

How life sciences organisations can decarbonise heat

Technology guide

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Understand your options for decarbonisation technology

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“For life sciences organisations, implementing decarbonisation technology is almost always the largest step to decarbonisation. It typically accounts for 50-70% of site emissions.

For most life sciences applications, there are several solutions, possibilities and combinations to choose from on the path to decarbonisation.

Knowing what the options are is the first step and so we have created this guide to help you become more familiar with the potential solutions.”

**Thanos Patsos, Service Director,
Sustainable Transition, Delivery**

Decarbonise efficiently

If you want to understand your carbon reduction options in detail, our Deep Dive audits can identify opportunities for energy reduction and process efficiency.

[Find out more about Deep Dive audits](#)

If you’re looking to future-proof your business and projects by planning decarbonisation measures in advance, our Optimal Implementation Plan service can help you minimise costs and risks, ensure compliance and enhance transparency.

[Discover the Optimal Implementation Plan service](#)

And if you know you want to focus on heat decarbonisation, read on...

Decarbonising heat in life sciences manufacturing

Why decarbonise heat?

Heat is one of the most carbon-intensive elements of pharmaceutical, biotech and med-tech manufacturing. Processes such as sterilisation, drying, fermentation, water-for-injection generation, and HVAC for cleanrooms all rely heavily on thermal energy. Therefore, when you're making carbon reduction plans in line with health sector requirements and/or your own targets, it's a key consideration.

Why read this guide?

For many applications across the life sciences industry there are several solutions to consider when it comes to heat decarbonisation, but choosing the right path is not always obvious. That's why our team of engineers created this detailed guide - to take you through the availability, maturity and key elements of each of the options. They've been navigating the complexity of manufacturing processes, across industries, for years, and can give specialist advice on the most efficient and effective ways forward.

A summary, in case you're short on time...

- Switching from gas power to the electrification of heat (using heat pumps and/or electric boilers) is increasing in popularity. The business case for an electrification solution is strong if cost savings can be calculated, but these are dependent on system efficiency, the relative price of electricity and the availability of a fuel source.
- Low carbon fuels (such as hydrogen and biomass) can provide a sustainable solution for heat decarbonisation, especially in replacing existing hot water or steam raising applications. However, their applicability largely depends on fuel availability of supply and location.
- Renewable heat sources (such as solar thermal and geothermal) are becoming more widespread as part of a mix of heat sources to decarbonise heat production. These can be effective where temperatures and underlying geology are favourable, but are largely dependent on location.

The rest of the guide explores the three topics above in detail.

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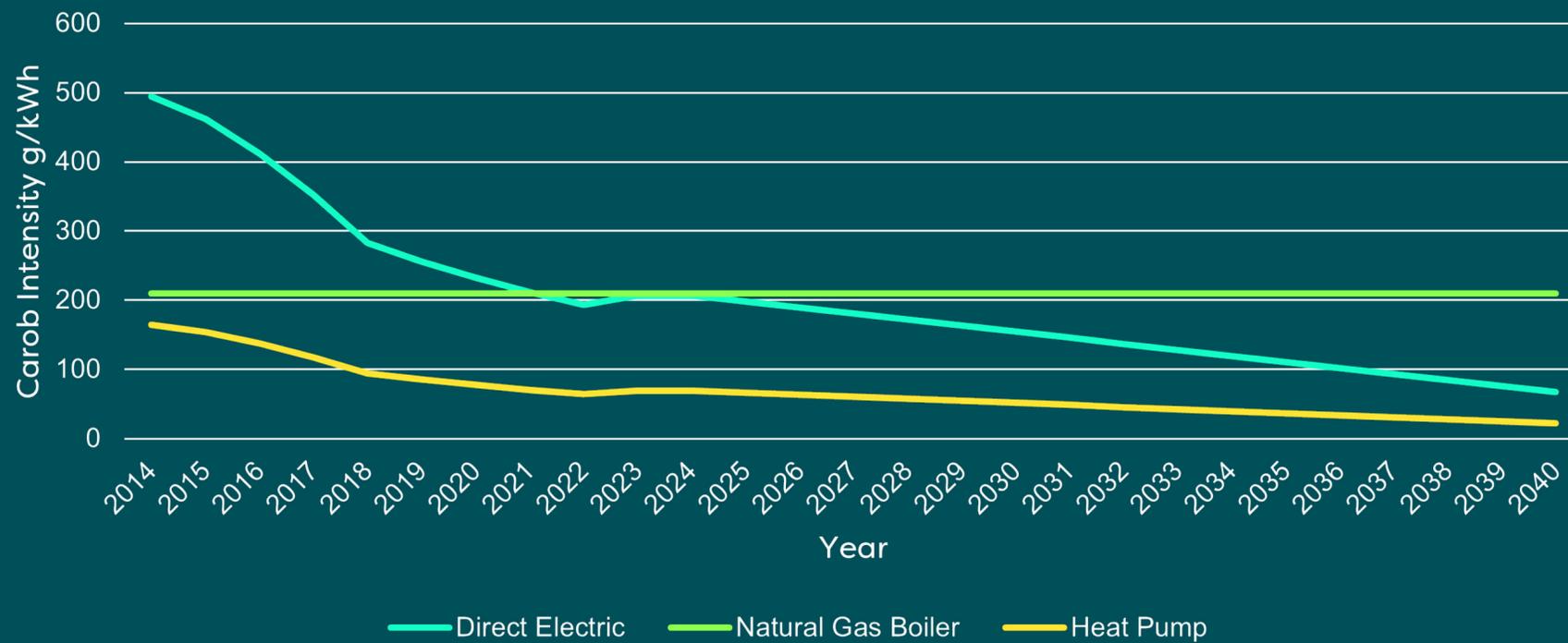
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Electrification of heat

Electrification of heat

Emissions Intensity of Heat Produced by Different Technologies in the UK

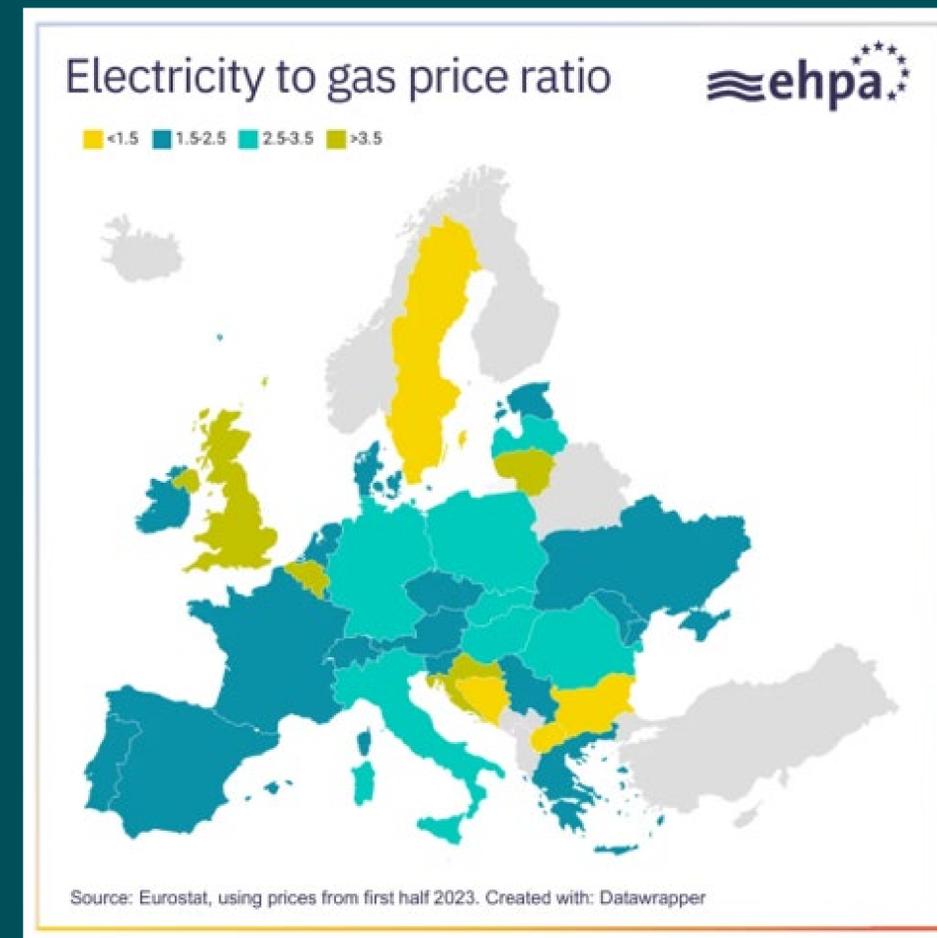
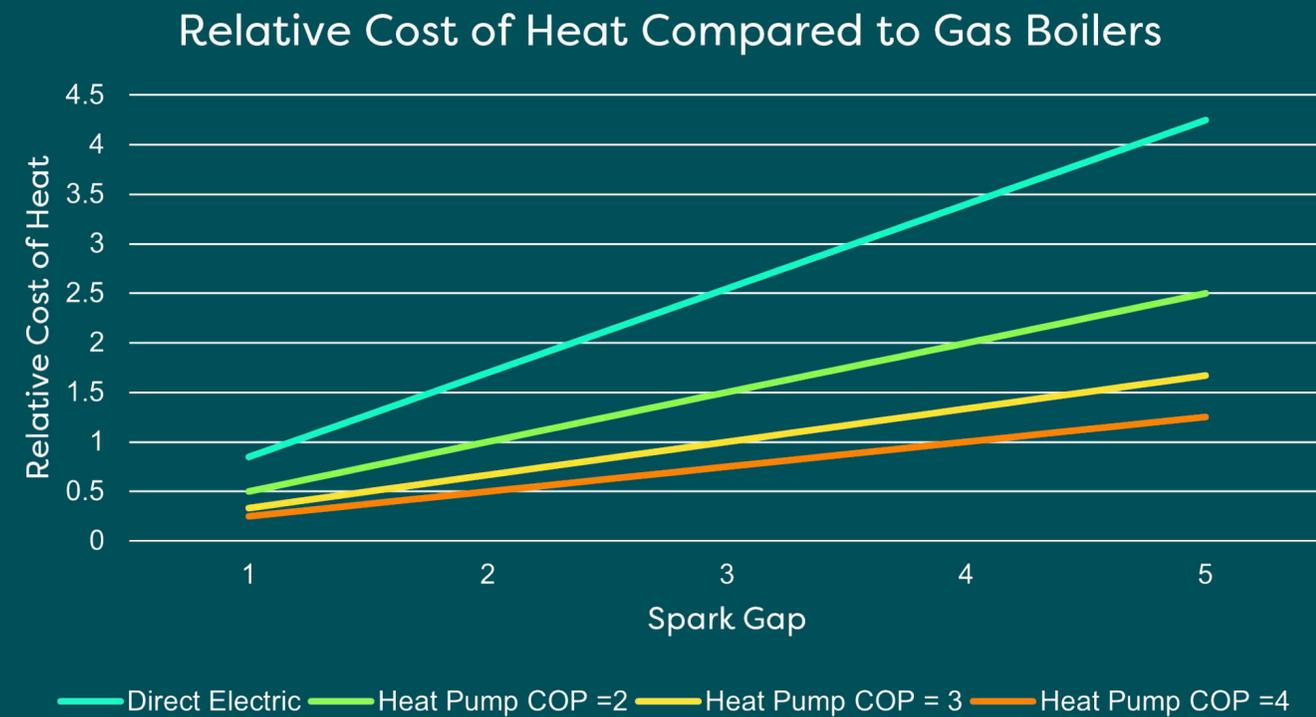


