HEAT PUMPS AND THE REFRIDGERATION CYCLE.

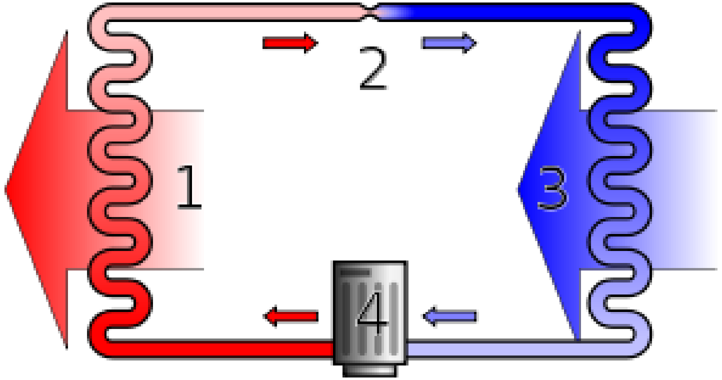
Agenda

1. What is a heat pump?
2. Efficiency
3. Types of heat pump
4. How they work?
5. Refrigerant cycle and circuits
6. Heat pump considerations
7. Questions

1.0
HEAT PUMPS

Heat Pumps
What does it mean?

- A **Heat pump** is a device that uses a small amount of energy to move heat from one location to another.
- Heat pumps are typically used to pull heat out of the air or ground to heat a home or office building.
- They can be reversed to cool a building
- Heat pumps and Air Conditioning in practice are much the same thing.



Heat Pumps
Pros and Cons

Pros

- Lower running cost
- Less maintenance
- Safety
- Environmental
- Provide cooling
- Long life span
- Grant schemes??
- New Builds compatible
- No fuel tank
- No combustion or explosive gases in the building

Heat Pumps
Pros and Cons

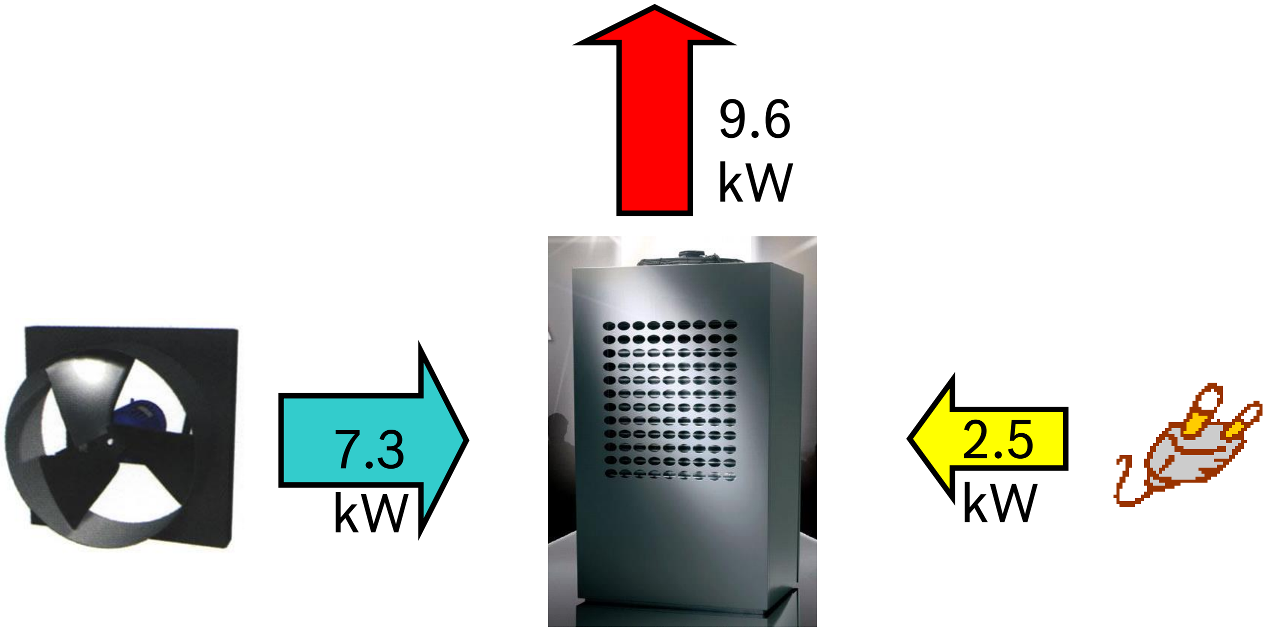
Cons

- Not always suitable for existing properties
- High upfront cost
- Difficult to install
- Cold weather
- Carbon neutral?
- Planning permission

2.0
EFFICIENCY

Efficiency
COP

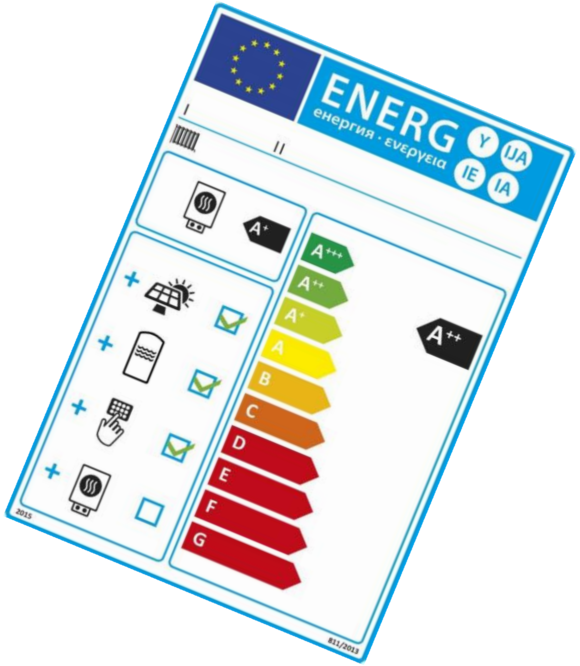
- COP. Coefficient of Performance
  - Efficiency expressed as a ratio
  - Useful heat energy produced to electrical energy consumption.



9.6 kW output / 2.5 kW electrical input = COP 3.8

Efficiency
SPF

- SPF. Seasonal Performance Factor
  - Ratio of annual heat generated to the annual electricity consumed.
  - SPF tells us how efficient the heat pump is on average.



Then the EU got involved

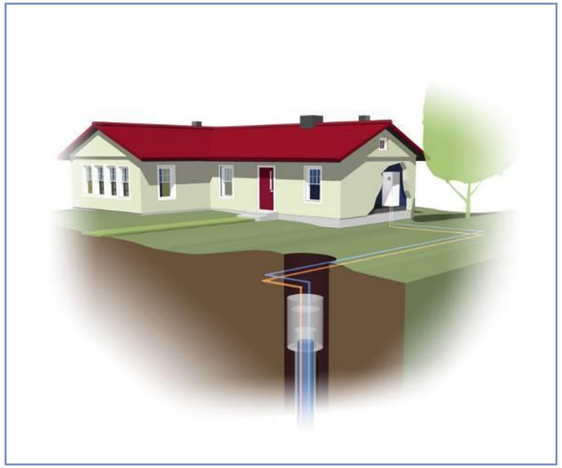
Efficiency
SCOP and SEER

- SEER.
  - Seasonal Energy Efficiency Ratio value in cooling

- SCOP.
  - Seasonal Coefficient of Performance value in heating

3.0
TYPES OF HEAT PUMPS

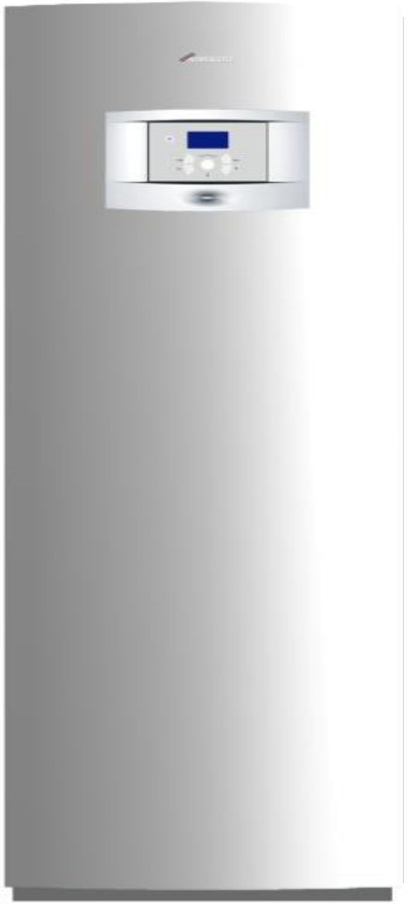
Types of Heat Pumps
Ground Source

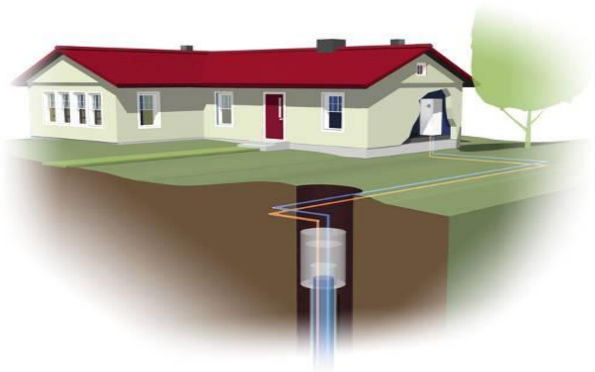


Types of Heat Pumps
GSHP

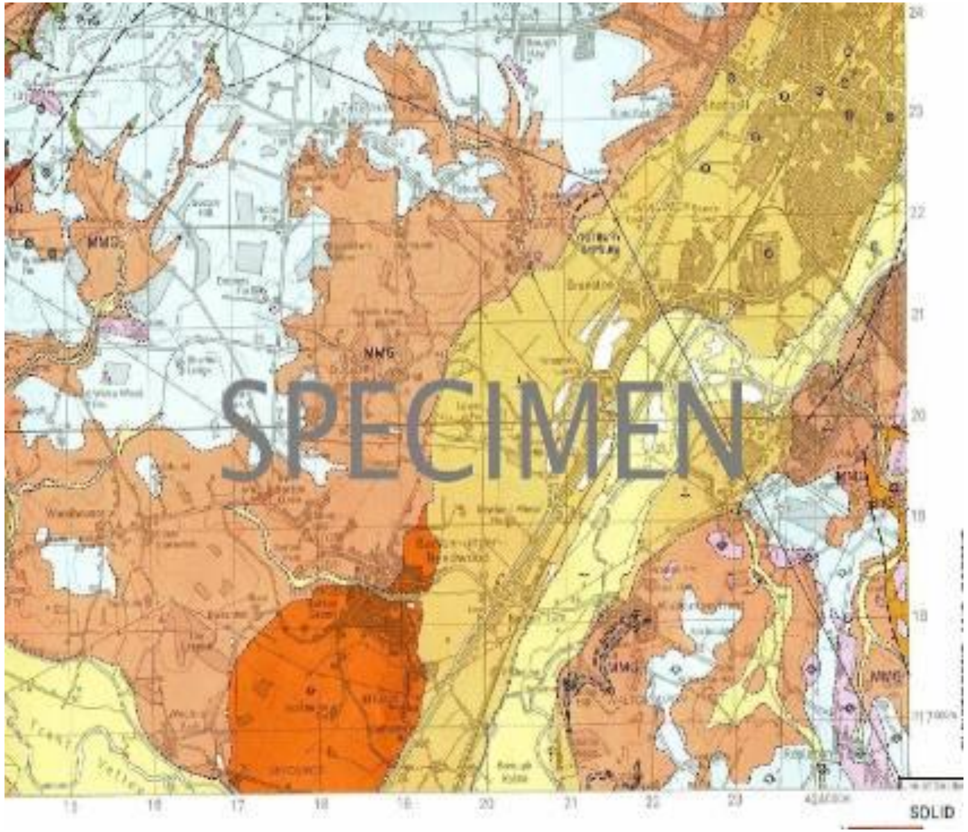
Seasonal Effect on Collector Temperatures

