EnergyREV

Smart energy engagement tools in local energy initiatives

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Contents

Executive summary

Deploying smart local energy engagement tools (SLEETs) in local energy projects enables users to better observe and control energy, and potentially become active participants in local energy management. However, our study of prevalence, effectiveness and inclusiveness of 84 SLEETs deployed in 72 local energy projects in the UK from 2008 to 2018 shows that they could be used to do much more than is currently the case.

Over half (58%) were information-driven SLEETs. Only 12% of SLEETs offered users the opportunity to control energy use, and 30% offered interaction.

Inclusiveness of SLEETs is recognised as vital for scalability and replicability of smart local energy initiatives, but only 21% of the projects deployed SLEETs that were inclusive for vulnerable groups and users on a low-income.

In the report, SLEETs were grouped into seven types and characterised by level of interaction and interface design. In-home displays and thermal imaging – described as information-driven tools – were most popular in community energy groups. Digital energy platforms (DEPs) – or interaction tools – were found to be most popular in smart local energy projects. In contrast, gamification, and digital voice assistants, despite having visual and aural interfaces and energy management systems that offer to control the extent of user's interaction were found to be less popular. Spatial analysis revealed SLEETs were mostly deployed in areas with grid constraints (technology), active community energy groups (people) and engaged local authorities (policy). Effective SLEETs helped to stimulate engagement amongst people (social engagement), and people and technology (operation and control), while inclusive SLEETs enabled inclusion of vulnerable households and those on low incomes.

These findings revealed the acceptance and implementation of smart energy initiatives in local areas can be enhanced by having effective and inclusive SLEETs in place that align with local users' requirements and are supported by local stakeholders to foster trust.

1. Introduction and background

To address the growing concern of climate emergency by limiting the global temperature rise to 1.5°C, the UK government has committed to a net-zero emissions target by 2050 (BEIS and Skidmore, 2019) (CCC, 2019a, CCC, 2019b). To meet its long-term carbon emissions reduction plan, the UK energy system is going through rapid change by becoming decarbonised, decentralised and digitised (Ford et al., 2019, Foxon, 2013). Local energy initiatives, whether they are community energy (CE), local energy (LE) or smart local energy system (SLES) initiatives can help to meet this obligation by delivering cleaner and cheaper energy services, while accelerating the transition by enhancing user engagement with the support of smart (digital) tools (UKRI, 2019). In response to changing policy and with development of technology innovations, the community energy sector in the UK went through rapid change showing a comparative upturn in 2019 (Robinson and Stephen, 2020) with the majority, including Community Benefit Societies (47%) and Community Interest Companies (CIC) (11%), focusing on energy generation, low carbon transport, energy storage and energy efficiency. CE initiatives include shared community actions to generate, manage, reduce and purchase local renewable energy (DECC, 2014), and emphasise community ownership, leadership and control (Walker and Devine-Wright, 2008). However, LE initiatives have a key role in the transformation of local energy systems through public-private partnership and with active participation of local authorities, driven by local economic growth, job creation and skill development (Bridgeman et al., 2019) through local energy generation, storage and distribution (CCC, 2019b). In contrast, SLES initiatives enable public and private organisations to develop smart technologies by addressing local energy issues, which can intelligently and locally link energy supply, storage and use. These can then be used along with power, heating and transport, in ways that dramatically improve energy efficiency and reduce energy costs to create more resilient communities through innovative and smart (digital) use of data in energy systems (Devine-Wright, 2019).

Deploying smart local energy engagement tools (SLEETs) in such local energy projects enables users to better observe and control energy and change their behaviour concerning energy use while becoming active participants in local energy management. This can potentially reduce carbon emissions and align energy demand and supply (Global Data Energy, 2019). SLEETs are not only technical devices, but also offer a means of interaction between: people and people, for social engagement, (Moustaka et al., 2019); people and technology, for operation and control, (Rodrigues et al., 2018); as well as technologies and technologies, for connectivity and communication, (Kleiminger et al., 2014). SLEETs can be effective in enabling reductions in energy use, carbon and cost, empowering users to participate in local energy markets and interact with peer neighbours to exchange energy, while improving user engagement (Morris et al., 2020, Casals et al., 2020, Vlaev and Dolan, 2015).

User engagement is key for the deployment of SLEETs, as identified by Balta-Ozkan et al. (2013) and Gangale et al. (2013), so the organisation offering the SLEETS can have an impact on how they are received. Users have low levels of trust in utilities and rarely engage in energy projects with them. A survey conducted by Koirala et al. (2018) on 956 participants to identify the impact of user trust on participation in community energy systems projects revealed that community trust has a vital role for user engagement, followed by community resistance, energy independence, and environmental concerns, as well as energy-related education and awareness about local energy initiatives.

Such concerns can be overcome if SLEETs are delivered through local trusted organisations, such as local authorities and local community groups, and use appropriate user engagement methods. Local government and local organisations have significant local trust (Barry et al., 2020) making it easier for users to accept new energy interventions when delivered through these reliable bodies. Such trustworthy intermediaries can develop new technology tailored to users' needs, including those of vulnerable users and those on low income, to ensure a fair distribution of the benefits of new interventions at a local scale. Despite the growing interest in SLEETs, there is a lack of comprehensive study investigating the various types of SLEETs deployed in local energy projects and examining how effective and inclusive they are in engaging users by setting out standard criteria.

This report examines the prevalence, effectiveness and inclusiveness of SLEETs deployed in local energy projects undertaken in the UK from 2008 to 2018 using a meta-study (cross-project) approach and statistical analysis of the meta-data gathered. The experience gained from this study in the UK can be applied to other developed countries deploying smart tools in local energy projects. The study begins with an assessment of the prevalence of SLEETs in the UK to indicate how widespread they have become across the country in the last few years. This is used to highlight which areas have a greater level of activity in deploying SLEETs, along with the reasons why. The study also evaluates the effectiveness and inclusiveness of SLEETs to identify how user attitudes, requirements and socio-economic benefits were accounted for in delivering smart energy interventions designed to bring a meaningful change to support the net-zero emissions targets and UN Sustainable Development Goals (SDGs) on delivering affordable and clean energy for all, climate action and sustainable cities and communities. Such an investigation can help to bridge the knowledge gap regarding the acceptance of SLEETs by answering questions on how valuable and usable SLEETs are in supporting users to become active participants in managing and controlling energy. It looks at how they become active participants in the energy market, and how to ensure SLEETs are deployed in a socially responsible manner. The learning from this study can be used to inform the next generation of SLES initiatives that UK government invests to meet the carbon emissions plan, as well as future local energy projects in developed countries that implement the same energy interventions to tackle climate change.

For more detail on SLEETs and the evidence to date, see Annex 1.

2. Methodology and framework to characterise SLEETs

A meta-study (cross-project) approach was adopted to identify what types of SLEETs were deployed across local energy projects, with the scope of the study limited to local energy projects undertaken in the UK from 2008 to 2018 covering major funding programmes on local energy initiatives. The learning from this study can then be applied to other developed countries that implement the same smart interventions. The methodological approach used systematic examination of academic (journal publications) and grey literature (e.g. project reports) to identify local energy projects and the type of SLEETs deployed in the projects to deliver social, economic or environmental benefits. (For more detail see Appendix 1.)

2.1 Analysis framework

An analysis framework was devised to characterise 84 SLEETs by interface- numeric, visual or voice-based and extent of interaction offered – information-driven, interaction and control (Table 1) in conjunction with the seven types of SLEETs provided in Table 3 in Annex 1.

Table 1: Framework to characterise SLEETs

Extent of interaction	Mode of communication (interface)		
	Numeric	Visual	Aural
Information	In-home displays (IHD)	Spatial mapping	–
	–	Thermal imaging	–
Interaction	Digital energy platforms (DEPs)	Gamification	–
Control	Energy management systems	–	Digital voice assistant

The prevalence of SLEETs was studied against the analysis framework to identify the functionality and applicability of the tools in the local energy projects and to indicate how prevalent SLEETs have become across the UK in the last few years. This was used to highlight which areas have a greater level of activity in deploying SLEETs, along with the reasons why. The projects were characterised based on the UK Energy Research Centre's (UKERC's) report on UK energy system demonstrators (Flett et al., 2018). These characteristics included lead actor (DNO, university, private sector, community group, local authority and partnership collaboration), funder (government, UKRI, DNO, EU and regulator), start year (2008 to 2018), type of initiative – community energy (CE), local energy (LE) and smart local energy systems (SLES) and energy vector (Electricity, Heating, Transport), as well as user engagement pathways.

