PATHWAYS TO INDUSTRIAL HEAT DECARBONISATION

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Heat decarbonisation is one of the greatest challenges to achieving the UK's commitment to deliver net zero by 2050. Industrial heat is still largely produced using fossil fuels, and the high temperature nature of such large amounts of heat makes its decarbonisation more challenging than in other sectors of the economy. The increasing costs of energy and carbon as well as the need for greater energy security are accelerating the transition towards decarbonised heating solutions.

The UK Government's Industrial Decarbonisation Strategy (2021) and the British Energy Security Strategy (2022) plan to support this transition by improving energy efficiency, accelerating the development of new low-carbon technologies, having a clear long-term hydrogen strategy and investing in carbon capture utilisation and storage.

In this guide we look at the available options to decarbonise process heat at industrial and manufacturing sites.

The UK was the first major economy to make a commitment to achieving net zero greenhouse gas (GHG) emissions by 2050. Decarbonising, or achieving net zero in the industrial sector is widely recognised as a significant challenge, but also a necessary step in achieving UK and international climate goals.

According to the Industrial Decarbonisation Strategy published in 2021, 70% of the UK industrial energy demand is for heat. The heating processes used in industry and manufacturing can often result in heat energy being lost through inefficiencies. An even bigger decarbonisation challenge though is the shift away from fossil fuels in high grade heat. And whilst electrification is set to play a significant part in decarbonising transport and domestic heating, the decarbonisation of industrial heat is more complex.

With energy prices reaching some of their highest levels and companies being put under increasing pressure to reduce emissions, a wider range of decarbonised heating solutions are being implemented, and the development of more low-carbon heating technologies underway. In addition, understanding the whole process energy use, as well as the Government's policy framework are also key to meeting the heat decarbonisation challenge and to realising the opportunities available.

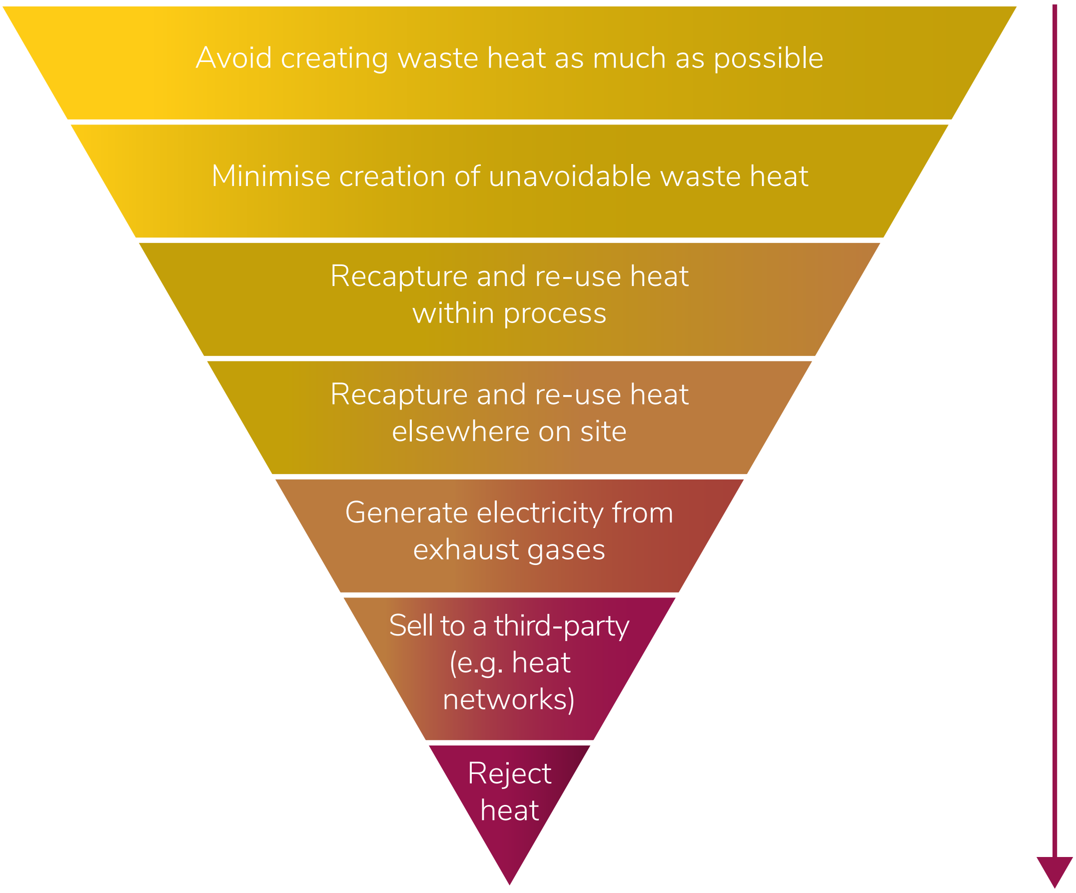
70% OF UK INDUSTRIAL ENERGY DEMAND IS FOR HEAT

