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Purely ornamental? Public perceptions of distributed energy storage in the United Kingdom

Pepa Ambrosio-Albalá[a,*], Paul Upham[a,b], Catherine S.E. Bale[a,c]

[a] Sustainability Research Institute, School of Earth and Environment, University of Leeds, Leeds, LS2 9JT, United Kingdom
[b] Institute for Environmental and Sustainability Communication (INFU), Leuphana University, Universitätsallee 1, C11.323, 21335 Lüneburg, Germany
[c] Centre for Integrated Energy Research, University of Leeds, Energy Building, University of Leeds, Leeds, LS2 9JT, United Kingdom

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ABSTRACT

Distributed energy storage technologies (DES) are expected to help in decarbonising the power sector, decentralising power sources and meeting the mismatch between the produced and consumed energy. However, the likelihood of the use and acceptance of these technologies will partly hinge on public perceptions. Here, we present results of three focus groups and dialogue from the city of Leeds (UK) held with members the lay public with and without personal experience of technology (photovoltaic panels) about public perceptions of distributed energy storage technologies at household and community scale. We apply and adapt the Energy Cultures framework, which was initially developed for understanding energy behaviours as mediated by individual psychological factors, by practice-based, energy-related culture and infrastructural elements. Accordingly, we connect what people *think*, *do and have* in energy contexts, to better understand perceptions of DES technologies as part of a broader renewable energy landscape (culture) that is both materially and socially constructed. We show how a variety of elements such as forms of energy consumption; costs; expectations of family members; previous experiences; perceptions of government and the municipal authority; and expectations about the technologies, are likely to shape acceptance and adoption of battery storage at the household and community level.

1. Introduction

A move towards less centralised, more integrated and interactive energy systems is increasingly understood as crucial to meet future energy challenges, supporting the development of a low-carbon electricity systems and helping to integrate renewable energy into future energy supply [1,2]. Distributed energy storage (DES) is relevant to both residential and commercial consumers [3]. As a term, DES includes energy in the forms of electricity, heating and cooling and includes various technologies, such as flywheels, hydro pump or heat storage systems, although in this paper we focus our investigation on small-scale battery (electricity) storage.

DES infrastructure located close to energy demand loads has the potential to provide key system and user-level benefits that cannot be provided by storage located at other points in the system, such as household-level peak demand shaving and embedded generation [4]. Accordingly, decentralised energy in general has received more attention in government policy and strategy in recent years, and local governments have ambitions for energy projects and initiatives [5] to deliver a number of benefits [6].

Overall then, renewable DES has the potential to support change in current centralised energy models, to more decentralised, lower carbon and collaborative models that are able to better manage energy input from multiple, typically renewable sources. DES generation and storage sources should provide the end user with local resilience, as well as assist grid operation by managing demand in such a way as to reduce peak loads. What is missing in the public domain, though, are the views of the end users, as citizen-consumers. Here we are concerned with how lay publics perceive domestic-level DES technology, before this technology has been introduced, on an anticipatory and hypothetical basis. As described above, DES offers potential benefits for these users in a posited future of more variable electricity supply. Yet we know neither how the scenario of DES as providing these benefits is perceived now, nor how they will be perceived in future, by end users themselves. Such information, we suggest, would be useful for informing the policy design and communication strategies of both commercial and public sector actors.

To shed light on these issues, we use the Energy Cultures framework

* Corresponding author.
E-mail address: P.Ambrosio-Albala@leeds.ac.uk (P. Ambrosio-Albalá).

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(ECF) [7–9], principally for its broad and integrative nature. Using the ECF as an interpretative lens enables us to identify a wide range issues in the 'receiving' energy culture that are relevant for acceptance of DES. While the ECF can be used for detailed analysis, here we use it to provide an overview of the issues that arise in exploratory, qualitative work in the United Kingdom (UK). We use a sample of both 'typical' members of the public, who are unfamiliar with DES, and, as an analogy of typical public exposed to storage technology, a group of local authority tenants with experience of household-scale battery storage as part of photo-voltaic (PV) systems *that they did not choose*. That is, who are not pro-environmental in attitude or motivation.

While the number of studies on public perceptions and the acceptance of renewables and new energy technologies has proliferated [10,11], there are as yet few studies of public perceptions of energy storage [12,13]. Of these, Romanach et al. [14] describe the results of a survey in which various issues relating to batteries at the household level are addressed, highlighting the paucity of our knowledge and areas for further research. In the Japanese context [15] there is also research on consumer perceptions of solar photovoltaic panels (PV) in relation to energy storage. This suggests that publics lack information about the potential benefits, and also that attitude-formation towards DES systems are in its infancy.

To our knowledge, though, there is as yet no publicly available research on the qualitative aspects, meanings and interpretations of DES technologies, partly because the deployment of energy storage technologies is still in the early stages and relatively unknown to the general public. In advance of the study, we anticipated that the main concerns about batteries would relate to cost, expectations of the technology and institutional design [16]. We also anticipated that individuals' previous experiences, together with their level of knowledge of the technologies, would likely structure their perception of DES technologies [17]. The results broadly supported our suppositions and provided more detail on the ways in which these issues can play out in practice.

The specific objectives of the paper are as follows. First, we aim to understand more about public perceptions and acceptance of batteries at household and community levels, bearing the above suppositions in mind. Second, using the Energy Cultures framework (ECF) [8,9], we aim to characterise issues relating to the uptake and acceptance of DES technologies, specifically in terms of the ECF and participants' meanings of technology in this context [18]. The core research questions are: (i) what are the characteristics of the prevailing energy culture(s) within which DES will need to operate; and (ii) what issues do these raise for public acceptance of DES? Thus we use the ECF both to explore the prevailing energy culture, and to identify how norms (expectations and aspirations), material culture and practices relating to energy may be influential in supporting (and hindering) the adoption of DES. We first begin with an overview of the nature and value of the ECF.

2. The Energy Cultures framework

Many theoretical lenses have been applied to the study of public responses to energy technology, with emphases ranging across causal factors and dimensions of the problem in relation to place [19–21]; practice [22,23] and habits [24–26]; institutional arrangements [27]; scientific knowledge [28]; socio-cognitive representations [29–33]; and risk perception [21,34]. In addition to this are micro-economic and behavioural economic perspectives [35,36].

Each of these and other approaches highlights and addresses particular aspects of the problem. However, the perspective that we use here, the Energy Cultures framework (ECF) is deliberately general, global and holistic. As a multidisciplinary perspective, the ECF is intended to allow the study of the individual as an autonomous agent, capable of making their own decisions and generating changes [8] within a wider perspective comprising values, beliefs and knowledge, the broader socio-cultural context, and the regulatory and market environment among others, all of which can affect or drive energy-related behaviours [8]. The ECF was initially developed to provide an understanding of why people would perform the same patterns of energy-related behaviours while it seemed 'logical' to change them, where that logic is based on some external criterion such as economic or financial cost. The perspective recognises individual agency to some extent but also attaches importance to external influences, e.g. place, time, culture or power relations, that could cause energy cultures to change or remain the same.

