




## Article

# Socio-Economic Benefits in Community Energy Structures

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**Abstract:** In this paper, the authors examine how a community energy group in the Meadows area of Nottingham in the UK adopted a model of local energy generation and storage as a means of combatting climate change, improving energy efficiency, enhancing energy security, and reducing fuel poverty. By prioritising local needs and managing expectations, this approach was seen to unite community members in acting on energy challenges while increasing knowledge, understanding, and awareness of energy issues in general. The results of the survey indicated that the respondents had a significantly high level of climate awareness (94%) and support for community energy (90%). Furthermore, evidence of the impacts and efficiencies of community energy and subsequent socio-economic benefits were identified, including 89% of respondents reporting a reduction in energy costs and 67% of respondents increasing their self-consumption. Importantly, the barriers experienced when trying to maximise the identified socio-economic benefits are highlighted and general recommendations given.

**Keywords:** community energy; community engagement; energy storage



**Citation:** Kiamba, L.; Rodrigues, L.; Marsh, J.; Naghiyev, E.; Sumner, M.; Empringham, L.; De Lillo, L.; Gillott, M. Socio-Economic Benefits in Community Energy Structures. *Sustainability* **2022**, *14*, 1890. <https://doi.org/10.3390/su14031890>

Academic Editor: Barry D. Solomon

Received: 17 December 2021

Accepted: 3 February 2022

Published: 7 February 2022

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## 1. Introduction

There is a stark realisation that time is running out to implement ways to counteract climate change and its impacts. In 2019, the UK's Climate Change Act was amended to constitute a legally binding commitment to end its contribution to climate change by 2050 [1]. This ambitious challenge will require a shift to a decentralised and mixed energy system to provide a source of clean and affordable energy. As a variety of renewables such as wind and solar energy are key components of the UK's commitments to reducing carbon emissions and increasing security of supply [2], challenges associated with their intermittency and variation need to be addressed [3]. It has been suggested that a suitable solution to this is the integration of distributed energy storage within community energy schemes [4]. Growing interest in community energy schemes has been driven by the view that they are suitable vehicles for tackling energy-related issues from a local needs-based perspective that have wider national implications [3]. By taking democratic control of local energy projects, community energy groups can create a strong base for the significant infrastructural and social change that is needed to reduce the impact of climate change through decarbonisation, and work towards building community resilience and cohesion and improving energy security [4].

In the UK, Community Energy England estimates that over 65,000 tonnes of CO<sub>2</sub> savings were made from the generation of renewable energy by community-owned projects in 2019 and £2.9 million was saved on consumer energy bills through community energy actions in 2020 [5]. However, community energy projects still account for less than 1% of total UK renewable energy capacity [6]. In 2014, the government's community energy

strategy envisioned that one million homes would be powered by community energy schemes by 2020, but, to date, only 67,000 homes benefit from such projects, due to the lack of sustainable business use cases [7]. Additionally, community energy research has mainly been centred on the individual technologies and issues related to their implementation [8]. This top-down approach focusses on adapting to the existing energy systems rather than exploring how communities can take control of their local energy system and reap the maximum benefits of doing so. Indeed, a recent systematic review of research on energy justice in community energy initiatives across Europe [9] and another examining societal engagement with socio-technical change in energy system transitions in the UK [10] revealed a deficit in exploring social inequality, as well as insufficient policy, which negatively affect the uptake of community energy initiatives.

The critique of the top-down approach is not to say that the only benefits of community energy should be socio-economic in nature. Community energy needs to be seen as more than just a socio-economic driver to allow consumers to have more control over their energy resources. What is needed is a more multifaceted approach that seeks to effectively integrate energy systems to not only include local generation of heat and electricity, flexible demand, and energy storage for self-provision of the local communities, but also to provide essential balancing and ancillary services to the larger smart energy system [8]. For example, there has been a massive proliferation of rooftop PV systems over the last 20 years, initially encouraged by feed-in tariffs (FITs). Whilst these tariffs may now have disappeared [11], there is still a demand to install consumer purchased household systems or community owned farm-based systems. However, the proliferation of PV generations within the lowest levels of the electricity distribution system has caused technical challenges for the network operators. Bottlenecks are exposed which limit further penetration of PV; growing generation coupled with increasing evening loading due to electric vehicles and the electrification of heating and cooking has led to large daily and seasonal variations in the voltage level seen by consumers; the power flow can reverse during the day, creating problems with electrical fault protection systems. The solution to these challenges also lies with community energy: locally installed batteries allow the storage of excess PV energy during the day, for use during the evening consumption peaks. These systems can be controlled at household level, but are better operated at scale, and this is where the true concept of community energy can bring significant rewards for the consumer [12]. However, currently, the trading of electricity at local levels requires a private wire network to operate within existing regulations, which makes the approach prohibitively expensive [13].

When this study was launched in 2015, community energy was considered a vibrant young sector that consisted of a number of dedicated people who were seeking to build up valuable assets for their communities [14]. A survey of 80 community energy organisations (representing 175 schemes) conducted by Community Energy England [14] found that the sector was facing a grim future, mainly due to changes in FITs and renewable energy policy. The knock-on effect of these changes resulted in the majority putting projects on hold or cancelling them (affecting 448 potential schemes). Fast-forward to 2021 when a wider review of 424 community energy schemes (including 290 in England) conducted by Community Energy England, Wales, and Scotland indicated that these organisations were refocusing in response to the aforementioned issues to include the tackling of fuel poverty and demand reduction, and exploring innovative business models on flexibility, low carbon transport, and local supply [5].

These views are identified in other studies on community energy such as [15,16], which review community energy models and their evolution. Away from the core business of employing renewables for energy generation, these aforementioned studies have suggested that community energy schemes can provide a wealth of other community services that can generate socio-economic benefits for communities. Even so, there remains a shortage of assessments that are backed by real-life data from multiple demonstration projects in the UK to help establish the intrinsic value of local community energy structures. Recent systematic reviews of community energy research and its agendas undertaken in 2016 [17], 2018 [18],

2019 [19], 2021 [20], and 2022 [16] highlight the direction of current research and the gaps that need to be filled, including the need to evaluate the benefits a community stands to gain from engagement in local energy matters and in line with a just transition; to monitor and quantify the impacts; to consider citizens' experiences within a centralised energy system; and to explore public participation and engagement to vitalise democratic mechanisms.

The paucity of assessments of the role of local energy systems, and particularly that of households and communities in the existing energy system and that of the future 'clean energy' system, is hindering the proliferation of sustainable community energy schemes [21]. The inability to accurately predict potential sustainable scenarios or use cases for community energy remains a key constraint in energy-related social and policy research. As it stands, users and investors are having to rely on prior knowledge and information and their own mental models of similar systems to make decisions on a solution's future potential [7]. This becomes even more complex in the context of multi-vector energy system interdependencies, which are linked to multiple energy markets and stakeholders. Consequently, there is dire need for quantitative assessments supported by empirical data from several demonstration projects to help establish the value of local community energy groups. The knowledge generated from these research outcomes will contribute to a carbon neutral energy system that enables a just energy transition to guarantee availability, affordability, and acceptability for all.

