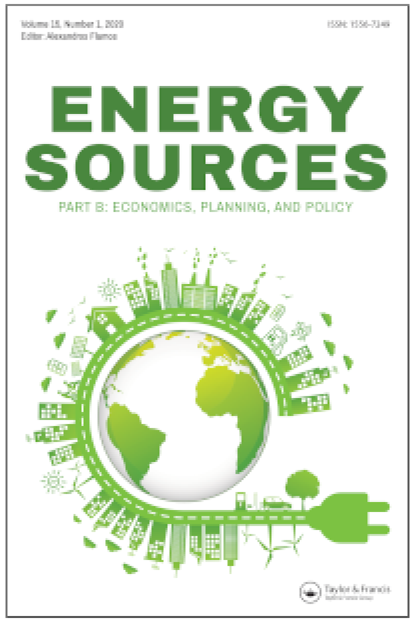

Exploring the potential of Heat as a Service in decarbonisation: Evidence needs and research gaps

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Abstract

The need to accelerate the decarbonisation of heating, as well as the rise of the 'smart home', mean that there is an increasing focus on the role of innovative consumer offerings in driving the shift to zero carbon domestic heating. In this context, Heat as a Service (HaaS) business models, which provide customers with an agreed heating plan rather than simply paying for units of fuel, are receiving increased attention. This paper explores HaaS based on insights from facilitated group discussions with key stakeholders, and learning from HaaS trials, in the United Kingdom. Results identified evidence needs and research gaps related to: addressing issues of trust between customers and suppliers, supportive policies, financing business models, and openness and interoperability of technology and data. Based on the findings, we propose policy and research recommendations to better understand the role of HaaS business models in decarbonisation.

Keywords: heat as a service, heat decarbonisation, energy services, evidence needs, smart heating

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1. Introduction

It is widely acknowledged in academic and policy landscapes that urgent and radical heat decarbonisation is essential to reducing greenhouse gas emissions compatible with the 1.5°C mitigation pathway (IEA 2019; IPCC 2018; Knobloch et al. 2019). However, decarbonising heating continues to be a big challenge. The sector remains dominated by fossil fuels, and thereby contributes to 40% of carbon dioxide emissions globally (IEA 2019). Yet, it is imperative to meet current demands for heating – which accounts for 50% of global final energy consumption – in order to support industrial and commercial processes, as well as provide space and water heating for homes and buildings (IEA 2019; IPCC 2018). Within Europe, a number of policy initiatives and programmes have been in place to support heat decarbonisation. These include, for example:

- the European Union's Heating and Cooling strategy (COM(2016) 51 Final) which provides a framework to improve heating efficiency, for example by using low carbon technologies and smart systems;
- the revised EU Renewable Energy Directive (2018/2001/EU) which sets an annual target of 1.3% increase in share of renewables for the heating and cooling sector from 2021-2030; and
- the UK's Renewable Heat Incentive which offers financial incentives for homeowners that adopt renewable heating technologies (BEIS 2018b; Connor et al. 2015).

However, progress in this sector remains slow. In the UK particularly, emissions from residential heating even continue to see increases (3.8% between 2017-2018) due to compounding factors such as high demand during colder winters and slow uptake of low-carbon technologies such as heat pumps, biomass boilers and solar water heating (Chaudry et al. 2015; Hanna, Gross, and Parrish 2016; Committee on Climate Change 2019). More innovative solutions are therefore necessary to complement and strengthen current policies and technological options in order to accelerate heat decarbonisation.

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It is within this context that this paper explores the potential of Heat as a Service (HaaS) – a business model innovation – in driving zero carbon heating. In the HaaS model, energy suppliers provide heat as a packaged service rather than simply as units of fuel. For example, consumers buy an agreed level of warmth rather than kWhs of energy. By 'paying for warmth' customers sign up for a heat plan that sets a heating schedule for their home, hour-by-hour and room-by-room using a smart heating control system (Energy Systems Catapult 2019d). With the rise in connected homes and digital technologies, service based-heating through HaaS may also support the deployment of energy efficiency measures and low carbon technologies as increased incentives are placed on the heat supplier to provide the agreed level of heating at the lowest cost (Energy Technologies Institute 2018b).

Recent studies (DELTA Energy & Environment 2019b; Energy Technologies Institute 2019) have noted potential benefits of service-based energy delivery models including simplifying complex future energy markets, enabling consumers to access new low carbon technology and supporting businesses to adopt demand side response mechanisms which help to reduce system costs. HaaS is therefore seen to deliver positive impact to multiple stakeholders from policy and industry as well as consumers. It is also regarded for its technology-agnostic approach to decarbonisation – with flexibility to incorporate innovations in heat networks, heat electrification and using hydrogen for heating (Energy Systems Catapult 2019c). Countries such as Germany and Denmark have energy providers offering HaaS since 2015 (Booth, Mohr, and Peters 2016; Amelang 2019; State of Green 2018); whilst in the UK, the first HaaS trial was launched in February 2019, with new living labs in 2020 across England and Wales (Energy Systems Catapult 2020).

Given the need to rapidly decarbonise heating, there is considerable interest in the potential of HaaS. However, there is currently limited evidence on how business models such as this

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might develop, the extent of their contribution to heat decarbonisation, and the challenges around consumer engagement, technology, and regulatory or policy needs for a wider roll-out.