Increase in renewable electricity production means that electricity is becoming a lower carbon source of heat than fossil fuels. This varies with region. Switching from gas to electricity is increasing in popularity in the decarbonisation of industrial heat. The level of decarbonisation (gCO₂/kWh reduction) will partly depend on the relative carbon intensity of electricity and current fuel source for heating and the type of electrification technology chosen.

Note: Historic UK Grid emission factors have been used for the period 2014 to 2023 and a linear extrapolation to a predicted grid intensity of 67 g/kWh in 2040.

Cost of heat electrification

The business case for an electrification solution will be dependent on the system efficiency, the relative prices of electricity and existing fuel source.



Graph shows electricity:gas price ratio

Based on Eurostat energy prices 2023. Graphic taken from The European Heat Pump Association: In which countries does the electricity price work for heat pumps? – European Heat Pump Association

In general, if the fuel: electricity price ratio is lower than the system COP the solution will provide operational cost savings.

Heat pumps overview

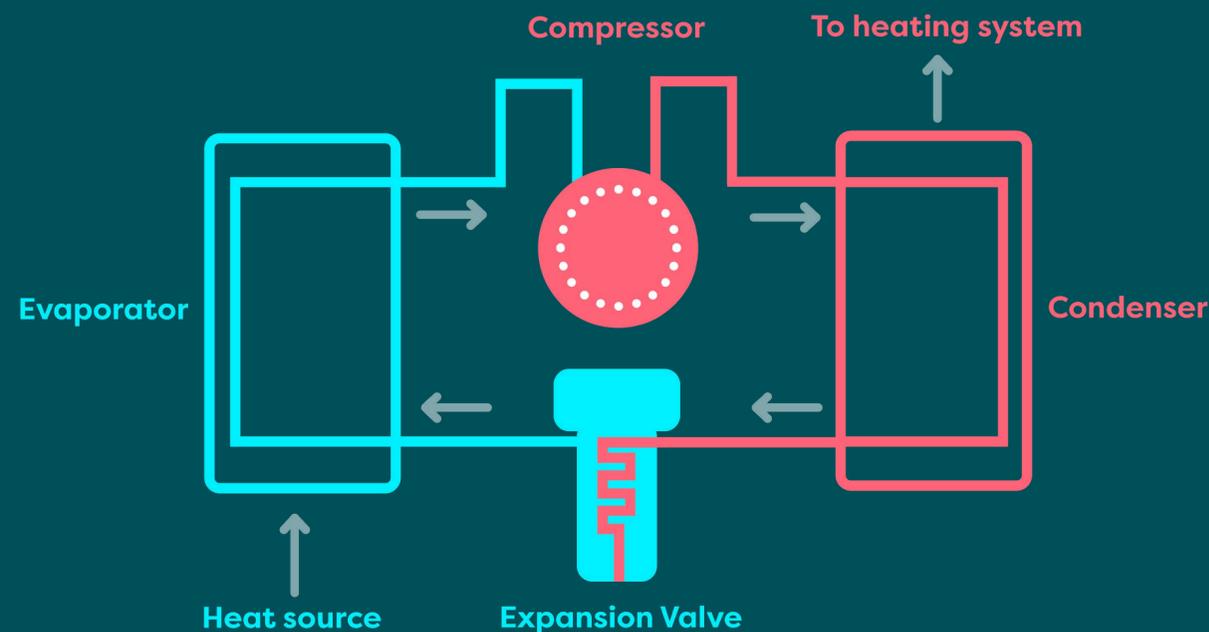
How a Heat Pump Works

A heat pump uses the refrigeration cycle to transfer heat from a colder heat source and then elevates (or 'pumps') the heat to a higher temperature for use in heating applications. Typical heat sources for a heat pump include air, the ground or waste heat.

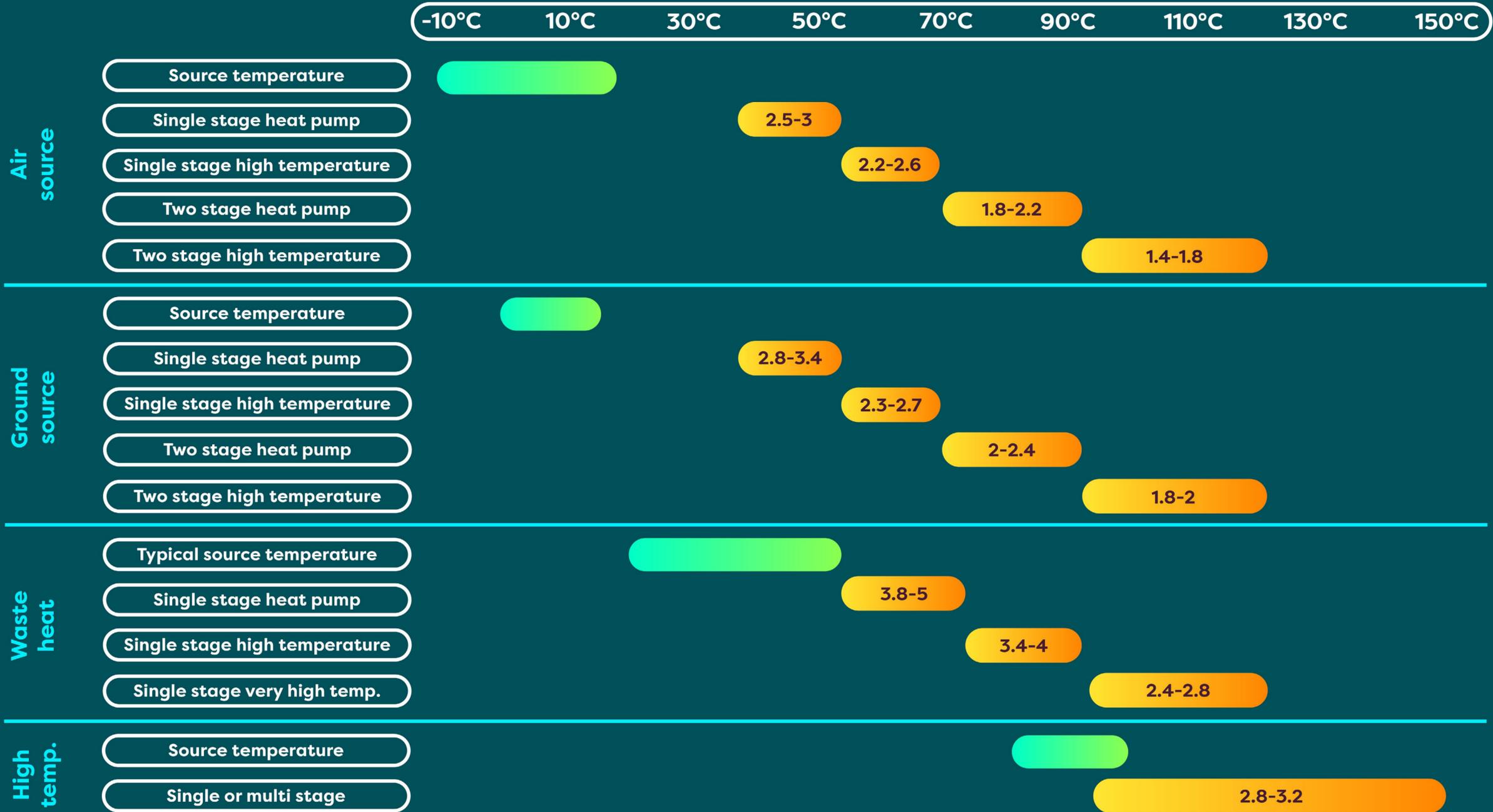
The performance of a heat pump is measured in terms of the Co-efficient of Performance (COP). This is the ratio of heat output to energy used by the heat pump to run the compressor and other components. The higher the COP the more efficient the heat pump.

