



Original research article

Low carbon heating transitions and Actor Network Theory: Entanglements with the fireside

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ABSTRACT

We share findings from 30 oral histories of home heating (1945 to present) gathered in the former coal mining town of Rotherham in Northern England. By analysing these rich personal accounts using Actor Network Theory (ANT), we reveal the coal fire (or coal-fired range) as a powerful actant shaping domestic life in the decades following the end of the Second World War. This exposes important, previously unacknowledged, relational-material entanglements with the fireside, which endure despite many decades of gas central heating in the UK. The nature and strength of these entanglements have implications for the socially and culturally sensitive handling of efforts (across Europe) to transition households to more technological low carbon heating systems, such as heat pumps. This paper sets out early findings from the UK component of a Europe-wide project which innovatively seeks to establish a social and cultural history of home heating in order to distil lessons for a more socially and culturally conscious transition to low carbon heating systems.

1. Introduction

The transition from fossil fuelled to low carbon domestic heating systems (i.e. heat pumps) is pressing but unfolding too slowly to support legally binding climate targets, suggesting that barriers to the transition run deeper than technological readiness and cost considerations. Our approach to exploring this problem combined rich personal accounts of heating transition in the past (oral histories), interrogated by an interdisciplinary team and filtered through the lens of Actor Network Theory (ANT). Through this novel application of ANT, we reveal relational-material entanglements with the fireside that endure despite many decades of gas central heating in the UK, enabling us to draw out what this means for the sensitive handling of domestic low carbon heating transitions. We also reflect on what our interdisciplinary approach (marrying history, energy policy, fine art practice and architecture) and the novel application of ANT to analysis contribute to scholarship and policy making in relation to domestic heating transitions.

This paper is associated with the international, interdisciplinary project 'Looking back to move forwards: a social and cultural history of home heating' (JUSTHEAT, 2022–2025). The project aims to understand how major changes to home heating since the end of the Second World

War have impacted our lived experience and how these impacts are experienced differentially across place, time and social groups. We aim to distil learning from these historic accounts to promote a more user centred and socially and culturally engaged transition across the UK and Europe. The project combines oral histories, archival research, a network of fine artists and innovative approaches to promoting dialogue between policymakers, practitioners and citizens regarding the future of heat. The project spans the UK, Romania, Finland and Sweden, but the present paper is focussed on the 30 oral histories collected in the UK in 2022/23 [1].

JUSTHEAT significantly advances the literature which seeks to examine past energy transitions to provide lessons for future shifts. There are two key blind spots within this literature that we aim to help address. First, the focus of existing studies is mostly on national and global scales (e.g. [2–6]), with the domestic sphere rarely featured. Second, although insights exist into the social context in which people create, deploy and use technologies (i.e. [7]), rarely have relationships between humans and evolving (heating) technology been explicitly interrogated. In focussing in on this relationship, we uncover complex and powerful material, relational and emotional entanglements with heat sources, with these entanglements being deeper in relation to some

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heat sources than others. Understanding this dynamic provides hitherto missing insights into why transitions to low carbon heating systems might be received with some reluctance and suspicion in some quarters. Whilst Hargreaves and Middlemiss [8] argue that, in a domestic energy context, we act relationally rather than rationally, here we explore how material and relational factors interact to produce relational materialities that can be hard to part with.

1.1. Structure of the paper

This paper comprises four sections in addition to this one. The next section provides a brief history of heating in the UK, setting the oral histories in context. We then outline how we have applied the oral history method and filtered the results through ANT as our novel approach to analysis. Relevant findings from the oral histories are then presented and analysed using ANT, drawing out the implications for the current transition. We conclude by reflecting on the value of our approach for understanding the implications of enduring attachments to the fireside for this transition.

2. Historical context

If the object of this paper is to expose what ANT can reveal about the material-relational entanglements between us and long-established fuels and methods of heating, then we must first understand how we arrived at these arrangements and how initiatives have sought to move us away from them. Understanding this aids appreciation of how we became so entwined with particular heating fuels, methods and technologies. Participants' accounts are deeply personal, but are also set against and shaped by political, economic, policy and infrastructural developments that shaped the fuels, methods, technologies and costs of home heating. Understanding these key events is not only important for setting participants' accounts in context but also, the findings from the oral histories provide vital understandings of the lived experience of these high-level events, something Darby [9] regards as a research priority.

2.1. Key events in Britain's heating history since 1945

In 1945, 95 % of homes in the UK still used coal fires and/or the coal-fired range for heating and hot water, as they had since the mid-19th century or earlier [10]. Access to coal was, however, heavily mediated by the post-war fuel crisis which extended the war time practice of fuel rationing until 1958 [11].

From the mid-1960s, the country embarked on an unprecedented period of domestic energy transition, the scale of which has never been matched since [12,13]. A combination of legislation: the Clean Air Act (1956) - introduced to clean up poor air quality caused by coal burning - and the concurrent discovery of massive reserves of natural gas (methane) under the North Sea, fast-tracked a national transition to gas home heating and the rapid decline of coal [1,14]. During the government-led natural gas conversion programme (1968–1977), the heating systems of 14 million households were substituted at an astonishing rate, with 40 million appliances converted to be compatible with natural gas over just under a decade [15]. This enabled a comprehensive shift from coal-fired heating of various sorts (i.e. open fires, ranges, coal-fired boilers) to gas fires and gas boilers. The transition was driven by strong leadership on the part of local and national authorities (the gas industry was publicly owned until 1986) as well as compelling public information and advertising campaigns on the part of the Gas Council [13] that captured the imagination and confidence of consumers.

The 1970s brought unrest in oil-producing nations causing massive peaks in oil prices, leading to economic crises (the 'oil crisis') and the rationing of energy once again [16]. Households faced massive inflation in the prices of commodities and regular blackouts to reduce energy consumption. The transition to natural gas (found in abundance off UK shores) helped ensure energy security and that domestic heating and

cooking were unaffected by volatility in the oil market, for those connected to the gas network. Nevertheless, increased financial pressure on households restricted heating during this period [17]. The direct impact of the oil crisis on mining households was lessened by the domestic coal allowance (concessionary coal) that miners received as part of their remuneration package.

