# Heat mapper: the challenge of decarbonising heat

The decarbonisation of heat in buildings is essential if the UK is to meet its long-term carbon targets. The UK Government's Building Energy Efficiency Survey (BEIS, 2014–15)* found that half of the energy savings required to deliver on these targets could be achieved through conventional energy efficiency measures. The remaining half will need to be addressed through more fundamental low carbon heating measures.

With a rapidly decarbonising electricity grid, attention is focussing on fossil fuel-based technologies, with the vast majority of non-domestic buildings in England and Wales reliant on gas boilers to supply heating and hot water. A dizzying variety of options are available to decarbonise these buildings at scale including hydrogen, air or ground source heat pumps, biomass, or district heating with low carbon fuels. Choosing the right technology can be difficult, with considerations around cost, ease of installation, comfort and carbon savings. This 'heat mapper' document outlines some of these considerations.

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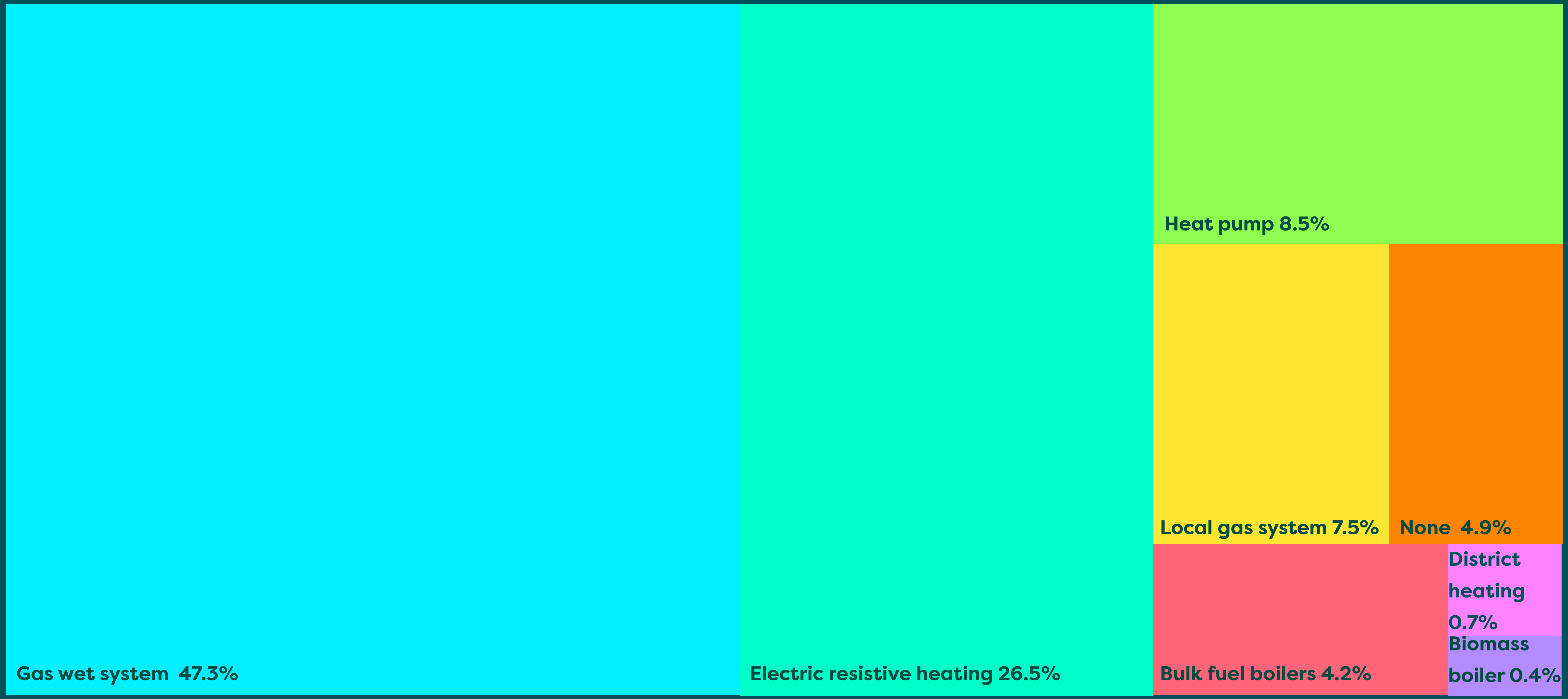
* https://www.gov.uk/government/publications/building-energy-efficiency-survey-bees

