Sustainability & Construction Team

Solution Overview

Bivalent Heating Systems

(Heat Pump + Gas Boiler)

MITSUBISHI ELECTRIC

Sustainability & Construction Team

Contents

Guide authors:

Zero Carbon Design Team: Chris Newman, Scott Evemy, Paul Binns & Rob Griffin

Document Outline

This is one of a series of documents produced by Mitsubishi Electric UK to assist with understanding a specific design concept and the potential benefits of that concept.

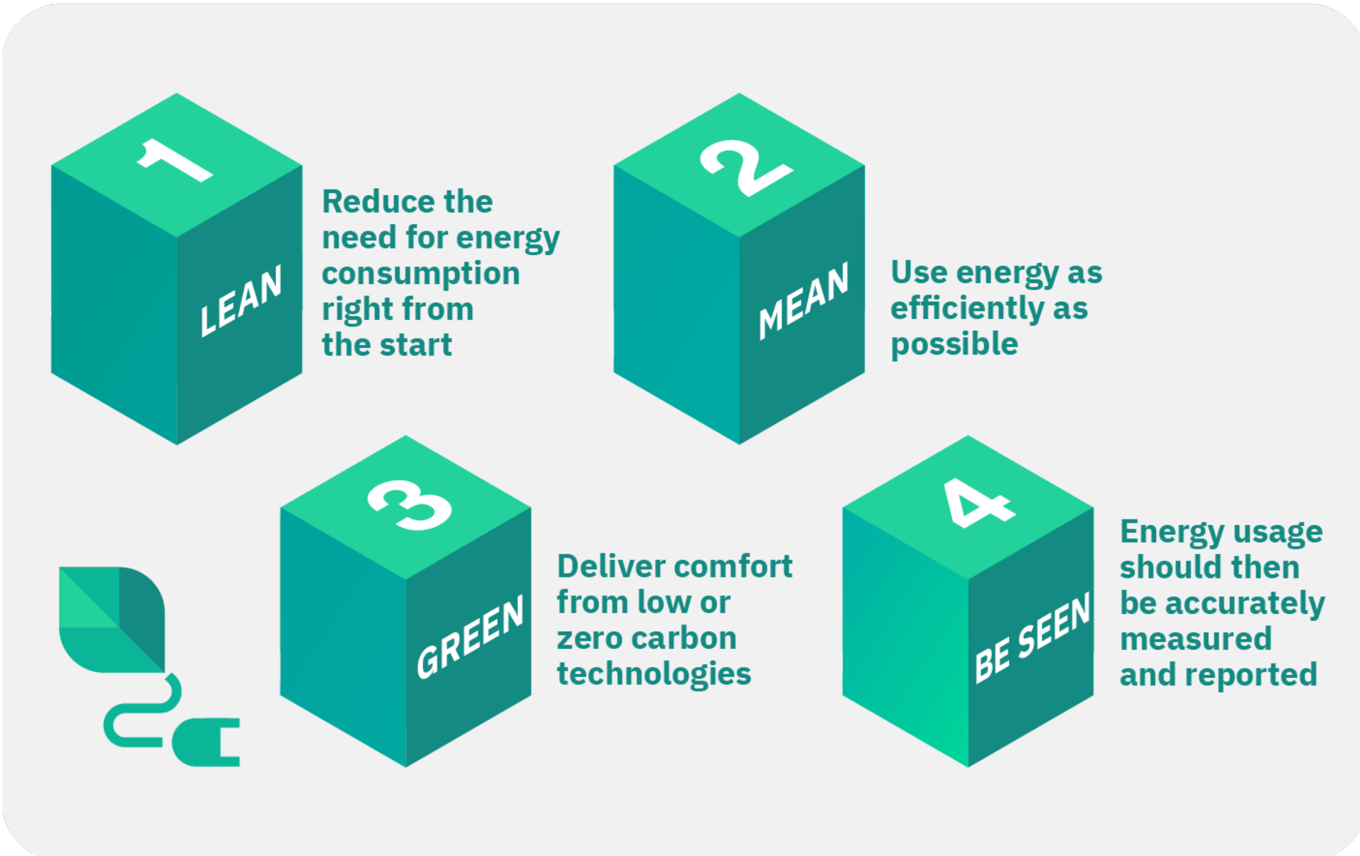
This document will set out the main factors to consider when proposing this type of solution and provide practical information to aid with the initial decision-making process.

Before considering any type of HVAC solution, it is important to first address the underlying requirements of the building in line with the overriding goal of achieving Net Zero green house gas emissions by 2050.

ON THE ROAD TO NET ZERO

Careful consideration should be given to the overall impact of any solution in terms of embodied carbon, operational carbon and energy efficiency.

- The baseline requirement for energy to heat / cool and ventilate the building should first be addressed using passive measures.
- An intelligent building management system or controls interface should then be used to ensure energy is conserved wherever possible.
- Renewable energy should be utilised whenever possible / practical with fossil fuels being displaced by scalable renewable sources.
- Energy usage should then be accurately measured and reported.



Concept Outline

The concept being explored within this document involves the use of heat pump technology to displace as much energy being delivered by a fossil fuel based alternative as possible.

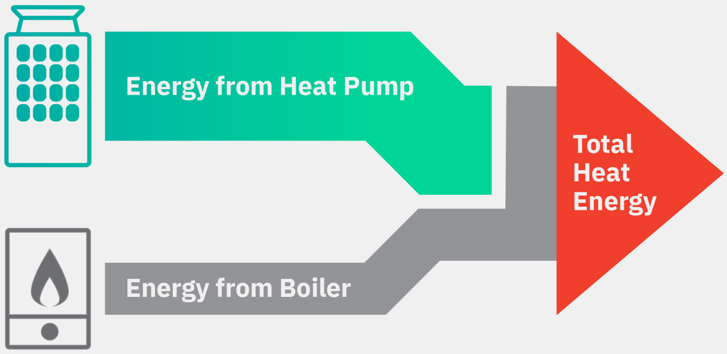
Constraints such as plant space, capital cost and electrical infrastructure can often limit the ability of a heat pump to completely replace an existing fossil fueled system, however the proportion of energy delivered by a low carbon heat pump can still be significant if intelligent combinations of heat pump and boiler are implemented.

There are 2 options available:

1. Bivalent Changeover

Heat pump working in isolation to the boiler.

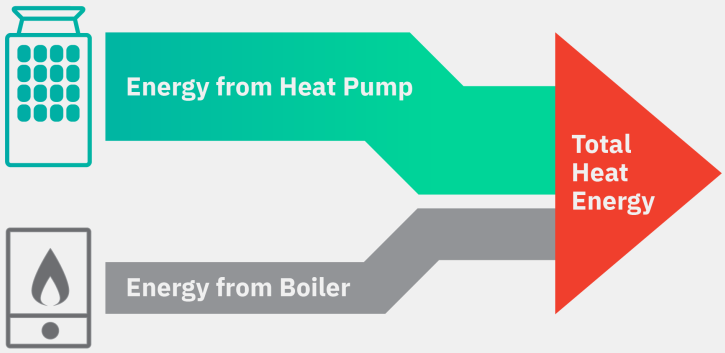
The heat pump operates as the lead heat source until it can no longer meet requirements whereby it stops operating and switches over to the boiler.