Against this background, this paper seeks to unpack current evidence needs and research gaps to understand HaaS, and its role in decarbonisation. It draws upon a stakeholder workshop conducted in the UK in September 2019 with heat sector participants from academia, industry, civil society, and government working. We begin with a review of literature on energy services and current knowledge on Heat as a Service. We then describe the methodological approach used to elicit insights from the participants in the workshop. Results were analysed and categorised based on discussions around opportunities, evidence needs, and research gaps that HaaS presents across (1) behaviour change and consumer concerns, (2) policy and regulation, (3) technology, data and analytics and (4) business models and financing. Finally, we conclude and propose recommendations for stakeholders in policy, industry, and research.

2. Conceptualising energy services

Whilst we define HaaS above as the provision of heat as a packaged service, i.e., consumers buying an agreed level of warmth rather than as units of fuel, it is significant to note that there is a considerable debate in relation to the wider concept of energy services. The term 'energy services' is utilised across a variety of contexts and disciplines with a wide range of differences in conceptualisation. Much of the literature emphasises that people demand, and derive wellbeing from, the services provided by energy rather than energy carriers themselves; however, beyond this overarching similarity, applications of the term are diverse (Fell 2017; Kalt et al. 2019).

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Fell's (2017) content analysis and review of the energy services literature identified 27 more or less distinct definitions of 'energy services'. The findings revealed that two, equally common but generally mutually exclusive, themes occurred most often:

1. 'Useful energy/work': the idea that energy services constituted 'useful energy' or 'useful work' in a way that is distinct from the energy use itself.

2. 'Benefit': the idea that energy services entail some kind of 'benefit' for human wellbeing.

Indeed much of the diversity in the energy services literature concerns differing conceptions of, or emphasis on, the service or functions performed by energy (useful work) and the ultimate desired energy services or states[1] (human wellbeing benefit) (see for example Sorrell and Dimitropoulos, 2008; Day, Walker and Simcock, 2016; Kalt et al., 2019). In order to integrate these two core ideas, Fell (2017, 137, emphasis ours) proposes a definition of energy services as "those *functions* performed using energy which are means to obtain or facilitate *desired end services or states*". Within this definition, heating (as an energy service) is therefore undertaken for the purpose of thermal comfort (end state).

Building on this definition, Morley (2018, 567) extends a sociological conceptualisation of energy services and develops, based on Shove (2003), a concept of 'meta-services' which takes a wider practice-based view of energy services to incorporate "'cultural services', such as cosiness and cleanliness, that just happen to depend on energy". Demand for energy-services is therefore an outcome of metaservices and there is scope for the introduction of more efficient, alternative heating and cooling technologies to underpin the emergence of

[1] Sometimes referred to as final services or capabilities.

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different expectations and experiences of comfort e.g., for heat pumps to be used for cooling or to keep temperatures higher. She argues for increased exploration of the meanings of service and the ways in which these evolve and proposes that whilst it is technically possible to deliver contracted levels of heating or cooling service to householders, "this is not the case with comfort. Since comfort depends on a diverse range of 'ingredients' across multiple systems of provision (clothing, diet, activities, furnishings and so on) even coalitions of utility companies and housing providers may find it impossible to orchestrate and re-negotiate such diverse configurations in more efficient ways" (Morley 2018, 567).

3. Current knowledge on HaaS

To provide context for this research, this section presents current knowledge on HaaS based on a review of academic and grey literature, experiences and outcomes of HaaS trials, existing business models in practice, and studies on the role and perceptions of customers to new energy business models.

3.1 Academic literature on HaaS

Although there has been a rapid increase in policy interest in delivering heat as a service in recent years (see for example BEIS, 2018; Delta EE, 2019b), there remains a very small amount of academic research that specifically engages with such business models, their policy needs or societal implications. A Scopus search of peer-reviewed literature in English returns just one reference to heat as a service (Sovacool and Martiskainen 2020), which

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although focussed on heating transformations only includes heat-as-a-service as a keyword and does not discuss the concept within the main body of the article[2].

Expanding the literature review to include the terms “energy as a service” and “energy services” reveals a much broader literature of almost 13,000 documents, almost exclusively employing the term “energy service[s]”. In common with Fell’s (2017) review of the energy services literature, much of this current scholarship is focussed on a number of overlapping contexts, defined as:

- service based renewable energy programmes in Global South contexts e.g. leasing packages for solar PV in Kenya (e.g. Adwek et al., 2019). This also includes work related to energy access where the term ‘modern energy services’ is commonly employed;
- Energy Service Companies (ESCos) that contract with large public and private sector consumers to supply energy services rather than billing directly for energy used (e.g. Hannon and Bolton, 2015; Capelo, Ferreira Dias and Pereira, 2018);
- energy modelling studies which seek to examine the role of ‘energy service demands’ (e.g. Fujimori et al., 2014);
- research relating to energy efficiency or the rebound effect (e.g. Sorrell and Dimitropoulos, 2008);
- the smart use of flexibility assets (such as storage) to manage network operation (e.g. Sarangi, Dutta and Jalan, 2012; Selim et al., 2017);

[2] Search performed in Scopus, using query: TITLE-ABS-KEY ("heat as a service" OR "heat-as-a-service")

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- explorations of how utility business models might develop as energy system decarbonisation progresses (Bryant, Straker, and Wrigley 2018; Hall et al. 2020);
- a considerable body of research considering the social drivers for energy demand and use (e.g. DellaValle, 2019; Strydom, Musango and Currie, 2020)

The ESCo literature may initially appear to be the most relevant to discussion of domestic HaaS models, and there is an established literature relating to service-based energy contracts in large public and private sector organisations (for example Hannon, Foxon and Gale, 2013; Suhonen and Okkonen, 2013; Bolton and Hannon, 2016). However, Nolden, Sorrell and Polzin (2016) found little evidence that energy service contracts have moved beyond well-established technologies to deliver innovative solutions with lower rates of return. Additionally, these models for energy efficiency improvements have not historically had much success in the residential sector due to the lack of economies of scale, difficulties in access sufficient data and the complexities of consumer behaviour (Rai, Reeves, and Margolis 2016; Cleary and Palmer 2019).

