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Catalogue of Heat Pump Delivery Models

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Executive Summary

This document provides a concise overview of potential solutions for technical energy delivery models for buildings that utilise heat pumps. In this catalogue, an energy delivery model is composed of four constituent parts, which must be given thorough consideration. For each constituent part, a technical solution must be selected. The composition is regarded as modular, i.e. in principle, every technical solution can be combined with each other. The following table provides an overview of the four constituent parts.

Table 1: Overview of all components of the energy delivery model

Heat Sources and Sinks	Centralised Distribution	Heat Release	Domestic Hot Water
Air - A	No Distribution - N	Radiators - R	Combined with main Heat Pump - Com
Ground - G	Risers in Shafts or Staircases – S	Convactor Heaters - Con	Separate Heat Pump - Sep
Water - W	Risers on Facades – F	Floor Heating - Flo	Direct Electrical - DE
Waste Heat - WH	Risers in Individual Chimney(s) – IC	Ceiling Heating - Cei	Combined with District Heating - DH
Local Anergy Grid - AG	Risers in Joint Chimney(s) - JC	Wall Heating (Internal) - WaH	
Solar - So		Facade Heating (External) - Fac	
Others - O			

In practice, it is notable that not every combination is feasible. Consequently, four decision trees (one per group) are provided to facilitate the reader's preliminary decision-making process. The reader is then able to obtain crucial preliminary information from the catalogue, according to their selection, and develop a fundamental understanding of the solutions and reasonable combinations. All solutions described within this catalogue are therefore concise and comprise only a few pages yet include the most essential information necessary for decision-making. This description encompasses the relevant climatic requirements for implementation, the necessary components, performance aspects and a listing of the pros and cons of the solution.

List of Abbreviations

A	Air
AG	Local Anergy Grid
Cei	Ceiling Heating
Com	Combined with main Heat Pump
Con	Convactor heaters
DE	Direct Electrical
DH	Combined with District Heating
F	Risers on Facades
Fac	Facade Heating (external)
Flo	Floor Heating
G	Ground
IC	Risers in Individual Chimney(s)
JC	Risers in Joint Chimney(s)
N	No Distribution
O	Other Heat Sources and Sinks
R	Radiators
S	Risers in Shafts or Staircases
So	Solar
Sep	Separate Heat Pump
W	Water
WaH	Wall Heating (internal)
WH	Waste Heat

1 | How the Matrix Works

The purpose of this document is to provide a concise overview of potential solutions for technical energy delivery models for buildings that utilise heat pumps. Given that systems based on heat pumps require more planning and technical fine-tuning than traditional fossil fuel systems, a comprehensive approach has been adopted.

An energy delivery model is composed of four constituent parts, which must be given thorough consideration:

- The heat source and sink in combination with the heat pump
- The heat distribution system
- The heat release system
- The domestic hot water system

Each part of the energy delivery model offers a number of possible options, meaning that there are numerous combinations possible. In order to accommodate all possible combinations and solutions, it was decided to introduce a code system. Each energy delivery model can be identified by a unique code consisting of four abbreviations. For example, the code “G-S-R-Com” describes an energy delivery model that consists of a ground heat pump (G), risers in the shaft/staircase (S), heat release in the residential units using radiators (R) and domestic hot water combined with the main heat pump (Com). The list of all abbreviations can be found in the beginning of the catalogue (List of Abbreviations) and in the headline of the corresponding chapter.

The information provided in this catalogue will enable the reader to develop a bespoke solution that is tailored to their specific situation. To assist the reader in identifying the most suitable solution, four decision trees have been developed. Each decision tree is for one part of the energy delivery model, and they have been designed to guide the reader towards the best solution. The decision trees can be found in Annex I– Decision Trees and before the corresponding part of the delivery model in this catalogue. In order to provide the reader with a solid understanding of the energy delivery model, each potential part is described in this catalogue.

In Chapter 2 |, the most relevant heat sources and sinks that can be used in combination with heat pumps are presented. In Chapter 3 | the most relevant heat pumps, utilizing the heat sources and sinks presented in the section before, are presented. In this chapter the (climatic) requirements, the components, the performance, and the pros and cons are addressed. The combination of these two is summarized in the first abbreviation of the energy delivery model code.

In Chapter 4 |, all energy distribution types in residential buildings are presented. In this chapter the (climatic) requirements, the components, the performance, and the pros and cons are addressed. The second abbreviation of the energy delivery model code indicates the used heat distribution system.

In Chapter 5 |, the most relevant heat release types in residential buildings are presented. In this chapter the (climatic) requirements, the components, the performance, and the pros and cons are addressed. The third abbreviation of the energy delivery model code indicates the used heat release system.

In Chapter 6 |, the most relevant solutions for domestic hot water preparation in residential buildings are presented. In this chapter the (climatic) requirements, the components, the performance, and the pros and cons are addressed. The fourth abbreviation of the energy delivery model code indicates the used domestic hot water system.

Finally, the catalogue presents recommendations and use cases for the most common energy delivery models for different building types in Chapter 7 |.

Heat Sources and Sinks

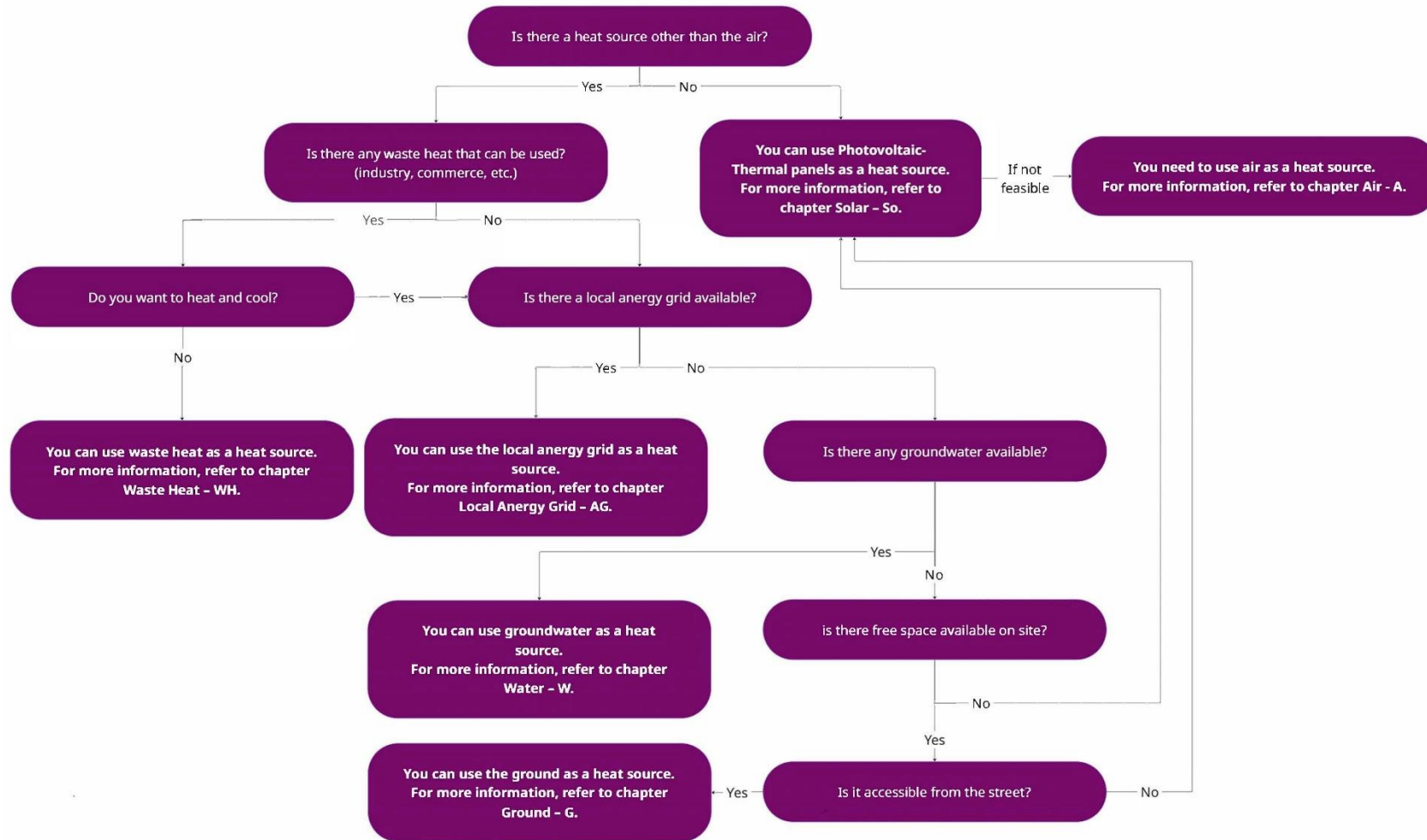


Figure 1: Decision tree of heat sources and sinks (Source: IBR&I, created with Miro (www.miro.com))

2 | Heat Sources and Sinks

Heat sources are media that supply heat to a building during the heating phase, while heat sinks are the same media that can absorb excess heat during cooling operation. These heat sources and sinks can include ambient air, nearby water, the ground, local energy grids, or others. The following sections cover the most relevant heat sources and sinks that are typically used in combination with heat pumps.

2.1 Air - A

Air-based heat pumps work by extracting thermal energy from the ambient air when powered by electricity, making them useful as both a heat source and a heat sink. One of the key benefits of using air as a medium is that it's universally accessible, which means air-based heat pumps can be installed almost anywhere. Additionally, they are currently the most affordable heat pump technology on the market.

However, one major drawback is their reduced efficiency in colder climates. As the temperature outside drops, the system has to work harder to extract heat, leading to lower performance compared to ground- or water-based systems.

A distinct feature of air-based heat pumps is the need for an outdoor unit, which can be challenging to place, especially in urban areas. Noise emissions from the unit might require sound mitigation measures, like sound insulation bonnets or rooftop installations. Besides, local regulations may apply, depending on noise levels, the visual impact on the surroundings, and the type of refrigerant used. In some situations, obtaining a permit from local authorities might also be necessary.

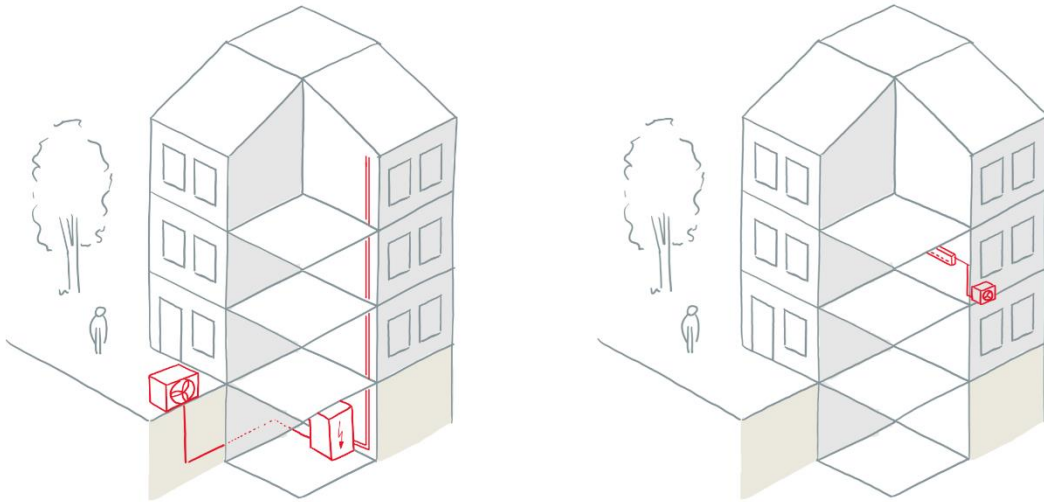


Figure 2: Exemplary configurations of air-based heat pumps (Source: IBR&I)

2.2 Ground – G

Ground-based heat pumps take advantage of the stable temperature of the earth to provide heating and cooling. These systems usually feature a closed-loop setup where heat is transferred to or from the ground using underground pipes. Because the ground temperature remains relatively constant throughout the year, this method offers reliable and efficient thermal energy, making it a solid choice for heat pump systems.

One of the main benefits of ground-based heat pumps is their high efficiency, as they are less impacted by outdoor temperature changes compared to air-based systems.

This results in consistent performance all year round. Moreover, they tend to have a longer lifespan since fewer mechanical parts are exposed to environmental factors, keeping maintenance needs relatively low.

On the downside, the initial installation costs are quite high due to the excavation or drilling required to install the piping system. Ground-based heat pumps also need a considerable amount of space, especially for horizontal systems, which might not be feasible on smaller properties.

Additionally, extracting too much heat from the ground can lead to significant temperature drops, reducing efficiency and potentially affecting the surrounding environment. Therefore, it's crucial to thoroughly assess local geological conditions and plan accordingly to maintain sustainable operation.

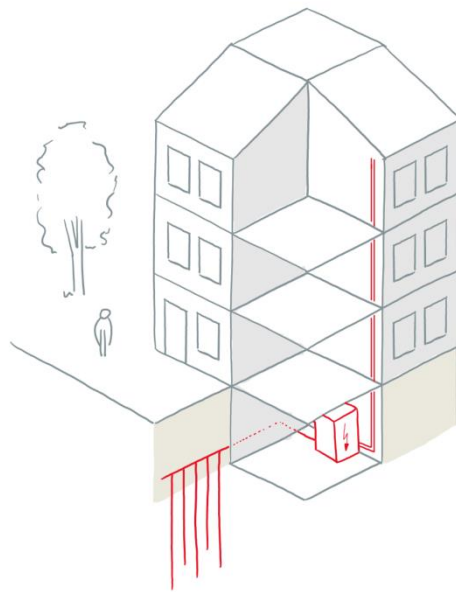


Figure 3: Exemplary configuration of a ground-based heat pump (Source: IBR&I)

2.3 Water – W

Water, specifically groundwater or well water, can serve as an effective heat source for heat pump systems, providing a viable alternative to ground-based or air-based systems. A water-based heat pump extracts heat from groundwater or surface water (e.g., lakes, rivers, or ponds) through a heat exchanger. This method is highly efficient because water temperatures remain more stable compared to air, offering a reliable and renewable energy source for heating and cooling.

For heating, the heat pump extracts heat from the water to warm the building. For cooling, the heat pump removes heat from the building and releases it into the water source. Cooling is only effective if the water source can absorb the excess heat without significantly raising its own temperature.

Water-based heat pumps offer high efficiency due to the stable temperature of water, leading to lower energy consumption and operational costs compared to air-based systems. However, these systems are dependent on the availability and temperature stability of the water source. The primary disadvantage is the requirement for a nearby, reliable water source. Additionally, the installation can be complex and costly due to the need for water source access and possible regulatory considerations.

Groundwater availability can also be affected by seasonal variations and changes in local rainfall patterns. In areas with low rainfall, the water supply might be limited, requiring careful assessment during system design to ensure the groundwater resource remains viable year-round.

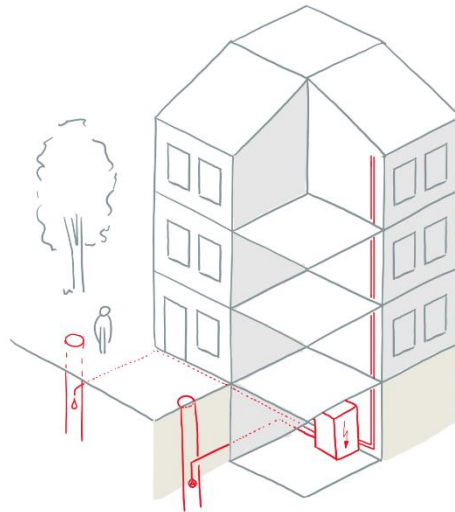


Figure 4: Exemplary configuration of a water-based heat pump (Source: IBR&I)

2.4 Waste Heat – WH

Waste heat is thermal energy generated as a byproduct of industrial or commercial processes that typically gets lost to the environment. Instead of allowing this energy to dissipate, it can be recovered and reused, significantly improving energy efficiency and reducing operational costs.

However, a major challenge with waste heat is that it often comes at relatively low temperatures, which limits its direct reuse. Heat pumps can step in by upgrading this low-grade heat to a more usable temperature. This way, waste heat can be integrated into industrial processes, building heating systems, or even district heating networks, as long as the economic and logistical conditions make sense.

Waste heat can come from various sources, like manufacturing processes, power generation, wastewater treatment, or air conditioning systems. Yet, contamination from dust, oil, or chemicals can be an issue, so proper filtration and material choices are essential to maintain efficiency and ensure longevity.

Despite these hurdles, utilizing waste heat can be highly beneficial since the energy itself is essentially free, apart from the costs of capturing and transferring it. This makes it a valuable strategy for improving energy efficiency, particularly when the heat source is consistent and predictable.

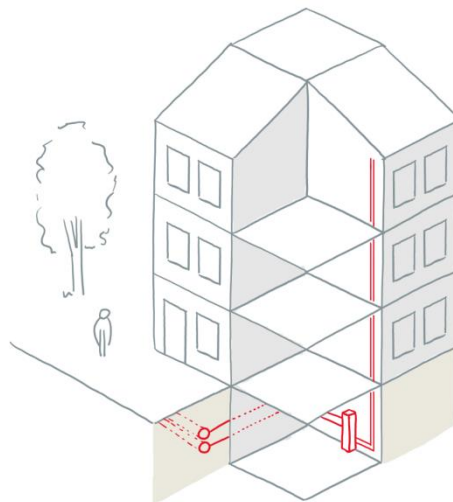


Figure 5: Exemplary configuration of a heat pump connected to a waste heat district heating network (Source: IBR&I)

2.5 Local Energy Grid – AG

Energy grids are designed to distribute low-temperature heat over long distances, allowing for efficient use of heat from various sources like waste heat, cooling processes, wastewater, or industrial activities. These grids operate with temperatures typically ranging from 8°C to 20°C, making them more cost-effective by reducing heat losses compared to traditional high-temperature systems. The low-temperature heat is often delivered via heat pumps, which elevate the temperature for individual buildings or systems.

In an energy grid, users can be "prosumers," meaning they both consume and produce heat. For example, in summer, cooling systems can contribute excess heat back to the grid, which can then be stored or redistributed. This bidirectional capability allows the system to flexibly handle both heating and cooling needs year-round. The system's low-temperature nature also makes it suitable for integrating renewable sources like solar thermal, industrial waste heat, or geothermal energy.