In direct response to this research gap, based on the experiences of a community energy group located in the Meadows in Nottingham, UK, the authors examine the potential socio-economic benefits of integrating energy storage within community energy initiatives. Additionally, the barriers they faced when trying to maximise on those benefits, such as inefficient government policy and regulations and high capital cost, are highlighted and some recommendations given. The key defining elements of this study and the community involved include:

- examining the integration of distributed energy storage in an existing community with a history of fuel poverty;
- an existing community with a significant number of PV installations seeking to explore how storage can be used by both generating and non-generating households within the UK's current centralised energy system;
- an existing community with a history of high awareness of climate change and energy efficiency
- and a tailor-made public participation engagement strategy.

## 2. Methods and Study Background

### 2.1. Methods

Traditionally, citizens are considered as passive energy consumers. Even where public participation in energy system development occurs, it usually takes the form of targeted consultations on singular issues [22]. Typical public participation routes are only partially available, with most projects only focusing on informing or consulting. Often little interest is paid to the role of end users in energy systems, despite their importance in reducing carbon emissions [23]. It has been well documented in a series of worldwide case studies [24,25] that, in energy projects, the engagement of end-users is highly shaped by expectations that are determined by the information delivered to understand the project, e.g., leaflets, public meetings, or exhibitions. Most of these user and stakeholder engagement methods depend on information and reach-out campaigns to involve all interested parties [25]. In addition to targeting a wider audience, often this attracts self-identified representatives who have prior interest in the chosen subject area and the means to participate [26].

Current methods in the social science of energy-related assessments, e.g., behaviour evaluation, perceptions and adoption of new technology, etc., mainly rely on surveys that can comprise of questionnaires, interviews, and focus group approaches [27]. Advanced techniques include the concept of contravision [28], which allows researchers to provide alternative scenarios of yet-to-be-developed solutions and hence enables participants to

visualise and imagine how these technologies might impact their daily practices. In this study, the authors sought to engage the end users with the aim of identifying the socio-economic benefits of the microgeneration of electricity and heat in conjunction with different types of energy storage within a community energy group. This was done via a series of ‘community engagement and public participation’ activities and comprised a series of interactions that were deemed suitable for all parties involved and at key project stages [29]. In step with similar energy assessments, as was highlighted above, this study relied mainly on the collection of data via a survey which consisted of two questionnaires and one focus group session. Samples of both questionnaires and guidance questions for the focus group session are available as part of the Supplementary Information of this paper. The survey was also supported by the use of public meetings which were held mainly to recruit participants and to keep the community engaged with the process, irrespective of their level of participation.

The first hurdle of the data collection process was raising awareness of the proposed project to encourage community members to attend the initial public meetings. To increase the impact of communication [27], a mix of direct and indirect communication techniques that made use of existing community links and networks were applied to publicise the proposed project and public meetings. As part of the targeted canvassing, the main direct method included sending letters to the existing community energy group members; households that had received PVs in a previous initiative; and community members who had shown an interest in saving energy in their homes. To reach the larger community, an initial public meeting was arranged and advertised via a flyer posted to residents and a mention made in the local magazine, ‘Meadows Matters’. To enhance the chances of successful public meetings, as was suggested by McComas [30] in their study of the theory and practice of public meetings, the meetings were planned to not only seek to achieve a certain outcome (e.g., participant recruitment) but to also involve the community in the process. Apart from presenting opportunities to introduce the proposed project, give information, and gather feedback, the use of public meetings and talks provided an opportunity to consult large numbers of community members, providing chances for them to influence the agenda and ask questions. The use of public meetings has been shown to enable large numbers of people to have their say and can also be used to demonstrate openness and transparency in research projects [10]. The initial public meetings were well attended. From a group of approximately 90 attendees, a list of 68 potential participants (each representing one local household) was collated.

The use of questionnaires was identified as being particularly useful for this study in identifying the attributes, behaviour, attitudes, and beliefs of the respondents in a standard format [31]. These quantitative data could be compared over time, for example, with other studies and at the initial and final stages of the project. Although questionnaires can have low response rates [32], to improve the credibility of the research findings, the drop and collect method employed by the researchers aimed to ensure higher response rates from participants. Two questionnaires were administered to participants. Both questionnaires were hand delivered to each household at an agreed time, allowing for the participants to fill out the questionnaire and return it in one visit. The questionnaire administration process was found suitable to facilitate a higher level of accessibility for respondents. Studies have shown that, when compared to online or telephone surveys, this approach delivers better results in terms of representativeness in the answers to questions [33]. To reduce the effect of social desirability on answers, care was taken to frame the questions to reduce the extent to which respondents would perceive that particular answers would be interpreted in a negative light [27]. Additionally, although the research team dropped and collected the questionnaires, these were filled out by the respondents to minimise the risk of respondents distorting answers to what they might think was ‘wanted’ [27].

The first questionnaire (pre-installation) targeted the 68 volunteer households and aimed to determine the physical characteristics of the potential participant property (to determine suitability for energy storage technology); to investigate the socio-economic

and occupancy characteristics of the household; and to ascertain awareness and views on energy efficiency in homes, climate change, community energy initiatives, and energy storage. Establishing participant views and occupancy characteristics at this early stage was deemed necessary to establish a base case by which resulting socio-economic benefits could be reviewed. The second questionnaire (post-installation) targeted participants who had received equipment following the initial survey and aimed to identify the socio-economic impacts of a community energy business model that had incorporated energy storage in households and communities. Views were collected with respect to energy storage for an individual (when storage is used in a single household) and for a community (involving the collective action of generating, purchasing, sharing, and managing energy in a local community). Additionally, specific questions related to the type of energy storage and the benefits and drawbacks encountered following its installation were raised.

To wind down the survey data collection process, a focus group session comprising 15 participants was planned. This was set up with a view to obtain more feedback from the participants who only received 'monitoring only' equipment; to capture information that might have been missed in the surveys; to better elaborate previous survey findings; and to improve the quality of conclusions drawn. Focus groups can be used to encourage active discussion and provide a time and resource efficient way of identifying and clarifying key issues [34]. To help create some ease around the discussion of the focus group session, a community member who was also a board member of MOZES helped pose the guidance questions while one of the research team members recorded the responses. In combination with other methods such as surveys, focus groups can provide follow up research to clarify findings from other methods [35]. Crucially, the aforementioned survey methods were framed as part of an ongoing and cumulative process that worked to prioritise local needs, review progress, and inform the participants and larger community about the project [29]. As was detailed in a previous work by the authors on the role of public participation and engagement in community energy schemes [26], this approach to local energy projects was found to be successful in facilitating decision making, relationship development, and capacity building. A similar approach based on this study was also taken in later work which aimed to increase user engagement in community energy schemes [36].

## 2.2. *The Community Energy Group and Its Role in Project SENSIBLE*

The Meadows is a primarily residential urban area, with a population of approximately 9000 residents, that is located to the south of the Nottingham city centre in the UK [37]. Historically, the Meadows has recorded high levels of fuel poverty and economic deprivation [38]. Despite these economic challenges, the Meadows has a tight social structure with a high level of community cohesion [26]. In 2005, a group of Meadows residents got together to find a local solution to fuel poverty and climate change. With support from the Nottingham City Council (NCC), the Meadows Partnership Trust (MPT), and Nottingham Energy Partnership (NEP), the residents set up the 'Ozone' project which sought to transform the Meadows into the first low-carbon inner city area in the UK. As part of this initiative, an area-wide energy plan was developed in collaboration with residents via extensive community engagement activities. This endeavour was successful in motivating, engaging, and promoting active participation among local people who took the energy plan forward and commissioned a study into the formation of a community energy group. Eventually this led to the formation of the Meadows Ozone Energy Services (MOZES) company in 2009 [39].

