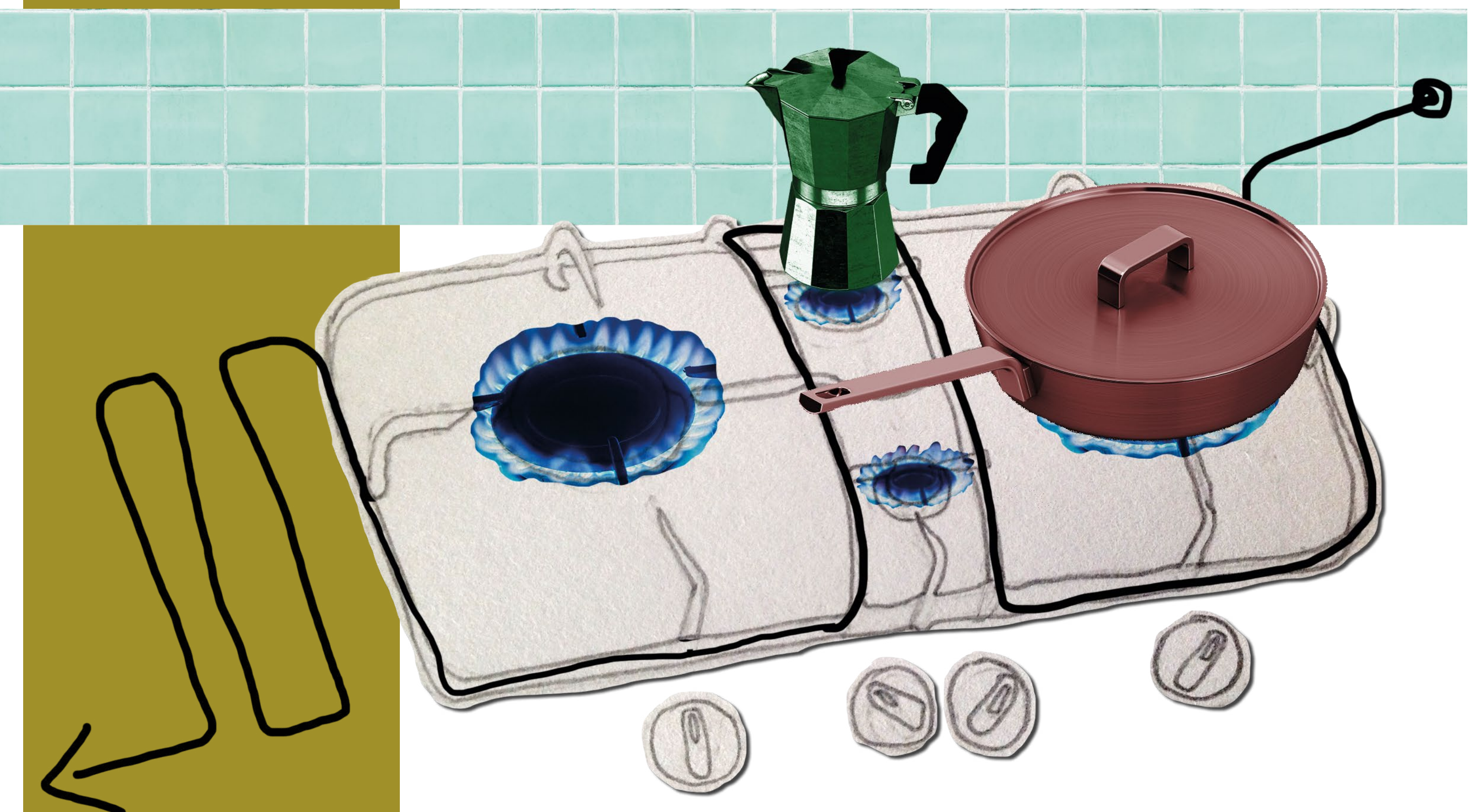
The social dimensions of moving away from gas cookers and hobs:

Challenges and opportunities in transition to low-carbon cooking



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The social dimensions of moving away from gas cookers and hobs:
Challenges and opportunities in transition to low-carbon cooking

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Executive summary

Introduction

This report is an outcome of the Energy-PIECES (Energy Policy Insights from Early Career Events and Secondments) project aimed at improving the engagement of Social Sciences and Humanities (SSH) related research with energy policy. As part of this project, a seven-week secondment with the Department of Business, Energy and Industrial Strategy (BEIS) focused on exploring the social dimensions of heat decarbonisation in cooking appliances, specifically moving away from gas cookers and hobs.

This report builds on interviews with BEIS's long-term heat strategy experts and key external stakeholders. It also includes review of secondary data on trends in cooking appliance use and an annotated bibliography of literature on the social implications of heat decarbonisation and sustainable food transitions more broadly that can inform policy.

The heat challenge

Heat is one of the UK's largest energy consuming and carbon emitting sectors and has been described as the most difficult to decarbonise. Most heat in buildings and industry is supplied through natural gas. The UK's Clean Growth Strategy identifies heat decarbonisation will likely involve alternative energy vectors like electricity and hydrogen. This will mean transition of existing cooking appliances away from natural gas. This will have social implications which require detailed analysis and understanding for optimal transition, such as understanding:

- How are current carbon-intensive cooking technologies part of existing cooking practices and broader social and material structures?
- What are the challenges and opportunities for cooking heat decarbonisation, in terms of consumer acceptance, carbon and energy reductions and business/market opportunities?
- What interventions are needed to realise policy objectives of heat de-carbonisation?

This report is a first step in trying to answer these questions. By placing the policy question of the social implications of a change in cooking technology within the wider understanding of cooking appliances as part of existing social and material contexts (further details in section 4), it is hoped that this report will help in designing more effective cooking decarbonisation policy.

Trends in cooking and appliance use

Research on the existing trends in consumer preferences and use of cooking appliances suggests that the function and performance of cooking appliances varies significantly by fuel type. Natural gas is still the preferred fuel source for hobs (~60% by 2020), while cooking with electric ovens is dominantly preferred (70% by 2020). Though natural gas is still the dominant fuel, induction hobs are gradually becoming more popular (24% of market share in 2017, and 28% users opting for future preference). While this increase in sales may be associated with their greater efficiency, heat control, safety and aesthetics; however, their use in and suitability for specific cuisines remains underexamined. In terms of cooking practices, literature reveals trends that show a reduction in time spent in cooking and eating meals at home and a greater tendency for eating out, especially among men, younger people and individuals who are single. Energy consumed in cooking at home has also decreased, both as a result of increased appliance efficiency and changing cooking methods that employ more pre-prepared food. Trends also show an overall increase in participation in cooking. Despite the increase in eating out practices, cooking at home remains a fairly consistent practice in the UK. Variations in cooking based on socio-demographics and the varying preference of cooking fuel types for certain cuisines suggests that the transition from natural gas to electric/induction hobs could have distributional impacts, in which specific social groups are affected more than others.

The social challenges and opportunities of a low-carbon transition

A review of the various social challenges and opportunities of heat decarbonisation is presented in an annotated bibliography. Owing to limited literature on the social implications of transition towards low-carbon cooking technologies, the social impact was explored more broadly in heat decarbonisation, technology transition, home retrofitting and sustainable food consumption. A multidisciplinary review of the literature is structured around Southerton et al.'s (2011) ISM framework, which conceptualises factors influencing behaviour in the Individual, Social and Material (ISM) context. This provides a more systemic opportunity of identifying the various change-agents at varying scales required for transition that can inform a holistic understanding of the social implications of heat decarbonisation in cooking technologies.

Conclusions

The transition to heat decarbonisation in the UK can have auxiliary effects of a shift away from gas cookers/ hobs in cooking technologies. While this report investigates the potential challenges, opportunities and subsequent policy interventions needed for this transition to occur smoothly, it also places this policy question within the wider understanding of cooking technologies as part of cooking practices that are embedded in broader social and material contexts.

Trends in cooking appliances and use show that while there are variations in cooking practices and fuel-type preferences based on socio-demographics that need to be considered in policy, cooking at home as a practice remains fairly consistent in the UK. This shows that a change towards low-carbon cooking technologies is almost certainly going to be needed in all but the most radical changes in home cooking practices.

In this regard, individualist interventions like targeted messaging, cost incentives and relevant information for technology decarbonisation are important. In addition, the social and material context broaden the scope of the challenge by recognising how a change in cooking technologies will affect cooking practices that are constrained by existing socio-cultural norms, cooking and technical skills, work and mobility routines, building and infrastructural alignments and interrelations with intermediaries (like landlords, installers and suppliers). This can offer opportunities of low-carbon transitions in a more systemic way, such as promoting more shared eating, cooking and social learning spaces, partnering with retrofit intermediaries, promoting service-based business models and aligning with organisations that play a catalysing role. Such an approach also highlights how the heat decarbonisation transition can be used as a 'trigger point': an opportunity for improving energy efficiency and reducing overall energy consumption in cooking. Hence, it could help inform a more holistic evidence-base for interventions and transitions with greater policy impact.

Recommendations

Recommendations for evidence and data gathering

- Existing national datasets[1] provide limited information on cooking technology and appliance use. More detailed information is needed in terms of variation in cooking appliances, fuel types, timings, contribution to peak loads, durations, energy consumption with respect to fuel use, demographic variations, cultural variations in cooking methods and fuel types, causal relationships and longitudinal change, etc.

- While survey and quantitative methods provide statistical results and generalisable datasets, there is also a need for more qualitative, in-depth, ethnographic and interpretive data to get a more detailed understanding of the nuances, meanings and interconnections that form current cooking practices.

- Demonstration projects, such as those undertaken by BEIS for hydrogen fuel testing are used to determine technological efficiency and performance of products/appliances. Such experimental projects can additionally be used to better understand performance-in-use by consumers and how technologies interconnect with existing routines and other practices.

- Due to higher user preference for gas cookers/hobs compared to electric/induction cookers/hobs, specifically in relation to certain cuisines and cultural factors, there is a need for evidence to distinguish between preferences based on user familiarity with existing technology and actual technology capacity and performance. This will determine the type of policies (information/awareness/skill enhancement or technological innovation/market research) that will be most suited for large-scale transition.

Recommendations for research

- Overall, there is limited academic research in the developed world that focuses on the social implications of transition to low-carbon heating and more specifically to low-carbon cooking technologies. This suggests the need to undertake primary research in this area. Further research also needs to be undertaken with regards to health implications of different cooking fuel types, as this can them inform the cooking heat decarbonisation policy.

- Compared to heat consumption for comfort, cooking practices and food-related habits are more personal, socio-culturally bound, gendered and varied in terms of socio-economic and ethnic groups. It is therefore necessary to recognise these differences and to design policy in accordance with the contextual nature of heat in cooking.

- Research on cultural differentiation of cooking/ eating in the UK and opportunities/triggers for cultural diffusion and social learning (e.g. through shared cooking spaces or intermediaries like celebrity chefs or cooking competitions) could potentially prove useful for designing policy for transition.

- Among the SSH literature, practice theories can provide useful insights into current cooking methods, techniques, routines and practices as well as food related habits (the latter has been the focus of research as shown in section 4.2). More emphasis needs to be given to cooking as a social practice and its interconnections with the material context for improved understanding and design of low-carbon interventions in cooking appliances.

Recommendations for policy

- Even though appliances will need to change regardless of changes in cooking demand, reframing the

1 Such as ECUK (Energy Consumption in the United Kingdom) and EFUS (Energy Follow-Up Survey)
https://www.gov.uk/government/collections/energy-consumption-in-the-uk
https://www.gov.uk/government/statistics/energy-follow-up-survey-efus-2011

policy question to focus not just on the change in technology (e.g. from gas cooker/hob to electric) but, as an option, to look at cookers/hobs as a constitutive part of a wider socio-technical regime of cooking/eating practices and food-related habits could open up new opportunities for meeting climate change targets. For example, a combination of strategies will be required to decarbonise heat in cooking/eating practices that go beyond replacement of appliances alone and change at the household level, but also includes change at the community level (social), and even the city level (material).

- Current heat decarbonisation policy focuses on public acceptance for transitions with 'minimum disruption', ensuring that the status quo is maintained. Energy and emission reductions are part of the brief, but only in terms of improvements in technological efficiency. There is a need to connect the policy dots between public acceptance for transition and the shifts required for carbon and energy reduction.

- Evidence suggests that there exists a public preference for natural gas cookers/hobs, which is unlikely to decline without a relevant suite of policy packages.

- Based on the above evidence, there exists a market opportunity to develop and innovate cooking appliances, to ensure that low-carbon technologies (like hydrogen or electric induction) provide a similar or better user experience. Policy could ensure capacity-building through a market support framework using legislation, carbon taxing and/or subsidies. For example, the increased role out of induction hobs could help prevent further lock-in to gas technologies.

- There is currently no energy and carbon labelling for hobs. Since the consumption and emissions from hobs is greatly dependent on how it is being used, highly visible information and certification, energy-saving advice and efficiency features may need to be specified for emission reductions – although we do note that equivalent labelling schemes have had little impact in and of themselves in driving energy/carbon savings.

- Instead of defining policies for decarbonising heat in cooking in isolation, combining less carbon-intensive cooking heat policies with health policies that 1) reveal potential negative health impacts of gas versus electric cooking and 2) promote the benefits of raw-food diets, low-heat cooking and less cooking times might gain greater traction.

General recommendations for heat decarbonisation

- Instead of focusing only on top-down approaches for decarbonising heat, greater attention should be given to bottom-up approaches (e.g. grassroots innovations) as well as to middle-out approaches (intermediaries, practices, supply chains, street level bureaucrats, community centres and councils, etc.).