Key considerations

- Identification of heat source and operating temperatures is critical.
- Space planning - plant footprint will be higher than traditional boiler systems.
- Temperature difference between heat source and heat output is a limiting factor.
- Higher temperature lifts can be provided by operating multiple stages of heat pumps in series at a lower overall COP.



Heat pump operating ranges



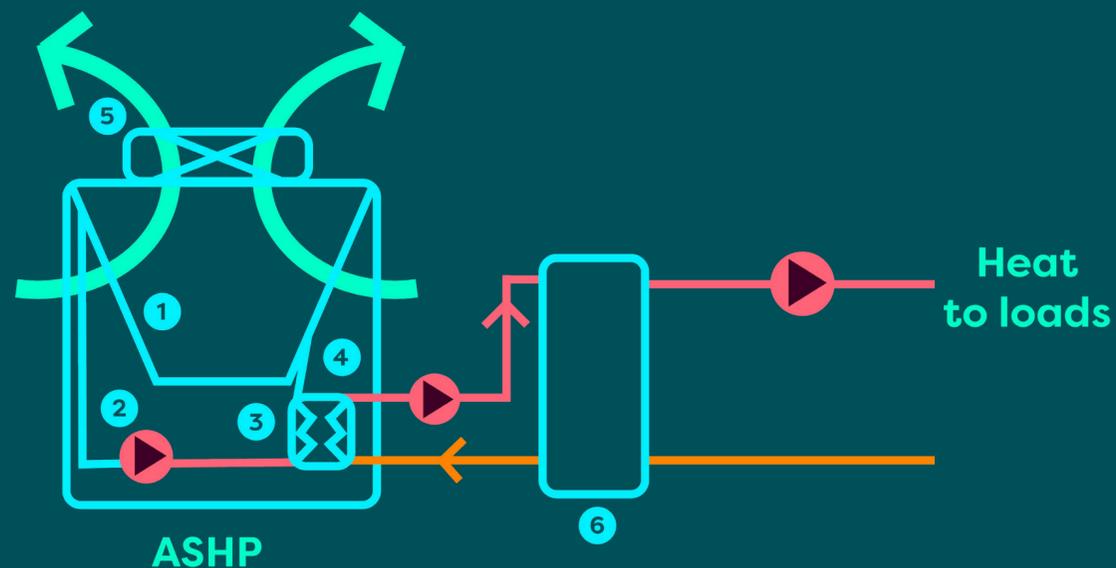
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Air Source Heat Pump (ASHP)

Air source heat pump uses fans to pull air across evaporator coils and extract heat from the air.

Heat delivered typically as low temperature hot water (LTHW). Best fit for low temperature applications e.g. clean rooms, sanitation, cleaning, drying and media/buffer preparation. Efficiency decreases as temperature of LTHW increases.

Maximum temperature of heat a limiting factor. Higher temperatures can be achieved with additional heat pumps in series.



ASHP

- 1 Evaporator coils
- 2 Compressor
- 3 Condenser
- 4 Expansion valve
- 5 Fans
- 6 Buffer tank

Technology maturity

In widespread use and readily available.

Potential net zero carbon impact

Good option for low temperature heat demands.

Fuel availability

Grid electricity readily available although capacity may be limited in some areas.

Capex

Higher Capex than conventional gas plant.

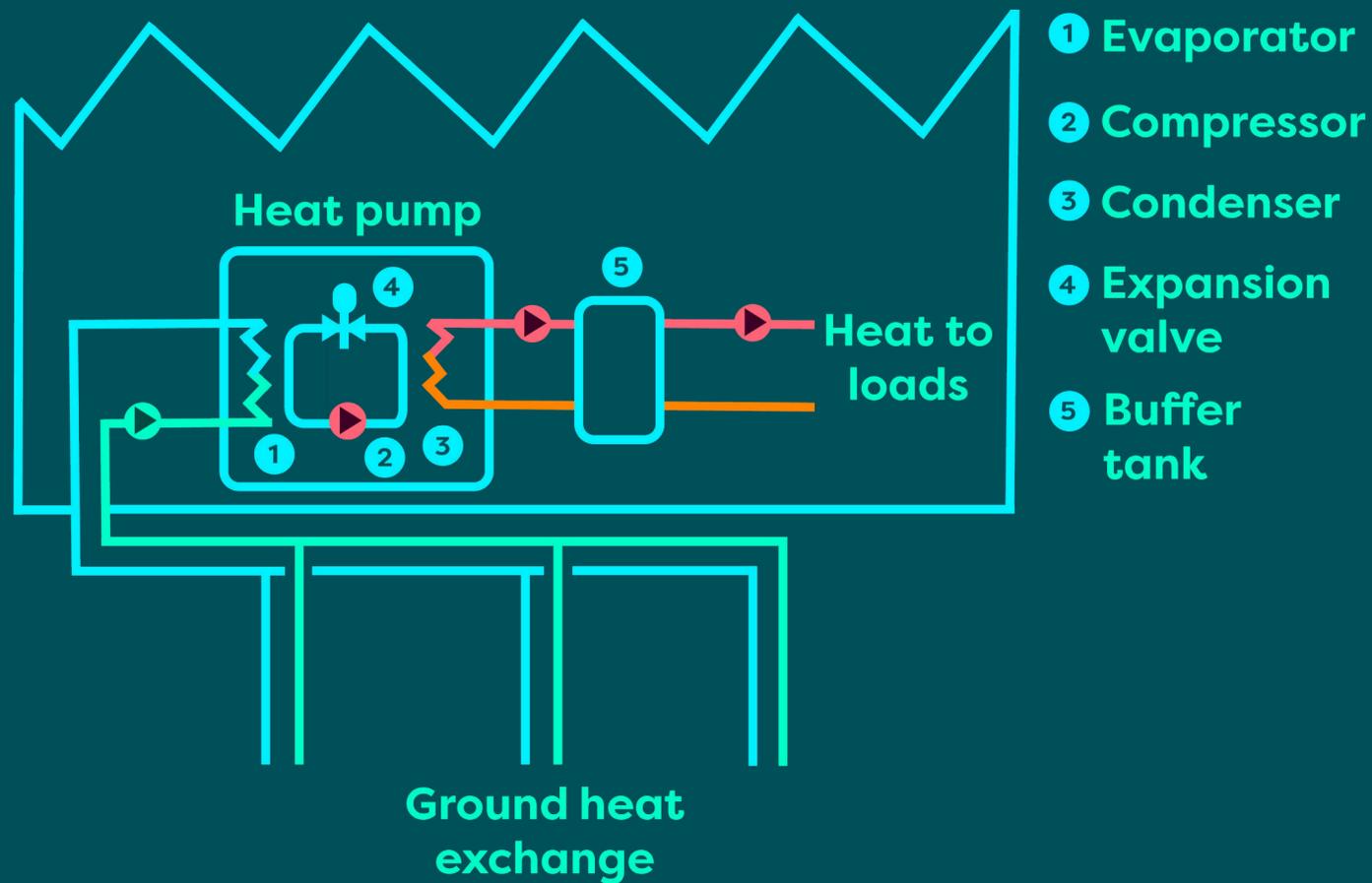
Opex

'Spark gap' dependent but potential for low fuel costs.