GETTING YOUR PRIORITIES STRAIGHT

Before we look at each of the four pathways to decarbonising industrial heat, we first need to understand the waste heat hierarchy. Opportunities to tap into and exploit waste heat are best identified by following the hierarchy, as shown below.

By exploring opportunities available at the top of the hierarchy and moving downwards, it prompts you to consider first the least technically complex and most economically promising opportunities for minimising waste heat.

THE WASTE HEAT HIERARCHY



WHICH DECARBONISATION PATHWAY IS BEST FOR YOU?

Pathway to heat decarbonisation	Heat Efficiency	Waste Heat Recovery	Fuel Switching	Carbon Capture, Utilisation and Storage (CCUS)
	BEST FOR TAKING THE FIRST STEP AND REDUCING DEMAND	BEST FOR MAKING THE MOST OF LOW-GRADE HEAT	BEST FOR REDUCING OVERALL EMISSONS	BEST FOR UNAVOIDABLE FOSSIL FUEL USE AND PROCESS EMISSIONS
How	Heat integration Process enhancement and valorising waste Combined Heat and Power (CHP)	Direct reuse via heat integration Use waste heat in absorption systems for the generation of cooling Use in steam turbines, Organic Rankine Cycles (ORC) for electricity generation Export to a district heating network Upgrade waste heat via heat pumps	Use of electric steam boilers and furnaces Use of biomass boilers and CHP Generation and consumption of biogas onsite to generate heat Hydrogen imported or produced onsite to generate heat	For the most challenging emissions, especially process emissions Facilitates achieving net zero In combination with biomass, facilitates achieving negative emissions
More info	Efficient generation, delivery and consumption of heat CHP reduces primary energy consumption and reduces energy bills	Waste heat can be reused to supplement process heat or provide space heating Recovered heat can drive absorption systems for cooling or power generation Recovered heat can be exported through district heating networks Heat pumps generate useful heat efficiently and can generate high temperature heat (including steam) if reasonable temperature waste heat is available for upgrade	Electrification, where possible, will be increasingly effective at cutting emissions Bioenergy is an option for decarbonising industrial heat for sites away from clusters, especially if generated locally as a waste fuel Onsite anaerobic digestion can create biogas which can be combusted for heat High temperature heat can be generated by combustion of low carbon hydrogen	Currently in development, with large-scale demonstration projects anticipated to run at the end of the decade Carbon capture key to achieving net zero, especially for industrial process emissions CCUS has a high heat demand, which can be sourced from process heat recovery By combining with bioenergy, greenhouse gas removal (GGR) can be achieved leading to negative emissions

PROCESS EFFICIENCY

Regardless of pathways taken towards decarbonising heat the first step should always be to maximise the efficiency with which heat is generated, delivered and consumed. Doing this will reduce energy costs now and provide a firm platform for embarking on the next steps towards further decarbonisation.

As well as saving money and reducing CO_2 emissions in the present, generating and consuming heat efficiently will reduce the capacity you need from low-carbon generation technologies. This means you can get savings from reducing your capital expenditure and reducing the quantities of low-carbon fuels in the future. Doing this first may also free up production capacity, enabling you to fulfil your production expansion plans, and eliminating the need for expensive investment in additional capacity.

A root-and-branch review of your processes can uncover many options for improving heat efficiency. The reviewing process should consider how heat is generated, how it is distributed to the point of end use, the efficiency with which it is consumed and whether and how any surplus heat can be recovered.