The study also evaluated the effectiveness and inclusiveness of SLEETs to identify how users' attitudes, requirements and socio-economic benefits were accounted for in delivering smart energy interventions to bring a meaningful change to support net-zero emission. The criteria for effective and inclusive SLEETs were selected based on UN Sustainable Development Goals (SDG) to deliver affordable and clean energy for all, and to make cities sustainable and inclusive. This was used because no systematic criteria were found in the projects or in the reviewed grey and academic literature to evaluate inclusiveness and effectiveness of smart tools in local energy projects (Table 2). Ensuring access to affordable, reliable, sustainable and modern energy for all will offer opportunities for all people through new economic opportunities and empowering, better education, more sustainable, equitable and inclusive communities (gender, age, income), and greater protections from, and resilience to, climate change by reducing energy use and carbon emissions (UN SDGs, 2020).

Table 2: Effectiveness and inclusiveness of SLEETs

SLEETs Effectiveness characteristics	SLEETs Inclusiveness characteristics
• Enabling behavioural response • Enabling carbon reduction • Enabling energy use reduction • Enabling learning • Empowering users	• Age • Gender • Socio-economic status • Vulnerability

Effective SLEETs enable behavioural response, carbon reduction and energy use reduction, as well as learning. They also empower users to be active participants in local energy management or become involved in local energy markets to trade surplus energy generated by prosumers or stored in battery storage. Inclusive SLEETs improve project acceptance and enhance user engagement by focusing on socio-demographic (e.g. age, gender) and socio-economic factors, vulnerability and barriers (trust, privacy and knowledge).

Pearson's Chi-square independence test was also carried out to identify the relationship between the characteristics of SLEETs, and the factors affecting prevalence, effectiveness and inclusiveness. To indicate the strength of association, Cramer's V test (Pearson's Chi-square based measure of association) was also carried out for unviolated data (if more than 20% of data in each category has an expected count less than 5, the assumption of Chi-square test is violated) giving a value between 0 (no association) and 1 (complete association).

3. Type of SLEETs

The meta-study identified 84 SLEETs that were deployed across 72 local energy initiatives, with some projects using multiple SLEETs to enhance user engagement. Dominant SLEETs were IHD providing energy feedback (n: 23) and thermal imaging highlighting heat losses from building fabric (n: 23). These were followed by DEP (n: 22) to help manage and control energy services or empower users to participate in the local energy market (Fig. 1).

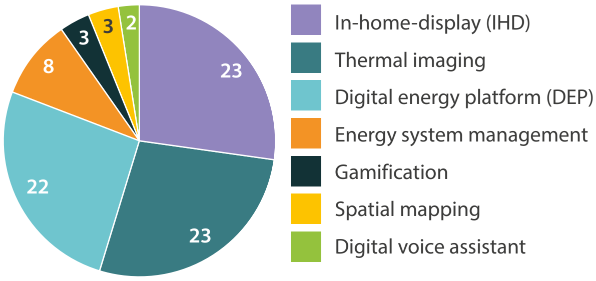

Figure 1: Type of SLEETs deployed in 72 local energy projects

It was apparent that information-driven tools (49 out of 84 SLEETs) with numeric (IHDs) and visual (thermal imaging or spatial map) interfaces (58%) were dominant amongst the projects, although they only allow users to monitor data. These were followed by interaction tools that covered 30% of SLEETs (n: 25), which enable users to interact with peer neighbours to exchange energy and to change behaviour. However, control tools (n: 10), despite enabling users to manage and control energy use and energy costs remotely, were less popular (12%). These included energy management systems (n: 8), as well as digital voice assistants (n: 2). Gamification tools with a visual mode of communication were also found to be unpopular (n: 3). To identify the relationship between the characteristics of SLEETs and the projects' key characteristics (prevalence, inclusiveness and effectiveness), as well as the choice of SLEETs in relation to the form of user engagement, whether informing, communicating, involving or empowering the Pearson Chi-square test was undertaken. It should be noted that if more than 20% of data in each category has an expected count less than 5, the assumption of Chi-square test is violated and the result may not be reliable, despite a statistically significant p-value (e.g. 0.01 and 0.05).

4. Prevalence of SLEETs in local energy projects

The prevalence of SLEETs was studied in relation to the characteristics of local energy projects that included energy vector (Energy (E), Heat (H) and Transport (T)), type of local energy projects (CE, LE and SLES), start year (2008-2018), geographic location, lead actor and funder. Because clean and multi energy vectors can contribute to decarbonisation of the energy systems with an alternative option to store or transport the renewable energy through services that can be enabled by SLEETs, offering more dynamic and flexible low carbon energy systems, the popularity of SLEETs across the multiple energy vectors was closely examined.

4.1 Energy vector

The majority of local energy projects deployed multiple vectors with E vector being dominant (n: 61), followed by H vector (n: 44), while T vector (e.g. EV charging points) was included in only 9 out of 72 projects (Fig. 2). Out of the total of 84 SLEETs, the number of SLEETs associated with E, H and T vectors were 73, 53 and 11, respectively – a SLEET could be deployed in projects with more than one vector, with the greatest number of overlap occurring with E and H vectors (n: 31). It was evident that DEP with numeric interface was a popular tool (22 out of 73 SLEETs) in the projects with E vector, followed by IHD (n: 19) with numeric interface, and then thermal imaging with visual interface (n: 16). Thermal imaging with visual interface was also found to be popular in the projects with H vectors (17 out of 52 SLEETs).

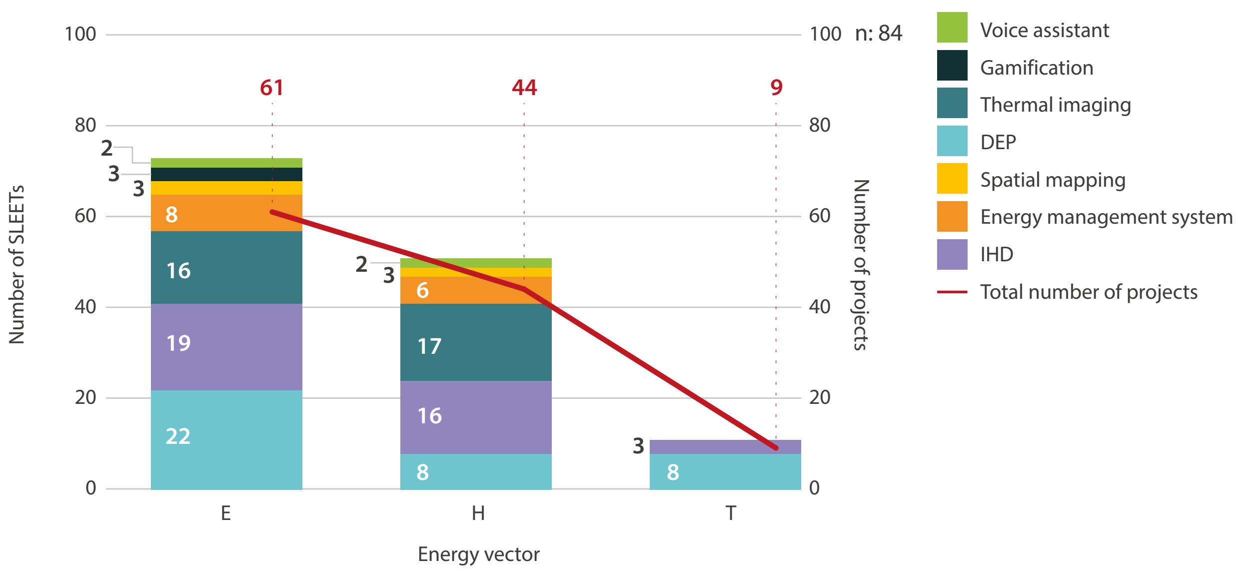

Figure 2: Energy vectors in relation to type of SLEETs

4.2 Type of energy initiatives and start year

The majority of SLEETs were deployed in SLES projects (38 out of 72 projects), followed by CE projects (27 out of 72 projects). DEPs as interaction tools with numeric interfaces were popular in SLES initiatives (21 out of 84 SLEETs), while thermal imaging as an information-driven tool with visual interface was found to be dominant in CE initiatives (n: 18) (Fig. 3). A Pearson Chi-square test between SLEETs and type of local energy projects (CE, LE and SLES) revealed strong associations between DEP in SLES and thermal imaging in CE projects (0.55 ≤Cramer's V ≤0.70 with df=2, P-values <0.001). Such relationships confirmed the interest in enhancing user engagement by digitalisation where smart energy systems were implemented. However, deploying thermal imaging across CE projects indicated the importance of improving energy efficiency in buildings to save energy costs and to reduce energy use and carbon emissions by getting local users involved at the heart of local energy services.

