UKERC
UK Energy Research Centre

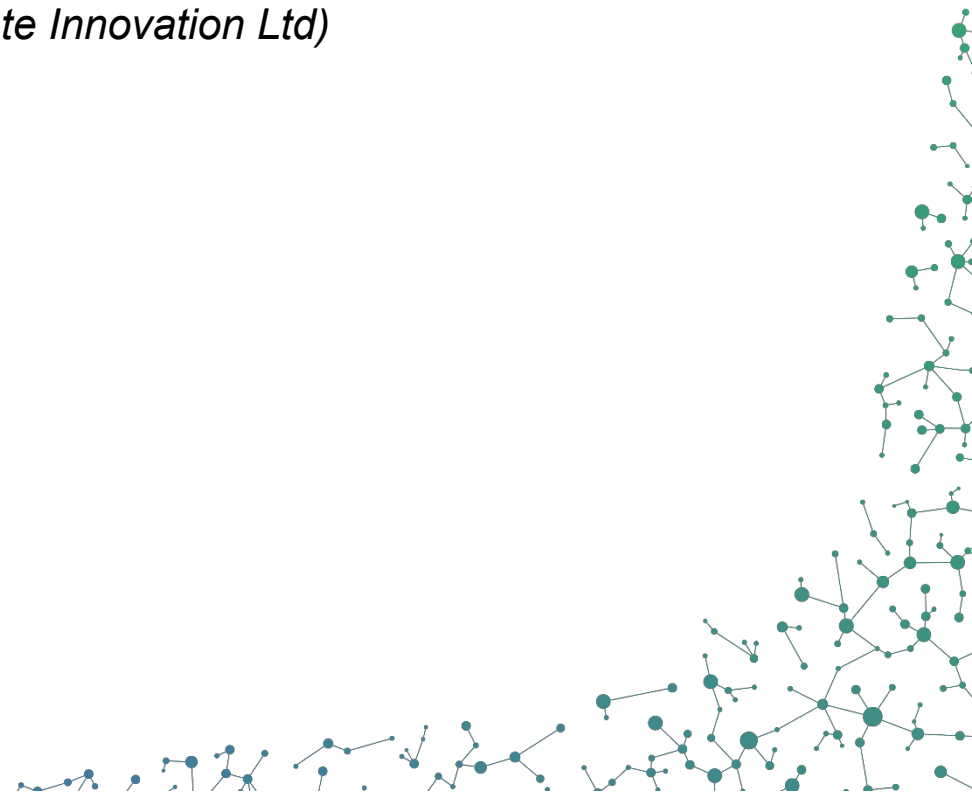
Heat

An Energy Data Centre Introductory Guide

Keelan Colechin (Cultivate Innovation Ltd)

Mike Colechin (Cultivate Innovation Ltd)

November/2024



Introduction to UKERC

The UK Energy Research Centre (UKERC) carries out world-class, interdisciplinary research into sustainable future energy systems.

It is a focal point of UK energy research and a gateway between the UK and the international energy research communities.

Our whole systems research informs UK policy development and research strategy.

UKERC is funded by UK Research and Innovation.

Document Purpose

This document is an introductory guide to the topic of ‘Heat’. It highlights the main concepts, policies and technologies which influence this topic area in the UK, and is written for those with limited prior knowledge of heat energy delivery. This document will not cover all relevant issues in this area but will serve as a starting point for those looking to research further.

