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 *Heating temperature limits*

			GAHP A	GAHP-AR	GAHP GS/WS	AY
Heating operation						
Hot water outlet temperature	maximum for heating	°C	65	-	65	-
	maximum	°C	-	60	-	88
Hot water inlet temperature	maximum for heating	°C	55	-	55	-
	maximum	°C	-	50	-	-

Once this indispensable verification has been successfully completed, it is advisable to evaluate a more advanced sizing approach compared to the pure calculation of winter peak power, aimed at both maximising the economic return on investment and verifying the indispensable compliance with any legal requirements relating to the use of renewable energy sources, or even the possibility of accessing incentives related to a minimum efficiency threshold of the system.
The approach aimed at maximising the economic return of the investment involves using absorption heat pumps to cover only part of the building's nominal heat demand (the so-called "base load"), delegating auxiliary boilers to cover the remaining share ("peak load"); the limited number of hours of operation per year at peak load usually reduces the overall contribution of the peak in terms of seasonal energy (and thus in economic terms).
The presence of legal requirements relating to a minimum threshold for the use of renewable energy sources may substantially alter this sizing criterion, and force the installation of a much larger (if not total) share of heat pumps, depending on the type of building and users served.
Even in the absence of a regulatory constraint on renewable energy quotas, the sizing may be influenced (in the direction of a higher power share of heat pumps compared to possible auxiliary boilers) by the desire to access incentives, usually related to the efficiency achievable by the generation system or building during the heating season.
It should be emphasised that absorption heat pumps maintain uninterrupted operation even at extremely low outdoor temperatures. Therefore, the role of auxiliary boilers is not that of backup units (as in a bivalent system typical of electric heat pumps, i.e. in which the boilers replace the electric heat pumps below a specific outdoor temperature), but is actually to integrate the power supplied by the heat pumps, which does not cover the peak load due to a technical-economic design choice.
These different sizing criteria are reflected in the choice of the best compromise between the number of heat pumps to be installed and the number of boilers, if any, against 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 turn depends on the geographical location of the building to be heated and on its usage profile.
- ► Operating temperature of the systems, also in relation to the characteristics of the heat pump model to be used.

In order to provide some useful general guidance, below is an analysis based on the calculation models provided by the European Directive 2009/125/EC and related ErP Regulations (Energy Related Products, 811/2013 in particular), as well as the European product standard EN 12309.
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.
Since the performance of the heat pump is influenced by both the outdoor temperature and the required water outlet temperature, making a rough calculation without resorting to complex calculation software may not be simple. In fact, such software requires the input of a series of data in order to be able to offer a usable result, data which is not always available, because, for example, you simply want to make a rough economic sizing for a possible space heating solution for a building whose construction details have not yet been precisely defined.
The graphs in the following paragraphs, on the other hand, offer a simple way to get an idea of the performance offered by a precise mix of heat pumps and boilers (represented by the percentage of the heat pumps' heat output compared to the system's total heat output, based on design conditions), depending on the climate zone and temperature profile.
For each of the temperature profiles, it is possible to determine, simply by consulting the graph:
- ► the percentage of energy produced with GAHP
- ► the seasonal average efficiency (SGUE) of the GAHP alone
- ► the seasonal average efficiency (SGUE) of the hybrid system with GAHP and auxiliary condensing boilers
- ► the seasonal average efficiency (SGUE) of the hybrid system with GAHP and auxiliary existing boilers (assumed with 80% efficiency)

It is essential to emphasise again how different sizing criteria are possible to assess the best mix between heat pumps and any auxiliary boilers. Correct sizing can never disregard a more complete evaluation of the system, which also involves the emission devices, necessarily considering their behaviour at heat pumps' operating temperatures and an evaluation of the targets linked to any performance requirements or to the exploitation of renewable energy sources.

The use of diagrams to quickly obtain information about the operation of the system is in no case a substitute for the calculation procedures required by the regulations in force and the relevant conformity checks with respect to all legal requirements for the design of systems or for access to incentives.

1.1 THE REGULATION 811/2013

Regulation 811/2013 sets forth:

- Three climate zones (warmer climate, average climate and colder climate).
- A reference building model.
- A typical seasonal temperature trend profile, in terms of bins. Bins represent the number of hours/year for which the system is expected to operate at a given outdoor temperature.

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

- Athens for warmer climate conditions (design outdoor temperature 2 °C)
- Strasbourg for average climate conditions (design outdoor temperature -10 °C)
- Helsinki for colder climate conditions (design outdoor temperature -22 °C)

1.2 THE STANDARD EN 12309

For the three climate zones described in Paragraph 1.1 *p. 2*, the system operating temperatures are defined within the product standard EN 12309 according to the type of distribution system (underfloor heating, fancoil, radiators, ...).
In particular, four temperature profiles are defined in the standard, each of which may be either fixed or variable outlet temperature according to a heating curve depending on the outdoor temperature (hence on 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
- very 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 outlet temperature is defined "high temperature" in EN 12309 (as listed above), while it is defined "medium temperature" in Regulation 811/2013.

2 MEDIUM CLIMATE

Table 2.1 *p. 3* shows the main data from the above-mentioned standards for the average climate (reference Strasbourg, design outdoor temperature -10 °C).

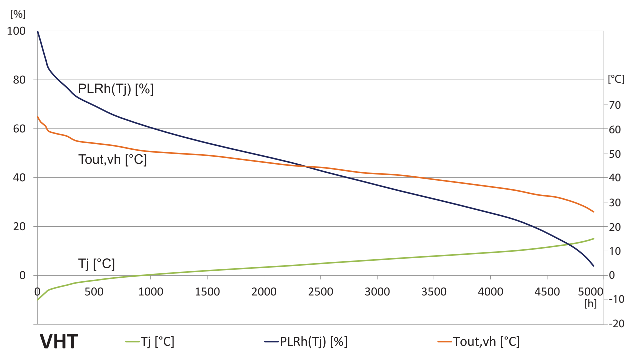
Table 2.1 *Table of medium climate ErP profiles*

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 in the following figures, for each temperature profile, let you appreciate at a glance the relationship between outdoor temperature, load profile (represented by the power percentage with respect to the design rated power) and system outlet temperature with reference to the number of cumulative 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. 3* below.