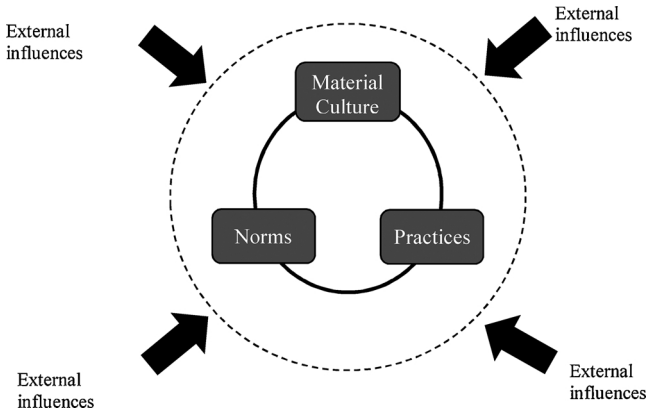

Fig. 1. The Energy Cultures framework (Stephenson et al. [7,9]).

The framework is composed of three elements: practices, material culture and norms (Fig. 1). These elements interact with each other to organise different views on energy use practices [8,37]. Here, practices are understood as everyday actions (both routinized and less frequent) that are common across social peers. The ECF also incorporates the acquisition of the material objects that enable people to enact and reproduce those practices [9]. The material culture are those available objects, technologies and individuals that can control, influence, and affect people's energy demand. The cognitive norms are expectations of a particular service or behaviour that are shaped by a specific meaning attributed to them. As such, within the ECF, cognitive norms include values, beliefs and attitudes. In addition, the ECF acknowledges the importance of external influences when shaping uses of energy and energy behaviours. A particular set of these three elements together with the external influences, give rise to a distinct energy culture, specific for one actor or group of actors.

The ECF can be applied at different levels (e.g. community, individual) and for different subjects of acceptance, as the previous definition suggests [38]. The ECF framework is particularly useful for understanding how energy behaviours are shaped by material objects, such as a PV system [39]. It has been applied in the field of mobility and transport [40], individual GHG reduction behviour [41] and the uptake of photovoltaic technologies [39].

Overall, the ECF draws on both psychological and sociological insights and has not (at least in its original design) been significantly concerned with arguments about potential ontological irreconcilability [42]. Rather, the aim has been to create a multi-factor framework that is comprehensible to natural scientists but defensible for social scientists [9]. That said, possibly the most contentious aspect of the approach is not so much its applied eclecticism, but rather the claim that an entity as abstract as energy should have an associated 'culture'. From a psychological perspective, attitudes have specific 'objects', and from the sociology of practice perspective, specific aspects of the material world (including technology) are an integral part of the account. Energy is a more general conceptual category than the types of specific technology and behaviour analysed within environmental behaviour or sociology of practice frames. One can readily conceive of a 'car culture' or a 'food culture', both of which have implications for energy use, but 'energy culture(s)' is substantially more abstract.

Yet we think the ECF valuable for several reasons. First, it likely

does have the claimed advantage of being readily comprehensible for non-specialists, though in this regard we can only speculate. Second, it is conceptually and theoretically inclusive, at least at an applied and descriptive level. Third, the way in which it gives equal weight to factors endogenous and exogenous to individuals makes it relational: people are viewed as in mutually influencing relationships with others and with the material world. This, in turn, means that significant parts of that world are not ignored for reasons of disciplinary or researcher (dis)interest. Fourth, and probably most important, while one can dispute the value of 'energy' as being rather intangible for cultural study, cultural studies per se have a history in social theory and anthropology that is both long and consistent with the ECF's inclusive nature. Hence Hays [43] defines culture as inclusive of beliefs, values, language, knowledge, common sense, material things, interactional practices and the ways of life established by these [43]. In other words, the ECF is able to draw on a long history of social theory [7], should analysts want to do this.

With this in mind, we study public acceptance and perceptions of DES technologies at the household level (individual) and local level (community) [38]. We elaborate on the local dimension through the views of energy consumers and residential 'prosumers' who produce electricity at home through solar photovoltaic panels on their rooftops. In this case, such 'prosumers' did not play an entirely voluntary role in choosing PV systems and this played a role in their views of prospective (hypothetical) DES. The role of such institutional factors is not uncommon and in general understanding the differentiated nature of presumption is crucial [3,44,45], despite such voices often being little studied [46].

Within the frame of the ECF [8,9], we focus on both public perceptions and the influences of contextual factors in the uptake of DES technologies. That is, how the different socially transmitted, symbolic and learned aspects ("cultures") [47] may affect the acceptance and uptake of DES technologies at household level. As broad themes of applied interest, we focus particularly on energy use, perceptions of the particular storage technology (batteries), and the possible role of energy scarcity (described as shortages in the focus groups)[1] as an influence on those perceptions.

3. Methods

Three focus groups and one small, two-person dialogue session were conducted in Leeds (UK) between February and March 2017. The duration of the focus group and dialogue was never longer than 90 min. A key theme of interest was the influence of prior experience with related technology all in self-reported terms. Two of the focus groups consisted of lay public in both rented and owned properties (without PV installed); the sample was recruited by a market research company and was age and gender-balanced (Table 1). The dialogue group and the third focus group included people who lived in council-owned properties with PV installed. This group was recruited through the city municipal authority. The households in this group were tenants who voluntarily agreed to have PV panels installed by the municipal authority, conditional on the house meeting the necessary requisites (e.g. a sunlit rooftop). The tenants have not borne the capital or maintenance costs of the PV panels. The tenants do not receive the feed-in-tariff payments from the PV (which instead provides revenue for the council), though they do benefit from the consumption of generated electricity.

Table 1
Demographic profile of focus groups participants.

Focus groups	Age	Participants	Technological experience
Focus group 1	(23-64)	4 Men 4 Women	No
Focus group 2	(27-60)	6 Men 3 Women	No
Focus group 3	N/A	1 Man 5 Women	Yes (PV installed)
Dialogue	N/A	2 Women	Yes (PV installed)

Selection for the groups was purposive, and the prosumer group provided contrast in terms of having relevant technological experience and their level of engagement with this. The nature of this experience consisted of actively deciding to have the PV installed; having a lived and ongoing experience with the technology; and having sufficient knowledge and level of understanding of the PV. Tenants were thus asked for consent before installing the technology, experienced the different stages of the installation process and experienced the effects of this on their household (e.g. whether they found the process intrusive, they received the necessary information about the technology). In relation to understanding the technology, here, the concept is construed regarding knowledge about the mechanical functioning of the PV also more generally in terms of perceived benefits or disbenefits. The inclusion of this group also reflected the local authority's interest in installing small-scale battery storage in the same households, again without requiring any financial investment by the households themselves.

3.1. Focus group protocol

Focus group questions were phrased so as to identify drivers and barriers to the uptake of DES technologies among a lay audience that included people with previous relevant technological experience (the prosumers) and people living in local-authority owned homes. Fig. 2 shows the stepwise information provision process for the focus groups and the dialogue session.

The focus group and dialogue were organised as a stepwise information provision process, in which people were presented information and discussed DES technologies. The information was conveyed in lay-terms, avoiding scientific terminology; regarding the content the research team worked with engineers who checked that the technical information was accurate and plausible. At every stage of the focus group, information provision was accompanied by pictures to illustrate the topic discussed. Information was provided in a phased way, to reveal both uninformed and informed views. As such, people built knowledge and familiarity with batteries in the context of wider DES issues by starting with a more general topic and narrowing down to the specific theme (DES technologies), before exploring their attitudes to this information.

