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What Makes Decentralised Energy Storage Schemes Successful? An Assessment Incorporating Stakeholder Perspectives

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Abstract: Decentralised energy storage is increasingly seen as being important for decarbonising local energy systems and the global market for such systems is expected to grow significantly. Several studies have looked into the technical development of decentralised energy storage systems, as well as examining how different business models can enable them to capture a variety of value streams. Recent work has also explored public perceptions of energy storage, yet so far there has been little focus on how the different dimensions affecting deployment interact together. Here, we present the result of a deliberative workshop which gathers stakeholders' views and addresses how the interplay between these three dimensions affects successful deployment. Our approach is holistic and integrative and utilises a participatory decision-making methodology. The findings of the research add substantially to the understanding of how decentralised energy storage schemes should be implemented. The research reveals that there are many aspects that can help to either facilitate or impede a storage scheme, and stakeholders perceive multiple ways to engage with the deployment of the technology. We show that the following four principles could contribute to achieving success: maximizing simplicity and clarity; managing expectations, uncertainty and risk; generating benefits for the community; and the involvement of trusted actors.

Keywords: decarbonisation; urban energy systems; stakeholders; technoeconomic; business models; public acceptance

1. Introduction

1.1. DES Technologies and Urban Energy Systems

Urban energy use is increasing rapidly around the world, with cities and other urban areas leading the way in deploying clean and decentralised energy solutions [1]. Globally, initiatives such as the C40 Clean Energy Network are promoting a wide range of local-scale renewable energy technologies to supply electricity to the residential, commercial and industrial sectors [2]. In the UK, the UK100 network of local authorities have pledged to shift their towns and cities to 100% clean energy by 2050 [3], and many more councils are declaring climate emergencies, often with the rapid expansion of clean, decentralised energy at the heart of their plans [4].

To meet these ambitions, decentralised energy storage (DES) options (such as small-scale battery storage) will need to be deployed at a much greater scale in order to integrate higher levels of variable renewable generation into distribution grids and support decarbonisation targets. Energy storage provides flexibility to the energy system [5] and offers demand management services to local communities [6], businesses [7], and network operators [8,9], especially where storage options are co-located with small-scale generation. As a result of these benefits, DES is receiving increased attention from local governments [10–12] and is often part of local strategic energy agendas [13,14]. This is part of a wider trend of local governments responding to the decarbonisation agenda by taking a more active interest and role in the generation and supply of energy, where previously centralised actors have led the way [15].

DES can take the form of either electrical or thermal energy storage. Thermal storage could be particularly useful to address the challenge of decarbonising heating and cooling [16], however in this work we focus on electricity storage and its ability to support the integration of distributed renewable energy sources in towns and cities. In the UK, the market for domestic-scale electricity storage technologies has developed rapidly over the last few years. This expansion has been driven by a number of factors, including the uptake of domestic solar PV, falling battery costs and new consumer business models. As a result, a large number of companies are now in the market, and several pilot schemes have been completed, helping to build an understanding of the value that battery storage can bring to users in practice [17]. In addition, global projections for the DES market as expected to increase significantly [18] and in order for this growth to be realised without creating distrust in the technology through poorly implemented schemes, the views of stakeholder and users will be critical.

We are therefore heading towards new urban energy system configurations, in which different options will be selected based on local contexts, and where sources of energy supply are being brought closer to the consumer, meaning that changes to the social and technical elements of the system will need to go hand in hand [19]. As a consequence, the further development of the energy storage market in the UK, both at community and household levels, will be dependent not only on the technical development of batteries, but also on the motivations and expectations of the different actors that will be involved, such as local government, technology providers, scheme developers, housing associations, and the public (as homeowners and tenants). These different actor groups will, of course, come with different and particular needs and expectations, and will relate to different aspects (technical, economic, and social) of the individual projects. Implementation of DES schemes will therefore need to address multiple issues across these different aspects.

From recent techno-economic assessments, it is known that if DES systems are installed alongside local renewable energy installations in the UK, such as home batteries with rooftop solar PV, and operated according to existing flat rate or Economy 7/ 10 tariffs (Economy 7 is an off-peak electricity tariff provided in the United Kingdom, that provides cheaper electricity for seven hours during the night. Economy 10 provides ten hours of off-peak electricity split between night, afternoon and evening; which makes it particularly useful for storage purposes), considerable opportunities to provide services to system operators and network operators will be missed, and the storage asset may not be profitable. Recent modelling has shown that home batteries operating according to time-of-use tariffs significantly miss out on the potential for peak shaving, and can even cause a "rebound peak" as large numbers of storage systems commence charging at the start of low tariff price periods [20]. This shows the need for smarter storage control, ideally with greater input from network operators. Even when used in community renewable energy schemes, energy storage remains prohibitively expensive if it is not used to provide grid or network services [21]. Similar issues around the high cost of energy storage schemes and the need to stack a variety of revenue streams to make them viable have been identified in other countries [22,23].

Successful business models need clarity on both the market arrangements in place and an appropriate regulatory framework for investment decisions to be made [24]. Moreover, ownership structures and contractual arrangements need to be clear so that it is easier to identify the optimal allocation of resources. Models that have been studied include those appropriate to both individual households and to groups of households or a community [25,26]. Business models need to account for the commoditisation of storage, appropriate location, and social and environmental impacts [27]. Here, market arrangements and regulation will heavily constrain which business models and ownership structures generate the best outcome for all the stakeholders involved in the deployment of DES.

However, for the business case to be viable, the technological development and business model innovation also need to consider the perspectives of end-user and consumers. Recent research shows that people's willingness to invest in or install technology at both the household and community level is shaped by a range of technical, economic and social factors [17,28,29]. Therefore, the deployment of DES needs to take account of the public's views on these issues.

While previous research has provided insights on the technical and economic performance of DES, likely business models for creating value, and the perceptions of the public, there is little work to date that has been carried out to understand how these elements might combine to shape the implementation of DES schemes by the range of stakeholders that will need to be involved. One exception is the work of Acar et al. [30], which used a multi-criteria decision-making method to explore the relative importance of economic, environmental, social and technical issues to energy storage deployment. Our work adds to the evidence base about the interplay between a range of factors that the literature has identified as being important to DES deployment.

1.2. Rationale and Objective of the Research

This paper is the result of an integrated research project that included collaborative activity with stakeholders, in which views on technology innovation, business models and public acceptance of DES technologies (batteries) were shared and discussed. Stakeholders were brought together in a workshop to explore the implementation of a hypothetical scheme to install batteries within households and in community ownership in a residential area in Leeds (UK) in 2018. The aim was to identify how such a scheme could best support energy provision to these households and what factors would be most important in deciding on the type of scheme to develop.