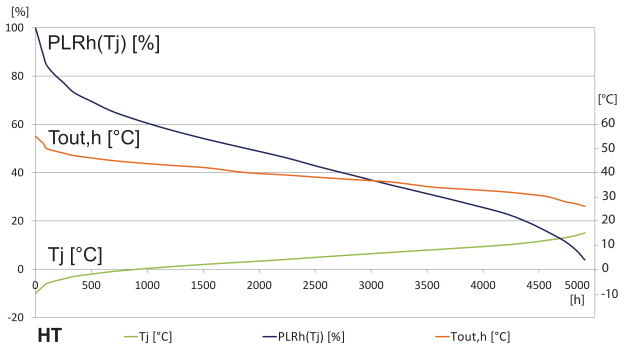
Figure 2.1 *Graph of VHT medium climate ErP profiles*



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

For the "high temperature" profile (HT) see Figure 2.2 *p. 4* below.

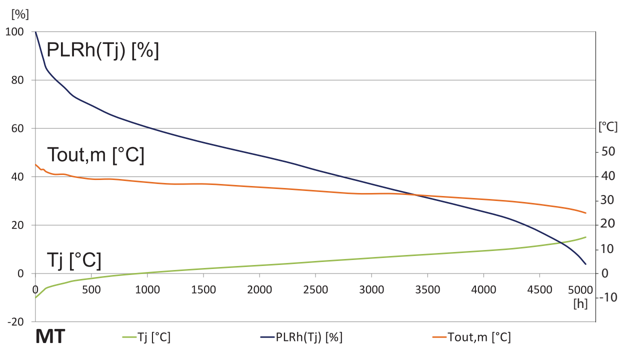
Figure 2.2 *Graph of HT medium climate ErP profiles*



Tj [°C] Bin outdoor temperature
PLRh(Tj) [%] System 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. 4* below.

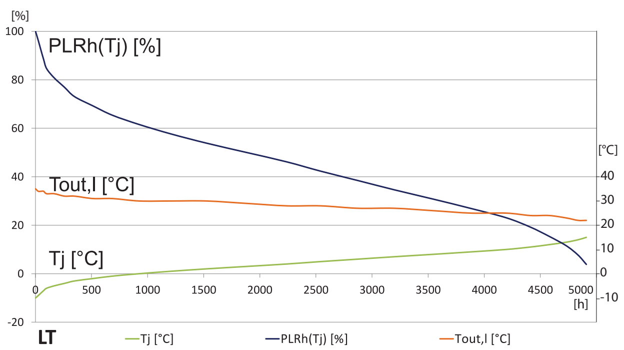
Figure 2.3 *Graph of MT medium climate ErP profiles*



Tj [°C] Bin outdoor temperature
PLRh(Tj) [%] System 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. 4* below.

Figure 2.4 *Graph of LT medium climate ErP profiles*



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

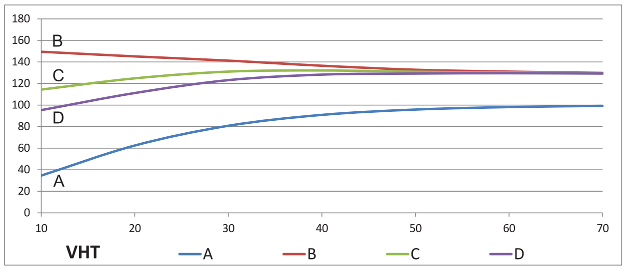
For each of the profiles, it is possible to determine, on the basis of the share of power covered with GAHP compared to the design power (both referring to the design conditions for the climate zone and the chosen temperature profile):

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

The graphs in the following figures show these data for the average climate zone and for each of the temperature profiles.

For the "very high temperature" profile (VHT) see Figure 2.5 *p. 4* below.

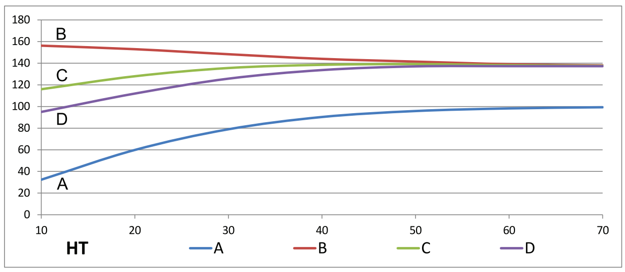
Figure 2.5 *Graph of VHT medium climate ErP energy performance*



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

For the "high temperature" profile (HT) see Figure 2.6 *p. 4* below.

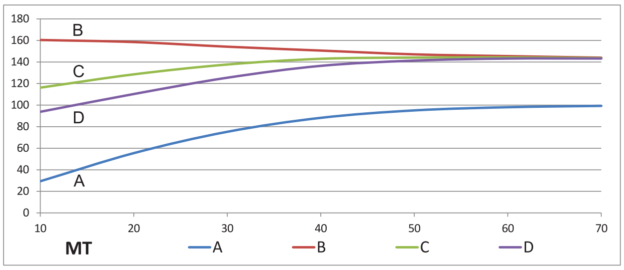
Figure 2.6 *Graph of HT medium climate ErP energy performance*



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

For the "medium temperature" profile (MT) see Figure 2.7 *p. 5* below.

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

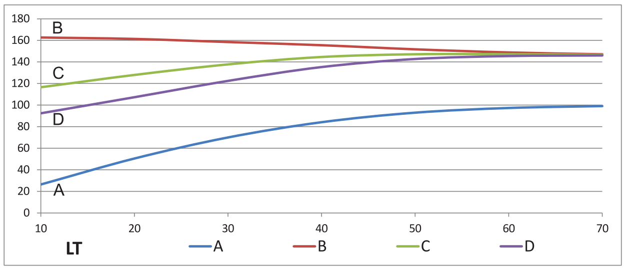


In abscissa the power percentage with GAHP compared to the design power (both calculated at A-10W45 conditions)

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

For the "low temperature" profile (LT) see Figure 2.8 *p. 5* below.

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 A-10W35 conditions)

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

3 HOT CLIMATE

Table 3.1 *p. 5* shows the main data from the above-mentioned standards for the warmer climate (reference Athens, design outdoor temperature 2 °C).