# Heat mapper

There are over 200 different HVAC systems in the non-domestic building stock.  A different set of low carbon alternatives exists for each




Gas-heated buildings dominate the non-domestic buildings stock.  They account for two-thirds of this total.

**Cooling systems are diverse- some have larger, centralised systems, while others have smaller localised systems.**

This presents different challenges when considering a low-carbon HVAC retrofit as the integration between the heating and cooling systems (sometimes with misaligned lifecycles) can favour different solutions.

**Around a fifth of buildings use direct combustion of natural gas, or direct electric resistive heating,  rather than a water-based system of pipework and emitters**

Different low carbon solutions will suit these building types.

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# Heat mapping

## Turns complexity into viable options

### Which building do you have?

There is a great deal of complexity when choosing a low carbon HVAC system. The choice can be overwhelming, with each having very different commercial and technical characteristics.

To help you, we have mapped a set of common building types to the low-carbon options. This should act as a starting point for your thinking.

Click on the link which best describes your building:

| Existing HVAC system | Low Carbon alternative |
|---|---|
| Gas boiler with radiators. No cooling system | Hydrogen boiler |
| Gas boiler with radiators/ FCUs. Local refrigerant cooling system | Air-to-water heat pump |
| Direct gas warm air heating. Mixed cooling systems | Direct electric heating |
| Electric resistive heating. No cooling system | ASHP/ Gas boiler hybrid |
| Gas boiler with radiators/ FCUs. Central water-based cooling system | Air-to-air heat pump |
| Direct gas radiant heating. Mixed cooling systems | Biomass boiler |
| Bulk fuel boilers with radiators. No cooling system | Ground/ water source heat pump |
| Gas boiler with radiators/ FCUs. Central air-based cooling system | District heating |

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# Natural gas/ bulk fuel boilers

**An air source heat pump might enable significant carbon savings**

**The most cost-effective solutions will typically involve retaining the existing distribution system and emitters and replacing the generation plant with a low carbon alternative such as a heat pump. Air-, ground- and water-source heat pumps will all offer significant carbon savings over existing gas boilers.**

The initial capital outlay is higher. Heat pumps are more expensive per kW of capacity than gas boilers. The unit price difference between gas and electricity (sometimes a factor of 5) can also make them more expensive to run.

Heat pumps can be cost effective if operated efficiently (in some settings heat pumps can achieve high 'coefficients of performance' – a measure of efficiency). For ground and water-source heat pumps (as well as district heating and biomass), contextual factors such as proximity to a heat source and local regulations are important.

**When a heat pump is installed, emitters may need to be replaced with larger alternatives to supply the same level of servicing.**

Heat pumps typically produce hot water at circulation temperatures lower than traditional boilers. In some cases this can be circumvented by using a 'high temperature' heat pump, operating at a lower efficiency to achieve higher circulation temperatures.

**In the long-term, hydrogen may also become an option.**

Research projects are underway to understand the degree to which hydrogen can be added to the gas mix.