Based on these views, this research draws lessons on how the technical, economic/business and public perception dimensions should interact and complement each other for the successful implementation of DES in urban environments. This research aims to answer "*why, who, where* and *what*" is needed to deploy DES technologies successfully, and "*how*" to implement it better. In doing so, we hope to identify the barriers and possible solutions to unlocking the potential of DES schemes, bearing in mind the full range of perspectives from different stakeholders likely to be involved in the development and implementation.

2. Methodology

We followed a participatory approach to the design and implementation of the research, using aspects of deliberative workshop and decision theatre methods [31,32] to investigate the issues of deployment of DES technologies from an innovative perspective.

2.1. Background Material and Participants

The prompt materials for the workshop were generated by the paper authors and other researchers in a wider research project (see http://sure-infrastructure.leeds.ac.uk/c-madens/ for further information) Most of the work that informed the prompt materials has been published separately [17,20,21,24,28] and the prompt material themselves are presented in full in the supplementary material file.

Participants were selected to represent a range of stakeholders who were identified as being key to the deployment of DES technologies in urban areas. Local authorities are showing an interest in DES schemes as a way to meet a number of their energy goals, especially as owners of housing stock, and they will likely be crucial to implementation. Other important actors include technology developers, energy scheme developers, electricity distribution network operators (DNOs), private housing developers, and regional authorities. We invited participants from all these sectors and had representation from all stakeholder groups aside from a DNO.

2.2. Decision Workshop Method

The main purpose of the workshop was to share and discuss experiences and opinions of DES technologies, in an immersive and collaborative environment. Significantly, we wanted to provide insights from our research on the technical, business model and public perceptions aspects of DES deployment in order to encourage the participants to reach collaborative decisions about how they envisaged projects could be successfully implemented. We encouraged participants at the workshop to share perspectives from their own experience and to engage in discussion both on the insights from our previous research and perspectives from other stakeholders at the workshop. From the range of methodologies to capture views and opinions, we combined the traditional setting of a deliberative workshop [33] with the evidence sharing and collaborative decision-making features of a decision theatre [32]. Arizona State University (ASU) originally developed the decision theatre prototype with the idea of visualising solutions to complex problems by employing technologies like high definition displays, computer systems, and tools and personnel [32]. This approach is helpful to make decisions under uncertainty and in a complex environment and to engage researchers, and community leaders [34,35], in areas such as security, sustainability or education. In the decision theatre, the data and/or a case study are used to simulate a situation and provide evidence that might inform decisions. The stakeholders involved then discuss the issues surrounding the situation and come to a decision [31]. The method allows participants to explore the process from the perspectives of the other members of the workshop, alongside their own. From this original approach, we modified the method to include elements of the deliberative workshop method (a small number of participants, in-depth discussion and exploration of the topic, developing their views to reach a common end position) [36,37] while bringing in evidence and data from our previous research that would be useful to visualise solutions.

During the workshop, we aimed to capture multiple perspectives and identify differences between stakeholders while exploring DES possibilities within a specific case study. The case-study scheme was left relatively open to enable flexibility in the discussion while giving enough detail to focus on the scope of the participants' discussion. The hypothetical case-study described the installation of batteries in 20 residential homes in Leeds, UK, with ten properties having solar panels and ten properties without solar panels. The households were family dwellings in both privately-owned and social housing estates. At a technical level, the size of the PV panel varied, but most were 2.5 kW installations and had around 6–8 panels. The batteries were intended to benefit both types of homes (Figure S1 and S2 for further details of the information given to workshop participants). The location of the battery storage could be either in homes or at the end of the street (community storage). A similar arrangement was previously tested with the lay public during focus groups [28].

For this research, the arrangement of the room and the prompt materials differed from those originally designed by ASU [32]. We used computer displays and visualisation of data and complemented this with relevant printed material when participants were required to do specific exercises (see Section 2.3 and 3). On the day, seven participants representing different stakeholders from a local authority, energy technology developers, a commercial housing developer, an energy supply company, a combined/regional authority joined the workshop (there were three last-minute dropouts from other organisations). This number allowed us to have an in-depth discussion and greater understanding of the subject, as expected from this type of methodology [38,39]. The participants were divided into two mixed groups for the workshop sessions containing different levels of expertise. Four researchers facilitated and documented the sessions and deliberation processes.

We recognize that the small number of participants, and the focus on scenarios based on a UK residential area, limit the generalizability of the results. However, the number of participants was appropriate to foster and enhance in-depth discussions and also to create a deliberation environment for the stakeholders. We were, unfortunately, unable to secure an attendee from a DNO, meaning that their views are not directly reflected in the results. Nevertheless, many of the workshop participants had experience of working with DNOs, and their involvement was mentioned at several points during the discussion.

UK modelling results were used because the participants are based in the UK and all their expertise and experience is set within the UK context. As the focus of the workshop was on the deployment of DES in residential areas, the participants were chosen on this basis.

It is not the purpose of the deliberative decision-making methodologies to produce fully replicable results. Instead, our intention was to explore different plausible options for DES deployment, based on stakeholders' preferences. Acceptance and deployment of new energy technology is mostly context-dependent, where regulations, policy options and public preferences play a determinant role for future deployment [40,41]. We therefore aimed at gathering views that are relevant to the particular context explored, rather than looking for results that are completely generalizable. Furthermore, we increased the robustness of the research by integrating methods and analysis from different disciplines. As a consequence, the conclusions of the research could be applicable to other contexts and we hope that our research will encourage others to explore similar issues in different countries and situations to identify where commonalities and differences exist.

2.3. Description of the Workshop Sessions

Stakeholders were organised into two groups and the workshop was structured in three sessions; every session comprised a series of research questions and lasted no longer than 75 min/session. The content and any instructions for activities were piloted before the workshop, to test that language was understandable at the expected level of expertise, that the instructions for the participatory tasks were clear, and that every issue was covered openly to encourage unbiased dialogue. The research was approved by the relevant University of Leeds Ethics Committee. Detailed written notes and audio-recordings were taken for all sessions. Recordings were anonymized and transcribed for analysis.

2.3.1. Technical and Economic Aspects

The first session was guided by the research question "How should decentralised storage systems be deployed in urban environments?". We expected the discussions to cover aspects such as improved self-consumption of solar generation, deferral of grid infrastructure upgrades, and the distribution of costs and benefits. The session was structured into two parts and covered: 1) the motivations for involvement and the pros and cons of DES, and 2) tariff options for a combined solar PV and battery scheme.

Organisational Motivations, Pros and Cons

In the first part of Session 1, the groups were asked to discuss their organisational motivations for wanting to see the development of schemes involving DES (though we recognise that participants and organisations may have hidden agendas that would not be elicited in by the workshop). The discussions were guided towards issues related to energy inequality, energy bills, community engagement with energy issues, greenhouse gas emissions, and air quality. Participants were then led through a discussion of the potential benefits and adverse effects of deploying battery storage within urban environments, and which stakeholders they believed would be impacted both positively and negatively.