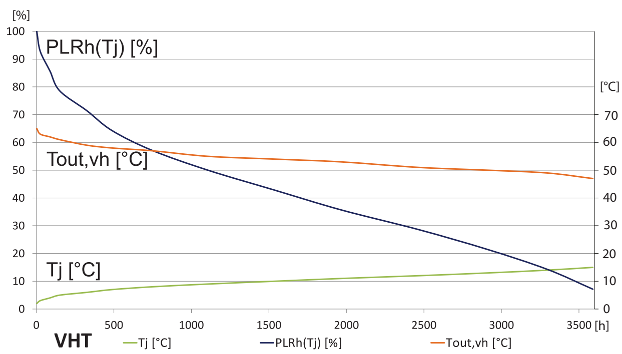
Table 3.1 *Table of hot climate ErP profiles*

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 in the following figures, for each temperature profile, let you appreciate at a glance the relationship between outdoor temperature, load profile (represented by the power percentage with respect to the design rated power) and system outlet temperature with reference to the number of cumulative 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* below.

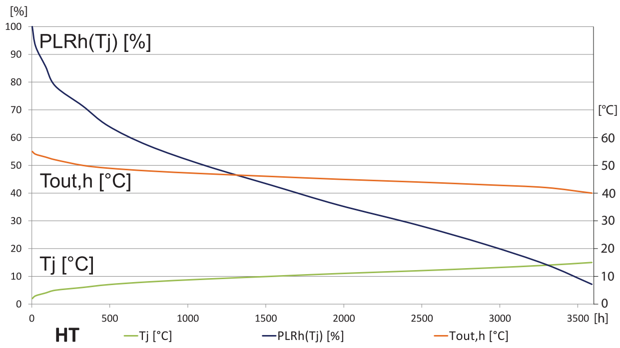
Figure 3.1 *Graph of VHT hot climate ErP profiles*



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

For the "high temperature" profile (HT) see Figure 3.2 *p. 6* below.

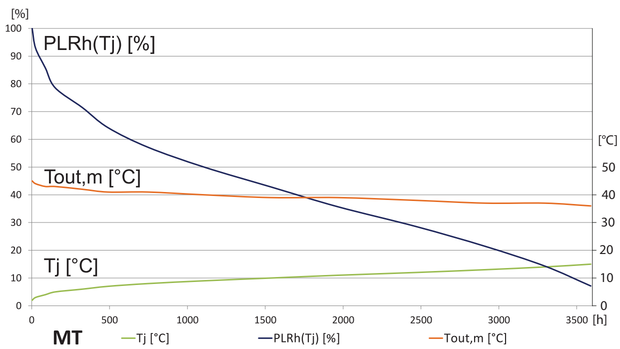
Figure 3.2 *Graph of HT hot climate ErP profiles*



Tj [°C] Bin outdoor temperature
PLRh(Tj) [%] System 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. 6* below.

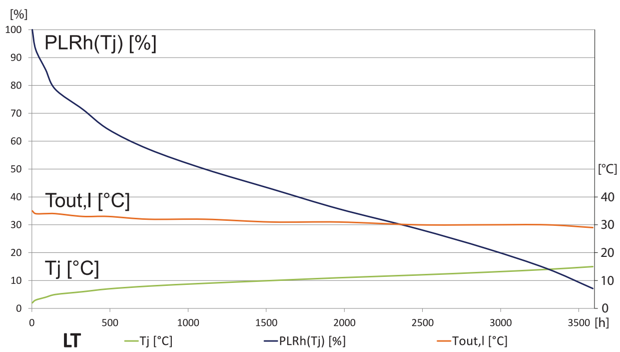
Figure 3.3 *Graph of MT hot climate ErP profiles*



Tj [°C] Bin outdoor temperature
PLRh(Tj) [%] System 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. 6* below.

Figure 3.4 *Graph of LT hot climate ErP profiles*



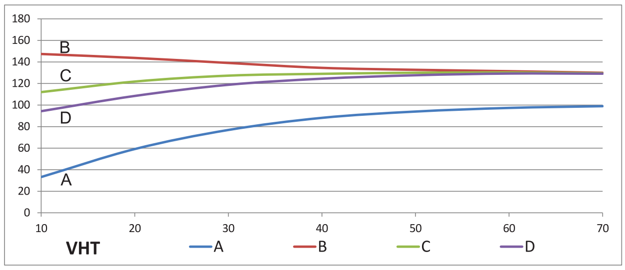
Tj [°C] Bin outdoor temperature
PLRh(Tj) [%] System partial load ratio at outdoor temperature Tj
Tout,h [°C] Temperature profile for low temperature operation

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

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

The graphs in the following figures show these data for the average climate zone and for each of the temperature profiles.
For the "very high temperature" profile (VHT) see Figure 3.5 *p. 6* below.

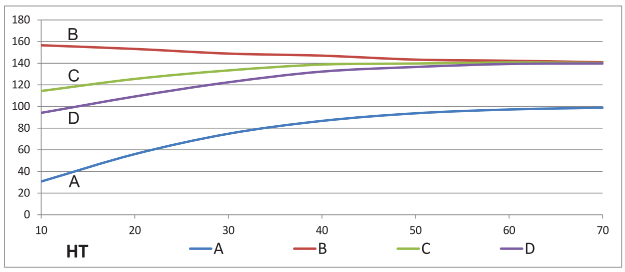
Figure 3.5 *Graph of VHT hot climate ErP energy performance*



In abscissa the power percentage with GAHP compared to the design power (both calculated at A2W65 conditions)
A Share of energy produced with GAHP
B SGUE (seasonal GUE) GAHP only
C SGUE (seasonal GUE) GAHP and condensing 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* below.

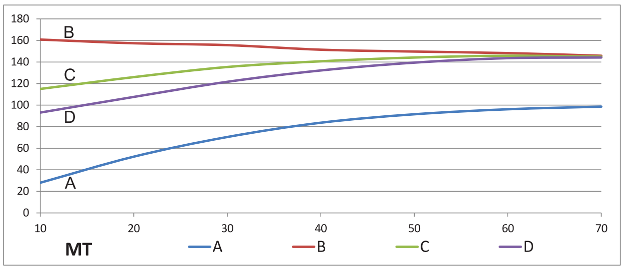
Figure 3.6 *Graph of HT hot climate ErP energy performance*



In abscissa the power percentage with GAHP compared to the design power (both calculated at A2W55 conditions)
A Share of energy produced with GAHP
B SGUE (seasonal GUE) GAHP only
C SGUE (seasonal GUE) GAHP and condensing boilers
D SGUE (seasonal GUE) GAHP and existing boilers (assumed with 80% efficiency)

For the "medium temperature" profile (MT) see Figure 3.7 *p. 7* below.