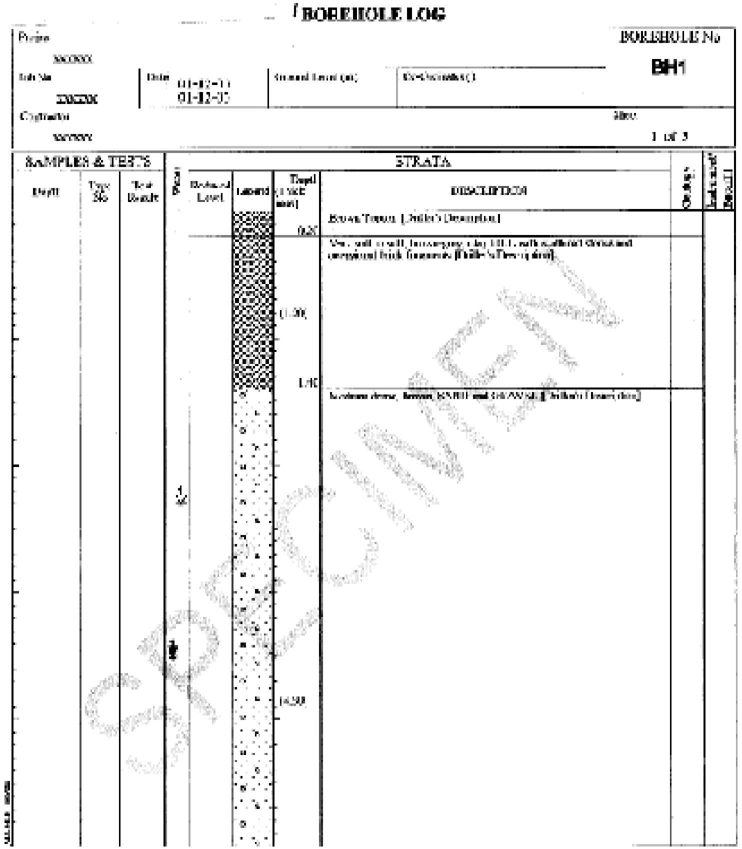
Types of Heat Pumps
GSHP Boreholes



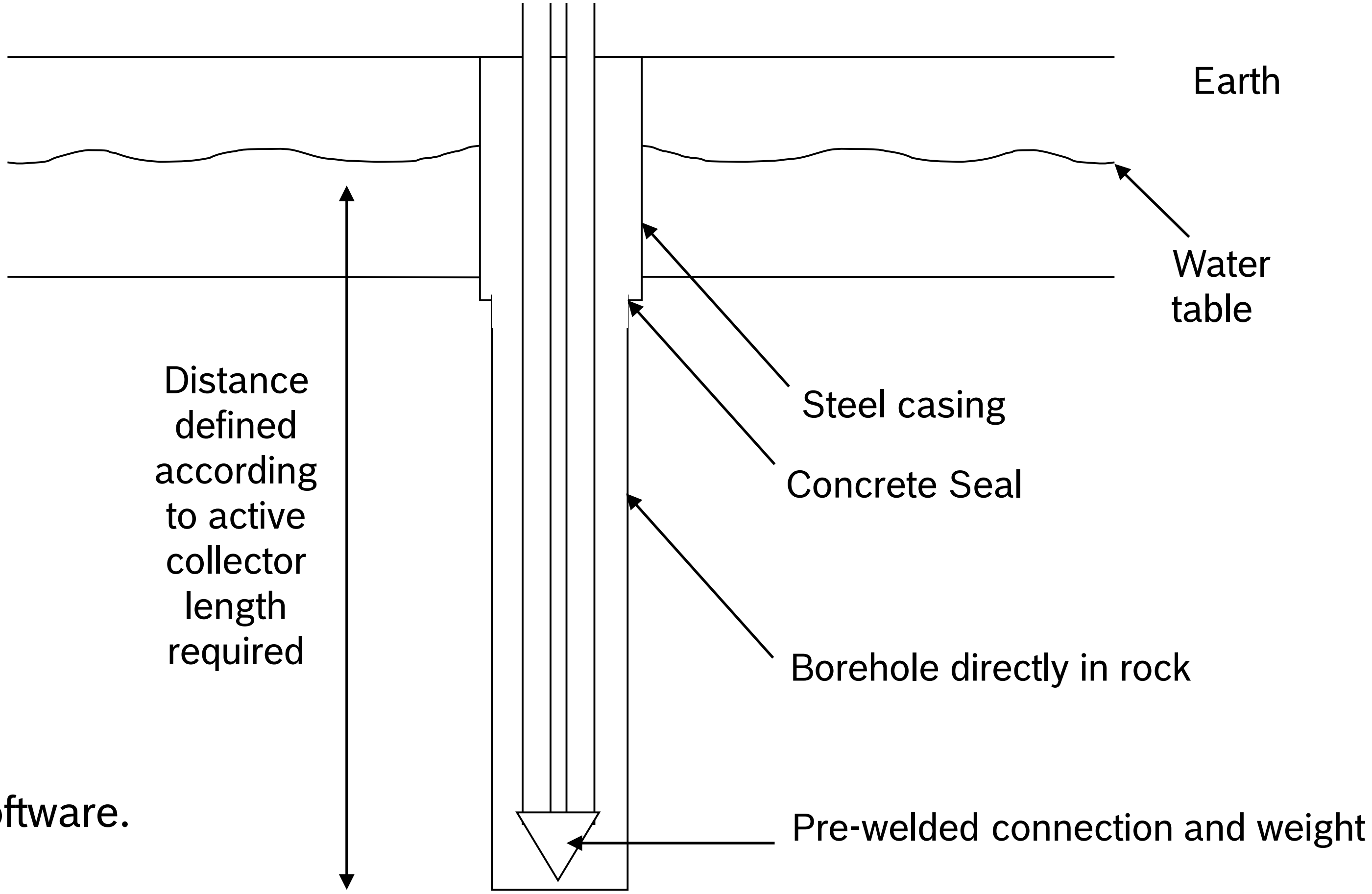


Types of Heat Pumps
GSHP Borehole Reports





Types of Heat Pumps
GSHP Boreholes



Depth of bore determined by sizing software.

Types of Heat Pumps
Multiple Boreholes

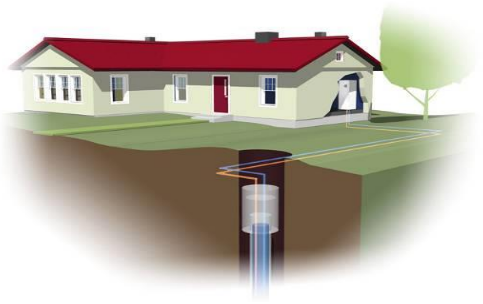
- Prior to commencement of Borehole work, a full closed loop Thermo-Geology and Drill Risk Report is required from a Specialist Geotechnical Company. This will provide Driller with geological conditions and thermal conductivity values which is required to calculate depth of borehole.

- Recommended Minimum distance between each borehole = 15m

- Irrespective of distance between boreholes, calculating overall depthsis not simply a case of halving the depth of one single borehole.

- 5m minimum distances are achievable but borehole depth will be affected

- Amount of Boreholes used will also affect depth



Types of Heat Pumps
Borehole

- Ground loop is filled with a mixture of water and propylene glycol (frost protection required up to -15°C)
- Probe head with double U-pipe (PE100) / field or factory welded
- Drilling hole is filled with a heat transfer back fill (bentonite cement mixture)

WORCESTER BOSCH

Types of Heat Pumps
Boreholes

Types of Heat Pumps
Drilling

Air or water is forced down through the holes and back up the outside

Types of Heat Pumps
Drilling





WORCESTER BOSCH

Types of Heat Pumps
Ground Loops

- 80-100 cm deep
- At least 80 cm between the tubes
- Energy extraction 10-20 W / m

WORCESTER BOSCH

Types of Heat Pumps
Ground loops

Types of Heat Pumps
Multiple loops or Boreholes

- Each circuit should be equally balanced

Types of Heat Pumps
Pressure test


- Pressure test the system with air for 3-4hrs up to 4 bar prior to filling with heat transfer fluid. Reduce to 2 bar when backfilling
- Exercise caution when disconnecting Air Compressor due to pressure build up

WORCESTER BOSCH

Types of Heat Pumps
Flushing of Groundloop

Run the unit until the glycol mix runs clear with no air bubbles visible this may take from 2 – 6 hrs depending on the size and type of collector

Types of Heat Pumps
GSHP models & COP

	Greenstore 6 System	Greenstore 7 System	Greenstore 9 System	Greenstore 11 System
Part No.	8 738 203 184	8 738 203 185	8 738 203 186	8 737 203 187
Output kW 0/35ºC[1]	5.4	6.6	8.7	10.2
Output kW 0/45ºC[1]	5.1	6.2	8.3	9.6
CoP* 0/35ºC[1]	3.96	3.82	3.84	3.97
CoP* 0/45ºC[1]	3.15	2.97	3.15	3.17
MCS certification no.	MCS HP0015/24	MCS HP0015/25	MCS HP0015/26	MCS HP0015/27

The Co-efficient of Performance is a commonly used measure of the efficiency of a heat pump system.

$$COP = \frac{\textit{Heat output of system (useful heat)}}{\textit{Electrical input from compressor and circulating pumps}}$$

According to EN 14511

Types of Heat Pumps
GSHP Pros and Cons

Pros

- Most efficient
- Groundworks can be done with footings
- Silent operation
- Long life expectancy
- Not effected by extreme weather as much
- Security

Heat Pumps
Pros and Cons

Cons

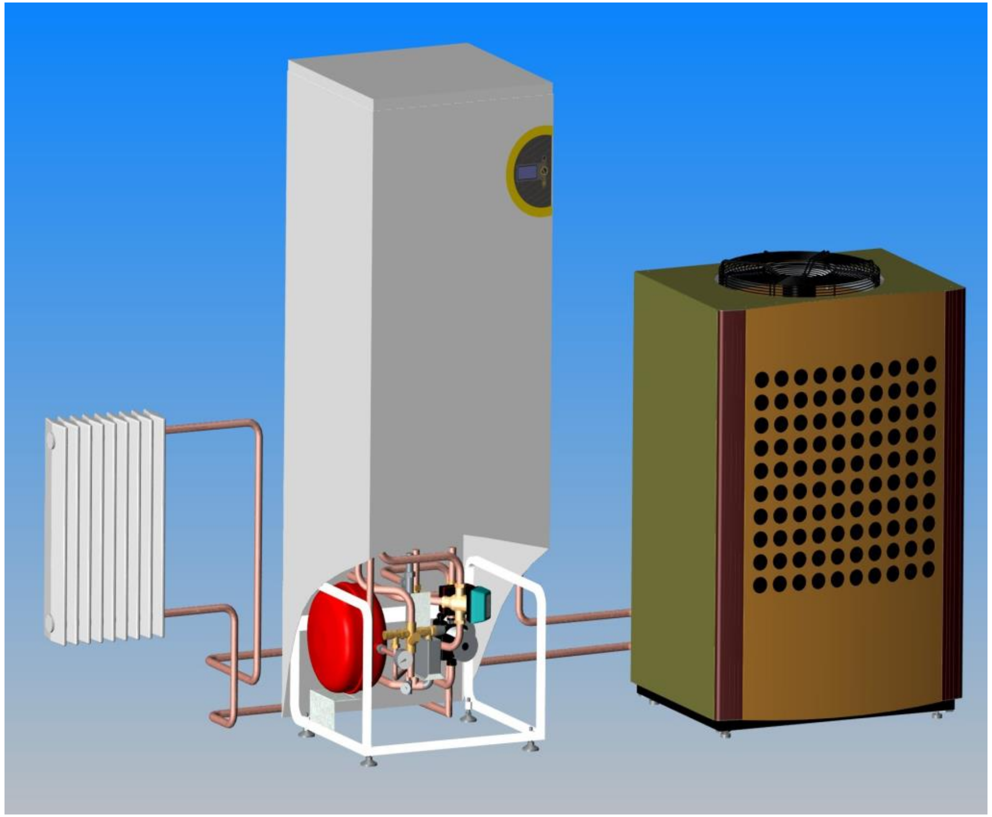
- Space of the collector array
- Size of the unit
- Cost
- Skilled installers
- Not suitable in all areas
- Not future proof
- Limit in size