- Recognition of key change-agents and where the responsibility lies for heat decarbonisation transitions. Focusing only on the individual context governs interventions that clearly delegate the responsibility to consumers/end-users, whereas focusing on the social and material contexts provide alternative governance frameworks, such as partnerships with intermediaries, taking advantage of specific trigger points such as life-course changes, facilitating socio-cultural learning spaces, and promoting service-based business models for market supply chains.

- Recognising that technology itself is a social construct and that technical change is a social, contextual, and temporally specific process. Hence understanding the need to integrate the consumer/end-user as an important stakeholder in all stages of the transition, including product innovation, legislation and roll-out.

- Acknowledging diversity and drafting different policy pathways to decarbonisation for different consumer groups; e.g. a separate policy for forerunners, with higher acceptance for decarbonisation and for those who are reluctant and would respond to step changes (e.g. price and income policies, incentives, subsidies and support, etc.).

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1. Introduction

This report is an outcome of the Energy-PIECES (Energy Policy Insights from Early Career Events and Secondments) project. The core objective of the project was to create an opportunity for PhD and Early-Career Researchers (ECRs) in the field of Social Sciences and Humanities (hereafter referred to as SSH) to present research that feeds into energy policy and engage with policy organisations and their agendas (c.f. Foulds and Robison, 2018). The two main activities of the project included: (1) a masterclass on how SSH can better connect with energy policy (making); and (2) a set of six-week secondments, taking place during January to March 2019.

The masterclass took place on 10 December 2018 and brought together energy-related SSH researchers and policy experts to explore ways to advance SSH's engagement with energy policy. The masterclass workshops and brainstorming sessions highlighted the need for SSH perspectives in designing energy policy and provided greater depth to the secondment brief, indicating potential challenges and opportunities, key stakeholders as well as signposting to relevant literature. The notes from the masterclass were reviewed and provided a good starting point for further study.

The seven-week secondment with the Department of Business, Energy and Industrial Strategy (BEIS) took place from 14 January to 28 February 2019, as part of their Energy Social Research Branch, and focused on exploring the social dimensions of heat decarbonisation in cooking appliances – specifically moving away from gas cookers and hobs. For this, interviews and discussion with relevant experts in BEIS' long-term heat strategy division were conducted, as well as some external communication with key stakeholders. In addition, this report builds on secondary data on trends in cooking appliance use, as well as a literature review of the social challenges and opportunities in heat decarbonisation and sustainable food transitions more broadly that can inform policy. This report also identifies key evidence gaps in existing academic and grey literature in the understanding and analysis of the social implications of changing cooking technologies. It, therefore, provides research and policy recommendations for future work.

The structure of the report is as follows:

- **Section 2** presents the background context and rationale for the research topic and the main research questions. It presents a brief overview of current UK heat emissions with more specific details on emissions and consumption from cooking;
- **Section 3** summarises some of the trends in cooking and appliance use. It looks at consumer use and preferences for different cooking appliances and fuel-types, variations in cooking and eating practices over time and in different sociodemographic groups;
- **Section 4** presents an overview of the academic and grey literature on the social challenges and opportunities in heat decarbonisation from various SSH perspectives, using Southerton et al.'s (2011) Individual, Social and Material (ISM) context framework;
- **Section 5** briefly outlines the interventions proposed by the various disciplinary perspectives to overcome the challenges and harness the opportunities in light of the ISM context and identifies policy gaps;
- **Section 6** synthesises the conclusions, reiterating the main objective of the report and the key evidence gaps in existing academic and grey literature; and
- **Section 7** provides recommendations for policy and future research.

2. Background

Heat accounts for almost half of energy consumption and around one third of overall carbon emissions in the UK. The Climate Change Act 2008 committed the UK to reducing greenhouse gas emissions by at least 80% by 2050, compared to 1990 levels (BEIS, 2017). So far, the UK has successfully cut down its emissions by 42%, mainly achieved through modernisation of the power sector and reductions in waste and industry emissions (BEIS, 2017), in addition to market-led developments (CCC, 2018).

Emissions from heat are the largest contributor to UK emissions with heating in buildings and industry accounting for 37% of total UK emissions (BEIS, 2018a). It is also the largest energy-consuming sector currently in the UK, with 44% of final energy consumption (ECUK, 2018). Hence meeting the remainder of the emission reduction targets will require decarbonising nearly all heat in buildings and most industrial processes. The UK government's strategic approach to decarbonisation involves shifting to low-carbon technologies with alternative fuel sources, such as heat pumps, hydrogen, bioenergy and heat networks (BEIS, 2018a). The final mix for transition will depend on a myriad of factors and policy goals, including existing infrastructure, location and contextual factors, where a one-size solution will not work.

According to the Clean Growth Strategy, heating is arguably the most difficult of the major energy-consuming sectors of the economy to decarbonise. While heat decarbonisation requires strategic economic and technological frameworks, its social implications and impacts are just as important and require detailed analysis and understanding for optimal transition. While substantial SSH-related research has been carried out in other aspects of the energy system (e.g. electricity generation technologies, energy efficiency improvements, demand reduction), there has however been limited focus on the social implications of heat decarbonisation and low-carbon technology transitions. This requires answering the following research questions, as set out by the priorities and preferences of colleagues in BEIS:

- How are current carbon-intensive cooking technologies part of existing cooking practices and broader social and material structures?

- What are the challenges and opportunities for cooking heat decarbonisation, in terms of consumer acceptance, carbon and energy reductions and business/market opportunities?

- What interventions are needed to realise policy objectives of heat de-carbonisation?

This report is a first step in trying to answer these questions in terms of the social implications for moving away from gas cookers and hobs. By placing the policy question of the social implications of a change in cooking technology within the wider understanding of cooking appliances as part of existing practices, structures and institutions, it is hoped that this report will help in designing more effective cooking decarbonisation policies and strategies.

2.1. Heat in buildings

The contribution of low-carbon heat sources to heat demand in buildings is currently around 4.5% of total building heat demand (CCC, 2018). The domestic sector accounts for the highest energy consumption for heat, almost 60% of total energy consumption in the UK (BEIS, 2018a). Most heat use in buildings and industry is supplied by fossil fuels; approximately 85% of UK households use natural gas for heating. Hence, households present a significant sector for achieving UK's carbon reduction goals. The transition towards heat decarbonisation is estimated to require low-carbon installations in 26-30 million homes in the UK (Douglas, 2015; Lipson, 2016). Moreover, within such a transition, the Energy Technologies Institute estimates that 20,000 households per week would need to switch from the natural gas grid to low-carbon heating between 2025 and 2050 (Douglas, 2015).

Cooking accounts for just 2% of total UK carbon emissions. However, if the buildings and industry sector shifts to alternative low-carbon heat sources, cooking fuels and related technologies and appliances will similarly need to shift away from natural gas as an auxiliary measure. This will have social implications that need to be identified and addressed for a smooth transition. For this, it is imperative to understand existing cooking practices, trends in heat consumption for cooking, and consumer needs and preferences for cooking appliances, which will be explored in section 3.

60% of total energy consumption in the UK takes place in the domestic sector. 44% of the total energy consumed is used for heating. For transition to low-carbon heating, cooking will need to be shifted away from natural gas as an auxiliary measure.

2.2. Heat in cooking

Although most energy consumption in homes goes into keeping homes warm for comfort (43%), 14% of the total energy is consumed for cooking and hot water, while an additional 5% goes into non-domestic cooking and catering services, specifically in the hospitality industry (BEIS, 2018a). In the catering industry, about 40% of the energy used in kitchens is for cooking, followed by refrigeration at 28% (AEA Technology, 2012). Cooking consumption is seasonally affected, with more cooking done in the winters than in summers. In 2017, cooking accounted for 13.66 TWh of electricity consumption (3.5MtCO_2e) in the domestic sector and 20.9 TWh (5.5MtCO_2e) in the service sector (see Appendix 1 for domestic cooking fuel breakdown).

Table 1: *Annual usage and running costs for electrical cooking appliances (Source: (EST et al., 2012).*

Cooking Appliance	Annual kWh usage	Running cost per year (£)
Oven (without hob)	290	42
Hob	226	33
Cooker with electric cook top	317	46
Microwave	56	8
Electric Kettle	167	24

The average annual household energy consumption for cooking appliances (including oven, hob, cooker, microwave, kettle, deep fat fryer and toaster) is 429-505 kWh (Table 1), with an average annual for all households of 460 kWh (EST et al., 2012). The relative efficiency of cooking increases for larger groups. A three- or four-person household consumes roughly the same amount of energy through cooking activities as an individual (Appendix 2).

DEFRA's Market Transformation Programme (MTP) forecasts that with existing policy measures cooking-related energy consumption will remain roughly the same by 2020, with no expectations of decreases in energy use from cookers and ovens. Electric ovens show reductions in total energy use, but this starts to increase from around 2022 due to a higher number of households and a shift in ownership to electric rather than natural gas ovens (DEFRA, 2009). According to Hager and Morawicki (2013) but the energy requirements for cooking can be prodigious and individual household energy use varies considerably. This review evaluates the current state of energy efficiency during household cooking in developed countries and identifies potential policy changes that may have an impact on reducing energy consumption. The primary factors affecting energy consumption include: (1, the total energy consumption in cooking depends on: (1) the production and transport efficiency of fuel sources (electricity, natural gas, wood, etc.); (2) the appliance (or end-use) efficiency; and (3) the behaviour of the consumer during cooking. These will be addressed in the next section.

To summarise, heat is one of the UK's largest energy-consuming and carbon emitting sectors and the most difficult to decarbonise. Most heat in buildings and industry is supplied through natural gas. The UK's Clean Growth Strategy involves heat decarbonisation through alternative energy sources like electricity and hydrogen. This will mean a transition of existing cooking appliances away from natural gas. For a smooth and effective transition, it is imperative to understand existing cooking practices, trends in heat consumption for cooking and consumer needs and preferences for cooking appliances, since heat in cooking depends on fuel efficiency, appliance efficiency as well as consumer use.

3. Trends in cooking and appliance use

This section presents a brief overview of the existing trends in consumer preferences and use of cooking appliances, cooking habits and associated sociodemographic variations.

3.1. Trends in cooking appliances

In the UK, 97% of households are estimated to own an oven (2017 data, in Statistica, 2019) and all UK households are assumed to have access to a hob (DEFRA, 2009). Recent trends have seen the decline of natural gas ovens (from 50% in 2005 to 38% in 2017) and rise of electric ovens (from 51% in 2005 to 64% in 2017) in households (Statistica, 2019). Generally, people tend to prefer electric ovens to gas ovens and hence sales of gas ovens are expected to decline. By 2020, it is predicted that 30% of Britain's ovens will be gas, and 70% electric (EST et al., 2012). As for hobs, natural gas is still the dominant fuel as many people prefer to do stove-top cooking with gas and it is expected to hold 60% of the market share, while 40% will be electric by 2020 (EST et al., 2012). According to DEFRA (2009), technological developments resulting in more user-friendly electric hobs are not expected to offset this trend. Moreover, trends towards easier-to-clean glass surfaces and a greater variety of burner sizes may also encourage more users to switch to natural gas. However, the increasing benefits and trends for induction hobs may offset the preference for gas hobs in the future (see Euromonitor International, 2017 in Appendix 3).

Interestingly, there is an EU Energy Label for electric and natural gas ovens (ranging from A+++: most efficient, to D: least efficient), but none for hobs. It is important to note that in the UK, the carbon intensity of electricity is currently greater than gas: gas accounts for 184g/kWh (assuming 100% efficiency) versus electricity at approximately 200g/kWh. However, the carbon intensity of electricity has been decreasing and will continue to decline under the decarbonisation of electricity generation via renewables, etc. Estimated projections show that by 2028, the marginal electricity grid intensity will be lower than gas (BEIS, 2018b). This will mean that electric appliances will produce far less emissions than gas in the future[2]. Moreover, the actual emissions depend on appliance efficiencies and life-cycle assessments (DEFRA, 2009), which need to be considered in carbon calculations. Further, the performance of cooking appliances varies widely depending on device type, fuel type and use. Actual efficiencies can vary substantially from estimated values, due to the impact of idle consumption, pre-heat input and user behaviour, leading to up to 30-50% variation in energy consumption (Griffin et al., 2012; Hager and Morawicki, 2013). The final energy consumption and carbon emissions are also dependent on the style of cooking (Appendix 4). For example, according to Clear et al. (2013), dishes prepared using the oven and grill are more energy-intensive than those using hobs. Also, more elaborate dishes, in terms of the number of cooker elements used for preparation, also result in higher consumption. However, oven cooking can be seen as a more convenient and healthier alternative to hob cooking (e.g. Halkier and Jensen, 2011). Hence, the style of cooking, choice of fuel-type and subsequent energy demands are very much dependent on user preference. According to Which?®, although natural gas cookers are still dominantly preferred, induction hobs have been increasing in popularity in past years. In future preferences for hobs, 42% opted for gas while 28% selected electric induction. This is partly due to reduction in costs but also driven by a general high performance in tests and evaluations. Dual-fuel use is also increasing in popularity. Current preferences in freestanding cookers[3] show the highest inclination to buy dual fuel electric ovens and gas hobs (37%), closely followed by electric ovens and induction hobs (24%). Meanwhile, preferences in range cookers[4] similarly show greater trends for dual fuel electric ovens and gas hobs (59%), followed by all gas (15%), electric and ceramic electric (13%), and then electric ovens and induction hobs (9%).

