiency (SGUE) of the GAHP units alone;
- The average seasonal efficiency (SGUE) of the GAHP hybrid system and supplementary condensing boilers;
- The average seasonal efficiency (SGUE) of the hybrid system GAHP and existing supplementary boilers (assumed with 80% efficiency).

The following Figures show these data for the medium climate zone and for each of the temperature profiles.

For the "very high temperature" profile (VHT) see Figure 4.5 *p. 8*.

Figure 4.5 *Graph of VHT cold climate ErP energy performance*

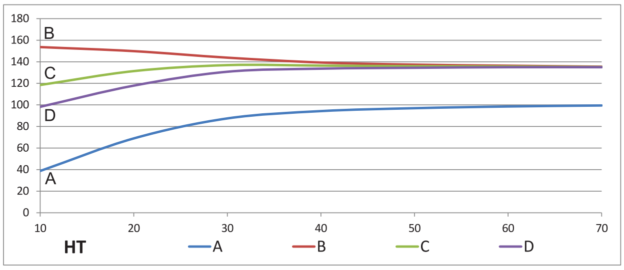


In abscissa the power percentage with GAHP compared to the design power (both calculated at A-22W65 conditions)

A percentage of energy produced with GAHP
B SGUE (seasonal GUE) GAHP only
C SGUE (seasonal GUE) GAHP and condening boilers
D SGUE (seasonal GUE) GAHP and existing boilers (assumed with 80% efficiency)

For the "high temperature" profile (HT) see Figure 4.6 *p. 8*.

Figure 4.6 *Graph of HT cold climate ErP energy performance*

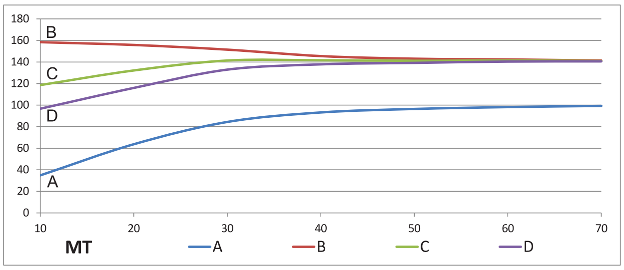


In abscissa the power percentage with GAHP compared to the design power (both calculated at A-22W55 conditions)

A percentage of energy produced with GAHP
B SGUE (seasonal GUE) GAHP only
C SGUE (seasonal GUE) GAHP and condening boilers
D SGUE (seasonal GUE) GAHP and existing boilers (assumed with 80% efficiency)

For the "medium temperature" profile (MT) see Figure 4.7 *p. 9*.

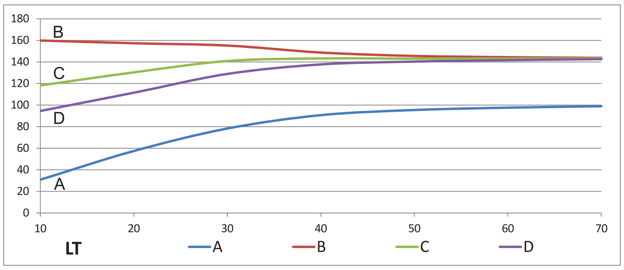
Figure 4.7 *Graph of MT cold climate ErP energy performance*



In abscissa the power percentage with GAHP compared to the design power (both calculated at A-22W45 conditions)

A percentage of energy produced with GAHP
B SGUE (seasonal GUE) GAHP only
C SGUE (seasonal GUE) GAHP and condening boilers
D SGUE (seasonal GUE) GAHP and existing boilers (assumed with 80% efficiency)

Figure 4.8 *Graph of LT cold climate ErP energy performance*



In abscissa the power percentage with GAHP compared to the design power (both calculated at A-22W35 conditions)

A percentage of energy produced with GAHP
B SGUE (seasonal GUE) GAHP only
C SGUE (seasonal GUE) GAHP and condening boilers
D SGUE (seasonal GUE) GAHP and existing boilers (assumed with 80% efficiency)