Types of Heat Pumps

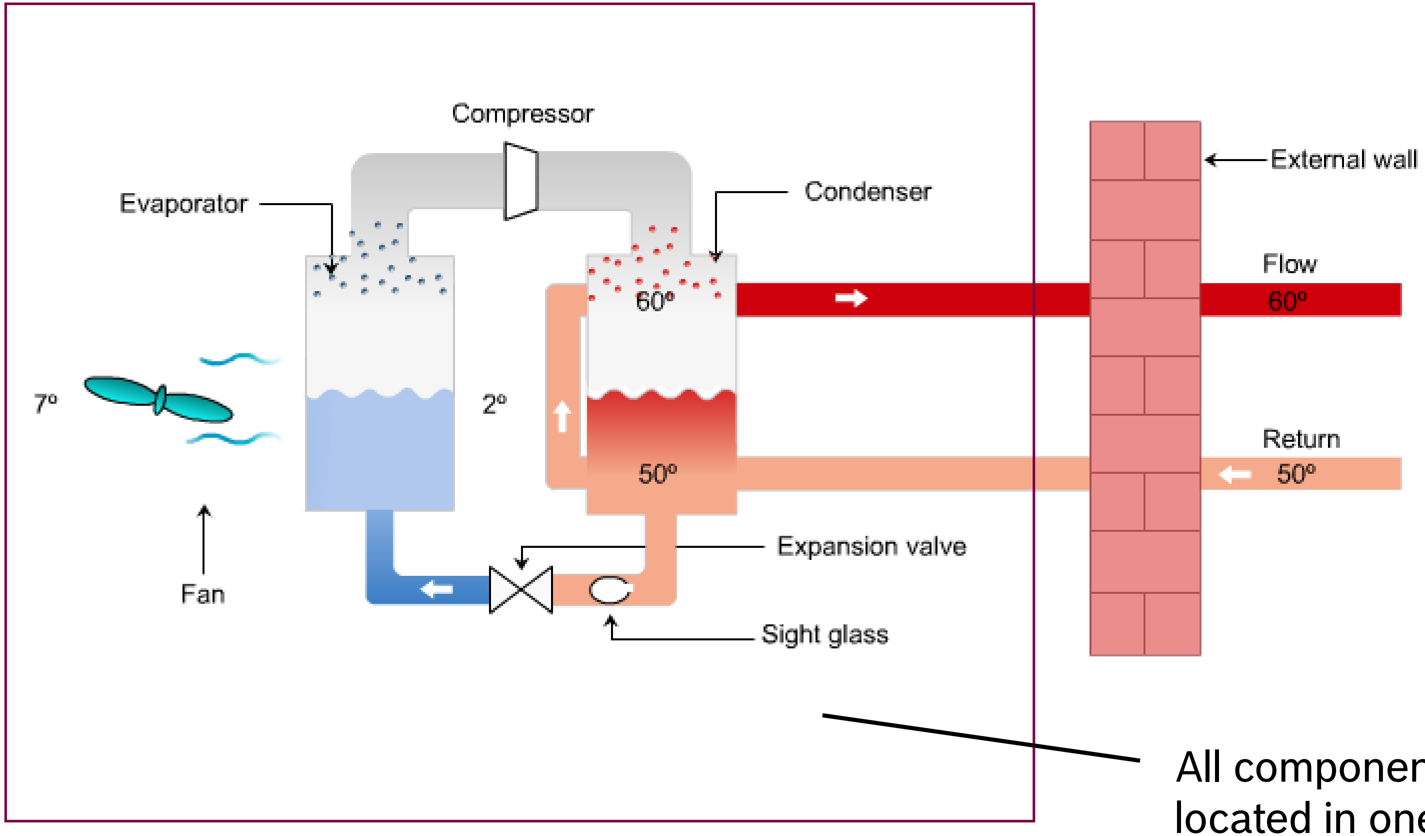
Air to Water

WORCESTER BOSCH

Types of Heat Pumps
Monobloc



Types of Heat Pumps
Monobloc

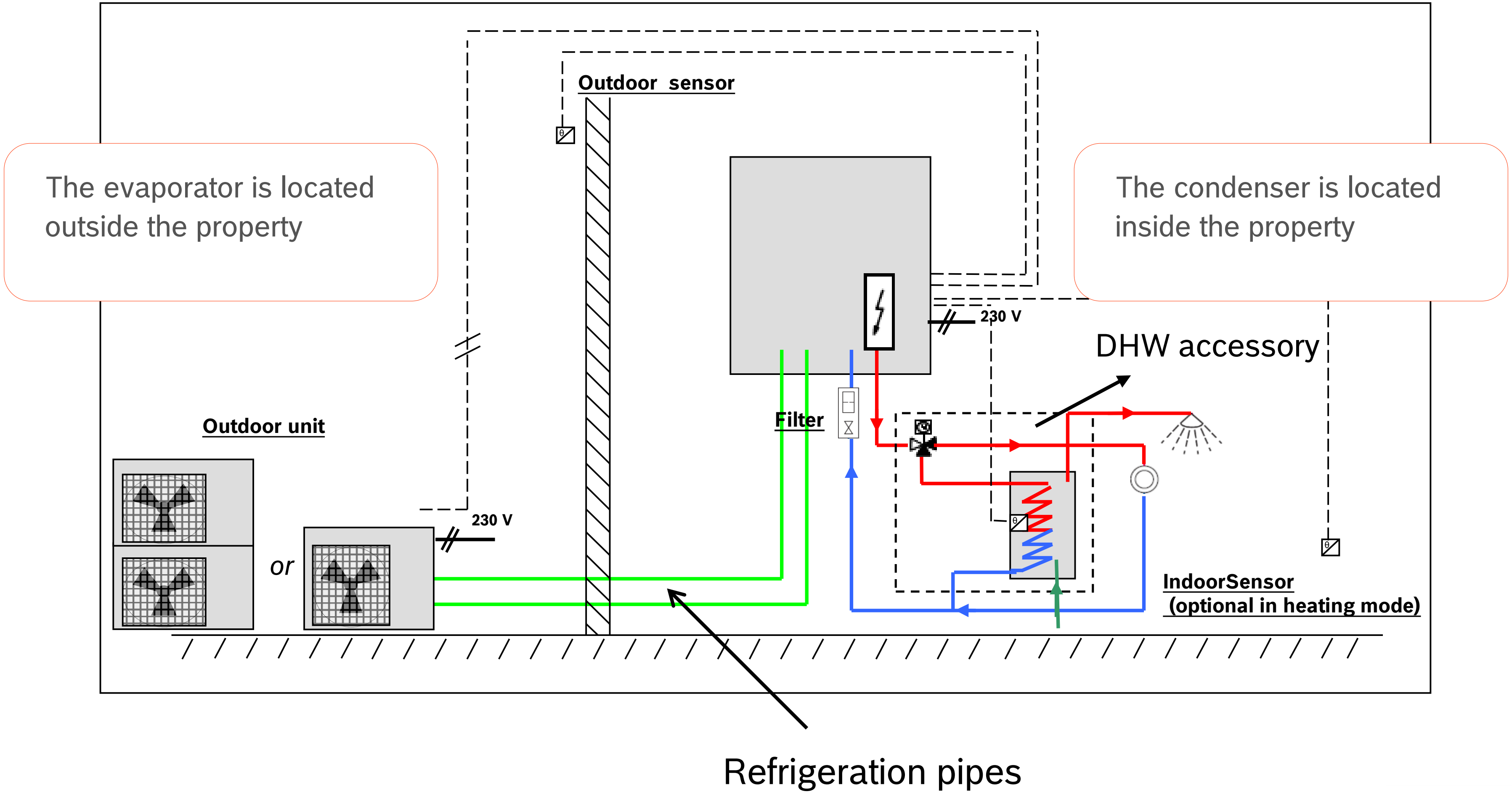


All components are located in one box

Types of Heat Pumps
Split system

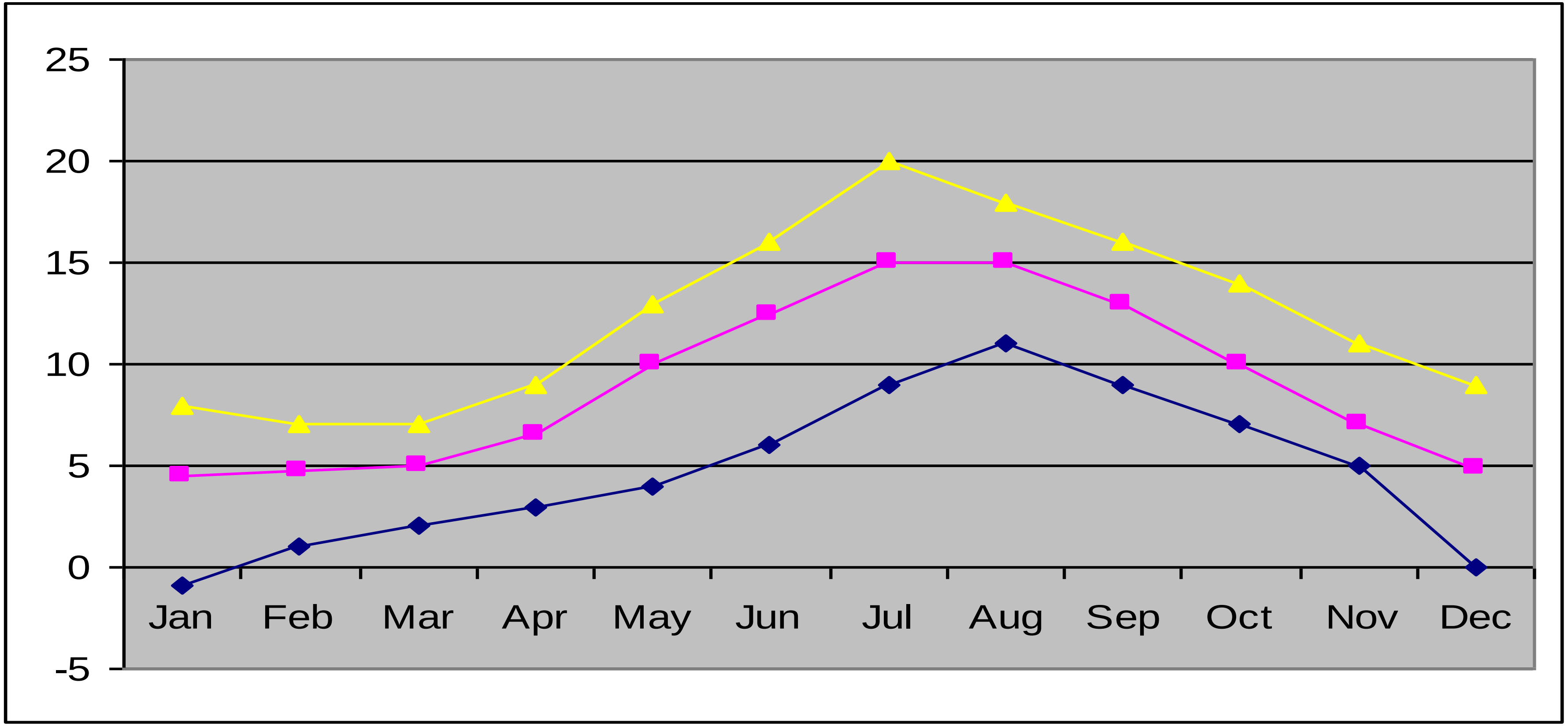
Types of Heat Pumps

Split System



Types of Heat Pumps

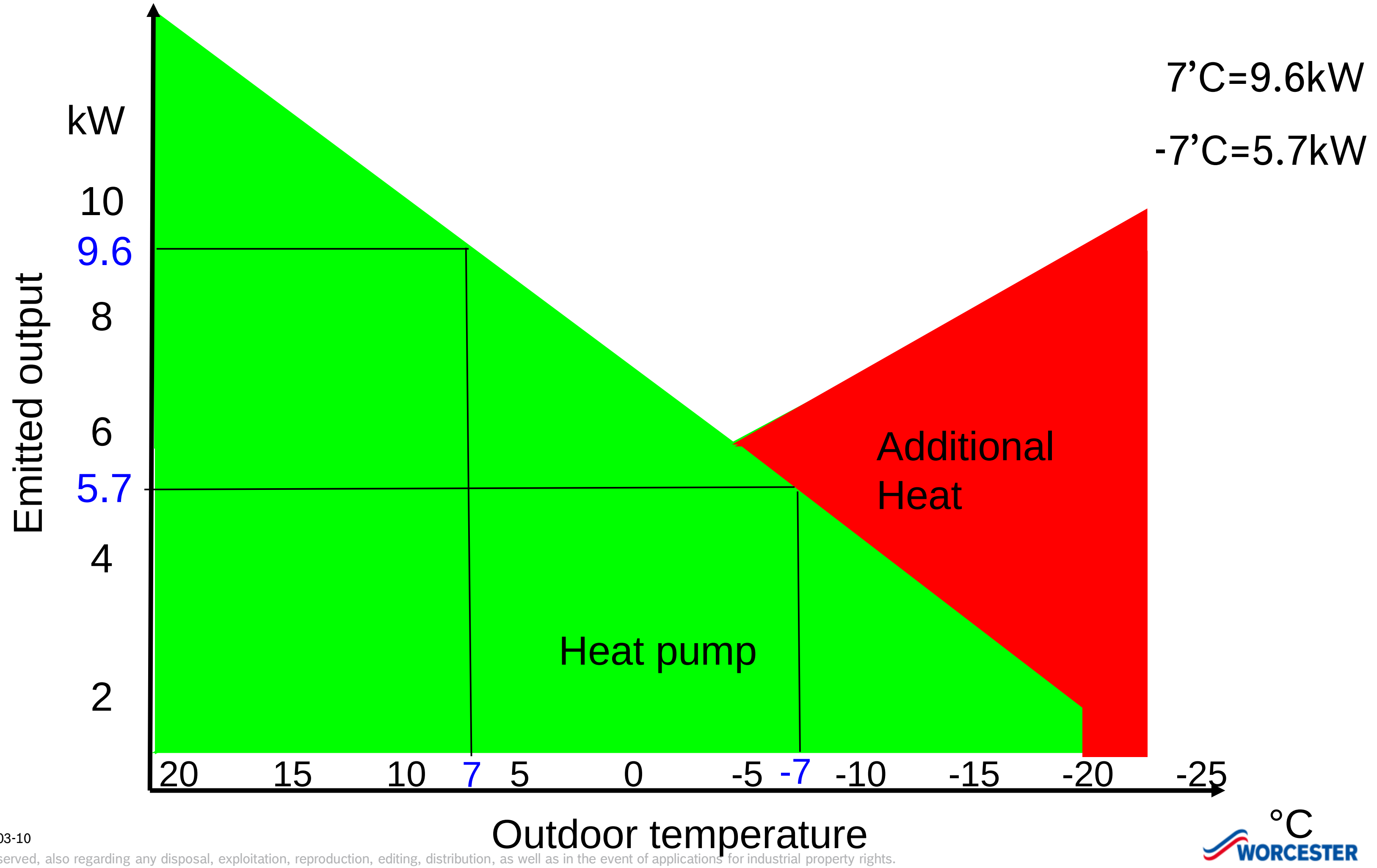
Outside air temperature Central England 1772 - 2007



Source www.metoffice.gov.uk/research/hadleycentre

Types of Heat Pumps

Emitted output Air / Water 9.5 KW @ 35'C flow



Types of Heat Pumps
ASHP Models and COP

	Greensource 6 System	Greensource 7 System	Greensource 9.5 System
Output kW 7/35ºC	5.5	7.1	9.6
Output kW 7/45ºC	5.1	7.0	8.6
COP -7/35ºC	2.4	2.3	2.5
COP 7/35ºC	3.7	3.4	3.8
COP 7/45ºC	2.9	2.8	3.0