Literature on residential retrofit financing provides some insights into how service-based approaches could engage customers with Brown, Sorrell and Kivimaa (2019) exploring how the design features of financial mechanisms for residential retrofit influence the success of business models. They suggest that mechanisms that reduce complexity by simplifying the customer journey are likely to achieve much higher levels of uptake but that finance alone is unlikely to be a driver of demand for whole-house retrofit, and so instead should be viewed as a necessary component of a much broader retrofit strategy.

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3.2 HaaS models in practice

The academic and grey literature specifically on HaaS is extremely small and few examples of HaaS in practice are evident. The most substantive academic discussion of HaaS appears to be by Skovshoved and Sandqvist (2017) in a Masters thesis on Industrial Engineering and Management, which aims to identify service opportunities in the heat pump business based on a customer value perspective. It provides a description of a business model offered in Denmark by a company called Best Green. Best Green offers a service they describe as HaaS whereby the end customer pays for heat produced by the heat pump, an annual service fee and initial installation costs but the heat pump is purchased and owned by the company (Skovshoved and Sandqvist, 2017). The target audience includes householders, municipalities and small commercial customers with consumers benefiting from low heat pump purchase prices due to bulk purchase and subsidies. The scheme aims to be simple and maintenance-free and remove hassle and risk for the end customer.

Whilst the Best Green example is referred to as HaaS by both Best Green (State of Green 2020) and Skovshoved and Sandqvist (2017), organisations may have differing conceptualisations of what defines a HaaS business model with Delta EE (2019b, 1) suggesting such business models require service providers to take on five specific risks, "all of which (other than energy price risk) have historically been borne by the customer". They define these as:

- Financial risk - Credit risk of providing a heating appliance for little or no upfront payment
- Technical risk - Routine maintenance and repairs for the heating appliance

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- Performance risk - Efficiency of the heating appliance, the heat distribution system and the customer's property

- Behavioural risk - Impact of customer behaviour on quantity and timing of heat demand

- Energy price risk - Fluctuations in wholesale energy prices

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Under such definition, the Best Green offering does not require the service provider to take on behaviour or energy price risk (as charges are made against kWh of heat rather than agreed temperatures) and is instead defined as "efficient asset leasing". Delta EE (2019b) identified a trial in the Netherlands which takes on all five risks. The trial, by energy supplier Eneco, involves customers being charged for a fixed monthly fee for 20°C warmth rather than heat generated.

In terms of research projects explicitly seeking to explore HaaS business models, only two such projects were evident in the literature; one in Denmark and one in the UK. The first was an ERA-Net Smart Grids Plus project "Markets, Actors and Technologies: A comparative study of smart grid Solutions" (MATCH) case study in Denmark. The case study focused on a demonstration project, GreenCom, which studied remotely-controlled demand side management via heat pumps and photovoltaics (Christensen and Friis 2017). However, the term HaaS appeared to be used as a synonym for remotely-controlled demand side management (with defined maximum and minimum temperatures) and it is not clear whether customers paid a fixed price for the maintenance of an agreed temperature plan, as in a 'classic' HaaS model, or whether they actually paid based on kWh used (as in a conventional energy-as-a-commodity model).

The second project was the Smart Systems & Heat programme (SSH) run by the Energy Systems Catapult (ESC) in the United Kingdom. Phase 1 of the SSH programme included a trial of a consumer orientated Home Energy Management System (HEMS) in 30 homes in 2016-17 which allowed multi-zone control of heating via a customer interface. The study revealed the extent to which comfort preferences are both personal and contextual to the room type. Additionally, workshops with a sub-set of participants and a control group explored how HaaS might work. The workshops indicated that that the majority of participants in the trial were enthusiastic about the idea of comfort and cleanliness as services, rather than energy purchases, whereas the control group of consumers were not enthusiastic about the idea of services (Energy Technologies Institute 2019).

The SSH programme also explored experiences of comfort in residential properties, highlighting significant latent dissatisfaction and emphasising the complexity of people's experiences of comfort. The project suggests that understanding the complex factors influencing energy behaviours and use are likely to be central to developing HaaS models to ensure customer propositions are viable and the risk of not meeting customer service commitments are priced correctly. This will require extensive data on building archetypes as well as from connected home devices. Such data would need to include insight on efficiency of the fabric of the home, performance of major appliances such as boilers, the way windows are used, the time of day when heat is needed most and so on (Energy Technologies Institute 2018b).

Building on the learning from stage one of the SSH programme, the Energy Systems Catapult created a 'Living Lab' of 100 homes to test Heat as a Service during the Winter of 2017/18. Each household received advanced heating controls and the chance to buy Heat as a Service in Warm Hours instead of kilowatt hours via Heat Plans (Energy Systems Catapult 2019e).

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Heat as a Service propositions (Heat Plans) were chosen by around half of trial participants and proved themselves attractive to a range of consumers and home heating requirements. Trial participants valued better control of their domestic heat and costs but chose to use this increased control in different ways, depending on their priorities (cost, comfort, flexibility); however, almost all decided to heat fewer rooms (Energy Technologies Institute 2018a; Energy Systems Catapult 2019a).