The participants were shown a small number of slides featuring typical solar PV output and electricity demand profiles over 48 h for a house with 2 kW of rooftop solar PV, the net demand profile (i.e., demand—solar PV output) of the house, and the net demand profile of an illustrative group of 100 houses with solar PV. These are shown in supplementary material Figure S1. The groups were asked to discuss the patterns of net demand and what they mean for the motivations, benefits and drawbacks of DES as discussed earlier in the session.

Tariff Options for Solar PV and Storage

The second part of Session 1 focused on a set of possible tariff options for households with solar PV and a home battery. It involved the presentation of a set of scenarios for typical houses with solar

PV. Firstly, example power profiles for a single house with solar PV and battery storage were presented for two scenarios. These showed how the limited capacity of battery storage systems could mean that peak grid export is unaffected by the presence of storage under the current regime of flat-rate tariffs, and how an incentive to charge in the middle of the day could reduce peak export, protecting the electricity network.

The participants were then shown bar charts of the average peak export and solar self-consumption in residential areas with high penetrations of rooftop solar PV (Figure S2), for four different scenarios. One of these featured no storage and a flat rate tariff (i.e., the status quo), and in the other three, each house has battery storage. These were: flat tariff, where storage is operated to maximise self-consumption of solar PV; export limit with flat tariff, whereby storage is operated to limit grid export to no more than a certain level, e.g., 60% of a household's rated PV capacity; and coordinated control, with storage operation planned using an optimal charge/discharge scheduling algorithm [6] having the sole objective of minimising peak export from the entire area.

The groups discussed the solar and storage tariff options, including whether self-consumption or peak shaving should be prioritised, and the acceptability of new types of tariffs.

2.3.2. Business Models

The research question that led this session was "Which business models would be best used for domestic energy storage projects?". The session was structured in two stages. First, we organised an open discussion about feasible business models for domestic energy storage from the perspective of the participants, i.e., What has/has not worked in their experience with storage, solar and/or similar initiatives? In the second stage, we provided each group with a partially completed business model canvas based on the energy storage case study [24]. Our business model canvas focused on several important components in order to streamline the complexity of the task presented and retrieve the key information required from the stakeholders. To meet this aim, the first three components were specified within the case study: 1) the problem (tackling climate change, while improving the economics of renewables and addressing fuel poverty); 2) the solution (solar PV and storage system that can access revenue stacking); 3) the end-user (both social housing and homeowners). The subsequent four components were left blank for the stakeholders to complete in small groups following a short presentation on business model canvassing: 4) unique value proposition; 5) cost streams; 6) organisations; and 7) revenue streams (Figure S3). Participants were asked to complete a series of tasks. First, each group brainstormed and captured what they saw as a unique value proposition and key organisation(s) needed for the implementation of the DES case study. Secondly, participants were asked to identify cost and revenue streams to/from the customers and organisations. This task helped to promote a discussion around who will pay for storage and who will benefit from the various revenue streams that could be generated from its implementation.

Finally, both groups briefly presented their ideas to the other group, leading into a general discussion around the best business models for domestic energy storage projects.

2.3.3. Public Perceptions and Acceptance

The research question guiding this session was: *What elements are needed to engage households with DES technologies*?

This session consisted of two parts. In the first one, each group explored and discussed the different factors that could determine the public acceptance of DES technologies with no restrictions. Stakeholders were provided with a table to be filled in with different options i.e., structural, social, economic factors (Figure S4).

In the second part, participants reflected both at individual and group level, focusing on three particular determinants: trust, fairness and expectations. These factors were highlighted as drivers for the acceptance of DES technologies in previous public perception research work [28]. Stakeholders were shown different quotations (Figure S4–S7 in the supplementary material) that were drawn from previous research on public perceptions of DES technologies.

The quotation about trust was:

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.

The quotation about fairness was a dialogue*:*

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: *If 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.*

Finally, the quotation about expectations reads:

I'd like that [being more involved with the deployment of energy storage] 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? (…)

The quotations were displayed on the screen, and each stakeholder was given one big card that included each of them (Figure S8 and S9 in suplemental material). gave input on *who* should deal with the issue addressed by each quotation. After a 15 min discussion on individual answers, the stakeholders reflected on *how* that particular issue could be solved and what resources would be required.

3. Results

This section presents the analysis of results obtained from the workshop; first on the technical and economic aspects, followed by the business model case, and finally, the stakeholder views on public acceptance. Figure 1 summarises the main results from each of the sessions.

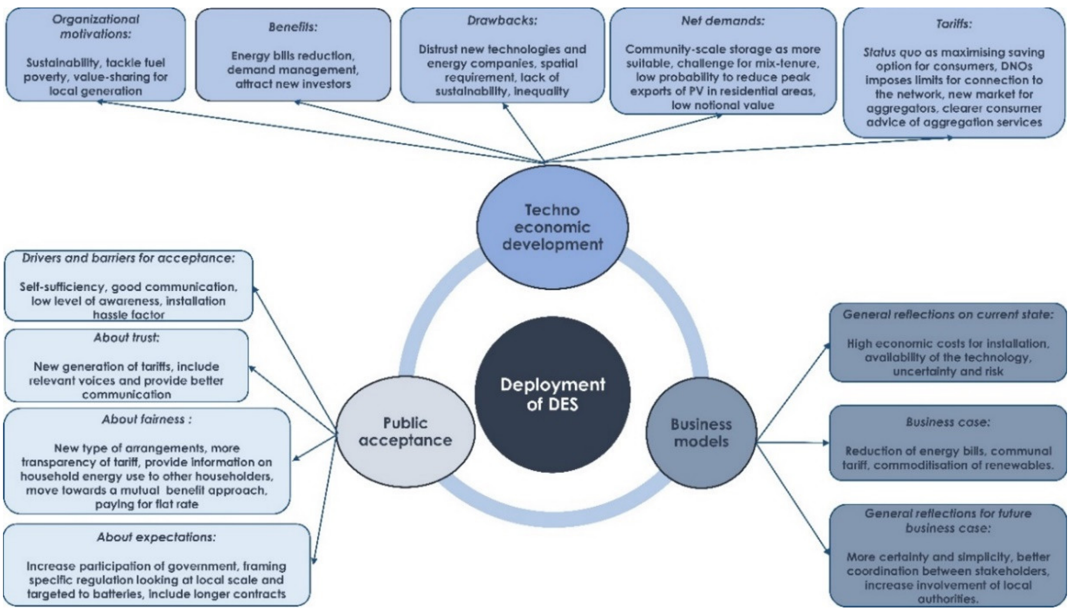

Figure 1. Summary of results.

