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People centric policy is needed to create a clean cooling pathway for UK homes

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ABSTRACT

As the climate continues to warm, overheating is becoming increasingly common, creating a range of heat-health issues, and leading to a growing demand for space cooling. How that cooling is provided is important, as there are passive and low impact options available, as well as more environmentally damaging active cooling. Without policy intervention, air conditioning (a form of active cooling) could easily become the default solution for cooling homes, locking-in direct and indirect greenhouse gas emissions, creating wider impacts for energy systems and equity, and risking air conditioning becoming a new social norm. To avoid this, policy makers need to act with urgency to drive low-carbon cooling whilst also creating the right conditions to support people to take sustainable and climate resilient behaviours. These issues should not be left solely to the market; rather policymakers need to develop a comprehensive, integrated approach to people and cooling. To support this, we provide insights from an avoid-improve-shift cooling decarbonisation framework, alongside an approach to behavioural and societal change that supports individuals whilst also shaping the wider environment in which decisions are made. Whilst focussed on the UK, the insights will be of relevance to other temperate countries dealing with the growing challenges of heat resilience and cooling decarbonisation.

1. Introduction

One of the impacts of climate change is the increase in the intensity and frequency of extreme heat events, exacerbating levels of overheating[1] within homes and communities (EAC, 2024a; Miranda et al., 2023). In cooler temperate climates like the UK, the existing building stock has not been designed to mitigate overheating risks and a range of heat-health impacts, including increased levels of mortality, morbidity and wider physiological stresses, are already being experienced (Conti et al., 2022; Howarth et al., 2019; Taylor et al., 2023). Cooling offers a solution to reduce these heat-health risks and there is an expectation that the demand for cooling will rapidly increase as the climate continues to warm (UNEP, 2023).

Cooling homes can be achieved through both passive and active (mechanical) approaches. Passive solutions involve heat gain reduction and airflow management, with building regulations and planning playing a key role in creating new buildings and places that are resilient to overheating, including urban designs to reduce urban heat island effects (ARUP, 2022; Lizana et al., 2022). Active cooling can be provided through a range of routes, from simple fans that provide thermal comfort (EAC, 2024a) through to air conditioning (AC) systems. While simple technologies such as fans have low energy consumption, AC systems are both energy intensive and require the use of refrigerants, contributing to both direct and indirect climate emissions and impacting energy systems and social equity (IEA, 2018; UNEP, 2023). As increasing temperatures drive cooling demand, there is a risk that AC systems, as the incumbent technology, may become the default cooling solution for many households (Lizana et al., 2022). People's strategies for managing and coping with increased temperatures and how policy enables or constrains different solutions and approaches will ultimately shape the cooling pathway for homes that emerges within any country. Understanding the opportunities to decarbonise domestic cooling while supporting people

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[1] Overheating relates to the energy balance between heat gains and losses. When the heat gains exceed the losses for a prolonged period overheating occurs (Taylor et al., 2023).

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to maintain thermal comfort through passive and low impact approaches will be vital. It is therefore important that cooling demand is framed as a dual challenge, encompassing both people and policy.

This perspective considers these issues in the context of the UK, which provides a useful example of a cooler temperate country that is seeing increased temperatures and an increase in cooling demand (Hoggett et al., 2024). Currently, it is estimated that the use of active cooling within UK households is low (BEIS, 2021), but the market is growing and expected to continue to do so as temperatures rise (EAC, 2024a; King et al., 2024). There has been a considerable growth in insights and activity around heat resilience and cooling in the UK, including consistent independent advice highlighting the need to prioritise heat-health risks (CCC, 2022, 2021; CCRA 3, 2021), two parliamentary inquiries covering heatwaves and sustainable cooling (EAC, 2024a, 2018), and a wealth of research activity across these issues (Brimicombe et al., 2021; Caio and Miller, 2021; Howarth et al., 2023a; Ravishankar and Howarth, 2024). At COP 28 in December 2023 the UK signed the Global Cooling Pledge, committing to the development of a national cooling action plan by 2026, and the government is working to better understand data gaps and future risks (DESNZ, 2023a, 2023b). How that action plan approaches cooling within homes remains to be seen. However, there has been a perception that there is a lack of urgency in respect of heat resilience, with cooling also seen as a policy 'blind spot', and approaches to date considered inadequate (Boyd et al., 2024; EAC, 2024a; Howarth et al., 2024; IEA, 2018; Khosravi et al., 2023).

