Sustainability & Construction Team

Solution Overview

Cascade High Temperature Heat Pumps

(Air Source Heat Pump + Water Source Heat Pump)

Contents

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Document Outline

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

This document will set out the main factors for consideration 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

Document Outline

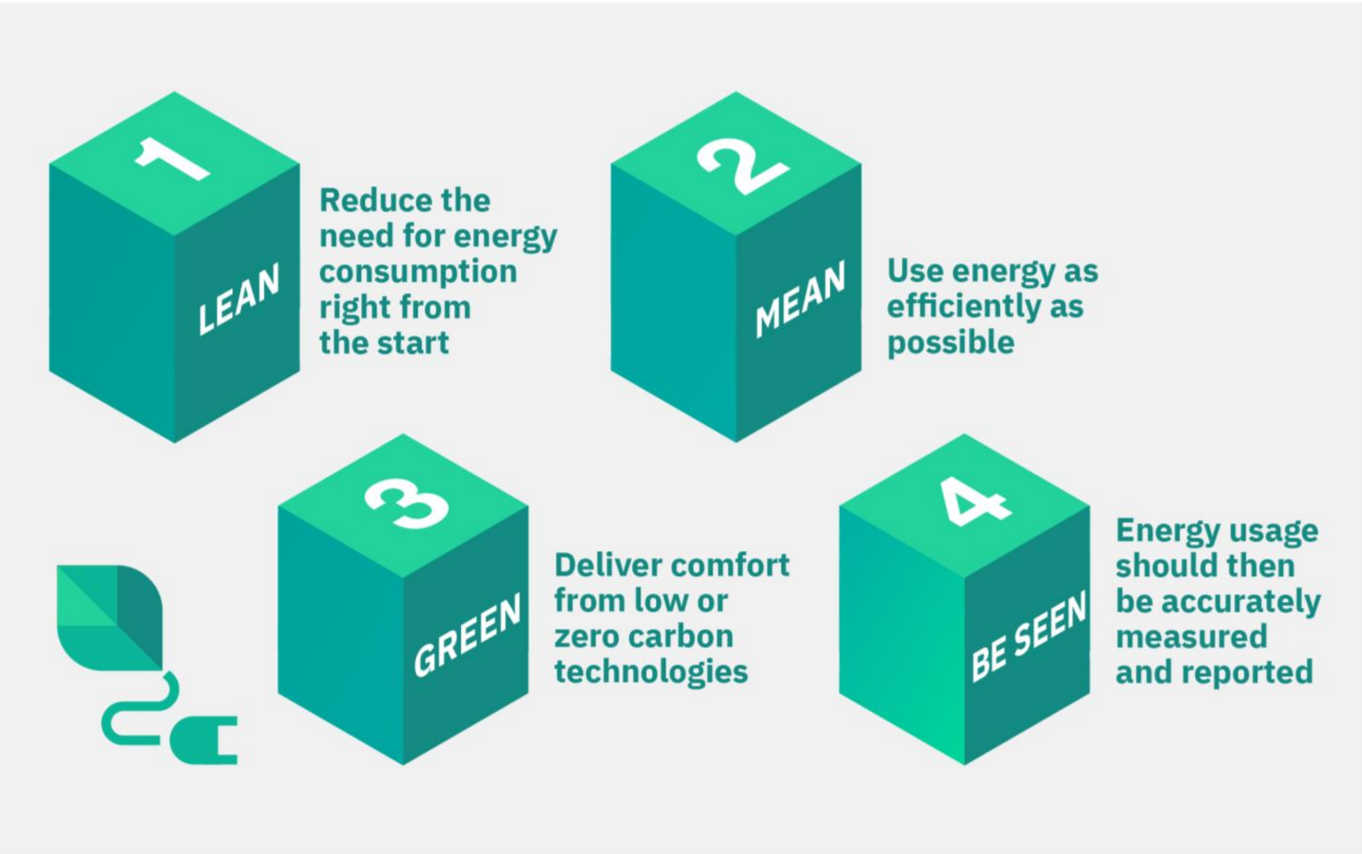
Careful consideration should be given to the overall impact of any solution in terms of embodied carbon, operational carbon and energy efficiency.

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 provide heating and / or hot water at high temperatures (>70ºC).