The pace of change showed no sign of easing in the 1980s, with the decade bringing devastation to coal mining communities across the UK as the Conservative government sought to rapidly deindustrialise and coal mines began to close [16]. Most of those interviewed in Rotherham were profoundly affected by prolonged periods of industrial action (i.e. the Miners' Strike) during this period. During strike action, wages and access to concessionary fuel were withheld, plunging those communities into what we now call fuel poverty.

By the 1980s and 90s, the UK's domestic energy profile looked completely different to how it did 30 years earlier with 95 % of homes (mainly in urban areas) heated by gas central heating. Where households had fires, in most cases, these would have been wall-mounted gas fires or imitation coal fires powered by gas or electricity. This era brought stabilisation of energy supply and pricing with sustained reductions in gas prices, although high interest rates pushed up other costs [18]. However, coal mining communities followed a different trajectory to much of the rest of the country, and continued to use coal, either because concessionary coal continued for some time after the closure of local coal mines or because some mines remained active until well after 2010.

The Kyoto Protocol of 1997 pushed climate change up the political agenda and triggered more ambitious standards for the energy performance of new homes [19]. Low carbon heating systems such as air source heat pumps (ASHPs) became more common, with installations peaking in 2011 and tailing off as a new coalition government came into power [20]. However, these developments are unlikely to have impacted beyond those living in new homes and certainly would not have benefitted many households in Rotherham.

Currently, the transition from gas central heating to low carbon heating systems (primarily ASHPs) proceeds slowly. Decarbonising domestic heating is a priority, accounting for 17 % of current emissions [21]. Progress is not non-existent, with dependency on gas central heating creeping down slowly from a peak of 95 % being heated via gas in 2018 to around 74 % in 2023 [22]. A significant milestone in the transition away from fossil fuelled heating also passed during May 2023, when bituminous (house) coal was banned in the UK, effectively signalling the end of coal fires [23]. These events all profoundly shaped the heating trajectories followed by our participants, although they rarely linked changes in heating arrangements to the wider societal, economic and political events that dictated them. This section demonstrates that the degree of personal choice that participants were able to exert over their home heating arrangements was minimal. Far from leading to dissatisfaction or frustration, this lack of choice goes unmentioned in most accounts and appears to have deepened the relationship between household and fire, as we go on to explore in our findings.

3. Methodological approach and case study background

3.1. The case for oral histories of domestic heating

Narratives of past heating transitions tend to operate at the grand scale [9], focussing on the triumphs of technology. Grand narratives neglect personal stories that reveal more complex and nuanced individual and household realities and social and cultural impacts, which Darby [9] argues offer deeper understandings of how high-level policy and technological change play out in often complex and unanticipated ways in everyday life.

Personal stories can be captured as oral histories [24], which are capable of revealing insights into both the pain and loss but also the excitement and hope of energy transition [25,26]. They also reveal the

entwinement between communities and their energy sources [27]. Oral histories reveal previously undocumented phenomena in the private world of the home and family, which technologists and policymakers rarely access, revealing the richness of human experience over time and how structural change impacts the personal [24].

This level of insight gets lost within grand narratives, making it difficult for those shaping current transitions to understand the true impacts of past decisions, to avoid repeating past mistakes and to address injustices wrought [1]. Oral histories unlock and capture these insights, which may seem mundane and insignificant, but which are *“more than peripheral to the serious business of energy policy and transition”* [9].

JUSTHEAT responds to critiques of grand narratives regarding our heating histories and aims to re-tell them as, what Foucault terms ‘effective histories’ that acknowledge diversity in the experience of history, revealing its messiness and “crooked contours” [28].

3.2. Application of oral histories

The oral histories were recorded in participants’ own homes, where there was consent to do so. This helped to situate participants’ minds and memories within the domestic space, as well as to feel more at ease. Each interview began with a standardised question that positioned the narrator’s thoughts temporally and on the topic at hand: “tell me about your earliest memory of keeping warm or feeling cold at home”. In line with the principles of oral history, researchers intervened minimally, interjecting only to keep the conversation on topic. The freedom afforded to participants to share what felt important to them led to coverage of a range of themes and topics in relation to home heating: heating technologies and fuels; supplementary heating; place identity; gender relations; domesticity, family, and everyday life; work and local economy; politics and policies; sensory experiences; and their own feelings and emotions in connection with home heating. Interviews lasted between 40 min and 3 h. The accounts were recorded, with permission, and transcribed verbatim.

3.3. The case study locations

The first of two JUSTHEAT UK case study locations was Rotherham, South Yorkshire. The town was chosen because of its strong connection with coal mining – which, for over 100 years was the first fuel for domestic heating and industry in the UK and beyond. It is also of interest due to its current above national average use of gas central heating systems – as the prevalence of such heating systems declines across the UK, seemingly Rotherham is being left behind, likely due to its delayed participation in the natural gas transition. We focused on three settlements within the conurbation: Wentworth, Whiston, and Maltby:

- **Wentworth:** a small rural village at the centre of a privately owned historic estate. The wealth of the estate was derived from mining. The estate owns the majority of the properties in the village and the practice of solid fuel burning in tenanted estate houses endures. Many of the properties in the village date from the early 1800s, are stone built and energy inefficient and do not have gas central heating.
- **Maltby:** a large township east of Rotherham, developed around the Maltby Main Colliery in the early twentieth century. Maltby’s last mine closed in 2013, but its cultural heritage remains intimately linked to mining. Maltby is a planned industrial settlement built between 1910 and the 1960s. Most households in Maltby were not connected to the gas grid until the late 1990s or 2000s.
- **Whiston:** a relatively affluent suburb, which has fewer direct connections to coal mining (although miners lived there), nevertheless, oral histories recorded in the area still highlight the historic centrality of coal in the community.

3.4. The oral history participants

Ten oral history participants were recruited from each of these locations. Participants were self-selecting and were exclusively aged 56 and over. There was an even split between male and female participants in Wentworth and Whiston, but a higher proportion of women participated in Maltby. All participants described working-class backgrounds in their oral history recordings. Most lived in social rented housing as children, had fathers who worked as miners or steelworkers, and mothers who worked as cleaners, in retail, or as farm labourers, in addition to unpaid domestic labour. Across the three focus areas, however, Maltby was the only one that reflected some continuity in this socio-economic status. Whilst all participants were now retired, employment for participants in Maltby had largely consisted of nonprofessional roles and only one participant out of ten was educated to degree level. Moreover, all participants from Whiston had held professional roles, and four out of eleven were educated to degree level or higher. Wentworth participants also held professional or semi-professional roles. Whiston particularly reflected the highest level of social mobility of the three areas in focus.