With support from a series of partners, MOZES has continued to play a key role in the Meadows by setting up a series of local initiatives which have also generated volunteer and paid job opportunities for community members. For example, in partnership with British Gas, MOZES has installed nearly 65 solar photovoltaic (PV) systems on domestic properties, three schools, and two community buildings. Unfortunately, due to a lack of government follow-through regarding FITs for solar PVs [39], MOZES has been unable to generate income from the majority of PVs installed as part of this scheme. Perhaps echoing

the strong spirit of resilience found in similar initiatives [40], MOZES has sought other innovative ways of meeting its energy goals. This has included securing interest-free loans from a credit union for vulnerable Meadows households to pay for energy efficiency work such as building fabric improvements. Supported by Scottish Power and NEP, MOZES has engaged a professional energy advisor who has worked to educate and advise residents of over 300 households, including visiting households for property assessments. MOZES continues to create better awareness of energy matters by regularly holding local energy workshops, setting up information stalls at local events, and working with local leaders to champion and encourage energy saving and generation schemes.

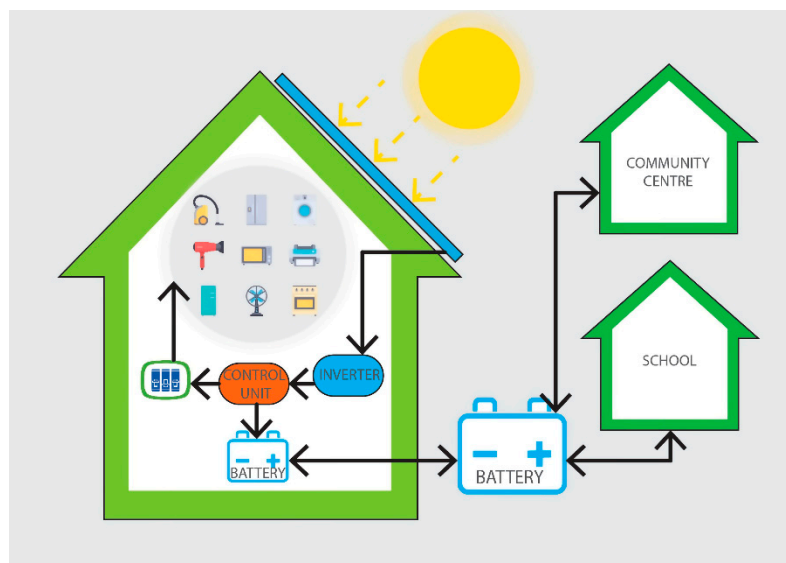
This study is based on research conducted as part of a major EU funded Horizon Research and Innovation Programme project which ran from 2015 to 2018. Project SENSIBLE (Storage-Enabled Sustainable Energy for Buildings and Communities) involved partners from six European countries and was featured in the Electricity Network Innovation Guide for Communities as an exemplar project in electricity network innovation [41]. Project SENSIBLE aimed to explore the technical, social, and economic aspects of the microgeneration of electricity and heat in conjunction with different types of energy storage. The project brought together a team from many areas of the energy trading sector including the most important members—the energy users themselves—who were represented by communities in Nottingham, UK and Évora, Portugal. The Nottingham Demonstrator Site in the Meadows was found to be particularly suitable as it has a significant amount of solar PV installations, varied housing types and tenures (including large areas of social housing and a core of older Victorian terrace houses), a favourable local grid configuration, and, very importantly, backing from the local community through MOZES.

In the Nottingham Demonstrator, two systems and test scenarios were considered (Figure 1). The first system converts solar PV, allowing users to power their devices with solar PV energy and turning any excess energy into thermal energy to be stored in the house's hot water cylinder. The second system either stored PV energy that would have been otherwise sold to the national grid or bought energy at cheap times, to use during expensive periods or when solar PV was no longer available. In addition, a series of test scenarios were run to examine how energy generators within the Meadows community could share surplus energy with other community members. Under this scheme, the local energy 'generators' or 'sellers' would be able to get higher prices for their energy than they would if they had sold it to the national grid. Similarly, the local 'buyers' would be able to purchase energy at a cost lower than what is offered by 'big' energy companies. Currently, the traditional power company and end-user model of public wiring and existing regulatory frameworks in the UK is very prohibitive [42]; it is clear that this deficiency is hindering the proliferation of community energy projects. The findings of Project SENSIBLE have since informed research undertaken by another University of Nottingham (UoN) affiliated local energy project in Nottingham, referred to as Project SCENe (Sustainable Community Energy Networks), which has implemented renewable heat/electricity technologies and energy storage at a community level scale [36]. It is anticipated that SENSIBLE, SCENe, and similar projects will inform the long overdue review of existing policy and regulation that is needed to support future smart energy networks.

### *2.3. Community Engagement and Public Participation*

The Meadows community engagement strategy was divided into three key elements that were defined based on the identified use cases. The first use case, which forms the focus of this study, supported a domestic component where the volunteer residents had one version of the energy storage technologies installed in their homes. As there were different house types involved, there was a need to match suitable technologies for each property. The second use case supported a community building, a local school with variable seasonal use, but with a large array of solar PVs already installed. The third use case was defined to support a new housing development where there was an opportunity to install a private network for ten houses. Unfortunately, due to significant delays brought on by ownership

and planning issues, which were worsened by economic uncertainty brought on by Brexit, this use case was suspended. Instead, this use case's objectives were met through laboratory simulations carried out by the UoN project team.



**Figure 1.** Project SENSIBLE's community energy strategy in the Meadows.

From the onset, the project team built on the tailored community engagement process to promote open communication, develop trust, and foster the community's participation throughout all the engagement stages (outlined in Table 1). The initial public events were well attended and enabled the creation of a database of interested parties. In these events, an outline of the proposed project and its potential benefits were presented. Additionally, case studies of similar energy projects in the UK and EU were highlighted to create better awareness around what was being proposed. Next, a survey of homes of the interested parties was conducted to determine their suitability. Similarly, the pre-installation questionnaire was administered to gather community views on matters broadly related to energy. Following these initial activities (Stage 1 and 2), offers were made to the most suitable parties (Stage 3). In Stage 4, the work was tendered, and the equipment installation undertaken. During this period, the project team offered support to the household volunteer residents, including mentoring participants through the process, checking on installations, and holding of regular meetings to discuss progress. Additionally, the project team collected participant views via the post-installation questionnaire and held public participation events to promote the project and disseminate its findings to the community (Stage 5 and 6). These public events included community energy workshops held in the use case 2 school (to target the younger members of the community) and at the local public library (open to all).

The project's approach to community engagement aimed to give the local community the chance to be involved from the beginning, and, even more importantly, it aimed to enable them to understand what was at stake, what benefits they might experience, and what problems might arise. The use of established community infrastructure, the leading role played by MOZES and the trust that came with this, as well as the involvement of local community champions, were central to enabling this. All together, these factors facilitated wide community outreach and a high level of project participation, with the majority of participants responding to the surveys and the focus group session. The next section is used to outline and discuss the findings of these activities.