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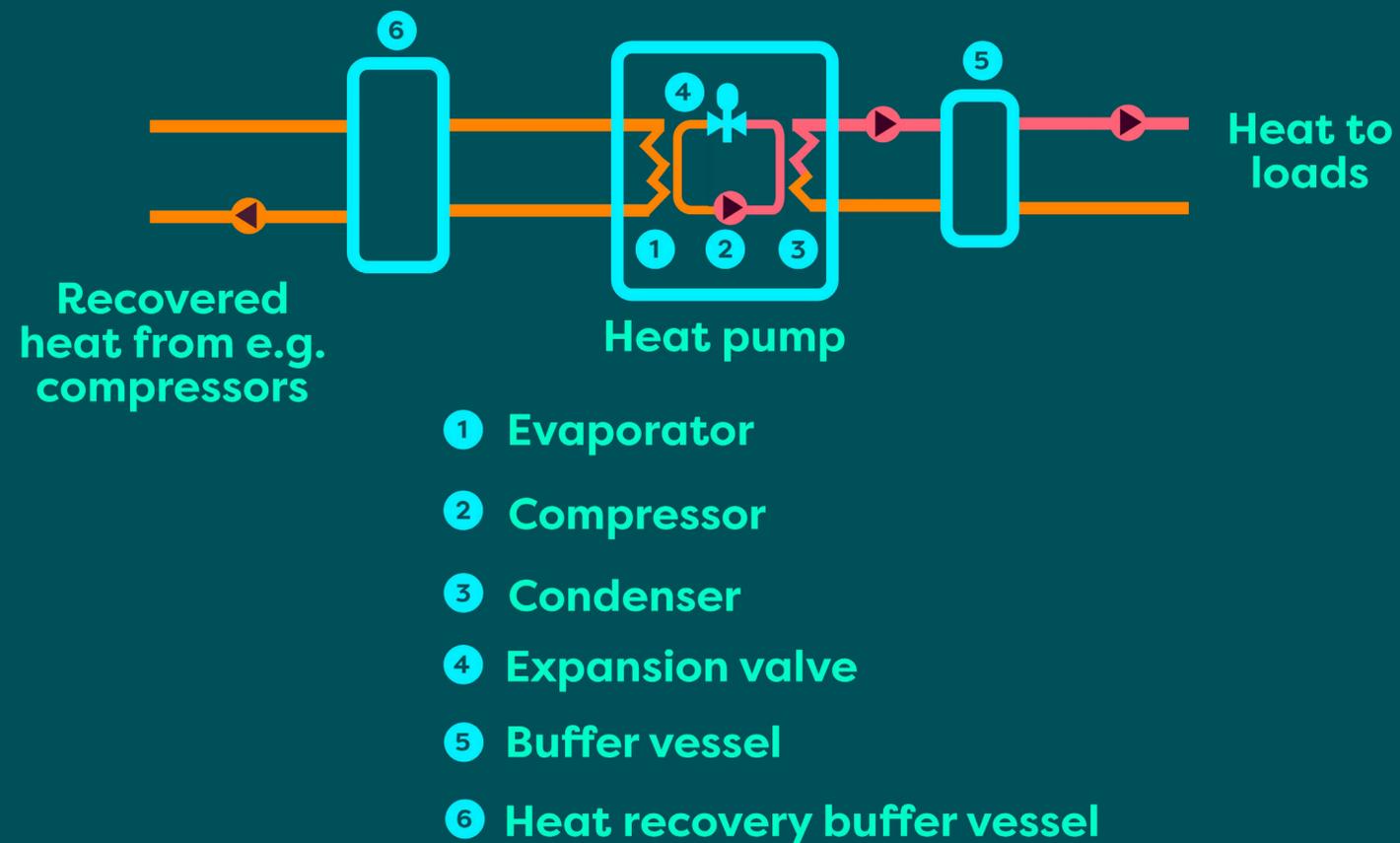
Ground Source Heat Pump (GSHP)

Ground source heat pumps extract heat from the ground with a network of heat exchange pipework or direct from aquifers. Similar heat distribution and temperature considerations to ASHP. Significant space and ground works required for the ground heat exchanger array.



Technology maturity	In widespread use and readily available.
Potential net zero carbon impact	Good option for low temperature heat demands.
Fuel availability	Grid electricity readily available although capacity may be limited in some areas.
Capex	Higher Capex than conventional gas plant and air source heat pumps.
Opex	'Spark gap' dependent but potential for low fuel costs.

Waste Heat Source Heat Pump



Waste heat pump systems use rejected heat as a heat source to deliver heat at higher temperatures.

Potential waste heat sources include air compressors, refrigeration systems and also fluidised bed dryers.

Typical operating temperatures are around 40°C for waste heat and 85°C on the output side. Higher temperatures can be achieved at lower COPs and with hotter waste heat sources.

Technology maturity

In widespread use and readily available but not as common as ASHP or GSHP.

Potential net zero carbon impact

Good option for sites with waste heat.

Fuel availability

Grid electricity readily available. Waste heat sources may be limited.

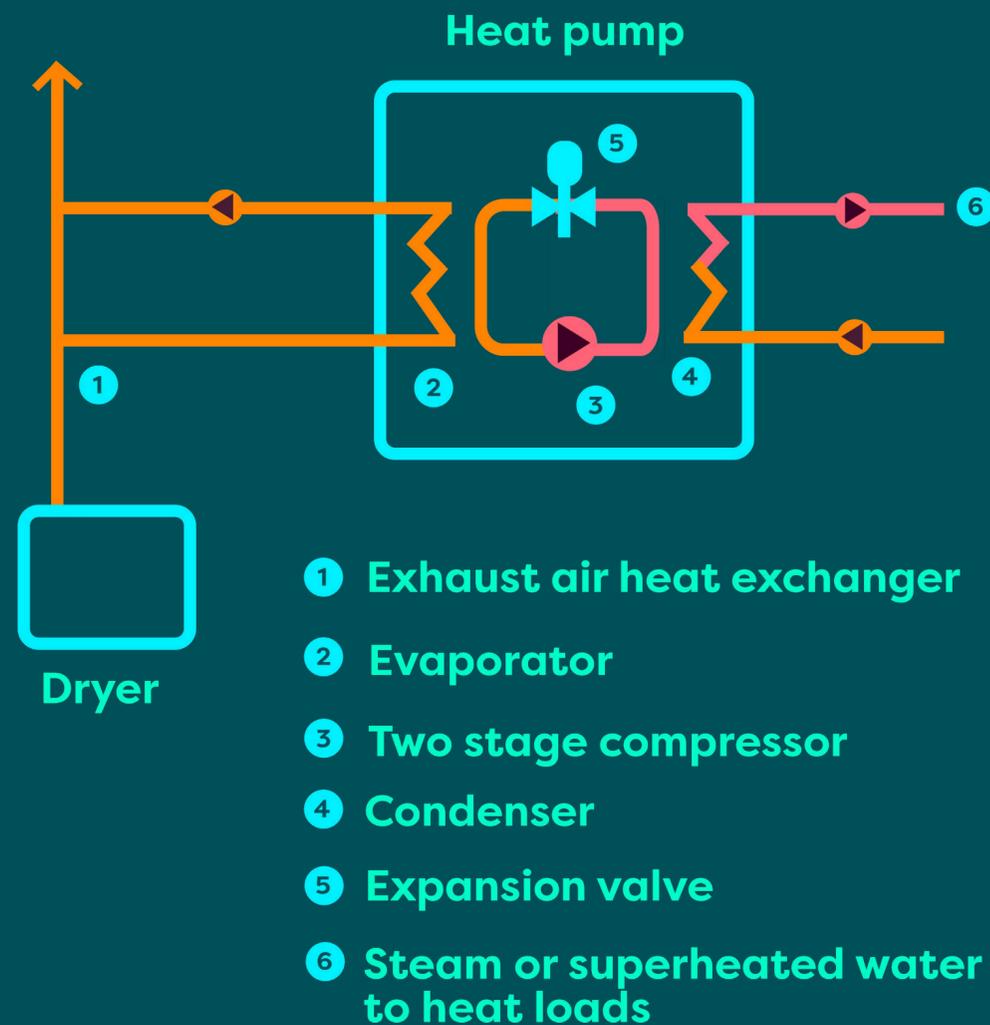
Capex

Higher Capex than conventional gas plant and air source heat pumps. Heat recovery systems attract additional cost.

Opex

'Spark gap' dependent but potential for lower fuel costs than ASHP/GSHP.

High Temperature Heat Pumps



High temperature heat pumps are available to deliver heat at up to 150°C using high temperature heat sources.