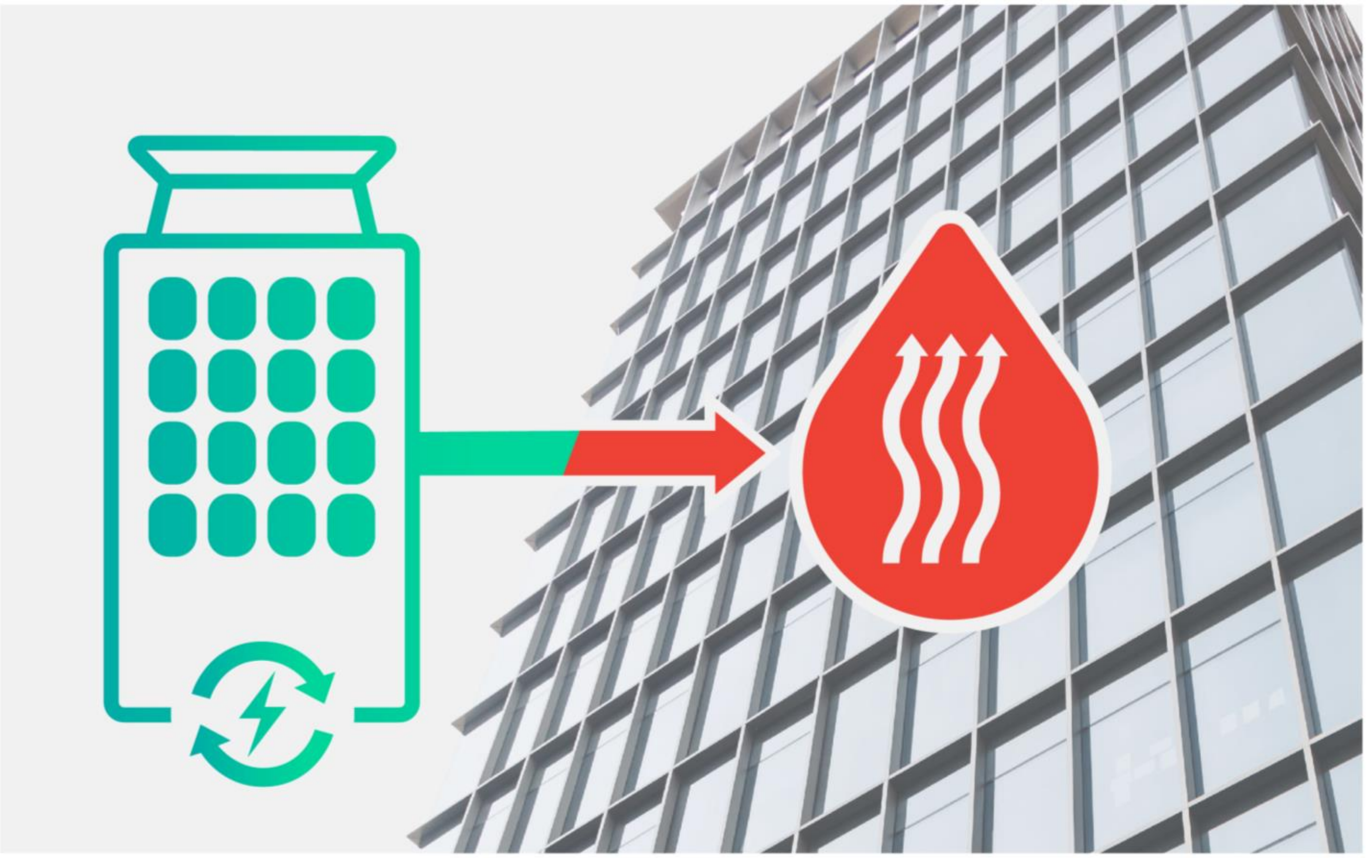
High temperatures can be difficult to achieve using heat pump systems due to many influencing factors such as;

The heat pump energy source - Air or Water source heat pump (ASHP or WSHP)

The refrigerant utilised within the heat pump - Temperature operating range & GWP

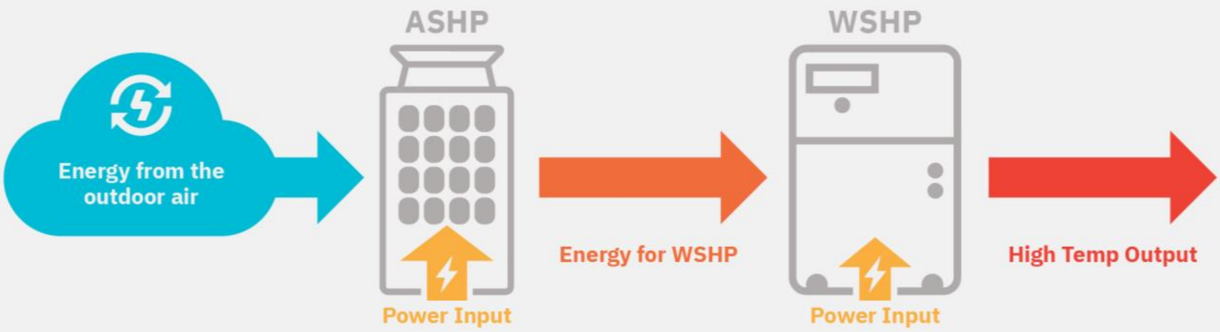
Minimum efficiency requirements - Operating costs & operational carbon emissions

Required capacity of system - Different compressor types for different capacities



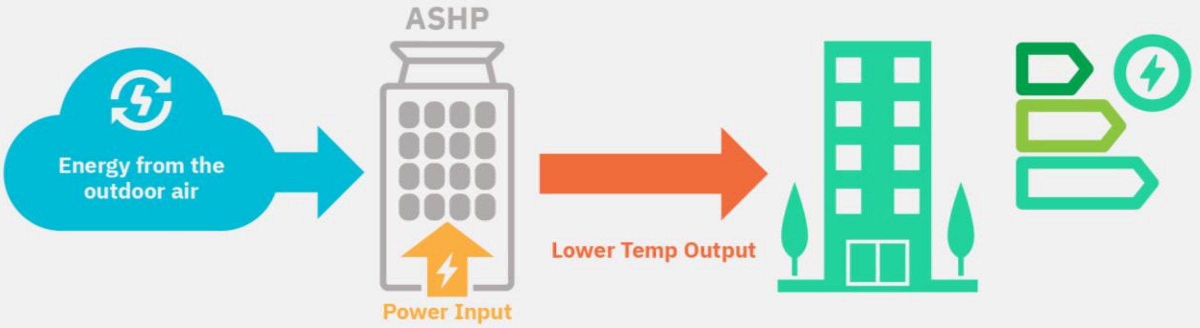
Concept Outline

By utilising an ASHP to absorb the abundance of low-grade energy available in the ambient air to produce low temperature water (approx. 25-55ºC) and then using this low temperature water as the energy source for a WSHP, much higher flow temperatures can be achieved (typically 75ºC+).



The above "cascade" arrangement of ASHP + WSHP can meet the higher temperature requirements of an existing project/application today, whilst also offering the ability to reduce flow temperatures in future once building improvements have been made.

This could be achieved by reducing the WSHP output temperature (therefore improving efficiency) or completely removing the WSHP allowing the ASHP to satisfy all of the requirements at a reduced flow temperature of ≤55ºC.