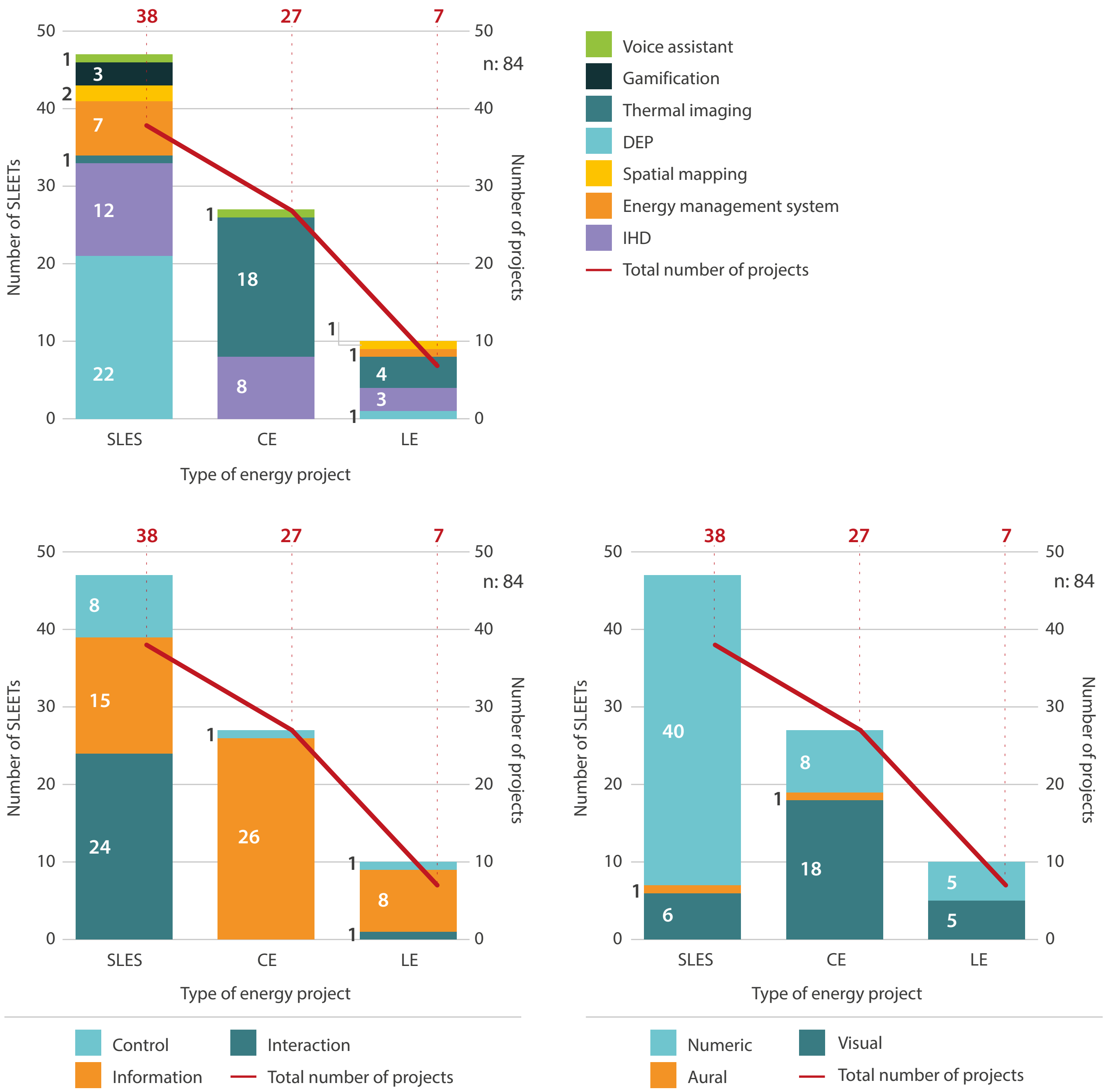

Figure 3: Type of local energy initiatives in relation to type of SLEETs (top), level of engagement (bottom-left) and model of communication (bottom-right)

Only SLES projects deployed a substantial proportion of interaction-driven SLEETs (24 out of 47 SLEETs). There were no interaction-driven SLEETs deployed in CE projects. Information-driven SLEETs were dominant in CE and LE projects. Control-driven SLEETs were only of note in SLES projects (8 out of 47 SLEETs). It might be expected that smart systems would be associated with a level of control.

Meta-study analysis revealed information-driven tools became popular in 2010 when the UK government introduced the LEAF programme to support communities to take action on energy efficiency and renewable energy within CE projects. Thermal imaging was dominant (22 out of 84 SLEETs) for highlighting heat losses from the building fabric, followed by IHD (n: 9) for providing energy feedback (Fig. 4). However, the increase was not sustained in subsequent years with changes to the UK energy policy for decarbonised energy systems. Further analysis by extent of interaction showed that before 2011, SLEETs were only information based. From 2011 onwards, interaction and control based SLEETs began to appear, with interaction based SLEETs becoming dominant from 2015.

Following the publication of the first ever community energy strategy in 2014 (DECC, 2014), which presented a decentralised vision of energy transition, the majority of the projects were found to use DEPs as interaction tools. DEPs supported users to become digitised in energy management and the local energy market, covering 16 out of 30 SLEETs deployed in the projects undertaken from 2014. This interest in the use of DEPs confirms how the popularity of SLEETs has changed over time, whether driven by digitalisation, grid balancing, or community inclusion to take advantage of the opportunities offered by national government policies encouraging the use of smart technologies and improving energy efficiency.