2. Bivalent in Parallel

Heat pump working simultaneously or in parallel with a boiler.

The heat pump operates as lead heat source with boiler topping up capacity or flow temperature when required.

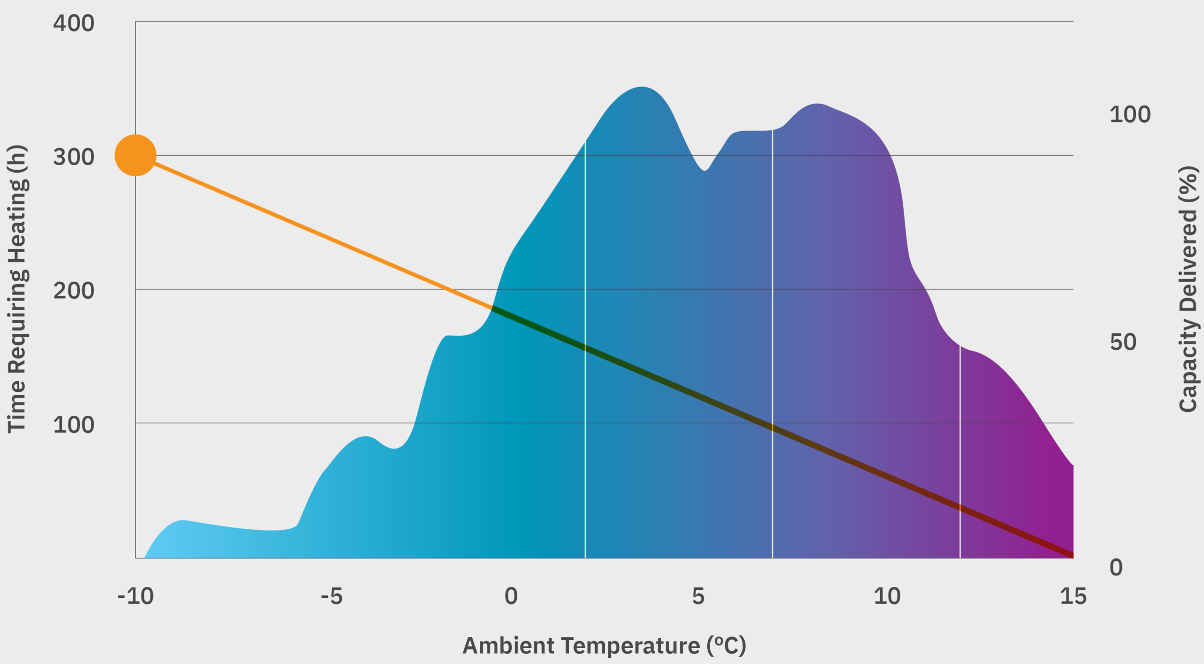


Energy Contribution vs Peak Capacity

It is important to note that the peak capacity of a heating system is measured in kW whereas the amount of heat energy delivered is measured in kWh i.e. **1kW of capacity delivered for a duration of 1hr = 1kWh**.

It is typical in the UK for peak heating capacity (i.e. 100% load) to only be required for a small number of hours in the year and therefore this makes up a relatively small amount of the total kWh of heat energy delivered - this can be seen in the below chart which is used to represent the typical weather profile of an average temperature country in Europe such as the UK.

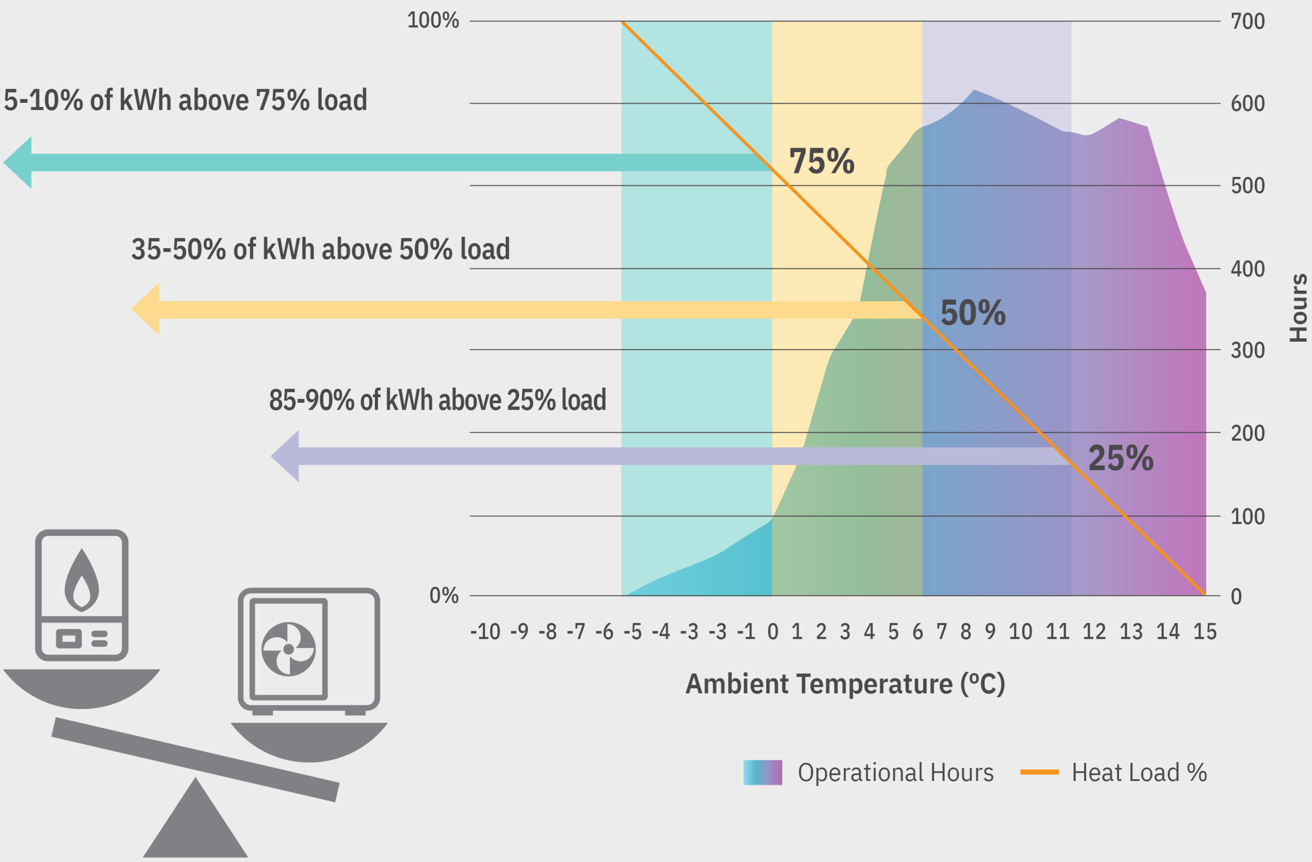
Figure 1



Example weather and heating load profile taken from EN14825 seasonal efficiency calculation.