Table 2 provides a comparison of cooking appliances based on fuel-type. While gas cookers/hobs provide some benefits over (solid plate and radiant) electric cookers – e.g. improved temperature control and instant

2 The Carbon Trust's 2012 Sector guide for Industrial Energy Efficiency Accelerator in the Contract Catering Sector recommends replacing electric ovens with gas combi ovens for energy reductions as well as reduction of 60,000 tonnes CO_2 per year. However, with the decarbonisation of the power sector, electricity will provids a less carbon-intensive alternative to gas use in cooking appliances in the future.

3 Small, 'standard' cookers, usually four cooking zones on hob, one or two ovens

4 Large, country-kitchen style ranges usually with at least two ovens and up to 7 cooking zones on hob

The total energy consumed in cooking depends on:

- **The production and transport efficiency of fuel sources (electricity, natural gas, wood, etc)**
- **Appliance (or end-use) efficiency**
- **The style of cooking and the behaviour of the consumer during cooking**

heat – induction cookers are designed to overcome some of these limitations by providing greater heat precision, with a rapid and responsive cooking controls. They are also designed to be aesthetically more attractive and safer to use. However, induction hobs can be used only with magnetic or iron-based utensils and will not heat aluminium and copper pots and pans. The performance of induction hobs for preparing specific cuisines (such as Asian and east-Asian) also remains to be tested, as they have still to gain mass-scale deployment. Further, communication with the Nationwide Caterers Association (NCASS) reveals the added advantages of the portability of LPG cylinders compared to electric cookers/hobs. For mobile catering services, using generators proves to be expensive, noisy, environmentally-unsuited, as well as a safety risk. The fuel type for cookers also seems to be dependent on the style of cuisine. This indicates that the transition from natural gas to electric/induction hobs can have distributional impacts, in which specific social groups are affected more than others. In addition, since natural gas cookers have the advantage of remaining operable in case of electric power outage, it will be necessary to ensure uninterrupted electric supply, especially during peak load hours, if natural gas cooking appliances are to be replaced with electric alternatives.

Another option currently under investigation by BEIS (2018c) is the replacement or adaptation of natural gas cooking appliances with hydrogen appliances or fuel. The key advantage in this transition is that hydrogen cooking appliances are thought likely to be able to match the key features of existing natural gas appliances, including appliance efficiency, lifetime, maintenance requirements, size and ease of use. However, since hydrogen has a higher flame speed, greater flammability range and is likely to burn at a higher temperature than natural gas, adapting existing natural gas appliances to hydrogen will require conversion kits, greater space, and possible reductions in performance, all of which offer technological and practical challenges – see BEIS (2018a; 2018c) for a detailed review of hydrogen appliances).

Table 2: *Comparison of natural gas versus electric cookers/hobs (Source: adapted from Which?, Griffin et al. (2012) and communication with homeowners and service-sector experts)*

PERFORMANCE	NATURAL GAS COOKERS/HOBS	ELECTRIC COOKERS/HOBS	INDUCTION COOKERS/HOBS
Cost	Cheaper to run (£17/year for 5hours/week)	At least twice as costly to run electric, dual fuel and induction (£40/year for 5hours/week)	
Efficiency	40-55%	74% (solid plate), 72% (radiant)	84%
Power rating	3-20 kW (average 9 kW)	1-10 kW (average 7.4 kW)	
Technical lifetime	19 years (12 years for commercial units)	15-19 years (average 19 years) (12 years for commercial units)	
Installation and maintenance	Need qualified professional accredited by the Gas Safe Register to install gas or dual-fuel cooker	No such requirement	
	Difficult to clean	Easier to clean	Keeps utensils clean and good as new as no blackening from fumes/ contact with plate
	Require greater ventilation (more moisture release from gas in heat)	Require less ventilation (as dry heat)	Minimal heat loss as directly heats the utensil and requires lesser ventilation
	Can be difficult to repair, costly, not easily available and taking longer time	Repair services are efficient and easily available and maintaining electric cookers is easier	
	Change from a gas to an electric cooker, or vice versa would require higher installation and replacement costs.		
Function	Lesser pre-heat time Rapid and responsive cooking: Instant and easy to control heat	Greater pre-heat time Slower response: Longer cooking time and stays warm for longer once turned off	Faster heating time than gas Rapid and responsive cooking: Fastest cooking time and easy to control heat.
	More power for cooking	Not the same level of power/heat	More powerful than gas
	More precise cooking- smooth transition of flame from low to high	Less precise Intermittent values for heat 1-6	Precise temperature control However, turns off when surface wet, greasy or not perfect contact with pan
	Noise from gas burning	No noise	
	Good for simmering, searing and char-grilling	Not as well suited to simmering, searing and char-grilling	Better at simmering at low temperature
	Especially suited to cooking Asian and east-Asian food	Generally, not preferred for making chapatis, rice and wok cooking	Needs further testing
	Grill: Instant heat but spreads heat poorly	Grill: Spreads heat well but slower to warm up. Better browning of food more evenly	
	Oven: Less even heat distribution	Oven: More even heat for cooking	
	Can use all types of utensils	Can use all types of utensils	Requires magnetic/iron-based utensils
Health and safety	Less safe to use and research suggests some health impacts from increased indoor air pollution*	Safer than gas but slower cooling of electric plate once turned off requires caution	Safer as the surface cools as soon as the cooking vessel is removed
Portability (for catering services)	Better portability in terms of LPG cylinders and cheaper to run	Difficult to get electricity connection in open spaces Alternatively, generators are expensive, loud, not very green, can be dangerous if become hot and need refuelling and often restricted by organisers	
	Better recovery rate$	Recovery rate twice that of gas	N/A

* For example, see Chauhan, 1999; Willers et al., 2006; Arbex et al., 2007; Vrijheid et al., 2012; Lin et al., 2013 among others.

$ Time taken by oil to come back up to temperature after having uncooked food added to it.

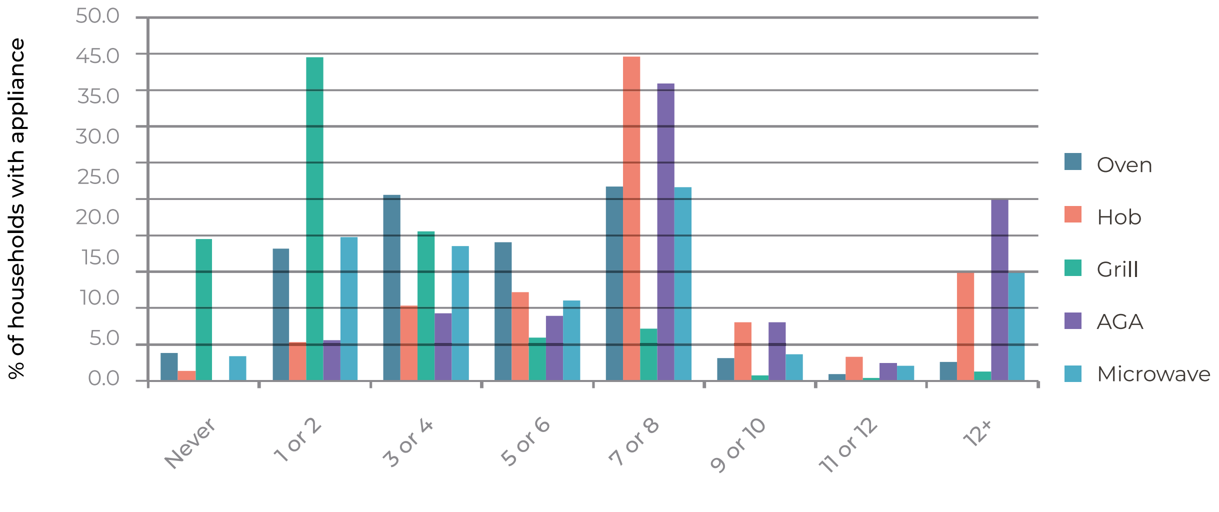
3.2. Trends in cooking at home, time spent in cooking and eating out

The typical use of different cooking appliances, according to EFUS 2011 (BRE, 2013), is shown in Table 3 and Figure 1. Hobs are used more frequently than ovens and grills. Cooking is mostly done in the evenings between 17:00 and 19:00. On weekends, cooking peaks are also seen during lunchtime, between 13:00 and 14:00 (Zimmermann et al., 2012). Compared to other countries, meals in the UK are spread over larger parts of the day, with flatter peaks and relatively shorter periods for lunch (12:00–14:00) and dinner (17:00–20:00) (Southerton et al., 2012). Powells et al. (2014) highlight how cooking and dining are amongst the least flexible practices in everyday routines. In addition, energy consumption associated with cooking and its associated appliance ownership is often considered non-negotiable (Foulds et al., 2016; Hoolohan et al., 2018). Hence cooking causes the largest peaks in household electricity demand during hours of national peak electricity load (Durand-Daubin, 2016), accounting for 30% of household power demand (the largest category) between 17:00 and 20:00 on winter evenings (as cited in Morley, 2014).

Table 3: *Typical use of cooking appliances per week (Number of occasions of use) (Source: BRE, 2013, p.20)*

Appliance use per week	Sample size	Median	25th Percentile	75th Percentile
Oven	2503	5.5	3.5	7.5
Hob	2448	7.5	5.5	9.5
Grill	2195	1.5	1.5	3.5
AGA	95	7.5	7.5	11.5
Microwave	2160	5.5	3.5	7.5

Base: all households in the EFUS 2011 Interview Survey owning each appliance (n=2616)



Base: all households in the EFUS 2011 Interview Survey owning each appliance (n=2616)

Figure 1: *Typical number of times cooking appliances are used per week (Source: BRE, 2013, p.20)*

Various studies look at the changing trends in the UK in cooking practices and time spent cooking/eating at home and eating out. The review of this literature provides insights into changing cooking and eating habits which can be useful in forecasting future trends and designing policy for low-carbon transitions and emission reductions.

Table 4: *Time allocation for cooking, eating at home and eating out in the UK (Source: Warde et al., 2007, p. 368)*

APPLIANCE USE PER WEEK	MEAN MINUTES FOR ALL RESPONDENTS		PARTICIPATION RATES (% OF SAMPLE)	
	1975	2000	1975	2000
Cooking and washing up	57	51	72	88
Eating at home	79	54	99	97
Eating and drinking out	11	25	32	43

Warde et al. (2007) conducted a comparative time-use analysis of cooking and eating practices in the UK in 1975 and 2000. The analysis revealed the amount of time spent cooking and eating at home has reduced over the years. Time devoted to cooking has fallen by 6 minutes in the UK, whereas time spent eating at home has dropped by 25 minutes (Table 4). Hence, the amount of time spent eating at home has fallen faster than the amount of time spent cooking. Various studies show similar trends of increased eating out practices (Warde et al., 2018), with eating out gradually becoming an ordinary routine endeavour (Paddock et al., 2017), often considered more economical, time efficient and convenient (Pfeiffer et al., 2017).

Durand-Daubin and Anderson's (2018) comparative study of changing eating practices over three decades (1974-2005) shows that although the time that lunch is eaten has remained largely unchanged, eating lunch has actually decreased significantly in Great Britain (7% less people are having lunch at peak time). Over time, dinner has come to be eaten and cooked later in the evening with a higher proportion of British respondents involved in cooking (over 15% in each half hour from 16:00 to 18:30). Their analysis shows that although eating at home has reduced, overall levels of cooking at home have remained fairly consistent. Southerton et al.'s (2012) study provides evidence of how institutional systems affect eating (and by extension cooking) routines in different countries. Britain has more employment in the service industries with scattered working hours undermining the collective timing of eating events.

Morley's (2014) study of cooking practices shows how cooking has diversified with increasing types, styles and range of products, along with other changes including reduction in the time spent cooking and the energy consumed. According to Morley, decline in energy consumption associated with cookers across Europe, although augmented by increased technical efficiency of cooking appliances, is associated more with changes in cooking as a practice. From 1970 to 2011, the duration of oven use is thought to have fallen because of the prevalence of microwave and pre-cooked meals, with cooking times typically ranging from 15 to 30 minutes shorter than those required previously for cooking with raw ingredients (as cited in Morley, 2014). Trends show that there is an increased participation rate in cooking but with an overall decline in the time and energy devoted to cooking and food preparation. Similar evidence is provided by Short (2007) in the distinction between 'proper cooking', a form of enthusiast or leisure cooking and baking which is trending, and 'routine cooking', which is the simpler form of providing routine meals. Moreover, studies show that respondents often express dissatisfaction with the amount of time spent preparing food, which is perceived to be better spent on other activities, such as socialising and spending time with family (Pfeiffer et al., 2017; Hoolohan et al., 2018).

3.3. Cooking and sociodemographic variations

Cooking in everyday life is practiced, organised and influenced by a number of influences, including the practical conditions of the cooking setting, the life experiences of cooking practitioners, the multitude of cooking skills, and the social relations and meanings related to cooking and eating (Halkier, 2009). EFUS 2011 shows that cooking and use of appliances is linked with sociodemographic characteristics such as household size, age of the household reference person and if children are present, etc. (Table 5).