Existing HVAC system

Gas boiler with radiators. No cooling system

Bulk fuel boilers with radiators. No cooling system

Low Carbon alternative

Hydrogen boiler

Air-to-water heat pump

Direct electric heating

ASHP/ Gas boiler hybrid

Biomass boiler

Ground/ water source heat pump

District heating

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# Natural gas/ bulk fuel boilers

**An air source heat pump might enable significant carbon savings**

**A reversable heat pump, supplying both cooling and heating may be preferable**

particularly if the replacement cycles of the existing heating and cooling systems can be aligned. For buildings that already have a large centralised cooling plant, the system is effectively already a heat pump, so it may be wise to focus on finding the right low carbon heat generation plant.

| Existing HVAC system | Low Carbon alternative |
|---|---|
| Gas boiler with radiators/ Fan coiled units. Local refrigerant cooling system | Hydrogen boiler |
| Gas boiler with radiators/ Fan coiled units. Central water-based cooling system | Air-to-water heat pump |
| Gas boiler with radiators/ Fan coiled units. Central air-based cooling system | Direct electric heating |
| | ASHP/ Gas boiler hybrid |
| | Biomass boiler |
| | Ground/ water source heat pump |
| | District heating |

**For small buildings with limited levels of servicing**

The use of direct electric heating may be a viable decarbonisation option, especially given the decarbonising grid. The significant multiplier between the price of gas and electricity in the UK can make this more expensive to run. An air-to-air heat pump is also not out of the question, especially if heating only needs to be provided in localised parts of the building.

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# Direct gas combustion, or direct electric heating

**Air-to-air heat pump**

Will offer the greatest carbon savings as well as cost savings (on a £ per carbon saved basis) due to high efficiencies. However, installation is expensive.

**Direct electrification**

Either through direct electric warm air heating or radiant heating – will be lower cost in the short term but may cost more in the long term. A significant transition of these buildings onto direct electric heating would also increase the challenge for the National Grid to manage demand and supply.

**Air-to-air heat pump (for warm air heaters and direct electric heating) and direct electric heating (for radient heaters)**

Existing HVAC system

Direct gas warm air heating. Mixed cooling systems

Direct gas radiant heating. Mixed cooling systems

Electric resistive heating. No cooling system

Low Carbon alternative

Direct electric heating

Air-to-air heat pump

**Buildings with direct electric heating**

An air-to-air heat pump offers a route to further decarbonisation.

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# The big question: hydrogen or heat pumps?

**There is a lot of debate around which of these two critical technologies will 'win out' in the long run.  Both have significant benefits and drawbacks**

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## Hydrogen

Allows us to make use of 'sunk costs' in the form of the UK's natural gas distribution system.  However, production is inefficient.  Hydrogen is typically produced from electrolysis (a 'lossy' process), has a lower energy density than natural gas and a less efficient combustion process**.  We also have no clear idea of what the unit price of hydrogen would be in the long-term, making forecasting highly speculative.

## Heat pumps

Technically using a combination of electricity and renewable energy – heat from air or ground or water sources.

However, a large-scale transition to electrified heating solutions presents major challenges.  Distribution Network Operators and the National Grid need to manage a potentially larger and very different demand profile, especially with growing numbers of electric vehicles and the prospect of more home-working post Covid-19.  There are also concerns around the global warming impact of refrigerant gases required to manufacture heat pumps at scale.

## So which?

Some industry commentators believe that hydrogen is unlikely to be a viable solution within the next ten years.  The hydrogen market has only recently seen the first commercial products - a large installer base will not exist for many years.  While the market and skills do not exist at scale for heat pump installation in the UK, installations in France, Germany and Scandinavian countries are significantly higher.

**https://www.cibsejournal.com/opinion/why-heat-pumps-can-help-and-hydrogen-cant/

# HVAC replacement summary

**Due to the uncertain future of hydrogen as a fuel source, heat pumps currently offer the most affordable and effective carbon saving HVAC alternatives.**

| | Most carbon saving alternative | Most cost effective (£ per carbon saved) alternative |
|---|---|---|
| **NG/ Bulk fuel boilers** | Ground source heat pump | Air-to-air heat pump |
| **Direct gas combustion** | Air-to-air heat pump | Air-to-air heat pump (for warm air heaters) and direct electric heating (for radiant heaters) |
| **Direct electric heating** | Air-to-air heat pump | Air-to-air heat pump |

Ground source heat pumps provide marginally higher carbon savings than air-to-air heat pumps but at a significantly higher capital cost, in most settings.