Overall, the focus groups were organised in three stages. First, people discussed their energy uses and habits and routines within the household. Information included two pictures: a graph of average energy demand for 24 h in 250 homes in the UK, and an image of a range of electronic appliances. In the second stage, people talked about DES technologies. In this section, information about technologies was introduced gradually (i.e. risk, technical aspects, aesthetics, location, costs), with participants being asked questions about awareness, familiarity and motivations for potential adoption or non-adoption. Pictures were shown including battery images and another picture including different types of batteries in different locations within a household environment. Finally, the third stage covered issues of potential, future energy scarcity in the UK. Participants with previous

[1] In terms of framing, the focus group participants were told that energy demand in the UK is increasing, domestic fossil fuel reserves are becoming scarcer. Moreover, in the UK the energy demand surpasses the actual capacity of the system, the import demand is increasing [48] DECC, The UK Energy in Brief 2012, London, 2012.and dealing with energy shortages may entail higher investments from both the private and public sector [49] N. Chestney, Britain faces huge costs to avoid power shortages with electric car plan, 2017. https://uk.reuters.com/article/us-britain-power-autos-analysis/britain-faces-huge-costs-to-avoid-power-shortages-with-electric-car-plan-idUKKCN1BC3VU. September 1, 2017).

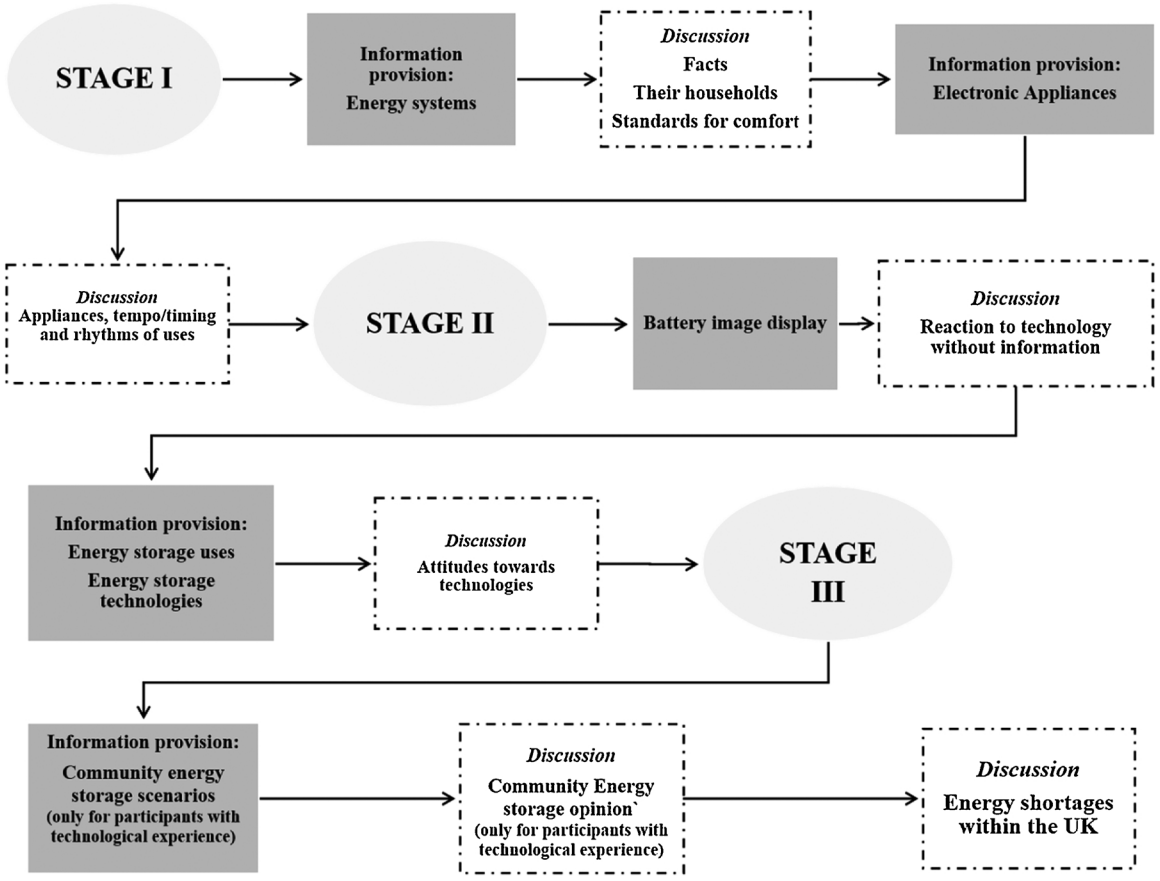

Fig. 2. Stepwise information provision process for focus groups and dialogue.

technological experience (PV installed) also discussed issues relating to community energy storage. Two images were displayed, one including headlines and newspaper articles about energy shortages in the UK, and a second one illustrating the two community energy storage scenarios.

The focus groups were audio-recorded, transcribed and coded with the NVivo qualitative data software analysis tool. Sub-codes were grouped into broader categories of themes, according to principles of the thematic analysis [50]. Further, the interpretation of the data was theory-driven, seeking to identify and distinguish differing energy cultures.

Fig. 3 above summarises the operationalisation of the ECF for this study by showing how the individual topics raised in the focus group discussion (three main aspects of the energy storage system which are both social and technical) are connected to the to the three main elements of the ECF (material culture, practices and norms). The material culture dimension was elaborated from the discussion of the energy uses and storage. The three topics of the focus groups informed the energy practices dimension. Elements related to the norms dimension were identified in the discussion about energy storage, energy shortages and community energy storage.

The coding process was used to operationalised that connection. Main codes noted were *actions, actors, attitudes, and context* and they also included a set of sub-codes. *Actors* were understood as those involved and exerting influence on any energy-related behaviours and usage. The sub-code included in this category were Government, family members, City Council, energy companies. We defined *context* as any effect of the environment, such as circumstances, objects or information that could determine the way that people effectively perform their acts (actions). These actions were related to the potential adoption of the technology or other material cultures. The code *context* included information needs, health and safety, impacts and outcomes, comfort, environment, energy certificates, scenarios; the code *actions* included battery uptake, hot water tanks uptake, lifestyles, uses of energy, energy storage options. At the individual level, we identified people's rationales and predispositions to act (attitudes and norms). The code *attitudes* included anchoring and objectifying, aesthetics, location, size, preliminary questions and concerns.

4. Results

When documenting the focus group results, we balance the outcome of the thematic coding with making the structure of the discussion in the groups explicit. This adds to classical content analysis in various ways [4], the most relevant of which here is that it allows (i) our own framing prior to analysis and (ii) connections (associations) between ideas generated by the group to be more apparent. We then analyse this descriptive account in terms of the ECF in more depth in the discussion section.

With the above in mind, the results are presented in terms of the stages of the focus groups (Fig. 2). We begin by describing the results from the energy uses topic (stage I), followed by the discussion on DES technologies - mainly batteries for household use (stage II). Finally, results relating to energy shortages and community energy storage are presented (stage III).