Table 5: *Cooking appliance use wrt sociodemographic distribution* (Source: BRE, 2013, p. 21)

Household characteristic	Characteristic category	Sample size	Oven use per week		Hob use per week	
			Mean	*95% CI*	*Mean*	*95% CI*
Children present	At least one child	807	6.0	(5.7, 6.2)	8.8	(8.5, 9)
	No children	1809	4.6	(4.4, 4.7)	7.4	(7.2, 7.5)
Age of Household reference person	16-34	395	5.6	(5.2, 6)	7.9	(7.4, 8.2)
	35-44	477	5.6	(5.2, 5.8)	8.1	(7.6, 8.4)
	45-54	524	5.3	(4.9, 5.5)	7.9	(7.5, 8.2)
	55-64	494	4.7	(4.4, 4.9)	7.7	(7.3, 8)
	65-74	426	4.4	(4.1, 4.7)	8.0	(7.5, 8.3)
	75 or more	300	4.0	(3.6, 4.2)	7.2	(6.7, 7.7)
Annual gross income of the HRP and partner weighted quintiles	1st quintile	611	4.5	(4.2, 4.8)	7.4	(7.1, 7.7)
	2nd quintile	578	4.7	(4.4, 5)	7.6	(7.2, 7.9)
	3rd quintile	499	5.0	(4.7, 5.3)	7.9	(7.5, 8.2)
	4th quintile	471	5.3	(5, 5.6)	7.8	(7.4, 8.1)
	5th quintile	457	5.4	(5.1, 5.7)	8.4	(8, 8.7)

Base: all households in the EFUS 2011 Interview Survey owning each appliance (n=2616)

Some trends observed in the EFUS 2011 survey and through reviewing the literature include:

- Older households, households with children present, households where someone is in during the day and households not under-occupying typically have a higher average use of ovens and hobs (BRE, 2013).
- From 1975 to 2000, trends show that household socio-demographic characteristics (such as differences of condition, of being unemployed or retired, or of belonging to a different social class) became less significant in influencing the time spent in eating practices, with lesser impact over time (Warde et al., 2007).
- An overall decline in time spent cooking and eating, specifically for young people and those who are single and/or without children (Cheng et al., 2007).
- A higher frequency of eating home-cooked meals is associated with being female, older, not working overtime and higher socio-economic group (measured by greater educational attainment and household income) (Mills et al., 2018).
- Eating meals out more frequently is associated with being student, male, working overtime and higher socio-economic groups (measured by greater educational attainment and household income)[5] (Warde et al., 2007; Bates et al., 2017; Mills et al., 2018).
- According to the Food & You Survey (2017), 96% survey respondents ate out, with 43% doing so at least once or twice a week. Variation by gender revealed that 50% of men ate out at least once or twice a week compared with 38% of women.
- From 1975 to 2000, there was a significant increase in overall participation in cooking. Although women still have greater responsibilities for cooking (67%

5 Education and employment status was not found significant in eating out patterns in Britain in 1975, but became significant in the last quarter of the 21st century (Warde et al., 2007)

compared with 30% men (Bates et al., 2017)), trends do indicate some shift in the gendered pattern of the division of domestic labour as more men did become involved (Short, 2007; Warde et al., 2007; Meah and Jackson, 2013; Morley, 2014; Durand-Daubin and Anderson, 2018).

- Total domestic work time for men has increased from 90 minutes per day in the 1960s to 148 minutes per day in the early 2000s, with time spent on cooking, cleaning and laundry increasing from approximately 20 minutes per day to over 50 minutes per day (Kan et al., 2011).

These sociodemographic variations show that a transition in the cooking technology and the resulting changes in the practice of cooking are likely to have distributional impacts, in which some segments of the population (e.g. women, older households, household with children, etc.) will be affected more than others.

To summarise, the function and performance of cooking appliances varies significantly by fuel type. Trends in cooking appliances based on fuel-type show that natural gas is still the preferred fuel source for hobs, while cooking with electric ovens is dominantly preferred. Although natural gas is still the dominant fuel, induction hobs are gradually becoming more popular because of their greater efficiency, heat control, safety, and aesthetics. However, their use in specific cuisines remains underexamined. The preference of cooking fuel types for certain cuisines suggests that the transition from natural gas to electric/induction hobs can have distributional impacts, in which specific social groups are affected more than others. In terms of cooking practices, literature reveals trends that show a reduction in time spent in cooking and eating meals at home and a greater tendency for eating out, especially among men, younger people and individuals who are single. Energy consumed in cooking at home has also decreased, both as a result of increased appliance efficiency and changing cooking methods that employ more pre-prepared food. However, where this means reduced energy and carbon emissions in households, it is important to note that pre-prepared meals and meals out of the home are typically more energy-intensive (Druckman and Jackson, 2010; Schmidt Rivera et al., 2014)2010; Schmidt Rivera et al., 2014. Hence, policy should take into consideration a much wider view of cooking and eating practices and subsequent carbon emissions with a whole-systems approach.

4. The social dimensions of low-carbon transitions in cooking appliances

This section looks at the various social challenges and opportunities that a transition to heat decarbonisation would entail. Since limited literature was found on the social implications of transition in cooking practices and/or change towards low-carbon cooking technologies, the social impacts were explored more broadly in heat decarbonisation, technology transition, carbon and energy reduction, home retrofitting and sustainable food consumption, as they provide certain similarities with the topic of research and can provide useful insights for the current research. A multidisciplinary review of the literature is structured around Southerton et al.'s (2011) ISM framework, which conceptualises factors influencing behaviour in the Individual, Social and Material (ISM) context. This presents a more comprehensive and systemic opportunity of identifying the various change-agents at varying scales that influence consumer use and preferences. A separate subsection is dedicated to research that takes a multi-method approach.

4.1. The Individual Context

This section includes literature that focuses on the individual as the primary frame of reference and investigates the various drivers for individual attitudes, values, beliefs and choices to understand consumer acceptance for a low-carbon transition. It includes concepts from behavioural economics, behavioural studies and social psychology, etc. Social psychology makes use of mental processes to determine individuals' perceptions, emotions, affective influences of valuation, risk assessments, cognitive operations, attitudes and norm internalisation to account for behaviour in response to a set of externally-derived positive motivators and negative barriers. It acknowledges that not all individual action is the result of rational decision-making. Behavioural economics investigates the (economic) decisions of individuals and usually adopts more experimental, hypothesis-testing methodologies. Most literature that tackles behaviour acknowledges the complexities involved in understanding behaviour and designing change but does tend to be inherently limiting due to its focus on the individual as the central unit of focus (or indeed analysis).

Lee, M.K., Kiesler, S. and Forlizzi, J., 2011. Mining behavioral economics to design persuasive technology for healthy choices, In: *Proceedings of the 2011 Annual Conference on Human Factors in Computing Systems - CHI '11*. Presented at the 2011 annual conference, ACM Press, Vancouver, BC, Canada, p. 325
This paper shows the influence of the presentation and timing of food choices in encouraging people to make healthier decisions by applying concepts from behavioural economics. Results show that people opted for more healthier choices when they were set as the default option and when asked to plan ahead. Further, people were also found to opt for more healthier food options when interacting with a human, as opposed to a robot or through online ordering systems.

> ***Key takeaway:*** *One idea for heat policy would be to use persuasion techniques like setting the optimal as the default option and allowing people to plan ahead for low-carbon technology transition.*

Luis, O., Val, M. and Kevin, B., 2012. Cooking behaviours: a user observation study to understand energy use and motivate savings. *Work: A Journal of Prevention, Assessment and Rehabilitation*, 41, 2122–2128.
The authors conducted an observational study to investigate how users interact with electric cookers, and how this can inform behaviour change for energy efficiency. Energy saving techniques for cooking on solid plate electric cookers were developed as a baseline, to be compared with university students' cooking behaviours. The study found that on average, the respondents consumed three times more energy than the baseline as well as using more time than recommended. Barriers identified in energy saving behaviour included usability problems, poor feedback, lack of a natural mapping of controls, and differences between how the appliances actually worked and the mental model held by the participants.

> ***Key takeaway:*** *Heat policy should recognise that in addition to appliance characteristics, human factors play an important role in cooker energy consumption and carbon emissions.*

Pelenur, M., 2013. Retrofitting the domestic built environment: investigating household perspectives towards energy efficiency technologies and behaviour. PhD thesis submitted to the University of Cambridge, Department of Engineering, Cambridge.
The PhD dissertation investigated the social barriers towards adopting energy efficiency measures and behaviours in the home, through street interviews in Greater Manchester and Cardiff. The key barriers identified are:

- Cost versus perceived benefits: While cost is a factor, the study shows that the significance of cost is diminished as a barrier if the benefits of the energy efficiency measures are unknown, or if they are perceived to be very low.
- Property itself: Limitations imposed by the property in terms of space availability, age, structure or heritage listing
- Personal behaviour: lifestyle; image; effort made for change; laziness; lack of time and convenience
- Landlord-tenant & housing/council: Split incentives or lack of authority
- Family / partner / housemate: Lack of influence of individual action in collective setting
- Beliefs / information & Institutional: Lack of expertise/knowledge; government incentives; and mistrust of energy companies or contractors

> ***Key takeaway:*** *While standard economic barriers such as cost were identified, significant weight was also given to constraints in personal lifestyles, family habits and lack of trust, which could also benefit heat policy.*

Pelenur, M.J. and Cruickshank, H.J., 2012. Closing the Energy Efficiency Gap: A study linking demographics with barriers to adopting energy efficiency measures in the home. *Energy, Asia-Pacific Forum on Renewable Energy 2011*, 47, 348–357.
The study identifies strong correlations between barriers affecting the adoption of domestic energy efficiency measures and demographic variables like gender; marital status; education level; type of dwelling; number of occupants in household; residence (rent/own); and location (Manchester/Cardiff). Findings suggest that:

- Awareness/information campaigns should target woman and residents living in semi/detached dwellings.
- Inter-occupant relationships affect adoption
- To overcome the landlord-tenant split incentive barrier, interventions should target: men; individuals who are single; individuals with a degree or more of education; flats and terraced homes; and tenants.

> ***Key takeaway:*** *Socio-demographic variations necessitate targeted policy interventions. Cooking varies substantially by socio-demographic factors and policy would benefit from clustering and targeted approaches.*

Mallaband, B., Haines, V. and Mitchell, V., 2013. Barriers to domestic retrofit: Learning from past home improvement experiences, In: Swan, W., Brown, P. (Eds.), *Retrofitting the Built Environment*. John Wiley & Sons, Oxford, pp. 184–199.
The research identifies a range of interrelated barriers to making home improvements to older, hard-to-treat homes. It suggests that policy for home retrofitting should consider factors including:

- Limited personal capacity to make home improvements due to life-stage or time commitments
- Perceived difficulty of a job
- Likely disruption
- Inability to reach consensus with partner/other household members
- Trust in the professionals and contractors who are part of the retrofit process
- Preference for piecemeal approach to change

> ***Key takeaway:*** *Acknowledging that individuals alone may have limited capacity for change. Heat policy that provides a similar piecemeal approach to low-carbon heating transitions in home may be more acceptable.*

Fell, M.J., Shipworth, D., Huebner, G.M. and Elwell, C.A., 2015. Public acceptability of domestic demand-side response in Great Britain: The role of automation and direct load control. *Energy Research & Social Science*, 9, 72–84.
This paper explores homeowner acceptability of a range of demand-side response electricity tariffs. Through an online survey of British bill payers, it shows that direct load control of heating was acceptable to many people in principle (within tight bounds and with override ability). The option of automation significantly improved people's attitude towards the unpredictable Dynamic time-of-use tariffs, as it was considered significantly easier to use with automation, provides a greater sense of comfort and control over timing. Time-of-use tariffs were rated highly for giving people control over spending on electricity.

> ***Key takeaway:*** *Acceptability for a new technology/transition increases if it is perceived to provide improved benefit or ease of operation. Heat policy would benefit from ensuring that alternative low-carbon cooking technologies provide improved experience to users.*

Frederiks, E.R., Stenner, K. and Hobman, E.V., 2015. Household energy use: Applying behavioural economics to understand consumer decision-making and behaviour. *Renewable and Sustainable Energy Reviews*, 41, 1385–1394.
By presenting an argument against financial incentive-based and rational-choice models, this article draws on behavioural economics and psychology to present the key cognitive biases and motivational factors that can explain energy-related behaviour. Drawing on relevant literature, the paper suggests some of the key barriers to change include:

- Retaining the status quo: sticking to default settings or deferring decision-making entirely (inertia)
- 'Satisficing': exerting only the effort needed to achieve a satisfactory rather than an optimal result

- Loss and risk aversion
- Sunk cost effect: People tend to become irrationally fixated on 'recovering' losses already suffered, discounting future costs and benefits, once invested in an endeavour
- Temporal and spatial discounting: People perceive things as less valuable or significant if further away in time or space, even with long-term benefits
- Conforming to social norms
- Rewards and incentives: both intrinsic and intrinsic, act as a motivating factor
- Free-riding effect: People reduce effort, withhold resources, or contribute less to the common good if they can gain the same benefits without paying for them, or believe others are enjoying benefits without contributing
- Trust: Trust in expertise and experience, perceived openness, honesty, and concern for others
- Availability bias: People tend to estimate the frequency of future events by drawing heavily on memory

Key takeaway: *Instead of using simple economic models, the factors identified above through behavioural economics can help also be used to design more cost-effective and mass-scalable heat policy interventions.*

Williams, H., Lohmann, T., Foster, S. and Morrell, G., 2018. *Public acceptability of the use of hydrogen for heating and cooking in the home: Results from qualitative and quantitative research in UK.* Madano, conducted for the CCC, London.