We explore these issues by first discussing the growing risks associated with a warming climate. We then examine the opportunities for decarbonising cooling, considering options to avoid the need for active cooling, improve cooling products, and manage cooling loads within energy systems. We then explore the central role of people in shaping cooling pathways within homes and how to best encourage and enable low carbon, climate resilient behaviours around cooling to emerge in order to prevent a default to AC systems. Finally, we discuss the need for, and importance of, framing complex issues of heat resilience and decarbonised cooling through the lens of a people-policy approach. Although focussed on the UK, the themes within this perspective offer valuable insights for other temperate countries faced with the challenges of rising temperatures and the adoption of cooling to manage overheating.

2. Increasing temperatures, increasing risks

The commitments made by countries to date for reducing climate emissions are not being met, and without immediate action and increased ambition, temperatures could increase to 2.6 °C to 3.1 °C by the end of the century (UNEP, 2024). This is well above the 2 °C target and the 1.5 °C ambition within the Paris Agreement (UNFCCC, 2016), with UNEP (2024) suggesting that whilst still technically achievable to remain within 1.5 °C, it will be unlikely without immediate action. Temperature records were consistently broken in 2024, with July seeing the highest daily global-average temperature ever recorded at 17.16 °C (C3S, ECMWF, 2024a); whilst September 2024 was the fourteenth consecutive month since July 2023 where global-average surface air temperature exceeded 1.5°C above pre-industrial levels (C3S, ECMWF, 2024b). These upward trends come on the back of record-breaking years of temperatures, with the last decade seeing the 10 hottest years on record and 2024 confirmed as the warmest, at 1.55 °C above the 1850–1900 average (WMO, 2025).

As well as increasing average global temperatures, heat extremes and heatwaves are also increasing in frequency, intensity and duration, with an expectation that this will continue (IPCC, 2023; Miranda et al., 2023). Such weather extremes have a wide range of economic, social and environmental impacts, including loss and damage to ecosystems, people, settlements and infrastructure (IPCC, 2022). A key concern from extreme heat relates to human health and wellbeing, the heat-health challenge, with high and extreme temperatures resulting in discomfort, morbidity, and mortality (CCC, 2022; Conti et al., 2022; Drury et al., 2021; IPCC, 2022; Ravishankar and Howarth, 2024; van Daalen et al., 2024; Vicedo-Cabrera et al., 2021). There are both direct and indirect impacts for people from high temperatures, and varying degrees of vulnerability. These are shown in Table 1.

An estimated 490,000 heat related deaths were recorded globally between 2000 and 2019 (Zhao et al., 2021) with risks increasing rapidly over the last 20 years (Lüthi et al., 2023). Recent analysis suggests that half the world's population has experienced all-time record temperatures for their location over the past decade (Hausfather, 2023) and within Europe temperatures have been *rising at roughly twice the global average* (C3S, WMO, 2024). European deaths from hot weather have risen by an estimated 30 per cent over the last two decades, *with an estimated* 62,000–72,000 heat related deaths occurring in the 2022 heat events (Ballester et al., 2023; Iacobucci, 2024). In cooler temperate countries like the UK, impacts from extreme temperatures are a relatively new phenomenon (Howarth, 2024; Taylor et al., 2023), but even in the UK there have been increases in the frequency and intensity of heat events, and unprecedented hot years, including 2022 when temperatures exceeded 40°C for the first time (NAO, 2023). In that year, there were an estimated 3200 to 4500 heat-related deaths (EAC, 2024a; NAO, 2023; ONS and UKHSA, 2022), and projections suggest this could increase to 7000–10,000 per year by 2050 without adequate adaptation (EAC, 2024a; Howarth et al., 2024; Kovats and Brisley, 2021). However, it is also clear that heat-related deaths are seen at relatively moderate increases in temperature (Jenkins et al., 2022), suggesting risks are more pervasive and prevalent. Increases in average summer temperatures, hot days and heatwave events across all regions of the UK are expected (CCC, 2023a; Slingo, 2021), with heat extremes seen as a key impact and risk (Kendon et al., 2024). There is therefore a need for urgent action on heat resilience (EAC, 2024a; Howarth et al., 2023a).