The infrastructure for an energy grid involves a network of pipes, and while the initial investment can be high, it is typically more cost-effective in new developments where space and uniform heating demand are more predictable. In older urban areas, retrofitting such systems can be challenging due to space limitations and high installation costs.

Heat storage, such as geothermal boreholes or water basins, is critical for balancing the heat supply and demand over time. The system's efficiency depends on maintaining a stable heat balance between heating and cooling needs, preventing temperature fluctuations that could hinder performance.

Energy grids offer an efficient and flexible solution for areas with both heating and cooling needs, but their success depends on careful planning, especially regarding heat storage and the integration of multiple low-temperature heat sources.

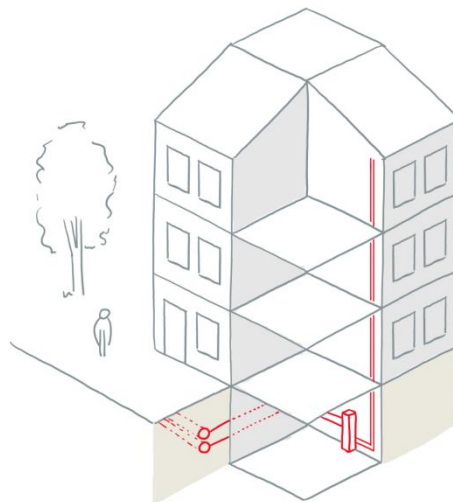


Figure 6: Exemplary configuration of a heat pump connected to a local energy grid (Source: IBR&I)

2.6 Solar – So

Photovoltaic-Thermal (PVT) or solar-based heat pumps combine the principles of air-based heat pumps with integrated solar energy generation, offering a highly efficient and self-sustaining solution for heating and cooling. Unlike conventional air-based heat pumps that rely solely on ambient air as a heat source and sink, solar-based heat pumps incorporate photovoltaic-thermal panels that generate both electricity and thermal energy.

The system operates by extracting heat from the surrounding air, similar to a standard air-based heat pump, but with the added benefit of preheating the refrigerant circuit using the thermal energy collected from the PVT panels. This improves efficiency, especially in cold climates where standard air-based heat pumps typically experience performance losses. Simultaneously, the photovoltaic cells within the PVT panels generate electricity, which can be used to power the heat pump itself, further lowering operational costs. An additional advantage of this systems is that the heat extracted from the panels helps maintain optimal photovoltaic performance by preventing the cells from overheating, a factor that can otherwise reduce their electrical output.

Despite their high efficiency, solar-based heat pumps are subject to certain limitations. Their effectiveness depends on solar radiation, meaning performance may fluctuate in regions with prolonged periods of low sunlight. Furthermore, installation complexity and initial costs tend to be higher than those of conventional air-based heat pumps due to the need for both solar integration and an optimized heat exchange mechanism.

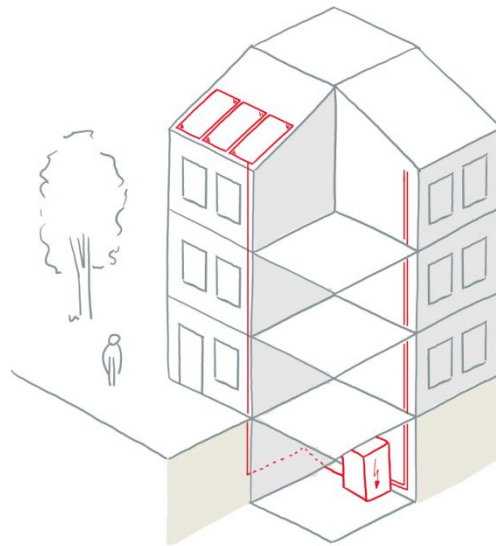


Figure 7: Exemplary configuration of an air-based heat pump with integrated solar energy generation (Source: IBR&I)

2.7 Others – 0

In addition to the above-mentioned heat sources and sinks that can provide all the energy required, this subchapter presents two further heat sources and sinks that can serve a supplementary role to the aforementioned systems.

Asphalt Collectors

Asphalt collectors, or thermally active road surfaces, are an innovative method for capturing solar heat from road infrastructure. By embedding heat-absorbing pipes or panels within asphalt, these collectors efficiently absorb and store solar energy during the day. The heat captured in the pavement is then transferred to a fluid circulating through the system. This fluid can be used as a heat source for heat pumps. The most common applications of asphalt collectors are in urban areas, highways, and large parking lots where roads are consistently exposed to sunlight. These systems serve as a supplementary energy source, providing heating and cooling solutions for surrounding buildings and infrastructure. However, proper design and integration are essential for ensuring optimal performance and durability.

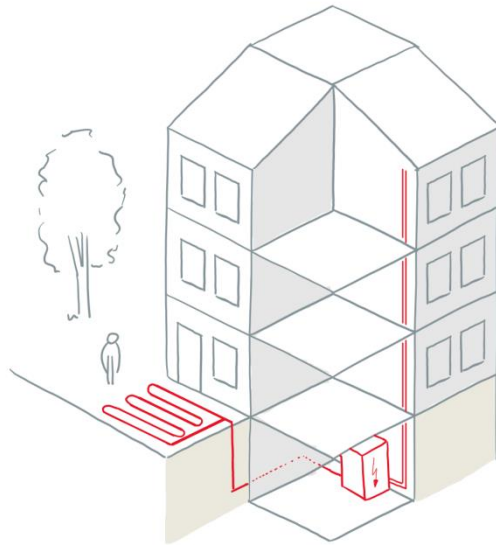


Figure 8: Exemplary configuration of a heat pump connected to asphalt collectors (Source: IBR&I)

Micro Combined Heat and Power (Micro-CHP)

Micro-CHP systems, including micro turbines, are designed to generate both heat and electricity simultaneously, making them ideal for small buildings or private homes. By utilizing the heat that would otherwise be wasted in traditional electricity generation, these systems achieve very high efficiency.

One of the key advantages of micro-CHP systems is their compact size, which allows them to be easily integrated into existing heating systems. This makes them a convenient and effective solution for homeowners seeking to improve energy efficiency while also reducing their reliance on external power sources.

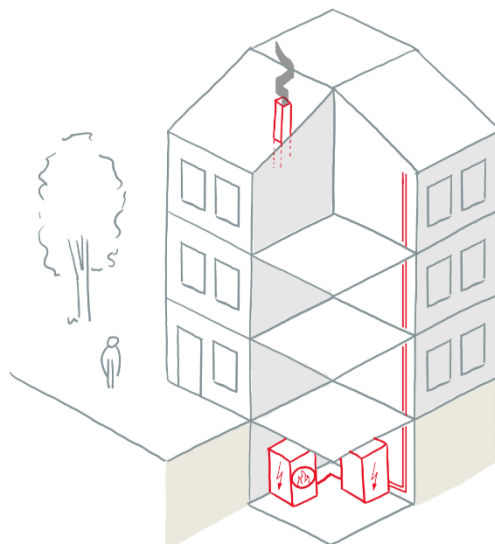


Figure 9: Exemplary configuration of a heat pump connected to a micro combined heat and power system (Source: IBR&I)

3 | Heat Pump Unit

A heat pump offers an efficient, cost-effective, and environmentally friendly solution for heating buildings and supplying hot water. Unlike traditional heating systems, it does not rely on combustion; rather, it uses a refrigerant to absorb thermal energy from surrounding heat sources and raise its temperature with the help of electricity. Even in environments where temperatures are low, there is sufficient ambient heat for the system to operate. Additionally, many heat pumps can also provide energy-efficient and eco-friendly cooling during the summer months. The following section presents the most relevant heat pumps, based on the heat sources and sinks presented in the section above. Please note that the combination of heat sink/source and heat pump is summarised in the first abbreviation of the energy delivery model code. Consequently, the heat pump itself does not have an abbreviation of the energy delivery model code.

3.1 Air-to-Air Heat Pump

3.1.1 (Climatic) Requirements

Air-to-air heat pumps are best suited to moderate climates where ambient temperatures rarely fall far below freezing. Modern systems can maintain full heating performance down to around $-15\text{ }^{\circ}\text{C}$; below this range (typically between $-15\text{ }^{\circ}\text{C}$ and $-25\text{ }^{\circ}\text{C}$) an auxiliary heater is required to sustain warmth. In damp climates, care must be taken since ice may form on the outdoor heat exchanger when ambient temperatures drop below approximately $5\text{ }^{\circ}\text{C}$. Air-to-air heat pumps are typically installed with the outdoor unit positioned on an external wall, roof, or on a dedicated ground stand in a location that provides ample airflow and protection from harsh weather. Locating the outdoor unit in a sheltered or sunny area can help reduce freezing effects. Indoors, the slim, wall-mounted air handling units are usually installed in individual rooms to deliver conditioned air directly, making them suitable for retrofit applications in European-style dwellings where ducted systems are less common.

3.1.2 Components

An air-to-air heat pump system typically consists of:

Outdoor Unit. A compressor, evaporator coil, and fan housed in a box that is generally installed on an external wall or roof. These units operate at noise levels of 40–60 dB, depending on the chosen model, which is similar to the noise level of a quiet library sound or moderate rainfall. If multiple loud heat pumps are installed on the same external wall of a building near windows, however, unpleasant noise levels may be expected.

Indoor Unit(s). An air handling unit/system (wall-mounted unit, floor mounted unit, ceiling cassette or air ducts) that directly heats the inside space. These units are relatively unobtrusive and quiet (operating at approximately 21–40 dB) and are typically controlled by a room thermostat or remote control. They circulate the internal air of the heated room, extracting heat from the refrigerant and releasing it to heat the area.

There are different layouts for air-to-air heat pumps, among which most common are:

Mono-Split System. A mono-split system consists of one outdoor unit connected to a single indoor unit. This layout is suitable for applications in single rooms or small spaces. The installation process is simple, and the system is relatively low in cost, making it an attractive option for small-scale heating and cooling needs.

Multi-Split System. In a multi-split system, one outdoor unit is connected to multiple indoor units. This configuration allows for the heating or cooling of multiple rooms independently, offering some flexibility and control. However, the system provides limited control compared to more advanced setups. Installation is more complex than the mono-split system, as it requires refrigerant piping to each indoor unit.

VRF/VRV System (Variable Refrigerant Flow/Variable Refrigerant Volume). The VRF/VRV system is an advanced multi-split system that modulates the flow of refrigerant to multiple indoor units. This system is highly efficient, making it ideal for commercial buildings and larger homes. It offers the ability to zone different areas and precisely control temperatures, providing more granular control compared to traditional multi-split systems.

Ducted System. The ducted system features a centralized indoor unit that is connected to air ducts, which then distribute conditioned air throughout the building. This system is particularly suited for commercial buildings or whole-house heating and cooling applications. However, it requires space for the ductwork, which limits its applicability in European-style buildings where ducted systems are less common.

Ceiling Cassette/Concealed Ceiling System. In this layout, the indoor units are installed in the ceiling, distributing air through vents. This type of system is aesthetically unobtrusive, making it a good fit for new homes or commercial spaces. However, it requires ceiling space and is generally more complex to install compared to other systems.

Depending on the local regulation, permits may be required for installing the outside unit on the external walls of the building as this affects architectural appearance of the building.

3.1.3 Performance

Air-to-air heat pumps are classed as reversible air conditioning units, providing both heating and cooling. Their efficiency is commonly measured by the coefficient of performance (COP) and the seasonal performance factor (SPF), typically ranging from 2.0 to 4.0. Performance is affected by external temperatures—the output declines as the ambient temperature drops, and defrost cycles are regularly initiated to clear ice buildup on the outdoor coil. The operational expenses of air-to-air heat pumps depend on their COP and the electricity costs. In general they are cheaper to operate than gas, if electricity is at maximum twice the price of natural gas. Air-to-air heat pumps, however, are the least efficient type of heat pump.

3.1.4 Pros and Cons

Pros

- **Dual Operation.** Provides both heating and cooling with a single system.
- **High Efficiency.** Higher efficiency than resistive heating and gas boilers, with high COP under favourable conditions, reducing energy consumption and associated emissions.
- **Price.** Air-to-air heat pumps are among the cheapest heat pump type on the market.
- **Ease of Installation (for small areas).** Air-to-air heat pump require are simple to install and require little space, making them suitable for apartments and small houses (up to 120 m²) without the need for ductwork.

Cons

- **Temperature Limitations.** Efficiency declines in extreme cold; defrost cycles and auxiliary heating may be needed, potentially interrupting comfort.
- **Noise Considerations.** While indoor units are quiet, the outdoor units may produce higher noise levels, and placement must be managed to minimize disturbance.
- **Installation and Regulatory Barriers.** Local planning, aesthetic, and noise regulations can complicate installation, particularly when positioning the outdoor unit.
- **Retrofit Challenges.** Existing buildings may require additional modifications—such as improved insulation or electrical service upgrades—to maximize system performance.

3.2 Air-to-Water Heat Pump

3.2.1 (Climatic) Requirements

Air-to-water heat pumps extract heat from the outdoor air in much the same way as air-to-air systems. They are best suited to moderate climates where ambient temperatures rarely drop too far below freezing. Modern units can deliver full heating performance down to around -15°C ; below this range (typically between -15°C and -25°C), auxiliary heating is needed to maintain the desired water temperature. As with other air-source technologies, proper placement of the outdoor unit is critical—installing it on an external wall, roof, or dedicated ground stand in a sheltered or sunny location helps reduce frost and defrost cycle frequency. These systems are especially popular in areas where water-based central heating is common, and they perform best when integrated with a well-insulated building that supports a hydronic distribution network.

3.2.2 Components

An air-to-water heat pump system typically includes the following key elements:

Outdoor Unit. Like its air-to-air counterpart, the outdoor unit contains a compressor, evaporator coil, and fan to extract heat from the ambient air. In split systems, this unit works in tandem with a separate indoor hydronic module; monobloc (or monobloc) systems integrate these components into a slightly larger outdoor unit.

Indoor Hydronic Module. The indoor component consists of a compact heat exchanger and control unit that is installed adjacent to a buffer tank or hot water cylinder. Here, heat from the refrigerant is transferred to water, which then circulates through the home's central heating system.

Distribution System and Heat Release. Heated water is distributed via water-based systems and released via radiators, underfloor heating, ceiling heating, or wall-mounted panels. More details are provided in Chapter 4 |and Chapter 5 |In addition, a hot water storage tank can provide domestic hot water for taps, showers, and other uses.

Ancillary Equipment. Items such as a buffer vessel, expansion tank, and associated controls help regulate the system and ensure efficient, stable operation.

3.2.3 Performance

Air-to-water heat pumps are evaluated primarily by their coefficient of performance (COP) and seasonal performance factor (SPF), with typical values ranging from 2.0 to 4.0. By heating water rather than air directly, these systems can supply higher temperature outputs, which is beneficial for both space heating and domestic hot water. Performance is affected by ambient temperature; as external conditions become colder, the unit's output decreases and defrost cycles are required to clear frost from the outdoor coil. However, operating at higher temperatures (e.g. for domestic hot water preparation) may negatively affect the COP of the heat pump. When paired with an effective hydronic distribution system and a well-insulated building envelope, air-to-water heat pumps offer lower operational costs compared to traditional fossil-fuel boilers.

3.2.4 Pros and Cons

Pros

- **Integrated Hydronic Heating.** Suitable for properties with existing water-based central heating systems. Air-to-water systems can directly replace gas or oil boilers, often without the need to replace the entire distribution network.
- **Dual Functionality.** Capable of providing both whole-house space heating and domestic hot water.
- **Suitability for Retrofits.** Particularly useful for upgrading old heating systems in buildings that already possess a hydronic network. Retrofitting can be more straightforward when existing pipes, radiators, or underfloor systems are retained.
- **Quiet Indoor Operation.** Indoor hydronic modules and associated components are typically installed in a mechanical room or utility space, keeping noise levels low in living areas.

Cons

- **Higher Initial Costs.** Installation tends to be more expensive than for air-to-air systems due to the need for a water-based distribution network, additional plumbing, and potentially a buffer tank or hot water cylinder.
- **Installation Complexity.** Retrofitting older buildings may require modifications such as upgrading radiators or installing underfloor heating, along with ensuring the hydronic circuit is compatible with the lower water temperatures provided by the heat pump.
- **Climatic Sensitivity.** Although effective in moderate climates, performance declines in very cold conditions necessitate defrost cycles and auxiliary heating.
- **Space Requirements for Mechanical Equipment.** The indoor module and additional components (buffer vessels, control units) require dedicated space, which can be challenging in some retrofits.
- **Regulatory Barriers.** As with air-to-air systems, local planning and aesthetic regulations may affect the placement of the outdoor unit, particularly if it is installed on an external wall.

3.3 Brine-to-Water Heat Pump

3.3.1 (Climatic) Requirements

In a brine-to-water heat pump, a solution of water and antifreeze (referred to as 'brine') circulates through a buried or submerged, closed-loop, ground heat exchanger in order to collect heat from the ground. Especially in an urban context, geothermal probes and surface collectors are a promising option for utilising the natural heat sink of the ground. Usually, these require a space of between 20 and 40 percent of the heated floor area.

The efficiency of heat pumps is directly related to the temperature of the heat source, with higher temperatures resulting in improved efficiency. The usable source temperature in the uppermost ground for surface absorbers exhibits significant seasonal fluctuations, ranging from 2 °C to 15 °C depending on the depth. In contrast, the ground temperatures expected for geothermal probes are more stable, with a range of 4 °C to 14 °C at depths of 10 meters or more.

The utilisation of geothermal probes offers significant potential due to their reduced invasiveness in comparison to surface collectors. During operation, they generate minimal noise and vibration, as they function solely as passive heat exchangers. The placement of probes on roads is a viable option, as it does not necessitate drilling through building foundations. The distance between probes must be carefully calculated, depending on the dimensions and power output of the probes in question. This is in order to prevent any potential negative impact on the individual probes' output.