3.1. Technical and Economic Aspects

3.1.1. Organisational Motivations

It became clear that there is a range of different reasons why stakeholders might become involved in storage projects. Participants representing local government discussed how they hope that DES might help to meet targets for CO_2 emissions reduction and air quality, reduce energy bills, tackle fuel poverty, reduce inequality, and help disadvantaged council tenants. The importance of reputation was also discussed, and the need for cost-effectiveness and equality. While talking about taking advantage of low carbon opportunities, one local council officer said: "We want to see that in an inclusive way. We don't want people paying over the odds for this stuff".

The groups talked freely about their motivations. A participant from a property developer explained that they want to create places where people want to live, make their developments sustainable, renewable and cheap, help to build a community, and create a long-term income. One participant from an energy company explained that the old supplier model is dead and that they are trying to reinvent the energy supply model. The participant explained that the company has a business which builds and regenerates large numbers of homes each year, and they foresee that solar PV and battery storage could be installed during this process.

A participant from a community energy company explained how they are motivated to use storage in community energy schemes to allow communities to maximise their use of the local renewable resource, keeping the value of local generation within the community. However, the participant noted that investment in storage is much lower down their list of priorities than other actions to maximise that value, such as encouraging demand response. One participant also explained how storage in a community energy scheme allows the value of local generation to be shared more equally amongst scheme members, rather than concentrating it and allows communities to offer demand flexibility to a range of stakeholders, primarily suppliers but also system and network operators.

3.1.2. Benefits and Drawbacks

The benefits of DES mentioned by both groups were broadly similar and covered some familiar themes. They discussed how storage could reduce energy bills and so provide more disposable income, benefiting customers, communities, and local authorities. One participant noted that storage could also provide a return on investment for asset funders. Positive environmental impacts of storage were identified by both groups, with one group explicitly discussing climate change and air quality. The other group discussed how storage could lead to larger renewables installations and alleviate constraints on renewable exports, allowing more renewables on the grid. Participants noted that storage deployment would attract investment and stimulate economic growth in a region. They also discussed how storage could offer increased energy flexibility and demand management, providing benefits to the system operator, network operator, and supplier. Improved security of supply for rural communities was also mentioned.

When considering who can benefit from storage, one participant noted that houses with roofs which are suitable for solar PV are sometimes nearby houses whose roofs are not suitable. Reinforcing this, and hinting towards the motivations for community energy, virtual power plants, and peer-to-peer trading, a local council officer says: *"We are looking at a project in back-to-backs* (back-to-backs are terraced houses that were built to the front and back of a spine wall running down the terrace, so the houses had no rear windows and no back gardens). *I was thinking, for every south-facing row of back-to-backs, you must have a north-facing row".*

There was little overlap between the drawbacks identified by the two groups, with the only common theme being a tendency to distrust new technologies, energy companies, and councils as landlords. One local council officer explained how a lack of understanding of new technologies could cause people to think that others will take advantage of them.

This lines up with previous findings [28], where focus groups involving social housing tenants with rooftop solar PV found that perceptions of equality and fairness are particularly important.

Considering potential customer concerns from the perspective of a project developer, the representative of a battery manufacturer explains: *"Benefit is the key there. An unequal distribution of benefits is potentially probable. We've fitted it in your house and we're using the asset, but what benefit do you see?"*.

Speaking on this, a participant from an energy company explained how they believe it is important to show customers a clear outcome, such as a reduction in their energy bill that was promised at the outset.

When one group was asked what negative aspects and concerns have emerged in storage projects that they have been involved with, participants mentioned spatial requirements, access during installation, flashing lights, and noise from cooling fans. Inequality came up again as an end-user concern, with some social housing tenants getting more benefits from solar PV than others because of the angle of their roof. Other concerns included the uncertainty of solar output and long-term government policy, and the sustainability issues around lithium for batteries. The participant from the community energy company noted that a "*fit-and-forget approach*" for storage can be viewed as a positive, but that it does not promote energy literacy or behaviour change around energy consumption.

3.1.3. Net Demands of Houses With Solar PV

As explained in the methodology, the participants were then shown typical patterns of electricity demand and solar generation in residential areas and asked to discuss these and what they might mean for the motivations, benefits, and drawbacks discussed previously. After an explanation of how clusters of houses with solar PV can cause export peaks to exceed import peaks, one local council officer talks about a previous residential solar PV project: *"That was the challenging part, of that it was* [the DNO] *that ruled out solar on some of the estates because these are the kind of estates that were knocked up in the '50s and '60s on the cheap, including the grid. (…) If we put in a whole load of panels on that estate, that bit of the local grid would have just fallen over"*.

Having noticed how large numbers of houses have a smoother electricity demand profile than individual houses, the community energy group participant suggested that perhaps community-scale storage systems make more sense than individual systems. The participant went on to say that a community storage system would require everybody to buy into it. A local government officer explained that the council could, in theory, impose community energy arrangements for their social housing, whereas doing this in a mixed tenure estate would present a more significant challenge. He also suggested that a community energy system could be part of the offer in new build developments and cited a recent development case. In the other group, the potential advantage of a community storage system was immediately highlighted by the participant from a community energy company, noting that rapid response to individual household demands could be complicated and cause substantial degradation.

Considering the coincidence of solar generation over large areas, one participant explained that the notional value of exported electricity could be very low (or even negative [42]) if there is a large amount of solar power available. It was highlighted that there are normally no mechanisms in place for rooftop solar PV. The effect of EV charging was also discussed, with one participant saying that it is unlikely to reduce peak exports of solar PV in residential areas as vehicles are typically away from homes during the day and charged overnight.

3.1.4. Tariff Options for Solar PV and Storage

In the final part of Session 1, the participants were shown the trade-off between using storage to maximise solar self-consumption or minimise peak solar export, using results from our previous research [20].

It was immediately noted by one of the groups that the status quo is the option that maximises savings for consumers with solar PV and storage because solar self-consumption is maximised. A participant from a community energy company explained that DNOs could use connection agreements to impose limits on the inverter capacity for anyone connecting solar PV to the network.

They stressed the importance of certainty and hard limits to network operators, who are wary of the possibility of a storage system not charging because of capacity constraints or demand patterns.

One theme that came through strongly in the discussions was the need for simplicity. One participant sums this up: *"I just can't imagine anybody even beginning to want to try and understand this. They'll just go, What's your cheapest? Just tell me what the cheapest is." (…) I just can't see anybody buying into this level of complexity. (…) Do they want the higher levels of sustainability? Not really. They just want the best deal"*.