The Co-efficient of Performance is a commonly used measure of the efficiency of a heat pump system.

$$COP = \frac{\textit{Heat output of system (useful heat)}}{\textit{Electrical input for compressor and circulating pumps}}$$

Types of Heat Pumps
ASHP Pros and Cons

Pros

- Cost
- Ease of installation
- Space
- Time

WORCESTER BOSCH

Heat Pumps
ASHP Pros and Cons

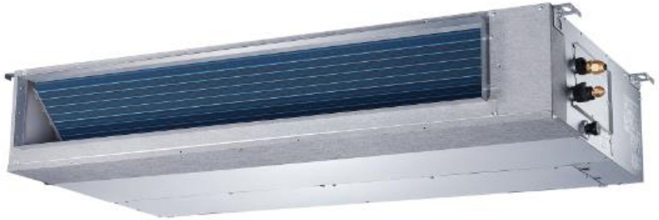
Cons

- Used most in worst conditions
- Noise of the outdoor unit
- Limit in size
- Defrost
- Location of outdoor unit

WORCESTER BOSCH

Types of Heat Pumps
Air to Air

Types of Heat Pumps
Air to Air



Types of Heat Pumps
AAHP Pros and Cons

Pros

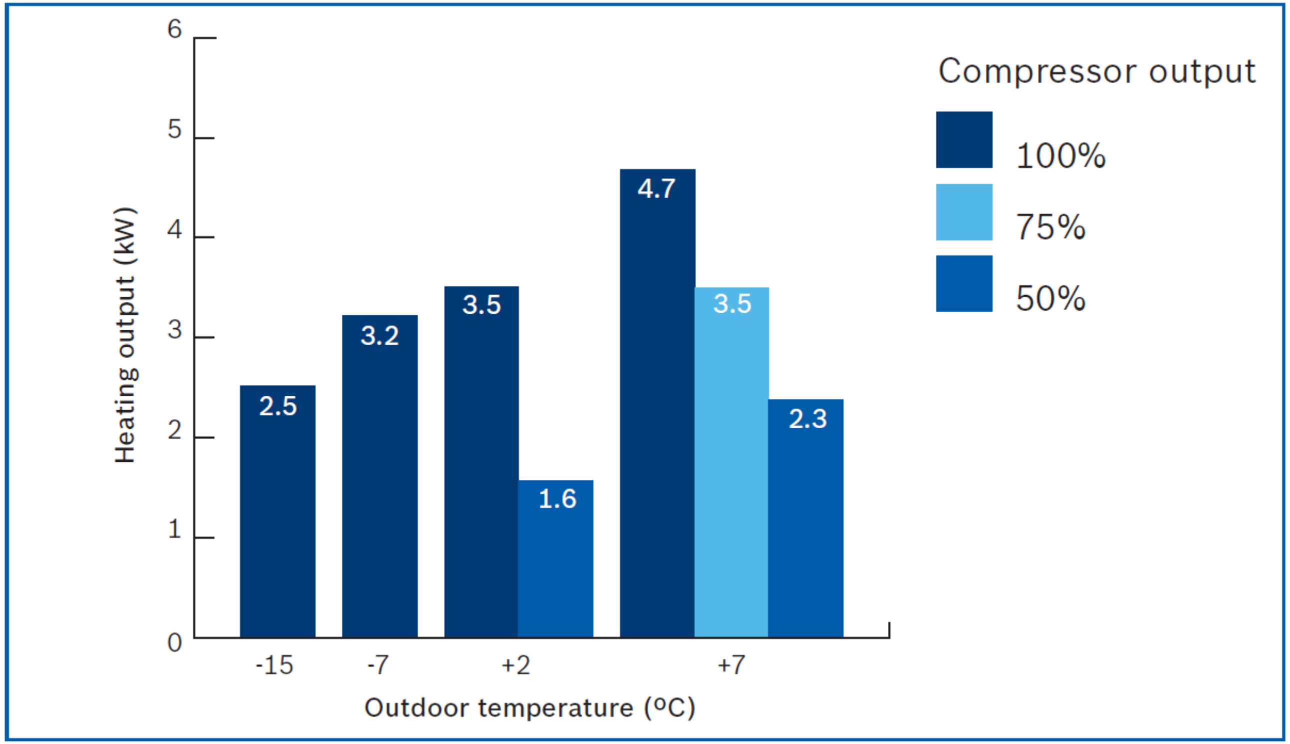
- Cost
- Super efficient
- Ease of installation
- Space
- Time
- Cooling
- Dehumidifier
- Air Purifying filter
- Instant heat or cool

Heat Pumps
AAHP Pros and Cons

Cons

- Noise of indoor and outdoor fan
- No DHW
- F Gas qualification
- Will only work in open space
- Location of indoor and outdoor unit
- Condense from both units
- Defrost
- Air movement

Types of Heat Pumps
COP against outside air temperature



The Co-efficient of Performance is a commonly used measure of the efficiency of a heat pump system.

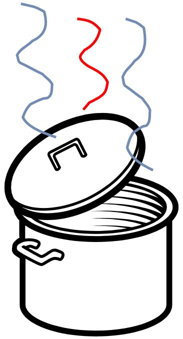
$$\text{COP} = \frac{\textit{Heat output of system (useful heat)}}{\textit{Electrical input for compressor and circulating pumps}}$$

4.0
HOW THEY WORK?

Basic Thermodynamics

Pressure / Evaporating-condensing point

80°C
0.5bar



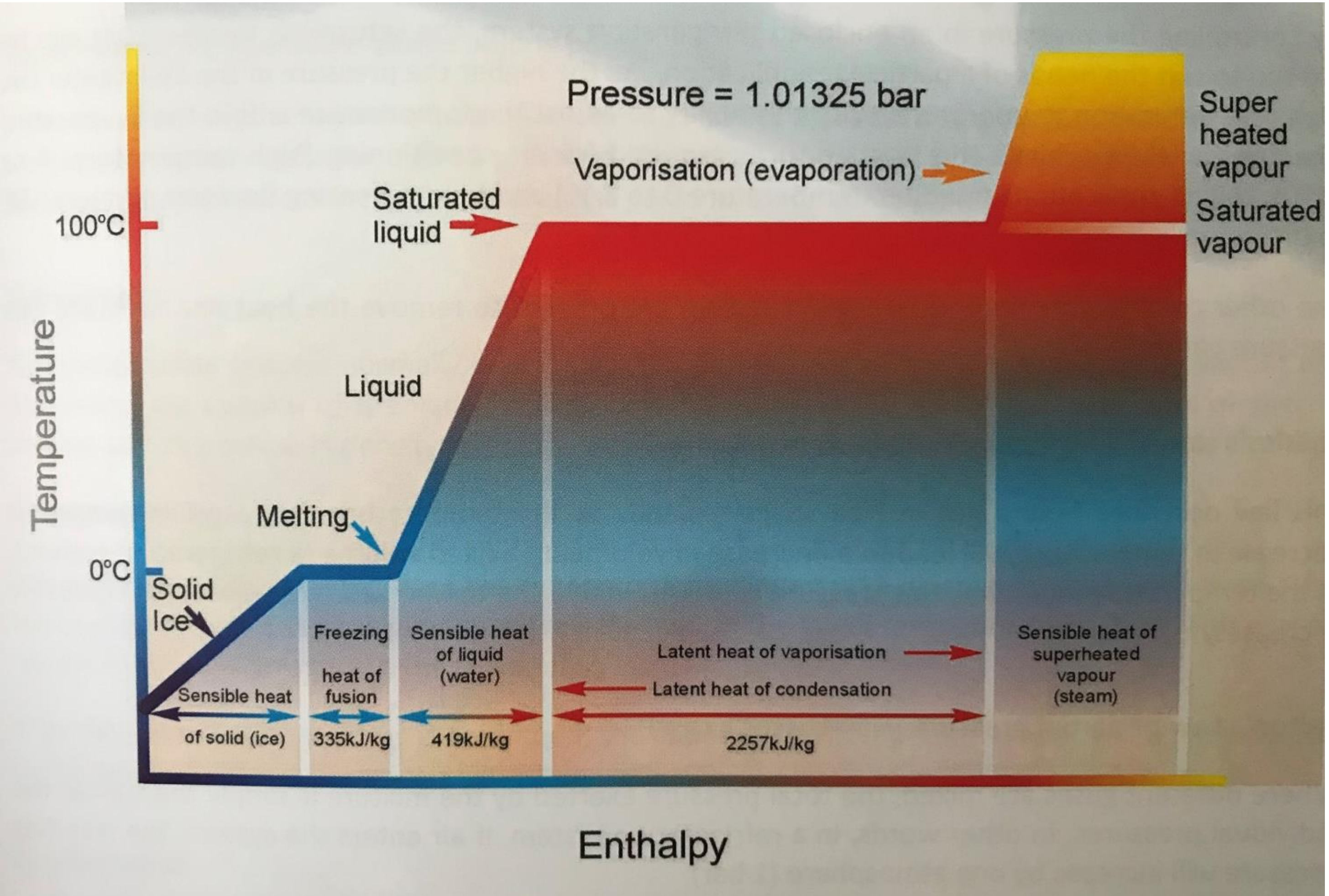
100°C

1bar

120°C

2bar

Basic Thermodynamics
Enthalpy



Enthalpy (heat energy) values for water at standard atmospheric pressure

Basic Thermodynamics

- Water absorbs more than fives times the amount of heat energy during the process of evaporation compared to the amount of energy absorbed when heating water up to its boiling point.
- A similar relationship is true of refrigerants, the main difference being the temperature at which they change state.