Whilst heat-health tends to dominate much of the research and policy attentions, high temperatures result in a wide range of other risks across the socio-economic landscape (Brimicombe et al., 2021; Ravishankar and Howarth, 2024). Impacts span economic losses across local, regional, and national levels (Boyd et al., 2024; CCC, 2022; Howarth et al., 2023a) including reductions in productivity from lost sleep, reduced concentration, alertness, and cognitive performance (CCC, 2022) and damage to natural environments, including stress on biodiversity (CCRA 3, 2021; NAO, 2023), and impacts on ecosystem services (EAC, 2024a; Howarth et al., 2024). Higher temperatures also affect the security, resilience and reliability of key infrastructure, including energy systems, with heat impacting the generation and distribution of electricity, reducing plant efficiencies (e.g. it is more difficult to cool down machinery, heat increases electrical resistance as materials expand), lowering generation capacities, and increasing the risk of outages (IEA, 2021; Yalew et al., 2020). More broadly, extreme heat can damage and disrupt transport networks, digital infrastructure,

Table 1
Impacts and vulnerabilities from high and extreme heat.

Impact	Risks
Direct	Dehydration, heat stress, heat exhaustion and heat stroke, exacerbation and increased risk of death from cardiorespiratory and other diseases, mental health issues, and adverse pregnancy and birth outcomes (CCC, 2022; Ebi et al., 2021; Tham et al., 2020; WHO, 2018).
Indirect	Increased risks of accidents, increased transmission of diseases, disruption to sleep, a growth in violence, increased hospital admittance and wider impacts on health services (CCC, 2022; Ebi et al., 2021; Howarth et al., 2024).
Vulnerabilities	Adults over 65 years, people with chronic diseases, those with long term illnesses or disabilities, people with drug and alcohol addictions, the homeless, people living in deprivation, and very young children, are particularly vulnerable to the effects of heat (EAC, 2024a; Ebi et al., 2021).

water supply, cold chains, and wider supply chains (Boyd et al., 2024; CCC, 2021; Fox et al., 2023; NAO, 2023). There is also the potential for cascading risks, reflecting the interdependencies that can exist between systems (CCC, 2023a; Howarth et al., 2023a; Townend et al., 2023). Many of these wider impacts will also affect people, including their health and well-being (Ravishankar and Howarth, 2024).

3. The importance of, and challenges for, cooling

Cooling offers a solution to mitigate some of the health risks brought by high temperatures within buildings (Caio and Miller, 2021; Carbon Trust, Cool Coalition, 2020) and its use globally is expected to rapidly grow as temperatures increase (UNEP, 2023). This includes cooler temperate climates like in the UK, where the housing stock has largely been designed for winter heat retention (Alrasheed and Mourshed, 2023; ARUP, 2022; Taylor et al., 2023), making it poorly equipped for dealing with summertime overheating (BEIS, 2021; Howarth et al., 2024).

It is estimated 20 per cent of UK homes already experience overheating in an average summer (Drury et al., 2021; EAC, 2024a; Howarth et al., 2024), and modelling suggests that this could increase to 90 per cent of homes at 2 °C of warming (ARUP, 2022). Multiple aspects contribute to overheating risk, including building archetype, tenure, occupancy and socio-economic factors (CCC, 2023a, 2022; EAC, 2024a; Taylor et al., 2023). An estimated 80 per cent of existing homes will be in use in 2050 and these have not been designed for overheating risks (CCC, 2023a, 2022). Even without taking account of heatwaves, it has been suggested that once we move towards 2 °C of warming several Northern European countries, including the UK, could see around a 30 per cent increase in uncomfortably hot temperatures, making homes dangerously unprepared for the future and requiring large-scale adaptation (Miranda et al., 2023).

As highlighted in Section 1, cooling within homes can be provided through a variety of routes. There are passive solutions, linked to urban and building level design and shaped more widely by occupant behaviour in terms of how the building is operated and run (ARUP, 2022; EAC, 2024a; Lizana et al., 2022; Taylor et al., 2023). Cooling can also be provided through mechanical, or active means, from simple technologies such as electrical fans through to room or building level AC systems. Free standing or ceiling fans can provide useful thermal comfort by increasing air velocity, with relatively low impacts in terms of energy use and running costs (EAC, 2024a; Rissetto et al., 2021; Taylor et al., 2023). AC systems in contrast are more energy intensive, resulting in indirect greenhouse gas (GHG) emissions from energy use if from fossil fuels, whilst also creating new challenges for energy system operation linked to peak loads and managing system constraints (IEA, 2021, 2018). AC systems can also result in direct emissions from the use of fluorinated gases (F-gases) or hydrofluorocarbons (HFCs) within refrigerants (Carbon Trust, Cool Coalition, 2020; Lizana et al., 2022; Park et al., 2021). Furthermore, AC systems also produce waste heat, which if dispersed into local environments, can further increase urban temperatures and exacerbate urban heat island effects (CCC, 2022), having additional equity implications in respect to access and use of AC. Active cooling therefore creates a range of societal, energy system and climate challenges driving further increases in local and global temperatures, which in turn leads to increased cooling demand (UNEP, 2023) - it is a vicious circle (Frost, 2022; Ouali et al., 2018).