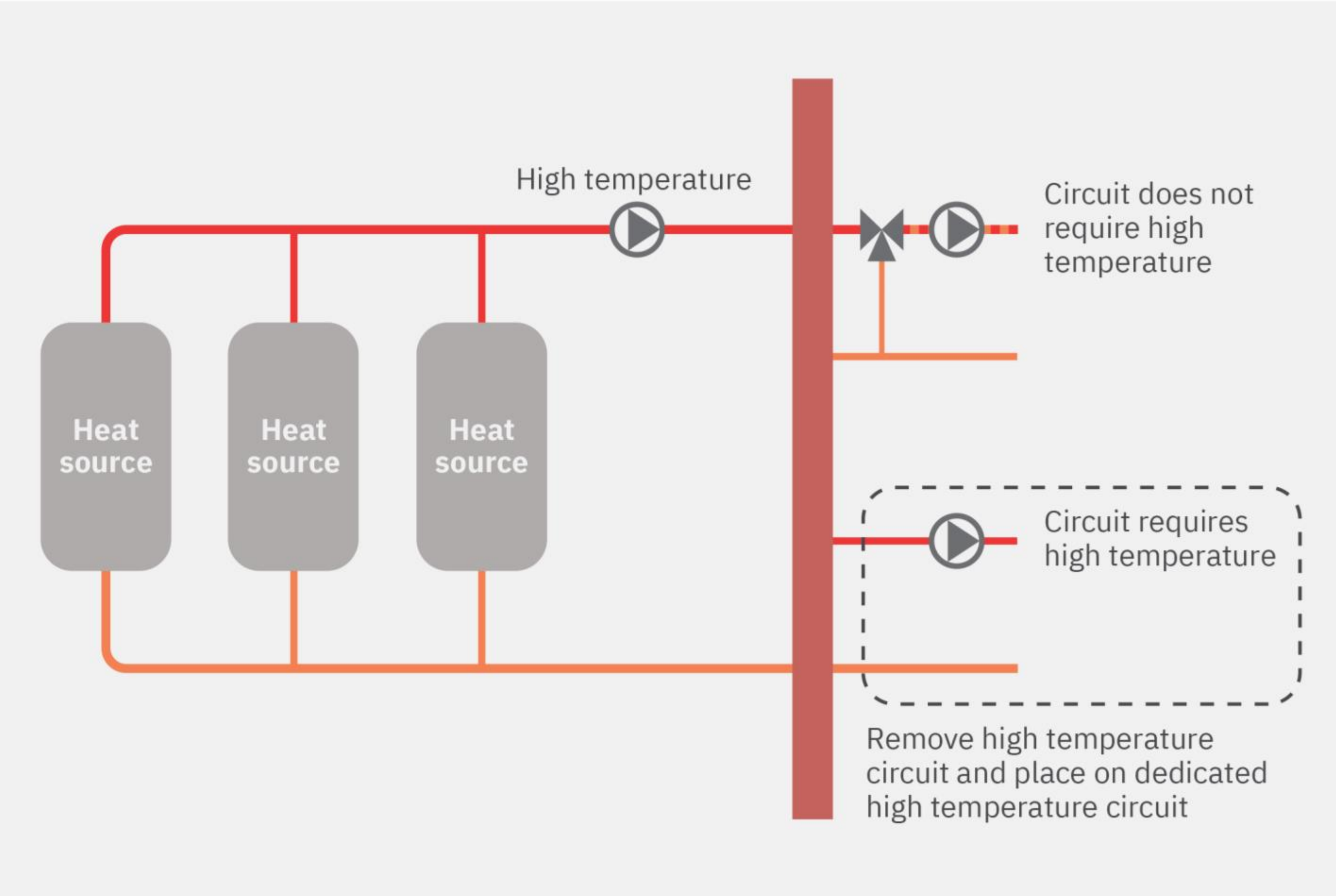


General Design Guidance

Hydraulic Arrangements

The requirement for high temperature flow water within a building should be analysed and reduced wherever possible. Whilst this may often require significant replacement of existing infrastructure, the reduction in energy consumption for the lifetime of the building will usually have an overall positive impact.

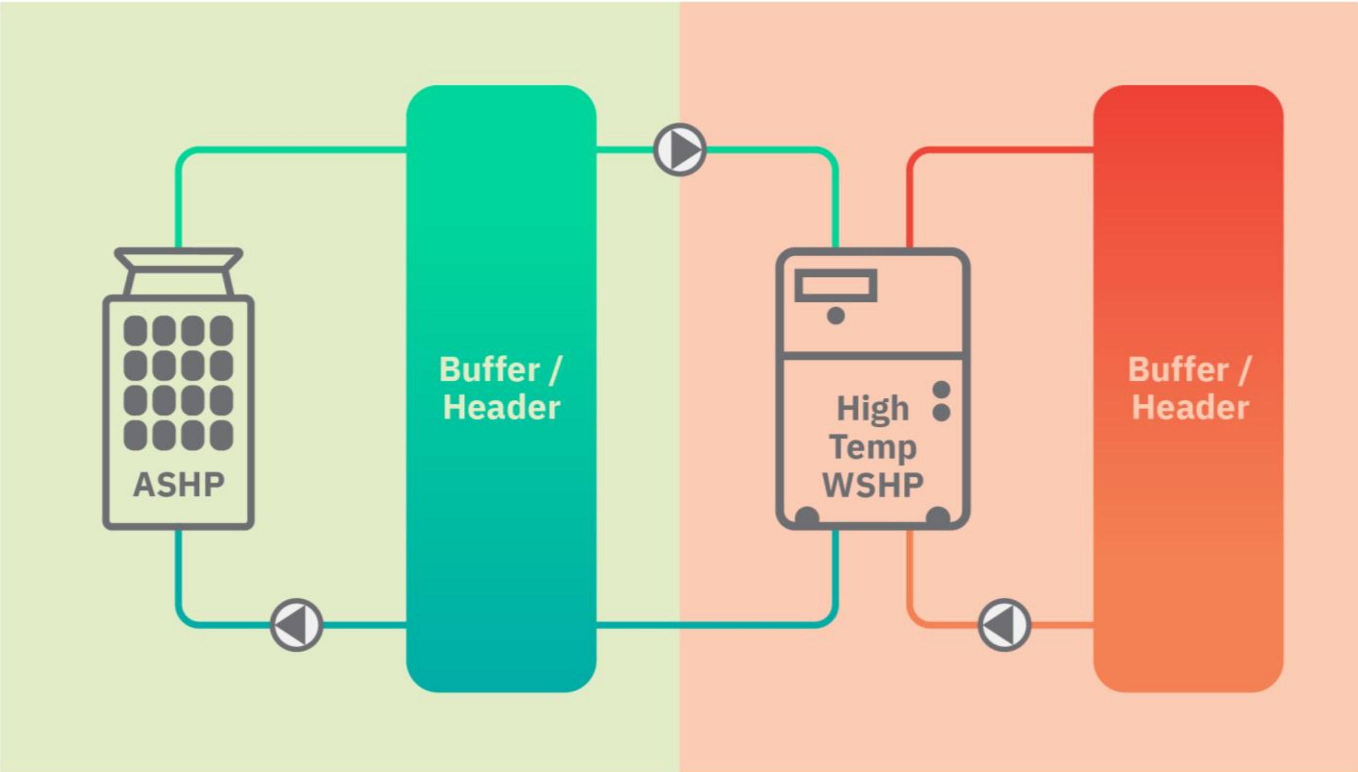
Often, high and low temperature circuits are served by the same heat source meaning that high temperatures are produced all of the time when only part of the circuit requires them - separating high temperature circuits and allowing other circuits to operate at lower flow temperatures will significantly increase system efficiency and reduce energy consumption.