GETTING MORE

Optimising the efficiency of heat generation, supply and consumption can open up benefits that go beyond just energy costs and emissions.

1. Heat generation

Is heat being generated in the most efficient way? For example, process heat can be generated from CHP as opposed to a heat-only boiler. The value of the electricity generated in the process makes this a very cost-effective approach as well as a very efficient use of fuels. CHP is often the best way to squeeze out the maximum economic value from increasingly expensive fuels while improving efficiency. You can generate steam and hot water more efficiently with the use of economisers, and recovering condensate from steam heating systems can reduce your consumption of gas by almost 10%.

2. Heat delivery

How is process heat delivered to where it's needed? For example, steam will be distributed around production sites to various plant, which can result in heat losses. Focusing on improvements to the steam distribution system (insulation, steam traps and elimination of redundant pipework can give you large savings in both costs and emissions.

3. Heat consumption

Depending on the process consuming the heat, there may be a range of actions which can be taken to optimise the efficiency with which the heat is consumed. One option which is commonly found is the recovery and reuse of surplus heat. The heat emerging as surplus from a process has already been paid for and so it makes sense to extract as much use from it as possible. In the section below we look at how to identify and exploit opportunities to recover and reuse heat.

WASTE HEAT RECOVERY

Industrial processes release vast amounts of heat as waste into the atmosphere, but this heat is not often recovered. This is a significant opportunity to improve process efficiency, reduce costs and even generate new revenue streams. Waste heat recovery can create significant savings with rapid payback times and is not always routinely explored in some sectors. Examples of waste heat that can be recovered include heat rejected from air-cooled refrigeration condensers and exhaust gases from a stack.

High-grade waste heat is very valuable. It can be re-used directly in the process generating it, in another heat consuming process on site or used to generate steam for power generation, thereby reducing your purchase of electricity from the grid.

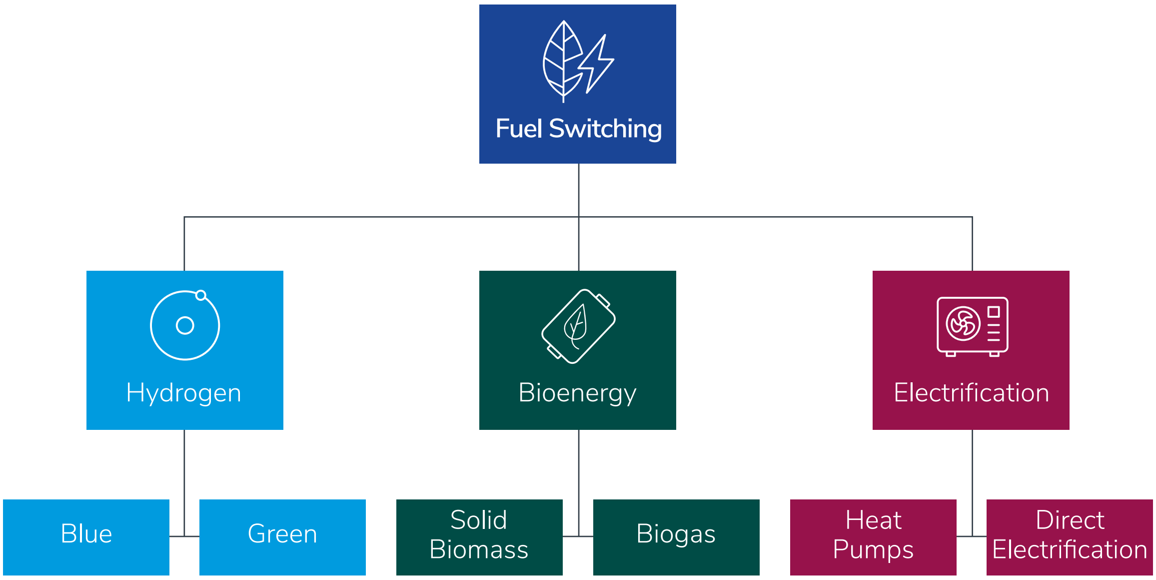
Low-grade waste heat can often be used by pre-heating process streams, driving absorption refrigeration systems to offset electricity consumed for chilling, feeding directly back into the process, generating power with an Organic Rankine Cycle system, or feeding into district heating, thereby generating a new revenue stream.