This report presents a detailed investigation of public acceptability of two alternative low-carbon technologies for heating the home: hydrogen heating and heat pumps. It identifies the following challenges:

- Communication and educational challenges: Limited knowledge of alternatives and awareness of need to decarbonise household heating or the implications of switching to low-carbon heating technologies
- Public acceptability: Lack of perceived tangible additional consumer benefit; concerns about effort and costs required by the public to install and use new heating technology; In the absence of clear benefit, tendency to choose least-worst option with fewest perceived drawbacks; rebound effect: perceived benefit of heating and cooling from heat pumps seen as advantage
- Perception for meeting modern needs: unfamiliarity with the new system (in case of heat pumps); additional space needs; lower responsiveness of heating system; integration of the system in smarter homes - technologies that are quieter, faster and concealed.
- Short-term versus Long-term viewpoints: Heat pumps preferable for less short-term inconvenience; hydrogen preferred in terms of long-term view of familiar, modern and convenient technology

Key takeaway: *Research suggests that public acceptability for low-carbon cooking technologies can be increased through ensuring minimum disruption, increasing familiarity and added consumer benefit.*

Lipson, M., 2018. How can people get the heat they want at home, without the carbon? Prepared by the Energy Systems Catapult (ESC) for the Energy Technologies Institute.

https://www.eti.co.uk/insights/how-can-people-get-the-heat-they-want-without-the-carbon.

This report provides guidelines for domestic heat decarbonisation considering consumer needs, behaviours and preferences, such as:

- The need for improved consumer satisfaction and experience with low-carbon transition
- Reluctance in facing the hassle, disruption and uncertainty of change
- Opting for the simpler to install, cheaper and more familiar option
- Trust and loyalty
- Differentiating consumer options and choices to meet diverse needs
- Need for developing local infrastructure for heat networks and shifting enough households to recoup construction and operating costs
- Opportunities for policy makers to harness emerging decarbonisation technologies and energy systems to reduce fuel poverty through more equitable business models
- If policy makers set the sector carbon targets, consumer feedback would drive energy service providers to improve the design, marketing, installation and pricing of low-carbon heating solutions.
- Energy service providers as intermediaries between district network operators, market vendors and consumers to drive carbon reduction in heating

Key takeaway: *Research suggests that policy should focus on improved consumer experience using consumer segmentation. Aligning with energy service providers as intermediaries and harnessing market forces can be a potential pathway to heat decarbonisation.*

4.2. The Social Context

This section includes literature that looks at factors beyond the individual in the social context, such as shared understandings, socio-cultural norms and meanings, as well as social networks and relationships and institutional influences. Instead of focusing on individualist causal factors and external drivers, social theories focus on endogenous and emergent dynamics, reproduced through social practices. Prominent among this literature are practice theories. Building on the sociology of consumption, practice theories focus on the habitual behaviour, everyday routines and social norms that shape the demands for energy, in which energy consumption is inherently an outcome of social practices.

Halkier, B. and Jensen, I., 2011. Doing 'healthier' food in everyday life? A qualitative study of how Pakistani

Danes handle nutritional communication. *Critical Public Health*, 21, 471–483.
This article contributes to the critique of the deficit model in public health communication by drawing on a case-study of food and cooking habits among Pakistan Danes. It shows how food provisioning, cooking, and eating are practical activities that are socially, culturally and symbolically organised and entangled in the conditions, resources, network relations, and negotiations of everyday life. Even when clear knowledge and awareness of healthy diets is available, food and cooking practices are negotiated in terms of the pleasures of taste, cultural expectations of appropriate food, managing of family time, and gendered relations.

> ***Key takeaway:*** *Information alone is insufficient to drive change or to ensure public acceptability. A similar approach for heat policy would suggest that communication for heat decarbonisation be tailored to the specific segments, catering to their specific values, needs and existing routines.*

Clear, A.K., Hazas, M., Morley, J., Friday, A. and Bates, O., 2013. Domestic food and sustainable design: a study of university student cooking and its impacts, In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13*. Presented at the SIGCHI Conference, ACM Press, Paris, France, p. 2447.
This study examines university students' food and cooking practices and subsequent energy consumption and GHG emissions and helps inform sustainable design for cooking and eating at home. Within this specific socio-demographic, the study highlights important food-related habits, such as:

- Convenience, price, pleasure and health
- Lack of specific cooking techniques and confidence to cook certain foods
- Gender-related food habits

It also identifies opportunities for sustainable intervention design, for example:

- Adding energy-saving features in cooking appliances to reduce overall CO2 emissions
- Digitally-mediated organisation of meals in communal housing and collective cooking inventory management

> ***Key takeaway:*** *This suggests that policy for heat decarbonisation in cooking should include improvements in technology, and also consider how cooking appliances are used to improve the skills/knowledge of practitioners.*

de Jong, A., Kuijer, L. and Rydell, T., 2013. Balancing food values: Making sustainable choices within cooking practices, In: *Proceedings of the Nordes Design Research Conference* 2013. Copenhagen/Malmö, pp. 127–135.
This paper explores the social aspects of food purchase and cooking at home and how these can be mediated towards more sustainable food practices. Conventional food choices were found based on demands for taste and quality from food experts, issues of health and nutrition, especially concerning children's diets, limitations in inspiration and knowledge, trustworthiness of information and the daily hassle of balancing quality and price. In addition, it shows the results of a digital food planner by which participants of the study were able to select daily dinner meals while supporting choices of sustainable food which reported on environmental impact, health and nutrition values, and purchase data, providing space for negotiating food values.

> ***Key takeaway:*** *This suggests to policy makers on heat that a more effective transition in cooking technologies may be achieved if a (learning/communicating/testing) space is provided for households to negotiate existing values, while opening up possibilities for changing cooking practices.*

Sahakian, M. and Wilhite, H., 2014. Making practice theory practicable: Towards more sustainable forms of consumption. *Journal of Consumer Culture*, 14, 25–44.
This paper explores how changes in practices occur and what levers exist for influencing change towards more sustainable consumption. Looking at bottled water use in London restaurants, consumption of high-fat foods in Oklahoma City (US) and the introduction of local food consumption in Geneva (Switzerland), the paper explores how social learning can initiate new communities of practice. It also highlights the pitfalls that need to be avoided, including:

- Rebound effects: Change in one practice to make it sustainable (e.g. avoiding bottled-water) can result in changes in other practices that are more carbon/energy-intensive (e.g. increased sale of carbonated beverages)
- Focusing only on one aspect of a practice (e.g. providing locally produce) might not be enough to instigate change, unless changes in other elements are also made (e.g. skills to prepare local produce)
- Understanding power relations: Some contributors can have greater power in changing practices through space and time than others (e.g. focus on practices in restaurants or homes)

> ***Key takeaway:*** *This suggests that one aspect of significance for heat policy is to focus on how and where social learning occurs, the value of demonstration projects and identifying key change-agents, such as homeowners, retailers, chefs, hospitality industry, kitchen retrofitters, market supply-chains, political campaigns, community initiatives, etc.*

Clear, A.K., Friday, A., Rouncefield, M. and Chamberlain, A., 2015. Supporting Sustainable Food Shopping. *IEEE Pervasive Computing*, 14, 28–36.
This paper explores the challenges in technology development that help users in developing sustainable food shopping practices. Through interviews and observational fieldwork in supermarkets, the study provides evidence of the complexity and interconnected nature of food in everyday life. It shows how food-related decisions are made by weighing different interests of multiple stakeholders, even within a single family, such as children's preferences, diets, tastes, family circumstances (e.g. visiting friends, occasional celebrations), cost and storage constraints, dietary restrictions, etc. Some insights offered include:

- Recognising the broader role of food within the context of daily life
- Negotiations between extravagance and economy

- Negotiations between convenience and care
- Efficiency and speed of preparation
- Sensitivity to contextual factors, such as work-related schedules, activities, planned events, current dietary interests, tiredness, and state of hunger.

Key takeaway: *This suggests that heat policy can benefit from understanding how a cooking technology fits within existing cooking/eating practices and other daily routines and propose interventions accordingly.*

Brons, A. and Oosterveer, P., 2017. Making Sense of Sustainability: A Practice Theories Approach to Buying Food. *Sustainability*, 9, 467.
This paper addresses the issue of accessing sustainable food from a practice theoretical perspective. Based on interviews and participant observation with students in Paris, it explores the modes of recruitment, modes of engagement, degrees of commitment, and bundles of practices that together determine food-related practices. The analysis shows that access to sustainable food is not necessarily determined by financial means only, nor by individual attitudes, but embedded in the complex networks of socially-shared tastes and meanings, knowledge and skills, and materials and infrastructure. Further, it highlights how people's participation in the practice of buying sustainable food may not stem from sustainability concerns, but can also come from other considerations, such as health worries and competing concerns, such as travel times and pressures on social ties.

Key takeaway: *This suggests to policy makers in heat that instead of only focusing on financial incentives, low-carbon cooking technologies may be more acceptable if they are part of socially-shared understandings, offer health/dietary improvements and fit better in existing travel/work routines.*

Pfeiffer, C., Speck, M. and Strassner, C., 2017. What Leads to Lunch—How Social Practices Impact (Non-) Sustainable Food Consumption/Eating Habits. *Sustainability*, 9, 1437.
This article explores consumer behaviour towards more sustainable food consumption through a qualitative assessment of eating practices. The research reveals that the practice of eating out is highly dependent on external factors like busy lifestyles, mobility routines and perceived lack of time. Nutrition knowledge and sustainable mindsets have little effect on eating decisions and participants show a high level of distrust towards quality claims. Changes in work and mobility patterns are very likely to affect eating out practices.

Key takeaway: *Change in cooking technologies for heat decarbonisation may have similar relational consequences on cooking and eating practices, lifestyles, time constraints, etc. Considering these relational factors may help heat policy in designing interventions that are more acceptable.*

Comber, R., Hoonhout, J., Halteren, A.V., Moynihan, P. and Olivier, P., 2013. Food practices as situated action: exploring and designing for everyday food practices with households, in: Proceedings of the SIGCHI Conference 2013. Presented at the Human Factors in Computing Systems (CHI), Paris, France, pp. 2457–2466.
This paper identifies the various challenges to healthy eating and argues that recognising food practices as situated action affords opportunities to identify and design for practiced, local and achievable solutions to sustainable cooking and eating. Through interviews and shop-a-longs, the study shows that cooking and food preparation are based on several factors, including:

- Time, finance, taste, weight management and food waste as top priorities
- Other factors include effort, habits, skill, knowledge, social demands, availability and perceptions of healthy food and uncertainty towards change
- Demographic factors, e.g. the absence of children allowed greater freedom in meal choices and eating out
- Shopping and cooking often fall into set routines e.g. outside activities and work schedules
- Domestic food practices rely on external factors like relying on other family member to prepare meals, take-away restaurants and supermarket ready meals
- Home is considered an ethical context for 'good' food assumed to be healthier, with entailed requirements and difficulties for the co-ordination of food consumption
- Quick meals and good meals are considered at odds with each other

Key takeaway: *Cooking/eating practices are bound by social values and relations, existing routines, demographic factors and existing knowledge and skills. Heat policy can benefit from understanding how a cooking technology transition will fit within existing cooking/eating practices.*

4.3. The Material Context

This section further expands the unit of analysis to the large-scale institutional and infrastructural systems of provision that both constrain and shape behaviour and in doing so, permit particular forms of consumption and demand. These influences include existing 'hard' infrastructures, technologies and regulations, as well as other 'softer' influences such as time and the schedules of everyday life. The focus is mainly on structural changes resulting in the emergence of new modes of production and consumption. The literature in this section foregrounds the role of technology and agency in transitions and the co-constitutive nature of technology and society. It mainly focuses on medium- to long-term processes of change as they affect societal regimes. This helps to highlight the change in the routine behaviours of all major actors involved at all scales of production, distribution and consumption.

Shove, E. and Southerton, D., 2000. Defrosting the Freezer: From Novelty to Convenience: A Narrative of Normalization. *Journal of Material Culture*, 5, 301–319.

This article provides evidence of how the role of the freezer changed from a novelty technology to a means of everyday convenience. Instead of simply looking at the gradual societal acceptance of the freezer, it shows that the normalising of the freezer took place alongside the development of frozen-food infrastructure, changes in the division of domestic labour, changing design and use of houses and kitchens, the development of out-of-town supermarkets, proliferation of freezer-dependent food and subsequent decline of local food stores. Amidst this changing system, the freezer transformed from a symbol of modernisation in the 1970s, a pre-condition for domestic and economic efficiency in the 1980s to a device of convenience in the busy 1990s. While the freezer allows its users to re-order shopping, cooking and eating practices, freezing, thawing and defrosting impose demands of their own, locking users into certain practices and habits.

> ***Key takeaway:*** *This suggests for heat policy that for a similar transition to low-carbon cookers/hobs, instead of simply looking at the societal acceptance, understanding ways of normalising new cookers/hobs through adjacent changes in cooking skills, cooking utensils, social norms, kitchen designs, market supply chains and supporting systems can prove beneficial.*

Spaargaren, G., Oosterveer, P. and Loeber, A. (Eds.), 2012. *Food Practices in Transition: Changing Food Consumption, Retail and Production in the Age of Reflexive Modernity*, 1st ed. Routledge, London; New York.
This book explores the long-term transitions in food provision and consumption in contemporary societies. Using transition theory, it investigates the complex and multi-faceted societal transformation implicated in the food regimes in OECD countries since WWII. It identifies the various stakeholders, institutions and change agents involved in the food transition and outlines in depth how food-related processes throughout the whole food chain have been redefined and transformed under growing influences of food safety; food security; catering and retail; consumer agency; food-related technological innovations; issues regarding sustainability and animal wellbeing; and the globalisation and (re)localisation of food production, distribution and consumption.