Potential high temperature heat sources may be limited in life science processes e.g. hot steam condensate, CIP/SIP discharge or high temperature fluidised bed dryers.

Heat delivered as steam or superheated water.

Additional implementation costs associated with heat recovery systems.

Technology maturity

Emerging technology - not in widespread use.

Potential net zero carbon impact

Can decarbonise a wide range of heat demands up to 150°C.

Fuel availability

Grid electricity readily available. Waste heat sources may be limited.

Capex

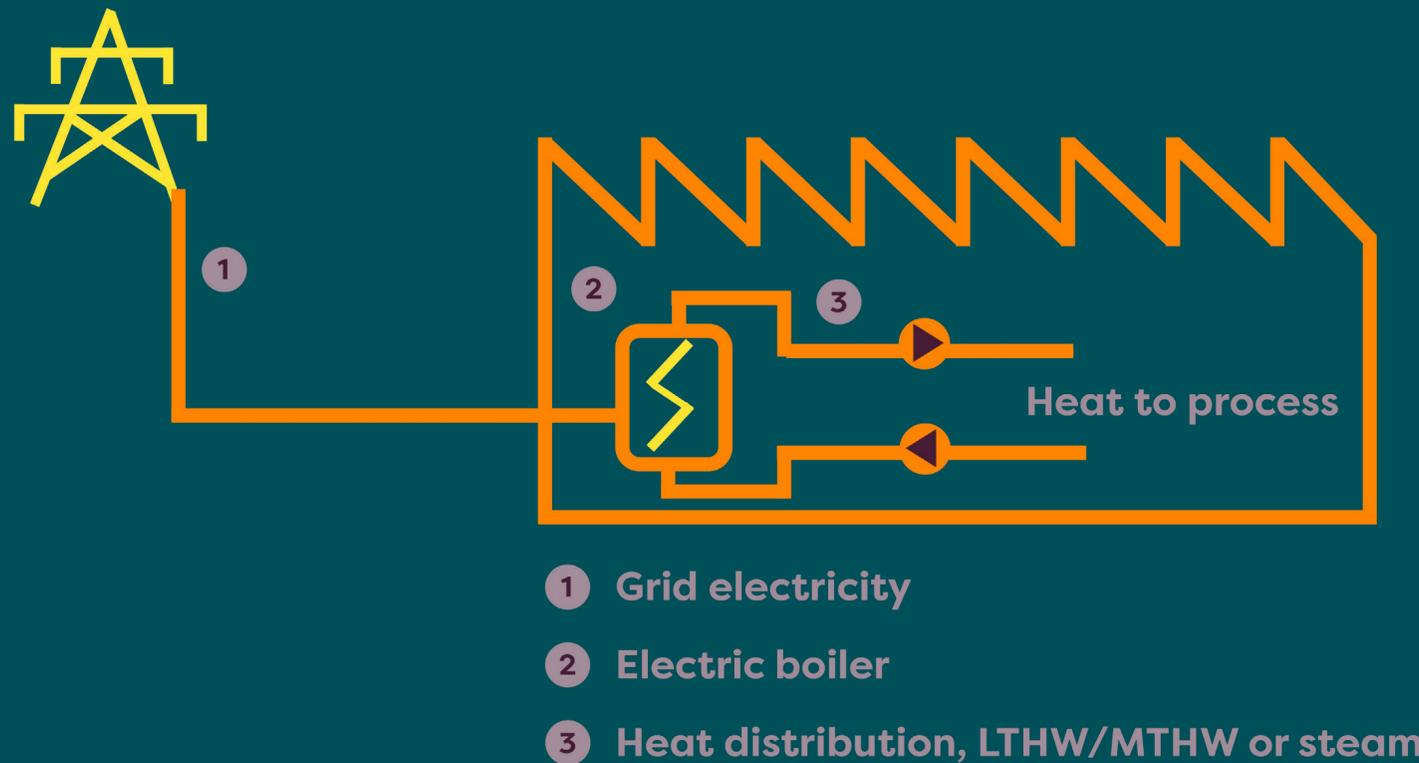
Higher Capex than conventional gas plant and air source heat pumps. Additional costs involved to collect waste heat.

Opex

'Spark gap' dependent but potential for lower fuel costs.

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Electric boilers



Electric boilers are similar to traditional boilers but operate on electricity through resistive heating elements or electrodes.

Heat can be delivered to LTHW systems or as steam which makes them applicable to a range of life science applications e.g. water for injection, cleaning/sterilisation and jacket heating.

Can be used at small scale to deliver heat to isolated loads or high temperature loads.

Capex investment significantly lower than heat pumps but opex much higher.

Technology maturity

Established technology.

Potential net zero carbon impact

Emissions in line with grid carbon factor.

Fuel availability

Grid electricity ready available. Greater peak capacity needed than heat pumps.

Capex

Lower Capex than heat pumps and comparable with gas boilers.

Opex

Much lower efficiency than heat pumps and electricity costs results in high Opex.

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Electrification of heat overview

	Air source heat pumps	Ground source heat pumps	Waste heat source heat pumps	High temp. heat pumps	Electric boilers
Technology maturity	High	High	Medium	Low	High
Potential net zero impact	Medium	Medium	High	High	Medium
Fuel availability	High	High	Medium	Medium	Medium
Capex	Medium	Low	Medium	Low	High
Opex	Medium	Medium	High	Medium	Low

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Expert overview



“In regions with a large spark gap it is critical that systems are designed to achieve as high a Co-efficient of Performance as possible to deliver operational savings alongside reductions in carbon emissions. Understanding the temperature profile of your processes is a key starting point for moving to heat pumps and more nuance is needed in design over traditional steam boiler systems.

Utilising waste heat sources (such as from refrigeration and air compressors, as well as fluidised bed dryers or hot steam condensate) can result in very high system efficiencies. Alternatively, electric boilers provide a convenient source of heat across most life sciences applications and are ideal within a decarbonised grid. However, current electricity prices and grid capacity can limit their application to situations such as isolated, high temperature processes.”

Matt Dickinson, Head of Service, Capital Projects

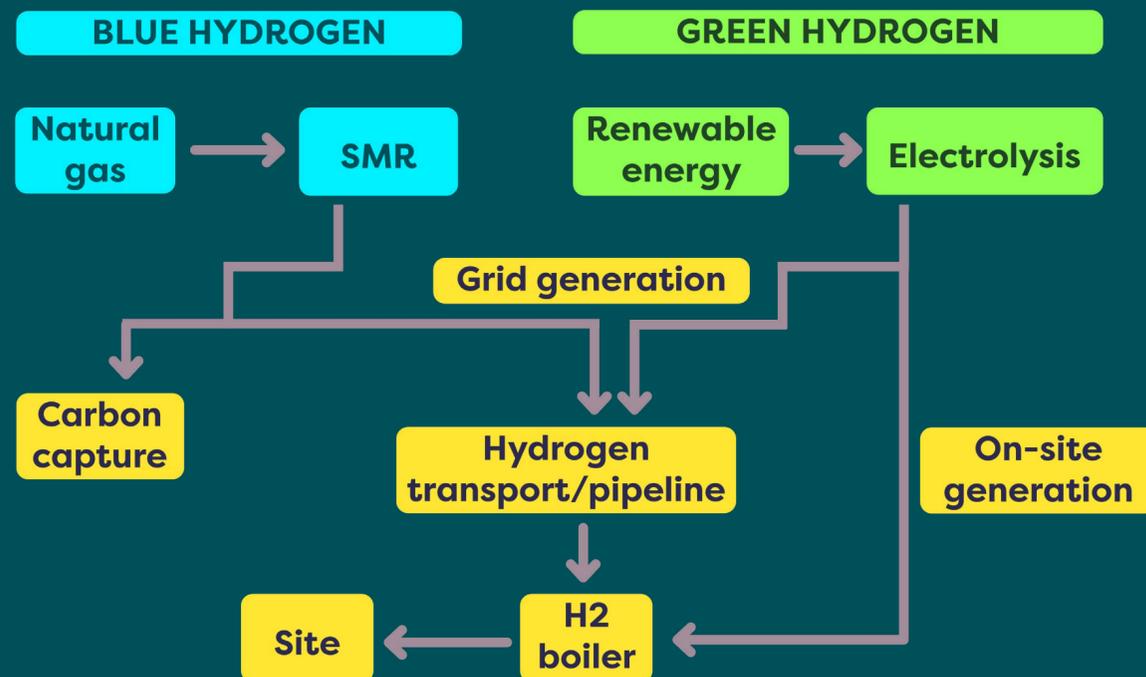
Low carbon fuels

Hydrogen

Hydrogen fuel can be derived from multiple sources (see table). Blue and green are planned routes for most future low-carbon hydrogen.

Hydrogen is a potential solution for the hardest to abate sections of industry with specific very high temperature requirements (e.g. chemicals, glass & minerals, iron & steel manufacturing).