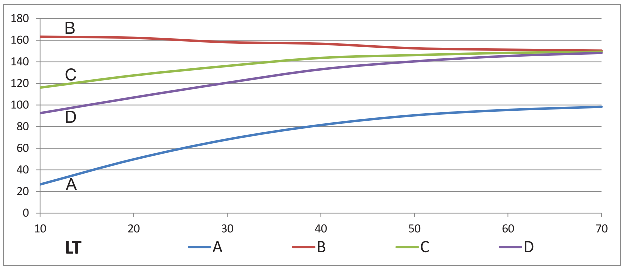
Figure 3.7 *Graph of MT hot climate ErP energy performance*



In abscissa the power percentage with GAHP compared to the design power (both calculated at A2W45 conditions)
A Share of energy produced with GAHP
B SGUE (seasonal GUE) GAHP only
C SGUE (seasonal GUE) GAHP and condensing boilers
D SGUE (seasonal GUE) GAHP and existing boilers (assumed with 80% efficiency)

For the "low temperature" profile (LT) see Figure 3.8 *p. 7* below.

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 A2W35 conditions)
A Share of energy produced with GAHP
B SGUE (seasonal GUE) GAHP only
C SGUE (seasonal GUE) GAHP and condensing 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 from the above-mentioned standards for the colder climate (reference Helsinki, design outdoor temperature -22 °C).

Table 4.1 *Table of cold climate ErP profiles*

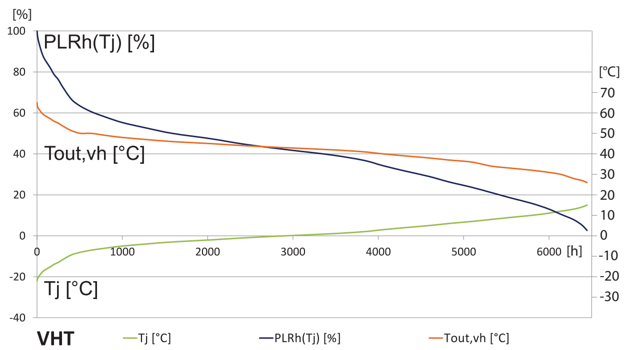
Tj [°C]	Hj [h/y]	ΣHj	PLRh(Tj) [%]	Tout,vh [°C]	Tout,h [°C]	Tout,m [°C]	Tout,l [°C]
-22	1	1	100	65	55	45	35
-21	6	7	97	63	54	44	34
-20	13	20	95	62	53	43	34
-19	17	37	92	61	52	43	33
-18	19	56	89	60	51	42	33
-17	26	82	87	59	50	42	32
-16	39	121	84	58	49	41	32
-15	41	162	82	57	49	41	32
-14	35	197	79	56	48	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

Tj [°C]	Hj [h/y]	ΣHj	PLRh(Tj) [%]	Tout,vh [°C]	Tout,h [°C]	Tout,m [°C]	Tout,l [°C]
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 in the following figures, for each temperature profile, let you appreciate at a glance the relationship between outdoor temperature, load profile (represented by the power percentage with respect to the design rated power) and system outlet temperature with reference to the number of cumulative 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. 8* below.

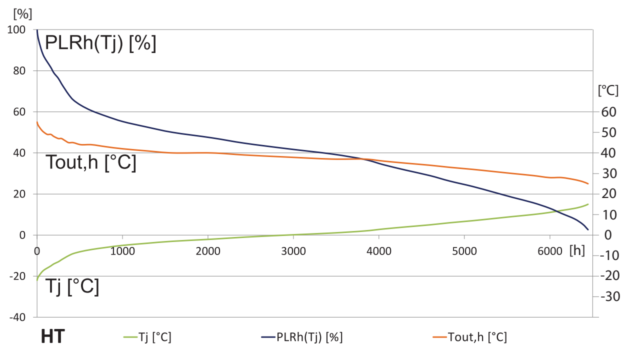
Figure 4.1 *Graph of VHT cold climate ErP profiles*



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

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

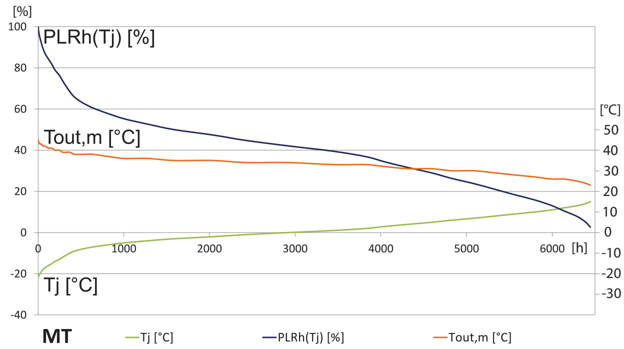
Figure 4.2 *Graph of HT cold climate ErP profiles*



Tj [°C] Bin outdoor temperature
PLRh(Tj) [%] System 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* below.

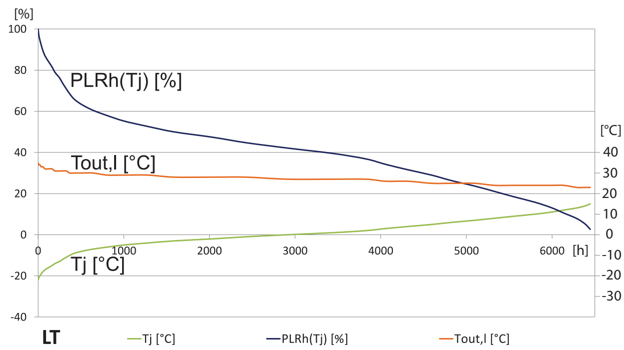
Figure 4.3 *Graph of MT cold climate ErP profiles*



Tj [°C] Bin outdoor temperature
PLRh(Tj) [%] System 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* below.