General Design Guidance

Hydraulic Arrangements

The below simplified diagram indicates how an ASHP might be connected to a neutral point (such as a thermal store or buffer vessel) with a WSHP then using the energy provided to this neutral point as its source energy - the WSHP would then provide the high temperature water it generates into the building (possibly via another neutral point to allow for flow rate differences).

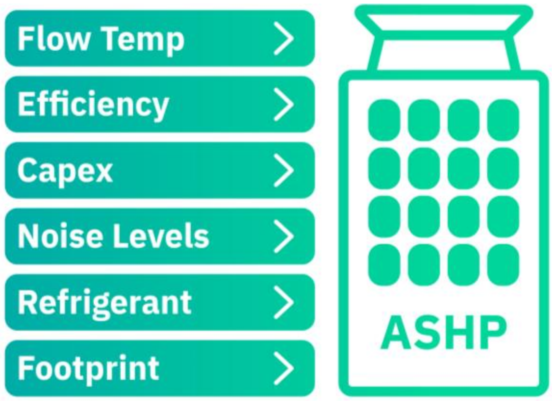


Design Considerations

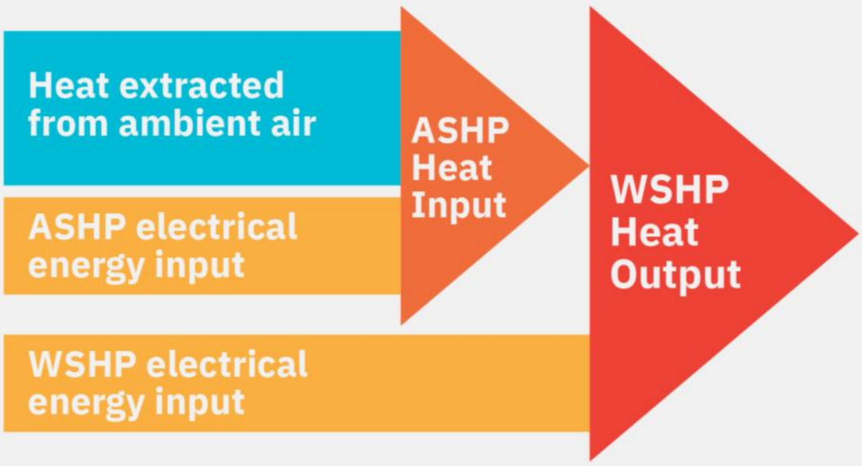
Minimum water volume in ASHP circuit.
Minimum water volume in WSHP (both source and building circuits of WSHP).
Minimum flow rate requirements. Design flow & return temperatures.
Safety protection devices and interlocks.
Water quality standards. Frost protection.

Selecting Air Source Heat Pumps (ASHP)

The primary factor to consider when selecting an ASHP is the flow temperature required, however, when using an ASHP in a cascade system, the flow temperature will typically be relatively low (>25ºC <45ºC) offering a wide selection of available units so other factors can be considered to base the selection upon.



Another important factor is matching the ASHP capacity to the WSHP source energy requirements - often, an inverter driven variable capacity unit can better match its capacity to the WSHP and provide higher efficiency.