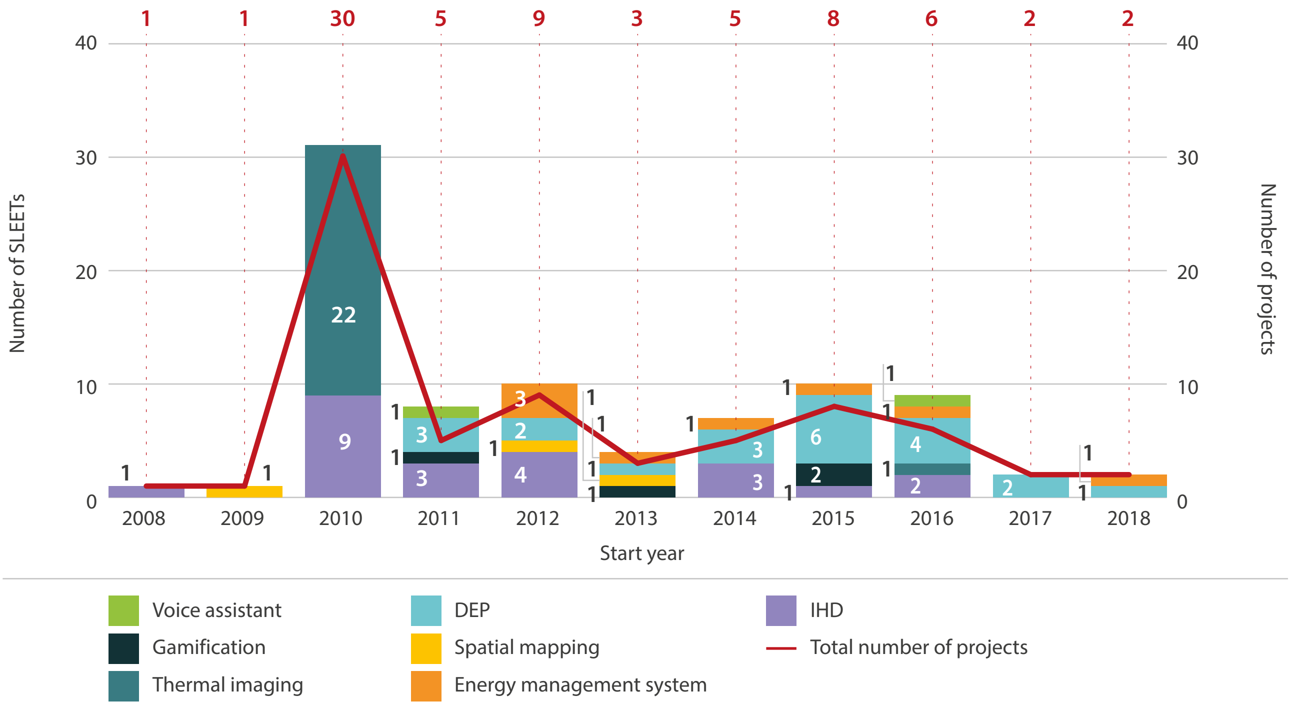

Figure 4: Projects start year in relation to type of SLEETs

4.3 Geographic location

Because local energy initiatives are area-based, the geographic location under different UK regions was closely examined and is presented in Fig. 5. The majority of SLEETs were deployed in projects in areas with both network constraints and a high concentration of community energy groups, as mentioned in the Community Energy Strategy 2014 (DECC, 2014) and presented in the Community Energy Hub online map (Community Energy Hub, 2020). These areas included South East England (25 SLEETs in 20 projects), Scotland (12 SLEETs in 10 projects) and the Midlands (12 SLEETs in 9 projects). IHD, DEP or thermal imaging were dominant. Interestingly, while information-driven tools were popular among the projects undertaken in South East England (15 out of 20 projects) and the Midlands (7 out of 9 projects), the majority of the projects in Scotland deployed interaction tools (7 out of 10 projects), possibly to overcome grid constraint (Jones et al., 2018, National Grid, 2020, ENS Group, 2012). These SLEETs may have been deployed in Scotland due to the surge in renewable electricity generation that met 97% of electricity demand by 2020 (Scottish Energy Statistics Hub, 2021).

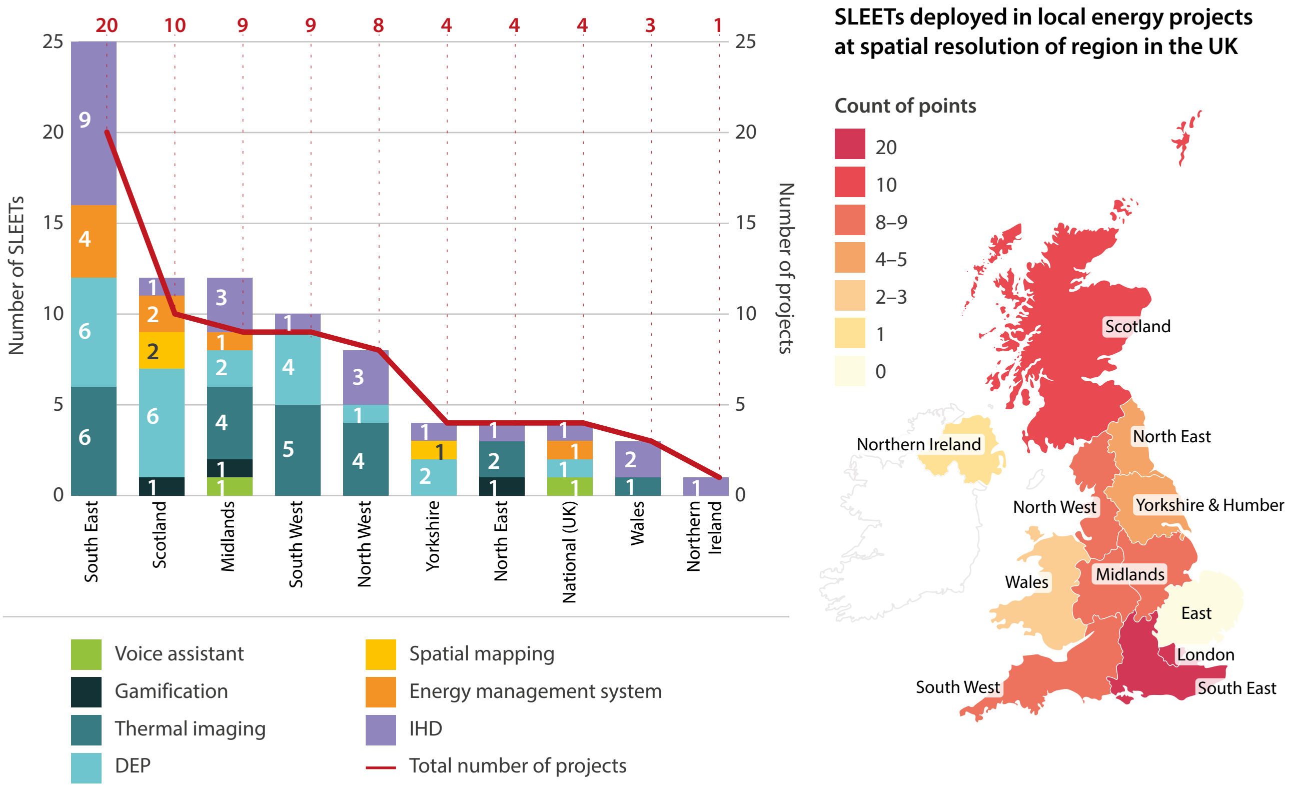

Figure 5: Geographic location of the projects in relation to type of SLEETs (left) and distribution of SLEETs in local energy projects in the UK at spatial resolution of region (right). Ordnance Survey (ESRI ArcGIS licence)

Spatial diffusion of SLEETs at spatial resolution of region, presented in Fig. 5 (right), confirmed deployment of SLEETs was prevalent in South East and South West England, Scotland and the Midlands. As evident in Fig. 6, deployment of SLEETs matched the engagement of active community energy groups (Robinson and Stephen, 2020, Community Energy Scotland, 2020), who acted as intermediaries to improve user engagement and maintain long-term participation in local energy projects. Local authorities (Department of Energy and Climate Change, 2015, Braunholtz-Speight et al., 2018, Tingey et al., 2017) and renewable energy technologies were also present (Department of Energy and Climate Change, 2015, Braunholtz-Speight et al., 2018, Tingey et al., 2017). It was also apparent that the energy engagement of local authorities in Scotland, Yorkshire and the Humber, South East, South West, North East and North West England, (Fig. 6 (right)) was broadly matched with distribution of SLEETs (Fig. 5 (right)), despite being at different stages in terms of engagement.