Figure 4.4 *Graph of LT cold climate ErP profiles*



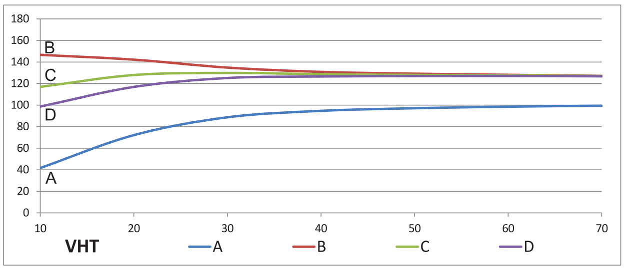
Tj [°C] Bin outdoor temperature
PLRh(Tj) [%] System partial load ratio at outdoor temperature Tj
Tout,h [°C] Temperature profile for low temperature operation

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

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

The graphs in the following figures show these data for the average climate zone and for each of the temperature profiles.
For the "very high temperature" profile (VHT) see Figure 4.5 *p. 9* below.

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

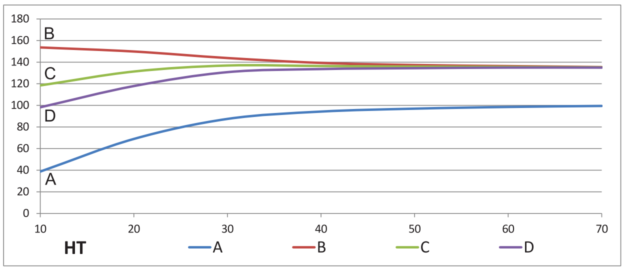


In abscissa the power percentage with GAHP compared to the design power (both calculated at A-22W65 conditions)

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

For the "high temperature" profile (HT) see Figure 4.6 *p. 9* below.

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

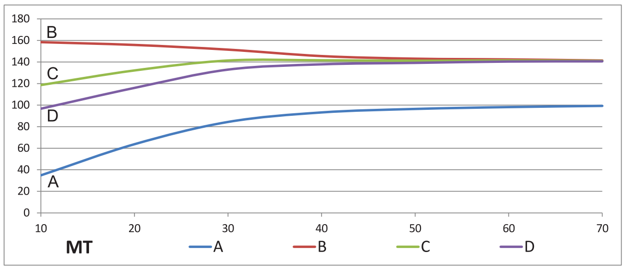


In abscissa the power percentage with GAHP compared to the design power (both calculated at A-22W55 conditions)

- A Share of energy produced with GAHP
- B SGUE (seasonal GUE) GAHP only
- C SGUE (seasonal GUE) GAHP and condensing 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* below.

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

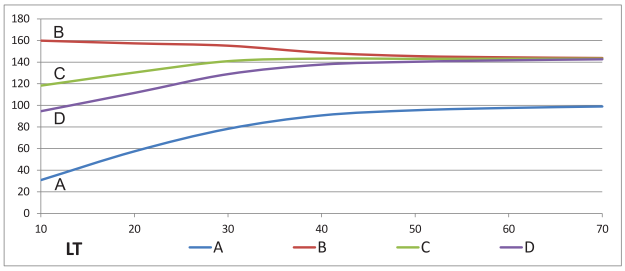


In abscissa the power percentage with GAHP compared to the design power (both calculated at A-22W45 conditions)

- A Share of energy produced with GAHP
- B SGUE (seasonal GUE) GAHP only
- C SGUE (seasonal GUE) GAHP and condensing 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* below.

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)

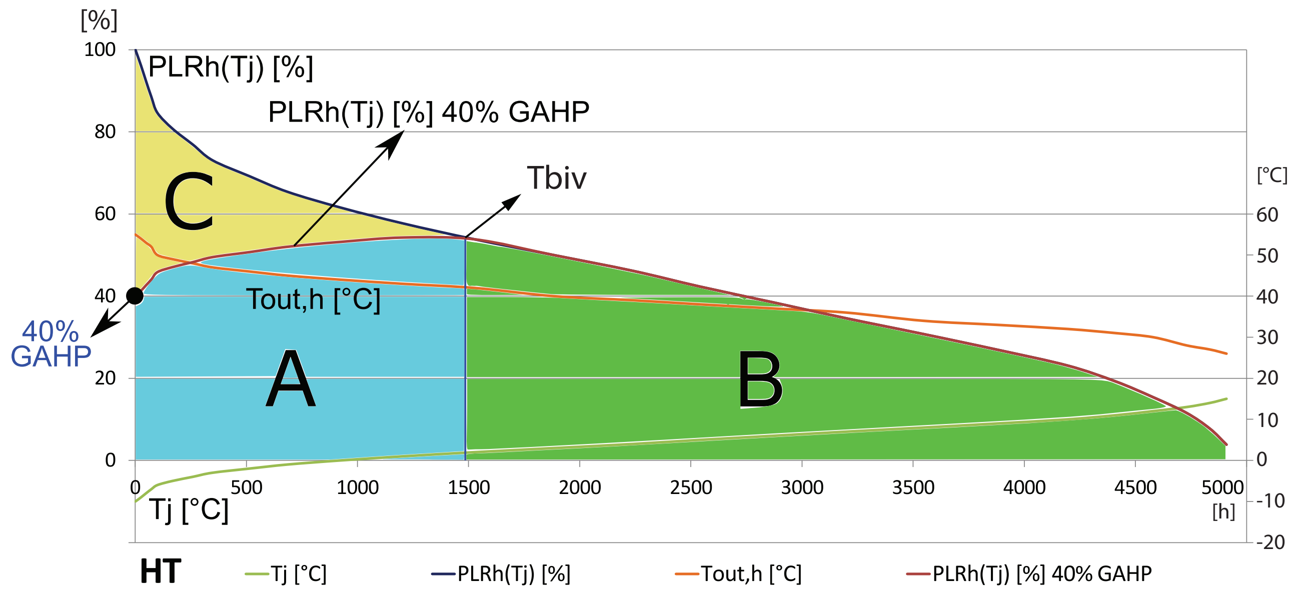
- A Share of energy produced with GAHP
- B SGUE (seasonal GUE) GAHP only
- C SGUE (seasonal GUE) GAHP and condensing boilers
- D SGUE (seasonal GUE) GAHP and existing boilers (assumed with 80% efficiency)