It is recommended that the geothermal probes be operated in a regenerative manner in order to ensure continuous balanced operation in the long term, thereby preventing the probe from cooling or heating the ground excessively. This means that the heat extracted from the geothermal probes in winter must be returned in summer and vice versa. The ground is employed as a natural heat source during the winter months and subsequently utilised as a heat sink in the summer months, thereby additionally providing a climate-neutral cooling solution for hot months. In certain cases, the cooling of buildings in summer may not be sufficient to enable full soil regeneration. In such instances, the deployment of additional technologies, e.g. of simple solar collectors is necessary.

Operation in free cooling mode is a viable solution. The heat transfer medium can be circulated between the interior space to be cooled and the heat sink, enabling heat exchange without the use of additional refrigeration systems. This process is virtually free of charge, as only auxiliary machines, such as circulation pumps, need to be operated.

Furthermore, a geological and hydrological report must be obtained for the subsoil. Depending on the location, it may be necessary to obtain a water licence. Overall, the cost and workload of this measure is classified as high. However, if local conditions on site permit, brine-to-water heat pumps should be among the preferred solutions because of their high technical efficiency, potential high performance and good scalability. In addition, there is a strong possibility that brine-to-water heat pumps can supply local energy grids in a technical efficient way.

An innovative solution is to transport brine or energy through a centralised distribution network in the building. Pioneering enterprises have already begun to offer this service. The advantage lies in reducing distribution losses to a minimum. In this case the brine-to-water heat pump unit must be installed in each customer's home and connected to the centralised energy grid.

3.3.2 Components

A typical brine-to-water heat pump system consists of the following key elements:

Geothermal probes or ground collectors. As the ground functions as the heat source and sink, it is necessary to implement an underground heat exchange system. This can be accomplished through the use of ground collectors or geothermal probes. Ground collectors are installed at a depth of approximately 1.5 to 2 meters, while geothermal probes are typically deployed at depths of up to 100 meters. Utilizing geothermal probes ensures higher efficiency. A key benefit of these underground systems is that they do not require the installation of a visible outdoor unit.

Heat medium. Brine is the fluid that flows through geothermal probes and ground collectors, extracting heat from the earth. It is usually a mixture of water and an antifreeze, such as glycol, to prevent freezing in colder months. With its high thermal conductivity, brine enhances heat transfer between the ground and the heat pump.

Brine-to-water heat pump. The heat pump, which is usually installed in the basement or a utility room, extracts energy from the brine and uses this energy to provide heated water for the heating system. The four main components of a heat pump's refrigeration cycle are the compressor, the condenser, the expansion device and the evaporator.

Centralised distribution. In order to use the heated water, a centralised hydronic distribution system is required. Please refer to Chapter 4 | for further details.

Heat release. It is vital to ensure adequate heat release in the units. Surface heating is beneficial but not necessary.

It is possible to achieve flow temperatures of up to 65°C for domestic hot water. However, at such high temperatures, the efficiency of the brine-to-water heat pump is expected to be notably lower. Please refer to Chapters 5 | for further details on heat release and domestic hot water.

In the case of centralised brine distribution, the heat pump unit must be installed in each customer's home.

3.3.3 Performance

As with all heat pumps, efficiency is commonly measured using the coefficient of performance (COP), which measures the momentary efficiency, and the seasonal performance factor (SPF), which shows the annual performance under real conditions. Brine-to-water heat pumps in combination with surface absorbers reach a SPF of 3,5 – 4, while combined with geothermal probes reach a SPF of 4 – 4,5.

The consistent temperature of the ground, as compared to the temperature of the outside air, ensures more consistent operation and high performance.

The operational expenses are directly related to the electricity costs as well as to the SPF.

3.3.4 Pros and Cons

Pros

- **Proven and mature technology.**

- **Operational Costs.** Brine water heat pumps are highly energy efficient, which means that running costs can be significantly reduced.
- **Dual Operation.** Provides both heating and cooling with a single system.
- **Low Noise.** Brine-water heat pumps are entirely fanless, resulting in near-silent operation.
- **High Lifespan.** Ground collectors and geothermal probes are known for their durability and low maintenance requirements.

Cons

- **Invest costs.** The expense of buying and setting up a brine-to-water heat pump is higher since it requires installing geothermal probes or ground collectors.
- **Regulatory Barriers.** It may be necessary to obtain geological and hydrological reports, as well as a water licence.

3.4 Water-to-Water Heat Pump

3.4.1 (Climatic) Requirements

Water-to-water heat pumps extract heat from a stable water source, such as a groundwater well, lake, river, or aquifer. They are highly efficient in regions where such water sources maintain consistent temperatures throughout the year. Unlike air-source systems, their performance is largely unaffected by seasonal fluctuations, making them particularly suitable for colder climates where air temperatures drop significantly during winter months.

However, their installation requires access to an adequate and sustainable water supply, along with compliance with local environmental regulations. Permits may be necessary for extracting and discharging water, particularly in environmentally sensitive areas. The temperature of the water source should ideally remain within a range of 5–20°C to ensure optimal efficiency. In colder climates, freezing of intake pipes and heat exchangers must be prevented through proper insulation and antifreeze solutions.

Additionally, the quality of the water source must be assessed before installation. Proper filtration and treatment may be necessary to prevent scaling, corrosion, or biofouling in the heat exchange process. Hard water with high mineral content can cause deposits that reduce efficiency over time, requiring periodic maintenance and descaling treatments.

3.4.2 Components

A typical water-to-water heat pump system consists of the following key elements:

Water Source and Intake System. This includes wells, submerged coils, or open-loop intake pipes that draw water from a natural or man-made reservoir. The system can be configured in two main ways:

- **Open-loop systems.** Water is extracted from a well, lake, or river, passes through the heat exchanger, and is then discharged back into the environment. These systems require proper filtration and adherence to environmental discharge regulations.

- **Closed-loop systems.** A heat-transfer fluid circulates through submerged piping, absorbing heat from the surrounding water. This design minimises environmental impact and reduces maintenance but requires significant initial investment in infrastructure.

Heat Pump Unit. This contains the compressor, heat exchanger, and control systems. The refrigerant cycle extracts heat from the water source and transfers it to the building's hydronic heating system. Modern heat pump units include advanced control systems for optimising efficiency and adjusting to variable heating loads.

Distribution System and Heat Release. Heated water is distributed via water-based systems and released via radiators, underfloor heating, ceiling heating, or wall-mounted panels. More details are provided in Chapter 4 |and Chapter 5 |In addition, a hot water storage tank can provide domestic hot water for taps, showers, and other uses.

Ancillary Equipment. Items such as a buffer vessel, expansion tank, and associated controls help regulate the system and ensure efficient, stable operation.

Pumps and Filtration. Additional pumps and filters manage water circulation and protect system components from contaminants, sediment, or mineral deposits. Open-loop systems, in particular, require robust filtration to prevent clogging of pipes and the heat exchanger.

3.4.3 Performance

Water-to-water heat pumps typically achieve high coefficients of performance (COP) ranging from 3.5 to 5.5 due to the stable temperature of the water source. Their efficiency remains consistent year-round, unlike air-source alternatives, which experience seasonal variations due to fluctuating air temperatures. The efficiency of the system depends on factors such as:

- The temperature of the water source (higher temperatures improve efficiency).
- The insulation and efficiency of the heat distribution system.
- Proper maintenance and water quality management to prevent scale formation and biofouling.

Compared to air-source systems, water-to-water heat pumps operate more efficiently in extreme weather conditions, making them ideal for colder climates and applications with high heating demands.

However, their effectiveness depends on the thermal properties and availability of the water source. In regions where groundwater levels fluctuate or freeze in winter, additional design considerations, such as deeper wells or insulated intake systems, may be necessary. Maintenance is crucial, particularly for open-loop systems, which require periodic checks to prevent clogging, scaling, or environmental contamination.

These systems are ideal for larger buildings or industrial applications where high heating loads and a reliable water source are present. They are commonly used in district heating systems, commercial buildings, and residential properties with access to suitable water sources.

3.4.4 Pros and Cons

Pros

- **High Efficiency.** Achieves superior performance compared to air-source heat pumps, particularly in colder climates where air temperatures drop significantly.

- **Stable Heat Source.** Consistent water temperatures lead to predictable performance without significant seasonal drops, reducing the need for backup heating sources.
- **Versatile Applications.** Suitable for space heating, cooling, and domestic hot water production, making them highly adaptable for different building needs.
- **Low Noise Levels.** Operates quietly, as there is no outdoor fan or air movement, making them ideal for noise-sensitive environments.
- **Long Lifespan.** Properly maintained systems can last 20 years or more, providing long-term energy savings.

Cons

- **Site-Dependent Installation.** Requires an adequate and legally accessible water source, which may not be available in all locations. Permits and environmental assessments may be required.
- **Higher Initial Costs.** Installation is complex and may involve drilling boreholes, digging intake channels, or installing submerged coils, increasing upfront expenses.
- **Maintenance Requirements.** Open-loop systems require filtration and treatment to prevent mineral build-up, corrosion, or biofouling. Regular inspections and water quality monitoring are essential for maintaining efficiency.
- **Regulatory Constraints.** Subject to environmental and water-use regulations, particularly for open-loop configurations that discharge water back into the environment. Some regions may have restrictions on groundwater extraction or return flow temperatures.

Water-to-water heat pumps provide an efficient and reliable heating solution in locations with suitable water sources. They offer high efficiency, stable year-round performance, and quiet operation, making them ideal for residential, commercial, and industrial applications. However, their feasibility depends on site-specific conditions, installation costs, and regulatory compliance. Proper design, maintenance, and water management strategies are essential for ensuring long-term performance and sustainability.

3.5 Photovoltaic Thermal Heat Pumps

3.5.1 (Climatic) Requirements

Photovoltaic Thermal heat pumps make use of the heat from the outside air which is collected through the thermal part of PVT panels on the roof. Underneath the sheet that produces electricity, a radiator-like network of tubes filled with cooling agent collects heat from the air. PVT heat pump solutions can be beneficial in different contexts. One of the main advantages is that due to the prevalence of an individual heat source, the energy needs are lower than with air-sourced heat pumps. In regions where there is no option for using ground sources, or the energy grid is already being used to its limits, PVT heat pumps can offer a solution.

For a house to be suitable for a PVT heat pump there needs to be access to a surface where the PVT panels can be installed. While PVT heat pumps are able to produce heating temperatures up to 50 °C, they function best when a house can be heated with low temperature radiators or floor heating. A high level of insulation is necessary to be able to heat a house with low temperature sources. For this type of heat pump a three-phase electrical connection is required. No additional permits are required for this heat-pump, apart from the ones required for the solar panels, if relevant. As there is no noise from the outside unit, there are no negative external

consequences for the neighbourhood. A barrier for PVT heat pumps can be the initial investment, which is significantly higher than for other heat pumps.

3.5.2 Components

PVT Panels. As the air is the heat source for this heat pump, it requires an external unit. In the case of PVT these are panels, which are either integrated into a solar panel, or can be placed underneath. This makes it possible to collect energy and heat at the same time. The thermal side of the panels consists of an input, where relatively cool heating medium is put in, a network of small tubes where the heating medium is warmed up by the outside air temperature and an output. The warmed up heating agent leaves the panel either going to the next, or flowing back towards the heat pump.

These panels are either integrated into solar photovoltaic panels or placed underneath, an external unit as used with air-to-water heat pumps is therefore not required. The only aspects visible outside are the pipes leading from the roof to the panels.

Heating medium. The fluid that flows through the thermal panels on the roof is called brine, extracting heat from the outside air. Similar to ground to water heat pumps, this fluid is a mixture of water and an anti-freezing agent, such as glycol, to prevent freezing in colder months. As brine consists of a mixture of fluids with high thermal conductivity, it enhances heat transfer between the air and the heat pump.

Brine-to-water heat pump. The warmed-up heating medium that comes back from the roof is used to heat up the water for central distribution. This happens in the heat-pump unit, which consists of the heating medium circuit, delivery circuit, compressor and circulation pumps. Most PVT heat pumps also have a control system in which installers can update settings.

Centralised distribution and Heat Release. For the distribution of warm water, the heat pump makes use of a central hydronic distribution system. In most instances, a central distribution system is already in place, and the heat pump can make use of the existing network. However, PVT heat pumps make use of lower flow temperatures, meaning that the delivery system must be able to give off its heat efficiently. Low temperature radiators or floor heating is therefore advised. More details are provided in Chapter 4 | and Chapter 5 |

3.5.3 Performance

PVT brine-to-water heat pumps generally perform well when the coefficient of performance (COP) is considered, which usually lies around 5,5 for space heating and 3,5 for tap-water heating. While other types of brine-to-water heat pumps have more consistent heat sources, the PVT version relies on the outside temperature and sunshine for its heat. Therefore, efficiency goes down in winter when there is less heat that can be derived from the outside air. Heat can usually be derived from the outside air up to $-10\text{ }^{\circ}\text{C}$, after which the back-up unit is used for heat. Cooling in summer can only be done passively if the night temperature is low enough, otherwise it can only be done actively.

As for all heat pump systems, the effectiveness is dependent of the degree of insulation of the house and the maintenance of the installation. Weather is an extra factor that can lead to different performance in different cases. Especially if used in combination with good settings and a buffer tank, self-consumption of the PV production can be increased, leading to a low energy demand of the heat pump.

3.5.4 Pros and cons

Pros

- **High COP.** this mode of heating is very efficient.
- **Self-consumption.** Allows for integration of energy production and energy use.
- **Operational Costs.** Brine water heat pumps are highly energy efficient, which means that running costs can be significantly reduced.
- **Dual Operation.** Provides both heating and cooling with a single system.
- **Low Noise.** Brine-water heat pumps are entirely fanless, resulting in near-silent operation.
- **Aesthetics.** Outside unit is placed under the solar photovoltaic panels, limited impact on the home appearance.

Cons

- **Invest costs.** PVT panels and a brine-to-water heat pump are expensive. In comparison to an air-to-water heat pump the investment is way higher.
- **Space.** Enough (roof-)surface is required to set up the installation.
- **Limited passive cooling in summer.**
- **Limited number of manufacturer-options available.**

Centralised Hydronic Distribution

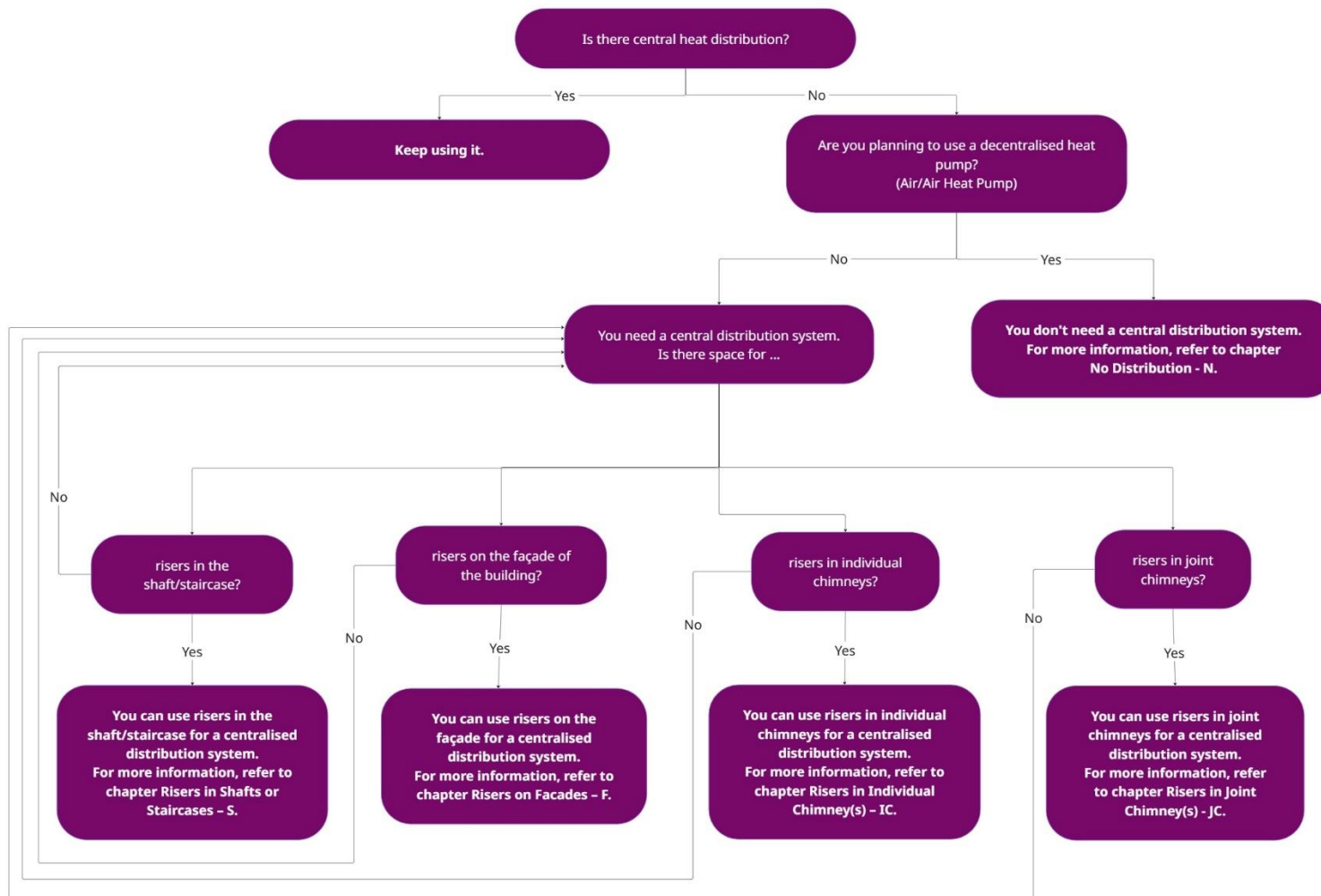


Figure 10: Decision tree of centralised heat distribution (Source: IBR&I, created with Miro (www.miro.com))

4 | Centralised Hydronic Distribution

A centralised hydronic heating and cooling distribution system encompasses all measures necessary within a building to facilitate the transportation of heating water, cold heating water (cooling) and hot water from the heat pump(s) to the residential units. In instances where a building has already been centralised, the existing hydronic heat distribution network can often be utilised without significant alterations. However, in the case of buildings that were previously heated decentral, the installation of a central heat distribution network must be carefully considered.

It is important to note that inadequate insulation of the central hydronic heating distribution system can result in significant energy losses. Nevertheless, even when adequate insulation is employed, distribution losses can be reduced only to a limited extent.