The potential for aggregators, storage developers and energy companies to offer grid services packages was discussed, and several participants noted that most consumers would prefer a simple, hands-off approach. A local council officer suggested that aggregators might offer a range of options, catering for different lifestyles and levels of engagement. They also stressed the importance of maintaining consumer choice and suggested that there could be a market for aggregators, with aggregator switching. This would require aggregators to be able to work with different storage systems, raising questions around regulation of DES and storage aggregation. Participants explained that there are some debate and uncertainty over the value of grid services, with customers concerned about whether they could be worse off by forgoing some solar self-consumption, and whether aggregators provide a fair return. Several participants highlighted the importance of providing clear consumer advice around aggregation services.

3.2. Business Models

One group suggested that the capital cost of DES is still too high to make an economic case. Experience shows that the costs of putting in place small pilot projects are often higher than the benefits delivered. While battery costs are expected to decrease over time, this not the case with the costs of installation and the inverters. Further concerns were highlighted about battery management; with instances of batteries being full when they need to store power, and depleted when power is needed.

The second group considered that uncertainty in costs and the distribution of impacts, the lengths of contracts—where payback periods are longer than contract lengths—and difficulties in arranging partnerships, are barriers to the adequate development of energy storage projects. This means that there can be low interest in an investment that is constrained by the payback period, which at the same times affects stakeholders' expectations on the business case. They also highlighted the role of psychological barriers, such as the level of expectations of the stakeholders. Sometimes a low level of familiarity by the customers can hinder deployment of energy storage. Finally, they highlighted the role of local authorities and the need for them to be more involved in energy storage projects, alongside a private developer.

The two groups then discussed distinct value propositions. The context suggested to the stakeholders included tackling climate change, the high number of households' in energy poverty in the UK and the high upfront costs of renewables technologies.

In one case, the business model was designed to be attractive to people living in a particular neighbourhood. It would include generation and storage, and the proposed tariff would generate a 10% decrease in costs. The second value proposition focused more on social housing and would offer a new tariff that would lead to a reduction in electricity bills for people in fuel poverty. In the case of the community/neighbourhood scale, the business model should ideally bring greater certainty, compared to current market arrangements. More certainty around energy costs would be useful, for example, following the rationale of fixed-rate mortgages (as people like certainty). Stakeholders suggested that tailoring the business model to a specific group and location can be a way to deliver greater certainty over costs. Another feature of the unique value proposition was around organisational arrangements and particularly the leadership of any scheme. For instance, if the business case involved the aggregation of batteries run by a manager, this would not require the local authority to be involved. However, the local authority could still be involved in creating an environment for that to happen. The general idea was that the business model should stand by itself irrespective of who leads it.

For the value proposition looking at social housing, potential organisations interested in this model could be the local authority, energy providers, installer and commissioner, energy supplier (they will be in charge of the relationship with the client), DNO, aggregators and third parties. The community model would include landowners, aggregators, energy retailers, community groups, and local authorities. The role of the local authority was especially highlighted as the actor in charge of creating the enabling environment and providing innovative ideas.

Different prospective roles and tasks were assigned to different actors during the discussions. For the model focused on social housing, the role of the energy supplier is relevant here, to provide the consumer relationship and metering arrangements that need to be in place. The aggregator could be a supplier or financer. Vulnerable customers must be prioritised in priority services registers (e.g. by DNO). The general view was that all the separate activities would need a high degree of coordination, and if possible, a way to integrate them all, so that it is easier for the user. For the community model, in terms of who should own the land or the property, stakeholders highlighted that it would not have to be necessarily a local authority, but it could also be the social housing provider. The role of the latter should also cover providing advice to new owners whenever a property changes hands.

Concerning the location of the social housing model, participants made clear that the scheme would not have to include council housing, but the scheme should be presented in a way that is appealing for investors to be commercially viable.

For the stakeholders, investing in energy storage entails risks. Expected cost streams for the social housing model were hardware costs (PV panel, inverter, battery, metering, anything done to lighting, potentially EV charging point), back-office systems (i.e., optimising software), commercial metering, installation and maintenance costs, Wi-Fi connection costs, replacement costs, reporting and billing costs. Some stakeholders also pointed out the planning permissions required for community systems, such as highways planning and building regulations. The community model would need a leading investor to be in charge of the capital investment and ongoing maintenance of the technology, as a way of simplifying the approach. Another layer about costs is that of the community scale generation, and stakeholders agreed that investors should be in charge of the main expenditure/payment for this case. All in all, the investment should come from the private sector as, at the moment, local authorities do not have a statutory role in energy matters.

In terms of tariffs, the idea would be to develop a communal tariff so the customer would pay less. This would need the support of the electricity regulator, OFGEM (National Authority for controlling energy prices and regulatory matters in the UK).

Participants felt it was difficult to predict what is going to happen with regards to prices. While a combined solar and storage model would give better self-consumption than solar on its own, the capital cost of the battery versus importing power from the grid could make the economic case weak. Possible solutions pass through having better communication with potential users and giving them the right information about the model they are going to be part of, so the consumer would have more clarity about what the investment will entail and would have as a return.

Sources of revenues could come from people paying their energy bills, but low bills would be the primary source of benefits for the tenants or homeowners, involving the energy supplier. The social housing model could be an opportunity for offering ancillary services at a national level and local level, avoiding peak energy charges (DUoS and Triads), and wholesale charges, income from the PV, or penalties for not offering services, savings to the supplier, was another potential revenue source. For the community model, the stakeholders mentioned that a potential source of investment could be crowdfunding. It is also an excellent way to engage the community but not in the early stages of the investment. Although the chances to be a realistic option are quite low, as they all agree. Currently, there is a low level of familiarity with energy storage among the population.

One local authority participant suggested a social model that could bring benefits to the household, which should be equally shared:

"(…) if you have opportunity for a household to make some money and for the stakeholder for example, the local authority to also benefit, and those benefits are fair, equally shared or fairly shared, and I think the important thing is that also needs to be explained very clearly at the very start".

Table 1 summarises the main elements in the discussion of the business models.

Table 1. Summary of results for the business case session.

Value Proposition	Revenue Streams	Cost Streams	Organisations
Social housing: reduction in energy bills, people in fuel poverty	• people paying their energy bills • ancillary services at a national level and local level • income from the PV, or penalties for not offering services • savings to the supplier	• hardware costs • back-office systems • commercial metering • installation and maintenance costs • replacement costs • reporting and billing costs • planning permissions required for community systems	• local authority • energy provider and supplier • installer and commissioner
Community/ neighbourhood scheme: generation and community storage, with a specific tariff for the model	• crowdfunding	• capital investment • ongoing maintenance of the technology,	• landowners • aggregators • community groups • local authority

While the value proposition and character of the business case were different for the two groups, there were some commons elements throughout the discussion: the importance of including local authority, the need for more certainty, and simplicity to reduce risks of investment. The resulting business model case was described as a community solar storage mode whose rationale would be to commoditise renewables, through an aggregator structure. In terms of users, there would be two options being social housing tenants and homeowners, both with and without PV, living in an urban area in semi-detached properties.