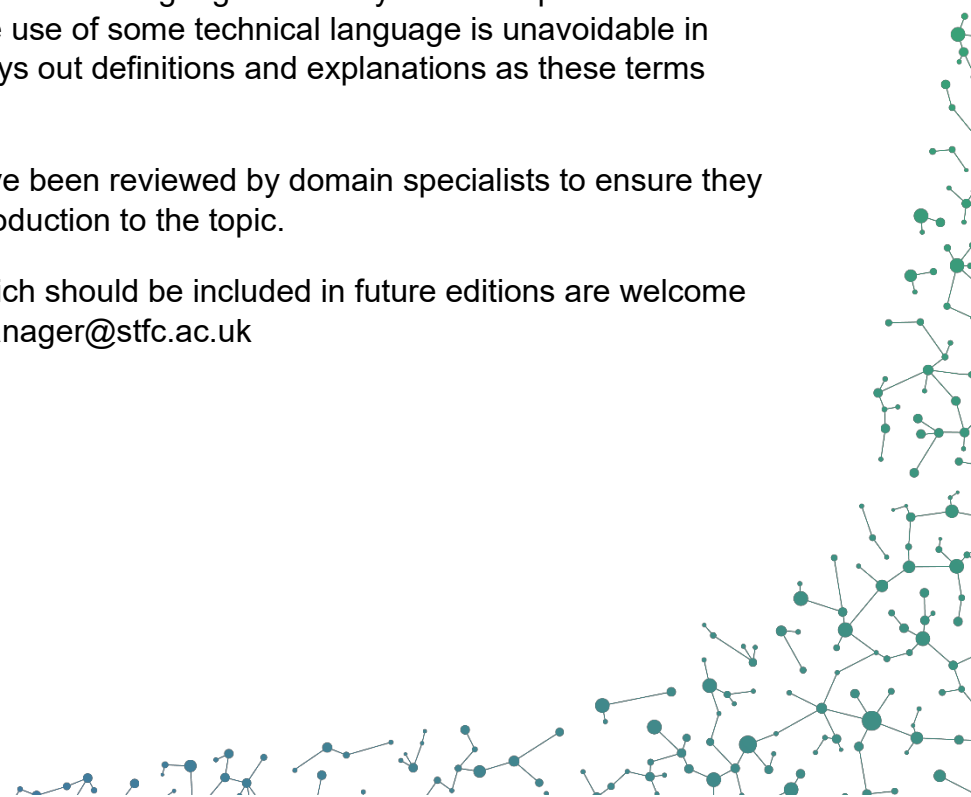
The ‘research and innovation’ section is based largely on projects which can be found in the UK Energy Research Centre - Energy Data Centre’s (UKERC EDC) projects database. This section is not exhaustive and focuses on publicly, rather than privately, funded research; as such, it will not cover all research in this area.

When referring to the role of UK Governments, the document focuses on policies rather than regulations or specific funding packages. Policies help to give a broad sense of Governments’ direction without getting into the technical details which may: a) distract from the key messaging of the document and b) be subject to frequent change.

This document avoids using technical language or acronyms where possible and is written in plain English. As the use of some technical language is unavoidable in such documents, this guide lays out definitions and explanations as these terms arise.

The contents of this guide have been reviewed by domain specialists to ensure they are a useful and accurate introduction to the topic.

Suggestions about factors which should be included in future editions are welcome and should be sent to EDCManager@stfc.ac.uk



1. Overview

Heating is central to our lives. In our homes, we rely on it for comfort, cooking and washing. Businesses need heating and cooling for productive workplaces and heat is integral to many industrial processes. It is the biggest reason we consume energy in our society (BEIS, 2018). While greenhouse gas emissions from heat generation in the UK have fallen by over a quarter from 1990 levels, they still account for the highest proportion of energy end use emissions (NESO, 2024). Although there is an ever-increasing adoption of lower carbon heat technologies, around 85% of our heating supply (commercial, industrial and domestic) still comes from burning fossil fuels. This proportion is even higher for domestic heating, at over 90% (DESNZ, 2023).

Reliance on fossil fuels for heat also carries risks for energy security and non-greenhouse-gas emissions which can be harmful to health. There are also concerns as to the heat efficiency of our homes. The Office for National Statistics (2024) has measured a median energy performance score of 'D' for buildings across the UK (on an Energy Performance Certificate scale of A to G). Several other metrics also point to the relative underperformance of the UK housing stock by European standards. Since it is expected that 80% of existing buildings will still be in use in 2050, retrofitting to improve their thermal efficiency will be vital, as will setting out more stringent insulation standards for new builds.

For the UK Government to achieve its ambitions of net zero emissions by 2050, emissions from heat will need to be cut dramatically, with the Climate Change Committee identifying it as a particular area of focus in its report to parliament (Climate Change Committee, 2024).

2. Government direction

The different tiers of government in the UK, from central government, through the devolved administrations, to local government can each influence the way heat is generated, used and regulated within their respective jurisdictions. UK central government and the devolved administrations have all published documents signalling their individual strategies for reducing the emissions from heating. Several local authorities have done the same in their Local Area Energy Plans (LAEPs) aimed at addressing the geographical specificities of their own heat infrastructure.

2.1 The UK Government

The UK Government has published a Heat and Buildings Strategy (BEIS, 2021a), outlining its priorities in solving the challenges surrounding heat decarbonisation.

They highlight the need to improve the thermal efficiency of our housing stock with approaches such as insulation 'retrofit' schemes. They also signal their support for the role out of heat pumps and heat networks, as well as promising to make 'strategic decisions' on using hydrogen for heat although it now looks unlikely that hydrogen will be used for domestic heating. The Industrial Decarbonisation Strategy (BEIS, 2021b) identifies hydrogen and biomass as being two key energy vectors for heat, and states the Government's support for accelerated electrification of industrial processes. They pledge various funds towards each of these solutions, as well as funding for continued research.

All of these policies are subject to change following the recent 2024 General Election in the UK.