The trials produced a large volume of data on household needs and home energy performance which enabled market segmentation based on temperature, space and timing of heat requirements (Energy Systems Catapult 2019a). The 2017/18 field trial also indicated Heat Plans or other service propositions could increase consumers' openness to switch from gas boilers to alternative low carbon heating with 58% of participants open to the idea of having an alternative low carbon heating system when replacing their gas boiler (as opposed to 36% of households in a segmentation survey of the wider population, n=3,000). This increased to 85% if participants could be given a guarantee that their current levels of comfort and cost could be met (which was the aim of the Heat Plans) (Energy Systems Catapult 2019f). The SSH2 field trial also explored issues of interoperability and identified key areas for future development of: commercially interoperable marketplaces, agreed open standards for the use of domestic connected devices, alignment of physical trading approaches, open data standards to allow for the movement of people's data, appropriate approaches to consumer protection (Energy Systems Catapult, 2019a). The ESC is continuing to trial HaaS models, including working with municipal supplier, Bristol Energy, to further understand economically viable ways of offering HaaS (Energy Systems Catapult, 2020).

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3.3 The role of consumers in HaaS

Recognising that digitalisation and technological change mean the retail energy market is expected to evolve rapidly in the coming years, the UK charity Citizens Advice commissioned a series of reports on how such changes may impact on different types of consumers (Crisp and Kruja 2019). The research identified some major barriers to accessing offers in a future market, including digital exclusion, financial barriers, and issues around consumer engagement and trust. In particular they identify consumer confidence in sharing data as a key issue in the development of HaaS models. A representative survey of UK adults by Citizens Advice revealed that 51% of respondents were not comfortable sharing near real-time energy usage data (Crisp and Kruja 2019).

A study by Delta EE for Citizens Advice reviewed six business models in order to explore the opportunities and barriers likely to emerge in the future energy retail market, including energy-as-a-service (DELTA Energy & Environment 2019b). They suggest the biggest barriers to energy-as-a-service relate to (1) physical aspect of the home (such as service standards not being guaranteed for unsuitable homes), (2) changes in circumstance (contractual uncertainty if consumer circumstances change), (3) trust (the unfamiliarity of EaaS and the need for redress to be clear), and (4) digital literacy (those without digital access or literacy being excluded). They also identified the benefits of EaaS for consumers, energy networks and policymakers as relating to their ability to simplify complex future energy markets, enable consumers to access new low-carbon technology and enable demand-side response. An additional study for Citizens Advice convened workshops with 106 consumers, who received information, and were asked about their views, on various new energy retail models. Their research on heat as a service revealed people had mixed views of this supply model. Consumers felt that homes need a high level of energy efficiency before

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this model can be viable. The fear of losing control was a recurring theme and long-term contracts were not popular. Participants were also concerned that consumers who are less digitally-savvy could be excluded from HaaS models and were unclear on how problems would be solved or routes to redress (Mulvey, McNab, and Morley 2019).

To date, there has been limited analysis of the equity implications of domestic energy- or heat-as-as-service business models. Recognising the need for greater analysis of these issues, Sovacool, Lipson and Chard (2019) analysed the justice implications of a number of domestic low carbon innovations and suggest that energy service contracts illustrate some of the potential tensions between affordability and decarbonisation benefits (as consumers contract for the same levels of comfort but at a lower cost and using less energy) and equity concerns (as only some householders may be offered contracts). However, the Energy Technologies Institute (2018b) propose that such service-based approaches could also allow policymakers to address fuel poverty through providing a route for the government to target subsidies based on paying service providers by results. For example, delivering improved affordability and thermal comfort would be the performance measures for the payment of subsidies rather than the number of homes that are insulated.

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Overall, both energy-as-a-service and, more specifically, heat-as-a-service business models are poorly defined in the literature. Additionally while there are (1) a small number of key projects and existing utilities exploring Heat as a Service business models, (2) established literatures exploring the key aspects of both heating behaviours and practices, and energy efficiency business model development, there remains a very limited literature that seeks to systematically examine the decarbonisation, human wellbeing and policy implications of HaaS models. This paper seeks to contribute to expanding this literature by offering insights from stakeholders, elicited through the participatory research approach described in Section 4.

4. Methodology

In order to explore the evidence needs and research gaps to developing Heat as a Service (HaaS), a stakeholder workshop was carried out in the UK in September 2019. Its aims were to discuss current knowledge on HaaS, both in the UK and internationally, and encourage debate about HaaS' potential as an energy delivery model. A total of 40 participants from academia, industry, civil society, and government sectors attended the workshop (Table 1). Participants were identified through purposive sampling based on the literature review, discussions with key organisations involved in HaaS trials and heat innovations in the UK, and promotion through the UK Energy Research Centre. The discussions were contextualised by presentations from two industry participants that have led trials of HaaS in the UK and a consumer protection organisation that has carried out extensive research on energy business models.

[Table 1 near here]

Table 1. Workshop participants by sector

Sector	**Number of participants**
Industry	18
Academia	16
Government	4
Civil Society	2

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The workshop was structured using Ketso, a toolkit in participatory planning and action research used to facilitate group discussions (Bates 2016; Wengel, McIntosh, and Cockburn-Wootten 2019). This flexible tool helps participants to visualise and order their responses to questions and captures a record of individual responses and group prioritisation of issues. Following the Ketso method, participants were divided into five groups and asked to discuss the following questions:

- What work is already happening in HaaS?
- What are the ambitions and opportunities for HaaS?
- What are the barriers and knowledge gaps for the HaaS model?
- How can the barriers and knowledge gaps identified be overcome?