For most life sciences processes with temperatures < 200°C, electrification is likely to provide a more attractive alternative due to its energy efficiency and availability.



Technology maturity	Green hydrogen (electrolyser) technology is becoming available, CCUS for blue hydrogen not currently available.
Potential net zero carbon impact	Potential for high temperature applications but depends on source of H2 and whether process is already electrically heated
Fuel availability	Very location-specific.
Capex	High capital for local generation via electrolyzers, uncertain costs for grid hydrogen. Onsite costs low, may need to change boiler burner.
Opex	Green H ₂ - very high. Blue H ₂ - likely to be more competitive vs. fossil fuels.

Hydrogen colours

Green - electrolysis from renewable electricity

Blue - fossil fuels with CO₂ capture

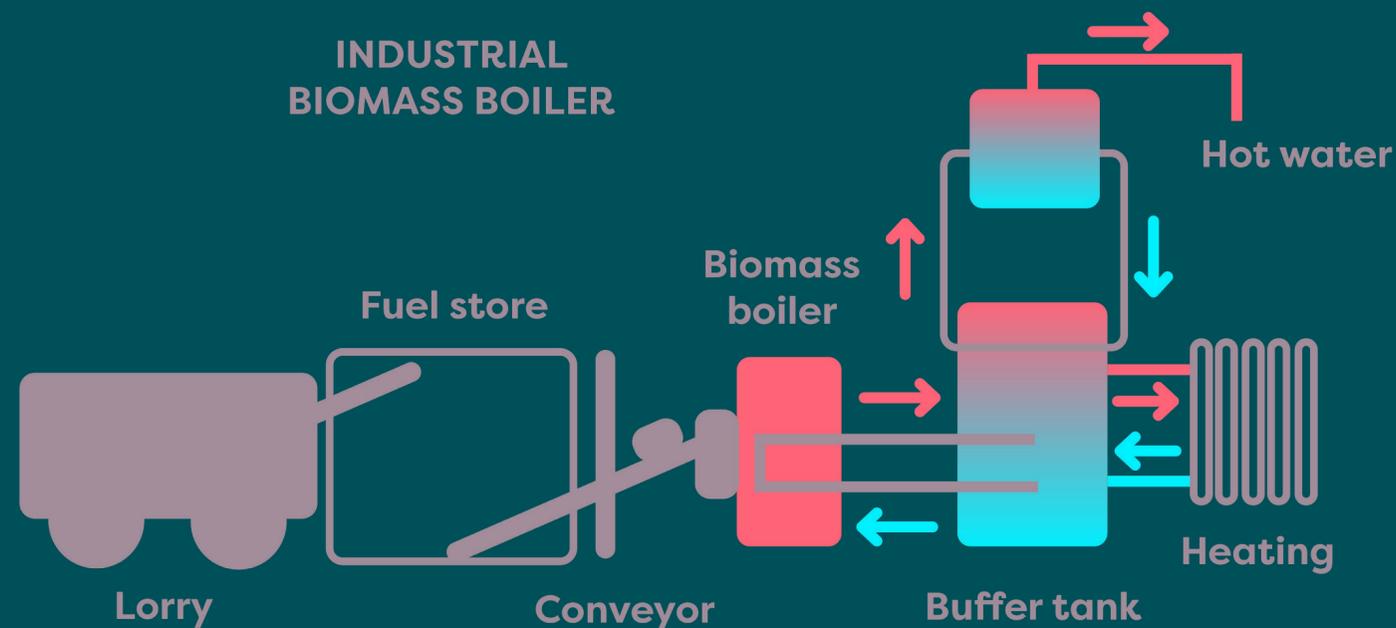
Grey - natural gas no CO₂ capture

Brown/black - coal no CO₂ capture

Pink - electrolysis from nuclear generated electricity

Biomass

Similar to hydrogen, biomass is expected to play a small but targeted part in the decarbonisation of industrial heat. Biomass is usually used for electricity generation, with carbon capture added in the future. Biomass can provide all the same heating functions as conventional fossil fuel systems, for example steam production, so it can be used to replace a conventional boilerhouse or CHP.



Technology maturity

Very mature technology. Practicality of running large industrial biomass plants can be challenging.

Potential net zero carbon impact

High for most life science applications for hot water and steam generation, provided sustainable biomass is sustainably sourced.

Fuel availability

Securing a long term, local & sustainable biomass supply is a challenge. High frequency of deliveries required – traffic on site.

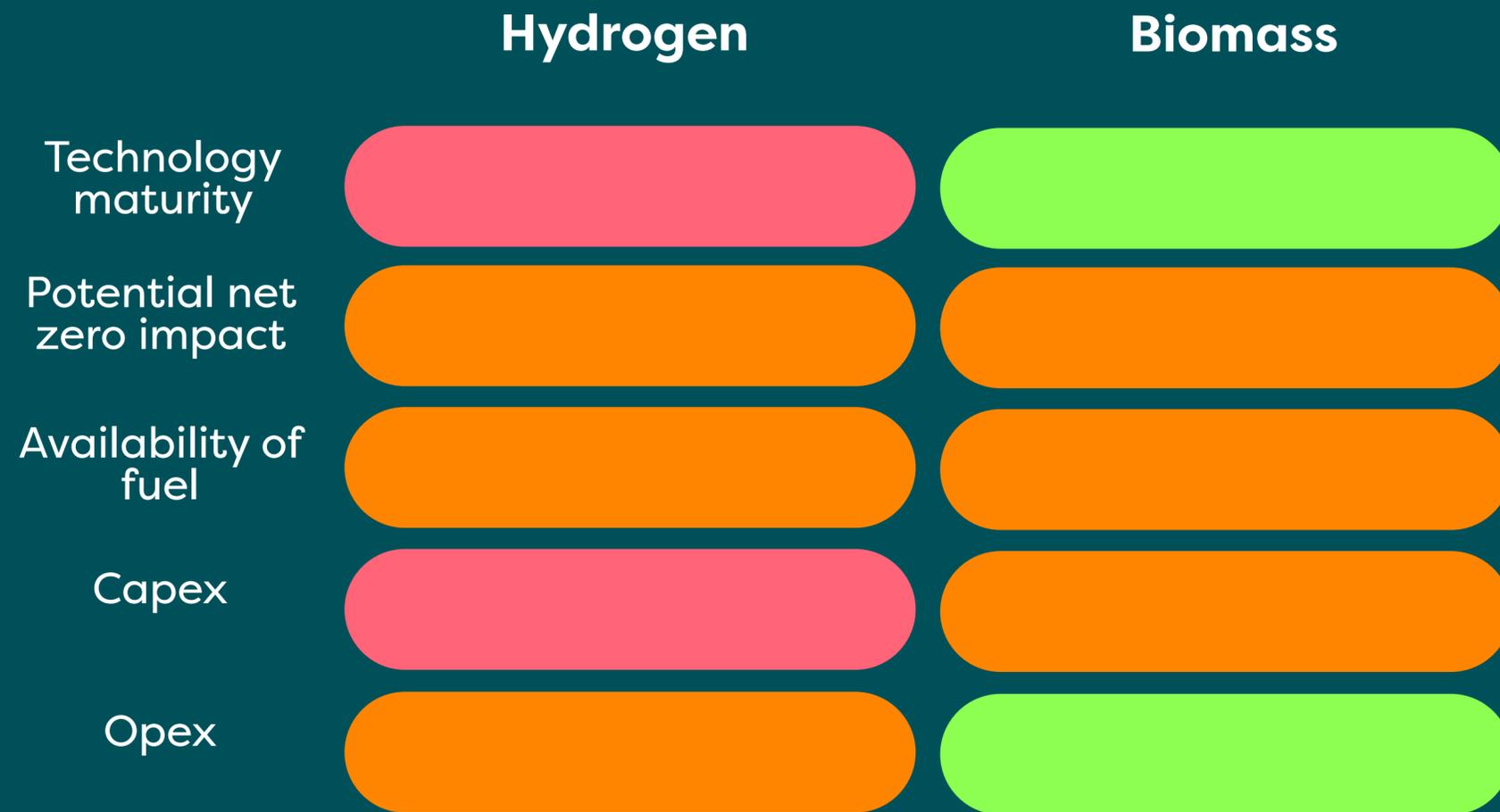
Capex

Up to 50% more than typical fossil fuel boiler, alongside additional capital cost relating to fuel storage.

Opex

Highly dependent on supply, but can be close to parity with traditional fossil fuel boilers.

Fuel comparison



Consider low carbon fuels



“Low carbon fuels can provide a sustainable solution for heat decarbonisation in the life sciences industry, especially in replacing existing hot water or steam raising applications, but their applicability will largely depend on fuel availability of supply and location. For most processes with heat demands of less than 200°C, electrification of heat might provide a more attractive alternative.”