Using a typical weather profile for a city in the North of the UK such as Manchester, we can see that only around 5 -10% of kWhs delivered are above 75% of the peak capacity of the system (shown in green), and only around 35-50% is above 50% (shown in Yellow), therefore a heat pump sized at 75% of the peak load can deliver up to 95% of the annual kWh heating energy and one sized at 50% of peak load could deliver up to 65%.

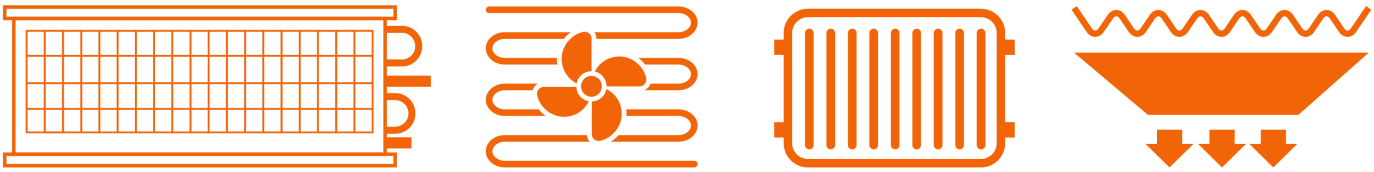
Figure 2



Peak Capacity vs Flow Temperature

When considering the capacity and delivered heat energy from a heat pump operating in combination with another heat source, the temperature of the heat energy is being delivered at is critical - not only because this significantly impacts the heat pump efficiency, but also this can be a limiting factor to the ability of the heat pump to deliver its capacity into the heating system.

The heat energy that can be delivered into a building by any heat source is limited by the connected heat emitters (e.g. fan coils, AHU's, radiators, radiant panels, under floor heating etc.).



Heat emitter capacity is impacted by the average temperature of the heat emitter in comparison to the space temperature it is trying to deliver its heat energy into.

For example - a heat emitter capable of delivering 10kW of capacity into a space with a mean temperature of 70°C and a space temperature of 20°C (therefore an emitter to room ∆T of 50K which is typical nominal radiator design conditions) will only be capable of delivering approx. 5kW if the mean emitter temperature is reduced to 50°C as the emitter to room ∆T would be reduced to 30K.

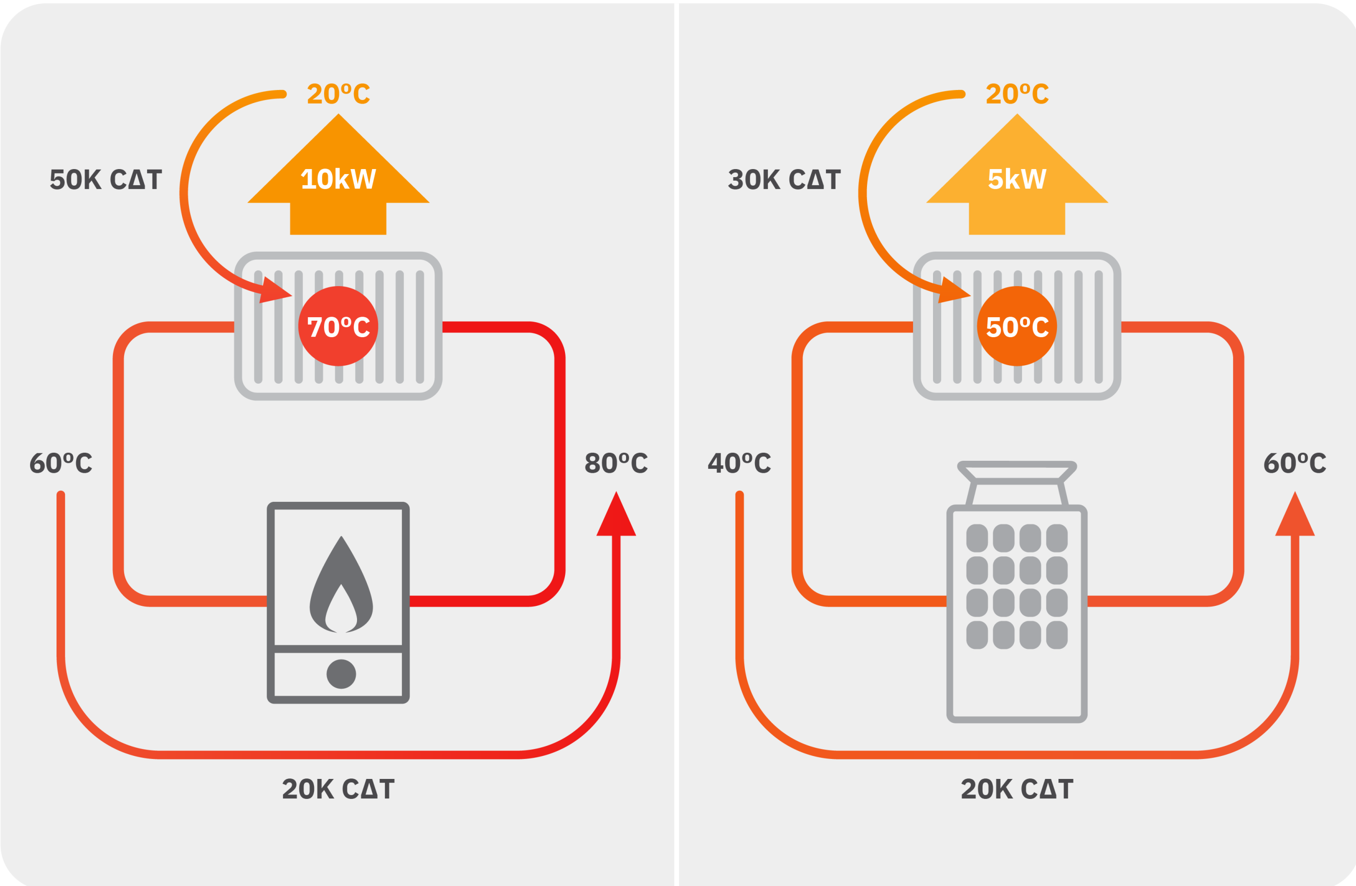
See example radiator de-rate chart

Delta T of mean emitter temp to room temp	Ratio of heat output
5	0.050
10	0.123
15	0.209
20	0.304
25	0.406
30	0.515
35	0.629
40	0.748
45	0.872
50	1.000
55	1.132
60	1.267
65	1.406
70	1.549
75	1.694

Example data taken from Stelrad radiator book 2021: [bit.ly/47nfh4o](bit.ly/47nfh4o)

Therefore, in a typical existing heating system operating at 80ºC flow temperature with a 60ºC return temperature (i.e. mean emitter temperature of 70ºC), connecting a heat pump that is operating at 60ºC flow temperature using the same water flow and return ∆T (i.e. mean emitter temperature of 50ºC) will result in the example heat emitter only being capable of delivering approx. 5kW.