4.1. Energy uses

Discussion in the groups about how people use energy began with a conversation concerning where people identify their most comfortable places in the house and different energy uses and patterns within the household. Comfort was chosen as a starting point because the UK has one of the oldest housing stocks in Europe, which impacts on thermal

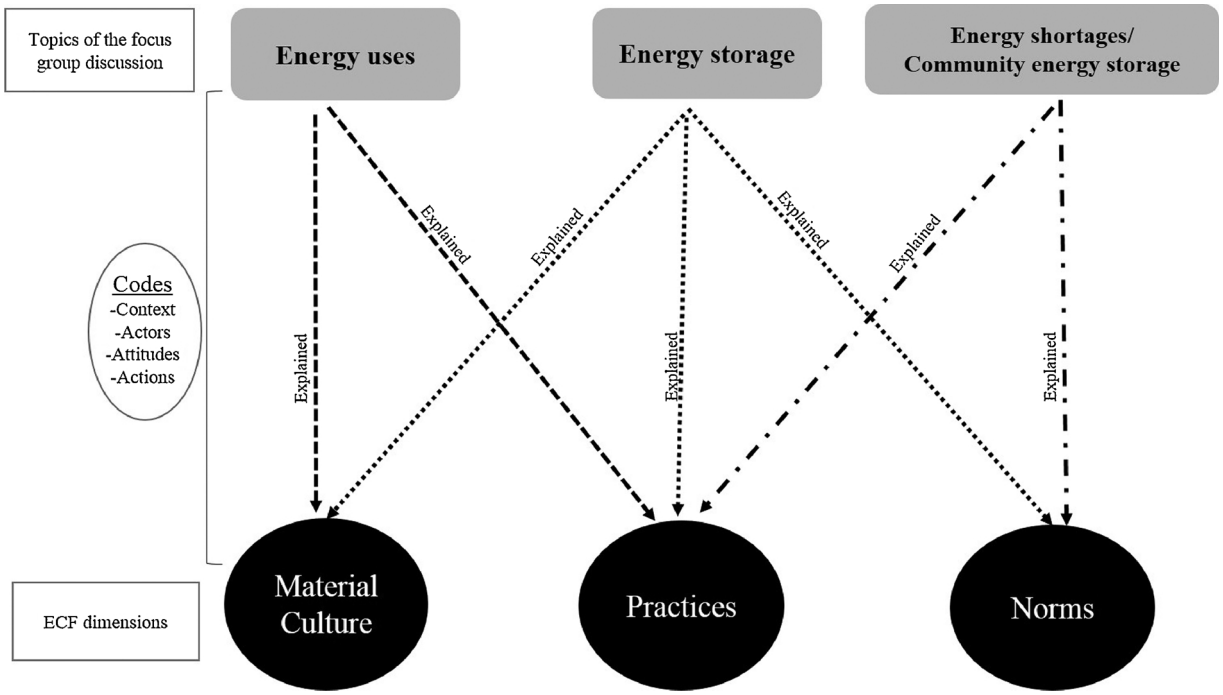

Fig. 3. Connecting the data with the ECF.

comfort for many and plays a significant role in fuel poverty [5]. There were no strong differences between the different focus groups in terms of perceptions of comfort: across groups, the idea of comfort was shared and connected to different domestic spheres. First, participants relate comfort with the sense of thermal comfort. They consider essential for their comfort at home is being warm or feeling warmth. Additionally, the participants connected the idea of comfort with routines and activities within the household. For instance, how electricity and use of energy allows them to maintain social relations within the house. Here two women talk about the feeling of thermal warmth:

> Moderator[2]: (…)*What would you consider essential for your comfort at home?*
> Female 4: *Heat, definitely, especially in the cold weather, yeah.*
> Female 3: *Heat, yeah, definitely.*
> Female 4: *Just to have the warmth in the whole house, rather than walking into a room and feeling chilly, or the whole house feeling chilly (…)*

For the prosumer group (participants with PV), energy and electricity is percieved as an element that gives security, e.g. leaving the light on when they leave the house so that other people think there is someone at home. In general, participants had a good level of knowledge about how the energy is used at home (which appliances consume most power) and are aware of how much they pay for their electricity. They know about home energy certification and are aware of the environmental implications of their consumption. A participant talks about how he is more conscious about controlling the energy at home:

> Male 1: *I haven't been doing it recently but I'm much more conscious about turning everything off, going round the bedrooms turning all kids'things off because they're the things that are always charging up and stuff so I did make an effort to go round turning lights, turning switches off, turn the TV off.*

People try to economise and are conscious about the way energy is used in the household. In particular, this is more prominent among families with teenagers. Across the focus groups, participants mentioned that children can affect adults' ability to control and manage energy consumption. This is exacerbated when parents have to spend substantial time out of home. One participant says:

> Male 2: *Our son's at home more than we are and we do make sure the heating is off before we leave but then he can quite quickly just put it back on again. We do try and control it where we can but it doesn't always happen that way.*

A similar conversation:

> Male 1: *There's no way you can control it [energy uses], as long as you have a kid! (…) Because, the first thing, every day, the same problem. I've got three kids; all the time when they are playing in the room, TV on, light on, go down, they can do whatever they want.*

4.2. Energy storage and distributed energy technologies

The second part of the discussion covered issues relating to energy storage and distributed energy technologies (batteries). Across the groups, the majority of participants had not heard about energy storage in this context before attending the focus groups, nor were they particularly interested in the topic. Nonetheless, a small number did have an informed understanding in this regard.

After explaining the idea behind energy storage and how this could be deployed in the UK, people's responses were positive towards this scenario happening in the future. However, they were of the view that an energy storage future would only materialise if it was cost-effective and subsided by the Government. Here, one of the participants from one of the lay public focus groups with sufficient knowledge about the topic, discusses this:

> Male 1: *It* [energy storage] *would need a massive amount of investment wouldn't it? I can't see me coughing up a month's pay for it then everybody else in my immediate neighbourhood all agreeing to do that. I can't see it would work unless it was very heavily subsidised or had a very strong financial advantage but for most of us (…)*

Moving forward into the discussion, people were asked about their

[2] Onwards denoted as M.

views on distributed energy storage technologies (mainly batteries) in particular. Participants' views were similar across the focus groups. Without prompting, few participants could recognise the technologies shown to them photographically. Once the storage systems were explained, participants anchored on solar panels to understand how batteries might operate. Mainly guided by the appearance, people initially expressed reluctance to having any of the batteries showed in the pictures in or outside their homes. However, once the function of the batteries was explained, people took a positive attitude towards them. In general, participants said that they would be willing to have a battery installed under three general circumstances: i) if this would be cost-effective; ii) if they could benefit from it; iii) and if it would allow them to continue performing their daily routines (the latter particularly highlighted by people with previous technological experience). For example, in relation to benefits, one of the participant of the lay focus groups states:

> Male 2: *I suppose at the end of the day it comes down to the fact what are the benefits for me and how long is it going to take me to get those benefits and to get back what I'm putting in. Ultimately I think that's the way that most people are going to look at it.*

Participants with PV already installed were particularly concerned about who was going to benefit *de facto* from the technology if they had it installed. For this group, one of the main issues (as said) was whether the battery would allow them to keep on performing their daily routines (e.g. using the washing machine) as currently practised. Indeed, these participants complained about not seeing much benefit from having solar panels installed. Given that they expected their electricity bills to be reduced and this had not happened, this led to suspicion of the local authority. There was a firm belief that the local authority ('the council') was taking advantage of *their* houses for producing energy and this experience led to them being suspicious about the benefits that a larger battery might bring. Nonetheless and as mentioned before, once the function of the batteries was explained, i.e. that they could store the energy to be used at a later point and hence reduce costs, their opinion about them was favourable. As this woman states:

> Female 1: (…) *Whereas this battery, if you're telling me I get three or four hours of energy, then I'd be happy with that because, you know, it's enough to do your washing.*

The discussion about types of batteries brought out different topics. The first was connected to appearance and aesthetics. Participants said that they would prefer a small battery, discreet and mainly out of sight or "boxed in". Below one participant from the lay public focus group comments:

> Male 5: *But I wouldn't want it on show though so it's the sort of thing you would be boxing in your house. If that was in your kitchen, you'd be boxing it in. I know it's not as big as a boiler but I still wouldn't want it in a room that I was going to be looking at it every day*

Similar reactions were found in the focus groups with participants with technological experience. Here the two women were laughing when talking about where to put the battery:

> Female 1: *No, or I wouldn't want that in my kitchen, I've got tiles, but somewhere in my porch or, you know, in a cupboard, I wouldn't have a problem with it. (…) I wouldn't mind having it, but I'd want that out of sight, I mean–*
> Female 2: *I suppose you could put an ornament on top of it or something.*

Mostly, the preferred location for the battery depended on people's previous experiences, personal context and needs. For some of them, placing the battery outside would depend on the size of the house, or the risk for it to be damaged by a household member, e.g. children.