**Table 1.** Use case 1: Community Engagement Plan.

Stage and Timeline	Activities
Stage 1—Engagement (2015)	<ul style="list-style-type: none"> <li>• Approach existing MOZES members</li> <li>• Contact PV owners</li> <li>• Public meetings</li> <li>• Talks and lectures</li> </ul>
Stage 2—Initial Survey (2015–2016)	<ul style="list-style-type: none"> <li>• Contact volunteers</li> <li>• Survey house for suitability</li> <li>• Administer the pre-installation questionnaire</li> </ul>
Stage 3—Offer (2016)	<ul style="list-style-type: none"> <li>• Establish best sites for selected energy systems/technologies</li> <li>• Make offers to volunteer households with the approved Project Agreement</li> </ul>
Stage 4—Installation (2016–2017)	<ul style="list-style-type: none"> <li>• Tender installations</li> <li>• Accompany contractor to agree on installation of equipment</li> <li>• Monitor and check installation</li> </ul>
Stage 5—Demonstration (2017–2018)	<ul style="list-style-type: none"> <li>• Collect equipment data, mentoring participants, administering the post-installation questionnaire and focus groups</li> </ul>
Stage 6—Promotion (2018)	<ul style="list-style-type: none"> <li>• Present key findings to the community</li> <li>• Prepare papers and lobby legislators</li> <li>• Develop the community energy group further</li> </ul>

### 3. Results and Discussion

#### 3.1. Pre-Installation Questionnaire (Stage 2)

At an initial community engagement event, 68 volunteer residents, each representing a single household, signed up to indicate their interest in Project SENSIBLE. Next, a representative from each household was invited to take part in an initial survey. This survey received an 81% response rate from a mixed range of respondents as shown in Figure 2. Similarly, the property descriptions revealed a variety of house types consisting of mid terrace (51%) or semi-detached/end terrace housing (38%), which were mainly owner occupied (89%). Additionally, the majority of properties surveyed were two or three storeys (94%) and two or three bedrooms (82%) with floor areas ranging from 90 to 109 m<sup>2</sup>. Overall, 70% of the properties consisted of older housing stock (pre 1919 to 1990) with most having a condensing combi boiler (60%) which was less than 5 years old (66%), and with no hot water cylinder (64%). The old age of most of the UK housing stock means that these homes tend to be draughty, costly to heat, and inefficient [43]. As with the majority of housing in the UK, the main source of heating for 98% of the surveyed properties was found to be natural gas. As 70% of the UK's domestic energy use is attributed to space heating [44], it is apparent that achieving national net-zero goals depends on ensuring that housing, such as those inhabited by the study participants, can be kept comfortable for occupants at low energy and environmental cost.

According to UNESCO [45], a high level of 'climate literacy' plays an essential role in increasing the adaptation and mitigation capacities of communities and empowering them to adopt sustainable lifestyles. In this study, respondent views on climate change and energy efficiency indicated a very high level of awareness. For example, an overwhelming majority of 95% respondents said that the issue of climate change was important to them, personally, compared to the national average of 70% (March 2016) and 76% (March 2020), recorded by the BEIS Public Attitudes Tracker [46] (p. 10). Additionally, 94% of respondents believed that individual households could influence the rate of climate change. Furthermore, 82% of respondents indicated that people should be made to reduce their energy consumption to



lower the rate of climate change. These findings indicated that the respondents were well equipped with an understanding of climate matters and that they could make informed decisions about their energy choices—a factor that is paramount to shaping a climate resilient community [46]. Energy efficiency is central to meeting the UK's net-zero targets; a growing body of research has also shown that it has multiple socio-economic benefits beyond energy consumption [47]. In this study, 68% of the respondents believed that their properties were energy efficient, with 65% indicating that they monitored energy use in their properties. These aforementioned percentages corresponded to the findings of the physical property survey that indicated these participants had loft and wall insulation as well as double glazed windows.



**Figure 2.** Respondents characterisation: (a) gender; (b) employment status; (c) age; and (d) qualification level.

When asked if they were satisfied with the price that they paid for energy, only 30% of respondents replied in the affirmative. Furthermore, 41% indicated that they had been unable to pay energy bills in the past and they wanted to adopt energy efficiency measures to protect themselves in the future. In Section 2.2, it was noted that when MOZES was set up in 2009, one of the challenges it aimed to tackle was fuel poverty. This feedback indicated that this is still an issue that demands attention. Indeed, a survey run by the NCC during the project period found that 14.6% of the households in Nottingham were living in fuel poverty [48]. Consequently, the NCC set out a long-term vision to tackle fuel poverty by developing adaptive whole house and person centred approaches, using data analytics, business models, behaviour change interventions, and smart technologies [48]. The local community, through MOZES, is contributing to making this vision a reality; their involvement in Project SENSIBLE provided a valuable opportunity to examine how community energy business models that integrate smart technologies such as energy storage can work to deliver low-cost clean energy to end-users and, as a result, contribute to eliminating fuel poverty.

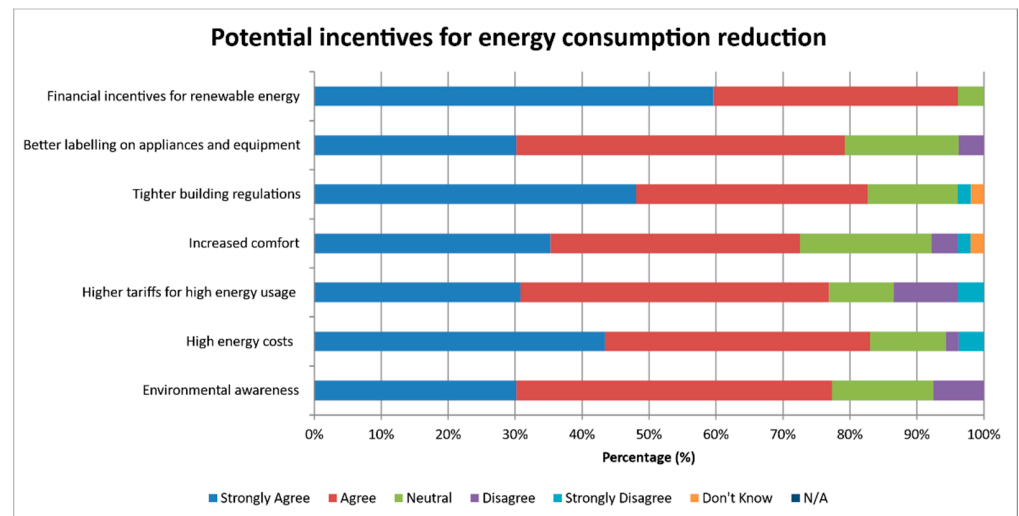
Although 92% of respondents were willing to implement energy efficiency improvements to their households, the potential cost implications were a major drawback. Whereas 82% of respondents indicated that they would be willing to invest in low cost measures of up to £500, only 50% felt they could afford more. Capital costs for energy efficiency improvements are a major barrier to achieving net zero goals in the UK [49]. This is true of technologies such as energy storage, of which, at current market prices, payback periods for domestic installations are estimated to be more than 15 to 20 years [50] (p. 30). It can be surmised that, whereas the respondents had a chance to benefit from the installation of energy storage equipment at zero monetary cost to themselves, it was unlikely that they would have been able to afford the same at current market prices. This finding also supports the propagation of energy storage for communities, as was trialled in Project SENSIBLE lab tests where, unlike costs related to an individual household storage, a community energy scheme that incorporates storage could provide an opportunity for economies of scale to be realised [51].