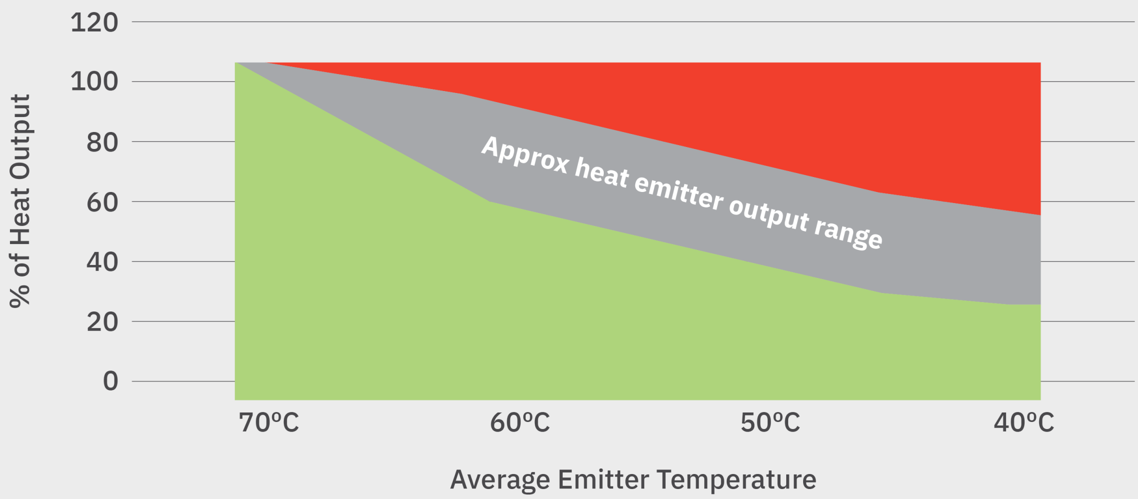
In this example, the maximum deliverable capacity by the heat pump will be 5kW irrelevant of the maximum capacity of the heat pump:



If selecting a heat pump which will operate at a lower water flow temperature than the existing heat source (i.e. Bivalent Changeover), heat emitter output capability must be considered when selecting the peak capacity of the heat pump to ensure all available capacity of the heat pump is able to be delivered by the heat emitters.

The chart below shows how typical heat emitter output might be affected by reducing the mean water temperature within the heat emitter.

Figure 3: **Heat Emitter Output vs Temperature**



This chart assumes the existing heat emitters are sized correctly to match the heat load requirements of the building at a mean water temperature of 70ºC and takes estimated de-rated performances from various different types of heat emitter and different manufacturer's data to provide a range of likely outputs at different temperatures.

If the proposed capacity and design temperatures of the heat pump fall within the **grey area**, the heat emitters may be capable of delivering the low carbon heat available from the heat pump at those conditions.

If the proposed capacity and design temperatures of the heat pump fall within the **red area**, the heat emitter is unlikely to be able to deliver the available capacity from the heat pump at those conditions.

If the proposed capacity and design temperatures of the heat pump fall within the **green area**, the heat emitters are likely to be able to deliver the low carbon heat available from the heat pump at those conditions.

In all scenarios, the specific heat emitters being used should be carefully evaluated to ensure they are capable of delivering the required output at the proposed design conditions.

Once the required flow temperature and peak capacity of the heat pump have been selected using figure 3 on page 10, the amount of annual energy delivered by each heat source can be calculated using the assumed linear load profile and appropriate BIN hours weather data as shown on figures 1 & 2 on page 6 & 7.

The example below shows a heat pump selected at 60ºC flow temperature to achieve a mean heat emitter temperature of 55ºC. To remain within the green area of the chart, the heat pump will be sized at 50% of the peak capacity of the building heating load - as a result, based upon the example weather profile used in figure 2, the heat pump could deliver up to 65% of the annual kWh of heat energy to the building (i.e. a heat fraction of 0.65).

Heat Emitter Output vs Temperature

Figure 4

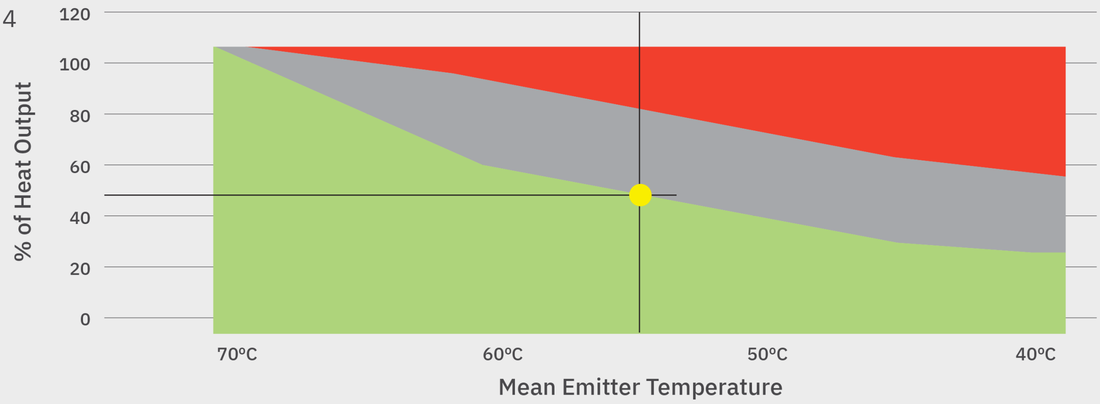
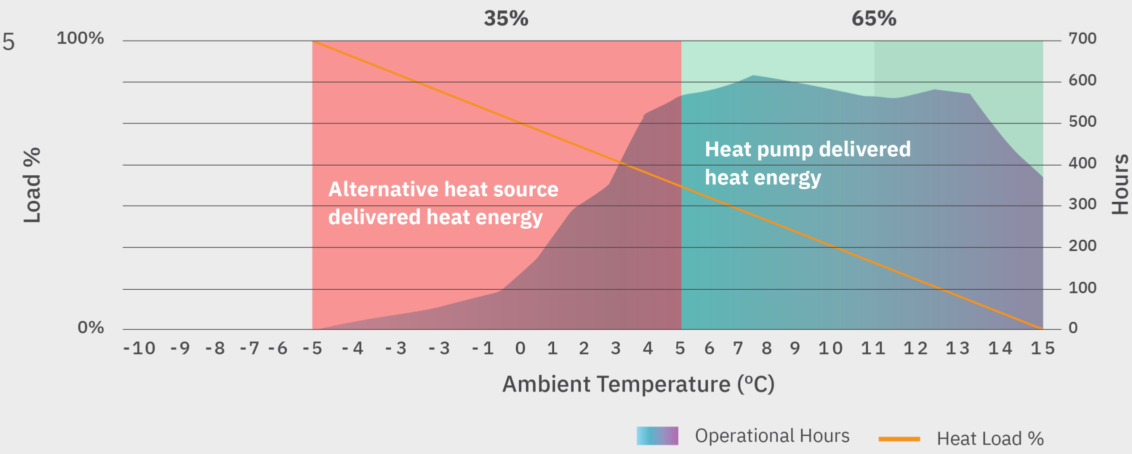