An innovative solution for centralised hydronic distribution is to transport brine or anergy through the central distribution network in the building. Pioneering enterprises have already begun to offer this service. The advantage lies in the almost complete reduction in distribution losses. In order to facilitate the distribution of brine or anergy, it is necessary for each customer to have a heat pump in their flat. The distribution solutions that are presented in this chapter are all capable of transporting water and brine as a heat transfer medium.

4.1 No Distribution - N

In buildings where a centralised hydronic distribution system is not in place, and where its installation is not planned for various reasons, this must be taken into account when planning the heating system and domestic hot water supply with heat pumps. In this case, the most suitable solution is the installation of decentralised heat pumps in individual flats or rooms.

4.1.1 Requirements

While there are no specific requirements, this solution will have a significant impact on the range of heat pumps that can be considered.

This option should only be considered once all other possibilities for centralisation have been thoroughly explored and all of them have been judged to be unfeasible.

4.1.2 Components

No components.

4.1.3 Performance

The overall system is likely to demonstrate lower efficiency in comparison to centralised alternatives. In addition, it is estimated that the costs for individual users are likely to be higher.

4.1.4 Pros and Cons

Pros

- **Savings on investment costs.**
- **Space savings.**

Cons

- **Error Prone.** Many decentralised, individual solutions are more susceptible to errors.
- **Costs.** The maintenance costs for tenants are higher as well as individual operational costs.
- **Multiple Units.** Use of many smaller heat pumps instead of one or a few centralised units.
- **Lower Efficiency.** From a technical standpoint, not the most efficient solution.
- **Missed Potential.** Missing out on utilization of potential synergies.
- **Limited Options.** Limited choice of potential heat pumps.

4.2 Risers in Shafts or Staircases – S

4.2.1 Requirements

Risers installed in dedicated shafts or staircases require sufficient space within the building's design. These shafts should be planned in central locations or along structural walls to allow easy access for maintenance. Adequate insulation is necessary to prevent heat loss and condensation buildup. Fire-resistant sealing and ventilation openings are also crucial to ensure compliance with safety regulations.

4.2.2 Components

A typical distribution system in shafts or staircases consists of the following key elements:

Pipe Material. Black steel, galvanized steel, copper, or high-temperature-resistant plastics (PEX, PP).

Insulation. Mineral wool, polyurethane foam, or synthetic rubber to minimize heat loss.

Joints & Connections. Welding (steel), soldering (copper), or crimping (PEX).

Access Panels & Fire Sealing. To enable maintenance and ensure fire safety.

In some cases, a separate pair of risers may be necessary for heating and cooling, depending on the building's requirements and the need to operate both systems simultaneously.

This centralized hydronic distribution system is fully compatible with all heat pumps and heat release units in the residential units.

4.2.3 Performance

This method ensures high system durability, with an expected lifespan of 25–50 years. Heat loss is minimized due to controlled indoor conditions, and maintenance is simplified thanks to easy accessibility. However, the need for space allocation and proper ventilation is essential for long-term performance.

4.2.4 Pros and Cons

Pros

- **Accessibility.** Easy access for maintenance and repairs.
- **Shielding.** Protection from mechanical damage and environmental factors.
- **Hidden Infrastructure.** Aesthetic solution with hidden pipes.
- **Versatile Installation.** Suitable for multiple utility installations (heating, water, sewage).

Cons

- **Space Demand.** Requires dedicated space, reducing usable floor area.
- **Costs.** Additional construction costs for shafts and fireproofing.
- **Condensation Risk.** Risk of condensation if not insulated properly.

4.3 Risers on Facades – F

4.3.1 Requirements

This installation method is suitable for retrofits or buildings with limited internal space. The hydronic risers must be securely mounted with brackets, adequately insulated, and protected from environmental exposure. Expansion joints are required to account for temperature-induced movement.

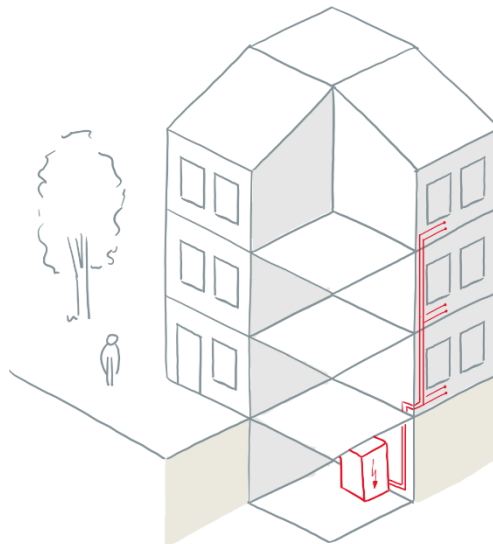


Figure 11: Exemplary configuration of a distribution system on the facade (Source: IBR&I)

4.3.2 Components

A typical distribution system on facades consists of the following key elements:

Pipe Material. Stainless steel, copper, or pre-insulated plastic (PEX/AL/PEX).

Insulation. Polyurethane foam with a weatherproof PVC or PE covering.

Mounting System. Spacers, clamps, and brackets to secure pipes.

Protective Covering. UV-resistant casing to enhance durability.

In some cases, a separate pair of risers may be necessary for heating and cooling, depending on the building's requirements and the need to operate both systems simultaneously.

This centralized hydronic distribution system is fully compatible with all heat pumps and heat release units in the residential units.

4.3.3 Performance

Risers installed on facades offer a cost-effective and flexible installation method. However, exposure to temperature fluctuations, rain, and UV radiation can impact longevity (15–30 years). Proper insulation and corrosion-resistant materials are critical for maintaining efficiency.

4.3.4 Pros and Cons

Pros

- **Retrofit Friendly.** Quick and easy installation, ideal for existing buildings.
- **No Space Loss.** Does not take up interior space.
- **Accessibility.** Simple access for expansion or modification.

Cons

- **Faster Degradation.** Exposure to weather conditions can accelerate wear.
- **Freezing Risk.** Risk of freezing in cold climates without proper insulation.
- **Aesthetics.** Can impact the building's aesthetics.

4.4 Risers in Individual Chimney(s) – IC

4.4.1 Requirements

Using an inactive chimney for hydronic risers requires a structural assessment to ensure adequate space and integrity. The chimney must be cleaned and sealed, and insulation should be added to prevent condensation and heat loss. Fire safety and ventilation compliance must also be considered.

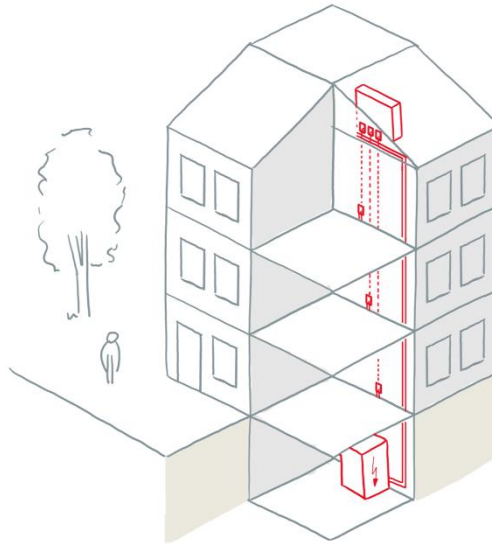


Figure 12: Exemplary configuration of a distribution system in individual chimneys (Source: IBR&I)

4.4.2 Components

A typical distribution system in individual chimneys consists of the following key elements:

Pipe Material. Stainless steel, copper, or high-temperature-resistant PEX.

Insulation. Polyurethane foam or mineral wool to maintain efficiency.

Fastening. Sealing flanges and spacers to secure pipes within the chimney.

Ventilation System. Prevents moisture buildup and ensures proper airflow.

In some cases, a separate pair of risers may be necessary for heating and cooling, depending on the building's requirements and the need to operate both systems simultaneously.

This centralized hydronic distribution system is fully compatible with all heat pumps and heat release units in the residential units.

4.4.3 Performance

This method efficiently utilizes existing infrastructure, reducing the need for additional installation space. With proper insulation and sealing, it offers a service life of 20–40 years. However, technical limitations related to chimney size and routing complexity may arise.

4.4.4 Pros and Cons

Pros

- **Space Efficiency.** Efficient use of existing space, avoiding new shafts.
- **Shielding.** Protects risers from external damage and temperature fluctuations.

- **Lower Investment.** Can reduce overall installation costs.

Cons

- **Limited Applicability.** Limited to buildings with suitable unused chimneys.
- **Verification Effort.** Requires cleaning, sealing, and verification of chimney integrity.
- **Condensation Risk.** Potential risk of condensation buildup inside the chimney.

4.5 Risers in Joint Chimney(s) - JC

With this type of centralised hydronic distribution, the risers are laid in a joint and disused chimney. The advantage of this system is its modularity, since each flat can be connected to the system individually, and the fact that no space is lost in the common area of the building.

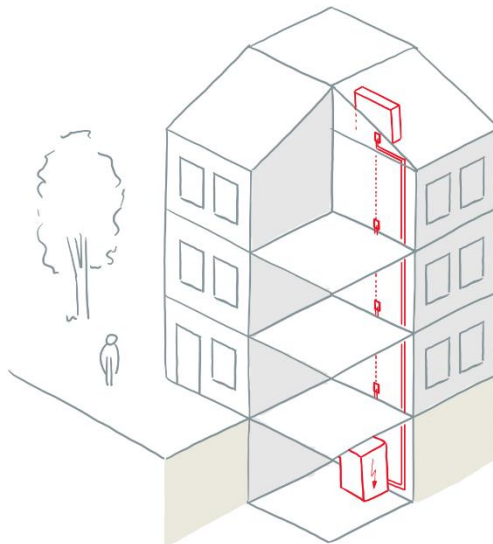


Figure 13: Exemplary configuration of a distribution system in a joint chimney (Source: IBR&I)

4.5.1 Requirements

The key requirement is that the building has a common chimney that is no longer in use after the heating system changeover and that all flats are connected to it. This variant is an ideal solution in cases where there is no space inside the building for hydronic risers and the façade cannot be used as an alternative.

4.5.2 Components

A typical distribution system in joint chimneys consists of the following key elements:

Pipe Material. Stainless steel, copper, or high-temperature-resistant PEX.

Insulation. Polyurethane foam or mineral wool to maintain efficiency.

Fastening. Sealing flanges and spacers to secure pipes within the chimney.

Ventilation System. Prevents moisture buildup and ensures proper airflow.

In some cases, a separate pair of risers may be necessary for heating and cooling, depending on the building's requirements and the need to operate both systems simultaneously.

This centralized hydronic distribution system is fully compatible with all heat pumps and heat release units in the residential units.

4.5.3 Performance

Any kind of centralization is very likely to demonstrate higher efficiency for the overall heating and cooling system in comparison to a decentralised alternative.

4.5.4 Pros and Cons

Pros

- **Minimally invasive.**
- **Expandable System.** Residential units can also be connected at a later date.
- **Space savings in common areas.**
- **Centralised Supply.** This centralised distribution system allows for the use of one or a few centralised heat pump units.

Cons

- **Costs.** Investment costs increase.

Heat Release

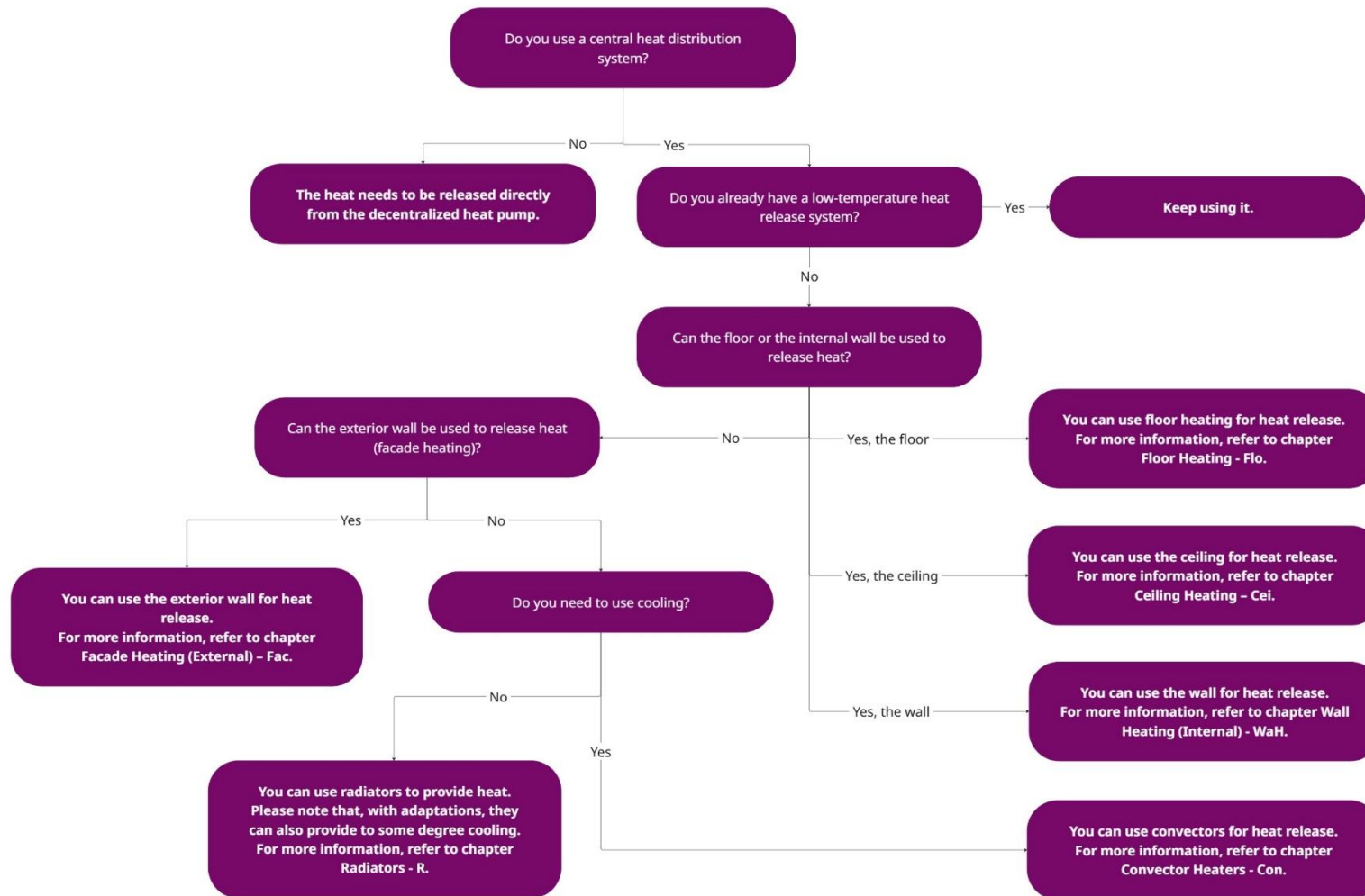


Figure 14: Decision tree of heat release (Source: IBR&I, created with Miro (www.miro.com))

5 | Heat Release

5.1 Radiators - R

The umbrella term radiator covers all wall-mounted radiators through which water flows. Radiators are available in a wide variety of designs, such as ribbed and smooth versions, historically also as sectional radiators, with different connection options, thermostatic valves, low-temperature versions and even with fan support.

A radiator exchanges heat with its surroundings (primarily air) through heat conduction, usually via a metal that conducts heat well. The air surrounding the radiator heats up and rises as a result of natural convection. The efficiency of a radiator can be increased by integrating small fans. These cause mechanical convection, which increases the air mass flow conveyed via the radiator. It is also possible to cool with radiators, but there are certain conditions and adaptations that must be met.

It should be noted that the performance of the cooling or heating mode depends largely on the connection type of the radiator. If the connection cannot be adapted for the corresponding operation, this is associated with a reduction in performance.

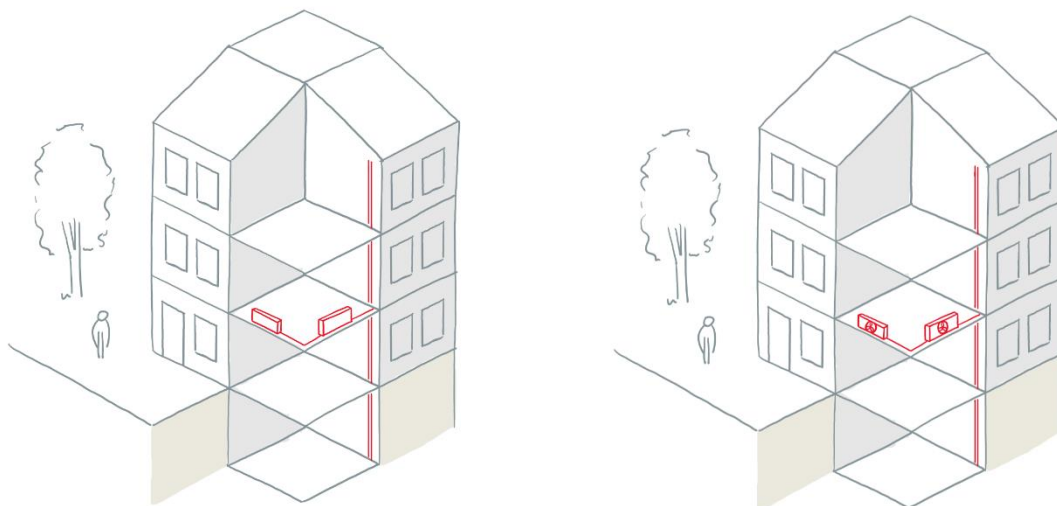


Figure 15: Exemplary configuration of radiators (Source: IBR&I)

5.1.1 Requirements

In cases where a suitable heat distribution system is already in place, a radiator optimised for low flow temperatures is an effective solution for heat dissipation. Should a combination of cooling and heating be required, it is essential to ensure that the connections can be altered accordingly.

The flow temperatures of such radiators in heating mode require at least 50 °C. State-of-the-art radiators, designed for low temperature require at least 45 °C.

It is also possible to use radiators for cooling purposes. The flow temperatures of such radiators in cooling mode are above the dew point of water of approx. 20 °C in order to avoid condensation.