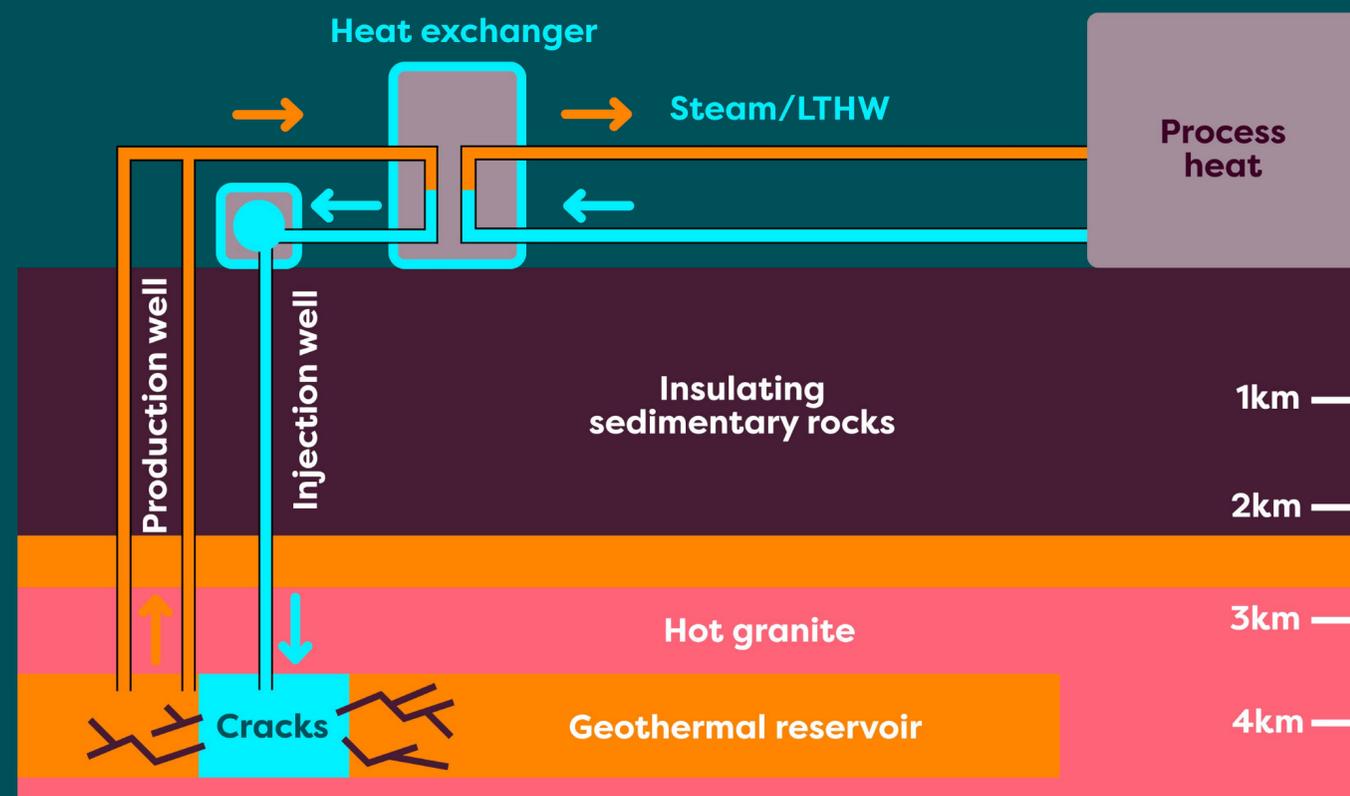
Jonny Pigott, Senior Consultant, C&I Performance & Resilience

Renewable heat

Deep geothermal energy

Geothermal energy is heat extracted from the earth. It has been used for thousands of years, e.g. in hot springs, and more recently has moved into industrial-scale projects for heating and electricity generation.

Deep geothermal heat is drilling wells of ~ 2,000–5,000m in depth into dry or wet rocks. Dry rock heat corresponds to areas of granite where water is injected into the first well, obtaining heat and being withdrawn through the production well (illustrated below). In wet rock conditions, the hot water (already present) is extracted, the heat is removed and the water is reinjected to heat up again. Deep geothermal heat can be obtained in a wide range of temperatures, from 20°C up to steam, but the grade of heat obtained is dependent on your location.



- Technology maturity** Use of geothermal energy is very mature. Deep geothermal heat extraction is becoming more common.
- Potential net zero carbon impact** Geothermal energy is a zero-carbon heat source. Can satisfy most hot water and steam applications in the life sciences industry.
- Fuel availability** Geothermal heat is very abundant, but the grade of temperature varies.
- Capex** High capital costs and risk, as confirmation of temperature is only possible through drilling the well.
- Opex** Heat is free once the wells are drilled. Stable long term heat source, can last 100+ years.

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Solar thermal panels

In solar thermal panels, fluid is circulated through solar collectors. Solar collectors can be flat plates or types of evacuated tube. Evacuated tube collectors offer higher efficiency and operating temperatures at higher cost.

The heat from these panels is generally used for domestic hot water production but can also be used in combination with other heat sources e.g. heat injection to boiler circuits.

Higher annual yields can be achieved at lower operating temperatures. Temperature output range typically 40°C to 70°C, making this potentially applicable to sanitisation, drying, cleaning and CIP applications.



- 1 Solar collectors
- 2 Buffer vessel
- 3 Heat exchanger
- 4 Heat source e.g. boiler

Technology maturity

Mature technology. Adoption varies by country.

Potential net zero carbon impact

Carbon-free heat but availability limited by solar. Limited to low temperature applications.

Fuel availability

Location and season dependent.

Capex

Good return but cannot replace existing plant.

Opex

Zero fuel costs.

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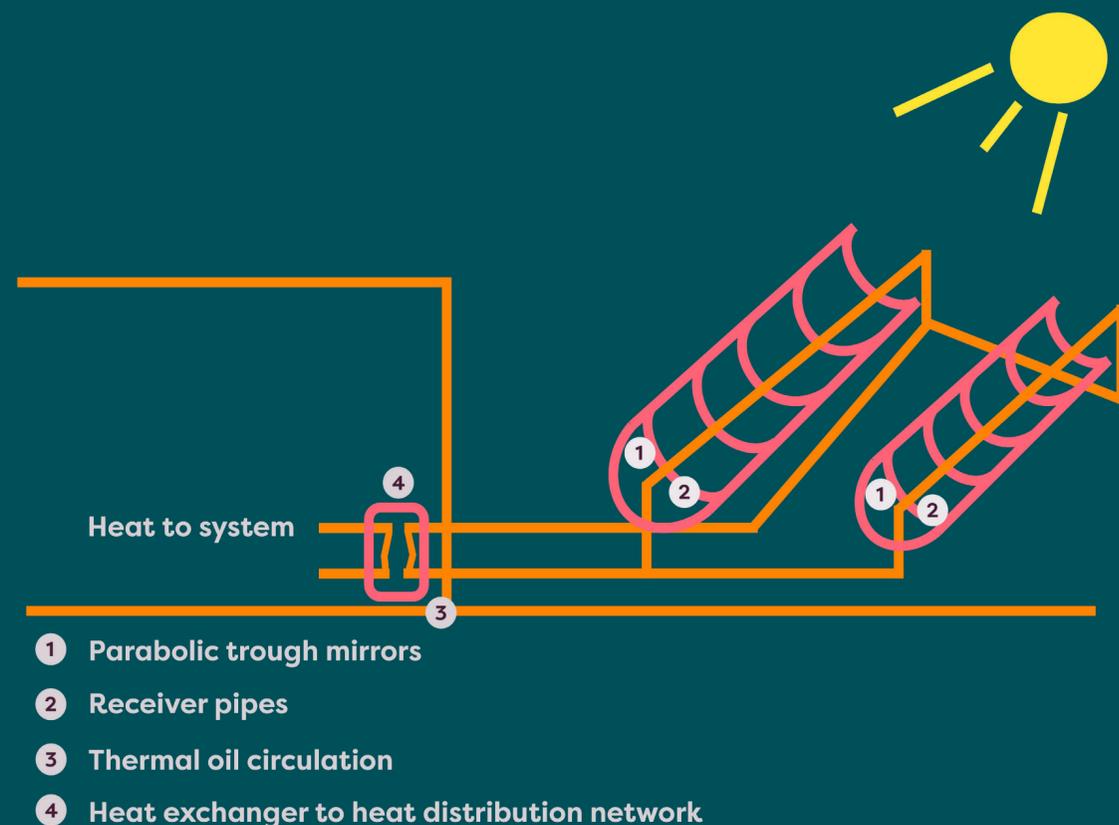
Solar thermal concentrators

Large-scale solar thermal concentrators used to focus light onto towers are not the topic of this guide. Here we concentrate on the most common form of solar concentrator in industrial heating applications.