At the global level, without policies to decarbonise cooling, by 2050 the installed capacity of cooling could triple while electricity demand could double, resulting in surging GHG emissions (UNEP, 2023). Creating cooling pathways towards near zero GHG emissions will be vital globally, and the Global Cooling Pledge was designed to help drive sustainable cooling actions (Cool Coalition, 2023; UNEP, 2023), with over 70 countries including the UK signing the pledge (DESNZ, 2023a). Cooling demand is expected to increase within UK homes (Hoggett et al., 2024), although data on the energy and refrigerant emissions from cooling is largely missing (BEIS, 2021; Rubin, 2023). A widely cited figure from 2018 estimated that around 5 per cent of UK households have some form of active cooling, with a suggestion that the number of units could rise from around 1 million today to 17–18 million by 2050 (BEIS, 2021; Sansom, 2020; Watkiss et al., 2021). Market research in 2021 suggested that there could be up to 84,000 annual installations of active cooling systems a year across new build and existing UK homes (BEIS, 2021). The UK Government is currently working to fill data gaps and better assess building level overheating risks and solutions, including energy demand and energy system impacts (DEFRA, 2023; DESNZ, 2023a; Rubin, 2023). However, there have been criticisms of a lack of urgency, with too much focus on gathering data, rather than taking action (Boyd et al., 2024; CCC, 2024; EAC, 2024a; Howarth et al., 2024). There is also a view that an integrated approach to overheating and cooling decarbonisation is needed (Hoggett et al., 2024), including better coordination across mitigation and adaptation (Howarth, 2024; Miranda et al., 2023), and a need for pace over policy perfection (Boyd et al., 2024).

International research on cooling decarbonisation identifies the need for action on passive strategies, higher energy efficiency standards for cooling equipment, and the fast phase down of HFC refrigerants (IEA, 2018; UNEP, 2023), whilst also working to ensure any use of active cooling is powered through zero carbon energy (Caio and Miller, 2021; Carbon Trust, Cool Coalition, 2020; UNEP, 2023). Collectively these approaches can be visualised through an avoid-improve-shift framework, and have been applied to the decarbonisation of cooling by the global Cooling Coalition – see Fig. 1 (Carbon Trust, Cool Coalition, 2020; Creutzig et al., 2018).

Fig. 1 shows that to decarbonise cooling, policies across urban environments, buildings, equipment and the energy system are all of importance (Carbon Trust, Cool Coalition, 2020; UNEP, 2023). Whilst the figure shows the UK policy landscape, there will be similarities to other countries, given the broad relationships to buildings, products, and energy systems (CCC, 2023b; UNEP, 2023). Such policies include:

- for 'avoid', those focussed at the building and wider planning levels, which can help to design out the need for cooling through passive measures, such as effective insulation and ventilation, natural and building level shading, the use of reflective surfaces and cool roofs, as well as green and blue spaces (ARUP, 2022; BEIS, 2021; EAC, 2024a; UNEP, 2023).

- for 'improve', better product standards to reduce energy and F-gas use, with policy packages that combine eco-design and labelling, minimum energy performance standards, and financial incentives, seen as the most effective route to transforming the cooling market (Cian et al., 2019; IEA, 2018).
- for 'shift', those supporting energy system change, including the decarbonisation of supply and actions to help flex and reduce demand to help manage peaks (D'Ettorre et al., 2022; IEA, 2018; UNEP, 2023).

For a decarbonised cooling pathway to emerge, action across the entire avoid-improve-shift framework is required. This can help to overcome a range of recognised barriers for sustainable cooling, across adaptation and mitigation, which include: increasing heat resilience of the built environment; downsizing cooling systems and cooling needs; and mitigating resource consumption and environmental impact (Lizana et al., 2022). In addition, within market-based economies, like that of the UK, interventions will be needed to shape what happens with cooling in the domestic sector. This is because AC is the incumbent cooling technology meaning it could easily become the go-to solution for managing overheating with other strategies, such as lower impact passive measures, overlooked (EAC, 2024a; Howarth et al., 2023b; Lizana et al., 2022; UNEP, 2023). Whilst it is reported that the market for domestic cooling within the UK appears to be relatively immature (BEIS, 2021),