Participants then wrote their ideas and placed them on central ‘clusters’ around four key topics: (1) behavioural and consumer issues, (2) policy and regulation, (3) technology, data and analytics, and (4) business models and financing. The groups then identified the issue/s they believe to be most important for each question. This process allowed everyone to work on their ideas in parallel and helped to obtain more structured results. Emerging themes from each topic were analysed, compared, and verified against the literature. These findings are presented in Section 5.

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5. Evidence needs, barriers, and opportunities for HaaS

This section presents the analysis of the themes that emerged from the stakeholder discussions as well as insights from literature on HaaS. It discusses evidence needs, barriers, and opportunities for implementing HaaS across four areas: behavioural and consumer issues, policy and regulation, data analytics and technology, and business models and financing.

5.1 Behavioural and consumer issues

With low carbon technologies such as heat pumps becoming more common, people's perception of *comfort* is likely to change in the future (Morley 2018). Offering HaaS therefore has the potential to unlock better consumer experiences, i.e., warmer or cooler homes, where the value proposition is a fixed price for heat over a set period, rather than kWh. HaaS may also be able to stimulate carbon emissions reductions as energy efficiency and smart technologies can be integrated into service plans. In addition there is emerging evidence that HaaS business models may increase consumers' openness to new technologies with the Energy Systems Catapult (2019f) Smart Systems & Heat programme Phase 2 field trial in the UK suggesting that people with experience of heat plans were more likely to want a heat pump. The trial indicated that while less than 0.1% of people who read an on-line advert wanted a free heat pump, more than 15% of people who took part in the trial were interested.

Despite these potential benefits, workshop discussions revealed that energy is generally viewed as a commodity rather than a service. Implementing HaaS will therefore be a transformative challenge for both the energy provider and the consumer. Ultimately, there was consensus amongst stakeholders that the HaaS system needs to be both fair, simple and

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support the transition to a net zero carbon future. However, consumers are unfamiliar with the HaaS concept and its value propositions and therefore show low interest. Stakeholders suggested that a lack of awareness about HaaS is one the biggest barriers to its deployment. This aligns with the findings of Citizen's Advice (Crisp and Kruja 2019) that the general lack of awareness on low carbon technologies may prevent households from adopting energy services.

Further research is needed to identify value propositions for different customers and to understand the consumer journey from considering HaaS to agreeing a contract and installing energy efficiency and decarbonised heating technologies. In particular, additional large-scale trials are required to explore consumer motivations and barriers and assist the development of more detailed consumer archetypes. Whilst commercial suppliers may develop such archetypes there is a need for regulators to also develop their understanding of consumer segmentation in order to both regulate suppliers and protect consumers effectively.

The ability of a home to achieve a certain level of comfort (or service expectation) is very dependent on a range of factors such as the equipment installed, how it is configured, and building efficiency. Buildings, and how they are used, vary enormously, even between those of similar type, age and size and one study of 290 identical homes found that the highest used twenty times as much heat as the lowest (Andersen 2012). As Delzendeh et al. (2017) identify, a diverse set of factors influence energy behaviours and further research is required in order to better account for occupant behaviour in building energy performance analysis.

There is also a need for the development of appropriate consumer protection measures to ensure consumers understand the benefits and risks of complex service-based offerings and have provision to adjust contracts if their circumstances change. The UK Heat Trust, which

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acts as an independent consumer champion for heat networks, was cited by participants as an example of a framework to hold suppliers to account and set expected standards.

Table 2 summarises the barriers, evidence needs, and research gaps related to behaviour and customer issues identified during the workshop. The main barriers centred on lack of customer awareness of HaaS, digital literacy, the length of contract with energy service provider and home efficiency. In order to address these, barriers, evidence needs, and research gaps are highlighted to help define the way forward. *[Table 2 near here]*

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Table 2. Behavioural and consumer issues for HaaS

Barriers	**Evidence needs and research gaps**
Lack of awareness about HaaS which may lead to lack of trust in third-party energy service providers	- Research to identify value propositions for different customer segments - Additional, large-scale HaaS trials to understand customer's motivations and barriers - Developing independent organisations (e.g. UK Heat Trust) to protect customer's interests
Low digital literacy of customers, especially those without access to a smartphone which may be needed in order to access HaaS energy settings (e.g., through applications that control temperature in each individual room and alerts about usage)	- Developing and testing programmes to improve digital energy literacy in target populations - Consumer research to explore the impact of presenting information regarding the risks and benefits of contracts in various ways
Length of contract with energy provider Consumers currently value short term contracts (1-2 years) and the ability to change provider	- Trialling of new platforms that compare and quantify benefits and risks for different energy/heat propositions to facilitate consumer decision making

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Barriers	**Evidence needs and research gaps**
	- Consumer research across a wider range of end user types and tenures
Energy use behaviours influenced by a diverse set of factors related to occupant's energy use and building energy performance	- Interdisciplinary studies to understand the interrelations between energy demand, business models, data and consumer behaviour - Large-scale studies which consider the impact of equipment type, configuration, building efficiency and use on the ability for service expectations to be met
Lack of clarity about consumer's willingness for disruption at home for retrofit and renovation needed for HaaS *and guaranteed efficiency* Service companies might not guarantee outcomes for energy inefficient homes and there can be insufficient space to install new equipment	- Development of a communication tool that integrates independent advice, consumers, and installers to help overcome consumer unwillingness for home disruption due to retrofits - Trialling HaaS as part of the retrofit package with the supplier coordinating energy efficiency retrofit, installation of new heating systems and controls, and financing.