5.1.2 Components

Radiators are typically installed beneath windows or in designated niches, and their specifications are defined in terms of *height*, *depth*, *width* and *type*. The number of radiators required for one unit is determined by the planned heating output. It is possible to purchase a wide variety of different combinations of dimensions.

Existing radiators can be fitted with small fans to improve convection, but this requires an additional power connection.

5.1.3 Performance

The key figure for radiators is the output power in *Watts*. This varies depending on whether the radiator is operated in heating or cooling mode and whether there are additional fans to increase convective heat transfer. The standard dimensions for a radiator are typically between 500 *W* and 1.5 *kW*. The output power calculated down to the room size is W/m^2 .

The use of low-temperature radiators is an effective solution when using a heating system based on heat pumps. The effort involved in replacing low-temperature radiators is lower and less expensive than installing panel heating systems. However, in some cases, higher water volumes may be required due to the lower temperatures at which these systems operate. This can necessitate replacing the connecting pipes in the building.

5.1.4 Pros and Cons

Pros

- **Proven and mature technology.**
- **Heating and cooling operation possible.**
- **Good retrofitting capability.**

Cons

- **Maximum cooling capacity only with correct connection.**
- **Low efficiency of installed radiators.**

5.2 Convector Heaters - Con

The term convector heater refers to heating units that primarily use convection to transfer heat to the surrounding air. These heaters can be either wall-mounted or floor-standing and come in various designs, including natural convection and fan-assisted models. Unlike radiators, convector heaters have a larger heat exchange surface, often with finned structures to enhance efficiency. Convector heaters work by drawing in cool air at the bottom, which is then heated as it passes through a series of metal fins. The warm air rises naturally or is forced by integrated fans, creating a consistent flow of heated air in the room. Some convector heaters are also capable of cooling when combined with a suitable heat pump system, but this requires careful consideration of condensation control.

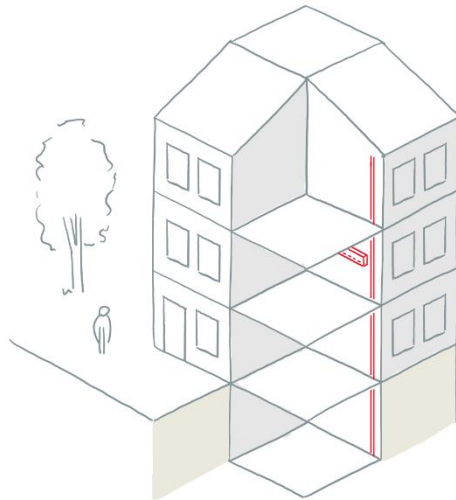


Figure 16: Exemplary configuration of convector heaters (Source: IBR&I)

5.2.1 Requirements

Convective heaters are particularly suitable for buildings with well-insulated envelopes and heat pump systems designed for low-temperature operation. They are an effective option when upgrading from older high-temperature heating systems, as they require lower flow temperatures than traditional radiators. For effective heating, flow temperatures of 35–45°C are typically sufficient. When used for *cooling*, convective heaters must operate at temperatures above the dew point to prevent condensation issues. Fan-assisted models improve performance in both heating and cooling modes.

5.2.2 Components

Convective heaters generally consist of the following:

Heat Exchanger. Usually made from high-conductivity metals (aluminium or copper) arranged in a finned structure to maximize surface area.

Casing and Airflow Channels. Designed to direct the movement of air effectively across the heat exchanger.

Integrated Fan (Optional). Improves the rate of air circulation for faster response times, though at the expense of a slight increase in power consumption.

Control Modules. Modern units may include sensors and smart control modules for remote diagnostics and dynamic performance tuning.

The required number of convective heaters depends on the room size and desired heating capacity. Since they operate at lower temperatures than conventional radiators, their surface area is often larger to compensate for the reduced temperature gradient.

5.2.3 Performance

Key performance metrics for convective heaters include:

Thermal Output. Typically between 500 W and 2 kW per unit, depending on the design and whether a fan is used.

Energy Efficiency. Determined by the heater's ability to distribute heat uniformly, often quantified in terms of output per square meter (W/m^2).

Response Time. Convector heaters typically heat up more quickly than traditional radiators due to the direct convective air movement.

5.2.4 Pros and Cons

Pros

- **Optimized for Low-Temperature Operation.** Well-suited for integration with heat pumps.
- **Rapid Thermal Response.** Enhanced convection dynamics provide quick adjustment to heating or cooling demands.
- **Modular and Upgradable.** Newer models support smart sensor integration and remote diagnostics.
- **Versatility.** Capable of both heating and, with proper control, cooling—provided condensation is managed effectively.

Cons

- **Fan Dependency.** Fan-assisted models incur additional power consumption and potential noise issues, which may necessitate further acoustic optimization.
- **Condensation Risk.** Cooling operations require precise temperature regulation to avoid condensation.
- **Higher Initial Investment.** Advanced control systems and modular designs may increase upfront costs compared to conventional radiators.
- **Installation Complexity.** The need to balance airflow, thermal mass, and heat exchanger design can add complexity, especially in retrofits of older buildings.

5.3 Floor Heating - Flo

5.3.1 Requirements

Floor heating systems, also known as underfloor heating (UFH), provide efficient and even heat distribution, making them well-suited for integration with heat pumps. They are most effective in well-insulated buildings where low-temperature heating can maintain comfort levels efficiently. Hydronic floor heating works particularly well with heat pumps, as it operates at lower water temperatures (typically 30–45 °C) compared to traditional radiators. These systems perform optimally in moderate to cold climates where continuous, steady heating is required. Proper floor insulation is essential to minimise heat loss and ensure effective energy use. Additionally, floor heating can improve indoor air quality by reducing airborne dust circulation, as it eliminates the need for convection currents associated with radiators.

Modern building regulations increasingly favour low-temperature heating systems like UFH, particularly in new constructions and energy-efficient renovations. Passive house designs and well-sealed buildings benefit significantly from the stable heat output provided by floor heating, ensuring thermal comfort without excessive energy use. In colder climates, supplementary heating may be required in extreme weather conditions, but UFH remains a highly efficient primary heating source when paired with a properly sized heat pump.

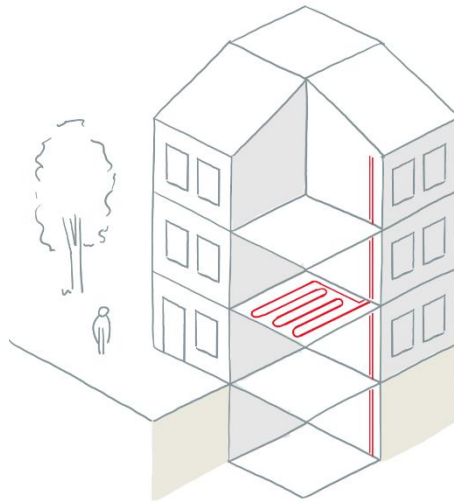


Figure 17: Exemplary configuration of floor heating (Source: IBR&I)

5.3.2 Components

A typical floor heating system includes the following key elements:

Piping Network. A series of flexible pipes (usually PEX or multilayer composite) embedded within the floor structure carries heated water from the centralized distribution. The layout can be a serpentine or spiral pattern to ensure even heat distribution. Proper spacing and pipe diameter selection are crucial for efficiency and optimal heat output.

Manifold and Control System. The manifold regulates water flow to different zones, allowing independent temperature control. It is connected to thermostats for optimised efficiency. Advanced systems incorporate smart controls, enabling remote monitoring and adjustment via mobile applications.

Insulation Layer. A thermal insulation layer beneath the piping minimises downward heat loss and improves efficiency. Reflective insulation may also be used to direct heat upward. Proper insulation thickness and material selection are essential for maximising energy savings.

Floor Covering. Suitable flooring materials include tiles, stone, and engineered wood, which allow efficient heat transfer. Carpet and thick wood flooring may reduce system efficiency. In some cases, underlay materials are used to enhance compatibility with different flooring types.

Heat Pump Connection. The heat pump and the hydronic distribution system supply low-temperature hot water to the heat release system. The integration of buffer tanks can help stabilise temperature fluctuations and improve overall system performance.

5.3.3 Performance

Floor heating systems are highly efficient when paired with heat pumps, as both operate at lower temperatures compared to conventional heating methods. The large surface area allows for gentle, radiant heat distribution, reducing temperature fluctuations and improving thermal comfort. The system's response time depends on the floor structure, with concrete screed installations having higher thermal mass and slower heating/cooling cycles.

The seasonal performance factor (SPF) of heat pumps is generally higher when used with UFH, as lower operating temperatures reduce compressor workload. Additionally, thermal stratification is minimised, ensuring uniform room temperatures and reducing overheating risks. Smart thermostatic controls and zoning options further enhance efficiency by allowing customised heating schedules for different areas of a building.

When used for cooling, hydronic UFH systems can operate in passive or active cooling modes. Passive cooling utilises naturally cool ground temperatures, while active cooling involves circulating chilled water through the piping network. However, condensation risks must be managed with appropriate control strategies and humidity monitoring.

5.3.4 Pros and Cons

Pros

- **High Efficiency.** Operates at lower temperatures, making it ideal for heat pump integration. Reduces energy consumption and improves heat pump efficiency.
- **Even Heat Distribution.** Provides consistent warmth across the room, eliminating cold spots and temperature fluctuations.
- **Comfortable and Silent Operation.** Radiant heat minimises air movement and noise, enhancing indoor comfort and reducing airborne allergens.
- **Aesthetic and Space-Saving.** No visible radiators, allowing greater interior design flexibility and optimised furniture placement.
- **Compatible with Cooling.** Some systems can be used for passive or active cooling in combination with reversible heat pumps, providing year-round climate control.
- **Improved Air Quality.** Reduces the circulation of dust and allergens compared to convection-based heating systems.

Cons

- **Higher Installation Costs.** More expensive to install than radiators, especially in retrofit projects due to labour-intensive installation and material costs.
- **Longer Heat-Up Time.** Systems embedded in concrete have a slow response time, requiring continuous operation for efficiency. Advanced control systems can mitigate this issue by using adaptive heating schedules.
- **Flooring Material Limitations.** Some floor coverings (e.g. thick carpets, solid wood) reduce heat transfer efficiency, requiring careful material selection.
- **Complex Retrofitting.** Installing in existing buildings may require substantial floor modifications, increasing labour and material costs. Raised floor systems can offer a less invasive alternative in some retrofits.

Floor heating systems present a highly efficient and comfortable heating solution when integrated with heat pumps. While initial costs and installation complexities may be higher, long-term energy savings and enhanced comfort make UFH an attractive choice for modern heating applications.

5.4 Ceiling Heating – Cei

5.4.1 Requirements

Ceiling heating systems use radiant heat transfer to warm indoor spaces, making them an efficient and comfortable solution when paired with heat pumps. They are best suited to well-insulated buildings where low-temperature heating can be maintained effectively. As with floor heating, ceiling heating operates at lower water temperatures (typically 30–45 °C), which aligns well with the optimal working conditions of heat pumps. These systems perform reliably in moderate to cold climates and are particularly useful where underfloor heating is impractical, such as in buildings with heavy furniture or specific flooring constraints.

Due to the nature of radiant heat, ceiling heating systems do not rely on air movement to distribute warmth, reducing dust circulation and improving indoor air quality. This makes them especially beneficial for allergy sufferers. Additionally, the placement of heating elements in the ceiling allows for a uniform temperature distribution, avoiding cold spots and ensuring a consistent level of comfort. However, proper insulation above the heating system is crucial to prevent heat loss and maintain efficiency.

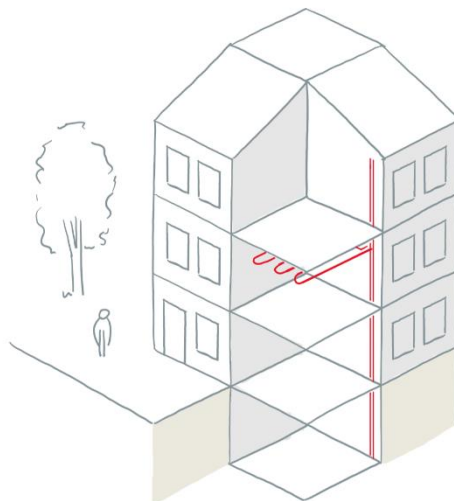


Figure 18: Exemplary configuration of ceiling heating (Source: IBR&I)

5.4.2 Components

A typical ceiling heating system consists of the following key elements:

Pipe or Panel System. Flexible plastic pipes (PEX or multilayer composite) or prefabricated radiant panels are embedded in or mounted on the ceiling. These carry the heated water from the centralized distribution. The design and layout of the pipes or panels must ensure even heat distribution and minimal temperature variations.

Manifold and Control System. The manifold distributes heated water to different ceiling zones, ensuring even temperature control. Room thermostats regulate heating levels, and advanced systems may include smart controls that allow remote operation and automation based on occupancy patterns.

Insulation Layer. A reflective or thermal insulation layer behind the heating elements minimises heat loss and directs warmth downward. The choice of insulation materials plays a significant role in improving overall energy efficiency and preventing unnecessary heat transfer into the ceiling structure.

Ceiling Covering. Gypsum board, plaster, or other heat-conductive materials cover the heating elements, ensuring efficient heat emission. The thermal conductivity of these materials affects the speed and effectiveness of heat transfer into the room.

Heat Pump Connection. The heat pump and the hydronic distribution system supply low-temperature water to the heat release system. Buffer tanks may be incorporated to stabilise temperature fluctuations and enhance performance during peak demand periods.

5.4.3 Performance

Ceiling heating provides uniform radiant heat distribution, similar to floor heating, but with faster response times due to lower thermal mass. When paired with a heat pump, it operates efficiently at low temperatures, enhancing the system's seasonal performance factor (SPF). Unlike convection-based heating methods, ceiling heating does not create strong air currents, improving thermal comfort and reducing energy loss through ventilation.

One of the primary advantages of ceiling heating is its rapid adaptability. The system can quickly adjust to changing heating demands, making it well-suited for spaces that require intermittent heating. Additionally, ceiling heating can be integrated with a reversible heat pump for radiant cooling during warmer months. By circulating chilled water through the system, it provides a comfortable indoor climate without the draughts or noise associated with traditional air conditioning systems. However, managing condensation risks is essential when using the system for cooling, requiring careful humidity control and insulation strategies.

5.4.4 Pros and Cons

Pros

- **Efficient Low-Temperature Operation.** Works well with heat pumps, reducing energy consumption and improving overall efficiency.
- **Even and Comfortable Heating.** Provides consistent warmth without draughts or hot spots, enhancing indoor comfort.
- **Quick Response Time.** Heats up faster than floor heating due to lower thermal mass, allowing for more flexible temperature adjustments.
- **Space-Saving and Aesthetic.** Eliminates the need for radiators or visible heating units, providing greater design freedom for interior spaces.
- **Cooling Capability.** Can be used for radiant cooling when connected to a reversible heat pump, offering year-round climate control.
- **Improved Air Quality.** Reduces the circulation of dust and allergens compared to convection-based heating systems, benefiting individuals with respiratory conditions.

Cons

- **Higher Installation Costs.** More expensive than conventional radiators or air-based systems due to specialised materials and installation requirements.

- **Limited Heat Retention.** Lacks the thermal mass of floor heating, requiring continuous operation for consistent warmth, particularly in poorly insulated buildings.
- **Furniture and Layout Constraints.** Heat radiation can be partially blocked by large objects, shelving, or suspended ceiling fixtures, reducing system effectiveness in certain room configurations.
- **Structural Considerations.** Retrofitting may require ceiling reinforcement or modifications to accommodate pipework or panels, increasing installation complexity and costs.
- **Condensation Risks in Cooling Mode.** When used for cooling, proper humidity control is essential to prevent condensation issues that may damage ceilings or insulation materials.

Ceiling heating offers an energy-efficient and comfortable heating solution, particularly in modern, well-insulated buildings. While the initial installation costs and structural considerations may pose challenges, the long-term benefits of improved comfort, energy savings, and aesthetic flexibility make it a compelling option for residential and commercial applications.

5.5 Wall Heating (Internal) - WaH

5.5.1 Requirements

Internal wall heating operates on the same principle as floor and ceiling heating, using radiant heat transfer to warm indoor spaces efficiently. It is well-suited for well-insulated buildings, where low-temperature heating can provide consistent thermal comfort. Typically operating at water temperatures between 30–45 °C, wall heating systems integrate well with heat pumps, optimising their efficiency. They are particularly effective in moderate to cold climates and serve as a practical alternative in buildings where floor or ceiling heating is not feasible.

Wall heating is especially beneficial in rooms with limited floor space or where ceiling heating may be impractical due to structural constraints. The placement of heating elements on walls allows for targeted heat distribution, making it an adaptable solution for various architectural layouts. To ensure optimal efficiency, proper wall insulation is necessary to prevent heat loss and maximise warmth retention within the living space.

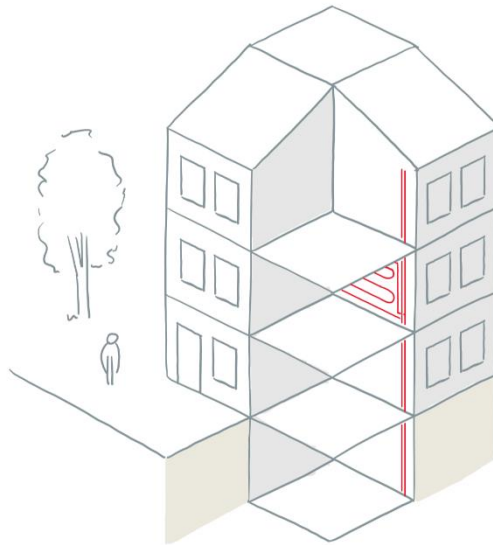


Figure 19: Exemplary configuration of wall heating (Source: IBR&I)

5.5.2 Components

A typical internal wall heating system includes the following key elements:

Pipe or Panel System. Flexible pipes (PEX or multilayer composite) or prefabricated radiant panels are installed within or mounted on interior walls, carrying heated water from the centralized distribution. The pipe layout can vary, with serpentine and meandering patterns being common for even heat distribution.

Manifold and Control System. The manifold regulates water distribution to different heating zones, with thermostats allowing precise temperature control. Smart thermostats can further optimise heating efficiency by adjusting temperature settings based on occupancy and user preferences.