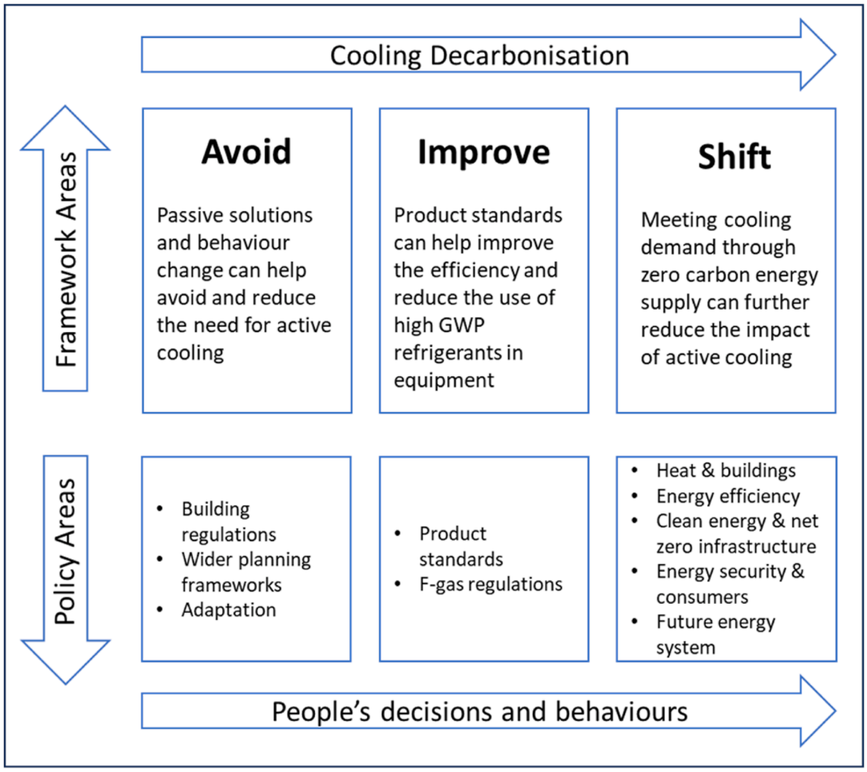

Fig. 1. The avoid-improve-shift cooling decarbonisation framework (Hoggett et al., 2024).

that could rapidly change as temperatures increase, with a suggestion that there is already an emerging market pull from consumers and a market push from manufacturers for active cooling technologies (Hoggett et al., 2024). In addition, neo-liberal market led policies also often fail to effectively support social outcomes, such as heat-health concerns (Bayliss et al., 2024; Jacobs and Mazzucato, 2016; Marmot, 2015). As such, consideration of how to shape the cooling market and people's role and interactions within it will be central to efforts to decarbonise cooling and reduce overheating risks across the avoid-improve-shift framework.

4. The importance of people

In respect to heat risks within the built environment, much attention in recent years has focussed on people's vulnerabilities, the heat-health challenge, as well as people's perceptions of risks and their adaptation responses to them (Howarth et al., 2023a; Kondo et al., 2021; Thomson et al., 2019a; Turek-Hankins et al., 2021). Embedding social and behavioural responses within heat-related policies will be critical to delivering their success (Howarth et al., 2019). Less attention has been paid to understanding how cooling might evolve in response to those heat risks, or the role of people in shaping different cooling pathways (Khosla et al., 2020; Khosravi et al., 2023; Thomson et al., 2019a) - particularly in cooler temperate climates where this is a new and emerging challenge (Hoggett et al., 2024).