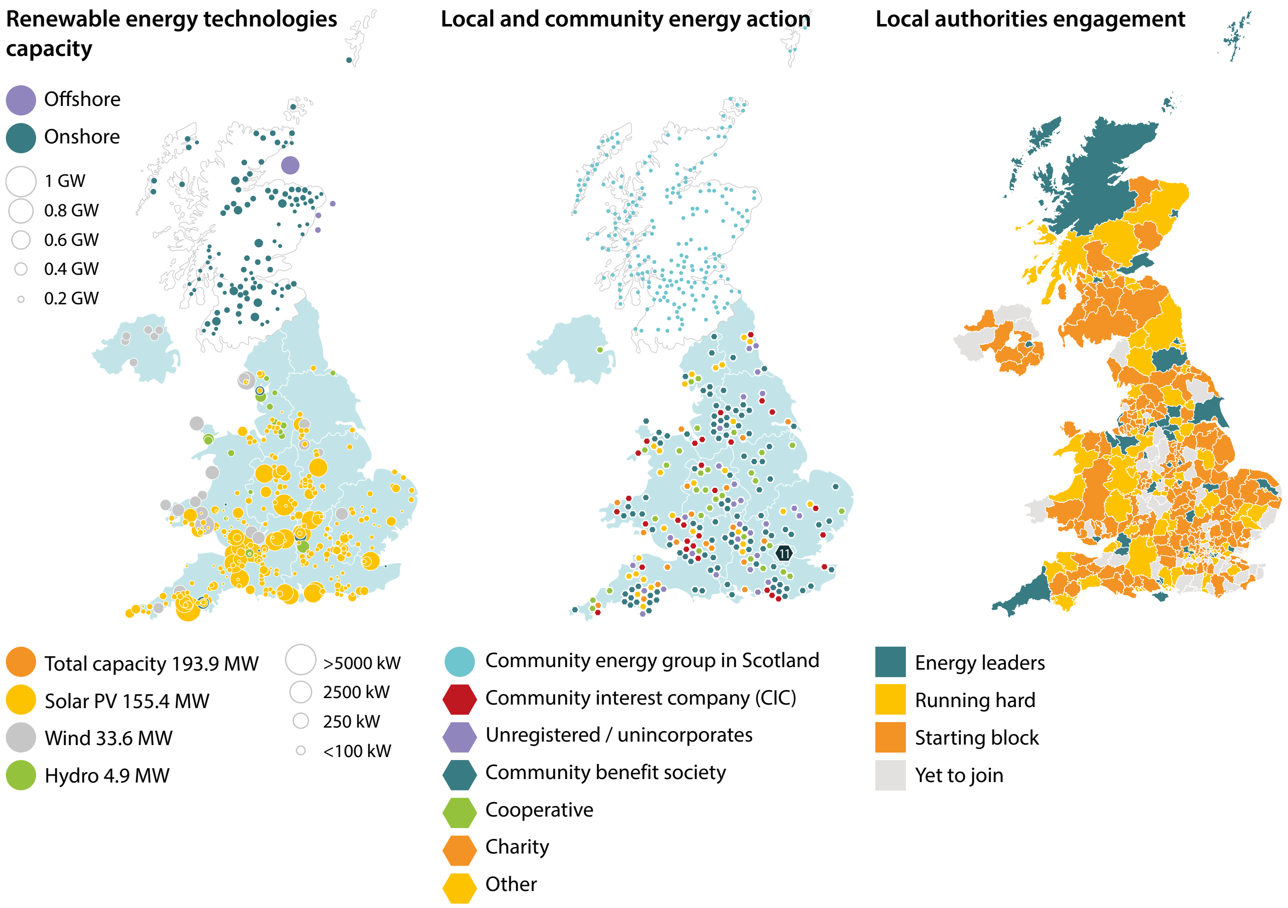

Figure 6: Spatial distribution of renewable energy capacity in England, Wales, Northern Ireland (Robinson and Stephen, 2020), and wind capacity in Scotland (BEIS, 2020) (left), local/community energy actions in England, Wales, Northern Ireland (Robinson and Stephen, 2020) and in Scotland (Community Energy Scotland, 2020) (middle) and local authorities' engagement (Tingey et al., 2017) (right)

4.4 Lead actors and funders

The meta-study revealed that the majority of DEPs as interaction tools were deployed in the projects led by DNOs and carried out to improve energy management and reduce network pressure. Thermal imaging with visual interface was popular in community group-led projects aiming to improve energy efficiency (Fig. 7). Analysis by extent of interaction showed that information-driven tools were popular among community group-led projects (24 out of 26 SLEETs) to engage users with local energy projects. For projects led by DNOs, SLEETs were mainly interaction based (14 out of 25 SLEETs), and numeric SLEETs were dominant (23 out of 25 SLEETs).

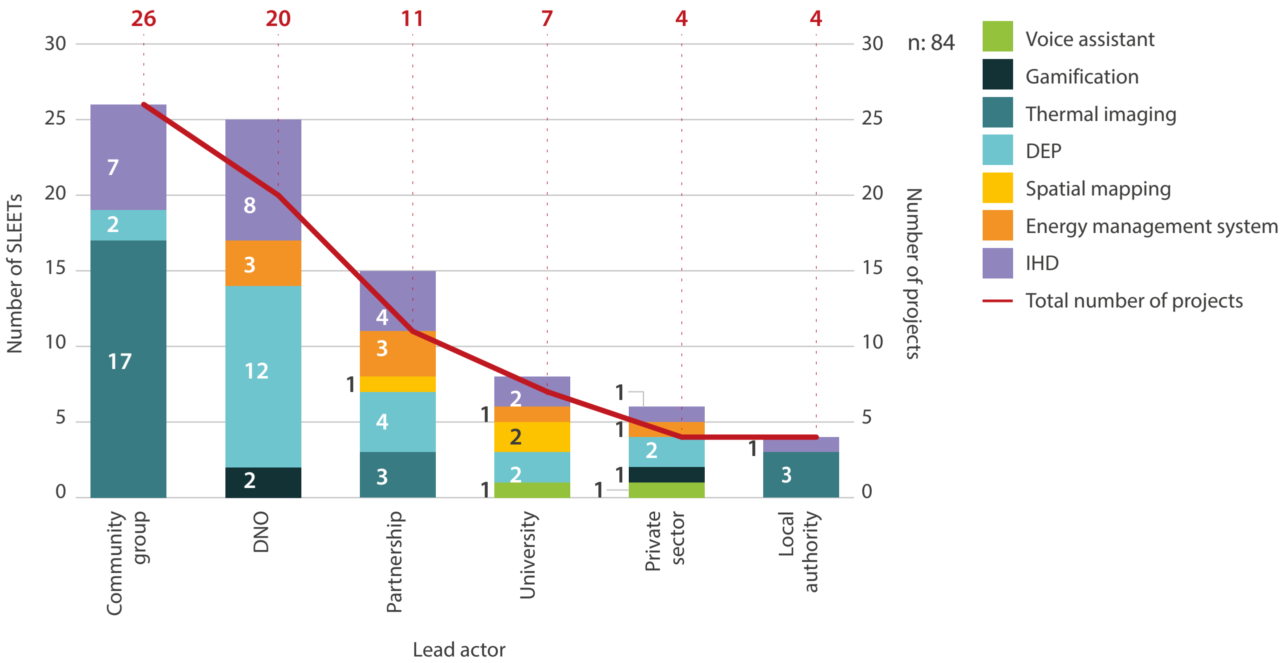

Figure 7: Lead actors of the projects in relation to type of SLEETs

The majority of the projects that deployed SLEETs were funded by the government to support net-zero carbon emission plans by reducing energy use and carbon emissions. In these thermal imaging and IHD were dominant (22 and 10 out of 34 SLEETs, respectively). The majority of the projects funded by regulator deployed DEP (n: 13) to involve users as active participants in local energy projects and engage them in local energy management and energy trading (Fig. 8).