Insulation Layer. A thermal or reflective insulation layer behind the heating elements minimises heat loss and directs warmth into the room. High-quality insulation materials enhance system efficiency by reducing unwanted heat dissipation.

Wall Covering. Typically plaster, drywall, or specialised panels that allow efficient heat transfer. Heat-conductive materials such as gypsum or clay-based plaster improve performance by ensuring rapid and even heat distribution.

Heat Pump Connection. The heat pump and the hydronic distribution system supply low-temperature water to the heat release system. Buffer tanks may be used to stabilise temperature fluctuations and enhance operational consistency.

5.5.3 Performance

Wall heating offers a comfortable and even heat distribution, similar to floor and ceiling heating. It provides quicker response times than floor heating due to lower thermal mass while maintaining efficiency at low operating temperatures. When combined with a heat pump, wall heating enhances the seasonal performance factor (SPF) by reducing energy demand.

Due to its lower thermal inertia compared to floor heating, wall heating systems can achieve the desired room temperature more quickly, making them suitable for areas requiring flexible heating schedules. Moreover, unlike convection-based systems, wall heating minimises air movement, leading to improved indoor air quality and reduced dust circulation. This makes it a particularly advantageous heating solution for allergy sufferers.

Additionally, it can function as a cooling system in summer when integrated with a reversible heat pump, circulating chilled water through the wall panels. This passive cooling effect reduces the reliance on conventional air conditioning systems, contributing to lower energy consumption and enhanced indoor comfort. However, to prevent condensation, humidity control measures must be implemented when using the system for cooling.

5.5.4 Pros and Cons

Pros

- **Efficient Low-Temperature Heating.** Well-matched with heat pumps for optimal performance and reduced energy consumption.
- **Even Heat Distribution.** Provides comfortable radiant heating with minimal air movement, improving indoor air quality.
- **Faster Response Time.** Warms up quicker than floor heating due to lower thermal mass, making it suitable for flexible heating schedules.
- **Aesthetic and Space-Saving.** Eliminates the need for radiators, freeing up interior space and allowing greater design flexibility.
- **Cooling Functionality.** Can be used for radiant cooling when paired with a reversible heat pump, reducing dependence on traditional air conditioning systems.
- **Silent Operation.** Unlike forced-air systems, wall heating operates silently, enhancing overall comfort within living spaces.

Cons

- **Higher Installation Costs.** More expensive than conventional heating systems due to material and installation requirements.
- **Furniture Placement Restrictions.** Large furniture pieces placed against heated walls can obstruct heat emission and reduce efficiency.
- **Retrofitting Challenges.** Installing in existing buildings may require wall modifications and careful insulation planning, increasing labour and material costs.
- **Limited Heat Storage.** Does not retain heat as effectively as floor heating, requiring more consistent operation to maintain comfort levels.
- **Potential Cooling Limitations.** When used for cooling, proper humidity control is necessary to prevent condensation on wall surfaces.

Internal wall heating presents an energy-efficient and aesthetically appealing heating solution for modern buildings. When integrated with a heat pump system, it delivers low-temperature heating with high efficiency, enhancing thermal comfort and reducing energy costs. While installation expenses and space considerations may pose challenges, the long-term benefits of improved air quality, silent operation, and dual heating-cooling functionality make it a viable option for residential and commercial applications.

5.6 Facade Heating (External) – Fac

5.6.1 Requirements

External façade heating is an innovative hydronic heating solution integrated into the building façade. It is typically installed between the existing external wall and an additional thermal insulation composite system. This setup is particularly advantageous for retrofitting of existing buildings where minimal disruption to the interior space is essential.

The key requirement for this system is a structurally sound exterior wall that can accommodate the additional layers of heating and insulation without compromising stability. The wall should ideally have a U-value of at least $1.0 \text{ W}/(\text{m}^2 \cdot \text{K})$ to allow efficient thermal activation. Additionally, it is crucial to consider the wall's geometry, as complex building structures such as balconies, loggias, and bay windows may increase the complexity of installation.

The exterior wall heating system is particularly suitable for buildings undergoing thermal retrofitting and can be coupled with any heat pump system. In summer, it can also be used for passive cooling when combined with a suitable heat sink, like the ground, groundwater or an energy grid.

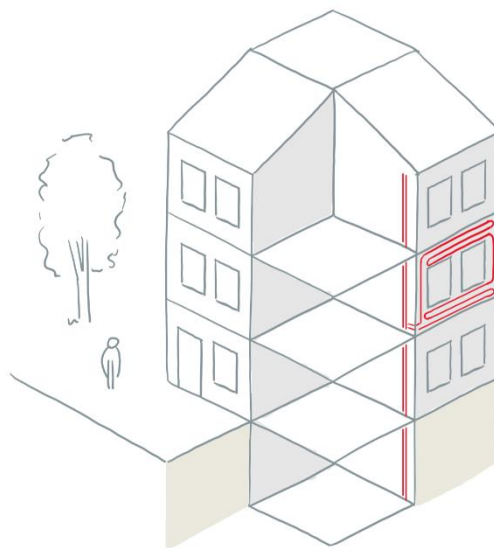


Figure 20: Exemplary configuration of facade heating (Source: IBR&I)

5.6.2 Components

An external façade heating system consists of the following components:

Heating Element. A network of pipes, often made from high-quality composite materials (e.g., PE-RT or aluminum composite), embedded either directly on the existing exterior plaster or within milled grooves on the wall surface. Capillary tube mats are commonly used to ensure even temperature distribution. The spacing of the pipes typically ranges from 20 to 25 cm, depending on the wall's thermal conductivity and system configuration.

Thermal Insulation Layer. An insulation layer with a thickness between 10 and 30 cm, applied over the heating elements to minimize heat loss and protect the system from external influences.

Outer Plaster Layer. A robust exterior plaster (such as lime-cement) applied as the final layer, providing protection against weather and mechanical damage.

Control and Regulation System. Smart control systems with temperature and humidity monitoring to optimize heating performance and prevent condensation during cooling operation. Remote control options are often included to enable flexible adjustments.

Distribution and Manifold System. Manifolds are usually installed in the basement or in insulated channels on the building's exterior, providing centralized distribution and easy maintenance access.

Ventilation System (if applicable). Ventilation ducts or air gaps may be incorporated to allow moisture control and avoid condensation within the wall structure.

Backup Heating Element (if necessary). An electric heating element can be integrated for emergency operation, especially in extremely low ambient temperatures.

5.6.3 Performance

The system can maintain a steady indoor temperature by continuously supplying low-temperature heat to the building envelope, thereby reducing temperature fluctuations and improving thermal comfort. The performance of an external façade heating system largely depends on the thermal characteristics of the building envelope and the efficiency of the heating source. Typically, these systems operate at low supply temperatures (25–35 °C), making them highly compatible with heat pumps.

The thermal output of the system is influenced by the pipe spacing, wall insulation quality, and the heating medium temperature. Optimal performance is achieved when the pipe spacing is approximately 25 cm, which prevents pipe kinking and ensures stable heat transfer.

In cooling mode, the system can be operated at lower supply temperatures (up to even 15 °C). However, condensation management is critical. Dynamic simulations have demonstrated that maintaining a supply temperature of 15 °C for cooling over a period of 10 weeks does not lead to moisture accumulation if the wall is appropriately insulated and ventilated.

5.6.4 Pros and Cons

Pros

- **Efficient Low-Temperature Heating.** Well-matched with heat pumps for optimal performance and reduced energy consumption.
- **Even Heat Distribution.** Provides comfortable radiant heating with minimal air movement, improving indoor air quality.
- **Minimal Interior Impact.** Installation occurs externally, minimizing disruption to indoor spaces.
- **Dual Functionality.** Can be used for both heating in winter and cooling in summer.
- **Aesthetic Integration.** The heating elements are hidden within the façade system, preserving the building's visual appearance.

Cons

- **High Initial Investment.** Installation costs are higher due to the complexity of integrating heating elements and insulation.
- **Slower Response Time.** Due to the thermal mass of the wall, the system responds more slowly to temperature changes.
- **Installation Challenges.** Requires precise installation to avoid pipe kinking and thermal bridging.
- **Complex Maintenance.** Retrofitting and repairs may require partial dismantling of the façade.
- **Condensation Risk in Cooling Mode.** Inadequate control or poor insulation may lead to moisture accumulation.

Domestic Hot Water

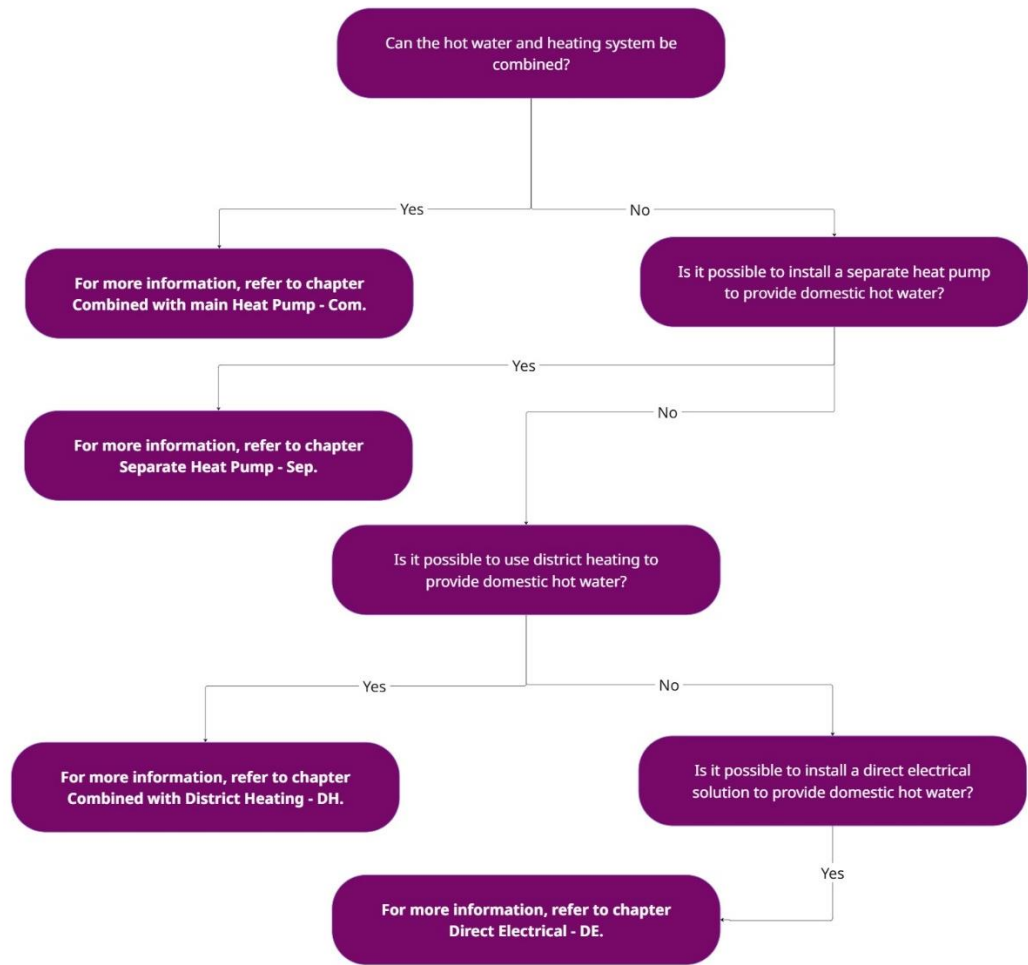


Figure 21: Decision tree of domestic hot water (Source: IBR&I, created with Miro (www.miro.com))

6 | Domestic Hot Water

In addition to the heating system, the provision of domestic hot water must also be considered when designing heat pump energy delivery models. This section presents a range of options for hot water preparation in conjunction with heat pumps.

6.1 Combined with main Heat Pump - Com

6.1.1 Requirements

A domestic hot water system integrated with the main heat pump provides both space heating and hot water from a single system. This approach simplifies system design, reduces installation costs, and optimizes space usage, making it a cost-effective and efficient solution. However, it is essential that the heat pump is capable of maintaining domestic hot water temperatures of at least 60°C to comply with hygiene regulations and prevent the risk of legionella contamination.

This system is particularly suitable for residential buildings where cooling is not required, as the integration of domestic hot water production with space heating can limit the ability to provide active cooling. The performance of the system depends on the efficiency of the heat pump, its ability to maintain the required temperatures, and the overall thermal design of the building.

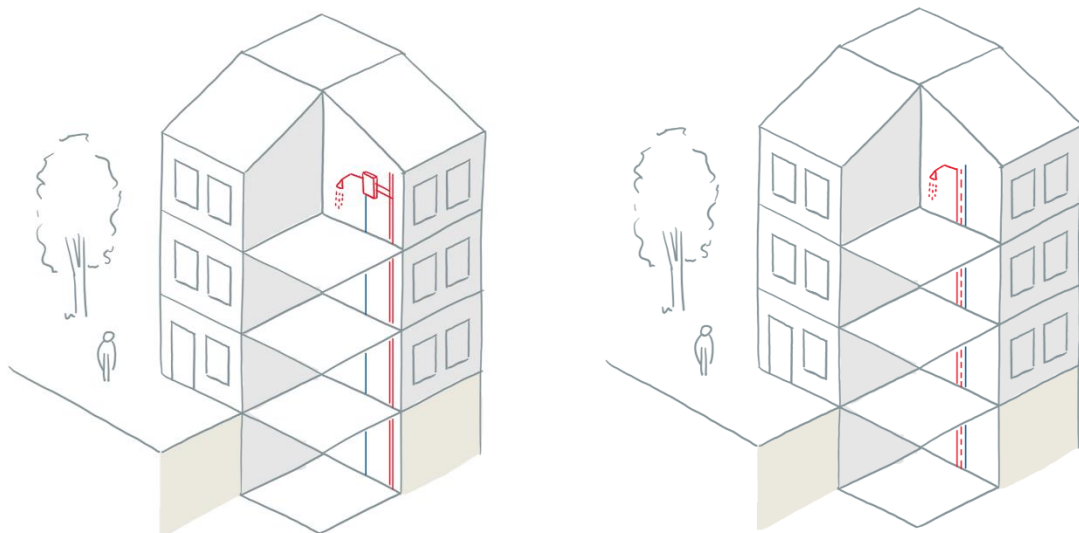


Figure 22: Exemplary configurations of centralized hot water supply, ready to be connected to the main heat pump (Source: IBR&I)

6.1.2 Components

A heat pump system that provides both space heating and domestic hot water typically consists of the following key elements:

Heat Source and Heat Pump Unit. The primary component that extracts heat from the designated heat source to provide both space heating and domestic hot water. It must be designed to achieve domestic hot water temperatures of at least 60°C.

Hot Water Storage Tank (if applicable). An insulated tank that stores heated water. Tanks with efficient insulation help reduce heat losses and improve system efficiency. Some systems use stratified storage tanks to optimize energy use.

Control System. A temperature and system management controller that regulates heating and domestic hot water production, ensuring efficient operation and compliance with hygiene requirements. Advanced models may include smart scheduling and monitoring functions.

Circulation Pump and Valves. These components manage the distribution of hot water within the system, directing heat pump output to either space heating or domestic hot water production as needed.

6.1.3 Performance

Heat pump systems combined with domestic hot water production provide high energy efficiency compared to traditional electric or gas water heating methods. The system's overall efficiency is measured by the coefficient of performance (COP), which varies depending on the heat pump's operating conditions and the required hot water temperature.

While heat pumps generally perform well in heating mode, their efficiency decreases when generating higher temperatures for domestic hot water. Standard air-source heat pumps, for example, experience lower COP values at elevated temperatures, potentially increasing energy consumption.

Since this setup prioritizes hot water production when needed, space heating may temporarily be interrupted while the system shifts to domestic hot water mode, which can impact comfort levels in colder climates. Proper system design and buffer storage can help mitigate these effects.

6.1.4 Pros and Cons

Pros

- **Integrated System.** Eliminates the need for a separate domestic hot water system, reducing complexity and installation costs.
- **Cost-Effective.** Uses a single heat pump system for both heating and domestic hot water, improving efficiency and lowering operational expenses.
- **Space Savings.** Reduces the number of required appliances, freeing up space in mechanical rooms or utility areas.
- **Energy Efficient.** Heat pumps provide a more sustainable and cost-effective solution to direct electrical water heating.

Cons

- **High Domestic Hot Water Temperature Requirement.** The heat pump must be capable of reaching at least 60°C to comply with hygiene standards, which may reduce system efficiency.
- **No Cooling Mode Possible.** Integrating domestic hot water production with the main heat pump prevents the use of the system for cooling, limiting application in climates requiring summer cooling.

- **Potential Heating Interruptions.** During domestic hot water production, space heating may be temporarily paused, which can impact comfort in colder regions unless properly managed with buffer storage.

A domestic hot water system combined with the main heat pump provides a cost-effective and energy-efficient solution for buildings where cooling is not required. However, the system's performance depends on the heat pump's ability to reach necessary domestic hot water temperatures while maintaining efficient operation. Strategic system design, including buffer storage and advanced controls, can help mitigate potential drawbacks and maximize overall comfort and efficiency.

6.2 Separate Heat Pump - Sep

6.2.1 Requirements

A domestic hot water system using a separate heat pump from the space heating and cooling system allows for independent operation, ensuring optimal performance for both applications. This approach is particularly recommended in buildings where cooling is required, as it avoids temperature conflicts between heating and domestic hot water production.

To maintain compliance with hygiene regulations and minimize the risk of legionella contamination, the dedicated domestic hot water heat pump must be capable of reaching temperatures of at least 60 °C. Additionally, a separate distribution system for domestic hot water is necessary, as temperature levels in the space heating and cooling circuits will vary throughout the year, particularly during cooling operation.

This system design provides flexibility, but it requires careful planning to ensure efficient energy use, proper integration, and space allocation for the additional equipment.