In terms of housing circumstances, the percentage of owner-occupiers within our sample in Maltby was high (80 % of participants) but 20 % were living in social rented housing. In Wentworth, the number of renters was significantly higher (50 %), but these properties were privately rented from the Estate. No residents in Wentworth were living in social housing and Whiston participants were exclusively owner-occupiers.

Only two of the oral histories were collected from participants from non-White backgrounds – they were both members of the same family. The research team hopes to gain further insight into the experiences of people from non-White backgrounds by expanding the oral history collection for Rotherham.

3.5. Approach to analysis

As an interdisciplinary team (the UK team), we needed an approach to analysing the oral histories that was accessible to all of us and benefitted from our different disciplinary perspectives. As such, we took a highly inductive, immersive approach which involved each team member listening to all of the oral history recordings in full and noting what seemed significant from our respective vantage points, as social scientists, historian, artist and architect. A workshop was held where we each reflected on what felt most significant, notable or new in the same set of oral histories and we all came up with different interpretations of the same phenomena. We felt that it was hugely beneficial for the same data to be viewed through a range of disciplinary lenses, enabling holistic exploration and avoiding interpretations that are narrow or skewed towards one disciplinary perspective. Our interpretations did not contradict each other, but were complementary, with each of our perspectives opening up new dimensions to our analysis.

Whilst listening to the oral history accounts, the lead artist also drew them at the speed of listening (see [Images 1–5](#)), a process of translation into movement and marks that adds an additional way of experiencing the stories for the drawer and for other researchers. The artwork produced is featured throughout this paper. This provided not only a method of analysis for the artist but also visually captured the relationships between heating technology, apparatus and fuel and household members, in a way that led us to consider the extent of this co-dependency and how it was not just pragmatic but emotional and culturally embedded. To test and explore this observation further, we needed a framework that could accommodate and unpick combinations of material and relational/affective phenomena, leading us towards ANT.

3.6. Applying Actor Network Theory to the study of home heating

This section provides an overview of ANT, as our analytical framework. As will be revealed, the oral histories expose interdependencies between human and non-human actants and how they must act in concert as a network or assemblage, to achieve an outcome. ANT helps to tease out and expose these networks and assemblages. An earlier publication associated with JUSTHEAT [29] demonstrates that ANT has rarely been applied to the study of domestic heating or heating transitions and where it has, most notably by Hanmer and Abram [30], its use has been confined to the study of how high-level actor networks enable or obstruct socio-technical transitions, including adoption of new domestic heating technologies at scale. Here we reveal the capabilities of ANT at a different scale: that of the household, using it to expose the intricacies of the crucial relationship between humans and their heat sources. A key motivation of doing so is to understand in more precise terms, our relational-material entanglements [31] with our heat sources and how they might impact upon and fare during heating transitions. Given that take up of low carbon heat sources is low, and how affordability can only go some of the way to explaining this, we believe that unpicking these entanglements may contribute hitherto missing understandings of why the current heating transition is not being embraced by households.

ANT is primarily used for exploring socio-technical processes. It recognises and embraces complexity and interdependencies, contending that the social, technological and material are interwoven. Within ANT, there is no division between society and nature, truth and falsehood, agency and structure and micro and macro level phenomena, amongst other things [31]. This philosophy resonates with our project, within which we accept all respondents' accounts as their truth and where we see social and cultural factors, technology, agency, structure, and micro and macro level factors (some implicitly, some explicitly expressed) fusing together in complex and sometimes awkward ways within participants' accounts of how they have kept warm. Further, ANT regards human and non-human actants as equal in value and agency (the principle of generalised symmetry) and contends that it is the relationships between human and non-human actants that create phenomena. It also resists strict delineation between the material and the relational, advancing a relational-materiality that recognises that material things only achieve significance in relation to other actants [31]. For example, a manual heating device remains inert until there is fuel and a human with the relevant skills, giving it reality and form and enabling the generation of heat.

Another relevant aspect of ANT is translation, which concerns the ongoing process by which certain actants come to dominate the network and (whether deliberately or unwittingly) assure their position [32]. Where that actant(s) is not effective as the dominant force or is deposed in some way, then the network may disintegrate/be reconstituted [32]. For example, the coal-fired range could be seen as the dominant actant in UK households at one point in time, becoming an obligatory 'passage point' [32] for accessing warmth, hot water and heat for cooking and defining the roles of other actants within the network (i.e. mother stayed at home to keep the fires going). As time goes on, the range becomes dissatisfactory to the other actants in the assemblage, perhaps because cleaner, less labour-intensive alternatives are emerging and/or the skills to operate it are not passed on, then network reinvention occurs. Multiple assemblages might also operate in parallel, for example: a human might be part of an assemblage involving more primitive heating technologies and more sophisticated ones at the same time (i.e. having a wood burner and a central heating system together).

Our application of ANT is modified and informed by the interdisciplinary team, comprised of social scientists, historian, artist and architect. All of these perspectives open up different capacities within ANT. For example, the historian and the oral histories allow a temporal stretch to the concept, recognising that actor networks are shaped by more than the present. The artistic process also resembles ANT, being a

compositional medium inherently able to hold together different elements and find forms for multiple and diverse relationships and ways to convey their depth visually. To illustrate this, we include a sample of the drawings made during listening and which formed part of the analytical process. These drawings reflect and visually represent the assemblages in focus within this paper.

ANT encourages the observer (in this case, the researcher) to open space for inquiry, rather than attempting to reduce data collection and analysis to something manageable and familiar [33]. In this sense, ANT is well suited to interdisciplinarity, by making space for different perspectives. It is, in essence, the opposite of deconstructivism, encouraging the observer to resist scrabbling to unpick the power dynamics and attribute the phenomena observed to underlying forces [34]. Instead, we are encouraged to expand not narrow our thinking, by considering questions like: who or what are the actants? How are the actants connected to one another and what is the strength of that connection? And how are they acting collectively (as part of an assemblage)? These questions form the framework through which we filtered our results for the purpose of this paper, seeking to answer these questions using the data we hold. This was not difficult to enact given the rich detail our participants chose to provide regarding their interactions with the fire.