5 SIZING EXAMPLE

The graphs set out in the previous paragraphs may be used to obtain useful sizing information, specifically to estimate the expected average seasonal efficiency of the generation system and the overall share of energy produced by heat pumps in relation to demand, as a function of the share of the design power covered by heat pumps.
Taking Figure 2.2 *p. 4* and related Figure 2.6 *p. 4* as an example, we assume that GAHP covers 40% of the design load (calculating the power output of the individual heat pump at the design conditions for that climate zone and temperature profile, i.e. in this example A-10W55), leaving the boilers to cover the remaining 60%.
Specifically, in Figure 5.1 *p. 10* we see how in the case in point we have:

- ► The GAHP system (area A, in blue), which has priority operation, will be at full power for approximately 30% of the total heating system operation time (4910 hours for the average climate zone, Table 2.1 *p. 3*). During this period, the auxiliary boilers (area C, in yellow) will modulate their output to follow the building load, as the heat output of the GAHP alone is not sufficient to cover the heat output demand of the building.
- ► For the remaining hours, the GAHP system will operate in partial load mode (area B, in green), autonomously covering the building load (auxiliary boilers off). In this case, the heat output delivered by the GAHP alone is higher than the heat output demand of the building.
- ► The bivalent outdoor temperature Tj corresponding to the transition between operation at full power (with the boilers intervening for complement) and the partial operation of the GAHP (with the boilers switched off) will be around 0 °C.

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



Tbiv [°C]	Bivalent temperature	Tout,h [°C]	Temperature profile for high temperature operation
Tj [°C]	Bin outdoor temperature	A	GAHP operating area at full load
PLRh(Tj) [%]	System partial load ratio at outdoor temperature Tj	B	GAHP operating area at partial load
PLRh(Tj) [%] 40% GAHP	Partial load ratio covered by GAHP assuming 40% power with GAHP compared to total design power	C	Auxiliary boilers operating area

Evaluating the ratio between the sum of areas A and B, which represents the amount of energy covered by GAHP, compared to the total area under the blue curve of PLRh(Tj), which represents the total heat output demand of the building, it is immediately clear that the energy share actually covered by GAHP is much greater than the 40% (which was the initial sizing assumption, i.e. covering 40% of the design power with GAHP), thus covering approximately 90% of the building's total heat output demand.
The fact that the GAHP system mostly delivers more heat output than the building's needs is not a problem as sophisticated control systems are available (see Section C01.11 for more details) that allow the generation system to be managed with appropriate capacity step levels, so as to optimise the energy supply (and consequently the gas consumption) to the building's actual needs.
Using the data shown in Figure 2.6 *p. 4* and referring to the coverage with GAHP of 40% of the design power (value 40 in the abscissa), it is possible to derive further data useful for assessing optimal sizing.
We can indeed derive that under these conditions:

- the GAHP will cover approximately 90% of the building's heat output demand
- The seasonal average efficiency (SGUE) of the GAHP alone will be 144%
- The seasonal average efficiency (SGUE) of the hybrid system with GAHP and auxiliary condensing boilers will be 139%
- The seasonal average efficiency (SGUE) of the hybrid system with GAHP and auxiliary existing boilers (assumed with 80% efficiency) will be 139%

With this method, it is therefore possible to calculate the energy share covered by GAHP as a function of the share of the GAHP's power output to the design rated power, but also to make a first estimation of the expected average seasonal efficiency for both GAHP alone and for hybrid systems, either with condensing boilers or with existing boilers.

First of all, it is therefore necessary to establish the percentage of power, compared to the actual value of the building's design load (which can be obtained either from rough estimates or from the appropriate calculation software), which allows the criteria defined as an objective to be met (maximising the economic return on investment rather than complying with any legal requirements relating to the use of renewable energy sources rather than accessing incentives related to a minimum efficiency threshold of the system, or other).
From the power obtained in this way, the number of GAHP required for the system can be calculated by dividing this power by the power output of the individual GAHP under the same design conditions (minimum outdoor temperature of the climate zone and the corresponding heating water delivery temperature).
Of course, the calculation is discrete in nature, i.e. the result must then be adapted to an integer number of GAHP.
Intuitively, you can understand how, in colder climates, a higher number of GAHP is needed to cover the same power share, while in warmer climates a lower number is sufficient.

5.1 AVERAGE ZONE, VERY HIGH TEMPERATURE

Let us assume that we have a heat output demand at design conditions of 400 kW and that we are in an average climate zone with a VHT temperature profile, i.e. very high temperature.
Consequently, the reference design conditions at which to calculate the power output of each individual GAHP will be A-10W65.
If we assume using heating-only GAHP A heat pumps for heating system, the power output of each GAHP A at design conditions (A-10W65) is 25,2 kW (see appliance performance tables in Section B01).
Several scenarios open up at this point, depending on the criterion according to which sizing is carried out:

- If the priority is to have the most efficient system, I will choose to cover all the power with GAHP A heat pumps. Consequently, the number of GAHP A to be installed will be (400/25,2) = 15,9. Consequently, the system will consist of 16 GAHP A. However, this is also the most costly sizing.

- If the priority is the best cost/benefit trade-off, I will choose to cover, for example, only 40% of the design output with GAHP A heat pumps, which will still ensure that the heat pumps cover approximately 90% of the building's heat output demand (as set out in the 5 *p. 9* Paragraph above, adapting the calculations to the different temperature profile). In this way, (400x0,4/25,2) = 6,3 units will be sufficient. Consequently, the system will consist of 7 GAHP A and three AY auxiliary boilers, two AY 100 and one AY 50.
- If the priority is to achieve a given share of renewable energy, appropriate simulations must be carried out, using suitable calculation software, to determine the share of renewable energy that can be achieved with a specific percentage of heat pumps in relation to the design power. Let us assume, for example, that by covering 80% of the design output with GAHP I can meet this requirement. Consequently, the number of GAHP A to be installed will be (400x0,8/25,2) = 12,7. Consequently, the system will consist of 13 GAHP A and an auxiliary AY 100 boiler. This sizing will be extremely efficient, but less costly than that based on GAHP A alone.

Depending on the criteria identified for sizing, optimal solutions can be identified on a case-by-case basis, which at the same time achieve the chosen objective and maximise the cost/benefit ratio.