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Barriers	Evidence needs and research gaps
	- Introducing a competitive system for saving carbon at various levels, i.e., individual, local and national to improve home efficiency

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5.2 Policy and regulation

Policy and regulation are key to enabling low carbon technologies and emerging business models whilst protecting consumer interests and ensuring social equity. The acceleration of heat decarbonisation is intrinsically connected with new policies and regulations that protect consumers, address fuel poverty, enable new revenue streams, incentivise low carbon solutions and increase resilience. The ETI argues that, although a shift to retailing energy services in place of units of energy may well happen over time, it is unlikely to happen naturally at sufficient pace to establish the conditions to decarbonise heat. Therefore, "commercial, policy and regulatory opportunities will need to converge if such services are to play a role in decarbonisation" (Energy Technologies Institute 2018a, 21)

Results from the workshop indicate that policy support will be needed at different stages of HaaS development to meet the needs of consumers, suppliers, and the heat decarbonisation agenda in a way that is equitable. Householders, for example, need support to cover investment costs associated with retrofitting properties with low-carbon heating technologies (e.g., heat pumps), and suppliers are unlikely to be able to integrate financing for such measures into HaaS without supportive policies or incentives. Results from ESC trials (2019c) also show that the financial viability of HaaS is not yet proven for both suppliers and consumers.

There is a lack of comparative studies of the development of HaaS models across different countries, and regulatory contexts, as well as the benefits and challenges of different 'varieties' of HaaS. As identified by Delta EE (2019b) there are several utilities already offering services branded as HaaS across a number of European countries, however the services offered and the allocation of risk between supplier and customer differs across models and future studies could explore the impact of differing regulatory contexts, financing mechanisms and contractual arrangements.

Additionally, there is a lack of understanding of policy conflicts related to HaaS. For example, in the UK there is growing interest in HaaS within policymakers (BEIS 2018b) and some awareness of the need for longer-term contracts under such models. However there is also an ongoing faster switching programme which seeks to ensure reliable next day switching by 2021 and potential misalignments between the two agenda are yet to be fully explored. In addition, the development of HaaS is dependent on wider research on heat decarbonisation including understanding how flexibility services and markets will evolve. Significantly, there is a need to address the potential for HaaS models to exclude some householders (for example due to physical aspects of the home resulting in difficulty in guaranteeing service standards) and how such business models should be integrated with energy efficiency subsidy programmes. Table 3 summarises the policy and regulation barriers for the consumer, suppliers and heat decarbonisation and highlights the respective evidence needs and research gaps. *[Table 3 near here]*

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Table 3. Policy and regulation challenges for HaaS

Barriers	**Evidence needs and research gaps**
No clear policy on social equity	- Exploration of how HaaS approaches could be integrated with fuel poverty programmes - Policy to ensure effective dispute resolution, redress and management of changed consumer circumstances - Consumer research to explore the impact of presenting information regarding the risks and benefits of contracts in various ways, including the use of scenarios
Switching regulation (between suppliers) and *the use of long-term contracts*	- Research to explore regulatory approaches to enabling long-term contracts whilst maintaining consumer protection measures - New regulatory support for utility bundles with rent, with an appropriate competition framework for providers

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Barriers	**Evidence needs and research gaps**
Supply Licensing conditions and tariff rules tend not to be supportive of HaaS	- Review of supply licensing to align future licenses and regulation with evolving business models; this would include the development of more modular, principle-based regulation to support innovation - Further use and analysis of regulatory sandboxes to test new business models
Lack of comprehensive heat decarbonisation strategy and policies in many countries Existing incentives are often underperforming or not aligned. For example, it is unclear the extent to which the assignment of rights within existing subsidies programmes (such as the RHI in the UK) inhibits HaaS models.	- Conduct a full-scale review of the policy and regulatory framework for heat, including assessment of how to create an attractive investment climate for heat as a service business models - Investigate the effect of radical policies that ban gas or make it more expensive and carbon emissions pricing - Long-term subsidies and incentives to accelerate heat decarbonisation

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5.3 Technology, data and analytics

HaaS models require extensive collection of energy consumption data from households, buildings and domestic connected devices, as well as information on consumer behaviour, heating practices and needs. This data could inform the design of an intelligent heating system that predicts how much heat each household needs, allowing suppliers to provide specific services based on demand and offer more advanced heat customisation. While these data and technology could provide benefits and opportunities for heat service providers and consumers, at the same time these could introduce more challenges for both.

Developing open standard data and interoperable systems which could exchange data and information and enable different services to work together is a new challenge in this area. Additionally, more connected devices at domestic level could provide opportunities for internal and external hackers to gain unauthorised access to the digital platform of the heating system. Finally, preserving consumer data privacy and trust between consumers and providers should be considered as a high priority challenge for HaaS models. The trade-off between data privacy and developing a highly tailored offering is a complex issue that needs to be further understood (Energy Technologies Institute 2018a). Understanding (and pricing) the risk of energy uses not meeting expectations is particularly central to HaaS models as the outcome (i.e. X number of warm hours) is guaranteed regardless of the amount of energy actually needed. To date the ESC trials in the UK have provided the most detailed publicly available information on the issues associated with developing HaaS models (see for example Energy Systems Catapult 2019b; 2019c; 2019d). However, the limited nature of existing trials means that there is significant uncertainty regarding whether HaaS models will result in better consumer experiences (i.e. warmer, cheaper homes) which are also lower carbon.