The next section of the paper provides an account of the findings from the oral histories, before analysing them using ANT in the Discussion.

4. Findings: memories of keeping warm at home

Participants rarely reflected on life beyond the households that they grew up in and subsequent households they have been part of. External factors which determined the fuels, technologies and methods that they used to heat the home, which dictated the cost and availability of fuel, were rarely mentioned, i.e. the national shift from town to natural gas, the miners' strike etc. Major events like The Clean Air Act (1956), pivotal in initiating the phase out of coal, and the energy crisis and rationing of the 1970s were explicitly recalled by a small number of participants, although more recollected the impact of these events (i.e. having to buy smokeless fuel, power cuts) rather than the events themselves.

The oral histories firmly establish the coal fire (whether an open fire or a fire powering a range) as the centre of the home in Rotherham in the immediate post-war era. It was depended upon for heat, hot water and cooking and daily life revolved around the immediate, warm space surrounding it. Keith (Wentworth), for example, recalled that the fire was "crucial to the household". Usually only one main fire was maintained in each home, perhaps two, and these were usually in the main living area(s). Memories of home heating in the era of the coal fire were abundant and intricate (Image 1). It was where participants went to first in their recollections and lingered the longest. As they moved into more recent eras of heating (i.e. gas central heating), recollections became more vague and less effusive, beyond remarking on improved levels of comfort and reduced labour and some references to disappointing experiences of early central heating systems, which were felt to give off an insipid heat.

Coal fires were remembered as comforting, bringing companionship, family togetherness and watching the flames brought a sensory, meditative quality that was widely enjoyed. The fireside was remembered fondly by most participants, particularly those who experienced them as children and were therefore shielded, to some extent, from the labour of maintaining them.

"Everything happened around the fire, it was the centre of the universe. It was the centre of family life. Food. Smell. Laughter."

(Female participant, Maltby)

"Obviously it [the fire] was the central point. As a treat, we used a long toasting fork to toast some thick bread. Toast has never tasted as good as that."

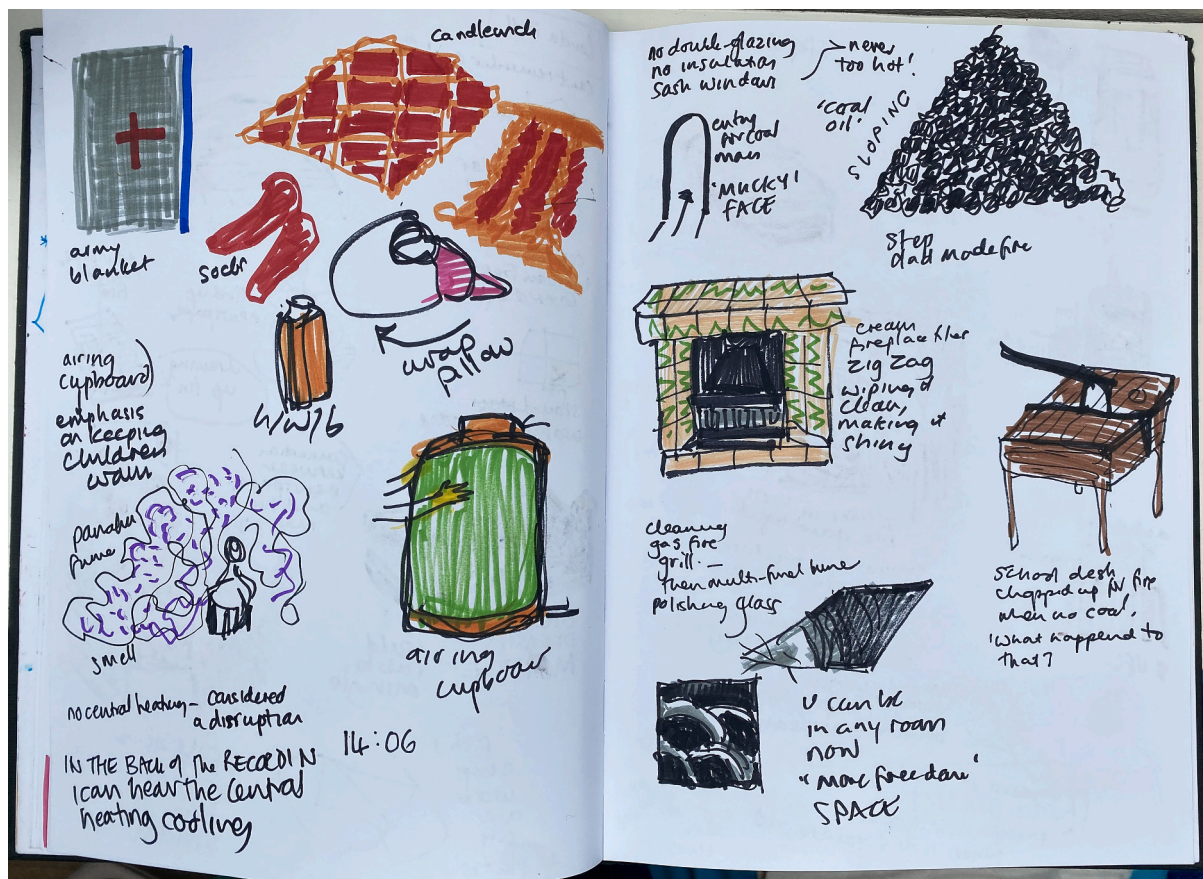


Image 1. Sketching the oral histories - pages from the UK artist's sketchbook showing the intricacies of keeping warm at home, by Becky Shaw.