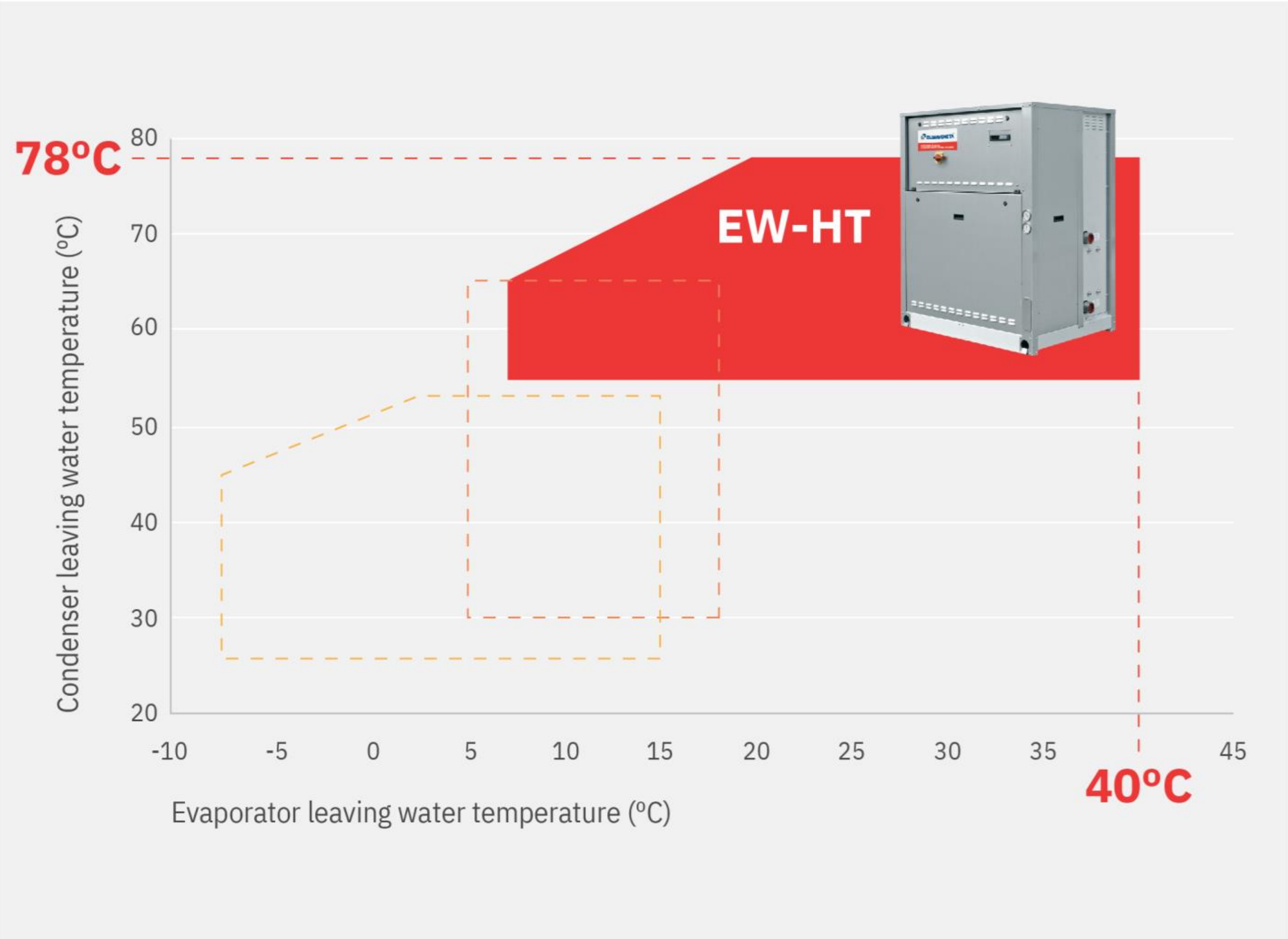
ASHP required capacity is calculated by deducting the WSHP input power (kW) from the WSHP heat output capacity (kW).

The efficiency of the ASHP should be calculated considering the seasonal efficiency at the required flow temperature.

Selecting Water Source Heat Pumps (WSHP)

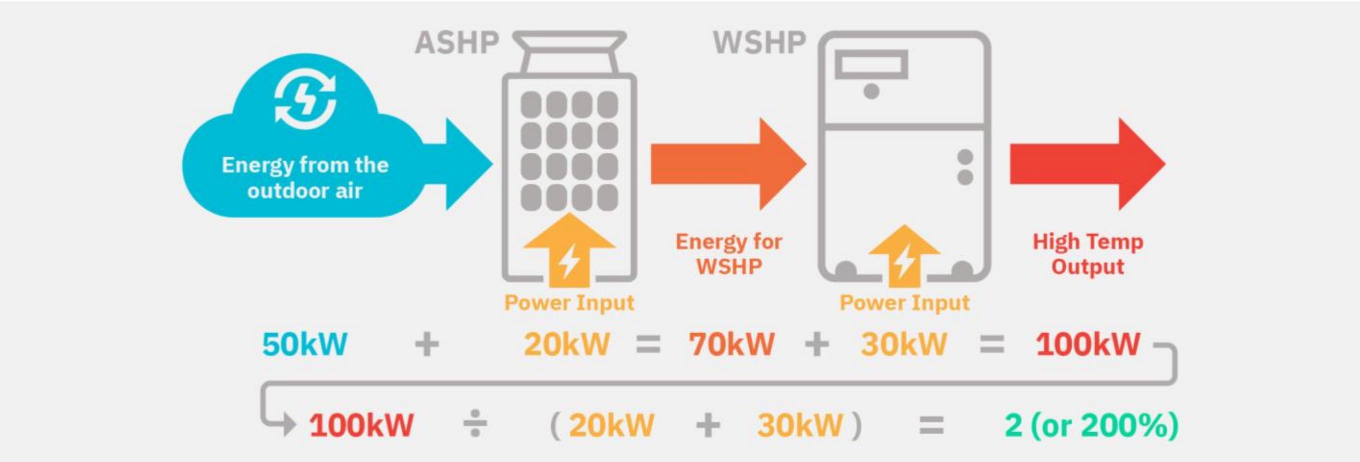
The main consideration when selecting the WSHP is also the required water flow temperature although ensuring the source water temperature being provided by the ASHP falls within the available operational window is also necessary.

The efficiency and capacity of the WSHP are both directly affected by both the flow temperature being provided into the building and the source temperature being provided by the ASHP - optimising these temperatures will ensure the best combination of cost and efficiency.



Calculating Cascade System Efficiency

The overall efficiency of a cascade arrangement of ASHP + WSHP is estimated by adding the predicted power input of the ASHP to the power input of the WSHP and then dividing the high temperature heat output of the combined system by this figure.



When calculating the efficiency of any heat pump system it is **important** to consider the efficiency over an entire period of operation rather than concentrating on a specific moment of operation -this is referred to as the “seasonal efficiency”.