> ***Key takeaway:*** *This suggests the importance of understanding historical transformations for heat decarbonisation. One idea for policy is to understand the practices, regimes and systems preceding the technology transfer and to forecast what successive regimes the technology transition will incur.*

Judson, E.P., Bell, S., Bulkeley, H., Powells, G. and Lyon, S., 2015. The co-construction of energy provision and everyday practice: integrating heat pumps in social housing in England. *Science and technology studies*, 28, 26–53.
This article explores how energy systems such as heat pumps are co-constituted through the habits and expectations of households, their technologies and appliances, alongside arrangements associated with large-scale sociotechnical infrastructures in a demonstration project in the North of England. It highlights how alternative modes of consumption create opportunities for renegotiation of new forms of interdependency between service providers, users and systems. Some key insights from the research include:

- Acceptance to change in technologies is disrupted by conventions and habits related to existing systems of provision
- Possibility of improvement (better control, less costs) is welcomed
- Negotiation/Compromise: Either the technology changes the practice or the practice results in re-shaping the technology
- Increased knowledge and information for technology adoption alone will not work without implications on systemic arrangements of energy provision and everyday practices
- Different satisfaction levels between different socio-demographic groups
- Inertia from intermediaries: landlords, installers and suppliers (lack of sufficient explanation and interpretation, post-installation advice, follow-up services and oversight)

> ***Key takeaway:*** *Similar demonstration projects for heat policy can provide useful insights into how alternative cooking technologies can create opportunities for renegotiation between users, service providers and socio-technical systems. The rollout of new technologies should be undertaken with consideration of these distributed relationships involved.*

Hanmer, C. and Abram, S., 2017. Actors, networks, and translation hubs: Gas central heating as a rapid socio-technical transition in the United Kingdom. *Energy Research & Social Science*, 34, 176–183.
This Actor Network Theory based article analyses the historical heating transition in UK homes from coal-fired to gas from mid- to late-twentieth century. It identifies the various actors involved in the transition including consumers, installers, manufacturers, designers, retailers, builders' merchants, regulators, etc. Through this historical analysis, it provides insights into the challenges faced and lessons for future transitions to low-carbon heating systems, such as:

- Low-carbon heating technologies such as district heating and heat pumps provide a similar, rather than improved service, which inhibits uptake
- Higher investment cost than the equivalent gas boiler
- Poor workmanship in retrofitting can lead to issues
- Space constraints in switching appliances that might need greater space
- Amount of disruption caused
- Challenges in a state-controlled, centrally directed programme as no obvious UK organisation with the scope or authority to effect major changes at a system level

Some of the lessons learned for successful transition and opportunities include:

- Improvement in heating service
- Reduction in operating costs
- Ensuring easy and cost-effective incorporation into existing systems and structures
- Opportunity for social energy equity with cheap, convenient and abundant fuel and secure supply chains

- Better alignment of the fuel, heating system and building design
- Identifying organisations that play a similar catalysing role (as Watson House) and identifying common characteristics and themes

Key takeaway: *One key lesson for policy based on the historical heat transition in the UK is that the uptake of a new fuel infrastructure was enabled by alignment, co-ordination and communication across multiple networks through 'translation hubs' (facilitating organisations).*

Brown, D., Kivimaa, P., Rosenow, J. and Martiskainen, M., 2019. Overcoming the systemic challenges of retrofitting residential buildings in the United Kingdom: A Herculean task?, In: Jenkins, K.E.H., Hopkins, D. (Eds.), *Transitions in Energy Efficiency and Demand: The Emergence, Diffusion and Impact of Low-Carbon Innovation*. Taylor & Francis, Abingdon, pp. 110–130.
This chapter investigates the immense task of a comprehensive upgrade of UK domestic buildings from a socio-technical perspective. It proposes the following solutions to the systemic challenges of retrofitting:

- Service-based business models: with integrated supply chains that effectively pair the technology with the useful end service, shifting incentives for resource efficiency onto suppliers and broader source of value focused upon aesthetics, increased property value, comfort, health and wellbeing alongside energy and carbon savings
- Retrofit financing: a capital cost that is low enough not to deter households and enable deeper retrofit measures to remain cost-effective; a simplified customer journey – with finance often arranged by the contractor or project manager, use of an existing repayment channel (e.g. property taxes), attaching the debt to the property not the householder (resolving the spilt incentive issue); and funding for broader sources of value, such as wider renovation work or essential home improvements
- Retrofit intermediaries: can stimulate, guide and manage different whole house retrofit projects, and aid the creation of a market for new retrofit business models and financing solutions

Key takeaway: *The three solutions proposed above can be easily translated to heat decarbonisation policies to provide similar opportunities for a smooth transition towards low-carbon home retrofits.*

Sweetnam, T., Fell, M., Oikonomou, E. and Oreszczyn, T., 2019. Domestic demand-side response with heat pumps: controls and tariffs. *Building Research & Information*, 47, 344–361.
This research presents the results of a field trial of a new control system to optimise heat pump performance under different time-use tariffs. Factors affecting the consumer acceptability of the system were determined through interview and questionnaire, including:

- Technical problems with automation and control
- Difficulty in understanding how to use and optimise
- Confusion and misuse due to lack of awareness of how heat pumps are more efficiently run
- Perceived lack of control and autonomy because of lack of feedback from the controller
- Disturbance and noise
- Alignment with existing building systems and infrastructure

Key takeaway: Acceptability of alternative low-carbon cooking technologies can be improved through similar field trials that ensure new cookers/hobs provide easy and improved use, improved control and fit within existing schedules, building systems and infrastructure.

4.4. Multi-model/Alternative approach

This section draws on literature that employs multiple and/or interdisciplinary models and frameworks for conceptualising demand reductions and transitions, transcending the boundaries of individual, social and material contexts. Such an approach is undertaken with the view of overcoming the limitations of single theoretical frameworks to provide a more comprehensive understanding and solution to the energy challenge. We hope that showcasing such literatures will spark further dialogue within and across BEIS.

Hoolohan, C., McLachlan, C. and Mander, S., 2016. Trends and drivers of end-use energy demand and the implications for managing energy in food supply chains: Synthesising insights from the social sciences. *Sustainable Production and Consumption*, 8, 1–17.
This paper provides a consumer-focused framework to devise, inform and evaluate potential interventions to reduce energy demand and emissions in food supply chains. It explores the relationship between production and consumption by reviewing trends in the food sector with implications for energy demand. In addition, it provides a multidisciplinary review of the literature on sustainable consumption structured around the Individual, Social and Material Context framework. These, together with a Life Cycle Assessment approach, are used to map and quantify emission hotspots in the food supply chain. The study reveals that production and consumption must be considered with the 'consumer' interactive throughout the supply chain.

Key takeaway: *A similar suggestion for heat policy is better integration of the consumer/end-user as an important stakeholder in all stages of the transition, including product innovation, legislation and roll-out.*

Bickerstaff, K., Hinton, E. and Bulkeley, H., 2016. Decarbonisation at home: The contingent politics of experimental domestic energy technologies. *Environment and Planning A: Economy and Space*, 48, 2006–2025.
This article presents an alternative approach to governance of domestic energy technologies, that goes beyond

human-centred models based on personal capacities and top-down techno-centric interventions. Drawing on three contrasting low-carbon energy technology projects in the UK, the study argues for a more experimental and provisional mode of governance for decarbonising domestic energy practices. The review of case-studies brings to light the contingency of domestic energy experiments in relation to two key factors: (1) the reordering of control, which addresses how devices intervened in everyday domesticities and accountability relations, relative to their design expectations; and (2) the ambiguity of design, which directs attention at the moral-political implications of such mundane devices, which extend beyond their immediate empirical effects at the level of energy-consuming practices. By examining the affective and calculative capacities of low-carbon energy technologies, Bickerstaff et al. foreground the role of such experiments in shaping and sustaining certain political and democratic arrangements.

Key takeaway: *This suggests that heat policy can also improve by focusing beyond individual capacity building and top-down infrastructural interventions towards experimental modes of governance that rethink the role of technology, interrupt norms and reframe demand (e.g. participatory design).*

Hoolohan, C., McLachlan, C. and Mander, S., 2018. Food related routines and energy policy: A focus group study examining potential for change in the United Kingdom. *Energy Research & Social Science*, 39, 93–102.

This paper explores the links between food-related routines and energy demand for improved demand management in the food system. Drawing on concepts from Social Practice Theory and social psychology, it uses focus groups with working parents, city dwellers and empty nesters to examine the role of social and temporal commitments in shaping food routines. It provides insights into how the different modes of provision, meals and methods of cooking used to navigate these commitments influence what is purchased and eaten. Further, it presents options for alternative less energy-intensive shopping, cooking and eating practices. This includes providing:

- Opportunities for social learning through intermediaries such as employers, retailers, chefs and teachers
- Reconfiguring product and service systems such as change in how food is cooked at home, including a wider variety of ready-meals and doorstep services that emphasise local/seasonal produce or vegetarian options, alternative modes of dining and tailored menu options
- Interventions in the temporality of cooking and eating, such as reducing cooking times, increasing temporal malleability of cooking by changing temporal structure of working through shorter working days and job-sharing arrangements
- Reconfiguring the social organisation of food-related routines by increasing the incidence of shopping, cooking and eating together

Key takeaway: *The aforementioned points are translatable to heat decarbonisation in cooking practices that can lead to lower overall cooking emissions. For low-carbon technology transition, heat policy can benefit from encouraging health outcomes and opportunities for social learning for skills development and alternative cooking techniques.*

Hargreaves, T., Longhurst, N. and Seyfang, G., 2013. Up, Down, round and round: Connecting Regimes and Practices in Innovation for Sustainability. *Environment and Planning* A, 45, 402–420.

This paper combines Social Practice Theory (SPT) and the Multi-Level Perspective (MLP) to present a more holistic understanding of sustainability transitions, using two empirical case-studies of sustainability innovation. The authors show that whilst SPT provides a better understanding of the dynamics and changing patterns of conventional everyday practices, the creation of novel sustainable systems and regimes can be better understood using an MLP approach. In the case of Eostre Organics (an organic food producer), while it was able to successfully establish a radical sustainable food niche and engage with the landscape level through messaging and information campaigns, it was unable to develop a stable regime since it failed to address the interrelations with other existing regimes (e.g. transport systems, access to market stalls, cooking skills, etc.).

Key takeaway: *For heat policy, the paper reveals that a transition in technology will be most effective when undertaken with due consideration to other interconnected practices and regimes (e.g. cooking practices and preferences, market trends, fuel infrastructure, socio-cultural norms and expectations, regulations and standards, etc.).*

O'Neill, K., Clear, A.K., Friday, A.J. and Hazas, M., 2019. "Fractures" in food practices: exploring transitions towards sustainable food. Agriculture and Human Values. ISSN 0889-048X (In Press)

This article explores factors that lead to changes in food practices through a socio-technical approach, combining SPT and MLP. By comparing food consumption practices in North West England in two differing consumer groups – supermarket shoppers; and sustainable food practitioners – the study identifies opportunities for transition in food practices at 'points of fracture':

- Life course changes: provide points of incremental change by fitting and conforming to mainstream processes of performing food
- Moments of radical change: When practices stretch and transform due to a deeper 'fracture' in conventional food practices

The paper suggests that 'sharing spaces' (e.g. ethical supermarkets, domestic food growing projects, community orchards, food assemblies, food festivals, foraging walks, eco cohousing) can provide the possibility for prompting and nurturing fractures that can lead to more sustainable food practices.

Key takeaway: *A similar approach for heat policy can make use of such 'points of fracture', such as life course changes and moments of radical change, as trigger points for enabling low-carbon technology adoption. One key idea for heat policy is to facilitate similar 'sharing spaces' that can help promote and encourage low-carbon technology transitions.*

5. Overcoming the challenges and harnessing the potential of low-carbon cooking transitions

The wide spectrum of SSH research provides valuable insights into how policy can engage with the social dimensions of heat decarbonisation and better understand consumer behaviour in different contexts (through different perspectives). It is important to note though that differences in the theoretical viewpoints, problem framings and analytical frameworks can result in conflicting standpoints, making it difficult to apply in policy. However, the purpose of this report is not to reconcile disparate concepts or to delineate disciplinary boundaries, but to bring attention to the vast array of SSH literature that exists and can inform a more well-rounded understanding of the social implications of heat decarbonisation in cooking technologies, as well as energy and carbon reduction in cooking and subsequent policy recommendations. The selected literature presented in the previous section – while by no means comprehensive – does indeed provide evidence of the varying frames of reference, scales and numerous change-agents involved. Based on the specific challenges and opportunities identified in the respective ISM contexts, different types of intervention approaches for cooking heat decarbonisation and transition in cooking more generally are proposed; examples of which are provided in Table 6.

Most policy reports, while addressing consumer behaviour and preferences, make use of the SSH literature focused on the individual context, gauging public inertia or acceptance for pre-determined technological transitions. The key objective is then to ensure minimum disruption to business-as-usual standards and routines. From this viewpoint, social implications with regards to low-carbon technologies are considered as 'barrier's or 'non-technical obstacles' that need to be overcome in order to realise the proven technical potential (Shove, 1999). This mainstream approach identifies the challenge with a specific perspective, such as cost-versus-benefits, loss and risk aversion, etc., and consequently presents solutions with a narrow scope for intervention. It also acknowledges the limitations of an individual's personal capacity in collective settings and material constraints. A focus on the social and material contexts reveals that cooking technologies and related food habits are not only dependent on individual preferences and choice, rather they are highly integrated and interconnected parts of larger work-home routines, social relations, health and dietary considerations, cultural understandings and food chain networks. The emissions from cooking are thus integrated in these larger networks, institutions and infrastructural systems.