On household energy consumption, 68% of respondents believed that heating and lighting accounted for the most and least energy use, respectively. This finding indicated a good level of awareness as it corresponded with the national energy use statistics. In the domestic sector, space heating accounts for the majority of energy use and at the moment this energy is mainly derived from natural gas, which is a carbon-emitting fuel [52]. All respondents revealed that they took certain measures to reduce their energy consumption, including reviewing energy performance labelling before buying appliances, rarely or never leaving electric equipment on standby or hot water running, and never using washing appliances at less than a full load. Additionally, views were sought on the incentives that would best enable the respondents to further reduce energy consumption in their homes. As shown in Figure 3, the majority of respondents either agreed or strongly agreed to the importance of financial incentives for the adoption of renewable energy (96%), high energy costs (83%), tighter building regulations (83%), better labelling of appliances and equipment (79%), higher tariffs for high energy usage (77%), and educational opportunities to improve environmental awareness (77%). The willingness of respondents to adopt these measures bodes well for NCC's fuel poverty strategy [53] and the more recent plans drawn up by government as a means of achieving net-zero carbon by 2050 [49]. There is a sense of hope that the government will follow through on its proposals [54] by boosting the funding needed to achieve these measures.

Community initiatives and energy storage revealed a great deal of support from the respondents. Almost all the respondents believed that shared energy initiatives can help to enhance energy efficiency (97%), build better infrastructure resilience (90%), improve social cohesion (91%), and reduce energy costs for individual households. Similarly, most respondents (90%) wanted to see their community manage their own energy and to share excess electricity with each other. On energy storage, most respondents believed that 'centralised energy storage within communities' can improve energy efficiency (89%) and that 'centralised energy storage within households' can improve energy efficiency (95%). It has already been established that climate change is important to the respondents and that they believe that people should reduce their energy consumption to reduce climate change impacts. This demonstrates that the respondents realise the link between shared energy initiatives, energy storage, and the improvement of energy efficiency.

There was a wide variety of large and smaller energy suppliers used by respondents. The majority stated that the key reasons for choosing their energy supplier included service, cost, combined service and cost factors, suppliers with green credentials, and 'loyalty' to a provider. The respondents either paid their bills monthly (69%) or quarterly (31%), with the majority on a dual fuel energy tariff (71%) and without access to an estimated bill (72%). Furthermore, 76% of respondents had a real time energy display such as a smart meter. Additionally, 69% of the respondents were found to have solar PVs installed and, of this number, 62% received a feed-in tariff. Also, 58% of those with solar PVs indicated that they had saved on their energy bills after installation, whereas 31% had yet to compare

their bills. A couple of respondents were also found to have additional renewable energy technologies, including one with a ground source heat pump and both with a solar hot water system.



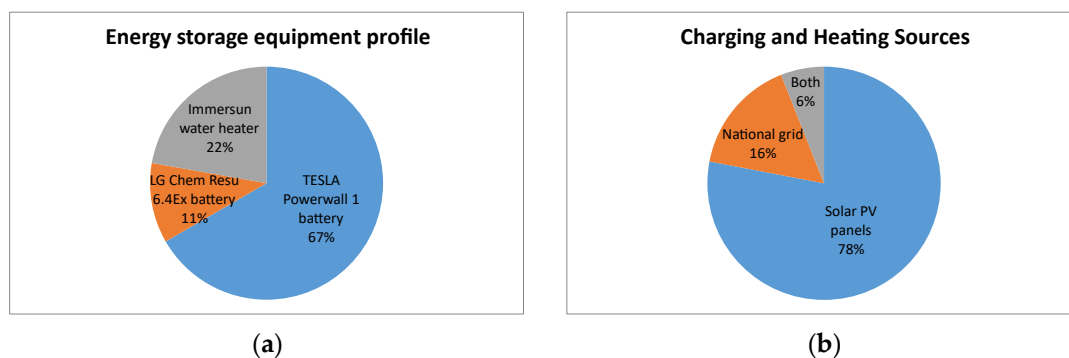
**Figure 3.** Potential incentives for energy consumption reduction.

To conclude, preferences related to participant involvement in Project SENSIBLE were sought. This feedback was also important as the researchers wanted to identify how best to design the equipment installation. From this it was established that the majority would be happy to get their PV inverter replaced (92%) and to have an energy storage system installed in their properties (98%); a minority indicated that they were undecided. Additionally, respondents were asked how they would prefer to monitor the energy storage equipment: 55% noted that they would prefer to do so via a display provided as part of the system, 28% indicated that they would like to use existing household screens or devices, and 17% had no preference. When asked what the prime motivation was for wanting to take part in Project SENSIBLE, the top three reasons included being ‘greener’ (37%), for the potential energy savings (30%), and for the potential monetary savings (19%). These answers supported the concerns raised regarding climate change and fuel poverty—both of which are key issues tackled by MOZES.

### 3.2. Post-Installation Questionnaire (Stage 5)

Following the installation of the energy storage equipment in 40 homes, a follow-up survey of all the households was conducted in November/December 2017. The results of this survey are discussed in this section. At this stage, 93% had used the equipment for periods ranging between 2 to 10 months, whereas 7% had used their equipment for a year (these initial installations were done for testing purposes prior to the full rollout). As is highlighted in Section 2, the energy storage equipment that was distributed to participants was varied to suit specific property conditions and existing equipment. The breakdown of this variation is shown in Figure 4.

When asked to reflect on the use of their energy storage equipment, 89% of respondents said they had a basic understanding of how the equipment ran and worked to save energy costs. Before the introduction of FITs in 2010, the only interaction that a typical domestic resident would have with electricity would have been setting up an account for supply from an energy provider [55]. Since 2010, some participants have since become generators of electricity. This is suggested to have greatly encouraged user acceptance of the energy storage equipment by participants [55]. Additionally, the drastic reduction and termination of FITs [39] meant that some participants were faced with a reduction of revenue, thereby hastening the need to adopt a viable alternative.