(Lynne, Maltby)

The practicalities of moving and handling fuel, building the fire, lighting it and maintaining it, were explained intricately by participants. Recognition of the fireplace as a 'focal point' which facilitated social and emotional connections within the household was pervasive, although the labour and grime of maintaining the fire and the discomfort of the cold space beyond it, were also widely recognised. The following quote from Mary, the only participant who still relied on a coal fire in the present day, illustrates the labour involved in its maintenance:

"I get up at 5am and I put the kettle on to boil. While the kettle boils, I get the fire cleaned out in the time it takes me to boil the kettle. I wear a mask and use a long brush. I've got it down to a fine art. Once a week, I brush out all the soot from behind those two doors, there are pipes which pump water round and heat the house. This fire heats the house. We have a chimney sweep once a year and I try and do it myself in between times. The soot is unbelievable. It makes such a lot of dirt. I am always cleaning. Soot everywhere. Not an easy method of heating but it is warm."

(Mary, Wentworth)

Lighting the fire and getting it going was recalled as a source of anxiety for some. The pressure to do so was considerable when the household relied on the fire for survival. Most participants described the same techniques for starting the fire, suggesting a shared understanding between households. There was a sense of pride in the application of fire-making skills and techniques and participants remembered parents being keen to upskill their children in relation to fire making, which was considered a vital life skill at the time. Graham (Whiston) proudly recounted how he was taught by his parents to make 'spills' out of rolled up newspaper, tied in knots so that it would 'burn slower' and help ignite

the coal. He explained that he would hold a sheet of newspaper over the fireplace so that air could only enter from the bottom, which would 'draw' the fire up and 'get the flames going'.

Small sticks (kindling) were also used, when available, for getting the fire going and were often foraged by children locally on behalf of their households. Several people also recounted the thrill of, as a child, being permitted to throw rubbish on the fire, to both fuel it and enable waste disposal (Image 3).

The coal fire or range were manual systems that did not evolve rapidly, meaning that knowledge about how to build and maintain a fire was passed between generations through repeated demonstration. It was widely remarked that the speed at which heating and domestic technology moves on now feels hard to keep up with and involves a constant process of upskilling, but with no obvious teacher to turn to:

"You realise how much your parents did to keep you warm. The things they instilled, teaching us to keep warm. That sticks in my mind. It's not that I don't appreciate advances in heating but probably because later on you realise just how much was put into it and appreciate it a little bit more."

(Female participant, Whiston)

There was great inequity in terms of access to fuel between those working as miners (who received concessionary coal) and those outside of that sector. To help overcome this, coal was shared within families and an informal economy of selling on surplus coal between households was established. Keith (Wentworth) recalled his father, an ex-miner, purchasing 'spare load'. Stewart (Whiston), whose father was a steelworker, remembered cycling to his grandfather's house to collect coal and wheel it back to his parents' house.

Coal merchants were relied upon in everyday life and were associated with some underhanded practices (e.g. underfilled bags, wet coal to

maximise profits). Stories of sexual exploitation emerged in relation to households who could not afford to pay. Desperate times were widely recalled (due to economic crises, industrial action), where the coal man had to be placated, furniture was burnt to make a fire or families scabbled around on waste heaps to find discarded lumps of coal.

The concessionary coal allowance received by miners, which outlived the decline of the mining industry by some decades, undoubtedly acted as a disincentive to transitioning to gas central heating in former mining communities. One participant (Christine, Maltby) recalled their family receiving concessionary coal well into the 1990s. After her father died (his death reduced the coal allowance), her mother decided to transition to gas central heating. Many households in Maltby moved to gas central heating 20 to 30 years later than most urban households and many in Wentworth have still not made this change. For some households, gas central heating had taken some adjusting to, not least because it could not be budgeted 'by eye' (looking to see how much was left in the coal store) and because it does not offer the same intensity of radiant heat, with several participants describing the convective nature of the heat as dissatisfying.

Decisions about who was responsible for lighting the fire often depended on the work patterns of the household, with some participants describing their fathers building the fire before leaving home for paid work and then mothers igniting it before the children got out of bed. Many recalled the hard life their mothers had lived specifically in terms of maintaining the fire(s) and being responsible for the thermal comfort of the family.

"Mum, bless her, had a life of drudgery trying to keep us all warm and fed. Must have been horrendous. Five children under ten and having all that to do. Mum was at home all day- that's all she did, looked after the fire, looked after the food. Lovely cosy memories but it was blooming hard work."

(Female participant, Maltby)

Care is imbued in participants' recollections about the domestic work of their mothers; deep enveloping care in the form of maintaining warmth through tending to the fire and knitting warm clothes, as well as cooking, baking, teaching children how to make a fire and reading stories around the fire (Image 2).

"The fire in the kitchen, the black range: it had a space above the oven where Mum put our gloves to warm them."

(Gillian, Whiston)



Image 2. Stories by the fire.
Drawn in response to oral histories from Rotherham by Becky Shaw.



Image 3. Different ways of playing with and by the fire during childhood.
Drawn in response to oral histories from Rotherham by Becky Shaw.

The lives of some mothers were recounted as being transformed by gas central heating and the critical mass of more affordable labour-saving appliances that emerged around the same time (from the 1960s onwards), including: plug-in heaters, gas fires, gas cookers, fridges, electric blankets and later, central heating (Image 4). There are recollections, though, of people finding long established ways of doing things and ways of structuring and organising domestic life, hard to part with.

Participants born in the 1940s and 1950s recalled childhood memories that resembled a Victorian childhood, with little change to the way homes were heated between their generation and that of parents and grandparents. Homes then modernised rapidly for many from the 1960s onwards with the diffusion of central heating systems and explosion of increasingly affordable domestic innovations entering the home. The enormity of this change meant that it was remembered.

Below, one participant describes how a move to a home with an early form of central heating, powered by coke (a byproduct of coal), liberated the family from the intensity of the daily regime that accompanied the coal fire. This change was brought about by a move to a modern home and provides an example of how a new form of heating system coalesced with other labour saving (i.e. washing machines) and portable devices (i.e. electric free-standing heaters) to seemingly make domestic life more joyous:

"I was then 17 (1967) when we moved to the Rockingham Estate. A new council estate. It had central heating but that was a coke boiler-not gas. It was like another Universe! It was comfortable. Everything became less intense- you didn't need so much clothing. Everything was light and airy and warm. Bright and lovely. The days of cooking on the fire were gone. We had carpets! Not just peggy rugs we'd made. It was like living in a palace. Fabulous! Someone still had to fill the coke bucket up but it was less intense. The boiler could run all day without anyone doing anything. They got a washing machine! Mum used to have to wash by hand. It totally changed everything. We felt like millionaires. Life was good. We had electric heaters in the bedrooms if we needed them and a gas fire in the front room. The boiler heated the water but we could use an immersion heater in summer. The boiler didn't have to go all the time- the gas fire could take the chill off. We got a fridge at that point- that changed life as well."