Individualist interventions like targeted messaging, cost incentives and relevant information for technology decarbonisation are important. In addition, broadening the scope of intervention to include the interconnected social and material contexts can provide a more comprehensive understanding of the challenge. For example, recognising how a change in cooking technologies and appliances will affect cooking practices that are constrained by existing socio-cultural norms, cooking and technical skills, work and mobility routines, building and infrastructural alignments and interrelations with intermediaries (e.g. landlords, installers, suppliers). This can offer opportunities of low-carbon transitions in a more systemic way, such as promoting more shared eating, cooking and social learning spaces, partnering with retrofit intermediaries, promoting service-based business models and aligning with organisations that play a catalysing role. Regarded in this way, the question is then not one of identifying 'barriers' to technological innovations and low-carbon transitions in cooking appliances, but rather it becomes an issue of looking at the socio-technical implications of moving away from carbon-intensive cooking/eating practices. Such an approach also highlights how the heat decarbonisation transition can be used as a 'trigger point': an opportunity for improving energy efficiency and reducing overall energy consumption in cooking. Hence, it could help inform a more holistic evidence-base for interventions and transitions with greater policy impact.

Table 6: *Challenges, opportunities and interventions for change in the ISM context*

Challenges	Opportunities	Interventions
Individual Context		
Costs versus benefits Lack of time Lack of awareness and information Temporal and spatial discounting Perceived difficulty and disruption Split incentives Demographic variations Lifestyles Trust Loss and risk aversion Lack of influence of individual action/capacity in collective setting (inter-occupant and social relations) and infrastructural constraints (material constraints of the property)	Improved design, marketing, installation, ease of operation and pricing of low-carbon technologies and appliances Opportunity for improved social equality and accessibility to low-carbon technologies	Rewards and incentives Targeted messaging and information (target women for 'routine cooking' and more general messaging for 'proper cooking'; highlight long-term benefits) Persuasion techniques like default option strategy and planning strategy Energy labelling and carbon targets Different options to meet diverse consumer choices and needs Flexible packages to facilitate piecemeal approach to low-carbon transitions Transition undertaken through trusted intermediaries (local tradesmen, energy service providers, celebrity chefs, etc.)
Social Context		
Changing technology in isolation w/o considering other elements of practice Rebound effects Home cooking perceived as healthier Eating out and quick meals perceived to be unhealthy Socio-cultural variations in cooking and eating practices and cooking methods based on fuel types Health concerns Social ties Contextual factors (e.g. work-related schedules, mobility routines, school schedules, etc.)	Opportunities of social learning through intermediaries (employers, retailers, kitchen retrofitters, chefs and teachers) Greater inclusivity and cultural awareness for different skills and techniques required in preparing different foods Changing how eating and cooking is organised in everyday life Opportunity for improving energy efficiency and reducing consumption during cooking Opportunity for a more synergised whole-house or whole-food demand reduction approach	Facilitating demonstration projects and 'sharing spaces' (ethical supermarkets, food assemblies, communal cooking, etc.) to open up possibilities for change Communication for heat decarbonisation be tailored to specific consumer segments, catering to specific socio-cultural needs Promoting uptake of low-carbon appliances and tastes for less carbon-intensive meals through cooking classes, shared meals and collective inventories Using 'points of fracture' such as life-course changes as trigger points Reduce domestic eating and increase the dominance of eating out with communal healthy dining facilities or continued eating at home but with demise in domestic cooking Adding energy-saving features in cooking appliances to reduce overall CO_2 emissions Work with workplace hospitality and catering to change how food is provisioned Drawing out connections with health/dietary improvements
Material Context		
Low-carbon technologies providing similar rather than improved experience Ensuring easy and cost-effective incorporation into existing systems and structures State-controlled, centrally directed programme Food/cooking safety and security Lack of proper alignment of the fuel, cooking appliance and building design Availability of market supply chains, food stores, supermarkets, retailers, etc.	Improved service through market technological innovation Understanding ways of normalising new cookers/hobs through adjacent changes in cooking utensils, social norms, kitchen designs, market supply chains and supporting systems Reconfiguring product and service systems such as change in how food is cooked at home Interventions in the temporality of cooking/eating, such as reducing cooking times and increasing temporal malleability of cooking	Legislation and carbon taxing Service-based business models Retrofit financing Retrofit intermediaries and organisations that play a catalysing role (Re)localisation of food/appliance production, distribution and consumption/use Wider variety of ready-meals and doorstep services, alternative modes of dining and tailored menu options Changing temporal structure of working

6. Conclusions

This report explores the social dimensions of heat decarbonisation in cooking appliances, specifically moving away from gas cookers and hobs. While heat decarbonisation requires strategic economic and technological frameworks, its social implications and impacts are just as important and require detailed analysis and understanding for deep and smooth transitions. As such, this report set out to answer the following research questions:

- **How are current carbon-intensive cooking technologies part of existing cooking practices and broader social and material structures?**

A review of trends in cooking and appliance use reveals the dynamic and ever-changing nature of cooking and eating practices. Cooking is not only an important contributor to the evening peak, it is highly bound and bundled within existing institutional systems, such as work and school schedules and social factors like cultural norms, food expectations and dietary considerations. Changes in infrastructures, marketing and retail, globalisation and sustainability in food supply chains have had a profound effect on cooking practices at home. Although time spent cooking and eating has subsequently decreased over the years, cooking as a practice remains fairly consistent in the UK, with increasing practitioners, e.g. through greater uptake by men. This shows that a change towards low-carbon cooking technologies is almost certainly going to be needed in all but the most radical changes in home cooking practices. Cooking appliance use and preferences are highly dependent on demographic factors like income and the structure of the household unit (presence/absence of children), but also on socio-cultural norms and variations among ethnic groups, which need to be accounted for in heat decarbonisation policies.

- **What are the challenges and opportunities for cooking heat decarbonisation, in terms of consumer acceptance, carbon and energy reductions and business/market opportunities?**

The individual context of cooking appliance use identifies barriers such as added costs; lack of time, awareness and information; perceived difficulty and disruption; split incentives; loss and risk aversion; and demographic variations in heat decarbonisation transitions. A more comprehensive understanding of the challenge can be developed with a wider focus on the social and material contexts. For example, recognising how a change in cooking technologies and appliances will affect cooking practices that are constrained by existing socio-cultural norms, cooking and technical skills, work and mobility routines, building and infrastructural alignments and interrelations with intermediaries (like landlords, installers and suppliers). This can offer opportunities of low-carbon transitions in a more systemic way, such as improved design, marketing, installation and pricing of low-carbon technologies; opportunities of social learning and cultural inclusivity; and reconfiguring product and service systems.

Individualist interventions like targeted messaging, cost incentives and relevant information for technology decarbonisation can be incorporated with broader interventions in the socio-material context, such as promoting demonstration projects and social learning spaces, partnering with retrofit intermediaries, drawing out connections with health impacts, better alignment with kitchen designs, incorporating energy saving features in new low-carbon technologies, promoting service-based business models and aligning with organisations that play a catalysing role.

- **What interventions are needed to realise policy objectives of heat de-carbonisation?**

Many policy reports acknowledge the need for deeper understanding of the drivers of consumer behaviour and consumption decision-making. They duly highlight the importance of working across the range of different disciplinary perspectives to address the social dimensions holistically and to achieve a smooth transition. However, there still exists a tendency to sustain emphasis on the individual context based on behavioural and social psychological models, while overlooking the broader, interconnected social, institutional and infrastructural dependencies and challenges that need to be fully addressed for large-scale transitions and to meet carbon reduction targets.

In this regard, individualist interventions like targeted messaging, cost incentives and relevant information for technology decarbonisation can be incorporated with broader interventions in the socio-material context, such as promoting demonstration projects and social learning spaces, partnering with retrofit intermediaries, drawing out connections with health impacts, better alignment with kitchen designs, incorporating energy saving features in new low-carbon technologies, promoting service-based business models and aligning with organisations that play a catalysing role. By presenting an overview of the challenges, opportunities and subsequent interventions proposed by the different SSH disciplinary perspectives in different contexts, it is hoped that this report will help in designing more effective cooking decarbonisation policies and strategies.

7. Recommendations

This report identifies some of the key social challenges and opportunities in heat decarbonisation of cooking technologies and appliance use. It further reveals some evidence gaps in existing national datasets, academic and grey literature in the understanding and analysis of the social implications of changing cooking technologies. It, therefore, provides research and policy recommendations for future work.

Recommendations for evidence and data gathering

- Existing national datasets6 provide limited information on cooking technology and appliance use. More detailed information is needed in terms of variation in cooking appliances, fuel types, timings, contribution to peak loads, durations, energy consumption with respect to fuel use, demographic variations, cultural variations in cooking methods and fuel types, causal relationships and longitudinal change, etc.

- While survey and quantitative methods provide statistical results and generalisable datasets, there is also a need for more qualitative, in-depth, ethnographic and interpretive data to get a more detailed understanding of the nuances, meanings and interconnections that form current cooking practices.

- Demonstration projects, such as those undertaken by BEIS for hydrogen fuel testing are used to determine technological efficiency and performance of products/appliances. Such experimental projects can additionally be used to better understand performance-in-use by consumers and how technologies interconnect with existing routines and other practices.

- Due to higher user preference for gas cookers/hobs compared to electric/induction cookers/hobs, specifically in relation to certain cuisines and cultural factors, there is a need for evidence to distinguish between preferences based on user familiarity with existing technology and actual technology capacity and performance. This will determine the type of policies (information/awareness/skill enhancement or technological innovation/market research) that will be most suited for large-scale transition.

Recommendations for research

- Overall, there is limited academic research in the developed world that focuses on the social implications of transition to low-carbon heating and more specifically to low-carbon cooking technologies. This suggests the need to undertake primary research in this area. Further research also needs to be undertaken with regards to health implications of different cooking fuel types, as this can them inform the cooking heat decarbonisation policy.

- Compared to heat consumption for comfort, cooking practices and food-related habits are more personal, socio-culturally bound, gendered and varied in terms of socio-economic and ethnic groups. It is therefore necessary to recognise these differences and to design policy in accordance with the contextual nature of heat in cooking.

- Research on cultural differentiation of cooking/eating in the UK and opportunities/triggers for cultural diffusion and social learning (e.g. through shared cooking spaces or intermediaries like celebrity chefs or cooking competitions) could potentially prove useful for designing policy for transition.

- Among the SSH literature, practice theories can provide useful insights into current cooking methods, techniques, routines and practices as well as food related habits (the latter has been the focus of research as shown in section 4.2). More emphasis needs to be given to cooking as a social practice and its interconnections with the material context for improved understanding and design of low-carbon interventions in cooking appliances.

Recommendations for policy

- Even though appliances will need to change regardless of changes in cooking demand, reframing the policy question to focus not just on the change in technology (e.g. from gas cooker/hob to electric) but, as an option, to look at cookers/hobs as a constitutive part of a wider socio-technical regime of cooking/eating practices and food-related habits could open up new opportunities for meeting climate change targets. For example, a combination of strategies will be required to decarbonise heat in cooking/eating practices that go beyond replacement of appliances alone and change at the household level, but also includes change at the community level (social), and even the city level (material).

- Current heat decarbonisation policy focuses on public acceptance for transitions with 'minimum disruption', ensuring that the status quo is maintained. Energy and emission reductions are part of the brief,

6 Such as ECUK (Energy Consumption in the United Kingdom) and EFUS (Energy Follow-Up Survey)
https://www.gov.uk/government/collections/energy-consumption-in-the-uk
https://www.gov.uk/government/statistics/energy-follow-up-survey-efus-2011

but only in terms of improvements in technological efficiency. There is a need to connect the policy dots between public acceptance for transition and the shifts required for carbon and energy reduction.

- Evidence suggests that there exists a public preference for natural gas cookers/hobs, which is unlikely to decline without a relevant suite of policy packages.

- Based on the above evidence, there exists a market opportunity to develop and innovate cooking appliances, to ensure that low-carbon technologies (like hydrogen or electric induction) provide a similar or better user experience. Policy could ensure capacity-building through a market support framework using legislation, carbon taxing and/or subsidies. For example, the increased role out of induction hobs could help prevent further lock-in to gas technologies.

- There is currently no energy and carbon labelling for hobs. Since the consumption and emissions from hobs is greatly dependent on how it is being used, highly visible information and certification, energy-saving advice and efficiency features may need to be specified for emission reductions – although we do note that equivalent labelling schemes have had little impact in and of themselves in driving energy/carbon savings.

- Instead of defining policies for decarbonising heat in cooking in isolation, combining less carbon-intensive cooking heat policies with health policies that 1) reveal potential negative health impacts of gas versus electric cooking and 2) promote the benefits of raw-food diets, low-heat cooking and less cooking times might gain greater traction.

General recommendations for heat decarbonisation

- Instead of focusing only on top-down approaches for decarbonising heat, greater attention should be given to bottom-up approaches (e.g. grassroots innovations) as well as to middle-out approaches (intermediaries, practices, supply chains, street level bureaucrats, community centres and councils, etc.).