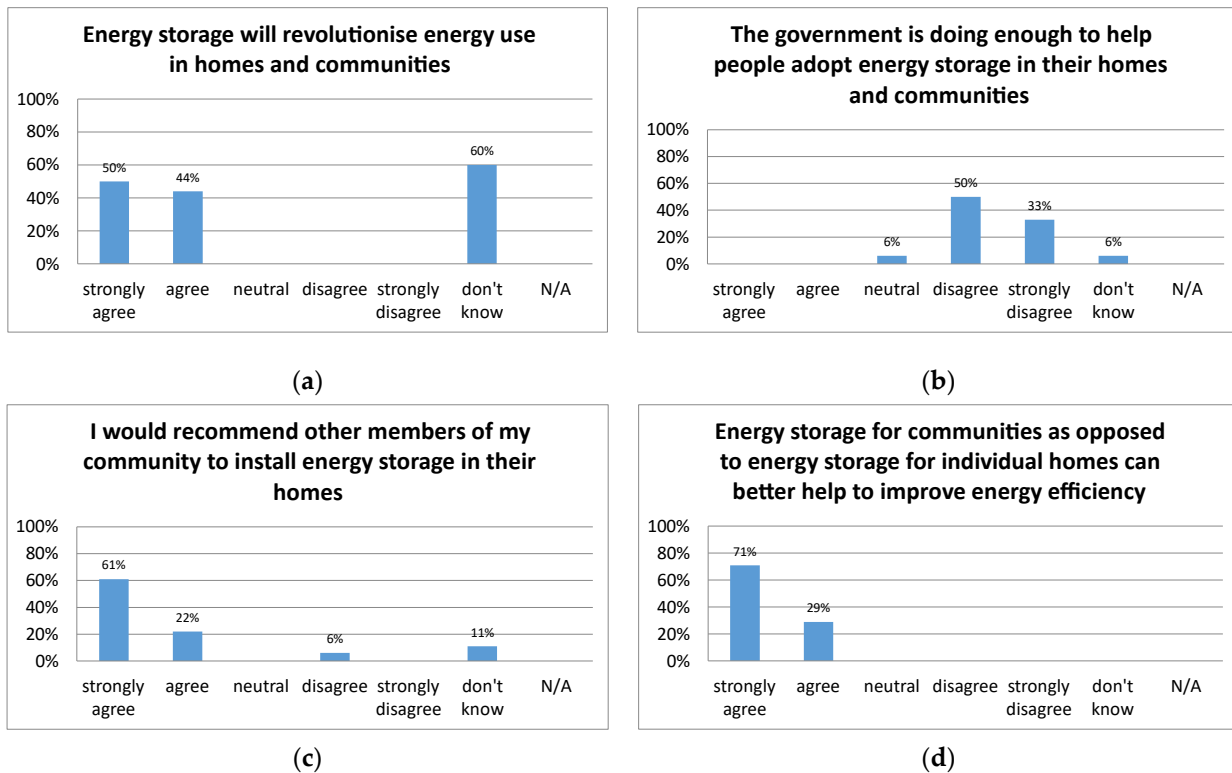
**Figure 4.** Equipment variation: (a) equipment profile and (b) charging and heating sources.

Views on community energy and storage were sought to establish any parallels to responses received from the pre-installation survey (Figure 5). Echoing past views, 94% of the respondents were convinced that energy storage would revolutionise energy use in homes and communities by enabling access at reduced cost. Where they had a surplus, respondents wanted to share this energy with their neighbours and at a lower cost compared to that of the national grid supply. As this is not doable due to current policy [13], 83% felt that the government needed to act fast to dismantle this barrier to community energy. A series of reports [56–58] indicate that the road to net-zero by 2050 will be driven by the faster adoption of renewables and that energy storage will be key to supporting this transition. However, to have a significant effect, household and community energy storage needs to reach a substantial scale. Currently, high capital costs and a lack of financial incentives means that this will be a drawn-out process if nothing changes [12]. A review of the impact on energy costs as a direct result of integrating energy storage equipment revealed that 83% of households had lowered their energy bills. The rest did not know as they had either not checked (11%) or not received (6%) their bills at the time of the survey.

In the pre-installation questionnaire, participants were asked to reflect on the main reasons for wanting to take part in the project. When asked to reflect on this question again, the top three reasons matched the previous ones and included the following: to be greener (44%), for the potential energy savings (41%), and to save money (19%). Additional commentary revealed that the majority of the respondents felt that, given their views on climate change and the impact of individual households in mitigating this, it was a natural step of progression. Additionally, some saw the installation of equipment as a personal statement (within the context of the community). When asked to rate the tangible benefits that they had experienced following the installation of equipment, the top ranked benefits included lower carbon footprint (46%), lower electricity bills (36%), and improved energy efficiency (20%). Less tangible benefits experienced by the respondents included increased self-consumption, improved energy security, and lower gas bills. A key objective of the Nottingham Demonstrator was to trial the impact of energy storage in increasing household self-consumption. The results indicated that 67% of the participants increased their self-consumption. This left out 11% who did not increase their self-consumption as they continued to use energy as it was being generated; 6% who did not know, and 16% who were discounted from this element of the study as they did not have solar PVs. Those who increased self-consumption were supported in doing so by making behavioural changes that included:

- Maximising the use of stored energy by shifting time of use;
- Being more mindful of local weather conditions affecting generation;
- Tracking household generation/storage/usage data;
- Running fewer electrical appliances concurrently to avoid overloading the equipment and shifting of energy supply from local generation to the national grid;
- Switching electrical appliances off when not in use and actively discouraging energy wastage by household members;

- Switching to low-energy light bulbs;
- Replacing single glazed windows with more energy efficient double glazed units.



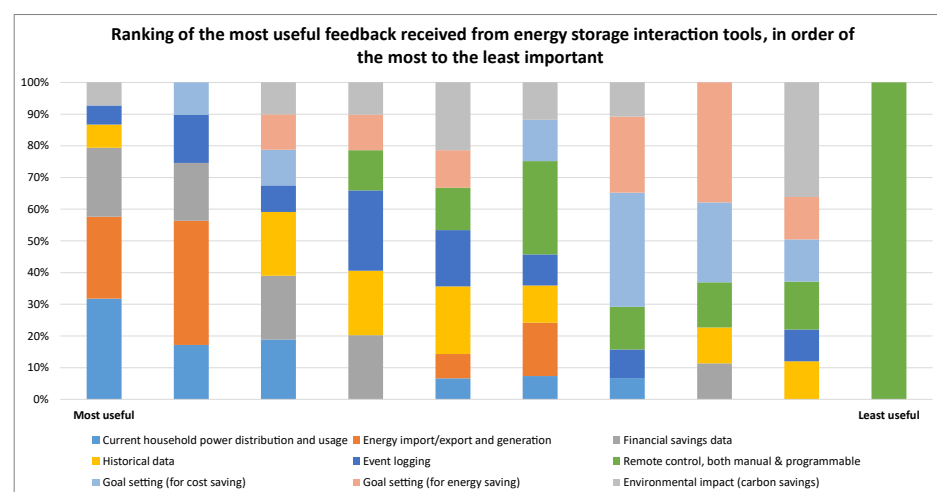
**Figure 5.** (a–d) Respondent views on community energy and energy storage.

These behavioural changes were not limited to those who increased their self-consumption; in fact, 76% of the respondents were found to have made similar adjustments with the aim of becoming more energy efficient. This high level of awareness was attributed to the engagement sessions led by MOZES where each household was mentored throughout the duration of the project.

The participants were encouraged to consider changing their energy supplier to receive a better tariff and service. A minority of 28% of households went on to make this change. By moving to the Economy 7 tariff, those without solar PVs could charge their energy storage equipment for less cost at night. Others indicated that they were motivated by the opportunity to sign up to a cheaper supplier who had adopted more renewables in their energy portfolios. Those who retained their original supplier and tariff said they felt obligated to do so as they had been with them for many years. This is in no way an isolated problem—people in the UK have been found to pay more than they need to for energy by up to £300 p.a. [7]. In 2019, it was found that 50% of energy consumers had remained on more expensive default energy tariffs despite knowing about cheaper options [59] (p. 5). Ofgem is now seeking ways of increasing consumer engagement to support consumers in making informed choices. This involves having energy suppliers work harder at engaging their customers through measures that include signposting of cheaper tariffs and removing hassles to switching tariffs and suppliers etc. [60].