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Table 4 summarises the barriers, evidence needs, and research gaps related to technology, data, and analytics. *[Table 4 near here]*

Table 4. Technology, data and analytics

Barriers	**Evidence needs and research gaps**
Lack of central data curation platform that would enable data management, maintenance, discovery and retrieval	- Large scale trials to enable data collection from various sources and facilitate data curation activities - Investigate how Internet of Things (IoT) technology can be used to provide big data generation and management for heat service providers - Research to better understand Information and Communication technology (ICT) needs related to data and suitable communication systems, understanding of how much data is needed, how often we need to collect and transmit data and which communication technology is the most suitable for such system

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Barriers	**Evidence needs and research gaps**
Barriers to learning Much of the data being generated in relation to HaaS is held by utilities and not shared more widely due to commercial sensitivity	- Increased research and data sharing by universities, NGOs and Governments.
Data privacy	- Exploration of solutions to protect customer data from unauthorised access or disclosure
Cybersecurity of HaaS digital infrastructure	- Explore solutions to protect HaaS digital infrastructure against confidentiality, integrity, and availability attacks. These attacks could be unintentional or intentional cyber-attacks such as Denial of Service attack to make heat services unavailable.
Interoperability of data and technology	- Development of agreed open standards for the use of domestic connected devices and their interfacing with multiple platforms.
Rate of change in ICT technology is higher than low carbon heating services,	- More research on how to provide future proof ICT technology for heat services

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Barriers	Evidence needs and research gaps
which could cause problems both for consumers and providers	
Limited (skilled) installer and technician capacity	- Funding for training installers and IT technicians - Development of industry guides on installation of low carbon technologies

5.4 Novel business models and financing

Novel business models can offer new value propositions for the consumer, unlock the market to new start-up technology companies and generate new revenue streams. Access to finance to fund heat decarbonisation is a key issue for homeowners and while HaaS business models have been identified as helping to address these challenges through enabling the packaging of heat and asset costs in a long-term contract is it yet unclear whether such models will be attractive to consumers or viable for suppliers.

Additionally, there is limited understanding of the interactions between HaaS and other evolving business models such as peer to peer or Time-of-use tariffs. While some existing studies seek to compare consumer attitudes across a range of emerging business models (such as Crisp and Kruja 2019), most such studies tend to be relatively small scale and assess consumer preferences based on abstracted descriptions of business models, rather than

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providing participants with tailored scenarios based on actual consumption and housing types.

Similarly, there is significant interest in the potential for households with smart controls, domestic generation technologies, storage, or other ability to shift demand, to play a significant role in balancing high variable renewables systems. Incentivising such flexibility services would require consumers to shift demand either electively (i.e., householders receive alerts about price changes and choose whether to adjust demand) or through automated processes and it is currently unclear how such arrangements would interact with HaaS contracts.

Table 5 summarises the barriers, evidence needs and research gaps around news business models and financing. The barriers identified during the workshop relate to asset ownership, house retrofit investability, access to finance for low carbon technologies, competition between suppliers and investor confidence in the security of revenue streams. *[Table 5 near here]*

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Table 5. Novel business models and financing

Barriers	**Evidence needs and research gaps**
Asset ownership (consumer vs. supplier) and risk of defaulting	- More research into consumer-supplier relationships to address asset ownership and mitigate the risk of defaulting. This should include exploration of mechanisms to allow

	HaaS contract renegotiation if consumer circumstances change.
Understanding whole-house retrofit investability under HaaS It is unclear the extent to which long-term contracts incorporating efficiency measures are viable or attractive for suppliers or householders.	- Comparative studies of the relative impact, attractiveness and costs of funding whole-house retrofit both within and outside of HaaS business models (i.e. comparison with low cost or free loans). - Testing of novel packages such as buy / build to let /rent with insurance and heat/energy delivery included.
Lack of finance to enable low carbon technology There is limited access to finance and incentives and government grants are essential	- Trialling of interest free loans from government to enable low carbon technologies and support heat decarbonisation - Studies of how different forms of asset financing (separate commercial loan, integrated in long-term contract, government backed loan etc), impact on HaaS viability and outcomes
Investor confidence in security of revenue stream	- Comparative studies of the development of HaaS models across

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There is a perception that low carbon technologies will increase bills especially in the private rented sector	different countries, and regulatory contexts, as well as the benefits of challenges of different 'varieties' of HaaS and learning from other service-based sectors (broadband, telecoms) to increase investor confidence - Develop a value proposition for HaaS that guarantees energy bills would not go up compared to the traditional energy as a commodity model

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6. Conclusions and policy recommendations

With the urgent need to meet global carbon reduction targets, Heat as a Service business models present an innovative approach to accelerating decarbonisation via a customer-focussed energy service that provides heating alongside the use of smart systems and low carbon technologies. However, lessons from UK trials and insights from stakeholders suggest that for HaaS to make a viable contribution to decarbonisation, a number of barriers related to behaviour change, policy, technology and financing need to be overcome. As analysis of stakeholder views and existing literature indicates, there are a number of evidence needs, research gaps, as well as opportunities that need to be explored around HaaS. Here, we summarise findings and propose recommendations for policy that could enable the uptake of HaaS business models and maximise its potential contribution to decarbonisation.