Understanding their functioning played an important role in deciding where to place the battery. For example, whether the battery would entail any fire risk, required maintenance or day to day adjustment and so on. Others preferred the battery to be placed inside due to "risks", which are not only understood in terms of health and safety issues, but also as contextual situations, i.e. vandalism. As one of the participants noted:

> Male 1: *According to my experience, I would wish this to be inside, because I did see it; (…) my brother's got some device, if there is a power-off, electricity, it just connects straight away to the battery*.

Another participant explained why she would place the battery outside her house, depending on the size of the battery:

> Female 2: *I would prefer to have it outside, because my gas meter is outside. I've not had anyone tampering with the gas meter, so I would prefer it be outside.*
> M: *Okay, and you…?*
> Female 3: *If everybody has an outside one, I'm not sticking mine inside! (…) I mean, if I have to choose, obviously the sizes–if there's a bigger size, it's obviously got to be outside, maybe in the back garden or somewhere(…)*

Less importance was given to health and safety issues than to battery size per se. Whether people owned or rented a house was also important. The local authority tenants with the solar panels would not invest in a battery themselves because the property does not belong to them. Some other participants would base their decision on the type of battery that could allow them to store more energy and consequently save money in the long run. Also the number of people living in the house would be a factor. One of the participants says:

> M: *So would you prefer to have a battery based on the number of people you have at home, or would you prefer to have, like, a big one, just in case? (…)*
> Female 1: *Yeah, that's what I'm thinking. So it wouldn't really matter, would it? Because I'm just thinking; I do suppose if it's cost-wise…I think I'd just have it onhow many people were in the house.*

The point was made that it was difficult to choose a certain type of battery without knowing what is going to happen in the future, i.e. increasing family members, change in property, etc. Here two participants from the lay public focus groups discuss this:

> Male 5: *The trouble with that for me is I might get one now for me living in my house that's got 2 people in it. Who's to say that isn't going to be 4 people in the next 2 years'time?*
> Female 1: *Or if you want to sell your house.*
> Male 5: *Or if you want to sell it, are people going to have to put a new battery in that house so I'm not going to buy it because I'm going to have to upgrade the house.*

After talking about various issues regarding batteries, people were also asked about what information they would like to have, to support making a decision on installing batteries. Here, two points were made: that quality of information is sometimes more relevant than quantity and that the content of information depends on previous experiences (e.g. with solar panels). For instance, people from the lay public group were more interested in receiving more information about how the batteries would work than the PV group. Whereas people with solar panels installed, were keener to know how this information would be conveyed. Again, expectations were determined by their previous experiences. Some participants mentioned that when they receive the electricity bills, they have difficulties in understanding them because they are too technical. Moreover, they struggle with understanding how much money they are actually saving and how much electricity they are using and producing from having their PV. Additionally, they wanted information individually-tailored for every circumstance. They would expect to have personal advice/assessment about which type of battery and where to place them would be adequate for them, based on the household's needs, e.g. how and when energy is used within the household, the number of people in the household, the characteristics

of the house One of the participants of the solar panel focus group confirmed this assessment:

Female 4: *Yeah, for your needs, the needs of your house, you know; this is how much electricity your solar panels have created; this is how much you've used. (…) to kind of assess how you live for a week, to see the peaks and troughs, when you use your electricity, to be able to work out that way what would benefit you better, using the electricity.*

With regards to information sources, participants said that it would be beneficial to identify one contact person who could help to resolve doubts or answer questions and who would be willing to help generally. For those with technological experience and in local-authority owned homes, ideally, this person or organisation should be someone "independent" and not directly related to the local authority or energy suppliers, e.g. the manufacturer or people who would install and maintain the battery. Such participants commented:

Female 4: *The council will be out for themselves, anyway, so…*
Female 1: (…) *basically, both the council and the energy suppliers are going to be out for themselves, so somebody independent to both, who's just there to tell you exactly what it is that you're using, what you're burning, what you're saving*

Participants from the lay focus groups, however, would prefer someone official e.g. from government:

Male 5: *It would be about trust so I'd want somebody I could trust and I would like to think I could trust the information the government provided me rather than 1 of 50 companies that would be telling me I needed this when this company said I needed this.*

In relation to the subject of information, people also discussed support during the installation process and control of the batteries, e.g. institutions in charge, consultation processes, etc. While they did not expect local or national governmental institutions to be involved, they would prefer this:

Male 4: *I'd like that from the government but I wouldn't expect. It would be nice to think that the government is with everybody else, (…) And it would be nice to think that the government would want to get involved and would want to really push this but are they really going to do it? Is it going to benefit them and their friends?*

4.3. Scenarios: energy shortages and community energy storage

The third part of the discussion was structured so as to elicit people's reactions in the hypothetical context of energy shortages in the UK. Here, they discussed their opinions on the role of consumers and users as well as private companies, after which they discussed their perceptions of DES technologies. Regarding energy shortages, participants were generally unwilling to pay a higher price for energy at peak times. At the same time, they were aware that electricity costs may rise at peak times anyway and that people "would have to pay" higher prices even if this is not preferred. In the lay public focus groups, discussion focused on how much the extra payment might be and some were willing to consider producing their own electricity under such a scenario. Even here, though, there was the desire to avoid changing their daily energy use routines.

Those with solar panels were more inclined to change their energy use patterns. In general, they took the view that there should be a change in people's behaviour, with more personal responsibility. However, they acknowledged that having children could hinder a family from controlling their energy usage.

M: *So, you were saying, then, maybe change your lifestyle?(…)*
Female 3: *I mean, the habits, it's all about the habits, you know, like leaving the light on, controlling your electricity–you know, like heating. It's just your lifestyle (…) I know my heating is on. You know, it don't go off automatically; I have to go upstairs and turn it to low level. Sometimes I am thinking,"Ah, oh come on, I'm not going. I'm going to go in a minute, I'm going to go in a minute,"you know, so you leave it for an hour, an hour, and it does make such a huge difference…*

For many of the interviewees across the focus groups, the government should have a more proactive role. For example, by having a stricter control of how energy companies increase their prices. Also, by investing in renewables and low-carbon initiative or by enhancing people's roles as prosumers:

Female 1: *If the government is saying that they've got these shortages of energy, why don't they just make every single household in the whole of the country have solar panels?*
Female 3: *Exactly.*
Female 1: *It would solve one huge problem (…) It's like one hand feeds the other; you scratch my back, I'll scratch yours, kind of thing, isn't it? Do you know what I mean? (…)*

Across the focus groups, participants considered that batteries would be a good solution in the context of energy shortages. While the uptake of batteries was considered as a good and plausible solution, participants viewed this as conditional on the cost.