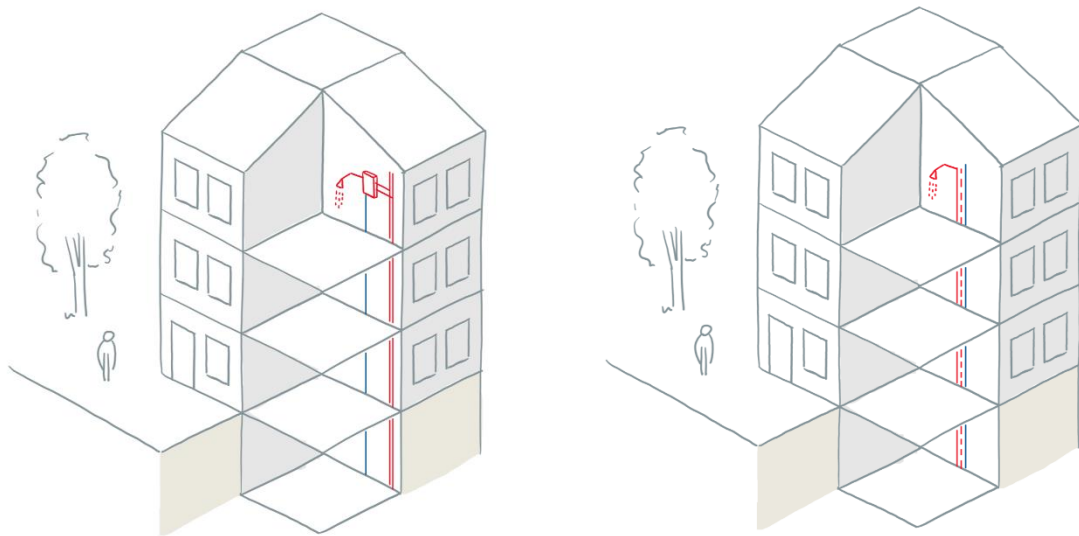


Figure 23: Exemplary configurations of centralized hot water supply, ready to be connected to the separate heat pump (Source: IBR&I)

6.2.2 Components

A system with separate heat pumps for space heating/cooling and domestic hot water typically consists of the following key elements:

Space Heating and Cooling Heat Pump. The primary unit responsible for maintaining indoor climate comfort by providing heating in winter and cooling in summer.

Domestic Hot Water Heat Pump. A dedicated unit designed to supply domestic hot water independently of the space heating and cooling demands. This heat pump must reach at least 60 °C to comply with hygiene standards.

Separate Hot Water Storage Tank. An insulated tank that stores heated water, ensuring a continuous hot water supply. High-performance insulation minimizes standby losses.

Independent Distribution Systems. Two separate hydronic piping networks – one for space heating/cooling and another for domestic hot water – to prevent interference between the two temperature zones.

Control and Regulation System. A smart management system that optimizes the operation of both heat pumps, ensuring efficient switching between heating, cooling, and hot water production.

6.2.3 Performance

Using separate heat pumps for space conditioning and domestic hot water ensures optimal efficiency and flexibility. Unlike combined systems, where heating and hot water demand can interfere with one another, this setup allows each system to operate independently, maximizing performance.

During cooling operation, the space conditioning heat pump lowers the indoor temperature without affecting domestic hot water supply. This is particularly beneficial in warm climates or buildings with significant cooling needs. However, having two separate systems increases initial investment and space requirements.

The efficiency of each heat pump is determined by its coefficient of performance (COP), which varies based on operating conditions. The space heating/cooling unit typically maintains high efficiency in moderate climates, while the domestic hot water heat pump may experience efficiency losses when producing water at 60 °C. Advanced models with high-temperature heat pump technology can mitigate this issue.

6.2.4 Pros and Cons

Pros

- **Cooling Mode Possible.** Unlike combined systems, this configuration allows for space cooling without compromising domestic hot water production.
- **Optimized Efficiency.** Independent heat pumps prevent temperature conflicts, ensuring both systems operate at peak performance.
- **Flexible System Design.** Can be tailored for different climate conditions and building requirements, offering enhanced control over heating, cooling, and domestic hot water production.

Cons

- **High Domestic Hot Water Temperature Requirement.** The domestic Hot Water heat pump must reach at least 60°C, which may reduce efficiency compared to lower-temperature heating systems.
- **Space-Intensive Setup.** Requires additional equipment and piping, increasing space requirements compared to a single integrated system.
- **Higher Investment Costs.** Installing two separate heat pumps and distribution systems increases upfront costs significantly.
- **More Complex System Design.** Requires careful planning and engineering to integrate both heat pumps efficiently.

A separate heat pump system for space heating/cooling and domestic hot water provides an efficient and flexible solution, particularly for buildings requiring cooling. By preventing temperature conflicts and allowing independent operation, this approach ensures optimal comfort and energy efficiency. However, the increased space requirements, installation complexity, and higher initial costs must be carefully considered during system selection and planning.

6.3 Direct Electrical - DE

6.3.1 Requirements

Direct electrical domestic hot water (DHW) systems use electric heating elements to heat water on demand or store it in an insulated tank. These systems are suitable for various climates but are most commonly used in areas where electricity is affordable or where alternative heating sources (such as heat pumps or gas boilers) are impractical. They provide reliable domestic hot water regardless of external temperatures, making them a versatile solution. However, due to relatively high electricity consumption, they are less energy-efficient than heat pump water heaters, especially in regions with high electricity costs.

Direct electrical domestic hot water systems are particularly useful in remote or off-grid locations where access to gas supply or district heating networks is limited. They are also a common choice in holiday homes, secondary residences, and commercial settings requiring a compact and independent hot water solution. To optimise efficiency, users may integrate these systems with timers, off-peak tariffs, or renewable electricity sources such as solar panels.

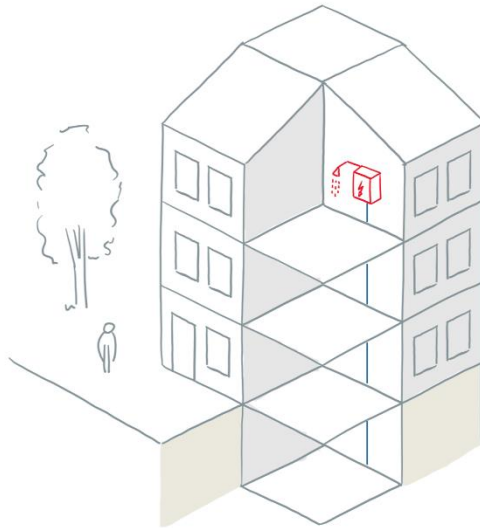


Figure 24: Exemplary configuration of direct electrical hot water supply (Source: IBR&I)

6.3.2 Components

A direct electrical domestic hot water system typically consists of the following key elements:

Heating Element. An electric resistance element immersed in the water tank or installed in an instant water heater unit, converting electrical energy into heat. Modern systems may include dual heating elements for faster water heating and improved efficiency.

Storage Tank (if applicable). Insulated tanks ranging from small point-of-use models to large household cylinders store heated water for later use. High-quality insulation materials reduce standby heat loss, improving energy efficiency.

Thermostat and Controls. A temperature control system regulates water temperature and prevents overheating. Advanced models may include timers and smart controls to optimise energy use, allowing users to set heating schedules and monitor energy consumption.

Safety Features. Pressure relief valves and thermal cut-offs ensure safe operation by preventing excessive pressure build-up or overheating. Some units also feature anti-scald mechanisms to maintain safe water temperatures.

Water Distribution System. Heated water is delivered to taps, showers, and appliances through a standard plumbing network. Point-of-use systems may be installed directly at sinks or bathrooms to reduce heat loss from long pipe runs.

6.3.3 Performance

Direct electrical water heating systems provide rapid and reliable domestic hot water but have a lower energy efficiency compared to heat pump-based solutions. Their efficiency is typically measured by their energy factor (EF), which is often close to 1.0, meaning nearly all electrical input is converted into heat. However, this is significantly lower than heat pump water heaters, which can achieve an EF of 2.0–3.0. While effective for small-scale or backup applications, these systems can lead to high operational costs if used as the primary domestic hot water source in energy-intensive households.

Despite their lower efficiency, direct electrical domestic hot water systems offer the advantage of instant or fast water heating, making them particularly useful in situations where immediate hot water is required. Instantaneous or tankless models eliminate standby heat loss, improving overall performance compared to storage tank systems. However, the system's energy demand remains high, making it important to consider energy tariffs and usage patterns.

6.3.4 Pros and Cons

Pros

- **Simple and Reliable.** Requires minimal maintenance and has a straightforward installation process.
- **Fast Heating.** Provides near-instant hot water, especially in point-of-use or tankless models, reducing waiting times.
- **Compact Design.** Small units can be installed in tight spaces, making them ideal for apartments and secondary water heating applications.
- **No External Infrastructure Required.** Unlike heat pump or gas systems, no ventilation or additional piping is needed, allowing flexibility in installation locations.
- **Compatible with Renewable Energy.** When powered by solar PV systems or other renewable electricity sources, operational costs and environmental impact can be reduced.

Cons

- **High Electricity Consumption.** Less efficient than heat pump water heaters, leading to higher energy costs and increased demand on the electrical grid.
- **Limited Sustainability.** Unless powered by renewable electricity, it has a higher carbon footprint compared to alternative domestic hot water solutions, making it less environmentally friendly.
- **Storage Limitations.** Tank models may run out of hot water during high-demand periods, requiring reheating cycles that increase energy use.
- **Not Ideal for Large Households.** May struggle to meet the hot water demand of larger families compared to heat pump or gas-based systems, especially during peak usage times.
- **Higher Operating Costs.** While initial installation costs may be low, long-term energy expenses can be significant, particularly in regions with high electricity prices.

Direct electrical domestic hot water systems offer a practical and convenient solution for providing hot water in a variety of settings. While their high energy consumption remains a concern, integrating them with renewable energy sources and smart controls can enhance their efficiency and sustainability. For households or businesses seeking a reliable, low-maintenance water heating solution, these systems remain a viable option, particularly in areas with affordable electricity or where alternative heating methods are not feasible.

6.4 Combined with District Heating - DH

6.4.1 Requirements

Domestic hot water systems combined with district heating are particularly suited to urban environments and regions with well-developed district heating networks. These systems efficiently utilise excess heat from industrial processes, renewable energy sources, or combined heat and power (CHP) plants, ensuring a stable and cost-effective domestic hot water supply throughout the year. In colder climates, district heating networks operate continuously, guaranteeing hot water availability even during winter months. In some locations, district heating is only active during the heating season, requiring an auxiliary system, such as direct electrical heating, a solar thermal system, or a small heat pump, for summer operation. The efficiency and sustainability of these systems depend on the district heating network's temperature levels, energy sources, and distribution efficiency.

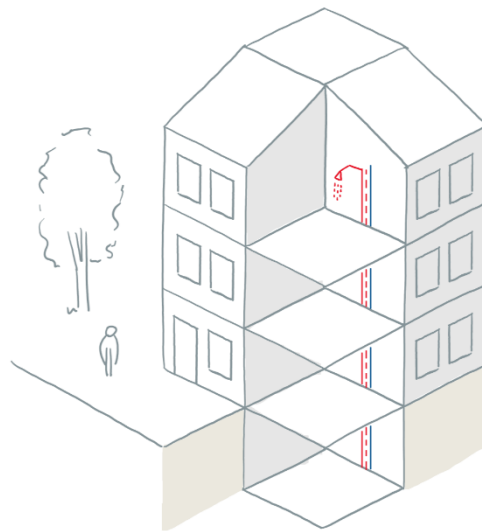


Figure 25: Exemplary configuration of centralized hot water supply, ready to be connected to the district heating network (Source: IBR&I)

6.4.2 Components

A domestic hot water system combined with district heating typically includes the following key elements:

District Heating Connection. A direct or indirect connection to the district heating network supplies heat for domestic hot water production.

Heat Exchanger. Transfers thermal energy from the district heating system to the domestic hot water circuit, either through an instantaneous water heating process or via a storage tank.

Storage Tank (if applicable). Insulated hot water tanks store heated water for later use, reducing peak load demands on the district heating system and improving efficiency.

Control and Regulation System. Thermostats, flow regulators, temperature sensors, and valves ensure optimal operation, maintaining consistent water temperature and minimising energy waste.

Backup Heating (if required). In summer-only district heating configurations, an auxiliary electric water heater, solar thermal panel, or small-scale heat pump may be integrated to maintain hot water availability during non-heating periods.

6.4.3 Performance

Domestic hot water systems that rely on district heating offer high efficiency, particularly when the network operates at optimised temperature levels. Instantaneous heat exchangers reduce standby losses by heating water only when needed, while storage tank solutions provide buffering capacity for peak demand periods. The overall seasonal performance depends on the district heating network's energy source, temperature regulation, and distribution efficiency. Year-round district heating systems provide a consistent, cost-effective, and low-maintenance solution for hot water supply. In summer-only configurations, the overall efficiency of the system depends on the backup heating method, with heat pumps offering a more energy-efficient alternative compared to electric resistance heating.

6.4.4 Pros and Cons

Pros

- **High Energy Efficiency.** Utilises waste heat, renewables, or CHP-generated heat, reducing overall energy consumption and carbon footprint.
- **Reliable Hot Water Supply.** Provides a stable, year-round hot water solution in areas with established district heating infrastructure.
- **Lower Maintenance Requirements.** Unlike individual water heating systems, district heating-based solutions have fewer moving parts and lower servicing needs.
- **Scalability.** Suitable for residential homes, apartment buildings, and large-scale commercial applications.
- **Potential Cost Savings.** Depending on the district heating tariff and fuel source, these systems can offer lower operational costs compared to individual heating solutions.

Cons

- **Dependency on District Heating Network.** Availability is restricted to regions with an established district heating infrastructure.
- **Potential Summer Backup Required.** In cases where district heating operates only in winter, an auxiliary heating source is needed, which may add to operational costs.
- **Heat Loss in Distribution.** Older district heating networks with high-temperature operation may suffer from energy losses, reducing overall efficiency.
- **Limited Temperature Control.** Domestic hot water temperature is influenced by the district heating supply conditions, which may not always be ideal for all applications.
- **Infrastructure and Connection Costs.** Initial connection fees and system installation costs may be significant, depending on local regulations and network access conditions.

Domestic hot water systems integrated with district heating present an efficient and sustainable solution for hot water production, particularly in urban areas with well-developed heating networks. Their ability to leverage waste heat and renewable energy sources enhances their environmental and economic benefits. However, their effectiveness depends on network availability, temperature stability, and seasonal operation considerations. For households and businesses seeking a reliable and low-maintenance hot water system, district heating remains a

cost-effective and energy-efficient option, especially when supported by an optimised network and, if necessary, a suitable backup heating source.

7 | Use Cases

7.1 Single-Family Units

Several heating configurations for single family units can be considered.

For single-family units **ground-based (G)** and **air-based heat pumps (A)** are recommended. In addition, solar-based **photovoltaic thermal heat pumps (So)** are a viable option if the climate is suitable.

Single-family units do not require centralised distribution.

Heat release for retrofitted single-family units typically can be achieved by **radiators (R)** and **convectors (Con)**. In the case of a new building **floor heating (Flo)**, **ceiling heating (Cei)** and **internal wall heating (WaH)** are recommended.

In the case of single-family units, it is most efficient to **combine** the production of domestic hot water **with the main heat pump (Com)** or to use **direct electrical (DE)** solutions.

7.2 Multi-Family Units

Several heating configurations for multi-family units can be considered.

For multi-family units' **ground-based (G)** and **air-based heat pumps (A)** are recommended. In addition, solar-based **photovoltaic thermal heat pumps (So)** are a viable option if the climate is suitable.

Multi-family units require centralised distribution. If possible, solutions that are located inside the building should be prioritised.

Heat release for retrofitted multi-family units typically can be achieved by **radiators (R)** and **convectors (Con)**. In the case of a new building **floor heating (Flo)**, **ceiling heating (Cei)** and **internal wall heating (WaH)** are recommended.

In the case of multi-family units, it is most efficient to **combine** the production of domestic hot water **with the main heat pump (Com)** or to use **direct electrical (DE)** solutions.

7.3 Historic Buildings

Several heating configurations for historic buildings can be considered.

The first step for historic buildings is to determine whether there is an available **energy grid (AG)** or **waste heat (WH)**. The next step is to assess the potential of available **water bodies (W)** or the **ground (G)** to be utilised as a heat source and sink. As an alternative solution, there is the option of installing centralised **air-based heat pumps (A)**.

Historic buildings require centralised distribution. If possible, solutions that are located inside the building should be prioritised.

Heat release for retrofitted historic buildings typically can be achieved by **radiators (R)** and **convectors (Con)**. As an alternative solution, there is the option of installing external **façade heating (Fac)** on the exterior walls.

All options are equally viable when it comes to domestic hot water solutions. However, the variants **combined with the main heat pump (Com)**, **separate heat pump (Sep)** and **direct electric (DE)** are recommended.

7.4 New Large-Volume Buildings

Several heating configurations for new large volume buildings can be considered.

The first step for new large volume buildings is to determine whether there is an available **energy grid (AG)** or **waste heat (WH)**. The next step is to assess the potential of available **water bodies (W)** or the **ground (G)** to be utilised as a heat source and sink. As an alternative solution, there is the option of installing centralised **air-based heat pumps (A)**.

New large volume buildings require centralised distribution. If possible, solutions that are located inside the building should be prioritised.

Heat release for new large volume buildings typically can be achieved by building **floor heating (Flo)**, **ceiling heating (Cei)** and **internal wall heating (WaH)**.

All options are equally viable when it comes to domestic hot water solutions. However, the variants **combined with the main heat pump (Com)**, **separate heat pump (Sep)** and **direct electric (DE)** are recommended.

7.5 Alternative Heating Combinations

In some cases, a conventional heat pump may not be the ideal solution for every homeowner. Households with very low energy demand may not benefit sufficiently from the energy savings compared to the high initial investment. Small homes, particularly those with limited financial resources, may face barriers to installing conventional air-to-water heat pumps. However, various alternative combinations can provide viable solutions for such scenarios.

This chapter explores alternative heating strategies that can enhance feasibility in situations where a standard heat pump installation may not offer an attractive return on investment. These approaches serve as exceptions rather than large-scale implementations, offering inspiration for tailored solutions.

7.5.1 Use Cases

Alternative heating solutions are particularly relevant for homeowners with low heating demand, space constraints, or financial limitations. The suitability of these combinations depends on factors such as the existing heating infrastructure, climate conditions, and the household's specific thermal comfort requirements.

For instance, homes with pre-existing air-conditioning systems may benefit from integrating heating functions, while residences with solar thermal installations can leverage their existing systems for domestic hot water production. Additionally, temporary or supplementary heating options may be viable where full-scale retrofits are impractical or unnecessary.