5.2 AVERAGE ZONE, HIGH TEMPERATURE

Let us assume that we have a heat output demand at design conditions of 400 kW and that we are in an average climate zone with an HT temperature profile, i.e. high temperature.
Consequently, the reference design conditions at which to calculate the power output of each individual GAHP will be A-10W55.
If we assume using heating-only GAHP A heat pumps for heating system, the power output of each GAHP A at design conditions (A-10W55) is 28,2 kW (see appliance performance tables in Section B01).
Several scenarios open up at this point, depending on the criterion according to which sizing is carried out:

- If the priority is to have the most efficient system, I will choose to cover all the power with GAHP A heat pumps. Consequently, the number of GAHP A to be installed will be (400/28,2) = 14,2. Consequently, the system will consist of 15 GAHP A. However, this is also the most costly sizing.
- If the priority is the best cost/benefit trade-off, I will choose to cover, for example, only 40% of the design output with GAHP A heat pumps, which will still ensure that the heat pumps cover approximately 90% of the building's heat output demand (as set out in the 5 *p. 9* Paragraph above). In this way, (400x0,4/28,2) = 5,6 units will be sufficient. Consequently, the system will consist of 6 GAHP A and three AY auxiliary boilers, two AY 100 and one AY 50.
- If the priority is to achieve a given share of renewable energy, appropriate simulations must be carried out, using suitable calculation software, to determine the share of renewable energy that can be achieved with a specific percentage of heat pumps in relation to the design power. Let us assume, for example, that by covering 80% of the design output with GAHP I can meet this requirement. Consequently, the number of GAHP A to be installed will be (400x0,8/28,2) = 11,3. Consequently, the system will consist of 12 GAHP A and an auxiliary AY 100 boiler. This sizing will be extremely efficient, but less costly than that based on GAHP A alone.

Depending on the criteria identified for sizing, optimal solutions can be identified on a case-by-case basis, which at the same time achieve the chosen objective and maximise the cost/benefit ratio.

5.3 COLDER ZONE, VERY HIGH TEMPERATURE

Let us assume that we have a heat output demand at design conditions of 400 kW and that we are in a cold climate zone with a VHT temperature profile, i.e. very high temperature.
Consequently, the reference design conditions at which to calculate the power output of each individual GAHP will be A-22W65.
If we assume using heating-only GAHP A heat pumps for heating system, the power output of each GAHP A at design conditions (A-22W65) is 22,2 kW.
Several scenarios open up at this point, depending on the criterion according to which sizing is carried out:

- If the priority is to have the most efficient system, I will choose to cover all the power with GAHP A heat pumps. Consequently, the number of GAHP A to be installed will be (400/22,2) = 18. Consequently, the system will consist of 18 GAHP A. However, this is also the most costly sizing.
- If the priority is the best cost/benefit trade-off, I will choose to cover, for example, only 40% of the design output with GAHP A heat pumps, which will still ensure that the heat pumps cover approximately 91% of the building's heat output demand (as set out in the 5 *p. 9* Paragraph above, adapting the calculations to the different climate zone and temperature profile). In this way, (400x0,4/22,2) = 7,2 units will be sufficient. Consequently, the system will consist of 8 GAHP A and three AY auxiliary boilers, two AY 100 and one AY 50.
- If the priority is to achieve a given share of renewable energy, appropriate simulations must be carried out, using suitable calculation software, to determine the share of renewable energy that can be achieved with a specific percentage of heat pumps in relation to the design power. Let us assume, for example, that by covering 80% of the design output with GAHP I can meet this requirement. Consequently, the number of GAHP A to be installed will be (400x0,8/22,2) = 14,4. Consequently, the system will consist of 15 GAHP A and an auxiliary AY 100 boiler. This sizing will be extremely efficient, but less costly than that based on GAHP A alone.

Depending on the criteria identified for sizing, optimal solutions can be identified on a case-by-case basis, which at the same time achieve the chosen objective and maximise the cost/benefit ratio.

5.4 WARMER ZONE, LOW TEMPERATURE

Let us assume that we have a heat output demand at design conditions of 400 kW and that we are in a warm climate zone with an LT temperature profile, i.e. low temperature.
Consequently, the reference design conditions at which to calculate the power output of each individual GAHP will be A2W35.
If we assume using heating-only GAHP A heat pumps for heating system, the power output of each GAHP A at design conditions (A2W35) is 40,9 kW (see appliance performance tables in Section B01).
Several scenarios open up at this point, depending on the criterion according to which sizing is carried out:

- If the priority is to have the most efficient system, I will choose to cover all the power with GAHP A heat pumps. Consequently, the number of GAHP A to be installed will be (400/40,9) = 9,8. Consequently, the system will consist of 10

GAHP A. However, this is also the most costly sizing.
- If the priority is the best cost/benefit trade-off, I will choose to cover, for example, only 40% of the design output with GAHP A heat pumps, which will still ensure that the heat pumps cover approximately 88% of the building's heat output demand (as set out in the 5 *p. 9* Paragraph above, adapting the calculations to the different climate zone and temperature profile). In this way, (400x0,4/40,9) = 3,9 units will be sufficient. Consequently, the system will consist of 4 GAHP A and three AY auxiliary boilers, two AY 100 and one AY 50.
- If the priority is to achieve a given share of renewable energy, appropriate simulations must be carried out, using suitable calculation software, to determine the share of renewable energy that can be achieved with a specific percentage of heat pumps in relation to the design power. Let us assume, for example, that by covering 60% of the design output with GAHP I can meet this requirement. Consequently, the number of GAHP A to be installed will be (400x0,6/40,9) = 5,9. Consequently, the system will consist of 6 GAHP A and an auxiliary AY 100 boiler. This sizing will be extremely efficient, but less costly than that based on GAHP A alone.

Depending on the criteria identified for sizing, optimal solutions can be identified on a case-by-case basis, which at the same time achieve the chosen objective and maximise the cost/benefit ratio.

6 APPLIANCE SELECTION CRITERIA

The main features of the appliances are summarised below, which will help you quickly identify the type of appliance that best meets your project needs.
The types of available appliances are divided into:
- Individual GAHP/GA/AY appliances
- Gitié 2.0 integrated package
- Link

The product configurator (accessible from the Robur website) is available for a guided selection of the most suitable appliance depending on the power requirements and the type of service required by your system.