Although biomass boilers can be a feasible low carbon alternative, they are less suited to buildings in densely populated areas due to the impact on air quality, an issue which was outlined in this 2018 Government Consultation. There is also uncertainty in the future supply of biomass in the UK.

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# Savings

**Across a variety of sectors and building types, the solutions outlined on the previous page yield significant carbon savings over business-as-usual operation (cumulatively from 2020 to 2050).**

| | Solution | Average carbon savings (kgC02e per $m^2$) | Average change in total costs (£ per kgC02e saved) |
|---|---|---|---|
| **NG/ Bulk fuel boilers** | Ground source heat pump | 1074 | +0.7 |
| **Warm air gas heaters** | Air-to-air heat pump | 581 | +0.2 |
| **Gas radiant heaters** | Direct electric heating | 280 | +0.9 |
| **Direct electric heating** | Air-to-air heat pump | 144 | -2.2 |

Moving away from gas systems reduces carbon emissions substantially but at varying costs. The switch from direct electric heating to heat pumps is more cost effective.

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# Heat mapping challenges

**Context is everything**

### There is no 'silver bullet'

The decarbonisation of heating in non-domestic buildings at scale will invlove more than one of these technologies. Choosing the right solution at an individual building level requires a consideration of many factors. Building owners and managers will need to think beyond typical investment timeframes. There is also a lack of alignment between the most 'carbon-saving' and 'cost-effective' option.

The factors that often drive the decision for a specific building include:

### 1. The existing cooling and heating arrangements

The right choice of low carbon alternative will require a consideration of the current distribution system (whether water, air or refrigerant based) and the degree of overlap in the refresh rates of the existing heating and cooling plant.

### 2. Local contextual variables

Such as proximity to heat sources, amount of space available for plant (e.g. ground arrays or biomass feedstores), or ability to increase local electrical infrastructure capacity.

### 3. On site energy management capacity and skills

With many of the low carbon HVAC technologies requiring a new and as yet underdeveloped skill-set in the UK.

### 4. Cost of decarbonisation

The disparity between what is the cheapest HVAC alternative and what offers the greatest carbon savings can potentialy lead to blurred visions of the best route to decarbonise heat.

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# Heat mapper

## Conclusions

### For ‘wet’ distribution heating systems,

heat pumps, biomass, district heating and potentially hydrogen can all offer carbon savings. Each are at different stages of technology maturity and offer different cost and carbon implications.

### For ‘dry’, air-based heating distribution systems,

air-to-air heat pumps or direct electric heating are the best decarbonisation options.

### Heat pumps look more viable than hydrogen in the short-term.

While the installer and skills base for both heat pumps and hydrogen is limited in the UK, it is more so for hydrogen, which give heat pumps the edge in the short term.

### The price difference between gas and electricity

Create economic barriers to heat pump uptake. The capital cost difference is also a significant current barrier/ disincentive. The solution is to consider future carbon pricing when making investment decisions in plant replacements which will be in operation for 15+ years.