3.3. Public Acceptance

3.3.1. General Factors Affecting Acceptance

Self-sufficiency and the autonomy that DES can offer were highlighted as the primary aspects that could act as a driver to increased acceptance. However, views on potential barriers dominated the discussion. Perhaps surprisingly, only one of the groups highlighted cost as a barrier to engaging with the technology. The main obstacles were seen as being related to psychological and social factors.

Levels of awareness and familiarity of the type of DES technologies available in the market were highlighted as the primary barrier to acceptance. The discussions on how to raise awareness included improving energy literacy and how to help people understand the technology in real life. Ideas included combining non-energy, independent, and trusted voices or celebrity culture, with a neutral perspective (e.g. from academics). This low familiarity is not due only to a lack of information; it also relates to how much of a priority is the technology or the energy system in people's lives is. In the words of one local authority officer: *"Yeah, there are just too many decisions in life and that's another one you don't need"*

There is a lack of knowledge and understanding of how the technology works and what benefits may be derived. This is a real challenge. Therefore, people might ask themselves why they would want a specific DES technology in their household. The local authority officer explains:*"(…) The way I perceived this was not quite at the delivery stage. It was more a case of, do I want this or do I not want this? I'm sorry if I keep coming back to this, I don't think the person on the street really has any interest in this at all, so therefore somebody at the front door saying, "You want a battery?", and that person is going, "Why?"*

Providing good communication was seen as a plausible answer to this. To build knowledge around a particular technology needs a clear communication and language strategy; this could help developing trust in the technology and the actors around it.

Advocacy was seen as an action to consider. As such, a concerted effort needs to be made on simplifying the communication of the technology benefits and how these are tailored to the final users. This was highlighted in the case of community storage schemes, where it is more challenging to describe how the benefits are shared between households. Participants suggested simplifying the positive element as much as possible. One of the stakeholders mentioned consumers' experience with energy bills and how people often struggle to understand them.

There should also be long-term feedback on what the technology is doing and what benefits this can deliver and an engagement process with the users beyond the installation phase—for instance, having an organisation that provides accessible support and offers a flexible customer approach that can help people getting closer to technology.

The aesthetics of the technology and how it can be integrated into the household was mentioned as a side element. The discussion was around the hassle factor of the installation phase and the consequences for the household. This can put people off regardless of the financial benefits they could obtain.

3.3.2. Discussing Trust, Fairness and Expectations

The discussion revealed that the three elements represented by the quotes (Section 2.3.3) are interconnected. The first quote was readily recognisable as an issue of lack of trust. Stakeholders suggested that this could have been the results of a weak process of communication. The perception was that there should be more active communication between the council and the people involved in the scheme described in the quote. Another suggestion was directed toward the central government and their involvement in helping people understand new technology. The example was given by a local authority officer who compares the situation with the early deployment of solar PV when the government was supporting deployment with a feed-in-tariff. Then, the role of the government was helpful to increase the level of awareness, although nowadays there are people that are not so familiar with the technology.

> "*To some extent, back in the 1990s when solar hadn't taken off and people didn't really know much about solar, essentially, now, it's made itself. The government helped the feed-in tariff to be higher and sold it, and now we all understand it, whereas in the past—I think there are still people out there who don't fully understand solar*".

Along these lines, another participant suggested that to increase awareness and trust—not only on the institutional side—new technologies should go with a new generation of tariffs introduced by the government to be entirely beneficial for the new users. More broadly, stakeholders pointed out the need for a relevant voice to take the lead on trust issues, i.e., the Citizens Advice Bureau or an ombudsman. In line with this, another suggestion was to build a brand that could be recognisable and give trust; a non-profit organisation with a long history and good reputation would be well-placed to create one.

Discussions about the second quote on fairness revolved around the rationale of communal energy storage initiatives, and the necessary context to deploy the scheme. In addition to the situation represented in the quote, some other ideas emerged on *what fair means* in the context of community energy storage. Interestingly, the conversation gave rise to what is fair in these types of schemes. Some criticism arose about how the communal models are arranged, the logic behind them, and whether it is seen as equitable. The stakeholders suggested more transparency on the characteristics of the scheme and how this works to reverse this perception. A clear definition of what are the rules, alongside a statement describing which version of fairness is being pursued for a particular project, would allow people to decide for themselves if they are interested in participating based on whether they share the principles of the scheme. Some others suggested that giving more information about how much energy each individual is producing can also help targeting issues of unfairness. As well, being clear that people are subjected to the same rules and obligations might help change perception of inequity. A representative from the energy company stated: *"Yeah, and once everybody realises, if everybody knows that the others are playing by the same rules, then it's seen as fair or could be. It could be quite radical, but so long as the same applies to each individual and people are not seen as being treated differently"*

According to the participants, people generally have the perception that energy belongs to their individual spaces and households. It is, therefore, challenging to see a model where energy would belong to a community. However, they believe that different ideas of what *fair* is—for different households—is not incompatible with a successful deployment of DES as long as the benefits are the same. Therefore, whether one would trust a neighbour or not, should not influence whether these initiatives are accepted.

One of the stakeholders mentioned that as it is right now, communal is not necessarily linked to mutual benefit and sharing but to competition, as mentioned before. It is more about ownership than shared value. One of the central reflections was whether it is necessary to have a well-established community to implement a storage scheme. One of the local authority officers, explains the idea of competition and the current rationale of the model according to his view: *"You need transparency, and I think this, unfortunately, is the way it is. It's an unworkable model. People feel it's inequitable because people aren't worrying about how much they're paying. They're worrying about people doing better than them. Whatever we might think, there's an element of that in all of us, and therefore, it's an unworkable system. (…) you've got to say to those two ladies or say to that female one, no, it doesn't work like that. Let me say, that is just not what happens. It is that we're all in it together and there is a tariff. That's why we've said a few times today, haven't we, you could try and keep things simple?"*

Here stakeholders pointed out that the role of the scheme operator (or whoever provides the service) is crucial to guarantee that the system is fair. For example, one suggestion to avoid situations of unfairness was that instead of paying for what they produce, people would be offered a flat rate.

Finally, the third quotation generated a dialogue about the actors involved in deploying energy storage and some technical and structural issues around it.

The role of the government shaped the conversation in both groups. As the participants highlighted, at the moment, there is no explicit policy or regulation regarding battery storage, and there are no measures in place to promote its adoption. A general perception is that the market is pushing things forwards and is moving faster than government regulation. Stakeholders suggested to look at the local scale; energy storage is an opportunity to provide local balancing of the overloaded grid and the constraints that come with the renewables. The role of the DNO was addressed too. More participation and involvement should be expected from them, as they are ultimately benefiting from storage if it means less power being exported to the grid from household PV systems.