Figure 5



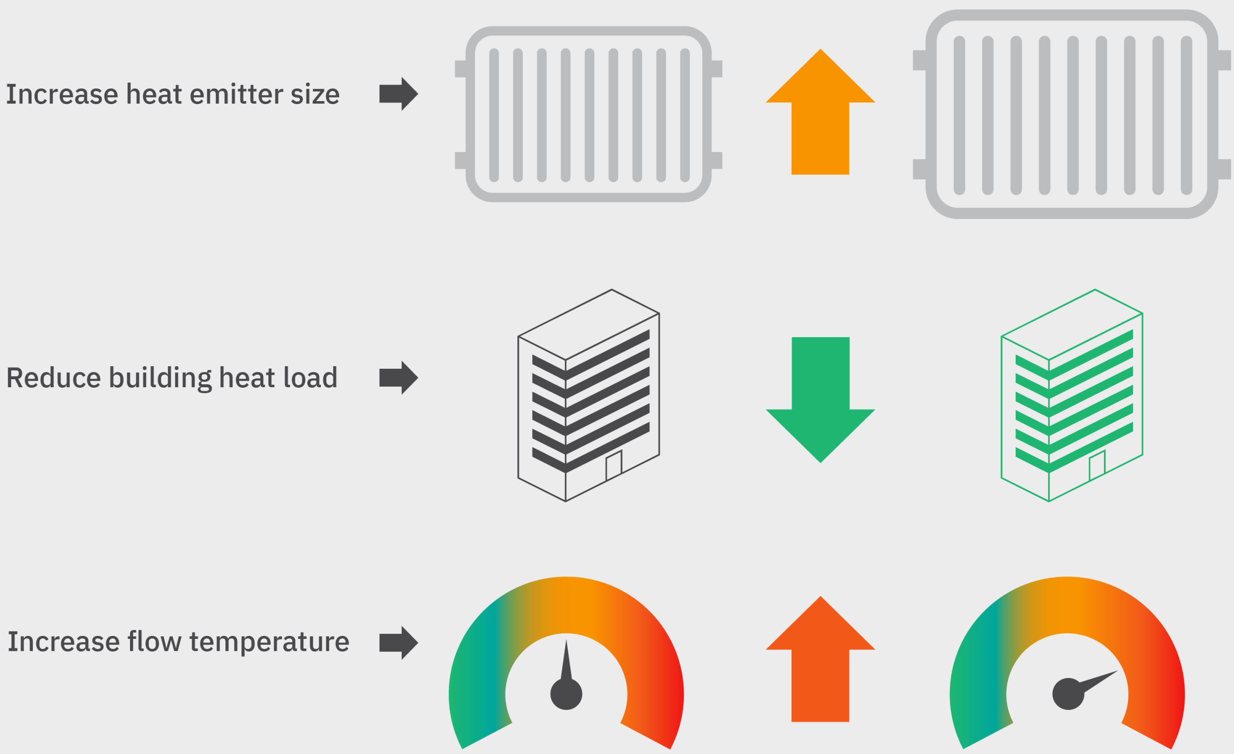
Using these design conditions, the ambient temperature at which the heat pump is no longer able to deliver enough heat energy through the existing heat emitters is +5ºC. As a result, the heat pump capacity should be calculated at +5ºC as this will be the lowest ambient temperature it will operate at, and the seasonal efficiency calculated only using hours of operation at ambient temperatures of ≥+5ºC.

This will result in improved heat pump seasonal efficiency in comparison to standard catalogue data as the heat pump will not be asked to operate during lower ambient temperature periods.

It is important to note that this is not due to the heat pump's inability to operate at lower ambient temperatures, but due to the inability of the existing heat emitters to deliver enough heat energy into the building with the lower flow temperatures being provided by the heat pump.

In order to increase the heat fraction provided by the heat pump, the heat emitters could be increased in size, the building peak heating load could be reduced using passive measures (such as insulation) or the heat pump flow temperature could be increased (although this would reduce the heat pump's efficiency).

Examples of methods to increase heat pump contribution



Taking an example whereby the heat pump is delivering the same flow temperature as the existing system (i.e. Bivalent Parallel), the heat emitters will not impact the capacity sizing of the heat pump as they can always emit the required heating capacity for the building, irrelevant of which heat source is providing heat to them.

As a result, the heat pump capacity can be selected to maximize its heat contribution, achieve the lowest overall carbon emission, lowest overall operating cost or to meet any other project specific criteria (such as available plant space, electrical capacity, cost restrictions, planned plant replacement strategy etc).

Figure 6 shows the relationship between the amount of annual kWh of heat energy delivered by the heat pump when sized at different percentages of the building peak load - the grey area shows the variation of results for different weather profiles across the UK.

Figure 7 shows how a heat pump sized at 50% of the peak building load would deliver its heat across the year with the heat pump operating independently until the 50% load point is reached (@+5ºC ambient temp) when the alternative heat source begins to contribute heat energy alongside the heat pump until they are both delivering an equal amount heat energy at the 100% load point (50% each).