In order to calculate the seasonal efficiency of the ASHP, assumptions must be made on what possible external ambient temperatures the unit may experience, how long it will spend at each of these temperatures, the temperature of water it is providing to the WSHP and also allow for any variations such as defrost operation and part load conditions.

For the purposes of this document, we have assumed 2 scenarios:

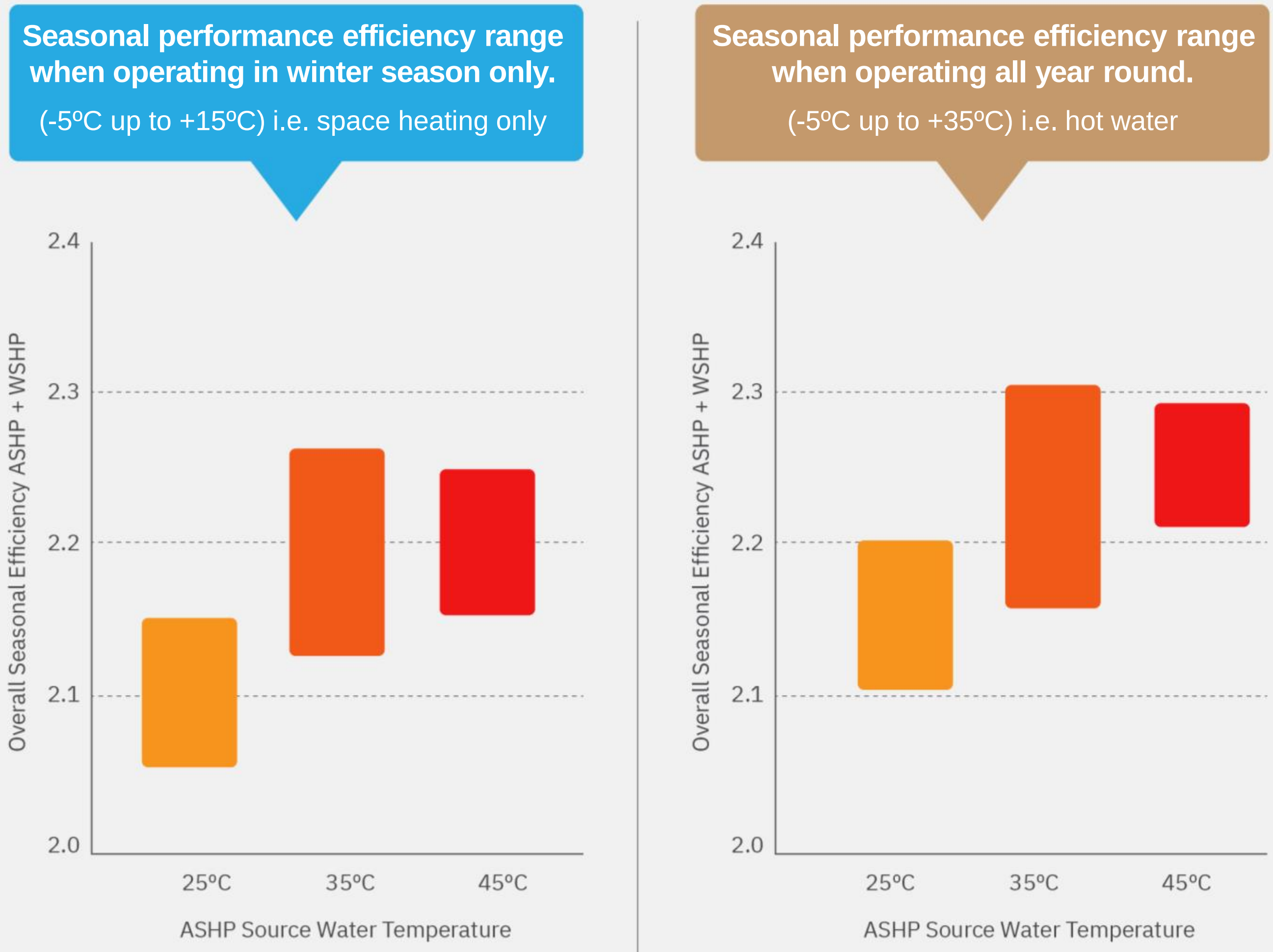
- The cascade system will operate all year-round with the ASHP experiencing temperatures from -5ºC up to +35ºC.
- The cascade system will operate only during the winter season with the ASHP only experiencing temperatures from -5ºC up to +15ºC.

The efficiency of the WSHP has been calculated assuming a fixed building load and a fixed water flow temperature as well as a fixed source water temperature being provided by the ASHP.
The above seasonal efficiency calculation was carried out for multiple combinations of ASHP and WSHP in various capacity sizes to provide generalised data.

Design Guidance

ASHP + WSHP (75ºC) - small modular

The charts below show the potential range of overall system performances when combining different ASHP model ranges with the same WSHP model range to provide **75ºC high temperature water** into a building. This data includes for different seasonal ambient temperature profiles against a fixed building load as outlined on page 11.