2.2 Devolved governments

The Scottish Government's Heat in Buildings Strategy (2021) focuses on many of the same technologies as the UK central government, albeit with a greater focus on heat networks and a lesser focus on hydrogen. They also place an emphasis on aligning their heating policy with the ideas of a just transition, addressing fuel poverty through more efficient homes, and giving local communities greater autonomy.

Similarly, Welsh Government's Heat Strategy for Wales (2024) places an emphasis on trying to make the transition to a lower carbon heating system more equitable. They do, however, state greater support for the potential of hydrogen than the Scottish Government, especially in industrial heating contexts.

The Northern Ireland Executive aims to support similar technologies again in their Path to Net Zero Energy (2021). They put a special emphasis on electrification, which they say is supported by their strong indigenous production capabilities, especially wind power. They also commit funds to supporting consumers through a 'one-stop-shop' for information on heat decarbonisation and reducing fuel poverty.

2.3 Local authorities

Many councils want to work with UK central government on climate action, and a common way of doing this is by developing an LAEP. Such a plan can help councils to identify which technologies should receive investment in their area and help them coordinate efforts to decarbonise 'on the ground'. They are key actors in heat network zoning and are often instrumental in the vital work of community engagement (Local Government Association, 2024).

3. Key solutions

There are multiple heat solutions with differing levels of deployment across the UK. Below are the technologies which are most likely to play a role in the UK's future heat infrastructure.

3.1 Established approaches

- **Direct Electric Heating** generates heat from electricity in several ways, from resistive heating (generally for heating buildings) through to electric arc heating (furnaces in industrial settings). These technologies are often not cost competitive with fossil fuels at present due to the relatively high cost of electricity. However, they have greater potential for decarbonisation as we decarbonise the electricity grid, making them a more viable long-term option.

- **Biomass fuels** are renewable fuels produced from organic materials, these can be crops grown specifically for use as bioenergy, or organic waste. While they do produce emissions at the point of combustion, they are widely considered to be a net zero fuel because any carbon that is released has recently been captured. Some biofuels can be used as 'drop-in' alternatives to fossil fuel hydrocarbons which makes them appealing for those heating processes which are hard to electrify. This energy vector comes in many forms with differing levels of adoption in the UK: from wood being burned in stoves, to biogas in the mains supply, through to newly developed biofuels. Bioenergy is seen as being particularly useful for decarbonising 'off-grid' buildings, meaning buildings with limited access to gas and electricity infrastructures.

- **Building retrofit and insulation** improves the heat efficiency of buildings, reducing overall energy consumption and reducing running costs for occupants. This includes material changes to buildings, such as loft insulation, double glazing, and wall insulation. It is seen by many as a 'no-regrets' solution to reducing emissions from heating but can face challenges due to the UK's diverse and, often, very old housing stock.

3.2 Building momentum

- **Heat Pumps** use electricity to warm buildings by moving heat from the external environment to the building, raising its temperature in the process. They can deliver more than four times the energy consumed as electricity whereas a boiler, by comparison, would always deliver less than the fuel consumed. Their potential for decreasing emissions is enhanced when they use electricity from a low carbon grid.

- **Heat Networks**, sometimes referred to as 'district heating', connect many buildings to a shared heat source via insulated hot water pipes. They are uniquely capable of harnessing a range of low carbon heat sources, for example geothermal heat and low-grade waste heat from industrial processes. However, they can suffer from issues of heat losses and are only effective in areas with a sufficient housing density.

3.3 Early adoption

- **Hydrogen** (and its compounds, for example ammonia) is already used in several industrial processes, but it has also been shown to work as a fossil fuel replacement for heat generation in combustion processes, both in domestic and industrial contexts. It can be produced using electricity through electrolysis, or from natural gas through a process of steam-methane reformation.

- **Geothermal** energy is captured by pumping or extracting water from the earth's crust. While it is not a new technology it has relatively limited adoption in the UK due to its relatively limited resource. However, the potential for accessing this energy source is looking ever more promising with the wider deployment of technologies such as heat pumps and heat networks. Work is underway exploring the potential for extracting geothermal heat from flooded mine works.

- **Waste heat recovery** is used quite widely within industrial contexts already, and in a small number of innovative heat networks. It is split into high temperature and low temperature heat recovery, with high temperature heat being reused in industry and low temperature in domestic and commercial settings through heat networks. It works best when a constant or dispatchable heat source, such as waste incineration, is coupled with a constant load. Its potential is enhanced due to the UK's innovative work on industrial clusters from which waste heat could be sourced.

- **Heat storage** is the process of capturing thermal energy and storing it for later use. It has been used for some time in industrial processes and heat networks, but has the potential to be used much more widely. It can take the form of heat batteries, hot water or oil tanks and a range of other technologies including potential geological storage in aquifers and redundant mine workings. It could play a much larger part in future heat infrastructure especially when combined with other technologies like heat networks.