Returning to the avoid-improve-shift framework in Fig. 1, the decisions, actions, and behaviours of people run across each area of the framework, with people's perceptions of risks, and possible interactions with policy and markets, all playing an integral role in shaping how cooling might be decarbonised within homes (Hoggett et al., 2024). For example, in respect to 'avoid', policy interventions that support and enable people to adopt lower impact solutions can help reduce the unnecessary purchase and use of active cooling (EAC, 2024a; Taylor et al., 2023), reducing the risk of AC systems becoming the default solution to cooling homes (Lizana et al., 2022). It is important to note here, the limitations of policy approaches grounded in theories of rational choice, filling perceived information deficits (Shittu, 2020; Strengers and Maller, 2014) including limitations to integrate situational knowledge and experience (Andor et al., 2022). Approaches integrating the socio-cultural, material and contextual elements of energy practices provide a useful lens to shape policy (Kammerlander et al., 2020; Munro, 2000). Here, practices in which energy consumption is embedded are placed at the centre of policy (Shove, 2004). Cooling demand could, for example, be viewed as embedded in the practice of working from home. Increasing the uptake of shading at household level could be facilitated through policy intervention which normalises, for example shutters and green infrastructure, supported by financial incentives and maintenance guidance. This broader framing could support the use of passive approaches, such as avoiding internal heat gains, managing airflow and ventilation, choices around clothing, diet, work, and exercise patterns (BEIS, 2021; EAC, 2024a; Lizana et al., 2022; Taylor et al., 2023). As well as helping avoid the need for active cooling, if passive steps are taken first, any future use of active cooling will increase its efficiency, enable flexibility, reduce costs, and energy demand within the energy system (BEIS, 2021; Hoggett et al., 2024; UNEP, 2023).

Policy and regulation also have a central role in helping to 'improve' cooling products within markets, but again, the actions and behaviours of people are vital (IEA, 2018; UNEP, 2023). This is particularly salient in the context of heat events, where patterns of distress purchasing have been observed (Hoggett et al., 2023). Information, advice and labelling can play an important role in helping people to actively choose more efficient cooling products (UNEP, 2023) as well as understand how to use and maintain them efficiently (BEIS, 2021; Lizana et al., 2022). The safe disposal of AC devices is also important for avoiding F-gas leakage and its associated impacts for GHG emissions (Lizana et al., 2022; Zhao et al., 2015).

In respect to 'shift', a wide range of policies will shape the impact of domestic active cooling within energy systems and the role of people is central to this (IEA, 2018; UNEP, 2023). Examples could include decisions linked to the use of other low-carbon technologies within the home, such as solar PV and energy storage, which could help meet cooling loads (BEIS, 2021; Khosravi et al., 2023) as well as supporting people to provide demand-side flexibility in respect to the timing of cooling demand, which could benefit both the energy system and the individual (D'Ettorre et al., 2022).

Looking at the broader literature on societal transformations in relation to energy and the climate, decarbonisation is not just about technology change, but also the role of people, their behaviour, actions and interactions with buildings, cooling equipment, and policy (Alrasheed and Mourshed, 2023; DESNZ, 2023c; House of Lords, 2022; Lizana et al., 2022; Smallwood et al., 2024; Taylor et al., 2023). Despite this, the tendency within policy is to predominately focus on technology innovations and supply-side solutions, rather than the demand-side, engagement of people and the role of behaviour (Creutzig et al., 2018; Howarth and Robinson, 2024; Prosser and Whitmarsh, 2022; Smallwood et al., 2024). There is also often an overreliance within policy approaches to simply provide information and advice, which whilst important, are not sufficient on their own to change behaviour (House of Lords, 2022), as the wider systems and social structures in which people are embedded also shape outcomes (Park et al., 2023). People also play multiple roles within society and system change, beyond resource consumption (Hampton and Whitmarsh, 2023; Prosser and Whitmarsh, 2022), and low-carbon and climate-resilient behaviours are shaped by individual knowledge and agency, social factors such as group identity and practical factors such as ease and price (Mitev et al., 2023). Therefore, to develop effective policies to encourage and enable low carbon behaviours, including those related to cooling, a more nuanced approach is needed (Prosser and Whitmarsh, 2022; Smallwood et al., 2024). A focus on community level policy interventions provides a useful example here, offering a sufficiently narrow context to take into account situational variables, such as socio-demographic factors, housing archetypes and tenure, access to green space and level of urbanisation. Policy could support, for example, interventions at multiple scales including neighbourhood greening, heat management training, community cooling centres and local cooling champions as trusted information touchpoints.

A useful approach to unpack these issues in relation to overheating and cooling is the downstream-midstream-upstream behavioural and social change framework illustrated in Fig. 2. This shows how policy interventions at multiple scales, encompassing both individual agency and wider social structures can be considered (Hampton and Whitmarsh, 2023; Mitev et al., 2023; Park et al., 2023). It provides a more comprehensive route to embed the importance of people into the challenge of adopting low impact cooling pathways.

Potential interventions to support this broader approach to behavioural and social change can also be linked back to the avoid-improve-shift framework. For example, downstream interventions that support behavioural change include information and advice to help people understand and reduce overheating risks, such as avoiding heat gains, managing airflows, and adopting passive cooling measures (EAC, 2024a; Taylor et al., 2023). Information and labelling can encourage the purchase of more efficient and lower impact cooling equipment (IEA, 2018). Whilst, in respect to 'shift', the extent to which people understand and are willing to flex cooling loads to reduce emissions and/or support the energy system will require clear and concise information and support, amongst other things (D'Ettorre et al., 2022).