(Sue, Whiston)

There was strong recognition of the benefits of central heating, especially when powered by reticulated natural gas which required no manual handling. It was praised for its cleanliness and for heating the

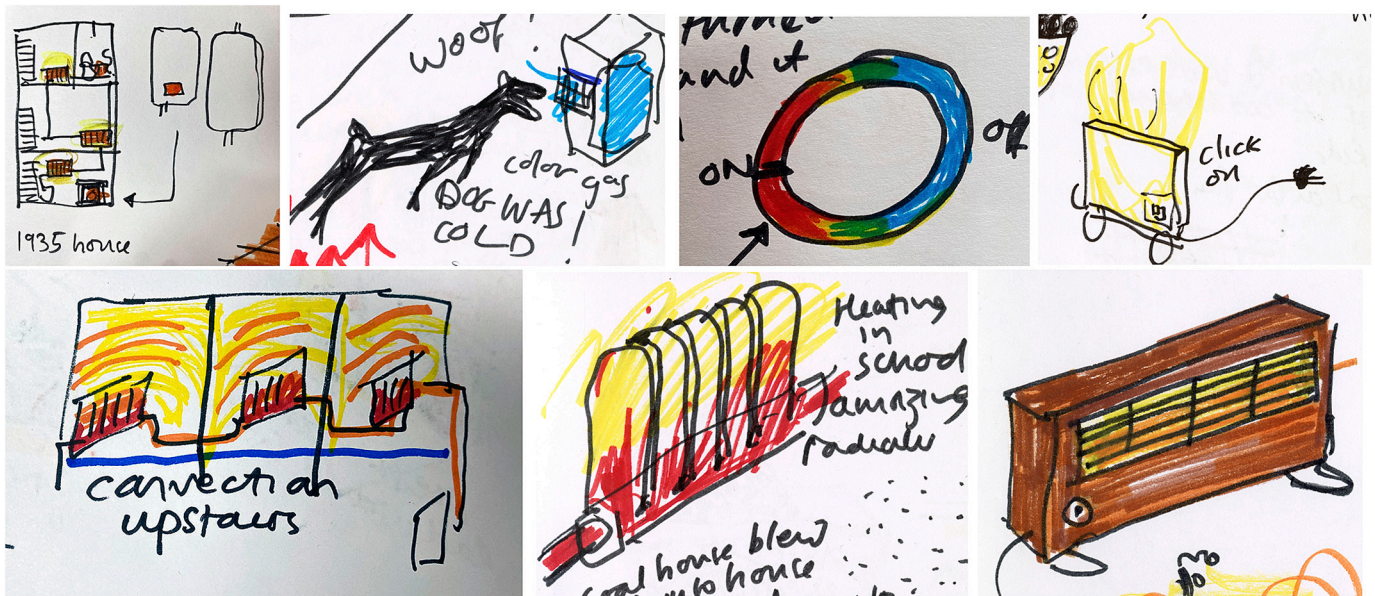


Image 4. Sketches showing changes to home heating arrangements including use of plug in heaters, which improved flexibility. Drawn in response to oral histories from Rotherham by Becky Shaw.

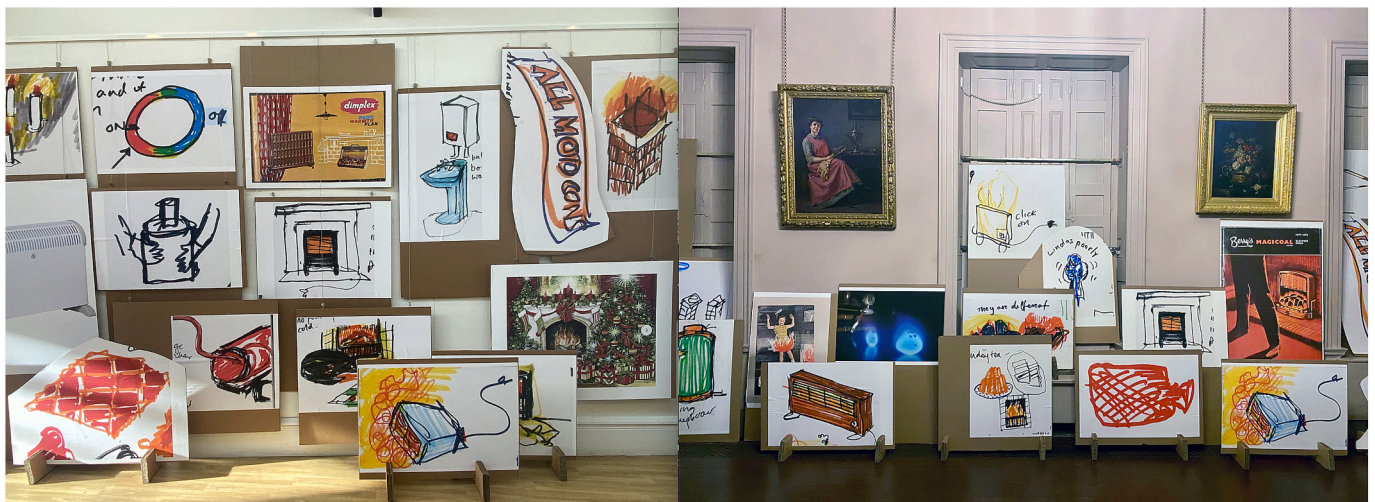


Image 5. Sketches drawn in response to oral histories from Rotherham by Becky Shaw, displayed at a local exhibition.

whole house, rather than one room.

At the same time, there was much less enthusiasm for this era of home heating and the experience it produced, than there was for the era of the coal fire. Liz (Maltby) remembered the change to gas central heating as ‘absolutely incredible’, describing it as a shift from ‘hard work’ and being reliant on fuel deliveries, to ‘all of a sudden’ using a switch for instantaneous warmth. She had no desire to return to a coal fire, but shared that she missed the ‘glow from a fire’ and had considered having an imitation fire installed to recreate this.