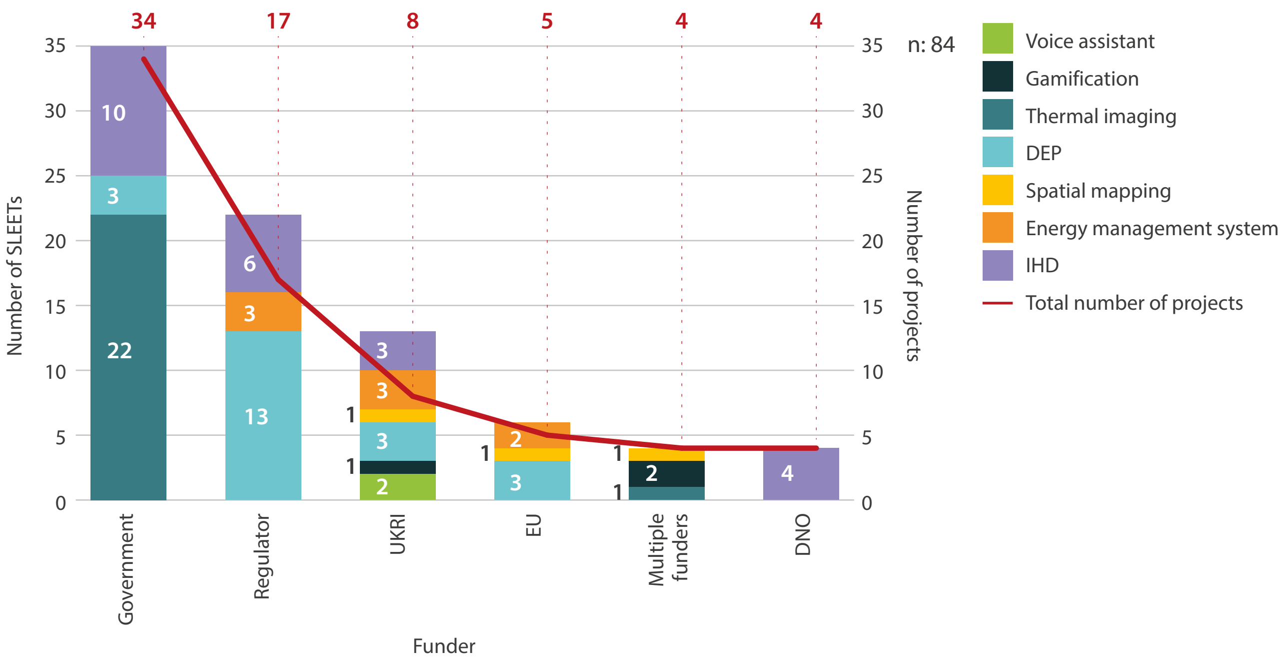

Figure 8: Funders of the projects in relation to type of SLEETs

Analysis also showed statistically significant relationships between user engagement methods and SLEETs. It was evident that where engagement was about informing and involving, information-driven tools with visual or numeric interfaces were deployed to encourage users to be involved in local energy projects, or to support them to engage through different activities such as training and consultation events or by providing incentives and offers. However, where user engagement was about involving, DEP was used to involve users in local energy management and trading of local energy through interactive tools that allow users to interact with peer neighbours who can offer energy services.

5. Effectiveness and inclusiveness of SLEETs

The meta-study also evaluated the effectiveness and inclusiveness of SLEETs in local energy projects by type of projects energy vector, geographic location, start year, lead actor and funder. Effective SLEETs enable behavioural response, and carbon and energy use reduction, while enabling learning and empowering users to become actively involved in local energy management or local energy markets to trade surplus energy generated by prosumers or stored in battery storage. Fig. 9provides the number of projects which reported specific effectiveness characteristics following the deployment of SLEETs. Each of the 72 projects could exhibit multiple characteristics of effectiveness and inclusiveness. Energy use reduction and carbon reduction were the foremost characteristics, present in 40 and 36 projects respectively, followed by behavioural response, cost reduction and empowering users. Only seven projects deployed SLEETs that enabled learning.

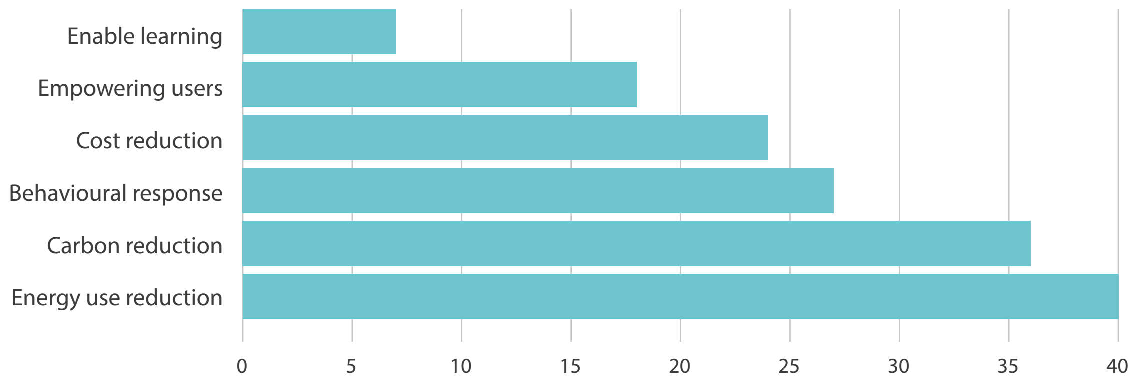

Figure 9: Number of projects reporting effectiveness characteristics

Analysis using Pearson's Chi-square test identified strong association between the type of energy initiatives (CE, LE and SLES) and effectiveness characteristics that included behavioural responses, energy cost reduction, carbon reduction and empowering users (P-value<0.01, 0.40< Cramer's V <0.35 with df= 2). In CE projects SLEETS were deployed to enable energy use and carbon reductions (n: 17 and 12 respectively) (Fig. 10). Within SLES projects, SLEETs were deployed to support users in behavioural response (n: 21 projects), as well as cost reduction (n: 21) and carbon reduction (n: 20). SLEETs were also found to be effective in empowering users in SLES projects to manage and control energy or to trade surplus energy generated by prosumers or stored in battery storage (n: 18). Only SLES projects deployed SLEETs that empowered users.

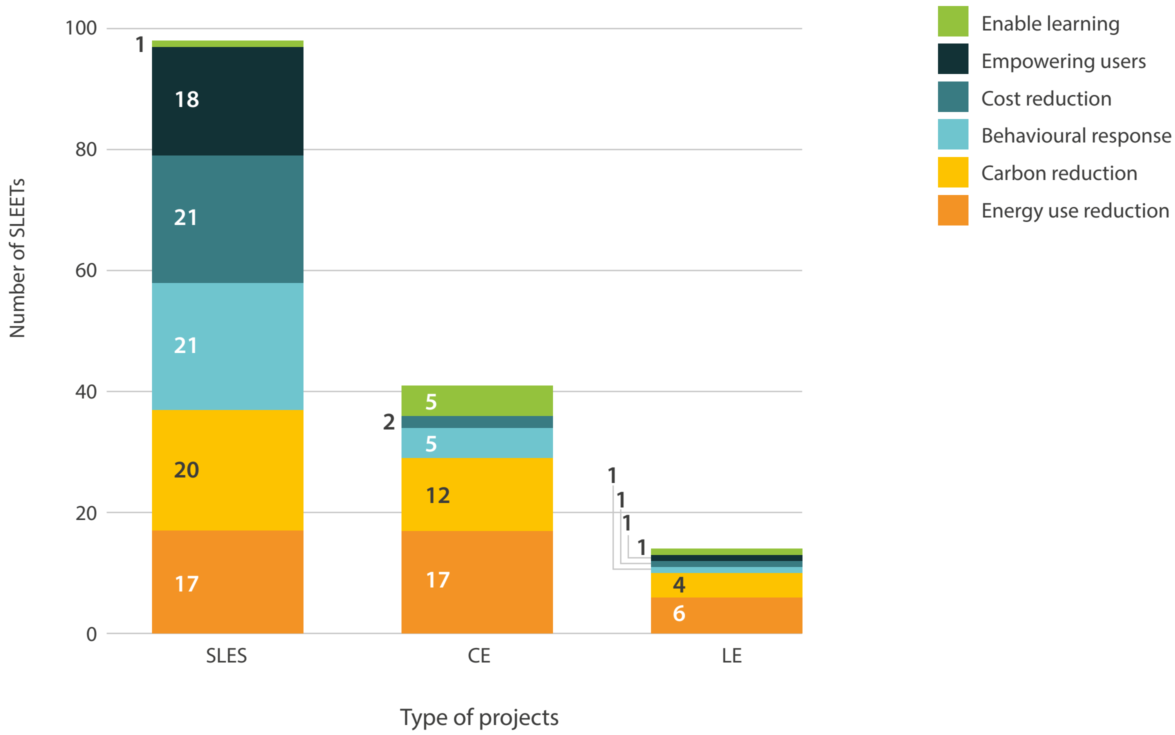

Figure 10: Type of local energy initiative in relation to effectiveness

SLEETs were more effective in enabling energy use and carbon reduction in the projects led by community groups (14 and 12 projects, respectively). Where the projects were led by DNO and funded by regulator (n: 5), SLEETs were effective in empowering users to become active participants in local energy projects. In contrast, when the projects were led by community group and funded by government, SLEETs were deployed to enable reductions in energy use and carbon (n: 14 and 12 projects respectively).

Meta-study analysis revealed that the majority of the projects did not consider whether the delivery mode of SLEETs was inclusive, since only 15 out of 72 projects deployed inclusive SLEETs to enhance user engagement and support vulnerable users and those on low incomes in saving and controlling energy effectively. The majority of SLEETs were found to exclude inclusive mode-delivery, with only 15 out of 72 projects considering the inclusiveness of SLEETs to enhance user engagement.