In addition, the use of mid-stream interventions can help shape the wider environment in which people make decisions on the use of active cooling. At a high level, clear and consistent messaging from government and its agencies on keeping cool through passive approaches, rather than just leaving it to the market, would help support social norms around passive cooling (EAC, 2024a). Whilst wider policy support could help incentivise and improve access to passive measures, including financial support for their adoption (Hoggett et al., 2024), which could also be extended to support the purchase of the most clean and efficient active cooling.

Upstream policy approaches can play a vital role in structurally shaping the whole cooling market to better enable a low carbon cooling pathway to emerge. As Hoggett et al. (2024) highlight, these approaches could include: direct support to help develop the passive cooling market, such as supporting the supply chains for manufacturing and the skills within installer networks; upskilling and building the retrofit supply chain, so that heat risks and passive cooling solutions are identified within existing intervention points, before AC is adopted; whilst

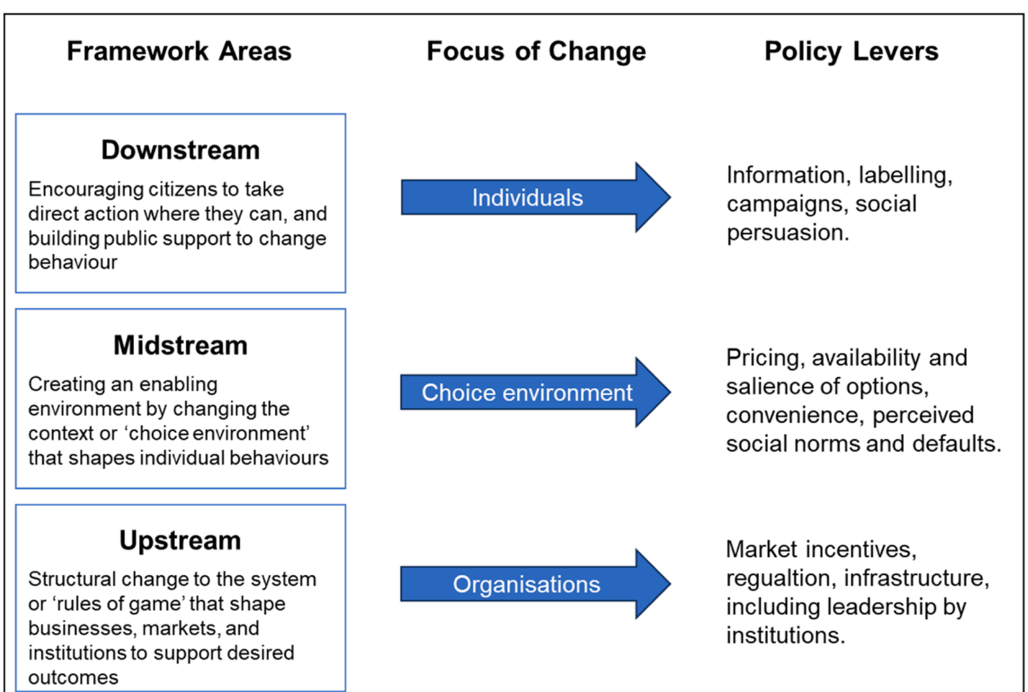

Fig. 2. The downstream-midstream-upstream framework for behavioural and social change. Adapted from (Park et al., 2023).

stronger regulation could also help to take the least efficient AC systems out of the market, and more quickly reduce the use of higher impact F-gases within domestic cooling equipment.

It is clear that embedding downstream, midstream and upstream thinking within policy making for cooling will be integral to supporting low carbon behaviours. It can support the individual, but crucially move beyond that to shape the landscape in which decisions are made. It sets out opportunities for leadership and coordination from government across their messaging and policy development, to support social change and low carbon outcomes (House of Lords, 2022). Linking these approaches to support behaviour change, to the wider avoid-improve-shift framework, would better enable a comprehensive approach to cooling decarbonisation.