In this stage, people with previous experience with PV provided additional comments on the different community energy storage scenarios. The scenarios were presented one at a time and discussion was sequenced accordingly. The first scenario involved having a set of renewables technologies (PV/wind farms) in a communal area and batteries spread across homes in a community. The second scenario described a single larger storage device that could serve many houses in the local area and which could be located at the local electricity substation. There, a private company would own the battery and people could pay for the use of the storage, such as by leasing or buying a portion of the available capacity.

On the whole, participants were more inclined towards the first scenario. The second one stirred up some controversy; people could not imagine the case where a community would share a battery bank or pay to use a portion of the battery. For this possibility to be successful, it should be "*a win-win situation*". That is, that the households would receive something in return, e.g. monetary compensation. Another issue that raised concern was how they could control and have knowledge about others' –mostly neighbours' - energy use.

In terms of ownership and management of the community-level battery, the participants disliked the idea of an external organisation i.e. network operator, or council owning and running the battery; according to a participant "*they would feel used*". Nonetheless, if they had to choose they would prefer the network operator rather than the council. Overall the possibility of sharing energy was seen as a controversial:

Female 1: *Well, it would be nice to think as a community you could but those days are gone now (…)Many years ago, we had a really good community. We had street parties, bonfire nights together. You don't do that no more. It's not very community orientated anymore.*
M: *Okay. So, you think this–you couldn't envisage this scenario?*
Female 1: *Not with the community, no.*

Paying for the use of batteries was not a plausible option either. Participants would only be inclined to have one big battery bank if it could be guaranteed that use would be equal and fair. Two related points were highlighted here: who would benefit from the energy stored and whether they could run out of energy.

The second issue of concern was the possibility of running out of energy and some people "overusing" it. As a "solution" an individual assessment was proposed to evaluate how people use the energy in the community:

Female 1: *I don't mind sharing so long as it's equal. I mean, obviously, if I'm not using my energy, by all means take it. But I wouldn't like to think*

that somebody in my streets decided to do–to use it all and there's none left for me. (…)

Female 2: *Especially those who don't work and they're in with the telly on all day long.*

Female 1:*it were fair, then yeah. (…) Rather than saying,"Oh well, you know, they're at home all day, so they can have whatever kilowatts, and she goes to work and her son goes to work, and they don't use as much Monday to Friday so we'll only give them so much". You know, if I want to do an extra wash I should be able to do an extra wash and it shouldn't be given to somebody that's at home all day.*

5. Discussion

Our main concern in this paper is to identify and comment on aspects of the existing energy culture that are likely to impinge on the acceptability of domestic and community level energy storage. In this regard it might be noted that when focus group participants are asked to respond to imagined technology in an imagined future, in this case the counterfactual of battery storage in a future of potential energy scarcity, they are to some extent being asked to respond differently to the way in which they would respond in present circumstances and neither they nor the researchers can be sure of the reliability of their modified response in terms of its correspondence with an actual future. Nonetheless we assume – we think with good empirical reason – that people do express the attributes of their present energy culture in their responses to the future imaginary.

The key elements of the ECF, namely material factors, norms and practices, are strongly interrelated and are held to combine to form a characteristic energy culture [8,9], with which either DES will need to either fit with, or that will need to somehow change. Of course the latter issue of cultural change raises many questions that we can only begin to touch on here. At issue here are the core research questions: what are the characteristics of the prevailing energy culture(s) within which DES will need to operate and what issues will this raise for the success of DES acceptance and implementation, assuming that culture continues as it is currently constituted?

At the most basic level, the ECF helps in mapping the empirics of the case to the ECF elements, much as the original heuristic intended [7]. Such mapping is far from unambiguous in practice, as several elements are often present simultaneously. Allocation is often thus a matter of emphasis. Indeed this is one of the key values of the ECF, namely to highlight that energy demand is a function of a broad range of interconnected factors and that all need to be considered to understand and intervene in an energy consumption domain. This does not necessarily mean that all are of equal importance or equally straightforward or difficult to change. What the interconnection does mean, though, is that definitive and exclusive mapping of factors to ECF categories is unlikely: such conceptual neatness occurs in the analytic realm, not in practice.

In any case, applying the ECF helps to describe how the differing views around DES technologies for potential users or consumers [8] are structured and how these influence a change in the material culture the uptake of batteries. Fig. 4 summaries public perceptions of DES technologies in terms of the ECF. As the framework anticipates [8,9], the elements of the prevailing culture are interrelated (i.e. our qualitative data map readily to – and hence support – the ECF). The elements outside the dashed circle represent external influences and these connect to other aspects directly influencing the three main dimensions of the ECF. Some external influences are not unidimensional, e.g. expectations of public institutions and fairness are elements connected to societal power relations or change in energy patterns and uses. Importantly other external influences are related to the what, how and from whom the information about the technology is delivered.

The differences between people with and without previous relevant technological experience (PV) were not primarily technologically focused and related instead to the PV group's previous experiences with the local authority as tenants. Specifically, the views of those with PV were strongly influenced by living in a local-authority owned home and unmet expectations of lower electricity bills. That this group did not respond differently to the idea of domestic battery storage lends weight to our choice of the group as representing 'normal' people exposed to relevant technological elements (the battery storage element of a PV system), rather than representing a pro-environmental or technologically-interested group. Regarding DES installation, for the local authority tenants, any decision would depend on the local authority's initiative or permission.

To this group, the most relevant norm was fairness. Their interpretation of this norm as involving some form of entitlement (to lower energy costs) differed from the local authority and served as a focal point for their grievances as tenants. Living with PV did lead to a greater understanding of batteries, a mix of the cognitive and material in terms of the ECF, but normative concerns dominated. This led to a different, shared response to the energy shortage scenarios that we posited, relative to the no-PV groups. While the no-PV groups viewed both the domestic production of energy and a moderate increase in electricity price as plausible and reasonable responses to energy scarcity, the with-PV group focused more on the need for changes in behaviour patterns. This seemed to arise more from their unsatisfactory experience with domestic electricity production (in turn, connected to not having received a financial benefit), than to any need to have changed their own behaviour while living with a PV-battery system.

In the sections below we discuss some of the findings in terms of the main elements of the ECF.

5.1. Material culture

The material culture of the energy domain as considered here is understood as the objects, technologies and physical aspects of the social environment that influence a household's energy practices and hence demand. As found empirically in studies previously framed with the ECF [39], in general the participants here are unwilling to install new technology in or on properties where they do not intend to live for an extended period of time. In general, uncertainties about what is going to happen in the future and issues related to family conditions represent an important limiting factor when considering battery installation. The type of property characteristics and tenancy type emerge as factors conditioning the size of batteries that people might want, and whether they would be inclined to install a battery at all.

While this is on the one hand a normative issue, it is also material in that it is a function of finite financial resources and the temporally finite nature of renting. This begs the question of how to reassure tenants and homeowners wary of making investments for which they may not see a return during their term of residence. Such issues are generic to other energy-related investments where payback periods extend long into the future. In the case of energy storage, a multi-level intervention is likely required: Burlinson and Giulietti [51] envisage three layers of business models that are relevant to city-scale energy, extending beyond conventional sales consumer models (core level 1); to those that support prosumers, third party aggregators, community groups, and municipal suppliers (level 2); and a third layer that contains the business models that augment the core layer by delivering specialised ancillary services, such as those that help enable industry code compliance. All are required to create a profitable case for energy storage [52].