Some participants brought their accounts right up to date, discussing climate change, some experimentation with modern, low carbon energy systems (i.e., ASHPs) (in Whiston) or discussing their fears about moving on from gas central heating. But the era of the coal fire was indelible in the minds of all those we spoke to.

“Fires have been with me all my life. In the next house, we had a wood burning stove put in the summer house- we had it on even in the summer. Loved it. You can’t get fires out of your blood.”

(Sue, Whiston)

Perhaps this is why, in Whiston, where means allowed, multiple participants had solid fuel burners installed in addition to central heating and described how they derived comfort and enjoyment from them.

Graham (Whiston) explained that he made ‘a conscious choice’ to invest in a multifuel burner because they wanted to ‘marry’ having the efficient ‘tucked away’ central heating system that gave them thermal security, with ‘a nice cosy warm fire’ in the living space. Because of the effectiveness of the central heating, it did not matter to Graham that the fire in the living room could not heat the whole house. Lynda added that the decision to install a multifuel burner was partly due to liking ‘the look’ and liking ‘the idea of having the fire’. Graham describes his burner as a ‘regression’ but also ‘lovely’ and ‘beautiful’. Graham thought his burner, in comparison to central heating, was ‘more natural’.

5. Discussion

5.1. The Actor Network surrounding the coal fire

Given the freedom to focus on what felt significant for them, all participants who remember the era of the coal fire (whether an open fire or a range) chose to foreground the relationship between their household and the fire. The fire was, as many participants expressed one way or another, 'the centre of the universe'.

Interestingly, the focus within the oral histories was rarely on the relationship between the participant themselves and the fire but tended to spotlight other household members and their roles. Often Mother and fire are central to the accounts, with these actants identified as being at the very heart of this vital, life enabling assemblage. Together, Mother and fire form a staunch 'passage point' [32] to warmth, hot water, food and feeling cared for. And, as a consequence of the need for the family to co-locate around the fire, Mother and fire also became the passage point to family togetherness (for better or worse) – an excellent illustration of a relational-materiality in practice.

Mother and fire were not the only members of this critical network, but they are portrayed as dominant within it. They each bring their own assemblages: for Mother, the heuristic skills passed down through generations by repeated demonstration, their hands, their time and so on. For the range: the metal it is made of and the systems and apparatus built into it also form part of the assemblage. Also crucial was the fuel: the coal delivered by the 'coal man' and provided by the employer or other family members and the kindling gathered by the children – all part of the assemblage. The fuel was the vital, bonding actant that could unlock the heat-making potential of the alliance between Mother and range.

The fireplace had no significance, beyond potentiality as a heat source, without the human actant (often Mother), but Mother had significance beyond this actor network – she was enrolled in a multitude of other networks, too numerous to list. Yet, regardless of how many other network actants were enrolled within, every component of the assemblage linked to the fireside is indispensable and if one component is lost, then the survival of the household is in peril. We heard that there were many times when this was the case – mainly due to interruptions to fuel availability caused by external events, including economic crises and industrial action. During these times, some actants fell dormant (i.e. the coal man) and additional actants needed to be enrolled into the network temporarily – for example, neighbours and members of the wider family to share their fuel, and/or the doors and furniture in the house to be burnt in lieu of coal. Throughout all of this, the network partially disintegrates and is reconstituted in response to the challenge [32]. Once the crisis passes, the original configuration appears to return.

The oral histories almost exclusively operate in the minutiae of everyday life, making an ANT analysis possible due to the detailed insights into the make-up of the assemblages in place. Within them, the strength of the interdependency between fire, fuel and household is so fierce that exogenous factors feel greyed out within the accounts – present and at work, but unspoken. This tendency appears to vindicate the contention within ANT that the micro and macro are fused, almost indistinguishably. Many of the drawings made in response to the oral histories reveal this, with each page of the sketch book connecting extensive activities, both those seen as important (fire lighting, keeping babies warm) and those considered less so, such as children's 'play' with the fire.

Also present in the oral histories is a sense that the stability of this actor network in the decades following 1945, whilst delivering consistency to family life and ensuring basic needs were met, effectively imprisoned Mother. We heard how children, in anticipation of their succession of their parents, were enrolled as more significant actants within the network when they were shown, as a rite of passage, how to light and maintain a good fire – skills that, in many cases, became redundant before they could be fully enacted, due to the gas transition.

From this point onwards, we see an explosion of the number and

range of actants involved in the network enabling thermal comfort at home – with a plethora of electrical and gas-powered devices becoming available and affordable. The dominance of the range or open fire begins to wane. Innovations, like electric heaters, can be used in lieu of the fire on milder days and anyone can operate them, not just Mother. As new labour-saving devices enter the home, Mother is remembered as entering different networks entirely, such as those surrounding external employment (if she was not already concurrently engaged in those networks). The network based around the range or fire disintegrated further as new actants emerged, such as local government officials, gas boilers and central heating systems, all advancing the substitution of coal devices for gas or electric.

Yet, crucially, many of the participants in this study have re-enrolled (by buying a log or solid fuel burner), at least partially, in the assemblage of human, fuel and fire, because, seemingly, this offers them access to the joy, intense warmth, and emotional comfort of the fireside that they crave. For others, this assemblage remains a necessity and it is noteworthy that in Wentworth, many households remain dependent on coal or wood. Here, there is another actant at work – the private landlord, blocking the passage point between householders and a modern heating system. However, it is clear that, aside from the escalating cost of coal, many households in Wentworth do not feel entirely dissatisfied with their current arrangements.

In most cases, solid fuel stoves are supplementary rather than the main heat source, but the assemblage between device, fuel and humans remains, albeit mediated by a broader range of standards, legislation and restrictions, which are all also part of the network. And whilst it might be assumed that this network will disintegrate once the generations for whom the fire was significant have gone, we suggest that the prominence of romanticised notions of life by the fireside in popular culture (particularly around Christmas time), mean that the desire may persist in future generations [35–37].