The frequency with which respondents interacted with the equipment ranged from multiple times in a day, daily, weekly, and even monthly. More information was sought to review the type and mode of interactions. The majority of respondents (44%) regularly accessed the online portal via their personal devices. This portal provided information on solar energy generated, power import/export, battery charge state, and energy usage. Other respondents noted that they regularly interacted with the storage equipment via the equipment display (22%), other monitoring equipment (11%), and other applications via

their smart phones and tablets (6%). Given the chance to select a single user interface to view their equipment related data, respondents indicated that they would prefer to use the online portal (31%), equipment display (25%), smartphone/tablet display (25%), and monitoring equipment (19%). Preference for the online portal was down to the comprehensive range amount of information available. Respondents were also asked about what they felt was the most helpful feedback that they received from the variety of interfaces. As is shown in Figure 6, the top three highly rated feedback options included ‘current household power distribution and usage’, ‘energy import/export and generation’, and ‘financial savings data’. Other notable feedback options included ‘event logging’, ‘historical data’, and ‘environmental impact (carbon savings)’. A minority of 17% of respondents indicated that they did not actively interact with the equipment; key reasons for this included not having a stable internet connection or not being able to easily access their storage equipment due to it having been set up out of the way.



**Figure 6.** Ranking of useful feedback received from energy storage interaction tools.

As was highlighted in Section 2, participant engagement was designed as a core element of the project. During the project, these opportunities helped update participants on project progress and enabled the collation of useful feedback. To measure the success of these initiatives, participants were asked for their views on them: 94% of the respondents indicated that they felt adequately informed and engaged over the course of the project, whereas 6% indicated that they did not know. Respondents were also asked to reflect on what they thought the project team had done well and what they could have done better. Most respondents indicated that they felt well informed at every stage of the project and that this led them to feel confident in their continued participation. Furthermore, respondents noted that if they did have an issue, they were able to air their concerns and an amenable resolution would be reached. This high level of engagement also resulted in wider impacts with 88% of respondents noting that they had become more involved in their local community energy group, MOZES, and other community matters. The nature of this involvement included talking to community members about their experience in Project SENSIBLE. Outside of the project, some had convinced others to join MOZES to join the push towards developing a community energy model in the Meadows.

As part of the participant engagement process, MOZES was very interested in feedback on future projects linked to their main aims. Choosing from a range of these potential future projects, 60% of respondents suggested that MOZES set up local eco-team initiatives to help community members garner knowledge to tackle reductions in carbon emissions. Additionally, 38% of respondents wanted MOZES to put up a local demonstration house to showcase retrofit improvements for energy efficiency. Another notable suggestion was that MOZES should organise more community workshops (including in local schools) to raise awareness on energy and environmental issues.

### 3.3. Focus Group (Stage 5)

To conclude the demonstration stage of the participant engagement plan, a focus group session was held in October 2018 to obtain more detailed information on participant perceptions. During the session, 15 participants were guided through a moderated discussion where a set of open-ended questions were used to initiate the discussion. All participants shared a positive outlook towards community energy and were eager to discuss what they could achieve beyond their own household installations. Each participant wanted to see the Meadows increase its energy generation and distribution capabilities, including sharing energy within the community. These responses echoed the views of other forward-looking communities in the UK who are eager to become active participants of the energy market [40]. Some participants reflected on their experience of setting up MOZES in 2009 and indicated a shift towards local energy independence was the next logical step. The participants were keen to emphasise that the community energy model provides a framework that can be utilised to meet local energy needs in a way that is secure, affordable, and sustainable. Capital cost was deemed a significant barrier to achieving this goal. For example, whereas participants understood that storage for communities rather than individuals could work out cheaper and provide a significantly larger capacity, it was felt that the cost of storage would still be prohibitive and outside the reach of MOZES and many of its members. Additionally, those who did not have solar PVs and now wanted them felt that the scrapping of FITs meant that it was unlikely that they would be able to afford them. The participants suggested that access to funding such as government grants could help overcome this obstacle and help bolster local, national, and international carbon emission reduction efforts.

The participants who had received energy storage equipment were asked to share key aspects of their experience. Those with solar PVs indicated that they had made significant savings, especially over the summer. Similarly, those on metered energy were saving on energy costs, including those who had not been on the Economy 7 tariff during the post-installation survey and had now switched to capitalise on cheaper energy bought at off-peak periods. These revelations showed that energy storage is not just the preserve of those who want to live off grid. Technological advances in storage mean that there is more potential for those with domestic renewable systems, metered energy, or both. Given that solar power with energy storage has not reached grid parity yet [61], there is still room for storage-only solutions where energy is sought from the grid without the need for capital investment in solar. This could work towards creating a smarter energy system where energy is stowed away at times of less demand and drawn from during peak periods [62].

The consensus was that participation in the project had inspired participants to be more energy efficient. Those with 'monitoring only' equipment appreciated the chance to track their energy usage, with some indicating that they now found it almost second nature to do so. All participants indicated that being able to track household energy usage had inspired them to save energy/money by changing some of their energy usage behaviours. Following feedback obtained from participants in relation to their interaction with the energy storage equipment, a visualisation tool was developed to enable participants to have a more comprehensive source of information on their household generation and consumption levels (see Figure 7). The original intention was to make the visualisation tool available to participants soon after the installation of the equipment (as a tailored alternative to the online portal). However, unforeseen delays impacted its development/launch. Nonetheless, this delay proved beneficial as the project team sought participant feedback on the type of information they would find most useful. From this, it was noted that the top three data sets participants were interested in included 'current household power distribution and usage', 'energy import/export and generation', and 'financial savings data'. In addition to individual household data, participants were given access to aggregated information that showed what was happening in the 'energy community' made up by the participants of the project. The visualisation tool received very positive feedback with participants suggesting that the tool would be a suitable replacement for their smart meters.



Figure 7. Screenshot of the visualisation tool interface—note the community energy tab (top right).

Overall, the participants felt that the benefits of energy storage far outweighed any negatives. One participant noted that they had changed their mind about the potential efficacy of the equipment, noting that, given their property already had solar water heaters and a ground source heat pump, they thought it was unlikely that their Immersun water heater would have much impact. Having made approximately £350 in savings, a pertinent comment from the participant summed up their experience: “I am constantly surprised at its efficiency!” Another participant with solar PVs and who had received energy storage noted that they had seen little change in their energy usage or savings. Even so, the participant explained that they lived alone and were home for most of the day; therefore, it made sense to share what energy they generated via a community battery. Yet another participant indicated that they were planning to move out of the Meadows and planned to install solar PVs in their new property, and that based on their positive experience they were exploring options for installing individual storage in their new home.

Participants agreed that taking part in Project SENSIBLE engagement opportunities and other activities organised by MOZES facilitated a higher level of involvement in community matters. The participants reiterated their satisfaction with the engagement processes with many paying complements to the installation team who they felt worked very diligently. Going forward, it was suggested that on completion of Project SENSIBLE, MOZES should facilitate more engagement sessions with other members of MOZES and the larger community such as ‘opening up’ participant homes to showcase the project benefits. Participants also indicated that the final planned community engagement event (to present the key findings of the project) would go far in galvanising the community by getting more people interested in matters related to community energy and energy efficiency at large. This open session was very well attended and was a testament to what MOZES has been able to achieve by drawing on community ‘power’. As part of Project SENSIBLE’s legacy, a non-technical booklet was produced and distributed. In addition to



showcasing the project's successes, the booklet also offers basic advice on energy efficiency in homes.