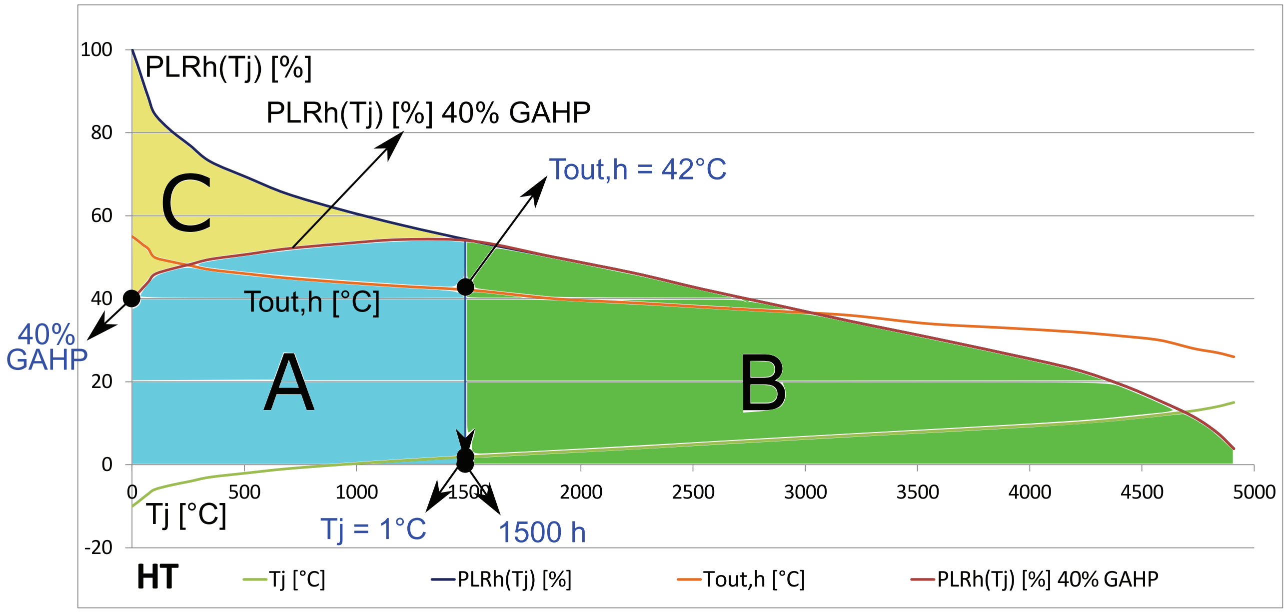
For the "low temperature" profile (LT) see Figure 4.8 *p. 9*.

5 SIZING EXAMPLES

The graphs set out in the previous Paragraphs may be used to obtain useful sizing informations, specifically for the selection of the threshold between base load and peak load (proportion to be covered with heat pumps with respect to design power).
Taking Figure 2.2 *p. 3* and related Figure 2.6 *p. 3* as an example, we assume said threshold between base load and peak load to be set at 40%, i.e. to cover with GAHP 40% of the design power (calculated exactly at the design conditions for the medium climate with HT temperature profile, i.e. A-10W55).
Specifically, in the Figure 5.1 *p. 10* you see how if in case in hypothesis you have:

- The GAHP system (which has operating priority) is at full power for about 1500 h (area A, in blue). In this period, the supplementary boilers power will be modulated to keep up with the building load (area C, in yellow);
- For the remaining hours the GAHP system will operate in capacity control (area B, in green), autonomously covering the building load (supplementary boilers off);
- The outdoor temperature Tj corresponding to the transition between base and peak load (i.e. the transition temperature between GAHP full power operation and capacity control operation) is equal to 1°C;
- The outdoor temperature Tj below which the supplementary boilers are turned on (GAHP still on at full power) is equal to 1°C;
- The delivery temperature Tout,h corresponding to the transition between base and peak is equal to 42°C;
- The delivery temperature Tout,h corresponding to turning on the supplementary boilers is equal to 42°C;

Figure 5.1 *Example of 40% sizing of design load with GAHP*



Tj [°C] bin outdoor temperature
PLRh(Tj) [%] plant partial load ratio at outdoor temperature Tj
PLRh(Tj) [%] 40% GAHP partial load factor covered by GAHP assuming 40% power with GAHP with respect to total design power
Tout,h [°C] temperature profile for high temperature operation
A GAHP operating area at full load
B GAHP operating area at partial load
C integration boilers operating area

By examining the comparison between the sum of areas A and B, which represents the amount of energy covered by the GAHP units, and the total area underneath the blue PLRh(Tj) curve one immediately sees how the energy share actually covered by the GAHP units is decidedly greater than 40% of the mere power sizing.
The data set out in Figure 2.6 *p. 3* may be used to obtain further useful data for assessing optimal sizing.
From the Fgure we can in fact realize that under these conditions:

- The GAHP units would cover about 90% of the building energy needs
- The average seasonal efficiency (SGUE) of the GAHP units alone is equal to 144%
- The average seasonal efficiency (SGUE) of the GAHP hybrid system and asupplementary condensing boilers is equal to 139%
- The average seasonal efficiency (SGUE) of the GAHP hybrid system and existing supplementary boilers (assumed with 80% efficiency) is equal to 134%

With this methodology it is therefore possible to calculate the energy share covered by the GAHP units as a function of the base/peak load share (calculated as percentage with respect to the design power), but also assess the expected average efficiency both for the GAHP units alone and for hybrid systems, either with condensing boilers or with the existing boilers.
Therefore, having established the base/peak threshold value that optimises the investment, one may infer the number of required GAHP units for the system from the building design load by dividing it by the power yielded by the individual GAHP under the same design conditions (minimum outdoor temperature of the climate zone and relevant heating water delivery temperature).
Naturally, the calculation is discreet by its nature, i.e. the result must then be adapted to a whole number of GAHP units.
Intuitively, one may understand how, in colder climates, a higher number of GAHP units is required to cover the same power share, conversely, a lower number is sufficient in warmer climates.

6 IN SUMMARY

From the above in the preceding paragraphs, the following sizing criterion can be drawn, valid in general terms:

- The optimal nominal thermal power share to be covered with GAHP units is between 30% and 40%;
- In the presence of warm climates and low delivery water temperatures it is recommended to move about 40%;
- In the presence of rigid climates and high flow temperatures it is recommended to move about 30%.