7.5.2 Possible Solutions

Several alternative heating configurations can be considered:

Air-to-Air Heat Pumps (Heating and Cooling Systems) with Separate Domestic Hot Water Solution: Air-to-air heat pumps, commonly known as air-conditioning units with heating functionality, can provide an efficient and cost-effective heating alternative in homes with low heating demand. These systems are particularly attractive for small residences where conventional air-to-water heat pumps require a higher initial investment. However, air-to-air systems typically require multiple indoor units to provide even heating across multiple rooms.

A separate domestic hot water solution is necessary since air-to-air heat pumps do not provide domestic hot water. In some cases, these systems are combined with existing gas boilers for domestic hot water, though this is not a long-term sustainable solution. A fully electric setup is possible, though less commonly implemented. Additionally, widespread adoption of air-conditioning units can contribute to the urban heat island effect, particularly in dense urban areas.

Solar Thermal Systems and Heat Recovery for Domestic Hot Water: Homes with existing solar thermal installations can enhance efficiency by integrating them into a heat pump system. While solar thermal collectors may not provide sufficient domestic hot water year-round for larger households, they can significantly contribute to domestic hot water supply in single-occupant homes. By connecting a solar thermal system to a smaller heat pump water tank, homeowners can reduce overall electricity consumption.

In combination with a heat recovery system, these setups can further optimize hot water usage. For example, recovered heat from shower wastewater can be used to preheat incoming water, reducing the energy demand on the heat pump. In cases where additional domestic hot water is occasionally required, an electric heating element can serve as an emergency backup. This approach offers a space-efficient solution while minimizing unnecessary energy consumption.

Electric Portable Heaters for Occasional Heating: For homes where only a few rooms require intermittent heating, portable electric heaters can be a practical supplementary solution. Many homeowners prioritize heating in the living room, while bedrooms and other less frequently used spaces may not require consistent heating. In such cases, the installation of additional low-temperature radiators may be unnecessary, and instead, a small portable electric heater can provide occasional heating-on-demand.

While portable electric heaters are highly inefficient when used as a primary heating source, they can be a cost-effective option for temporary heating in specific situations.

Infrared Heating Panels for Small Rooms with Short-Term Use: In rooms that are used for short periods—such as bathrooms—infrared heating panels can provide targeted warmth with minimal energy consumption. Unlike conventional heaters, which warm the air, infrared panels directly heat objects and people within their range. This approach can reduce the heating demand on the primary system while avoiding modifications to the home's existing radiator or piping system.

7.5.3 Conclusion

Alternative heating solutions offer flexible and cost-effective options for homes where a standard heat pump installation is not financially or technically viable. By integrating existing infrastructure and combining different heating technologies, homeowners can achieve improved efficiency while minimizing installation costs. However, these solutions remain highly situational and are not intended for widespread adoption.

If case studies demonstrate that certain combinations work effectively in multiple scenarios, they may serve as a basis for new, scalable heating models in the future.

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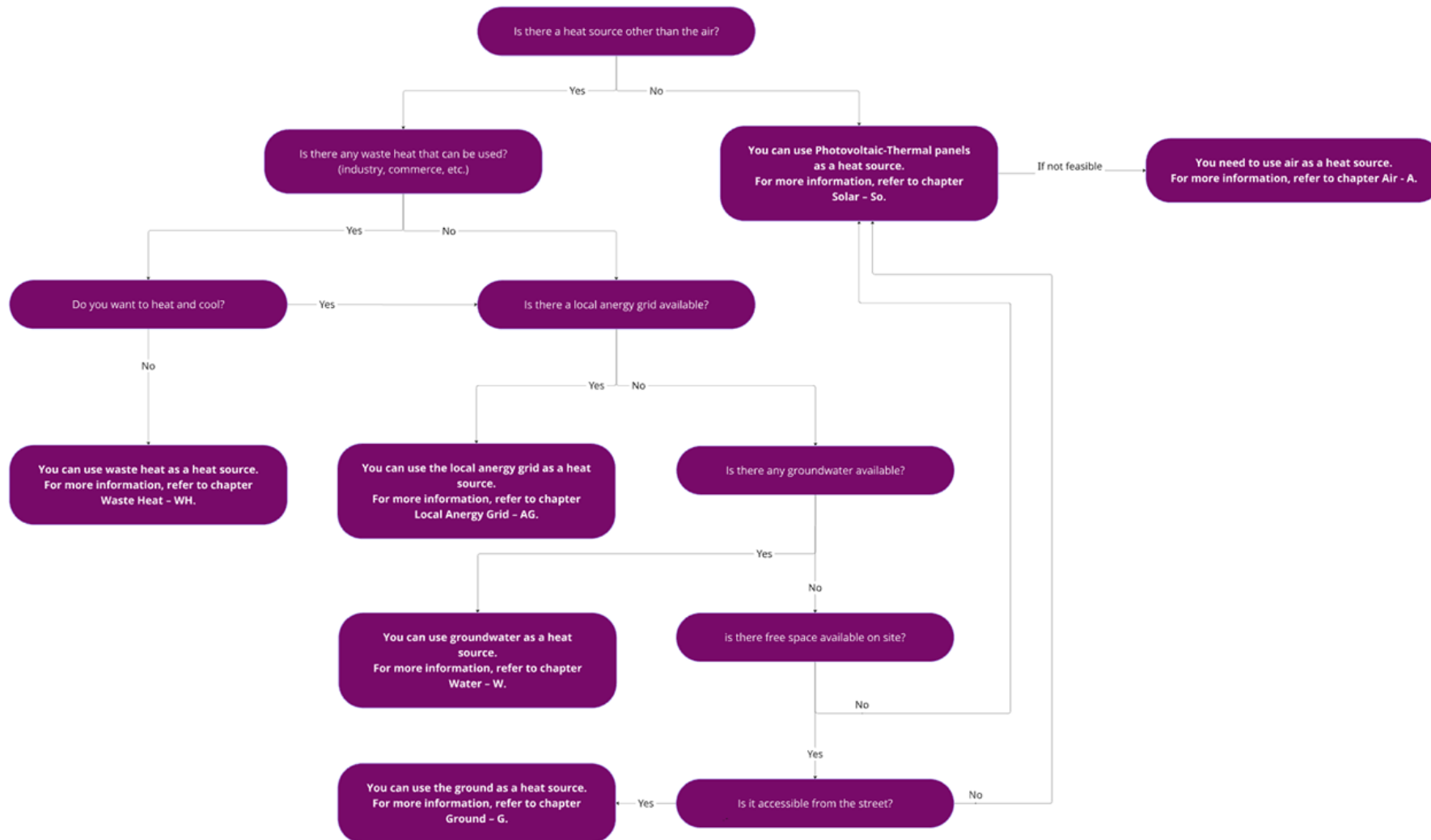
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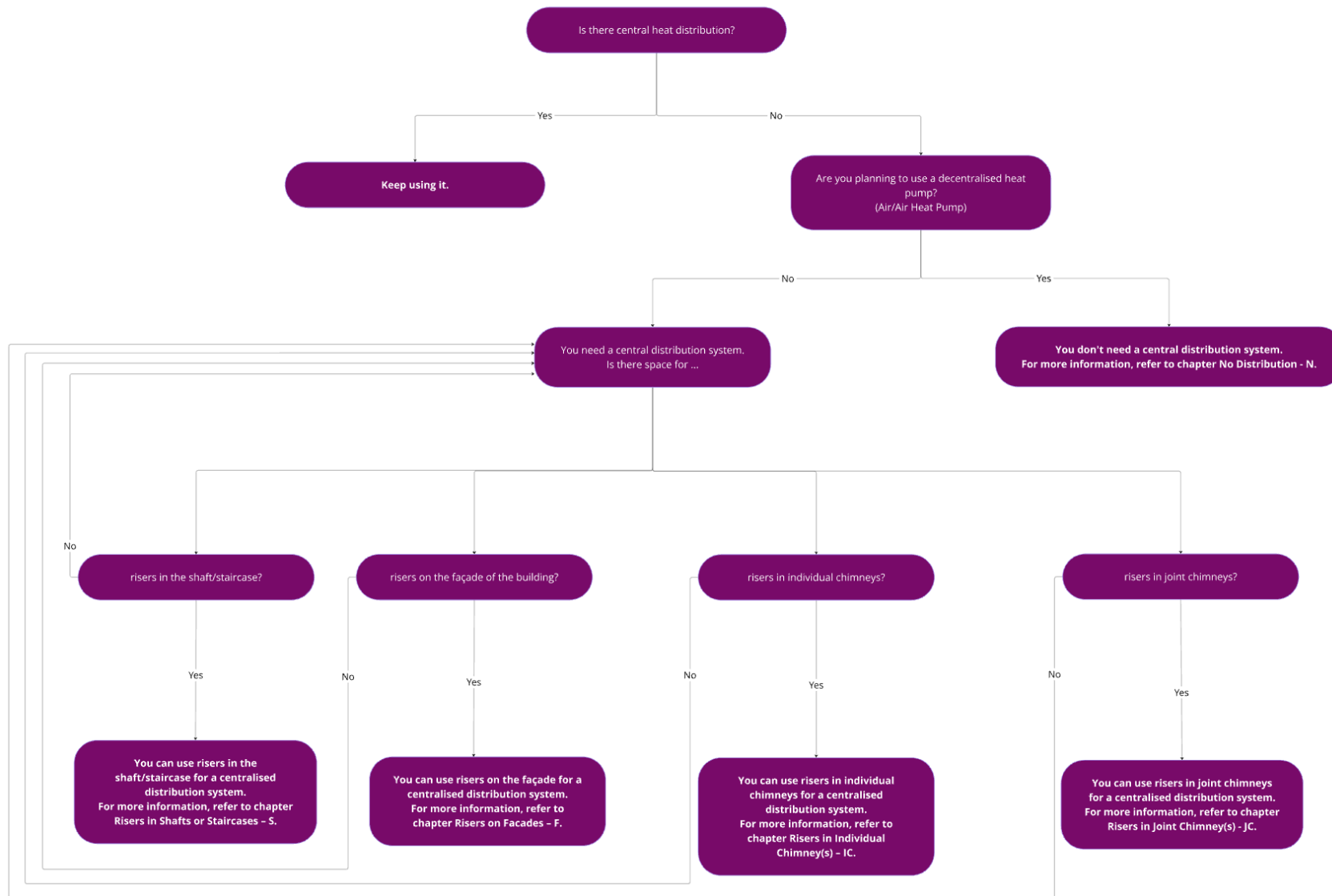
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Annex I– Decision Trees

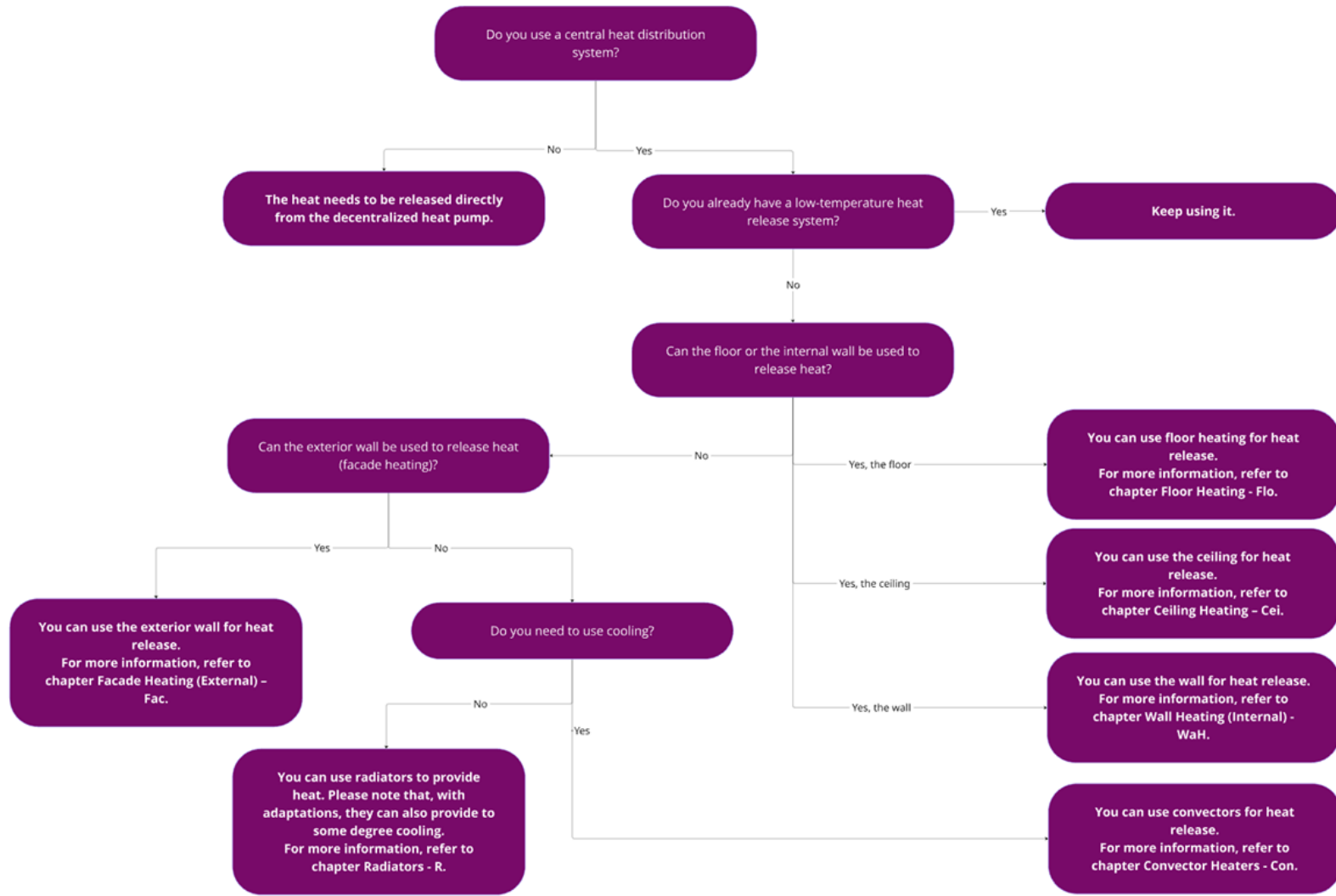
Heat Sources and Sinks



Centralised Hydronic Distribution

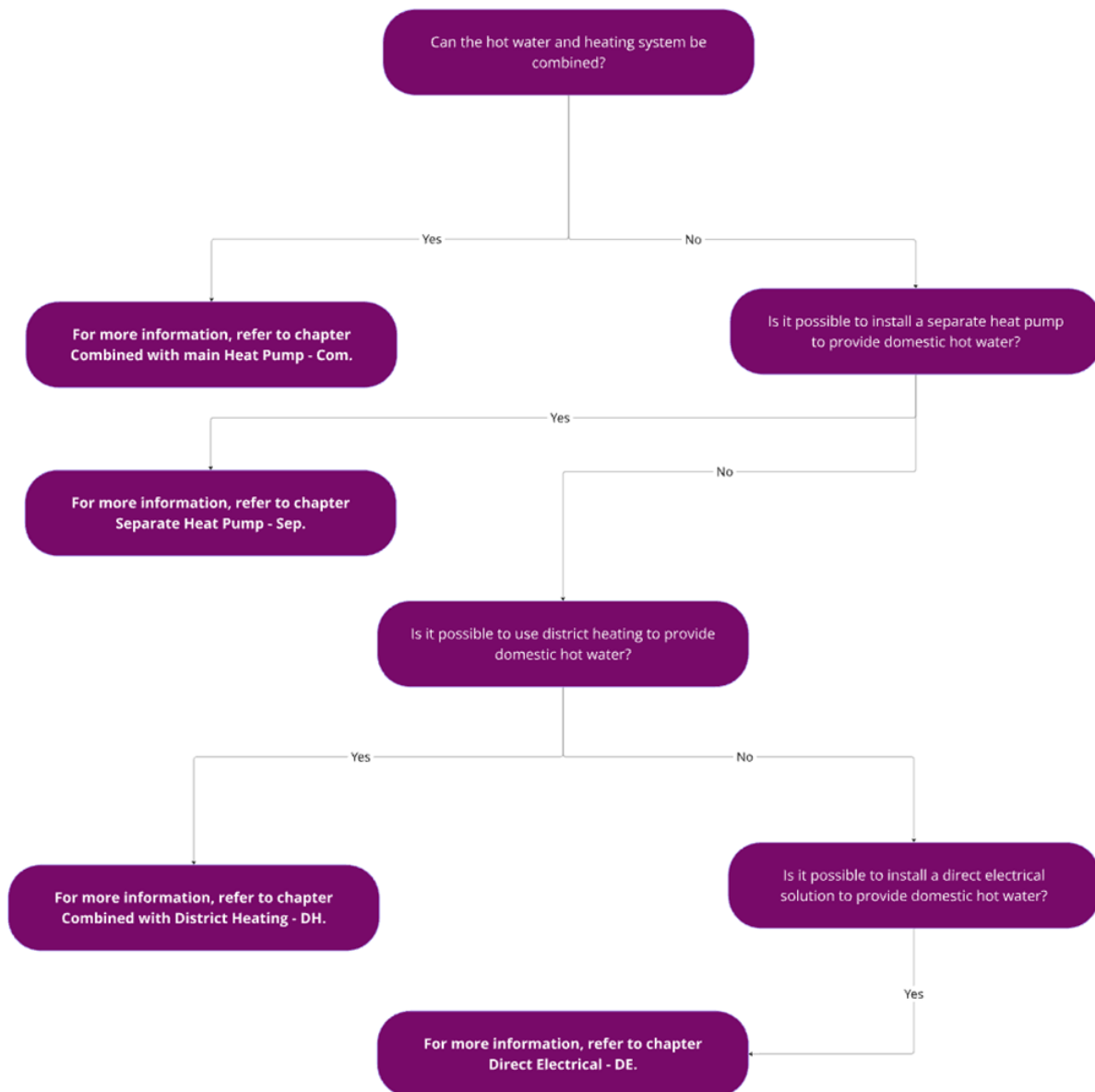


Heat Release





Domestic Hot Water





www.energyagency.at/en/installres

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