Parabolic trough reflectors reflect sunlight into a receiver pipe at the focus of the mirror. Thermal oil in the receiver pipe is heated.

Temperatures in excess of 300°C are possible, but temperatures up to 200°C are more typical for thermal applications. The thermal oil transfers heat to the heating system for steam, MTHW or thermal oil heat distribution.

Applications are limited to sunny climates. Life sciences applications could range from cleaning/CIP to water for injection and applications requiring steam e.g. autoclaves, steam-in-place.



Technology maturity

Technology is in use but not widespread. Limited suppliers.

Potential net zero carbon impact

Carbon-free heat but availability limited by solar availability. Wide range of hot water and steam applications.

Fuel availability

Location and season dependent.

Capex

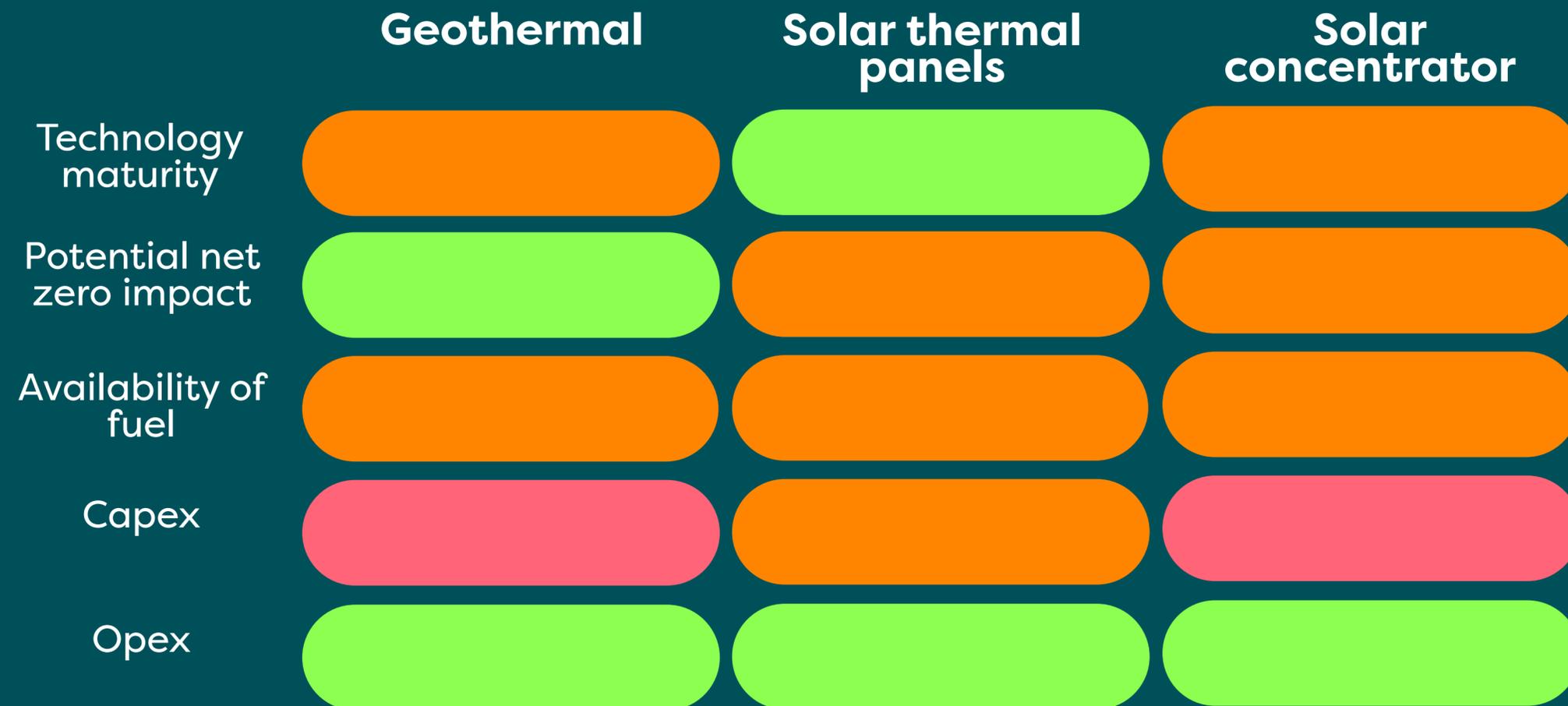
High installation costs. Alternative heat sources still required when solar energy is not available.

Opex

Zero fuel costs.

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Renewable heat overview



Expert overview



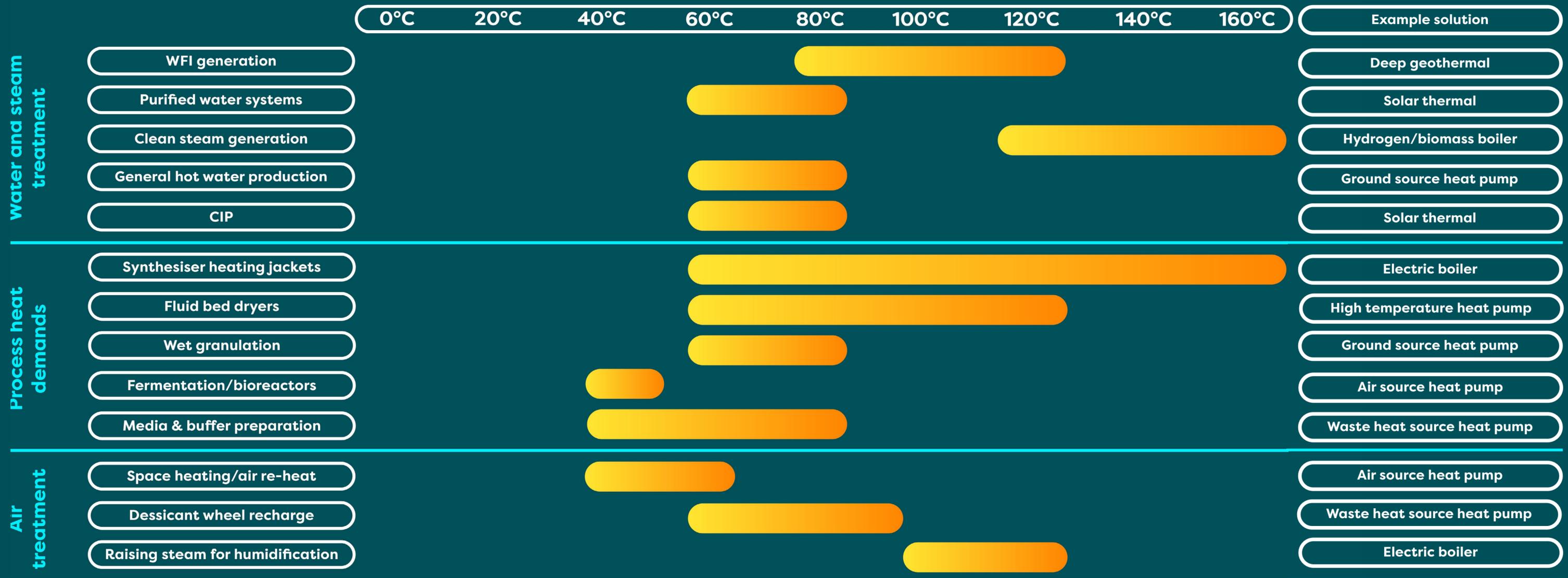
“Solar thermal and geothermal heat sources are becoming more widespread as part of a mix of heat sources to decarbonise heat production in industry. As with the application of heat pumps, it is essential to understand the temperature profile of the heat using processes. In sunny climates parabolic trough type collectors can deliver high grade heat in excess of 200°C making this technology ideal for life sciences applications requiring steam e.g. autoclaves, steam-in-place applications.

Temperatures around 50°C are more common for plate type solar systems, which can satisfy part of the cleaning/CIP demand and HVAC heating demand in cleanrooms.

Where the underlying geology is favourable, geothermal heat is a potential source of carbon free heat with low operating costs. Temperatures will also vary widely from location to location. Engaging with specialist contractors is essential to understand the potential at your site.”

Matt Dickinson, Head of Service, Capital Projects

Consider these technologies in light of your heat demand



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How we can help

Low-Carbon Heat Blueprint

If you've reached a point where you need to upgrade heat infrastructure quickly and don't have a full decarbonisation roadmap, you're probably trying to weigh up your options.

Our Low-Carbon Heat Blueprint service typically takes three to four weeks and is just a quarter of the cost of a full decarbonisation roadmap. It will give you the information you need to optimise heat use, generation and distribution, avoid carbon dead ends and make a clear and confident business case.

You'll get low-carbon heat solution concepts tailored to your site and business goals, a credible project definition, and a robust investment case - everything you need to fast-track effective decarbonisation.

[Browse the service document to find out more](#)

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