There is also an issue with the timings of contracts concerning big energy infrastructure and the payback periods for small investments. A local authority suggested that current contract periods are too short for incentivising new productions of batteries or another type of energy infrastructure. Below is the reflection of one local authority officer: *"I suppose they would say, if the solution is within the house (…), in terms of energy investment, generally speaking, having no policy makes investment really difficult. (…) So, nobody is building big batteries anymore because they've got 18 months, the contract, and that's all they've got so they're not going to do it. Nobody's going to build a power station. No one is building power stations because why should you?"*

The lack of clear legislation from the government can be counterproductive as DES investments need some support to be appealing for investors to move forward. Current payback periods on DES mean that it is challenging to encourage people to put money down. Stakeholders wanted more clarity on the topic; they proposed to look at the experience of other European countries as examples.

4. Discussion

This research generated results from a deliberative workshop discussing elements shaping the deployment of DES in urban environments. Following the logic of the implementation of the scheme and around decision processes in developing DES, we identified both drivers and barriers for its implementation from the techno-economic, business and public acceptance domains. Here, we discuss factors that affect the choice of an appropriate DES scheme, the value that it can provide different stakeholders, as well as lessons for future implementation.

4.1. Choosing a DES Scheme: Why, What and Where?

The initial discussions revealed a wide range of economic, environmental and social reasons for *why* participants were interested in being involved in distributed energy storage projects. Most of these reasons were related to opportunities and challenges that are arising due to changes in the urban energy system, particularly the expansion of distributed sources of renewable energy generation or as a response to sustainability challenges and climate change requirements. Therefore, motivations to deploy DES respond to the current environmental and social challenges deriving from the low carbon energy transition [43] and as an answer to the current UK decarbonising strategy [44–46].

The expectations of *what* DES can deliver are very diverse and meeting them will depend significantly on the extent to which the technology can help catalyse positive changes on the broader energy system. The benefits identified range from savings on electricity bills to households (although the economic case is not always compelling [47,48]), through alleviating constraints on the local distribution grid [49] to helping meet climate change targets [50]. However, participants also cautioned that a lack of trust in the technology itself and those organisations developing DES schemes could be a substantial barrier to uptake, which has been already shown in several studies examining public perceptions of DES [17,28,51]

The picture was further complicated in discussions around *where* DES technologies would be most suitable. Here the conversation highlighted multiple options, including installing a battery in a single household or as a community scheme serving a street, retrofitting them in an existing housing development or integrating them as part of a new build housing project and the benefits from installation in owner-occupied housing, as well as social housing.

4.2. The Value of DES: Who, How and When?

Discussions around *who* would gain from DES reflected the multiple potential benefits and included householders, the wider community, local authorities, house builders and energy companies. The need for a clear value proposition for a particular DES scheme was highlighted. Particularly the need for a better understanding of the distribution of risks [52] and rewards to scheme participants. Once again, this links to the importance of managing expectations of the different stakeholders from the outset [53,54]. Participants also highlighted reputation as being of key importance, meaning that the introduction of DES would need to be seen as leading to fair and equitable outcomes for those involved. Furthermore, for some stakeholders, energy storage remains a relatively low priority compared to other approaches, such as promoting greater demand response.

Much of the workshop discussions centred on *how* practically to develop a viable DES scheme. Here two issues stand out. Firstly, the upfront costs of DES are a significant barrier to implementation[47]. Many existing pilot projects are not economical on a commercial basis and, while the costs of the batteries can be expected to fall [55], other elements such as the cost of inverters and installation may not. This points to the importance of having an appropriate regulatory system [56] and finding the right business model to finance the installation of DES. Key elements highlighted were the desirability for private sector actors to fund the upfront costs as this would be difficult for both households and local government, the need for certainty around cost and revenue streams and the likelihood that organisations such as aggregators would need to be involved in accessing revenue streams associated with providing ancillary services to the wider energy system. The second issue was around the need for a simple proposition that could be clearly communicated to consumers. This implies better defined roles for those involved in the deployment of DES schemes. Here trust is key [17] and communications with the public would need to come from a trusted source. Participants felt that public and voluntary organisations, such as local authorities and those providing citizen's advice, would be appropriate.

The question of *when* DES projects should be developed was not explicitly addressed during the discussions. However, a number of factors point to the likelihood of growth in DES projects over the next few years. These drivers include the rapid increase seen in distributed renewables, such as PV (up almost 40% in the last five years [57]), fresh impetus given for local decarbonisation action by the climate emergency declarations of UK local councils, many with net-zero carbon targets of 2030 or even earlier, and the interest of stakeholders demonstrated by their attendance at the workshop.

4.3. Lessons for the Future Implementation of DES

The multiplicity of views and options highlighted by this research show that there is no one, single, successful approach to the implementation of DES in urban environments. This stems from the variety of needs and interests that surround an energy technology such as storage. Energy storage is highly energy system dependant [58], and every energy storage technology belongs to a broader sociotechnical system. Different cultural patterns and lifestyles favour preferences for different technologies and innovation [59,60]. Decarbonising processes should be tailored to the specific context, as acceptance of new energy technologies is not a one-size-fits-all solution. There is also room for both private and public actors to have an important role. A clear understanding of this context, including the potential users of DES, their needs and previous experiences with energy technologies, can help lead to successful implementation.

Our discussions revealed that any potential DES scheme has many facets associated with it, and the following four principles could be instrumental in delivering success:

- The need for simplicity and clarity
- Managing expectations, uncertainty and risk
- Generating benefits for the community
- The involvement of trusted actors

A clear message coming from the workshop was that the deployment of DES in homes or the community must take into account the needs and concerns of householders, and that simplicity and clarity are both key to this. The value proposition must be straightforward and easy to understand, with clear ongoing feedback on how well the storage system is performing in terms of providing a financial return or increasing consumption of on-site renewable energy in order to build trust. Any scheme also needs consumers to feel that it is fair; this relates both to the distribution of benefits between businesses and consumers, but also, for instance, between different groups of consumers in a community scheme.

The need for simplicity was particularly evident when participants discussed potential tariff options to enhance the value of DES by providing support services to the local distribution network. There exist several different options in this area, including enforcement of maximum levels of peak solar PV export and coordinated control of storage systems. However, participants generally believed that an aggregator model would be best, as long as households understand and accept the distribution of benefits, and get clear feedback on the performance of the service. There should ideally also be the option to switch aggregator in a similar way to switching supplier, but this would require increased levels of regulation and standardisation.