5.2. Future actor networks of low carbon home heating

In the pre-central heating era, there exists a tight and steadfast assemblage based around the fire. Ideas of generalised symmetry (the notion that human and non-human actants have equal value and agency) and relational-materiality (the critical co-dependency of humans and material things) remains intact in this manual heating scenario utilising relatively primitive technology (the range or open fire). However, as technology evolves, these principles become diluted, with human agency reduced and all actants no longer equally interdependent. Human and heating apparatus are no longer the joint passage point to heat. This can be seen in relation to gas central heating supplied via the gas network, where we have the non-human actants of, *inter alia*, the boiler, control panel, radiators and gas supply (a fuel source requiring no human handling at point of use).

Once installed, the control panel requires a minimum of one interaction with a human and it will continue to provide heat until the equipment fails. The option of exerting more agency over the system is available and desirable but not essential. One participant illustrated this point, explaining that her grandson had set her thermostat on a pattern that works for her and she does not need or want to touch the control panel.

Looking deeper into the system, humans are still heavily involved in enabling the gas network through the extraction and distribution of gas and so on, but under future Artificial Intelligence (AI) and advanced technology scenarios, our roles could become diminished further [38]. It may be argued that the principle of generalised symmetry remains possible to achieve until the point where human agency is superseded, because we have the potential to interact with our modern heating systems (i.e., GCH and ASHPs) more than the minimum necessary.

From an evolutionary perspective, if we feel in control of our environment then we have a better chance of survival [39]. When things feel out of control, we feel we are in danger [40]. This may occur where we

are not at least of equal value and agency to technology within an actor network. Applying ANT to domestic heating reveals how the long-established assemblages between human and non-human actants are disrupted by increasingly independent technologies, resulting in an asymmetry between human and non-human actants that is experienced as a loss of control. We see this in remarks made by participants about technology “moving too fast” for them.

To make technological advancement more palatable, do we need to integrate a more manual component, even if it is effectively a placebo? Our participants seemed to take comfort in having manual options for warming a space, because this provides a route to warmth, if the technological systems break down or feel outside of our control. The solid fuel stoves that more affluent participants enjoyed offer this safety net and this may be part of their appeal. We cannot be completely sure of all of the factors driving the affinity of our participants for burning solid fuel at home and their lack of enthusiasm for the next generation of technology. In light of this, we offer the arguments and questions in this paragraph as provocations and stimulus for future research and innovation in heating systems to help ensure that they provide what end users want and need.

Regardless of our pull towards manual heating, increasingly complex technological solutions to home heating are inevitable. Turning solid fuel into heat is a physical and chemical process and requires little more than an operator, a fuel, a spark and a container for the fire. Harnessing the heat in the air or the ground to heat buildings requires additional actants in the form of technology that translates a latent heat source into warmth, but reduces our agency. This technologically dependent route to warmth favours the digitally included – those with the assemblages in place to enrol effectively in actor networks with these technologies. Whilst the simple, manual processes around the fire could be passed on heuristically generation after generation, digital literacy is arguably less easily imparted between different family members. In essence, the assemblage required to operate a modern, technology heavy heating system is more exclusive.

6. Conclusions

Oral histories subjected to expansive interdisciplinary analysis reveal nuanced insight into how heating transitions play out in the personal world of the home, an environment saturated with relationships and entanglements, between humans and material things. Through oral histories, research participants lead researchers towards the relationships that feel most significant. Amongst our participants, relationships with the fireside were foregrounded. Examining these relationships can provide clues about the likely response of households to heating transition and their support needs in this context. Amongst our participants, the era of the solid fuel fire acts as a benchmark against which subsequent eras are measured, particularly in experiential terms. Those who hold these attachments to solid fuels can find it difficult to reconcile the different quality of heat created by modern systems and the asymmetric power balance between technology and human (exacerbated by the speed of technological advancement), with their expectations. This cannot mean that we continue to burn solid fuels, but it might mean that we have to make concessions to these preferences, such as allowing households to hold on to valued manual ways to heat (i.e. a log burner) until they are comfortable with a new system. It may also mean that we have to work harder on heating innovation, especially the experiential dimensions of low carbon heating systems, re-creating and integrating some of the unique benefits of the fireside.

Those who still cherish or feel connected to the era of solid fuel burning, especially those living in former mining areas, may need more persuasion to join new assemblages based around a heat pump, for example. Those without the full set of competencies to join these new assemblages may need more support in a practical sense. But, often, the most stubborn obstacles will not be about useability of the apparatus, or know-how, but about invisible emotional ties to long established

assemblages, within which we were actants of equal importance to the technology. As such, emotional support and recognition of the pain and loss bound up with energy transitions, especially in places built around fossil fuels, might have to be part of the support package. In essence, viewing the relationship between humans and particular heating technology through ANT enables appreciation of the multiple points at which a new actor network might fail to establish itself or disintegrate. Once we are aware of these fallibilities, we can implement strategies to avoid them.

Returning to Hargreaves and Middlemiss's [8] assertion that, in a domestic energy context, we do not act rationally, we act relationally, we contend that we in fact act based on relational-material entanglements. Policy promoting heating transition must take account of the strength of these relational-materialities, and policymakers must take care not to view the challenge from the confines of their own entanglements and the assemblages they are able to join from their positions of relative privilege, for example: having the digital and technological literacy to enter an actor-network involving a heat pump.

Our contribution to the literature is fourfold: first, we demonstrate the value of combining oral histories with interdisciplinary analysis for revealing hitherto hidden interdependencies between humans and domestic heat sources, established over time. Second, we demonstrate the value of ANT for interrogating these relationships and establishing how they are formed, reinforced and why they are valued. Third, we convert these insights into policy and practice learning, revealing how heating transitions can evoke an emotional response, including feelings of a loss of agency and loss of enjoyment. Fourth, we add to the important contention that domestic energy consumption is bound up with social relations, positing that our response to domestic energy arrangements is in fact shaped by relational-materialities.

CRedit authorship contribution statement

Aimee Ambrose: Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Kathy Davies:** Investigation, Formal analysis, Data curation. **Lindsey McCarthy:** Formal analysis, Data curation. **Becky Shaw:** Supervision, Methodology, Formal analysis, Conceptualization. **Sally Shahzad:** Investigation, Formal analysis.

Declaration of competing interest

We do not perceive any relevant conflicts of interest.

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Data availability

Data will be made available on request.

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