Water

100 Deg C

R407c

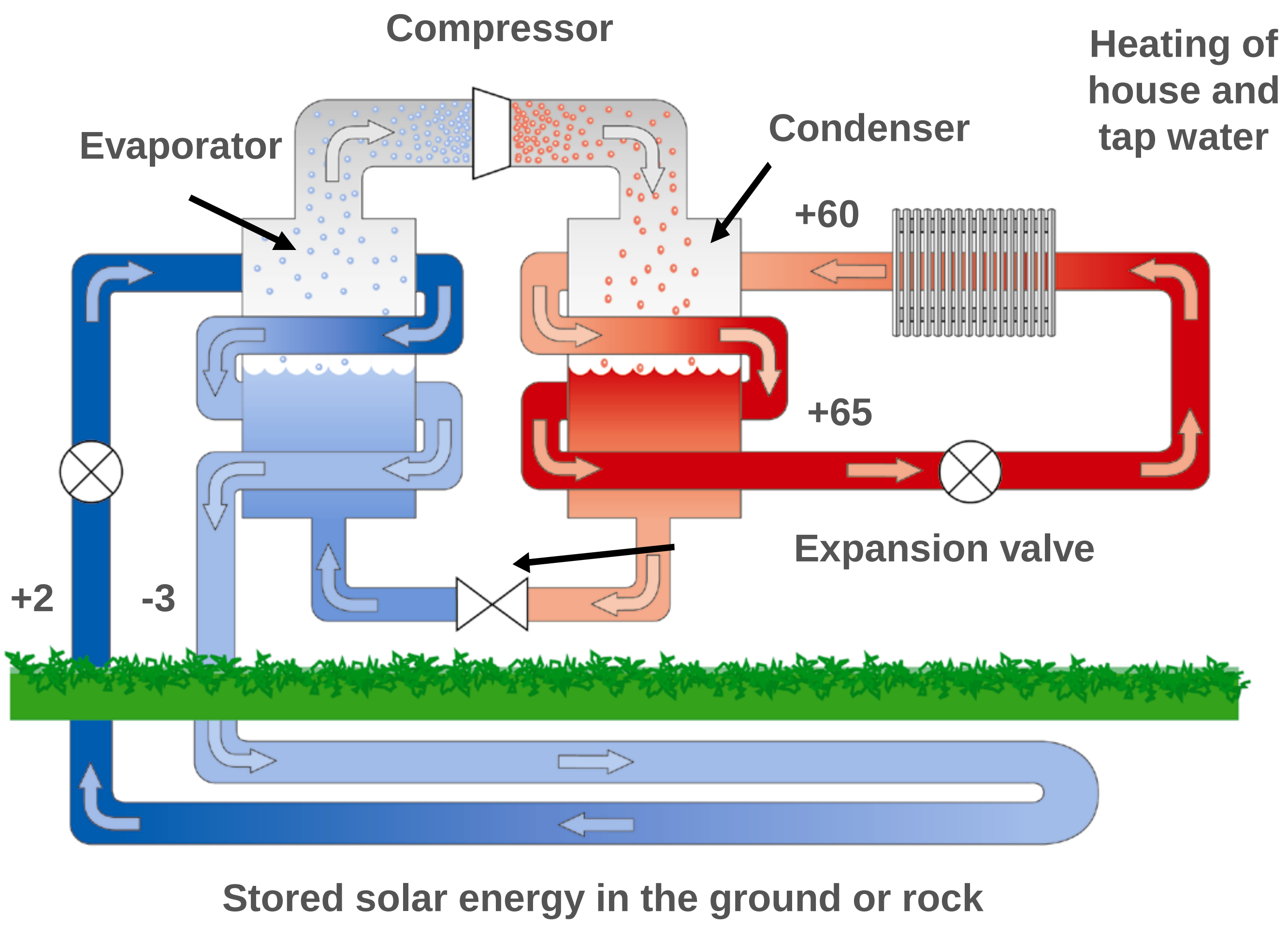
-43 Deg C

R32

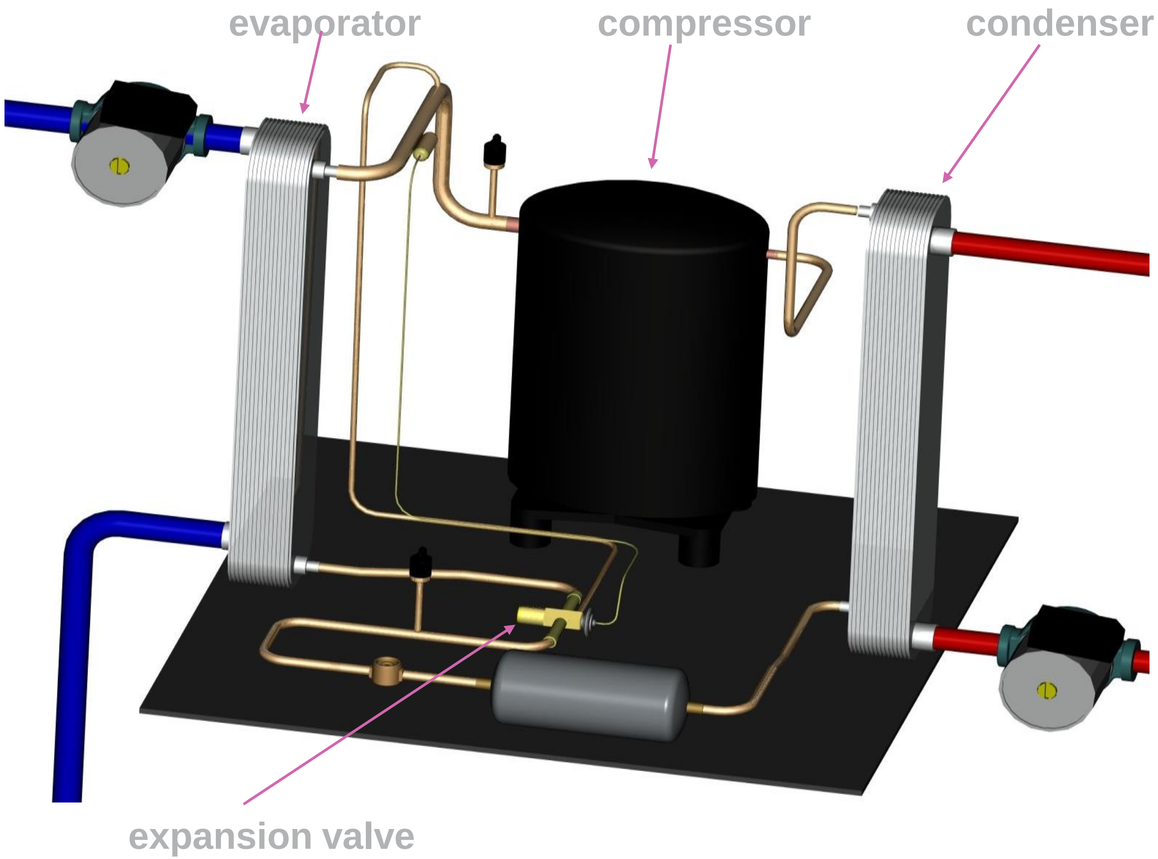
-51 Deg C

5.0
REFRIGERANT CYCLE AND CIRCUITS

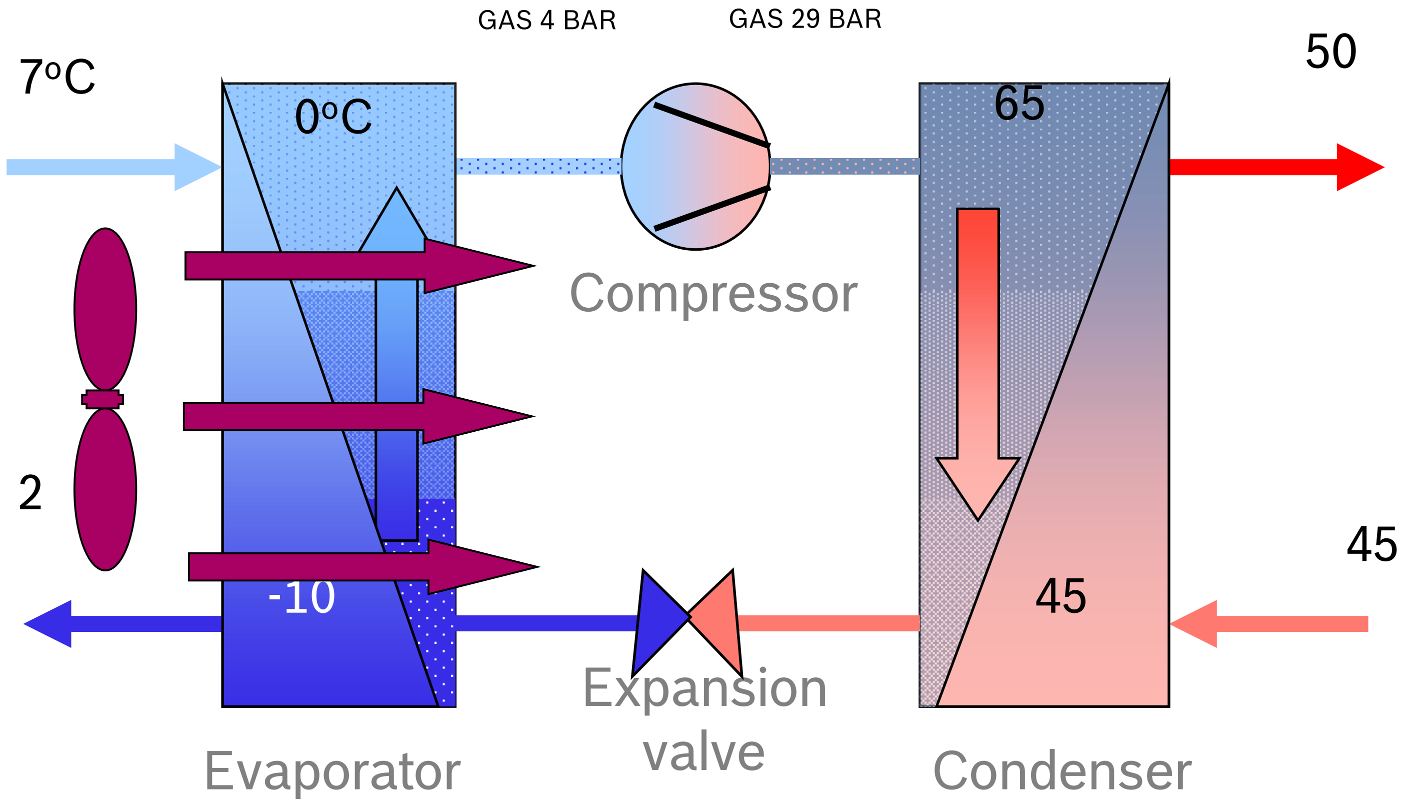
Refrigerant Cycle
GSHP



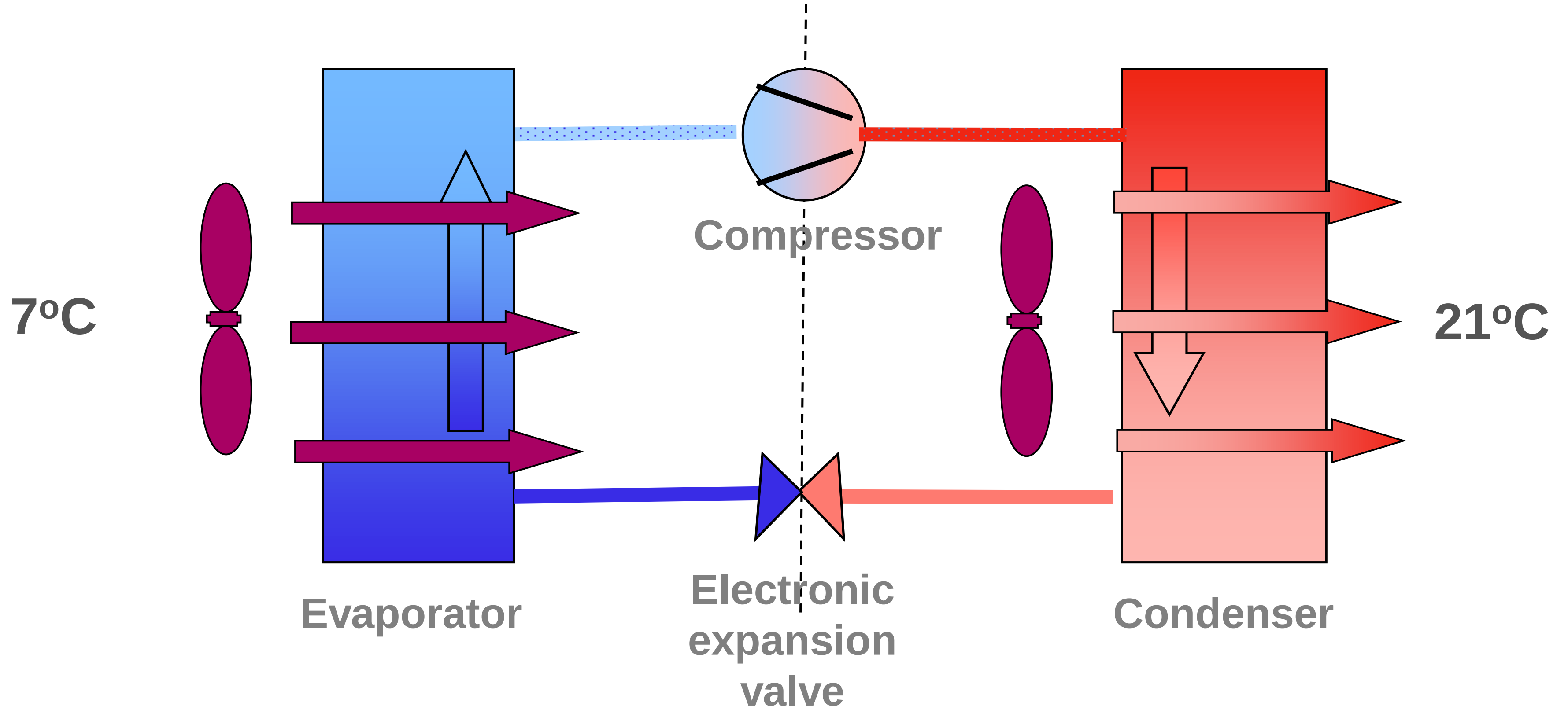
Refrigerant Circuit
GSHP



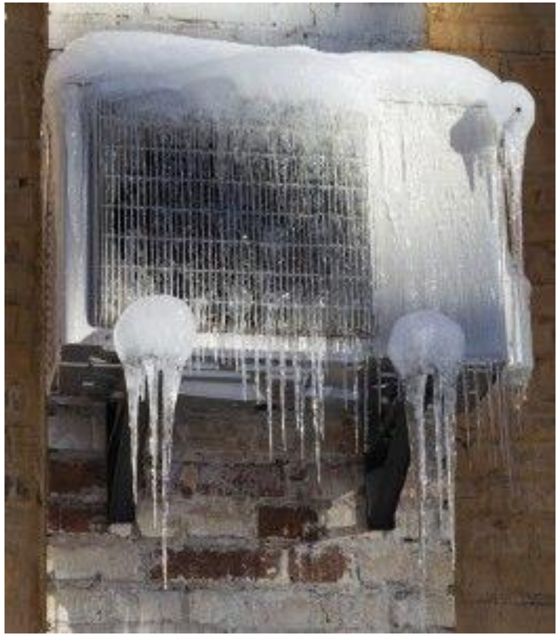
Refrigerant Cycle
ASHP



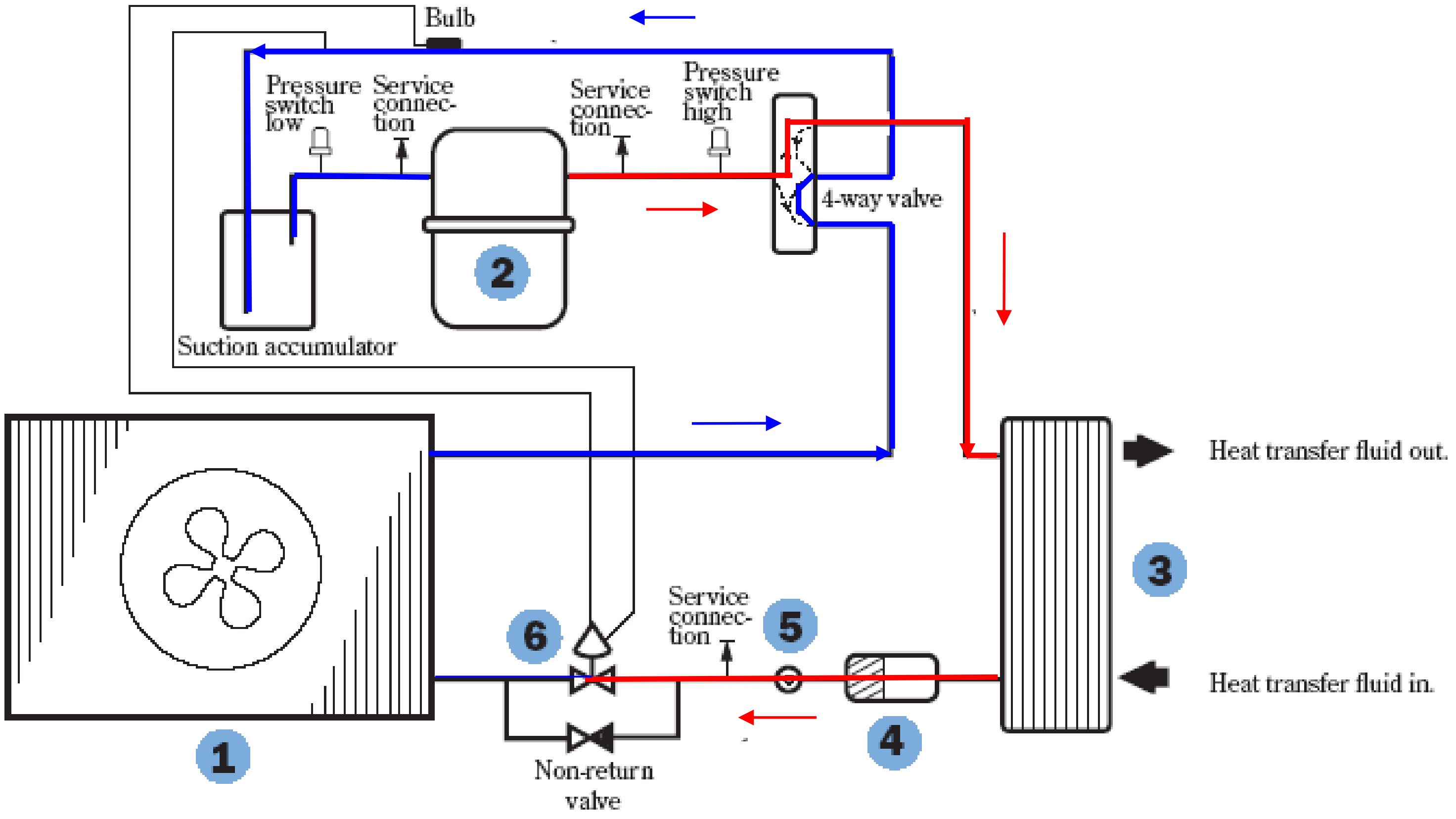
Refrigerant Cycle