Some of these key solutions are better suited to one context than another. For example, heat pumps will be more useful in domestic/commercial heating, and arc furnaces will likely only ever be an industrial heat source. However, many of these technologies can have uses in both industrial and non-industrial contexts, with unique opportunities arising from the meeting of the two (such as with heat

networks). Similarly, buildings near industrial plants could use hydrogen or biofuels and make use of the local supply infrastructure to deliver their heating requirements.

With all these solutions social practices and user behaviours are an important consideration. They can influence the operational effectiveness and efficiency of many technologies, but just as important are the decision-making processes of actors at all levels of engagement from governments through to households. These have a significant impact on the rate of deployment of the various solutions for heat decarbonisation.

4. Research and innovation

As would be expected, there are many similarities between the Government's priorities and those of the research and innovation community. The following gives an overview of the research priorities for the solutions listed above.

4.1 Direct electric heating

Research in this area largely focuses on industrial uses, trying to make electrification of high temperature industrial processes more viable, and industrial electrification more generally affordable. Some centres are trying to identify how the development and adoption high temperature electrification technologies could be accelerated. Others are examining energy cost and infrastructure connectivity as they are two of the main barriers to the adoption of industrial heat electrification. There is limited research into the role of direct electric heating in domestic settings as this is a mature technology and priorities have shifted towards heat pumps and heat networks. Infra-red heating panels are one example of a domestic technology which has recently been receiving research focus, but much like direct electric heating this is much less efficient than heating by heat-pumps.

4.2 Biomass

The production of biomass fuels continues to be of research interest, whether that be crop production, advanced pre-treatment, or waste-to-fuel conversion. Given there is a limited supply of biomass in any given year, research is also trying to establish which end uses should be prioritised. Part of this is establishing the role that biomass could play in providing alternative sources of heat as we start to rely more on electrification as a means of decarbonising the energy system. There is also interest in how carbon capture and storage can be utilised when burning biomass

(BECCS) to make these processes not just renewable or low carbon, but carbon negative.

4.3 Building retrofit and insulation

Building retrofit and insulation are well-established technologies. Research in this area is primarily addressing the social and economic barriers to improved building retrofit and insulation. This includes research on improving access to retrofit finance, improving public awareness of the benefits of insulation, and key standards and guidelines. Skills shortages are often cited as a key barrier to the scaling up of retrofit efforts, and so some research aims to identify the exact skills needed and the best methods of cultivating and sustaining them in the construction industry. There is also some research assessing the longevity of different retrofit solutions, something which should allow long-term cost-benefit appraisal.

4.4 Heat pumps and heat networks

For heat pumps and heat networks the research is focussed on scaling up their deployment. While some research on heat pumps and heat networks still looks at trying to improve their technical performance, much of it now concentrates on the economic and social elements of their adoption. This includes researching policy interventions through which these could be effected. Much of this research takes the form of whole systems heat and energy infrastructure modelling aimed at anticipating and understanding the challenges of a mass roll out of these technologies. The rise of these research fields has corresponded with the decline of research into direct electric heating in homes, combined heat and power, and solar thermal heating technologies.

4.5 Hydrogen

Research on hydrogen for heat also resonates with the UK Government's position, with funding and effort being funnelled towards it, yet with a cautious approach to its potential. This research is largely split between studies into hydrogen's feasibility (supply infrastructure and efficiency), safety/environmental impact, and economic impact. Others have focused on the specific use cases of hydrogen heating, especially in industrial processes such as glass making where hydrogen has been presented as an especially viable alternative to natural gas. While some studies are still investigating hydrogen's domestic heating potential, focus is shifting towards industrial applications. There is also a growing portfolio of research projects looking at the production, transport, and use of "green ammonia". Hydrogen is a contentious

subject within the research community, with arguments for and against its systemic use along technical, economic and environmental lines.

4.6 Geothermal, waste heat, and heat storage

Some research is looking into the potential for heat networks to harness geothermal and mine-water energy, as well as industrial waste heat. There are already projects in cities such as Bath that demonstrate how geothermal energy can be harnessed, and the UK Government is working with the Coal Authority to explore how we might 'unlock' heat in mine water as an energy source. As for waste heat recovery, this is seen as a solution with promise given the UK's world leading research on industrial clusters and the opportunities they afford. There is some research exploring novel thermal battery technologies but also some substantial work examining the use case for heat storage in providing supply and demand side flexibility to the energy system. Similar work is also examining the potential interactions between these three solutions. While these technologies are in the earlier stages of development/adoption, they are perceived to hold a lot of potential in a UK context. This is in part due to our high population density resulting in high heat density per unit of area which is a requirement for effective heat networks.

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