6.1 Uncertainties around consumer preference, building performance, and policy frameworks, limit HaaS uptake

Whilst there is considerable policy and industry interest in the potential to develop service-based heating business models, there remains limited knowledge about the potential for such models to accelerate uptake of decarbonised heating systems. In theory, the more granular understanding of consumer preferences and building performance required to offer HaaS could also enable businesses to offer tailored contracts that incorporate energy efficiency retrofit and decarbonised heating technologies. However, there remains significant uncertainty regarding how to manage risks between the supplier and consumer, and in financing such offers.

Similarly, despite the potential for HaaS business models to deliver better consumer comfort and simplify future energy markets, it is important to note that many national policies and programmes to decarbonise heat are underperforming or under-ambitious. For example, the Renewable Heat Incentive in the UK has delivered significantly lower numbers of low carbon heating systems than anticipated and there is considerable consensus that a more ambitious approach is required (Connor et al. 2015; Committee on Climate Change 2019). Without comprehensive policy frameworks to support the roll out of decarbonisation heating technologies, the extent to which HaaS business models will deliver decarbonisation is unclear.

The development of HaaS is also dependent on developing a much more detailed understanding of building energy use and consumer behaviour. This includes the integration

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of quantitative and qualitative research findings in energy simulation tools, analysis of the impact of interior design (space layout, fixtures and fittings) on occupants' behaviour and the use of psychological-cognitive behavioural methods (Delzendeh et al. 2017). The development of local flexibility services and markets has the potential to have a significant impact on the viability of decarbonised HaaS offerings.

As discussed in Section 2, experiences of 'comfort' in relation to domestic heating are influenced by a complex range of social and cultural factors. Current experimentation with HaaS business models is only just beginning to explore how conceptions of comfort may change as alternative heating and cooling technologies are adopted. For example, while the ESC Smart Systems & Heat programme indicated that most participants chose to heat fewer rooms, none of these households had installed a heat pump where differences in the operation of the heating system have the potential to change perceptions of comfort and/or heating practices.

6.2 More trials are needed to address consumer concerns and lack of understanding of HaaS

Understanding the complex factors influencing energy behaviours and use are likely to be central to developing HaaS models to ensure that customer propositions are viable and the risk of not meeting customer service commitments are priced correctly. This will require extensive data on building and consumer archetypes as well as from connected home devices.

Accordingly, addressing concerns around trust, energy service provision, and lack of understanding of HaaS will require more trials that consider different customer groups and their motivations. This can allow HaaS providers to offer tailor-fit solutions with a variety of

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technology options and financing plans that address risks for both suppliers and customers. As energy systems become smarter and more connected there is a need for policymakers and regulators to develop a much more detailed understanding of consumer archetypes, to support this any publically funded HaaS trials should ensure that detailed analysis is made widely available.

6.3 HaaS requires supportive policies for market development and regulation

There is consensus among stakeholders that stronger policy strategies are needed for heat decarbonisation. Specifically for HaaS, current market regulations are restrictive and not set-up for delivering smart energy services (e.g., in terms of supply licensing, tariffs, lack of government subsidies and incentives for homeowners and tenants). These limit customer uptake and pose risks to current and potential suppliers, who are already faced with the challenge of finding economically viable solutions to offer HaaS. Supportive market policies will therefore be necessary to incentivise suppliers to incorporate efficiency measures and decarbonised heating technologies into HaaS business models.

There is also a need for further research on the equity implications of HaaS models. As identified by Sovacool, Lipson and Chard (2019) there is significant potential for HaaS models to exclude some consumers from being offered contracts. Whilst the Energy Technologies Institute (Energy Technologies Institute 2018b) have argued that HaaS models could, in principle, be compatible with fuel poverty programmes if government subsidies were targeted based on service targets (thermal comfort and affordability) such an approach relies on governments developing policy measures to address the potential exclusion of some householders.

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6.4 Open, interoperable and secure data are key to deploying HaaS

Alongside technology-related challenges such as the effect of electrifying heat on power networks and limited skilled capacities for installing low carbon technologies, HaaS is faced with data management issues in terms of data privacy, interoperability between systems and lack of a central platform curating data.

There is therefore a clear need to ensure that data used in delivering HaaS is open, interoperable and secure. Data openness needs to balance issues of consumer trust, incentivising energy service retailers to invest in customer relationships and, allowing competition in service offerings. These complex commercial and consumer issues need to be further understood and linked to debate of data use by wider ICT organisations (Energy Technologies Institute 2018a).

6.5 Best practice energy services from other countries can inform HaaS development

With HaaS only beginning to gain attention in many countries, there is considerable scope for learning from European countries that have offered different HaaS business models. For instance, Best Green in Denmark offers asset leasing with a performance and savings guarantee; whilst, Thermondo in Germany offers consumers a package comprising asset leasing, heat delivery, maintenance and insurance. The Energy Systems Catapult in the UK are trialling an outcome based 'warm hours' model and Eneco, in the Netherlands, are trialling what Delta EE (2019b) describe as a fully outcome based HaaS model where agreed temperatures are delivered by a heat pump for a fixed monthly fee.

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6.6 To facilitate HaaS, opportunities for consumers, experts, and industry to work together should be explored

Across discussions on behaviour change, policy, technology and financing, HaaS stakeholders emphasised the need for partnerships, specifically the need to connect installers, consumers and experts in order to facilitate HaaS. This entails promoting low carbon heating systems, sharing insights about what works and does not work and improving the dialogue between government, industry, academia and consumers. These, together with other opportunities and solutions explored in this paper could potentially enable HaaS to play a much wider role in heat decarbonisation.

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