Air to Air



Refrigerant Circuit
Air Source Problem

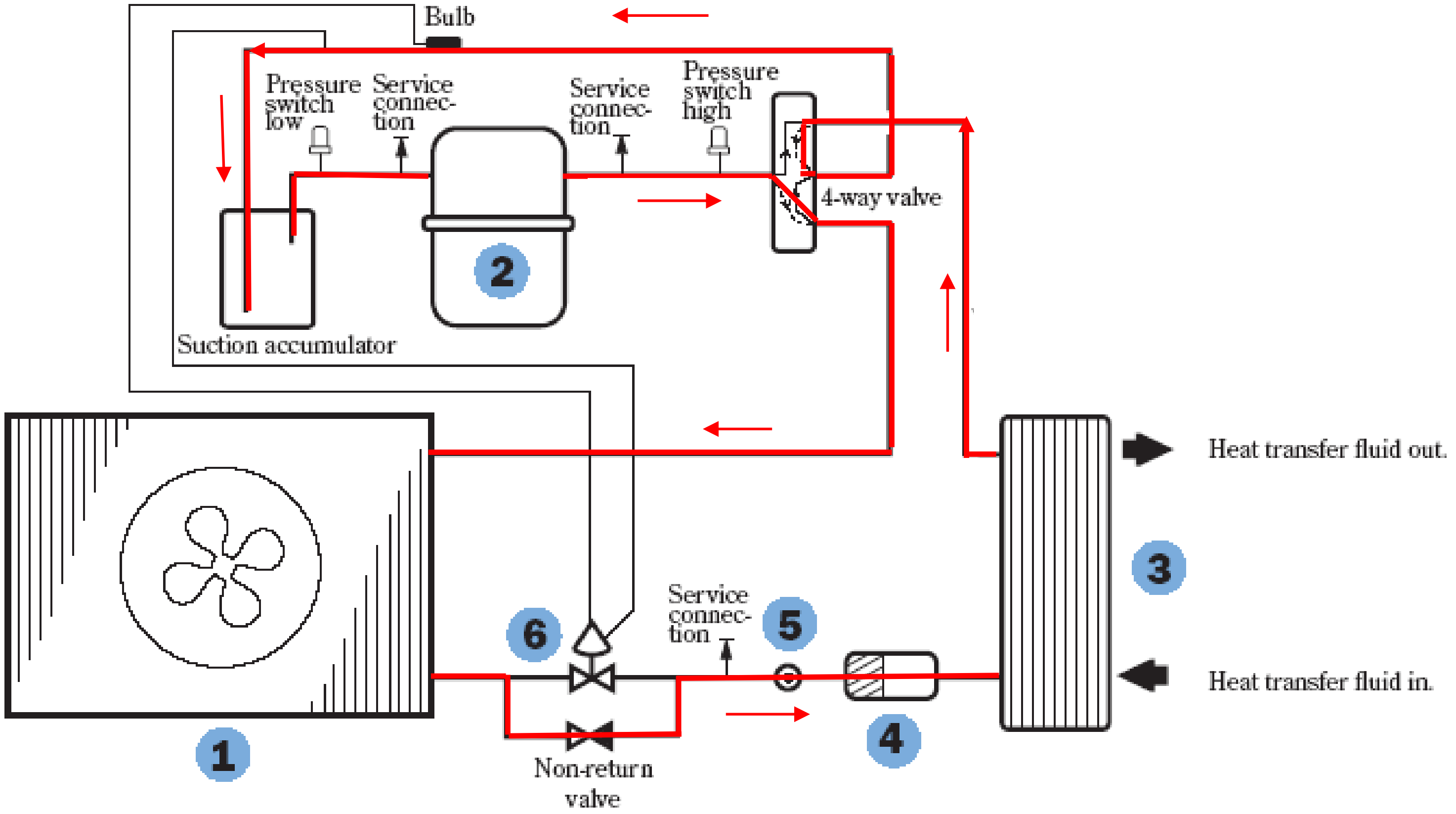


Refrigerant Circuit
ASHP Normal Mode



1 – Evaporator
2 – Compressor
3 – Condenser
4 – Dryer
5 – Sight Glass
6 – Expansion Valve

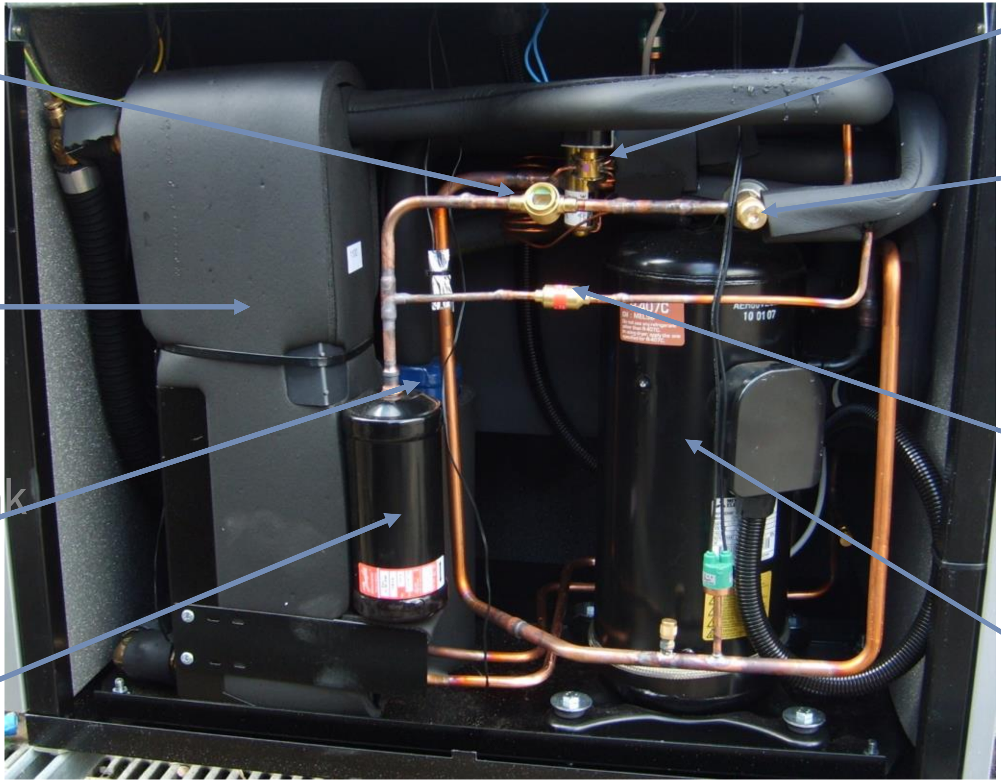
Refrigerant Circuit
ASHP Defrost



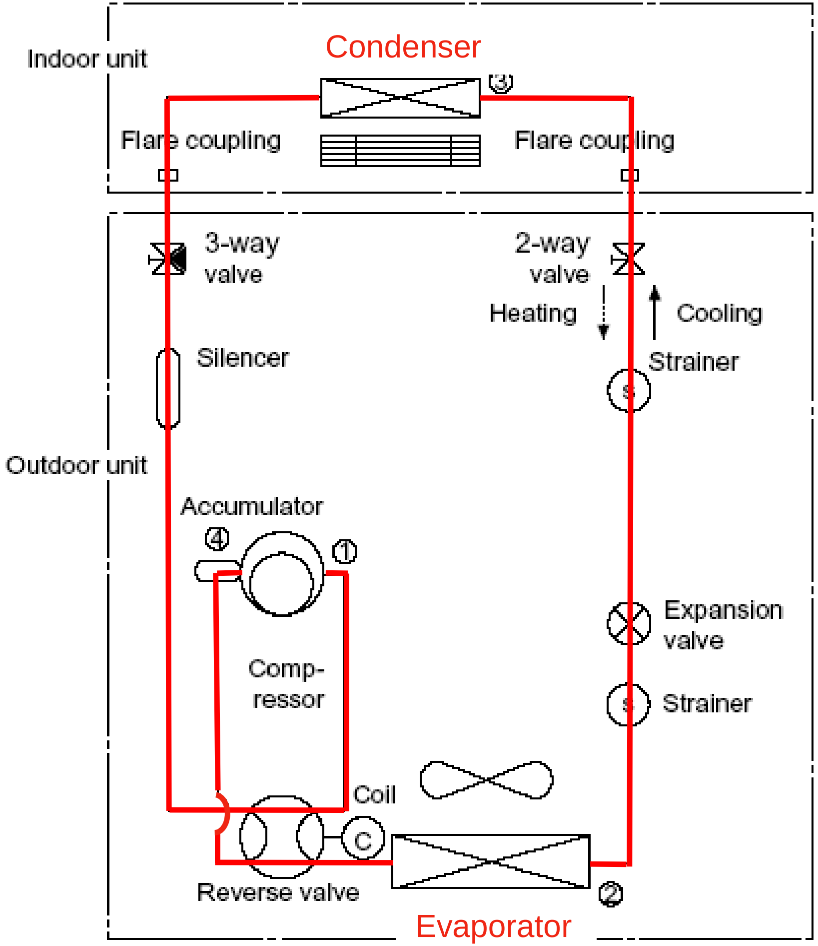
1 – Evaporator
2 – Compressor
3 – Condenser
4 – Dryer
5 – Sight Glass
6 – Expansion Valve