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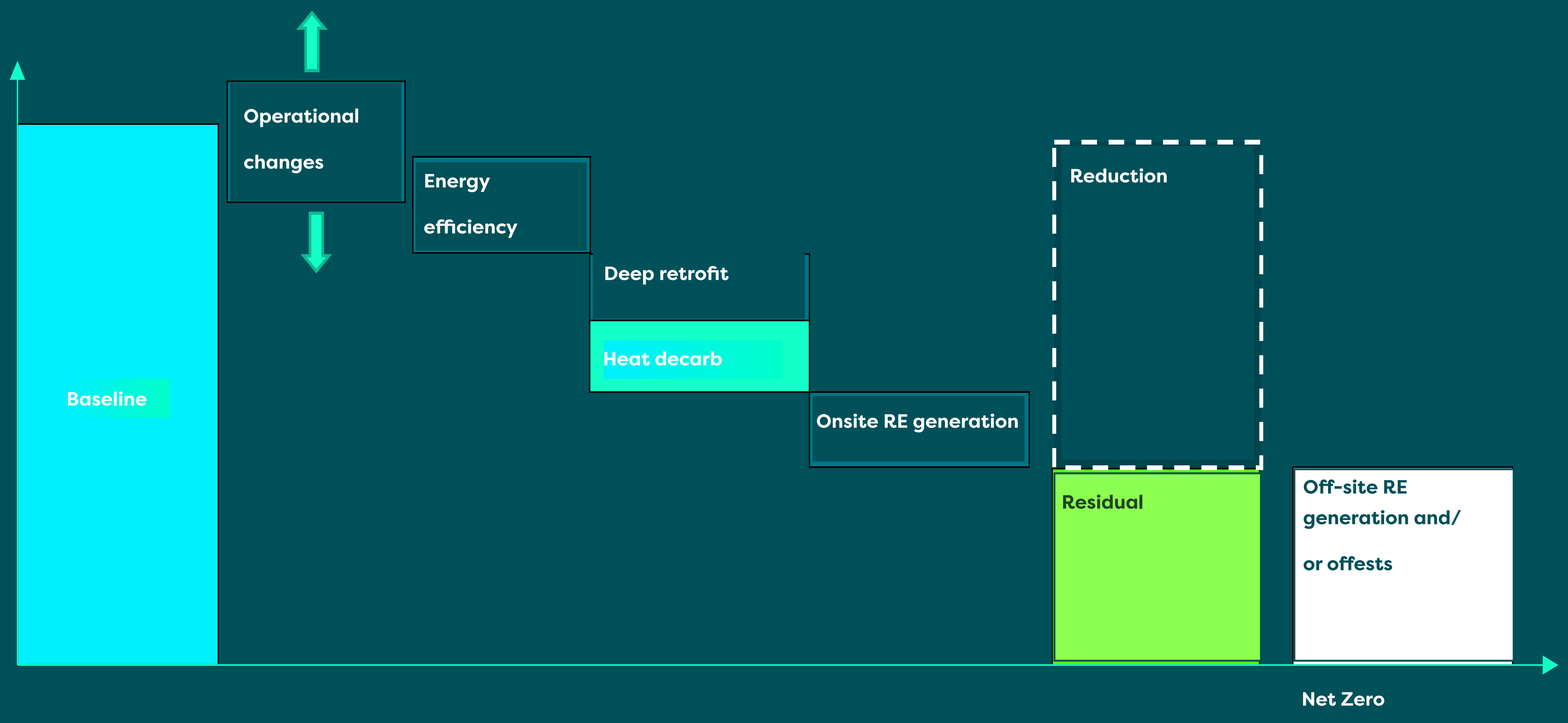
# How we can help

**Our powerful, market-leading pathway analysis tools provide detailed cost and performance modelling for a range of low carbon HVAC technologies. This is an essential component of a robust 'net zero' strategy.**

### Heat decarb: one part of a wider journey

The costs and opportunities presented by a switch to low-carbon heating technologies need to be understood in the context of the wider journey to net zero carbon. This includes measures such as energy efficiency and on site renewable energy generation.

Each of these steps have different costs. Depending on the technology, the decarbonisation of heat can be one of the most capital-intensive stages of the journey and one of the largest in terms of carbon saving impact.




### Our services

We use our sound engineering knowledge to advise leading real estate investors and property management companies on 'net zero' strategies. We provide detailed, fully costed pathways to achieving their net zero commitments.

Verco's Aim for Zero model leverages our work with UK Government developing the evidence base for building energy use, energy efficiency potential and low carbon HVAC technologies. Using this model we can predict the cost and performance impacts associated with retrofit of low carbon HVAC technologies. This provides unbiased, critical insight into which strategies will deliver the best return in terms of cost or carbon.

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Find out more