- Recognition of key change-agents and where the responsibility lies for heat decarbonisation transitions. Focusing only on the individual context governs interventions that clearly delegate the responsibility to consumers/end-users, whereas focusing on the social and material contexts provide alternative governance frameworks, such as partnerships with intermediaries, taking advantage of specific trigger points such as life-course changes, facilitating socio-cultural learning spaces, and promoting service-based business models for market supply chains.

- Recognising that technology itself is a social construct and that technical change is a social, contextual, and temporally specific process. Hence understanding the need to integrate the consumer/end-user as an important stakeholder in all stages of the transition, including product innovation, legislation and roll-out.

- Acknowledging diversity and drafting different policy pathways to decarbonisation for different consumer groups; e.g. a separate policy for forerunners, with higher acceptance for decarbonisation and for those who are reluctant and would respond to step changes (e.g. price and income policies, incentives, subsidies and support, etc.).

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10. Appendix I: Domestic energy consumption by fuel and cooking appliance

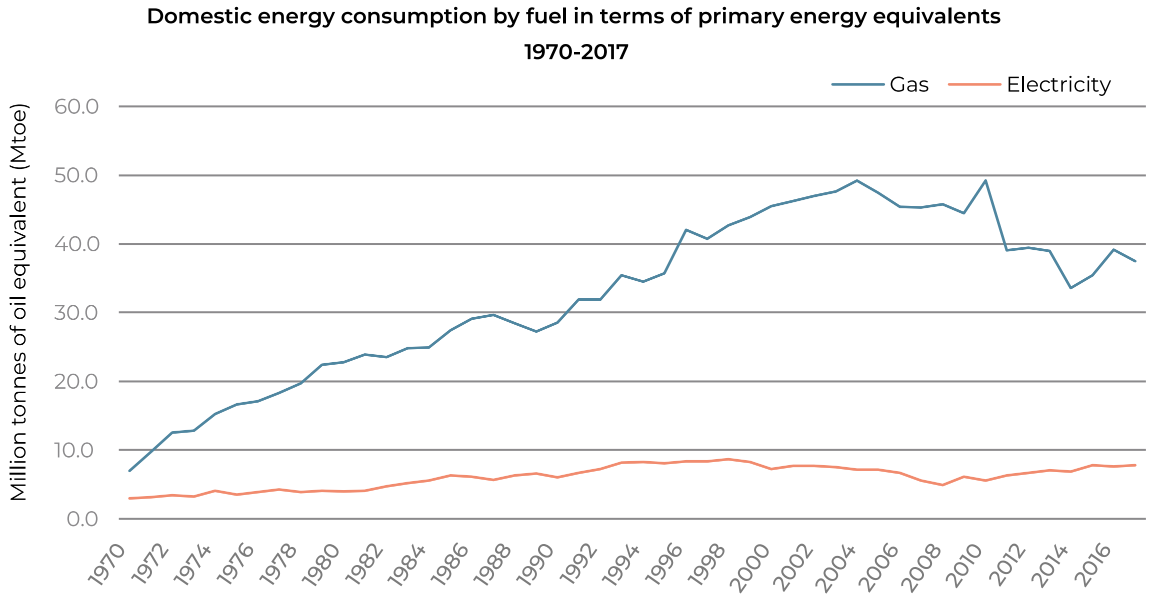

Figure 2: *Domestic energy consumption by fuel in terms of primary energy equivalents 1970-2017. (Source: ECUK, 2018)*

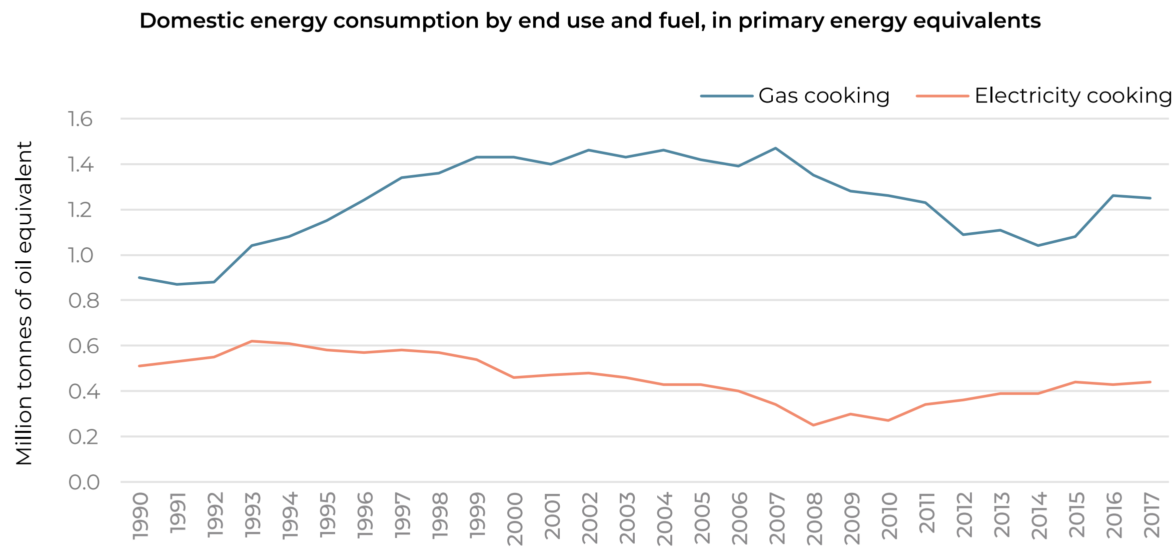

Figure 3: *Domestic energy consumption by fuel in cooking in terms of primary energy equivalents 1970-2017. (Source: ECUK, 2018)*

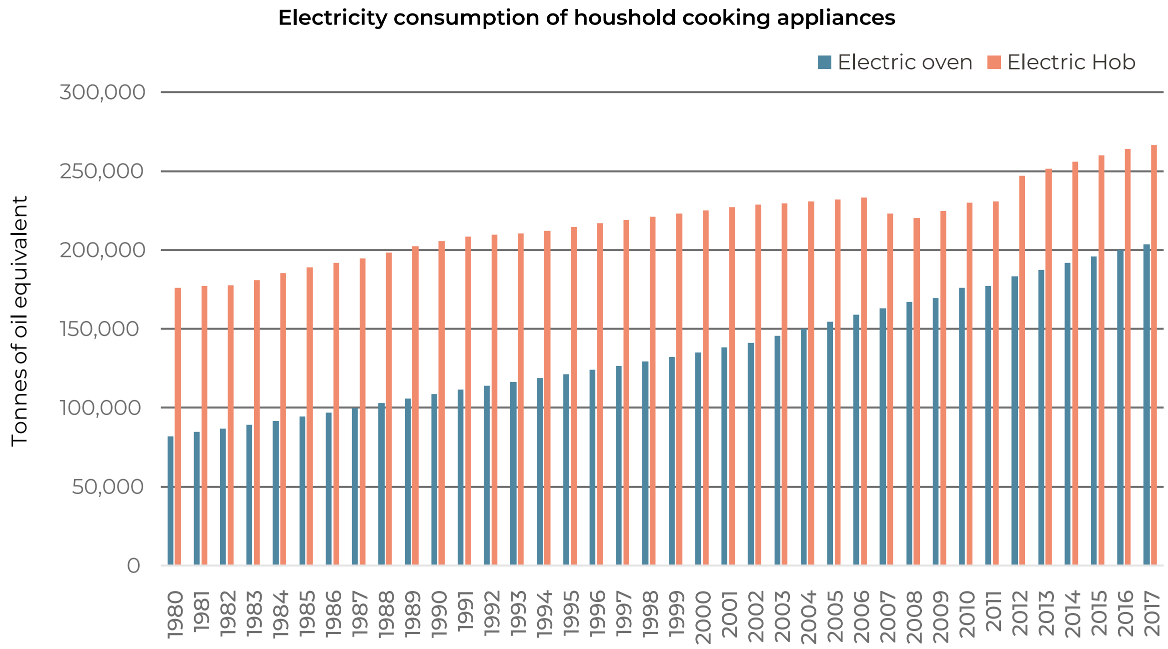

Figure 4: *Electricity consumption of household cooking appliances 1980-2017. (Source: ECUK, 2018)*

11. Appendix II: Annual electricity consumption for cooking per person per family unit size

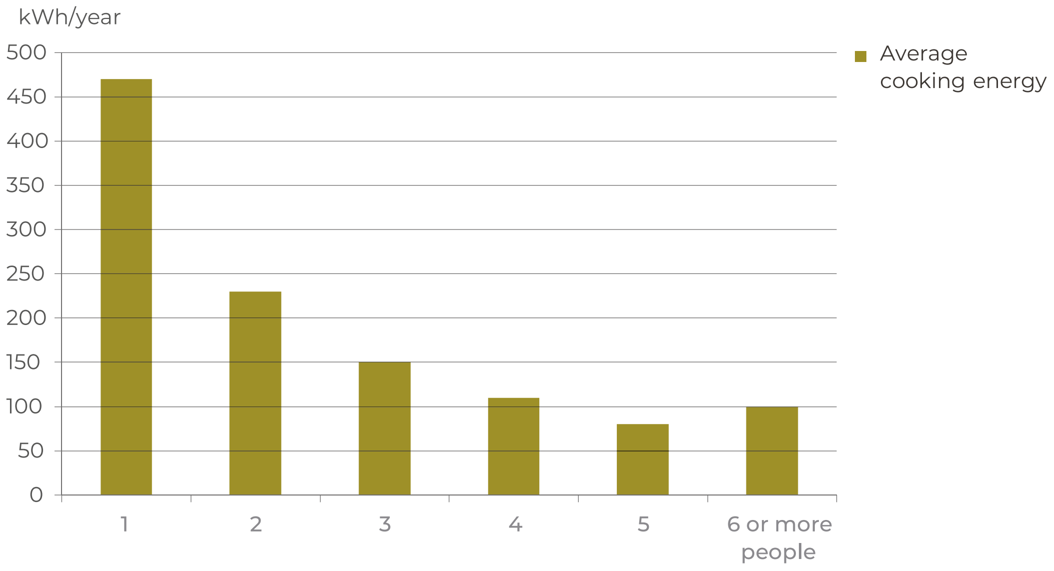

Figure 5: *HES annual electricity use for cooking per person per family unit size, England 2010-11 (kWh/year)*

12. Appendix III: Sales of Built-in Hobs by Format 2012-2017

Table 7: *Sales of Built-in Hobs by Format: % Volume 2012-2017 (Source: Euromonitor International, 2017)*

% retail volume

	2012	2013	2014	2015	2016	2017
Gas	46.4	46.3	45.5	45.0	44.7	43.9
Mixed	4.9	4.8	5.0	4.5	4.0	3.5
Standard Electric	18.5	18.4	16.5	15.0	14.5	14.1
Vitroceramic	13.0	12.8	12.5	13.9	14.2	14.4
Induction	17.2	17.7	20.5	21.6	22.6	24.1
Total	100.0	100.0	100.0	100.0	100.0	100.0

Table 8: *Forecast Sales of Large Cooking Appliances by Category: % Volume Growth 2017-2022 (Source: Euromonitor International, 2017)*

% volume growth

	2017/18	2017-22 CAGR	2017/22 Total
Built-in Large Cooking Appliances	4.9	2.5	13.2
Freestanding Large Cooking Appliances	-0.3	-0.8	-3.8
Built-in Hobs	4.4	3.5	18.9
Ovens	4.8	1.6	8.2
Cooker Hoods	4.6	2.1	10.9
• **Built-in Cooker Hoods**	5.8	3.1	16.4
• **Freestanding Cooker Hoods**	2.6	0.5	2.7
Cookers	-1.7	-1.4	-6.7
Range Cookers	3.0	0.5	2.4
Large Cooking Appliances	3.0	1.4	7.0

13. Appendix IV: Variations in energy consumption based on cooking technique

Table 9: Potential energy savings associated with various cooking techniques (Source: as cited in Hager and Morawicki, 2013)

TECHNIQUES	REDUCTION IN ENERGY [a] (%)
Cooking method	
Simmering (approx.90 °C) rather than boiling (100 °C)	69–95[b]
Steaming rather than boiling	9–56
Passive cooking [c]	17–23
Simmer with a pot lid	50–85[d]
Bake at lower temperatures	4–13
Cookware	
Using a pan with a diameter larger than the heat source	31–40
Using non-distorted, flat pans	42–68
Using a larger pot size (based on the ratio of the energy-to-volume)	42–63
Food volume	
Filling pot to capacity	20–49
Cooking larger quantities (based on the energy-to-mass ratio)	78–83[e]
Baking more than one portion at a time (based on the energy-to-mass ratio)	43–75[e]
Monitoring product	
Monitoring internal temperature	19–50
Stirring	3–14[f]
Soaking	
Soaking prior to cooking (for certain foods)	3–19[g]

[a] Calculated from total energy data presented by the authors: % Reduction = 100 - [(Es/Et) * 100], where Es is the energy required for the energy conservation method and Et is the energy required for the typical/traditional method.
[b] Largest reduction achieved by the use of the pan lid.
[c] Use of residual heat after termination of the heat source to finish cooking the product.
[d] At 100 °C, the differences were negligible.
[e] Percent reduction in the specific energy (or energy required divided by the mass of the product).
[f] This is the percent reduction in time to cook at the same temperature with and without stirring. Energy usage was not reported; however, energy savings should be comparable since the temperature was constant.
[g] Values reported only for rice.

Energy-PIECES

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