Figure 6: **Heat Pump Size vs % of kWh Delivered**

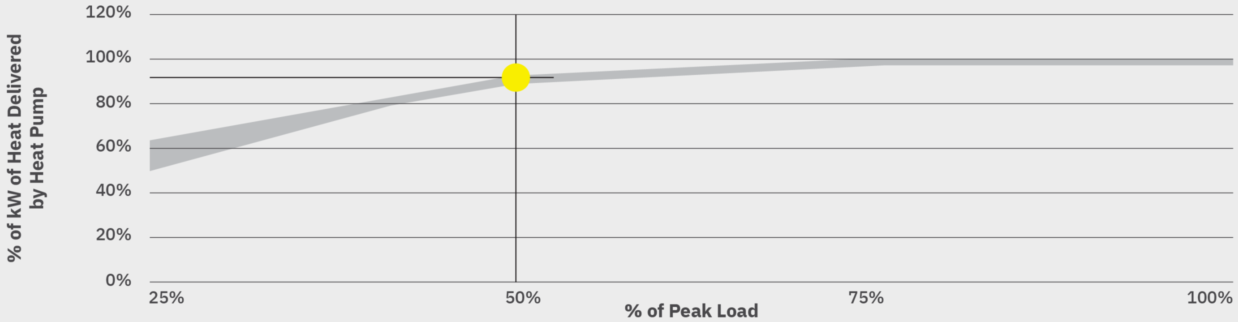
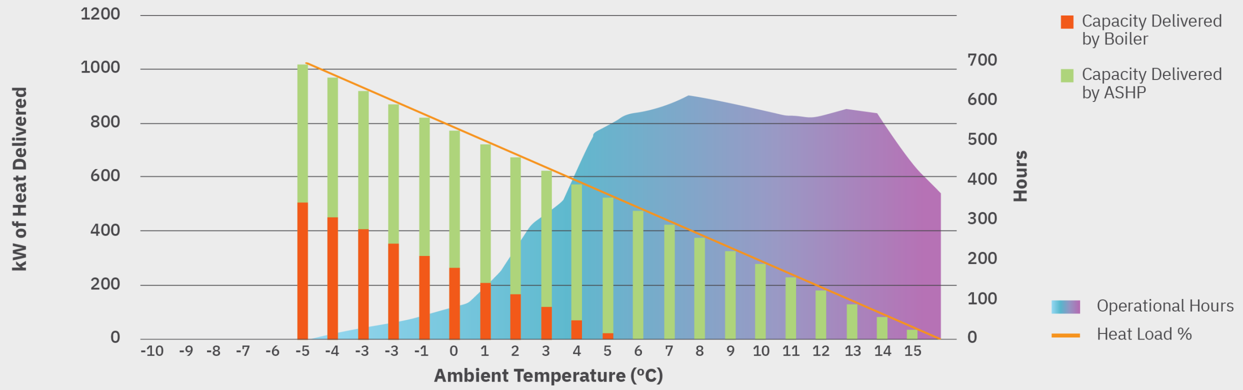


Figure 7: **Total Heat Delivered**

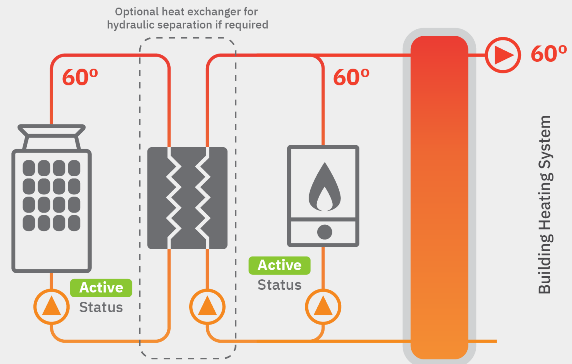


This example shows that a heat pump arranged in parallel with an alternative heat source and sized at approx. 50% of the building peak load could deliver over 90% of the annual kWh of heat energy (depending upon the weather data used).

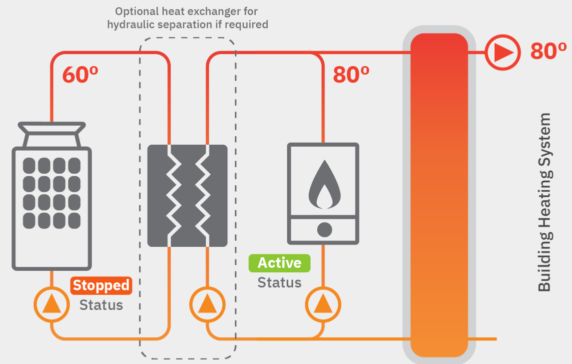
Flow Temperature vs Hydraulic Arrangement

The flow temperature of heat delivered by a heat pump into a heating circuit which has another heat source present will dictate the necessary hydraulic arrangement and required BEMS controls.

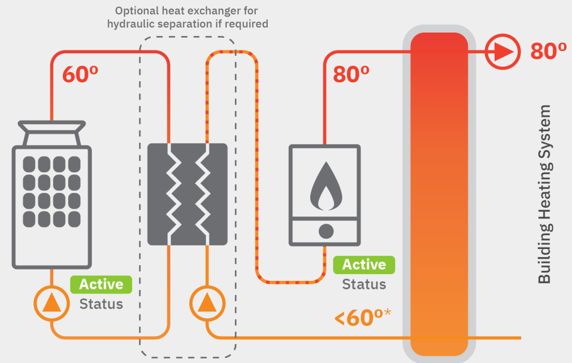
If the heat pump is capable of delivering the **SAME FLOW TEMPERATURE** as the other heat source then they can be arranged in parallel with either heat source able to operate independently or simultaneously.



If the heat pump is **NOT** capable of delivering the same flow temperature as the other heat source then they can still be arranged in parallel but only one heat source **OR** the other will be able to operate.



If the heat pump is **NOT** capable of delivering the same flow temperature as the other heat source then they can be arranged in series for the heat pump to increase return temperature.



*Note: Heating system return temperature must be lower than heat pump flow temperature to allow heat pump to operate.

With any of the above example configurations it is important to ensure that adequate controls are put into place to ensure correct sequencing and operation of different pieces of equipment within the same circuit.

Carbon Comparisons

In order to calculate potential carbon savings between different capacities, hydraulic arrangements and system configurations we must estimate the annual energy used for each option and multiply that by the carbon factor associated with that energy consumed.

For gas fired systems we associate a carbon factor in line with the current building regulations of **0.210Kg/CO_2/kWh** which remains fixed for the lifecycle of the system.

We have associated a Carbon factor of **0.233Kg/CO_2/kWh** for grid electricity (note - this is likely to reduce over time as the electricity grid decarbonises further increasing Carbon savings of bivalent solutions).

Figure 8: **Bivalent Changeover**

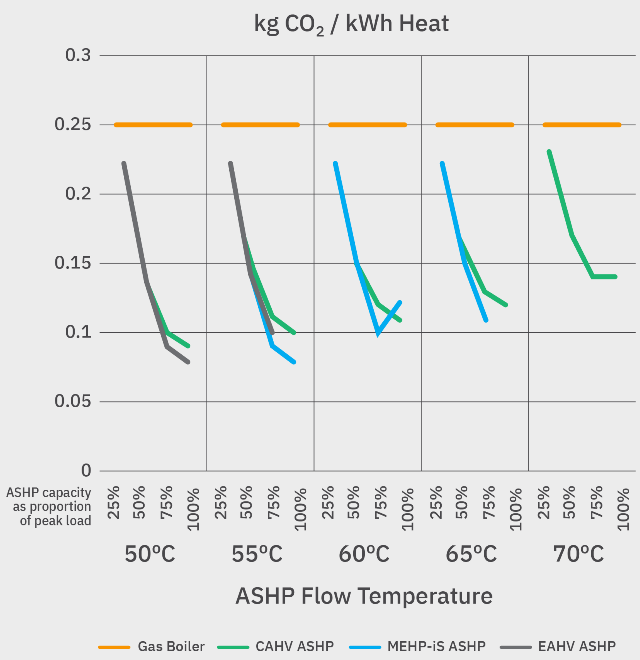
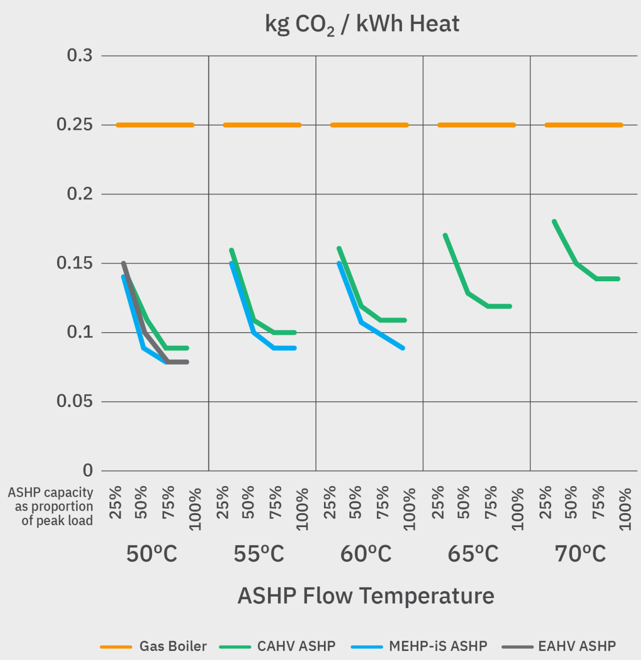