A second significant challenge with the complexity inherent in a DES scheme is uncertainty. Uncertainty is a common feature in any energy technology innovation process [61,62] and the associated investment [61,63]. For the participants in the workshops, a key area of uncertainty surrounded the best organisational structure for developing a DES scheme. Two divergent visions were discussed. One approach would be to take responsibility and control away from the household and place it with investors/developers who would finance the scheme and recoup their costs from the revenue generated. Householders would potentially benefit through regular payments or lower energy tariffs.

In contrast, another option would be to put the client who would ultimately benefit from the energy in a central role. While it was clear who should be involved and who could benefit from the scheme, there was no consensus about which tasks should be assigned to whom. For instance, who should be responsible for developing the business model, who should be in charge of technology maintenance, or how much flexibility the business case would allow households and/or investors to change arrangements. Given that DES has undergone rapid technology development in recent years, a further area of uncertainty was associated with when current technology might be made obsolete by new innovations. How to distribute this risk amongst stakeholders, as well as the implications for lengths of contracts, was another area where participants had more questions than answers.

The complexity and uncertainty around the DES model can lead to it being seen as a risky investment. However, some of this risk might be offset by the fact the new energy technology schemes are context-dependent, so allowing for a custom-made scheme. Allowing more flexibility can also be considered as a tool for effective design and implementation of a DES scheme. Giving users the ability to decide on the roles for each of the stakeholders, or consider their needs and preferences, would probably be beneficial to avoid concerns of unfairness and increase trust, as these have been shown to be determinant factors in shaping acceptance of new energy technology [28].

We also suggest paying attention to the role of expectations. While expectations about technology development are constrained by material culture [64], they play a crucial role and are influential in the innovation process and conditions of uncertainty [65]. Expectations can assist with coordinating actions within a group and help towards strategy building [66–68]. Importantly they can guide investor behaviours [66,69], in particular when an investment is needed under conditions of uncertainty. Sendstad and Chronopoulos [70] propose that sequential investment can help to deal with these conditions of uncertainty, including when the policy context is not fully developed, as it is the case with DES. We encourage the developers and stakeholders involved in a DES scheme to pay more attention to expectations. Understanding how those expectations are managed is valuable in learning who will be willing to invest and take risks, and how the business case and the technology can meet both users' and developers' expectations.

Our research reveals and corroborates what is commonly accepted, that there is a difference between the motivations, priorities and criteria for success between public and private organisations involved in DES schemes. For the private sector, a successful scheme is one that can be made to work financially. In contrast, the public sector is keen to identify non-economic values and opportunities as a way to improve the attractiveness of investments in energy technology. For local authorities, the purpose of technological development goes beyond financial profit to provide opportunities for environmental improvement and social justice. While it is not only about the technological object but also the service it provides [71], technology developments often do not benefit low-income households [72]. Further work is therefore needed to understand better how DES can generate benefits to the community in terms of projects, for instance, through deployment in community schemes serving disadvantaged areas. Previous research has demonstrated that people are more inclined to support community energy storage when the benefits flow into the community [28]. The use of energy storage could look at delivering services and addressing supply to the community or provide sustainable development options for vulnerable and energy-poor people [73].

We also encourage a more proactive involvement from local and public authorities as they are a source of trust and reliability [17,74]. New means of involvement for learning could be found. For instance, in the process of a shared learning, companies who provide energy services would get to learn from working with multiple different councils, etc.

Crucial to engaging and attracting new customers is information and knowledge about DES. As revealed by other research [17,29], the workshop participants highlighted that one of the main issues is to tackle is the low level of awareness of energy storage technologies.

To counteract this, it would be helpful to elaborate a clear narrative delivered not only by actors in the private sector but also by the public sector. Attention needs to be paid to the content of that information, as it is useful to garner trust from the public. Appropriate communication strategies should be put in place that mention why new technologies are needed in the current context of decarbonisation, and the benefits that apply to society as a whole and to individual households. The narrative should include objective reasons for why people would choose to join the energy scheme, in such a way that users can see it works and could understand the uses of the technology—despite the uncertainty and risk that tend to go hand in hand with business models innovation.

That message to be delivered should also be faithful to the limitations, not to raise false expectations. And hence, to give responses to issues like trust and fairness. Communication agents should be concerned about presenting neutral and realistic information as it has been proven that they are compatible with generating positive attitudes, emotions (affect) and interest in the technology. Indeed, positive feelings can lead to or support positive environmental attitudes [28].

5. Conclusions

DES will play a key role in future urban energy systems. It offers new opportunities for citizens to re-shape their relationship with energy production and use, can provide multiple services to the wider energy system, and help government and local authorities to increase distributed renewable generation and meet carbon reduction targets. While presenting many opportunities, the implementation of DES is still in its early stages, and more understanding is needed of the interplay between the technical, business and public acceptance domains and how these can be combined effectively to encourage greater deployment.

This paper has given an account of the interplay of these factors by integrating the views of the stakeholders involved in its deployment. The approach used the rationale of the decision theatre methodology, which encourages different stakeholders to deliberate on DES in an environment in which they could understand and reflect on other participants' standpoints. In doing so, it has helped to illuminate how those domains should interact and complement each other for the successful implementation of DES in urban areas.

The findings suggest that, in general, DES schemes need more simplicity and clarity for the business case to be accepted by the public and investors. While this is still a difficulty, appropriate partnerships between the private and public sectors, such as local authorities, can counter-balance the potential adverse effects of the inherent uncertainty that goes hand in hand with the development of innovative energy technologies. Therefore, it is crucial to revisit the role that government and the local authorities play at the moment, in such a way that local authorities can find the legitimacy and resources to become more involved in local energy issues while complying with the national market and regulatory frameworks. Also, communications with consumer and end-users need to be prioritised, looking into not only the messaging but also the means of communication.

The current investigation would have benefitted from including stakeholders from other organisations and different locations so that we could integrate other visions. Although some work has already been undertaken on public perception of DES, an additional line of research would be to include members of the lay public/ end-users alongside other stakeholders. Further work could then examine our claim that DES schemes are context-dependent—and so are the decarbonising processes—by testing specific business cases.

Finally, the research has demonstrated the imagination, flexibility and openness with which stakeholders are engaging with DES deployment. While there are still barriers to overcome, our results demonstrate that there are multiple ways in which DES schemes can be successfully configured and so provide solutions to different stakeholders' needs and priorities.

Supplementary Materials The information included in the supplementary material provides the reader with the full details of the methods and presentation materials. The supplementary material includes the work in the fields of technology, business and social science that informed the prompt materials for this workshop and that has been previously published in scientific journals [as per this paper references of the research are 17, 20, 21, 24, 28]. Also, it includes the prompt materials themselves and their respective justification for each of the three session (e.g. charts and graphs on the technoeconomis considerations, the business model canvas used, and the templates with quotes used to illicit discussion among the stakeholders from the public perception session).

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