Ultralow-grade heat with seemingly no value can be made useful by upgrading it with heat pumps to temperature levels that are more useful for process heat. It can also be used to drive absorption chillers, provide space heating or hot water, or by being fed into district heating networks.

FUEL SWITCHING

Direct fired processes, such as furnaces with radiant tubes and traditional alcohol stills, could decarbonise by switching to low carbon fuels.

CHP boilers, gas turbines, engines and fuel cells can all be part of fuel switching or can be used to transition to net zero with planning.



Heat pumps and electrification

The electrification of heat via heat pumps is increasingly becoming an important part of the decarbonisation of industrial heat. Heat pumps are able to extract ambient heat and upgrade to temperatures capable of displacing conventional fuel used for the generation of space heating and hot water. However, industrial (high temperature) heat pumps are now available and can efficiently and cost effectively generate steam, when there is a heat source of suitable temperature. As well as being an efficiency and cost saving measure, this is also a fuel switching measure towards electricity which is becoming ever more decarbonised.

There are commercially available heat pumps that can efficiently reach temperatures of 160°C, assuming waste heat of an appropriate grade is available on site. In the next decade, delivery temperatures could rise to 200°C through research and innovation.

Electric steam boilers can provide heat from renewable sources and can be managed to run only when green electricity is available.

Bioenergy

Biomass and biogas can be used either through heat-only boilers or CHP units. They can be deployed to rapidly decarbonise heat and may be the most attractive heat decarbonisation option for sites off the gas grid and unable to electrify due to the need for higher temperatures or the presence of other barriers, such as cost or local grid constraints. When employed with carbon capture, negative emissions can be achieved if the biomass is sourced sustainably, and the carbon dioxide is permanently stored. The UK Government intends to publish the new Bioenergy Strategy later this year (2022) which will outline the best uses of biomass and waste through to 2050 as well as provide an update on sustainability criteria.

The Bioenergy Strategy 2022 is expected to prioritise bioenergy with carbon capture and storage (BECCS) in line with the recommendations of the Climate Change Committee (CCC) in its 6th Carbon Budget.

Sites considering switching to biomass should consider the feasibility of installing CO_2 capture and permanently storing the captured carbon as this allows sites to be categorised as greenhouse gas removals (GGRs) and achieve negative emissions. The government is considering mechanisms to award negative emissions (options include support under the CfD or under a UK ETS scheme).

District heating

Companies operating in industrial clusters or near metropolitan areas can benefit from a local District Heat Networks (DHNs) by either supplying the network with waste heat (see above) or using heat from the network itself. Taking heat from a DHN is a fuel switching option, since switching to lower carbon fuels may be more economically viable for the centralised heat generation plant at the heart of a DHN than at the individual industrial site level.

Hydrogen

Hydrogen can be used to abate emissions associated with the generation of very high temperature heat. Green Hydrogen (sourced from renewables) is a clean option, but there are challenges to overcome such as the large-scale production and supply of this type of hydrogen. However, government drivers and incentives to support the transition to a future hydrogen economy are likely to increase the longer-term availability and viability of hydrogen as a fuel.

The cost of hydrogen is expected to become more attractive in the years ahead. Numerous pilot projects are in operation globally and many technology providers currently produce 'hydrogen-ready' engines or turbines that can operate on a blend of hydrogen and natural gas and in some cases 100% hydrogen. With the British Energy Security Strategy (2022) outlining (and doubling) the government's hydrogen production ambition to 10 GW capacity by 2030, now is a good time to consider the future of systems and their hydrogen readiness.

Carbon capture, utilisation and storage (CCUS)

Carbon Capture, Utilisation and Storage (CCUS) offers a means to decarbonise hard to abate industrial processes, for which fuel switching cannot provide a total solution or in case there are unavoidable process emissions that must be addressed. CCUS involves the separation of carbon dioxide from cleaned exhaust gases. The recovered CO_2 can be permanently stored underground or used in other industrial processes. The CCUS process is typically carried out through absorption or carbon scrubbing, but there are a number of alternatives, such as those being developed for carbon capture in specific sectors such as cement.

It is also possible to achieve negative emissions though bioenergy combined with carbon capture and storage (BECCS), which can offset other emissions or could create carbon credits to sell, thereby generating a new revenue stream. A comprehensive carbon capture plan and techno-economic analysis will help even the biggest emitters achieve net zero.