Figure 9: **Bivalent in Parallel**



Assumptions; Gas boiler 85% efficient, Grid emission of 0.210g/kWh Gas, Grid emission of 0.233g/kWh Electricity. Mitsubishi Electric CAHV-R450, EAHV-M1500, MEHP-iS-G07/0102.

Operating Cost Comparisons

In order to calculate operational cost differences between different capacities, hydraulic arrangements and system configurations we must estimate the annual energy used for each option and multiply that by the cost/kWh associated with that energy.

We have assumed a cost ratio of **1:3 for gas vs electricity**
(i.e. 1kWh of electricity will cost 3 times that of 1kWh of gas).

Figure 10: **Bivalent Changeover**

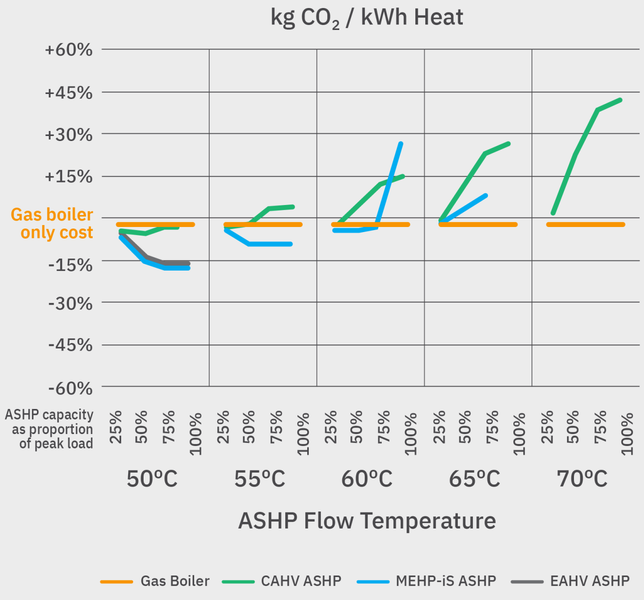
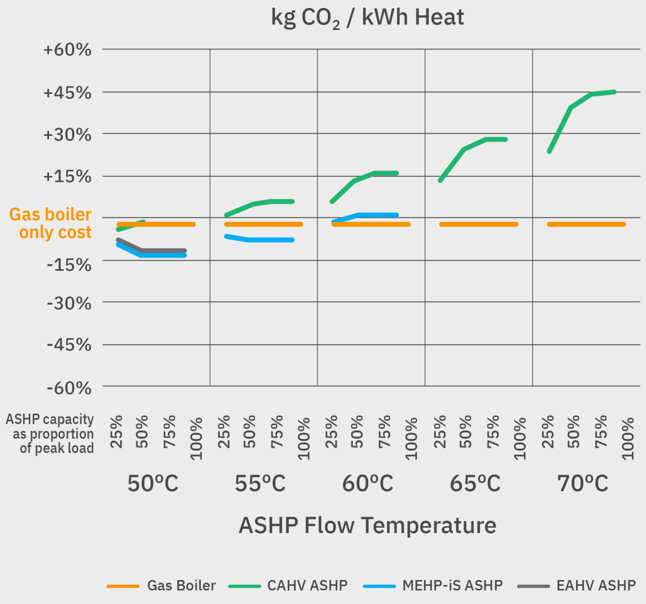


Figure 11: **Bivalent in Parallel**



Assumptions; Gas boiler 85% efficient. Mitsubishi Electric CAHV-R450, EAHV-M1500, MEHP-iS-G07/0102.

Summary

The optimum selection, sizing and configuration of a heat pump when used as part of a bivalent system can be derived based upon;

- **Current flow temperatures**
- **Existing heat emitter capabilities**
- **Heat pump heat share**
- **Carbon emissions -** However, additional practical considerations may also impact heat pump selection such as;

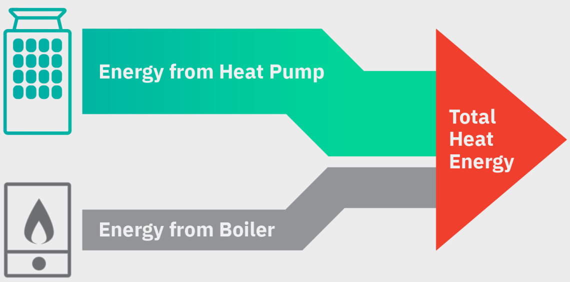
Plant Space

Electrical Capacity

Noise Levels

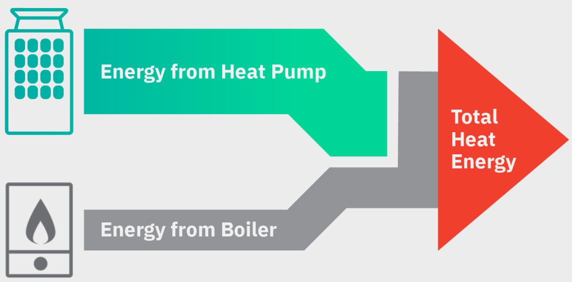
Capital or Operational Cost

Bivalent Changeover:



- ✓ No need to change heat emitters
- ✓ Ideal first step to decarbonise
- ✓ Optimum heat pump size = 50-75% of peak load
- ✓ Can achieve up to 65% Carbon saving
- ✗ Heat pump not operating at all times
- ✗ Heat Pump heat share can be low

Bivalent in Parallel:

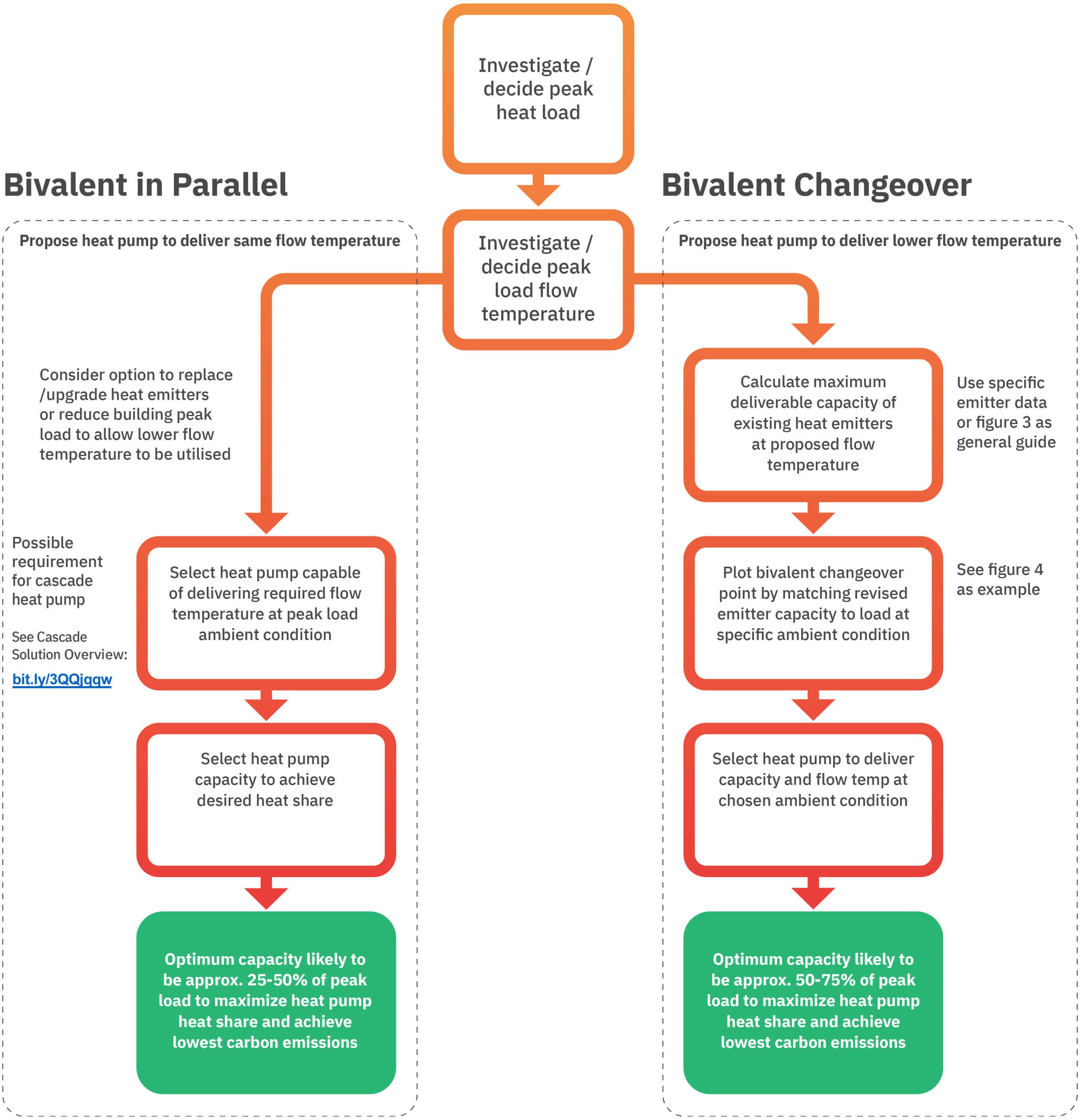


- ✓ Lowest overall Carbon emissions
- ✓ Heat pump heat share very high
- ✓ Optimum heat pump size = 25-50% of peak load
- ✓ Heat pump operating at all times
- ✗ More complex system design - flow temps vs heat emitters
- ✗ More difficult to integrate hydraulically

Overriding consideration should be given to the wider plan for decarbonising the building and reducing scope 1 emissions.

Either configuration of bivalent system should be considered an ideal first step in achieving these goals and used as part of an ongoing upgrade of the building overall.

Bivalent solution quick selection process



Further Information

Click the links below or scan the QR code.

Email: Sustainable.construction@meuk.mee.com

Or visit: les.mitsubishielectric.co.uk/sustainable-construction

Embodied Carbon Brochure

bit.ly/46tQhr4

Commercial Heating Brochure

bit.ly/40TPgak

Cascade Solution Overview Document

bit.ly/3QQjqqw

Sales Contacts

Corporate Sales: 0870 3000 070
London South: 01737 387170
London North & East Anglia: 01707 282480

Birmingham: 0121 329 1970
Manchester: 0161 866 6060
Bristol: 01454 202050

Scotland: 01506 444960
Wakefield: 01924 241120
Ireland: +353 (0)1 419 8800

MITSUBISHI ELECTRIC
Changes for the Better

Telephone: **01707 282880**
MELSmart Customer Services & Support: 0161 866 6089

Option 1 - Air Conditioning Technical
Option 2 - Spares
Option 3 - Warranty
Option 4 - Heating Technical
Option 5 - Returns
Option 6 - Product Training & Site Services

Middlesex: 020 8783 1008
Scotland: 01786 450 348

email: **livingenvironmentalsystems@meuk.mee.com**
les.mitsubishielectric.co.uk

@meuk_les @green_gateway
Mitsubishi Electric Living Environmental Systems UK
Mitsubishi Electric Cooling and Heating UK
mitsubishielectricuk_les
mitsubishielectric2
BLOG thehub.mitsubishielectric.co.uk

UNITED KINGDOM Mitsubishi Electric Europe Living Environment Systems Division, Travellers Lane, Hatfield, Hertfordshire, AL10 8XB, England. Telephone: 01707 282880 Fax: 01707 278881
IRELAND Mitsubishi Electric Europe, Westgate Business Park, Ballymount, Dublin 24, Ireland. Telephone: (01) 419 8800 Fax: (01) 419 8890 International code: (003531)

Note: The fuse rating is for guidance only. Please refer to the relevant databook for detailed specification. It is the responsibility of a qualified electrician/electrical engineer to select the correct cable size and fuse rating based on current regulation and site specific conditions. Mitsubishi Electric's air conditioning equipment and heat pump systems contain a fluorinated greenhouse gas, R410A (GWP:2088), R32 (GWP:675), R407C (GWP:1774), R134a (GWP:1430), R513A (GWP:631), R454B (GWP:466), R1234ze (GWP:7) or R1234yf (GWP:4). *These GWP values are based on Regulation (EU) No 517/2014 from IPCC 4th edition. In case of Regulation (EU) No.626/2011 from IPCC 3rd edition, these are as follows. R410A (GWP:1975), R32 (GWP:550), R407C (GWP:1650) or R134a (GWP:1300).

Green Gateway greengateway.mitsubishielectric.co.uk