Within the limited number of inclusive SLEETs, the majority of the tools were deployed to actively involve users on low income to alleviate fuel poverty (14 out of 15 projects), followed by involving vulnerable users (n: 7). The majority of projects which deployed inclusive SLEETs were SLES projects (n: 10). Out of the projects which deployed inclusive SLEETs, 11 projects occurred between 2014-2016, coinciding with the introduction of the Renewable Heat Incentive (RHI) for the domestic sector in 2014 and publication of the first ever community energy strategy in the UK. This demonstrates how local energy policies can involve diverse users to overcome local obstacles such as fuel poverty. Despite the low number of projects with inclusive SLEETs, it appeared that vulnerability became supported across the projects over time. Communities and the public sector were more likely to deploy inclusive SLEETS. These included groups led by DNOs (n: 7), universities (n: 6) or community groups (n: 5), groups funded by government (n: 6), UKRI (n: 6) and regulator (n: 5).

6. Linking key findings on SLEETs and user engagement

Meta-study revealed that majority of SLEETs were information-driven, focusing on analytics and unidirectional tools (58%). Over one-third of SLEETs offered some level of interaction to enhance user engagement. They allowed users to interact with other local users or organisations to stimulate behaviour change. Only 12% of SLEETs offered users the capability to manage and control energy despite the fact that these tools with some level of control can play a major role in energy demand reduction, as detailed in UKERC's 'Smart Power Sector' scenario of smart grid futures (UKERC, 2014). SLEETs with capability to control heating and electricity use can also support to shift energy use during the peak hours in response to price signals for local grid balancing (Schweiger et al. (2020) and Vázquez-Canteli and Nagy (2019). Greensfelder et al. (2011) also identified that enabling users to manage energy use remotely, such as pre-heating the building when energy price is low, can save up to 14% on energy costs.

Evidence from beyond the meta-study shows that to enhance user engagement with local energy and to reduce energy demand, SLEETs need to move beyond information-driven flow; they should not only offer users sets of information about energy but also facilitate interaction between local users and organisations and allow them to control energy use. Such support helps users to participate in local energy markets and change behaviour, possibly through DEPs and gamification, while enabling control through energy management systems and digital voice assistants. To deliver the best experience for users and encourage user engagement, SLEETs need to be accompanied by adequate training and delivered through trusted intermediaries such as local community groups. These intermediaries can facilitate aggregation of learning, providing advice, creating networks and shaping policy as identified by Sovacool et al. (2020), Grandclément et al. (2015) and Hyysalo et al. (2018). Interestingly, none of the SLEETs identified were accompanied by training of users through inclusive modes of delivery (e.g. in-home visit, community event). Training of users in SLEETs is vital for maintaining user interest in SLEETs and avoiding unintended consequences

The meta study also identified associations between the type of local energy projects and type of SLEETs that were deployed. DEPs with interaction levels of engagement were found to be popular in SLES projects where DEPs aimed to enhance local grid balancing and facilitate local energy trading between peer neighbours and local organisations. This was detailed in a working paper on digital energy platforms (Morris et al., 2020) prepared as a part of the Energy Revolution (EnergyREV) programme established in 2018 and sponsored by the UK's Industrial Strategy Challenge Fund. There has been a rise in SLES projects focused on local economy and routes to market following the lunch of UK Industrial Strategy.

Information-driven SLEETs were found to be dominant in CE projects (96% of SLEETs in CEs), possibly driven by the UK government funded by the Low Carbon Communities Fund and LEAF programme which aimed to improve energy efficiency and social learning. The role of community groups in providing advice and supporting energy use reduction and behaviour change was revealed by Klein and Coffey (2016), Boyle et al. (2021) and Watson et al. (2020), who studied the role of community energy groups in energy transition.

SLEETs can potentially enhance user engagement by considering the socio-technical benefits of local energy that match user requirements (Francis et al., 2020). However, the meta-study identified that only 21% of the local energy projects deployed SLEETs with an inclusive mode of delivery that engaged with vulnerable and low-income groups. It was apparent that there was a lack of interest in deploying SLEETs to address requirements of vulnerable users such as elderly and disabled users, those in fuel poverty and who do not have access to digital technologies. Inclusiveness of SLEETs is vital for improving user acceptance of smart local energy initiatives, as identified by Suboticki et al. (2019) who emphasise the impact of socio-demographic and users' habits on energy use. Digital voice assistants can be appropriate for vulnerable users and those who do not prefer to use a smart mobile app or smart thermostat. They can also allow people with reduced mobility to interact effectively with energy systems. However, such SLEETs were only used in two out of 72 projects only. Likewise, gamification was used only in three out of 72 projects even though delivering financial incentives such as vouchers through gamification methods can encourage low-income users to get involved in local energy management.

Bent and Kmetty (2017) found that inclusive SLEETs tend to be tailored to user interest and requirements. For instance, for low-income groups, this can mean framing advisory messages through SLEETs that use economic benefits of shifting energy use during the peak period. For those users with an interest in technology, SLEETs can provide advice on how smart thermostats can help to manage heating remotely through a mobile app. In contrast, for the elderly, an appropriate voice controlled SLEET could be developed that allows users to control energy verbally and advise them on how to adjust time and temperature controls to reduce energy use without compromising their comfort.

The acceptance and implementation of smart energy initiatives in local areas can be enhanced by having effective and inclusive SLEETs in place that align with local users' requirements and are supported by local stakeholders to foster trust. To maintain long-term user engagement and for SLEETs to become widespread, data transparency is vital to enable users know what data are collected, for what purpose, by whom and for how long, as found by Suboticki et al. (2019) and Schweiger et al. (2020). Without data transparency, users may lose rapidly lose trust in SLEETs despite showing initial interest in engaging with SLEETs. Data transparency was not a key aspect considered in the projects as identified in this meta study.

7. Conclusion

This report used a systematic meta-study approach to investigate the prevalence, effectiveness and inclusiveness of SLEETs deployed in local energy projects undertaken in the UK over a decade. An extensive review of grey and academic literature identified 84 SLEETs deployed across 72 local energy projects in the UK from 2008 to 2018. An analysis framework was devised to characterise SLEETs by extent of interaction (information, interaction and control) model of communication and interface design (numeric, visual or aural). SLEETs were grouped into seven categories. IHDs and thermal imaging as information-driven tools and DEPs as interaction-driven tools were found to be most popular in CE and SLES projects respectively. In contrast, gamification tools offering interaction between users (with visual interface), energy management system, and digital voice assistants as control driven tools were found to be less popular. Only 12% of SLEETs offered control and 30% offered interaction as opposed to 58% of information-driven SLEETs.

The prevalence of SLEETs was examined against key features of local energy projects including start year and type of local energy projects, with SLES projects being dominant with a focus on digitalisation of energy. Spatial distribution of SLEETs revealed that the majority of SLEETs were deployed in areas (South East England, the Midlands and Scotland) with a high capacity for renewable energy technologies (technology) and grid constraints (Jones et al., 2018, National Grid, 2020, ENS Group, 2012). They also occurred where there was the involvement of active community energy groups (people) and engagement of local authorities with local area energy action (policy).

DNOs were identified as the dominant lead actor in the deployment of interaction-driven tools to users to become active participants in local energy management. Community groups focused on information-driven tools such as IHDs and thermal imaging to enable energy efficiency and activities relating to energy demand reduction. Looking forward, there is an opportunity for community energy groups to take more of a role in advocating interactive tools to enable users and communities experience the energy management benefits they provide.

While inclusiveness of SLEETs is recognised as vital for the scalability and replicability of smart local energy initiatives, only 21% of the projects studied, deployed SLEETs that were inclusive for vulnerable groups and users on a low-income. Given the restrictions on face-to-face interactions imposed by the Covid-19 pandemic, the role of SLEETs has become increasingly vital in allowing interaction amongst people (social engagement), and enabling control between people and technology (operation and control). Control-driven and interactive SLEETs that allow diverse users to manage energy use effectively can help to reduce grid constraints by shifting energy use from peak hours if coupled with incentivising users to encourage them to reduce energy demand. However, only two projects were identified which used voice assistant control and this is an area which requires further development to ensure inclusive modes for delivery are provided for vulnerable users.