The participants were also encouraged to discuss any negative aspects they encountered during their involvement in the project. A delay in the delivery of equipment was the main issue raised. Even so, those who were impacted by this felt that the explanation surrounding this was fair (a project partner was forced to pull out due to unforeseen circumstances) and that they appreciated being kept updated on the situation and its resolution. Another issue raised by some participants who lived in the smaller terraces was the size of the equipment. Although they had been made aware of the sizes prior to their involvement [39], they still wished that there had been smaller ones available. Despite these teething problems, the participants felt that they were at the cusp of an energy revolution and were glad to be taking part in a study that would go on to inform others. In addition, it was felt that the link between MOZES and the UoN worked well in taking them one step closer to energy independence. As a result, most wanted to see MOZES continue to engage in similar research initiatives. This positive feedback validated Project SENSIBLE's approach of working with the participants, through MOZES, to adequately inform them, manage unrealistic expectations, and to facilitate constructive engagement throughout the project life-cycle.

To close the discussion, views were sought on what MOZES should do next. In addition to views shared in the last questionnaire (Section 3.2), other suggestions included seeking grants to buy hybrid solar panels (which work well when not sunny and can be used to generate electricity and heat water), pay insurance for existing solar PVs, and to conduct energy efficiency improvements (e.g., external insulation). The participants put forth a suggestion to get a row of terrace householders in the community to sign up and have insulation put on their front and back walls—it was suggested that this would work well to encourage others in the community to follow suit. Indeed, it has been shown that community groups, especially those that have an established track record such as MOZES, can be a powerful way to engage local communities to spur use of external wall insulation which has been shown to be fundamental to cutting heat losses [63]. Other notable solutions touched on transportation initiatives and included shared electric vehicles (EVs) and electric bikes (to be charged from public charge points). It was noted that the Meadows has limited parking and that this would encourage more people to reduce dependency on polluting private vehicles. This view is in step with current government thinking—as prices of EVs fall, models are diversifying and charging networks are being rolled out [64,65]. As of 2020, MOZES members were able to follow through on sourcing an EV which is used on a car-share basis. In partnership with NEP, MOZES have also secured £1.5 million of the Climate Action Fund (National Lottery Funding). They plan to use this funding to equip the community with the knowledge, skills, and support required to move their net zero carbon agenda forward.

#### 4. Conclusions

As the UK sets out on its path of clean growth, there is a need to draw together all the resources that will enable it to mitigate climate change and achieve net zero carbon by 2050. More energy from renewables will be generated and stored closer to where it is used and the excess of this sent through the national grid. This decentralised and mixed energy system can increase security of supply, reduce transmission losses, and lower carbon emissions. However, small to medium sized energy schemes that encompass community energy schemes are finding it near impossible to compete with large existing energy suppliers. A growing body of research, including studies such as this one, has considered studies based on real-life projects and local communities, and shown that community energy schemes and projects will be key in bolstering this emerging smart and decentralised energy system. The potential impacts and benefits of community energy schemes extend outside of the core business of energy production. As has been revealed in this paper, there are clear potential socio-economic benefits to community energy structures when combined with energy

storage solutions, including improved community resilience and cohesion, heightened pro-environmental awareness and behaviours, higher uptake of renewables, local energy infrastructure improvements, development of social capital, acceptance of sustainable energy technologies, and poverty alleviation.

In this study, using a series of surveys and a focus group session held in the Nottingham Demonstrator, participant views on climate change, energy efficiency, community energy, and energy storage were identified. Most participants (94%) believed that the issue of climate change was very important to them and that people should be made to reduce their energy wastage to diminish its effects. A similarly high number of participants (90%) supported the idea of a local distributed community energy model. In resonance with this and their collective standpoint on individual climate change liability, the majority of participants indicated that their prime reasons for wanting to take part in the project were to be greener, for the potential energy savings, and for the subsequent monetary savings. Following the installation of energy storage equipment, participants were asked to reflect on the tangible benefits that they had experienced because of their engagement in the project. Perhaps most strikingly, 89% of participants indicated that their storage equipment had permitted them to maximise the gains from their solar PVs by storing 'free' energy and/or accessing metered electricity purchased for a cheaper price at off-peak times. Further to this, 89% of participants were found to have reduced their energy costs, with 67% of those who already had solar PVs increasing their self-consumption by incorporating some behavioural changes. Based on their experience in the project, 83% of participants indicated that they would recommend the installation of energy storage to others. A caveat to this advice was the cost of storage for individual households, which they admitted would be out of reach for most, including themselves. Instead, they believed community storage with government support, such as grants, to be a better opportunity to lower capital costs for community energy.

In addition to the environmental and economic benefits, participants felt that their engagement in the project had helped them cultivate a greater sense of pride in their community, with all noting that they were interested in continuing to be active in MOZES and other community matters. Aided significantly by input from MOZES, Project SENSIBLE's community engagement strategy was key in nurturing trust between participants and project partners. By tailoring opportunities for dialogue and keeping the process transparent, the project started off easily and in a participatory manner, allowing participants to engage meaningfully. From the onset, engagement opportunities were used to inform, consult, involve, collaborate, and empower the local community throughout the entire duration of the project, and even upon its completion. Furthermore, the use of existing community networks meant that the local community was placed in a position of power—allowing them to control a significant amount of the process. The success of this strategy is evident given that 94% of participants indicated that they felt adequately engaged at all stages.

The opportunities created by the local community energy group, MOZES, through its engagement in Project SENSIBLE have showcased the effectiveness of distributed energy storage in boosting social capital and reducing fuel poverty in local communities. To replicate a similar energy storage model, at a larger scale and in other communities, stakeholders need to be aware of the significant policy, financial, environmental, technical, and behavioural barriers to the propagation of energy storage. Local, national, and regional differences mean that it is not possible to review issues on the basis of universal principles alone. Local social factors have been shown to have a key role to play. At this point in time, we are surrounded by calls for an energy revolution in response to climate change, and the case for renewables has never been stronger. The opportunity for energy storage to improve the reliability of these clean energy sources is ripe. As has been shown in the Nottingham Demonstrator, community energy schemes can combine renewables and storage; unite people in tackling local energy challenges through local equity, participation, and control; and deliver local socio-economic benefits while increasing awareness and understanding of

energy issues. To maximise their full potential, a significant number of policy and economic barriers need to be dismantled as the UK carves its path towards a devolved clean energy system. As was exhibited by the conclusion to COP26, eliminating these barriers is not expected to be easy, but, faced by a new dawn, the only realistic strategy is one that is led by placing communities at the heart of this process.

**Author Contributions:** Conceptualisation, L.K., L.R. and J.M.; methodology, L.K., L.R. and J.M.; formal analysis, L.K. and L.R.; investigation, L.K., J.M. and E.N.; data curation, L.K.; writing—original draft preparation, L.K. and L.R.; writing—review and editing, L.K., L.R., J.M., E.N. and M.S.; visualization, L.K. and L.R.; project administration, L.E. and L.R.; funding acquisition, L.E., M.S., L.R., L.D.L. and M.G. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by the EUROPEAN UNION through the Horizon Research and Innovation programme, grant number 645963.

**Institutional Review Board Statement:** The study was conducted in accordance with the Declaration of Helsinki, and approved by the Faculty of Engineering Ethics Committee of the UNIVERSITY OF NOTTINGHAM (15 December 2015).

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The data are not publicly available due to privacy reasons.

**Conflicts of Interest:** The authors declare no conflict of interest.

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