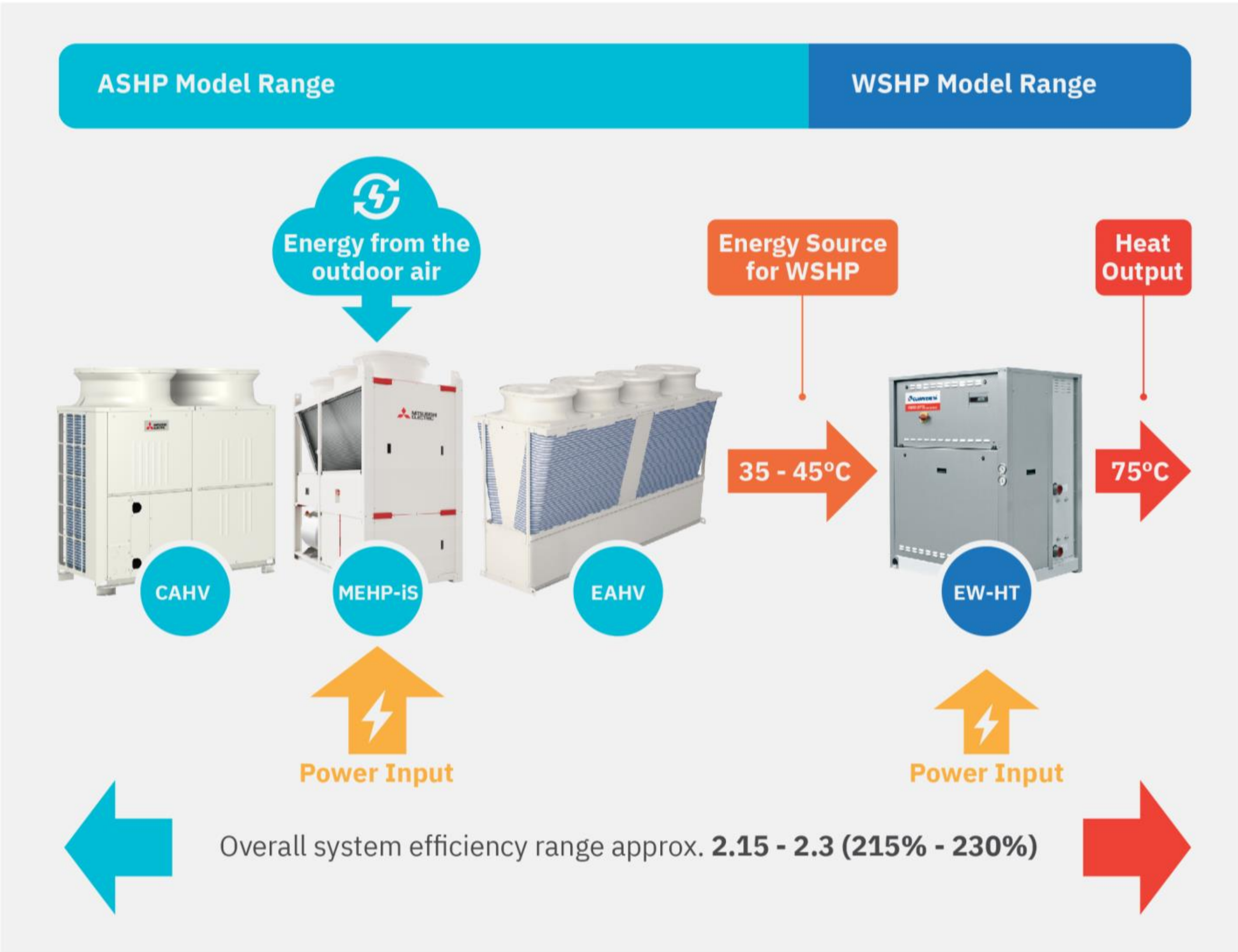
Example comparing 5 different model ranges of ASHP in combination with WSHP to provide 75ºC high temp water.

Design Guidance

ASHP + WSHP (75ºC) - small modular

In this capacity range, the highest efficiency combination of ASHP + WSHP for all year-round operation and winter only operation utilizes one of our modular ASHP units (EAHV, CAHV or MEHP-iS) in combination with our EW-HT high temperature WSHP.

The best balance of temperature from the ASHP to be provided to the WSHP to maintain both capacity and efficiency of the cascade system is 35 - 45ºC depending upon the specific combination.