A final important social consideration in the relationship between overheating and cooling in homes is equity (EAC, 2024b; Thomson et al., 2019b). This includes considerations in relation to the access and use of cooling, as well as broader considerations relating to peoples sensitivities to the risks of overheating (Thomson et al., 2019b); with the ability to respond to heat risks being influenced by a wide range of social-economic, environmental, and demographic factors, which are not shared equally across society (EAC, 2024b; Ellena et al., 2020; Kennedy-Asser et al., 2022; McLoughlin et al., 2023). Beyond income, vulnerability can be influenced by housing quality, housing tenure, access to green space, and levels of local pollution, with more vulnerable people often facing additional challenges around the costs of cooling, for both passive and active solutions (EAC, 2024b; FOE, 2022; Kennedy-Asser et al., 2022; Shade the UK, 2022). It will therefore be important, as part of the policy challenge for decarbonising cooling, to find ways to ensure all people are able to keep cool within their homes, linking to wider efforts to enable just and equitable energy transitions (Carley and Konisky, 2020; Huang et al., 2023; Miró, 2023).

5. Putting UK homes on a low carbon cooling pathway

Given the ongoing evidence of rising temperatures and poor progress to date on reducing the emissions that are driving them, the frequency and intensity of extreme heat events looks set to worsen. This will create new challenges in relation to equity and will further impact the ongoing heat-health challenges associated with overheating and lead to growing demands for cooling within homes. Without sufficient policy intervention there is a strong possibility, given its incumbent nature and wide availability, that AC systems will become the go-to solution for many consumers. If this becomes the prevailing social norm for cooling homes, it will lock-in a high impact cooling pathway which could increase GHG emissions, that will be difficult to move back from, but this is not an inevitable outcome.

Looking at the UK as an example of a cooler temperate country, the domestic cooling market is currently relatively immature and as such, there is a window of opportunity to shape the direction that cooling within this sector might take. As the UK works towards creating a national cooling action plan by 2026, it will be important to ensure that this includes a detailed plan for homes and clear mechanisms to encourage low-carbon cooling options. We suggest that more intervention than expected will be needed by government to secure such an outcome. In particular new building regulations may need to be further reformed to limit overheating and policies to drive heat pump adoption may also need to consider cooling.

Within this perspective, we have set out the need for decarbonising cooling within homes through an avoid-improve-shift framing. By taking action across all three areas, policy makers can take a comprehensive approach to shaping the cooling pathway that emerges. In addition, there is a strong need to focus on the role of people and the factors that shape their decisions and behaviour, with downstream, midstream and upstream interventions all vital enablers of low-carbon cooling outcomes. Collectively these frameworks can help to overcome many of the policy silo's that currently exist and provide a route to the development of a coherent and comprehensive approach to cooling decarbonisation.

Policy support for a passive first approach is a no-regret option that can help protect people's health, support equitable outcomes, make homes more resilient, and help reduce the likelihood of AC systems being adopted unnecessarily. It may be, as temperatures continue to rise, that AC will increasingly be needed to help keep homes cool, but by taking a passive first approach, it should help push back the adoption of AC systems further into the future. This will buy time for policy development and innovations in technologies, supply chains and wider lower impact cooling solutions. Passive first will also help to ensure that once active cooling is adopted, it can be used more effectively and efficiently. In addition to helping avoid the need for cooling, policies to improve cooling products and markets will continue to be needed, as will ways to ensure that cooling loads are effectively managed within energy systems to reduce demand and emissions. Downstream information and advice will play an important role across the avoid-improve-shift framework, helping people reduce and manage risks, whilst encouraging behavioural and societal change. However, this will be insufficient if not also supported by more effective midstream and upstream actions that change the wider 'choice environment' as these also shape decisions and outcomes, and as such would help shift social norms and expectations on the need for active cooling, and ultimately help to make low carbon cooling behaviours the easy and accessible choice.

There is a window of opportunity to shape the cooling pathway that will emerge within UK homes over the coming years and decades. An approach that combines actions across the avoid-improve-shift framework and embeds people in policy interventions can reduce the impact of cooling, support equity, and help to avoid AC becoming the new social norm. Whilst focussed on the UK, overheating and cooling are emerging issues in many temperate countries and as such, the challenges and opportunities we discuss within this perspective are more widely relevant.

CRediT authorship contribution statement

Hoggett Richard: Writing – review & editing, Writing – original draft, Conceptualization. **Lowes Richard:** Writing – review & editing, Conceptualization. **King Louise:** Writing – review & editing, Writing – original draft, Conceptualization. **Ugalde-Loo Carlos:** Writing – review & editing, Funding acquisition. **Demski Christina:** Writing – review & editing, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

No data was used for the research described in the article.

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