WORCESTER BOSCH

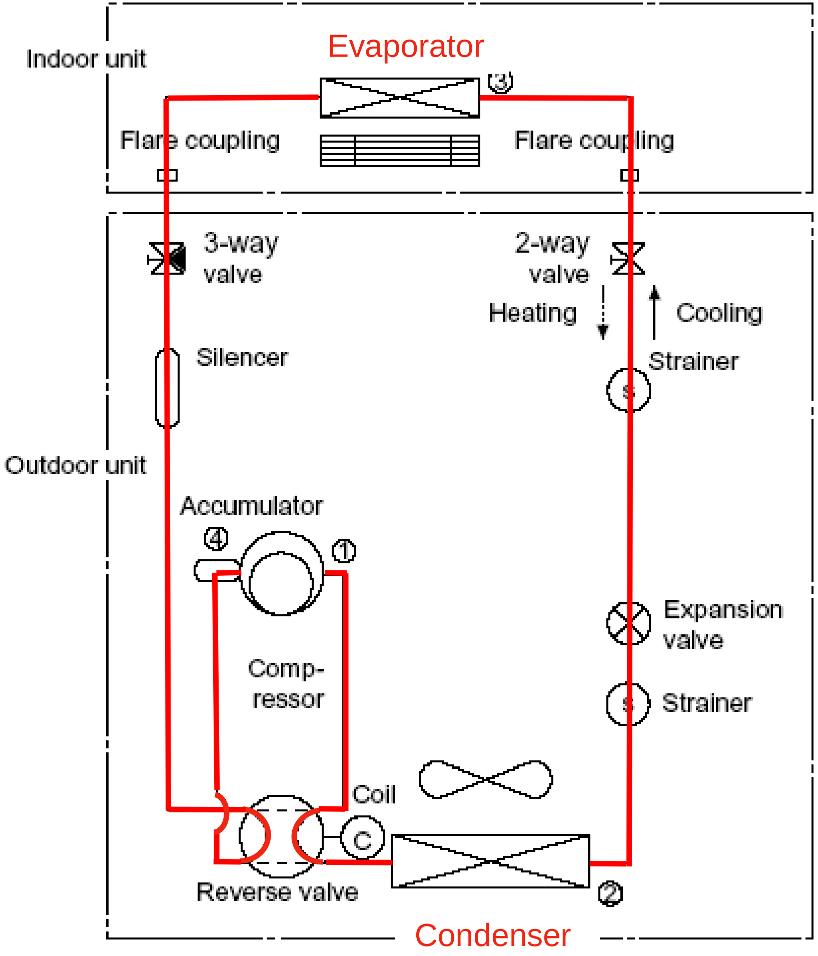
Refrigerant Circuit
ASHP



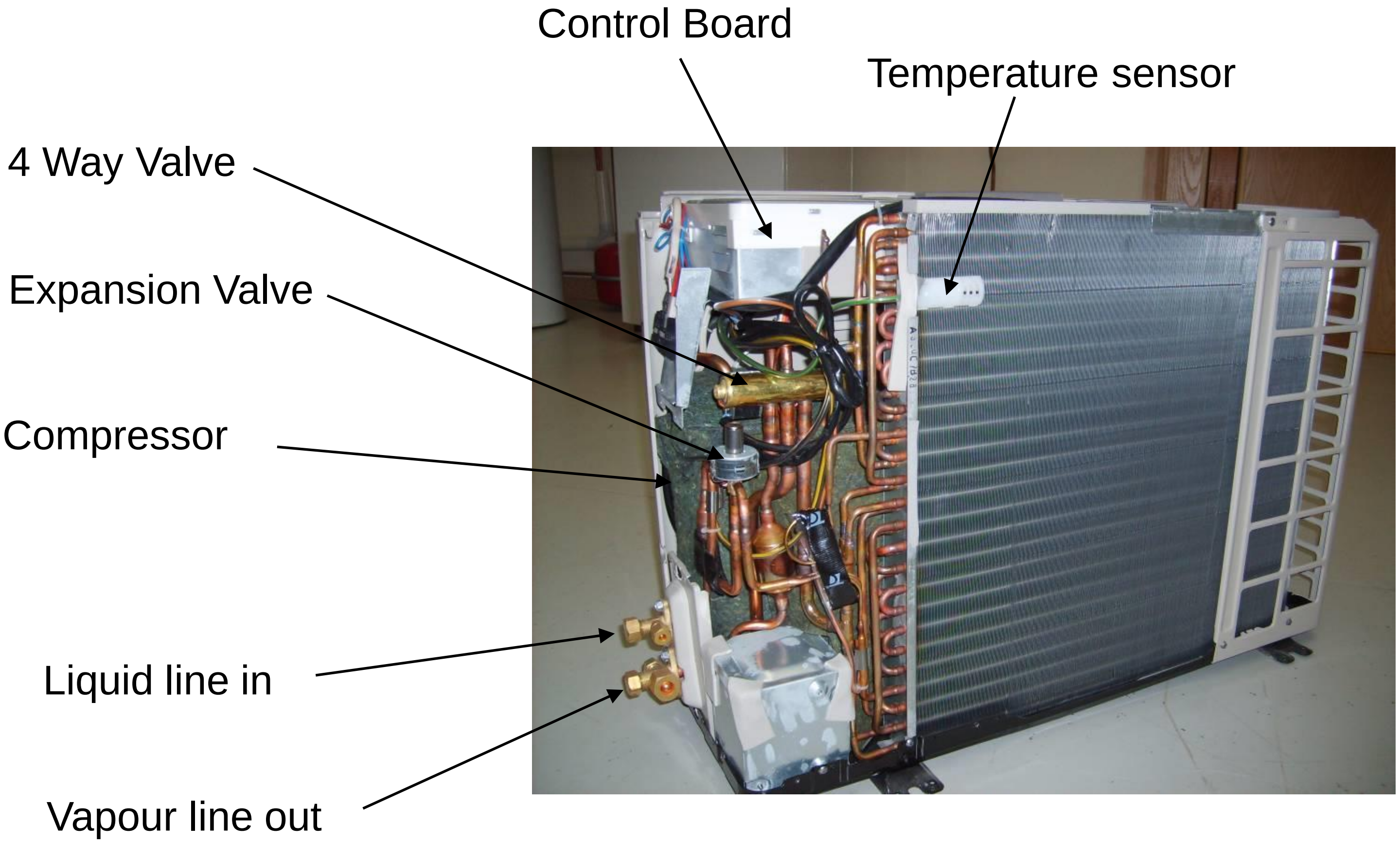
Refrigerant Circuit
Heating Mode



Refrigerant Circuit
Cooling and Defrost



Refrigerant Circuit
AAHP



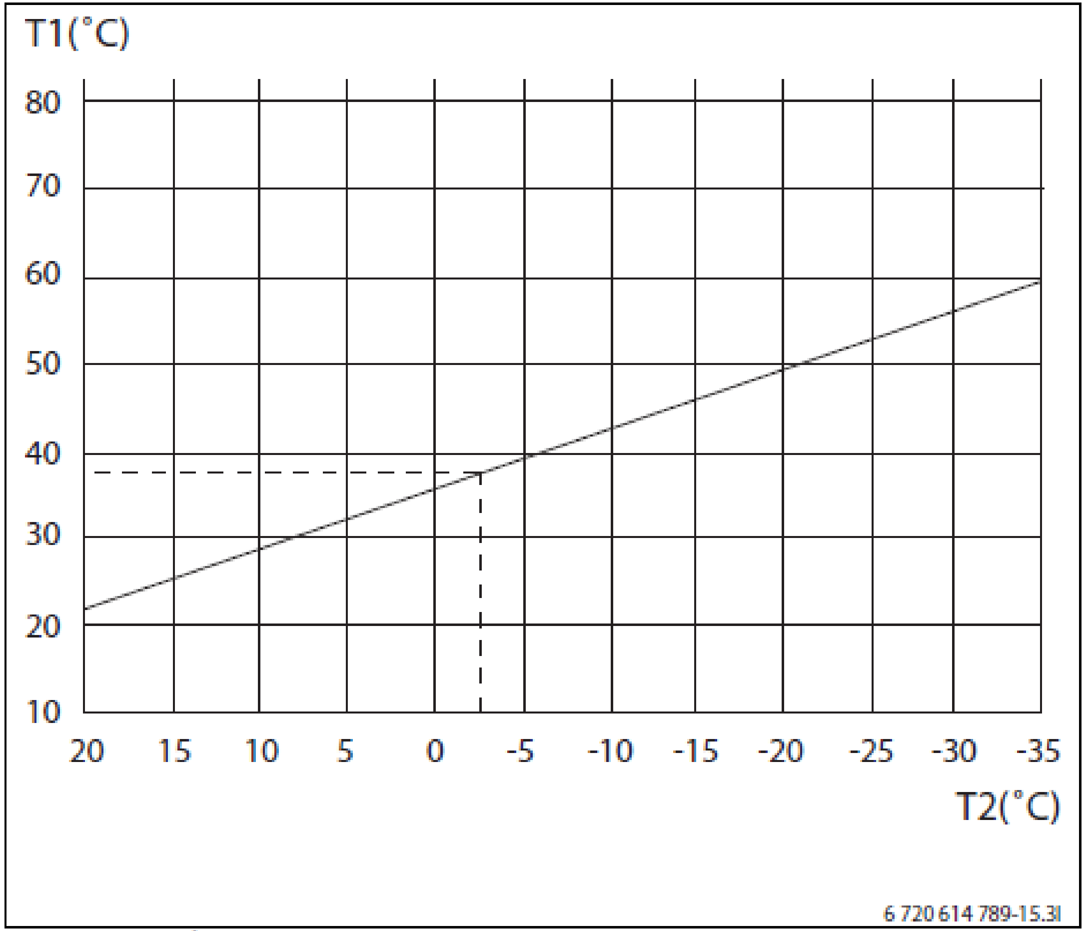
6.0
HEAT PUMP CONSIDERATIONS

Heat Pump Considerations
Weather Comp

Heat curve settings (Default)

The table shows the factory set heat curve for a radiator system on a GSHP.

At an outside temperature of -2.5 ^{0}C the flow set point is 37.4 ^{0}C

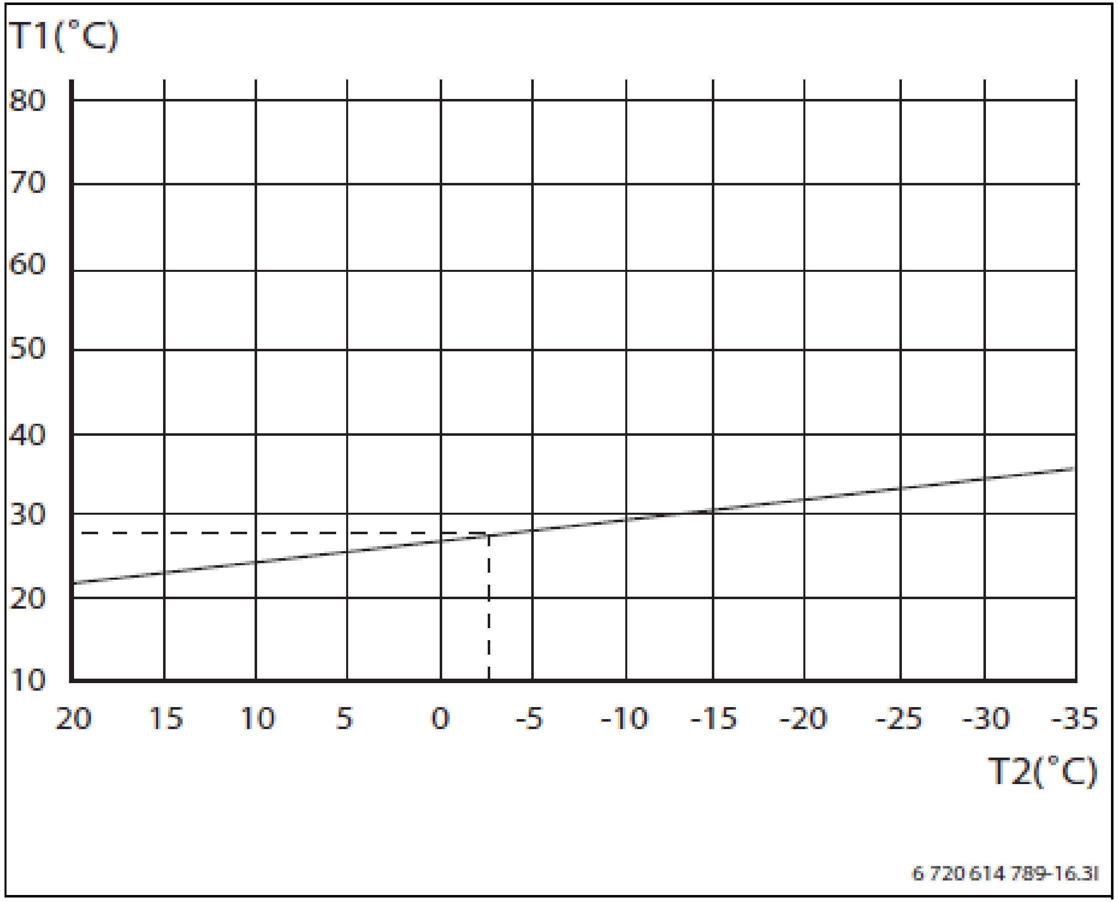


Heat Pump Considerations
Weather Comp

Heat curve settings (Default)

The table shows the factory set heat curve for an underfloor system on a GSHP.

At an outside temperature of -2.5^{0}C the flow set point is 27.2 ^{0}C



Heat Pump Considerations
Correct Sizing of Radiators

EXAMPLES OF RADIATOR SIZING;

Catalogue radiator outputs are based on a mean water to air temperature difference (ΔT) of 50°C

$$\Delta T = \frac{\text{Flow temp + Return temp}}{2} - \text{Room temp}$$

conditions

A room has a radiator installed, with a catalogue output of **1000 Watts** in order to raise the air temperature in the room to 20°C when the outside temperature is -3°C.

flow

Therefore the radiator output is **1000** x **0.400** = **400 Watts** (65% less than for a standard boiler and 47% less than for a condensing boiler)

Temperature difference (ΔT) °C	Conversion Factor
25	0.400
30	0.510
35	0.643
40	0.759
45	0.878
50	1.000
55	1.126
60	1.254

Table 1: Conversion Factors for different temperatures

Sources Domestic Heating Design Guide & BS 5449: 1990

Heat Pump Considerations
House type

100 – 130+ W/M^2

40-50 W/M^2

30 – 40 W/M^2

Heat Pump Considerations

Sizing Heat Emitters

The emitters need to be accurately sized to the lower flow temperatures delivered from the heat pump.

If you intend to offer MCS or funding in the future to the customer the emitters need to be at least 3 star rated.

Reducing fabric and/or ventilation heat losses can move a room up to the next specific heat loss band, making it easier to achieve a good SPF.