WANT TO LEARN MORE?

WEBINAR RECORDING ON INDUSTRIAL DECARBONISATION

In this webinar, our energy experts explore the biggest issues in industrial decarbonisation, uncover practical solutions to bring down energy costs, and reveal ways to reduce carbon emissions. We look at:

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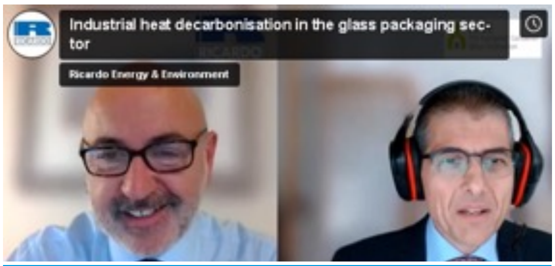
- Why industrial decarbonisation matters: strong reasons to take action now
- Optimising efficiency: immediate steps you can take
- Fuel switching: more options to reduce future energy use and to decarbonise
- Decarbonisation in the food and drink industry

SECTOR PERSPECTIVES ON INDUSTRIAL DECARBONISATION

In this video series we explore sector perspectives on industrial heat decarbonisation. What are the biggest issues for these sectors? What action is already being taken? What decarbonisation technologies will be relevant for the sector in future? And what initiatives and support are available to those making the transition to a low carbon future?



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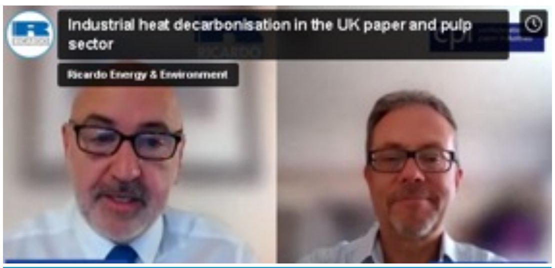

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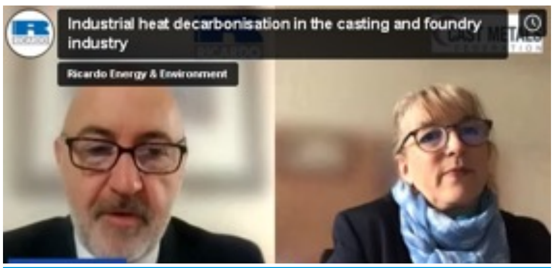

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RICARDO CAN SUPPORT YOU

Our World-leading Industrial Heat Decarbonisation expertise

Ricardo specialists are involved in heat decarbonisation projects across a range of industrial sectors. From identifying process limitations causing poor fuel utilisation, through providing solutions to waste heat, to identifying a roadmap to map the most cost effective route to net zero, our expertise will tackle the challenge of decarbonising heat:

PROCESS EFFICIENCY AND WASTE HEAT RECOVERY

- Heat balance studies
- Heat efficiency opportunity identification and optimisation plans
- CHP feasibility studies and owners engineer services
- De-steaming opportunity identification, analysis and modelling
- Heat recovery opportunity identification and technical and financial feasibility studies

FUEL SWITCHING

- Evaluation of technical and financial feasibility of low carbon heat sources
- Technology appraisal and due diligence
- Assessment of decarbonisation options using bioenergy
- Assessment of environmental impact including carbon savings, feedstock sustainability, air emissions and water and soil impacts

CCUS

- Assessment of new innovative CO_2 capture technologies
- Concept development, feasibility studies and FEED studies
- Whole system analysis and comparison of technologies covering gas, coal and biomass fuels in a wide range of sectors including power generation, chemicals, gas processing, refineries, iron and steel and cement
- Life cycle emission analysis of energy systems with CCUS
- Evaluation of policy mechanisms and review of worldwide regulatory regimes for supporting CCUS
- Development of innovative concepts for monitoring CCUS networks
- Economic impact assessment of CCUS projects and assessment of value added to the UK from clean abatement technologies with CCUS
- Assessment and due diligence of CO_2 removal technologies in the Anaerobic Digestion (AD) sector for biogas upgrading

GET IN TOUCH

Contact us to arrange an informal discussion with one of our Industrial Heat Decarbonisation experts:
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