5.2. Practices

Practices are understood in the ECF as everyday actions, which can include the acquisition of material objects that enable reproduction of

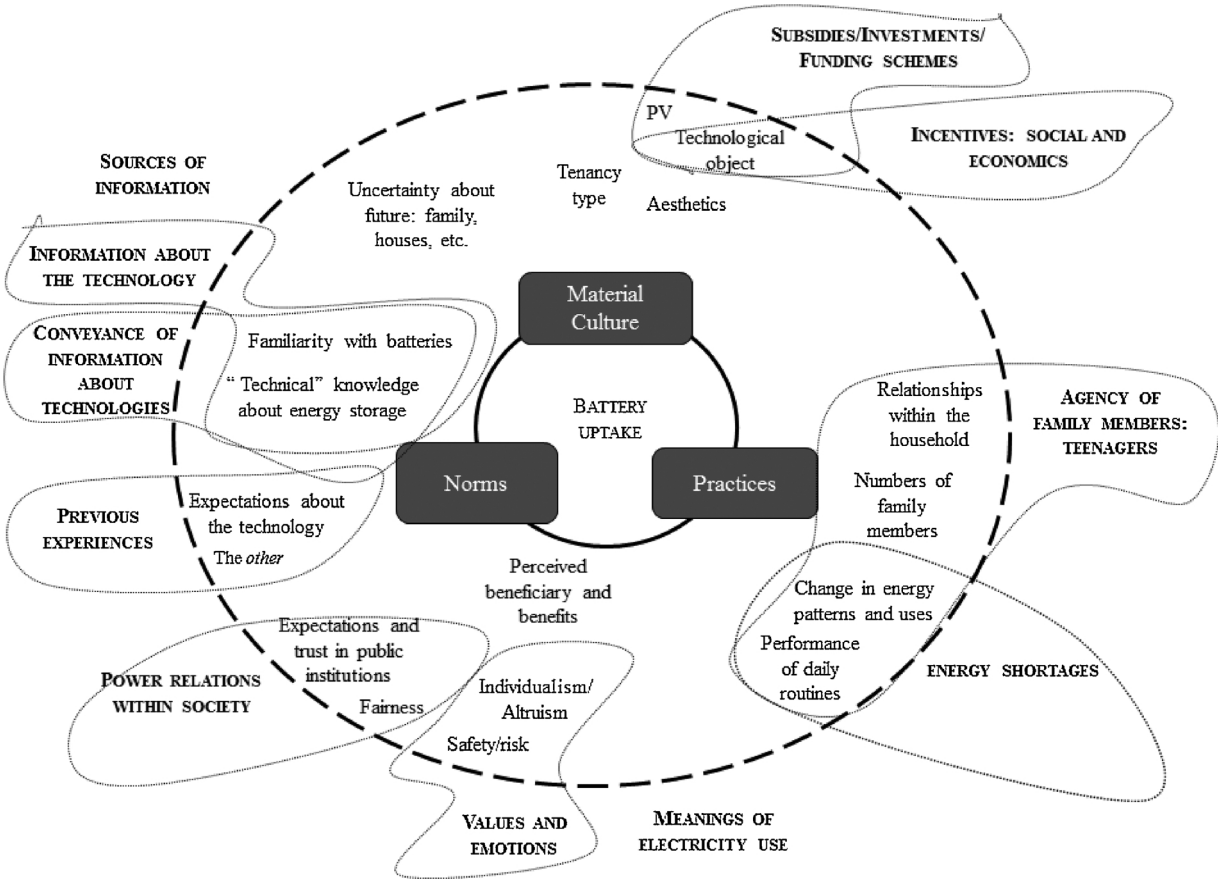

Fig. 4. Energy Cultures framework for potential adopters of DES technologies.

those practices [9]. Stephenson [7][3] discusses the relationship between the ECF and practice theory in some depth, noting the parallels between the ECF proposition that culture constrains and structures, and the idea of Praxis as the totality of human action, doing the same [53] Praxis in this sense is differentiated from Praktik as specific routinized actions, the concept of which has been deployed to considerable effect in the energy social sciences [54].

The practices (Prakitk) of the participants here are influenced by contextual elements from within the household (agency exerted by the certain family members) as well as those outside of the household. Within the household, key influences on practices are the relationships between family members; associated degrees of control over the way that energy is used; and simply the number of family members. While participants tend to be aware of the way the energy is used in their household, they reported having little or no control over the electricity use of adolescents at home. Adolescents may be less conscious than parents regarding saving energy [55,56], or the appliances used by the adolescents may use consume in sum more energy than those of their parents. Here, agentic capacity is reflected in the way that the energy is used (for the type of practices they are engaged in [57]), rather than being part of a decision-making process relating to the energy use within the household. Indeed, positive attitudes were revealed when participants understood that a battery could help reduce the extra costs generated by the youngest members of the family.

[3] Stephenson (2018) wonders whether Bourdieu's notion of habitus might help further theorisation of the ECF. In this regard it might be noted that – at least in our understanding – Bourdieu conceives of individuals as having a habitus, whereas culture is usually thought of as a shared, collective entity. Nonetheless one might also think in terms of a cultural habitus and increasingly individualised cultures. These are issues for further thought.

5.3. Norms

In the prevailing energy culture of the participants, it is the normative dimension – that in which the ECF categorises attitudes, values and beliefs - that is most influential for the uptake of (hypothetical) batteries. Initially, the participants associate domestic-scale batteries with solar panels or boilers. Thus they cognitively connect to existing objects of the material culture that are already embedded in their daily routines. This includes, mainly for the with-PV group, an understanding of the role of battery technology in the home as well as having implications for aesthetic preferences (large batteries being likened to domestic boilers).

We know from previous studies of technology acceptance that individuals' scientific and technical knowledge and also corresponding levels of education can be positively correlated with propensity to accept new technologies [58]. What we have probed here is the specific nature of that knowledge; the ways in which that knowledge is shaped and communicated by others; and the interactions of such knowledge with contextual beliefs, such as have been formed through experience with the local authority. In addition, levels of familiarity with the concept of DES were very low, with only some of the with-PV group having heard of DES. Nonetheless, once participants as a whole were informed of the role of DES, they generally developed positive attitudes towards both energy storage and batteries. The discussion thus revealed the importance of personal experience and the experience of significant others, for understanding how the battery might operate. Experience with the public institutions and other technologies (e.g. PV) were also influential regarding the perceived and expected attributes and benefits (or otherwise) of the batteries. Experience with family members and friends influenced perceptions of where best to locate batteries and what behaviours were likely to compromise their fair and efficient

functioning.

The ECF builds on the way in which cultural theories aim to explain and understand actions through symbolic and cognitive structures of meaning [7]. When discussing the relationships between their practices and their norms, participants highlight the importance of meanings of electricity uses within the household. These meanings are connected to what people consider comfort and are also intimately related to the idea of performing usual practices and activities. Here, we show how comfort goes beyond the thermal [59]. For participants, the understanding of comfort represents not only a sensorial perception [60] i.e. feeling warmth, but also represent an everyday practice and activity, a routinized behaviour (being present in the house) connected to wellbeing (reassurance of safeness when they are within the home and when they are out) [61]. One could view the key defining characteristic of this energy culture as one of a prioritisation of autonomy and hence a resistance to external influence. However this norm is closely bound up with a norm of change avoidance, such that the extent to which participants actually use whatever autonomy they have is not clear. Perhaps this might be interpreted as a norm of wanting to preserve the *option* to act without additional constraint (in terms of energy related activity), as much as or more than wanting to exercise that option.