	Temperature Star Rating	Heating circuit flow temperature °C	Likely space heating SPF		Oversize Factors for other emitters			Underfloor heating screed			Underfloor heating Aluminium panel		
			GSHP	ASHP	Domestic Fan Convector/Fan-assisted Radiator	Standard Radiator	Fan Coil Unit	with TILE	with WOOD	with CARPET	with TILE	with WOOD	with CARPET
Room specific heat loss less than 30 W/m²	★★★★★★	35	4.3	3.6	4.3	6.8	5.0	FS:300	FS:300	FS:200	FS:200	FS:200	FS:150
	★★★★★☆	40	4.1	3.4	3.1	4.3	3.5	FS:300	FS:300	FS:300	FS:300	FS:300	FS:200
	★★★★☆☆	45	3.7	3	2.4	3.1	2.6	FS:300	FS:300	FS:300	FS:300	FS:300	FS:300
	★★★☆☆☆	50	3.4	2.7	2.0	2.4	2.1	FS:300	FS:300	FS:300	FS:300	FS:300	FS:300
	★★☆☆☆☆	55	3.1	2.4	1.7	1.9	1.7	FS:300	FS:300	FS:300	FS:300	FS:300	FS:300
	★☆☆☆☆☆	60	2.8	2.1	1.4	1.6	1.5	FS:300	FS:300	FS:300	FS:300	FS:300	FS:300
Room specific heat loss 30 to 50 W/m²	★★★★★★	35	4.3	3.6	4.3	6.8	5.0	FS:300	FS:100		FS:100	Reduce heat loss	
	★★★★★☆	40	4.1	3.4	3.1	4.3	3.5	FS:300	FS:200	FS:150	FS:200		
	★★★★☆☆	45	3.7	3	2.4	3.1	2.6	FS:300	FS:300	FS:300	FS:200	FS:200	FS:150
	★★★☆☆☆	50	3.4	2.7	2.0	2.4	2.1	FS:300	FS:300	FS:300	FS:300	FS:200	FS:200
	★★☆☆☆☆	55	3.1	2.4	1.7	1.9	1.7	FS:300	FS:300	FS:300	FS:300	FS:300	FS:300
	★☆☆☆☆☆	60	2.8	2.1	1.4	1.6	1.5	FS:300	FS:300	FS:300	FS:300	FS:300	FS:300
Room specific heat loss 50 to 80 W/m²	★★★★★★	35	4.3	3.6	4.3	6.8	5.0	FS:100	Reduce heat loss		Reduce heat loss		
	★★★★★☆	40	4.1	3.4	3.1	4.3	3.5	FS:200					
	★★★★☆☆	45	3.7	3	2.4	3.1	2.6	FS:300	FS:100	FS:100	FS:150		
	★★★☆☆☆	50	3.4	2.7	2.0	2.4	2.1	FS:300	FS:200	FS:150	FS:200	FS:100	
	★★☆☆☆☆	55	3.1	2.4	1.7	1.9	1.7	FS:300	FS:300	FS:200	FS:200	FS:150	FS:100
	★☆☆☆☆☆	60	2.8	2.1	1.4	1.6	1.5	FS:300	FS:300	FS:300	FS:200	FS:200	FS:150
Room specific heat loss 80 to 100 W/m²	★★★★★★	35	4.3	3.6	4.3	6.8	5.0						
	★★★★★☆	40	4.1	3.4	3.1	4.3	3.5	FS:150					
	★★★★☆☆	45	3.7	3	2.4	3.1	2.6	FS:200			FS:100		
	★★★☆☆☆	50	3.4	2.7	2.0	2.4	2.1	FS:250	FS:100	FS:100	FS:150		
	★★☆☆☆☆	55	3.1	2.4	1.7	1.9	1.7	FS:300	FS:200	FS:150	FS:200	FS:100	
	★☆☆☆☆☆	60	2.8	2.1	2.1	1.6	1.5	FS:300	FS:250	FS:250	FS:200	FS:150	FS:100
Room specific heat loss 100 to 120 W/m²	★★★★★★	35	4.3	3.6	4.3	6.8	5.0	Reduce heat loss			Reduce heat loss		
	★★★★★☆	40	4.1	3.4	3.1	4.3	3.5						
	★★★★☆☆	45	3.7	3	2.4	3.1	2.6						
	★★★☆☆☆	50	3.4	2.7	2.0	2.4	2.1						
	★★☆☆☆☆	55	3.1	2.4	1.7	1.9	1.7						
	★☆☆☆☆☆	60	2.8	2.1	1.4	1.6	1.5						
Room specific heat loss 120 to 150 W/m²	★★★★★★	35	4.3	3.6	4.3	6.8	5.0	Reduce heat loss			Reduce heat loss		
	★★★★★☆	40	4.1	3.4	3.1	4.3	3.5						
	★★★★☆☆	45	3.7	3	2.4	3.1	2.6						
	★★★☆☆☆	50	3.4	2.7	2.0	2.4	2.1						
	★★☆☆☆☆	55	3.1	2.4	1.7	1.9	1.7						
	★☆☆☆☆☆	60	2.8	2.1	1.4	1.6	1.5						

Changing the emitter specification can reduce the flow temperature and therefore increase SPF.

Changing the emitter type can enable the emitter to operate at a lower temperature.

Changing the floor covering on UFH can reduce the required emitter temperature.

WORCESTER BOSCH

Heat Pump Considerations

Oversize Factor

Room specific heat loss 80 to 100 W/m²

Temperature Star Rating	Heating circuit flow temperature °C	Likely space heating SPF: GSHP	Likely space heating SPF: ASHP	Oversize Factors for other emitters: Domestic Fan Convector/Fan-assisted Radiator	Oversize Factors for other emitters: Standard Radiator	Oversize Factors for other emitters: Fan Coil Unit	Underfloor heating: screed: with TILE	Underfloor heating: screed: with WOOD	Underfloor heating: screed: with CARPET	Underfloor heating: Aluminium panel: with TILE	Underfloor heating: Aluminium panel: with WOOD	Underfloor heating: Aluminium panel: with CARPET
★★★★★★	35	4.3	3.6	4.3	6.8	5.0						
★★★★★☆	40	4.1	3.4	3.1	4.3	3.5	PS≤150					
★★★★☆☆	45	3.7	3	2.4	3.1	2.6	PS≤200			PS≤100		
★★★☆☆☆	50	3.4	2.7	2.0	2.4	2.1	PS≤250	PS≤100	PS≤100	PS≤150		
★★☆☆☆☆	55	3.1	2.4	1.7	1.9	1.7	PS≤300	PS≤200	PS≤150	PS≤200	PS≤100	
★☆☆☆☆☆	60	2.8	2.1	2.1	[illegible]	1.5	PS≤300	PS≤250	PS≤250	PS≤200	PS≤150	PS≤100

3 stars

SPF 2.7

80 to 100 W/M²

Oversize factor 2.4

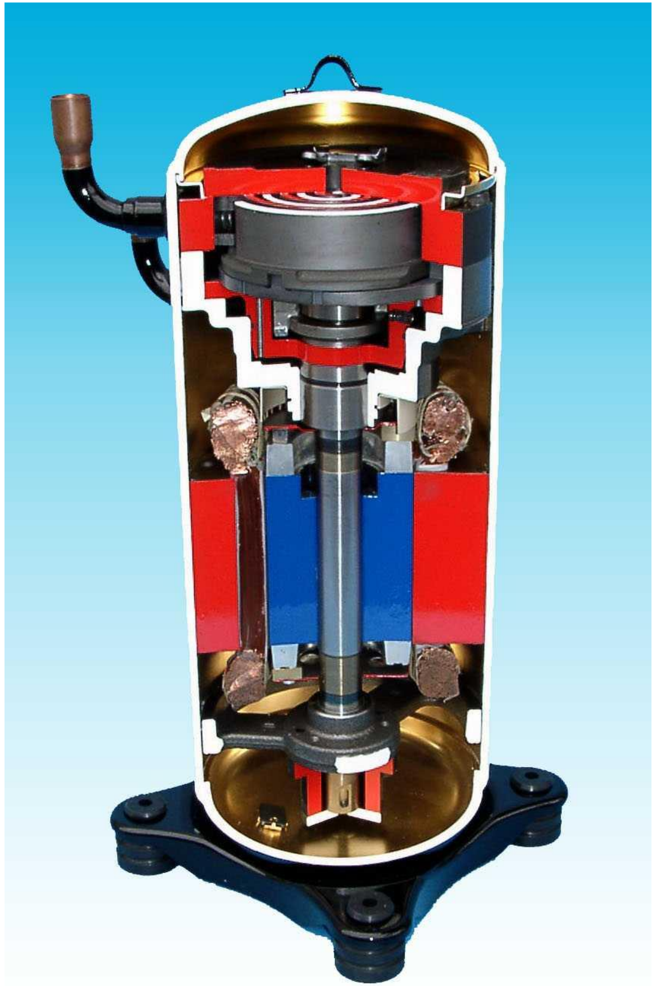
Radiator flow temperature

Heat Pump Considerations
Electrical connections

Scroll compressor

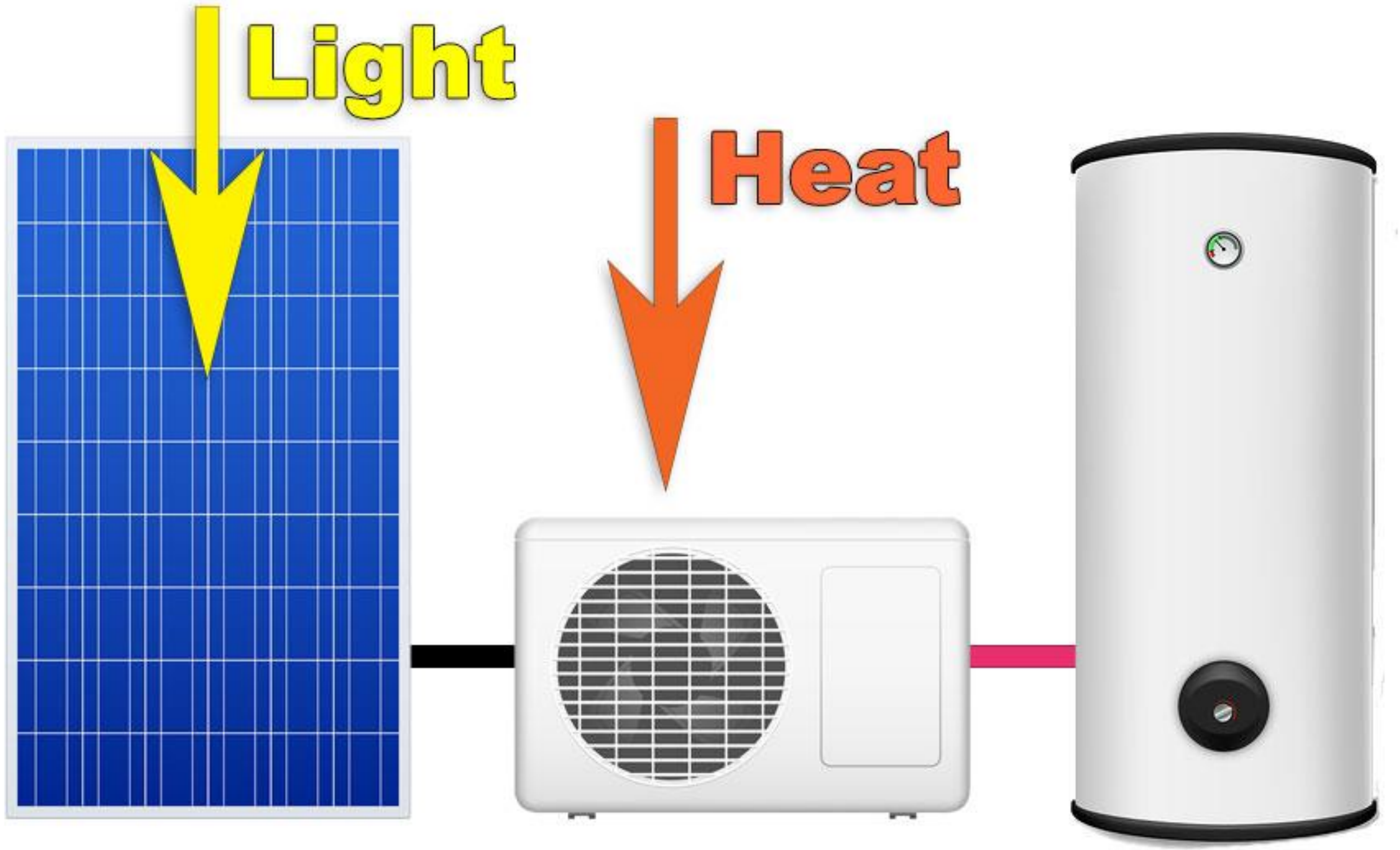
- Fixed speed
- Inverter driven

Values for electrical connection					
Electrical supply		230V 1N~50Hz			
Fuse, slow; with electric additional heat 3/6/9 kW[4)]	A	25/40/63	32/40/63	32/50/63	40/50/63
Nominal power consumption compressor (B0/W35)	kW	1,17	1,48	1,78	2,09
Max. current with soft starter	A	<35			



Heat Pump Technology's
DHW Heat pumps

Heat Pump Technology's
PV Add on



7.0
QUESTIONS

THANK YOU

TRAINING@UK.BOSCH.COM
0330 123 0166