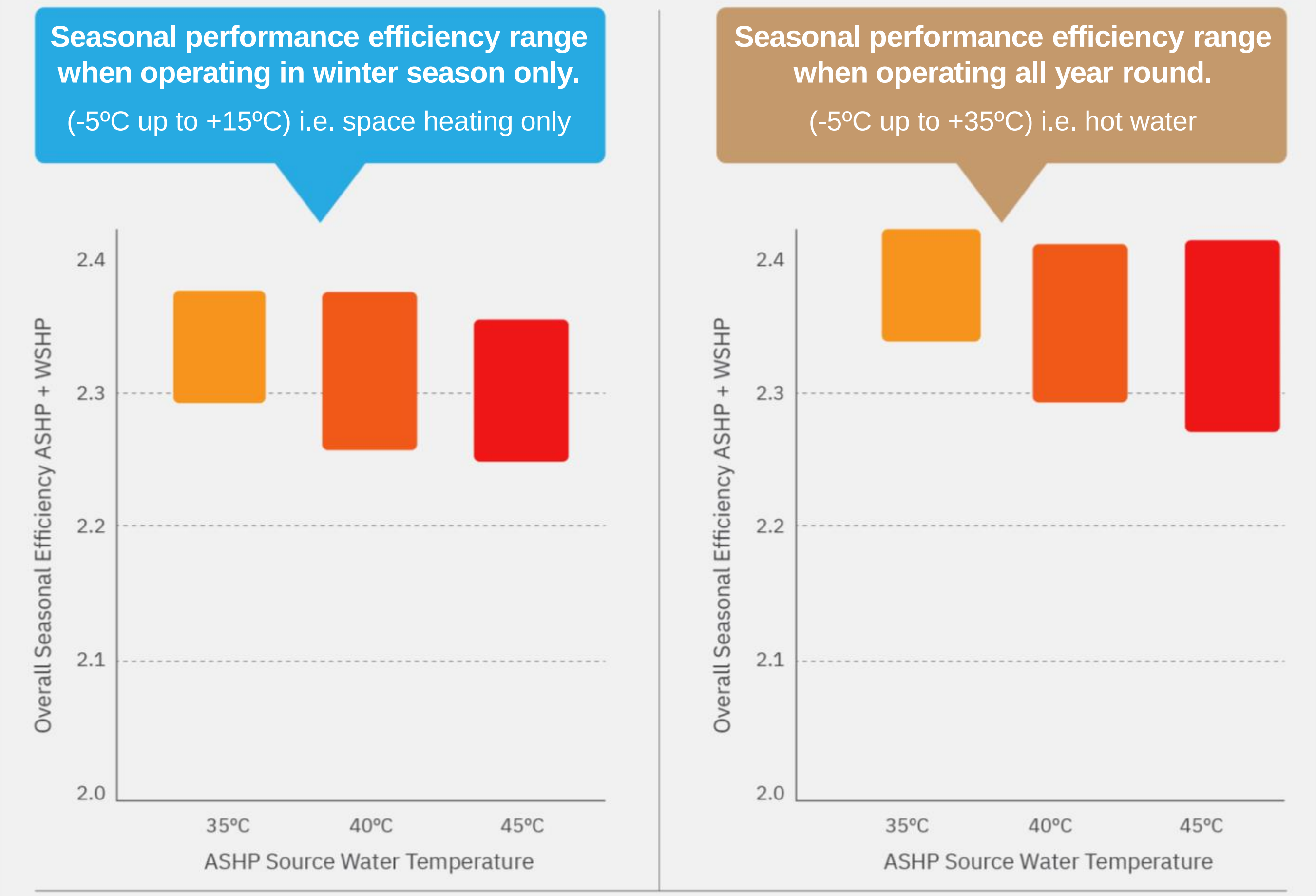


Design Guidance

ASHP + WSHP (80ºC) - bespoke large capacity

The charts below show the potential range of overall system performances when combining different ASHP model ranges with the same WSHP model range to provide **80ºC high temperature water** into a building. This data includes for different seasonal ambient temperature profiles against a fixed building load as outlined on page 11.

Note: The WSHP product is bespoke, designed and built to order based upon your requirements.



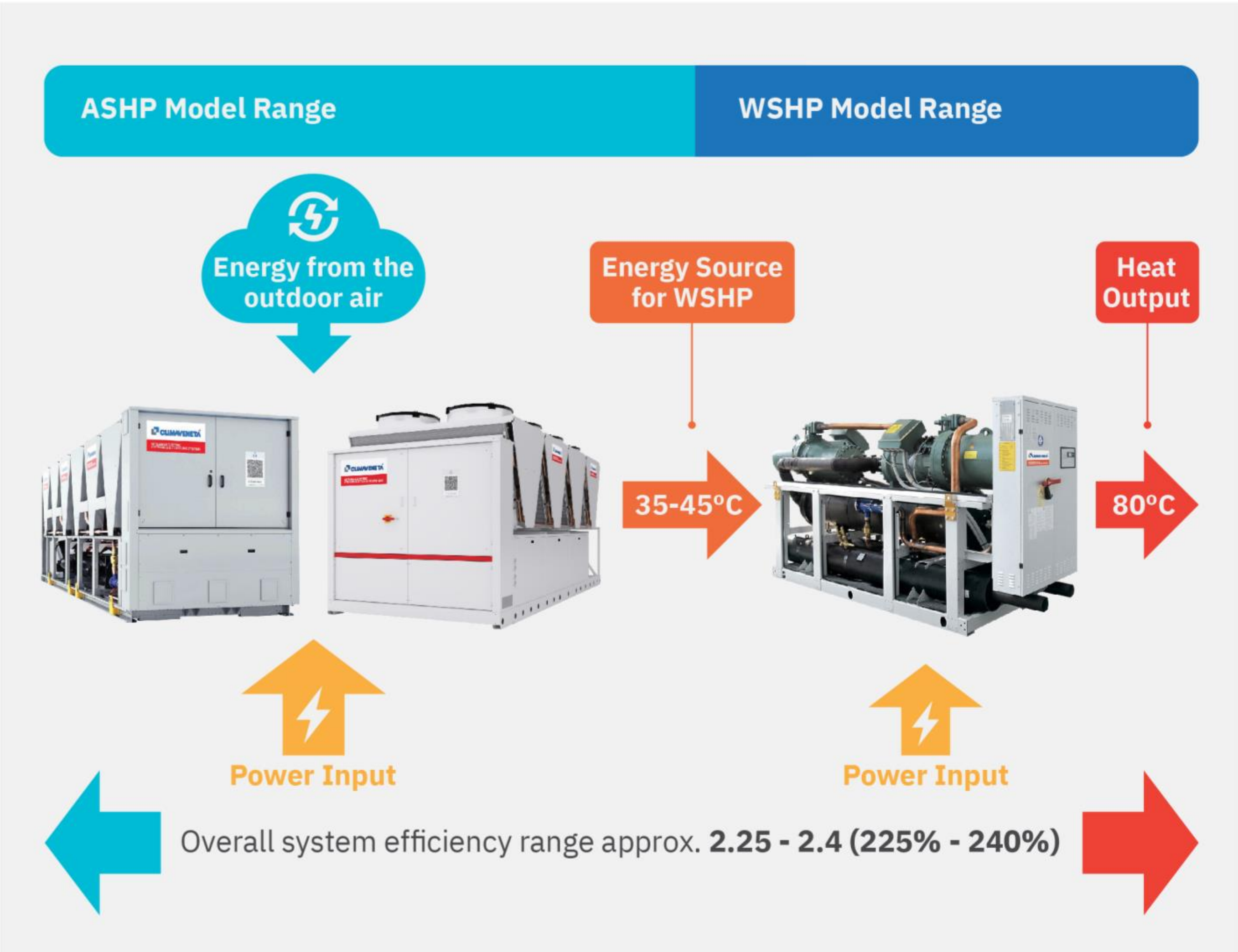
Example comparing 5 different model ranges of ASHP in combination with WSHP to provide 80ºC high temp water.

Design Guidance

ASHP + WSHP (80ºC) - bespoke large capacity

In this capacity range the highest efficiency combination of ASHP + WSHP uses our i-FX-N-G05 or NX2-N-G06 ASHP in combination with our bespoke high temperature WSHP.

ASHP flow temp has less influence on overall efficiency at this capacity range, therefore ASHP flow temp can be adjusted to vary WSHP capacity to best match the building load.



Further Information

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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).

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