We know that it takes time to change people's behaviour. Also, that successful behaviour tends to be repeated and give rise to routines and habits [62,63]; this also applies in the field of energy uses and practices [64]. It is therefore not surprising that people expect batteries to help them to maintain their normal lifestyles and more generally to the expectations that people have of new technologies [65,66]. Above all, though, people expect the technology to allow them to maintain their existing, energy daily routines. If such expectations are unmet, the potential acceptance of technologies can be jeopardised [67] and the effect of unmet expectations can result in a low diminishing level of technology acceptance [67].

As found in many studies of technology acceptance, issues of ethics and trust figure highly [68]. In this study, perceptions of fairness were a strong influence on attitudes relating to the potential installation of batteries and the acceptance of a community-level energy storage option. People had strong and specific expectations as to what would be reasonable and acceptable in these circumstances, particularly in scenarios of battery sharing, echoing previous findings of the perceived benefits of a technology being deeply intertwined with expectations about - but not only - the technology [66,67]. Participants' expectations also related to those actors with influence in the technological landscape, and not only to the performance of the technology [66]: these included the local authority and central government, energy providers and electricity network operators. On the whole, people expect that the government should ensure robust legislation, sufficient funding and should function as a reliable source of information about energy storage.

Furthermore, ethical considerations around the process of battery installation and the way that shared batteries can be used were key elements in the conversation about DES technologies. Participants in the focus groups hoped that the battery installation process would be fair and legitimate. For them, this means taking into account their individual needs and views, particularly in a communal environment, which UK citizens are no longer used to. In the context of community energy storage, the idea of fairness is shown to bring up a set of dilemmas [69] despite an environmental rationale [70], leaving community energy storage perceived as rather implausible and contentious. These dilemmas include a resource dilemma [71,72], as people perceive that they would be sharing limited resources (the capacity and power delivery of the battery) under conditions of "free access". Second is a social dilemma [73] as individual interests (having enough access to perform daily routines) clash with collective ones.

Here, trust is connected to expectations and perceptions of the degree of control that participants expected to have over the battery, its use and power output; and hence their willingness to be engaged in a community storage initiative. Building trust with third parties and engaging people in acceptance of new technologies can be demanding and its significance easy to underestimate. This can be more difficult in cases where the technology is only in its first stages of its deployment [74]. Engaging people with new technologies has proved to be more difficult after poor experiences in the past. Even when new or additional information is available, a lack of trust can be more important [75]. At early stages of deployment, perceptions of fairness particularly influence trust [76,77].

People, in general, tend to be more cooperative when they have information about how others would behave [78]. Moreover, we know that people use others' outcomes as a reference point with which to judge whether their own outcomes are fair. Information provision, in this context, thus has an important role to play if collaborative behaviours are to be encouraged, but clearly the content of that information will be critical. The kind of information about energy storage, how this should be delivered and who should deliver it was identified by the participants as a notable feature of the energy culture (as mentioned above). Initiatives relating to the promotion or deployment of community energy storage will need to be aware of these dilemmas and that they occur in a context of deep social uncertainty [79] vis a vis community members' knowledge and assumptions of how proximate others (their neighbours) will use the energy that they may be asked to share. Trust in the actors involved will play a pivotal role and informational strategies will need to account for this too. The perceived risks of using a technology can also influence expectations [65] and also potential uptake. As in other studies assessing renewables technologies [13], here, perceived risk had some (albeit minor) impact on perceptions of batteries at the household level. Such perceptions should not be overlooked.

6. Conclusions, recommendations and reflections on the ECF

Using exploratory focus groups and the EDF as an explanatory lens, we have sought to identify and characterise aspects of the prevailing domestic UK energy culture that raise issues for acceptance of domestic and community-level distributed energy storage. The overall approach is consistent with the actor-centred approach that the ECF takes to culture [7] by which is meant that culture is created and recreated through people's actions *in relation to meaning*. Moreover "Culture is public because meaning is" (Geertz, 1973) [80]: perhaps not always, and perhaps the sizes of the publics vary, but meaning is often shared and this is the case here.

Hence several focus groups held in the city of Leeds (UK) with members of the public with and without experience of photovoltaic (PV systems found that differing experience with PV had little influence on perceptions of hypothetical domestic and community scale battery storage. This stands somewhat in contrast to other studies regarding people being more positive or having stable opinions about new technologies in the post-installation stage and over time [11,21]. The reasons for this contrast lie in the specific circumstances of our PV-experienced group, who did not receive the reduction in energy bills that they expected. This was not because of any failure in the PV systems, but because of the institutional arrangements: their housing contracts with the local authority did not take account of energy generated by the PV. The benefits were thus socialised rather than individualised. While this may seem a case-specific circumstance, it also may not be and illustrates how attempts to deploy low carbon technology (be this PV or batteries to smooth patterns of grid demand and supply) risk being derailed by non-technological factors.

This aside, attitudes to domestic scale battery storage were found to be generally positive, although people did need to be given convincing reasons for their hypothetical installation. Once these were accepted, then despite the hypothetical nature of the exercise, people engaged meaningfully in discussing how and where they would deploy the batteries, as well as the issues of concern to them. Notable among these

was the issue of children and young people thwarting attempts to manage or reduce energy consumption. Also important is what appears to be a norm of wanting to preserve the option to act with some autonomy, whether or not that option is actually exercised.

While we haven't explored issues of *national* cultural traits here, the above issue of autonomy would be worth exploring in further cross-national work. We know that cultural traits can differ markedly in terms that include those related to autonomy [6] and that there have also been attempts to connect these traits to attitudes to low carbon energy [7]. The issue of autonomy per se also merits closer examination, as it is not clear exactly what individuals' priorities were in relation to this value – and – more importantly – what contingencies might surround it. It is unlikely that autonomy would be seen as desirable at any cost.

Relatedly, attitudes to community-scale battery storage were strongly sceptical when notions of sharing were involved and it is clear that very careful institutional design and information provision would be required to secure acceptance of such schemes – at least in the UK or locations with similar cultural traits. Participants anticipated a tragedy of the commons situation (without using the term), and would want reassurance that sharing would be on a fair and equitable basis. Of course, this raises the question of what would be considered fair and equitable, and we see this too as a key direction for further research. Given that people also had some difficulty accepting the need for energy storage at all, this too merits further work, particularly regarding how the need and its benefits might be best communicated before any adverse impacts of renewables-based intermittency become apparent. At the same time, it should be noted that people usually come to situations with attitudes formed through prior experience and in this case, particular experience with and perceptions of the local authority have shaped perceptions (fairly or unfairly). Again this is not an easy context in which to intervene in terms of successful communication and expectations management.

Regarding the ECF, we find that the framework functions as a useful heuristic, allowing us to organise and reflect on a wide range of factors in a way that is more inclusive than a psychology-only perspective [8]. The idea of there being multiple possible cultures in relation to energy use – and the observation of these at different scales – also helps to stimulate thinking on further research directions in terms of how different households, demographic segments, nationalities and entities may differ in terms of the nexus of norms, attitudes, behaviours or practices [46] and material experiences. These cultures will likely need different types of communication, informational, institutional and contractual offers, given likely differing responses.

A further value of the ECF - regarding which we would concur with its originators [8] – lies in its comprehensibility for non-social scientists. For more specialised and narrowly specified forms of analysis, we would defer to the psychological and sociological perspectives that the ECF draws upon. Here we have only begun to open up some of the public perception issues that might be explored in relation to energy storage, but offer a first understanding of a topic that will likely become increasingly important as renewable energy deployment accelerates and DES infrastructure and policy is itself deployed as part of power grid management strategies.

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