Please refer to Section B for a more detailed description of the characteristics of each appliance.

6.1 SINGLE UNITS

The individual appliances are further divided into:
- GAHP heat pumps
- GA chillers and chiller-heaters
- AY boilers

It is possible to have several individual units on the same system, but it should be considered that the choice of a Link, in this case, offers multiple advantages in terms of simplified design and installation and control effectiveness.

6.1.1 GAHP heat pumps

Heat pumps in the GAHP range are:
- GAHP A: gas and aerothermal renewable energy absorption heat pump, modulating and condensing, for hot water production up to a delivery temperature of 65 °C (70 °C at 50% of maximum thermal input), for outdoor installation. Heat output for each unit (A7W35): 41,3 kW.
- GAHP A Indoor: gas and aerothermal renewable energy absorption heat pump, modulating and condensing, for hot water production up to a delivery temperature of 65 °C (70 °C at 50% of maximum thermal input), for installation in a technical room. Heat output for each unit (A7W35): 41,3 kW.
- GAHP-AR: gas and aerothermal renewable energy absorption heat pump, reversible, for hot water production up to a delivery temperature of 60 °C and alternatively cold water down to a delivery temperature of 3 °C, for outdoor installation. Heat output for each unit (A7W35): 37,8 kW. Cooling output for each unit (A35W7): 16,9 kW.
- GAHP GS HT: gas and geothermal renewable energy absorption heat pump, modulating and condensing, for alternate or simultaneous production of hot water up to a delivery temperature of 65 °C (70 °C at 50% of maximum thermal input) and cold water even at negative temperatures (minimum delivery temperature -5 °C), for outdoor or indoor installation. Heat output for each unit (B0W35): 41,6 kW.
- GAHP WS: gas and geothermal renewable energy absorption heat pump, modulating and condensing, for alternate or simultaneous production of hot water up to a delivery temperature of 65 °C (70 °C at 50% of maximum thermal input) and cold water down to a delivery temperature of 3 °C, for outdoor or indoor installation. Heat output for each unit (W10W35): 43,9 kW.

6.1.2 GA chillers and chiller-heaters

- GA ACF: gas absorption chiller for residential/commercial/industrial cooling systems with chilled water down to 3 °C.
- GA ACF HR: gas absorption chiller-heater with heat recovery exchanger, for residential/commercial/industrial cooling systems with chilled water down to 3 °C, plus hot water from the heat recovery exchanger up to 75 °C (e.g. DHW production).
- GA ACF TK: gas absorption chiller for systems and process applications with chilled water down to 3 °C, in continuous operation all year round.
- GA ACF HT: gas absorption chiller for very hot climates, for residential/commercial/industrial cooling systems with chilled water down to 5 °C, with outdoor air up to 50 °C.
- GA ACF LB: gas absorption chiller for negative temperatures, for refrigeration systems with chilled water down to -10 °C (glycol required).

6.1.3 AY boilers

- AY 35: modulating gas condensing boiler with sealed chamber for hot water production up to a delivery temperature of 88 °C, for indoor or outdoor installation, effective power 33,4 kW.
- AY 50: modulating gas condensing boiler with sealed chamber for hot water production up to a delivery temperature of 88 °C, for indoor or outdoor installation, effective power 49,2 kW.
- AY 100: modulating gas condensing boiler with sealed chamber for hot water production up to a delivery temperature of 88 °C, for indoor or outdoor installation, effective power 98,4 kW.

6.2 GITIÉ

There are three Gitié 2.0 families available:

- AHAY: Integrated package consisting of a GAHP A absorption heat pump and an AY condensing boiler
- ARAY: Integrated package consisting of a GAHP-AR reversible absorption heat pump and an AY condensing boiler
- ACAY: Integrated package consisting of an GA ACF absorption chiller and an AY condensing boiler

Each of these is further split as each Gitié 2.0 can be set up with either a AY 35 or AY 50 boiler.

- AHAY35: Heat output for each unit (A7W35): 77,4 kW
- AHAY50: Heat output for each unit (A7W35): 94,3 kW
- ARAY35: Heat output for each unit (A7W35): 73,8 kW. Cooling output for each unit (A35W7): 16,9 kW
- ARAY50: Heat output for each unit (A7W35): 90,8 kW. Cooling output for each unit (A35W7): 16,9 kW
- ACAY35: effective power 33,4 kW. Cooling output for each unit (A35W7): 17,7 kW
- ACAY50: effective power 49,2 kW. Cooling output for each unit (A35W7): 17,7 kW

6.3 LINK

Thanks to the possibility of combining several individual gas-fired heating/refrigeration modules (GAHP/GA/AY modules) on the same Link, a large number of configurations can be realised, with the aim of meeting the specific requirements of the system to be served while avoiding oversizing and consequent energy wastage.

For the choice of the Link it is always advisable to refer to the product configurator (accessible from the Robur website).

7 IN SUMMARY

From what has been said in the previous paragraphs, it can be concluded that it is generally not possible to identify a single sizing criterion, as the objectives of the sizing itself can also be very different, from the simple maximisation of the economic return on the investment to the verification of compliance with any legal requirements concerning the use of renewable energy sources, or the possibility of accessing incentives related to a minimum efficiency threshold of the realised system.

Such different criteria necessarily lead to very different conclusions.

Generally speaking, we can state that for the simple optimisation of the economic return on investment, the optimal sizing is obtained with a heat output share with GAHP that, under design conditions, lies between 30% and 40%.

For criteria related to possible renewable energy quotas, the advice is to use special calculation software that can quickly check whether the assumed generation system is able to meet the requirement. Usually, these criteria require heat output shares with GAHP, at design conditions, greater than 80%.

For criteria related to the minimum threshold of system efficiency, an initial estimate can be made, as described in Paragraph 5 *p. 9*, using the energy performance graphs related to the specific climate zone and to the specific temperature profile considered, based on the heat output share that is estimated to be covered with GAHP, and then verifying them using appropriate calculation software. As can be seen from the graphs, even rather low GAHP heat output shares make it possible to achieve very high levels of system efficiency, even in the case of coupling with existing low-efficiency boilers.

Once the sizing criteria have been identified, the actual choice of appliances is made on the basis of their characteristics, as detailed in Paragraph 6 *p. 12*.