Overall, there was a lack of control-driven tools across the projects. Only 18 out of 72 projects deployed SLEETs, which empowered users with local control.. To sustain user acceptance and trust, policy-makers need to ensure that data transparency is promoted in terms of what data are collected, by whom and for what purpose. To build feedback loops, it is also worth capturing the actual experiences of different user groups (socio-demographics, vulnerabilities, low-income) with different types of SLEETs in the future. As the energy system in the UK and internationally becomes increasingly decarbonised, decentralised, digitalised and democratised, the integration and evaluation of SLEETs should become part of delivering local energy initiatives. Past experience shows that the highly relevant outcomes of SLEETs may not naturally filter their way through to policy-makers. Understanding the insights on user engagement and user participation gathered through SLEETs may require increased policy-maker effort.

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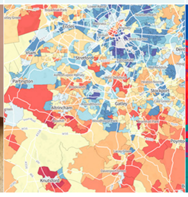
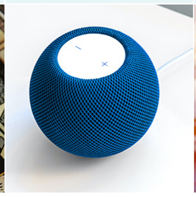
Annex 1: Evidence to date

Characteristics of SLEETs

In this report, SLEETs are categorised into seven groups of digital tools (Table 3) based on the type of communications offered that were identified through the meta-data gathered as a part of this study on local energy projects. These were grouped into three forms of communication: information-driven, interaction and control.

Table 3: Type of SLEETs

Information-driven SLEETs			Interaction SLEETs		Control SLEETs	
In-home display (IHD)	Spatial mapping	Thermal imaging	Digital energy platform (DEP)	Gamification	Digital voice assistant	Energy management system
						

Information

Information-driven tools support users in monitoring energy related data and provide feedback to users with numeric or visual interface that include In-home display (IHD), thermal imaging and spatial mapping tools. An effective feedback method is key to encourage users in their decision- making process and change behaviour in energy use to save energy costs (Vlaev and Dolan, 2015) and allows users contribute to local energy plans. IHD as one type of information-driven tool provides real-time energy feedback in numeric format allowing users to notice sudden spikes in energy use, energy costs and carbon emissions. An IHD is connected to a smart meter via wireless sensors and transfers data to utility companies (Science and Technology Committee, 2016, Herrmann et al., 2018). Schultz et al. (2015) studied the impact of energy feedback through IHD in improving users' energy use in 393 single-family homes in South California and identified that providing energy feedback via IHD could reduce households' energy consumption up to 9% since users became more responsible in using energy by understanding spikes that affected energy costs. Darby and Liddell (2015) identified that smart meter roll-out in the UK along with deployment of IHD in the domestic sector could improve users engagement with local energy projects and encourage them to reduce energy use. Although implementing such technology supports reductions in energy use and energy costs, it does not enable users to bring about meaningful change in their behaviour by managing and controlling the energy services and users may stop using feedback tools after a while due to a lack of this ability.

A spatial mapping tool with visual interface provides a flow of information through an interactive platform by creating a detailed map of the environment. This tool allows users to interact with the real world to obtain energy flow across scale at different locations, e.g. power track mapping tools allowed users to track live power outages at national level (SSEN, 2019). The Leeds Heat Planning tool (Bush and Bale, 2019) and a GIS-based technique that was developed in local energy projects in Dublin to enhance user engagement through spatial mapping strategy (Gartland, 2015b, Gartland, 2015a) were found to facilitate decision-making plans by allowing users to visually explore local energy demand and supply. These tools enabled local authorities to design evidence-based energy policy by matching local energy demand with local energy resources and fuel poverty, and improve development of local energy projects at an early stage (Gartland, 2015b, Gartland, 2015a).

An infrared thermal imaging tool is an information-driven tool that enables users to explore the energy efficiency of buildings and identify heat loss through building fabrics visually by translating thermal energy into visible light. A study carried out by Boomsma et al. (2016) in Cornwall within the Eden Project revealed householders were more likely to improve energy efficiency measures when they received tailored thermal images of their homes compared to non-tailored reports. Despite the benefit of spatial mapping and thermal imaging tools in supporting users in the decision-making process, users can find it difficult to interpret the data or navigate through the digital system. This makes it vital to train users to take advantage of the tools.

Interaction

Gamification and digital energy platforms (DEPs) are two types of SLEETs that facilitate interaction between users, peer neighbours and local organisations, enabling reductions in energy use and energy costs and helping to change behaviour.

A gamification-based tool that can be accessible through interactive software or apps (Johnson et al., 2017) uses game-based features to assess energy use, improve behaviour and motivate users to become involved in local energy projects (Beck et al., 2019). It also provides economic benefit and allows users to compete in an entertaining way with peer neighbours to reduce energy demand (Strengers, 2013, Faheem et al., 2019) without direct engagement or dialogue (Woodcock and Johnson, 2018). AlSkaif et al. (2018) revealed gamification-based tools can improve user energy-related behaviour and energy efficiency, increasing user-engagement by providing bespoke energy feedback and advice. The HomeBeat tool developed in California and Australia also encouraged reduction in energy use and energy costs amongst householders during peak hours by providing personalised goals and incentivised plans that allowed users to compete with peer neighbours (Greany, 2016). The visualisation of information and a chance to win a game and obtain financial rewards can maintain engagement for the long-term, as highlighted by Kazhamiakin et al. (2016) and Konstantakopoulos et al. (2019).

DEPs can also support users to manage energy services and allow them to interact with peer neighbours to exchange energy (ESC, 2019a). DEPs for home energy services integrate smart systems to deliver user-friendly, personalised smart energy service plans including flexibility and grid service platforms, as well as peer-to-peer (P2P), local energy trading and management platforms (ESC, 2019b, Hardy and Morris, 2019). DEPs can enable users to reduce network pressure during peak hours by reducing energy demand as demonstrated in a Dutch local energy project (Verkade and Höffken, 2017). As highlighted by Bird and Chitchyan (2019) and Dorahaki et al. (2018), providing financial rewards to shift energy use from the peak hours could motivate users to participate in grid balancing programmes and overcome the issues of peak energy demand. Such interventions were successfully implemented in Greenwich Energy Hero (Greenwich Energy Hero, 2020) and the SAVE programme (SAVE, 2019a), two programmes in the UK that were undertaken to encourage user engagement.

These tools could be beneficial for low-income users; matching peak energy demand and supply and reducing network pressure through automated smart tools could lead to savings up to 15% of annual energy costs, according to the US Regulatory Assistance Projects (RAP) (Lazar, 2011). .

DEPs can also facilitate peer-to-peer (P2P) energy trading between users and prosumers (Ofgem, 2016). Parag and Sovacool (2016) identified that P2P platforms can facilitate investments in local renewable energy and storage systems and turn demand-responsive energy trading into profitable deals at the local community level to reduce peak loads and balance the grid. However, it is vital to deliver motivational psychology through a trusted intermediary to ensure sustainable participation of users and prosumers into the existing P2P electricity market, so that surplus energy can be sold through energy platforms at a cheaper rate than the national rate (Tushar et al. 2019).

While interactive tools can be effective in changing behaviour and reducing energy use by incentivising users for their performance and by making comparisons with their peers, where these tools are used through mobile, tablet or web-based applications, vulnerable users such as the elderly and those who are not digitally skilled may find them hard to access.

Control

Energy management systems as control-driven tools enhance user engagement by allowing users to control and manage smart energy appliances, obtain energy feedback and monitor energy use remotely via smart phones, tablets or voice assistant devices. A customer model app developed in the UK SAVE project (SAVE, 2019b), coupled with peak banded pricing technology and a dynamic pricing scheme, was found to encourage users to reduce energy use. This was because it provided real-time and historic energy data, allowing users to track and control energy consumption remotely and to receive rewards for reducing energy use at peak hours. Dwivedi and Shimi (2015) found users preferred to use energy management systems to obtain energy feedback and energy bills since the systems could reduce the effort of data collection, while allowing the users to control energy use remotely. This is a similar finding to that from the British Gas HIVE project, which supported users in controlling heating energy and hot water remotely via an app to save energy (British Gas, 2019). Interaction in control-driven tools can be manual (user-driven) or automatic. Smart energy automation hubs such as Alexa-driven tools (Colon, 2015) or digital voice assistants allow users to verbally manage and control energy services and obtain feedback. This approach was adopted in SCENe projects in Nottingham (Rodrigues et al., 2018). It was apparent that the voice command technique was effective in encouraging energy efficient behaviour since it enabled users to identify how their behaviour affected energy consumption. This technique allows the digital assistant to act on the user's behalf to improve energy efficiency and provides a valuable capability for vulnerable users or those who prefer not to use a smart app, making it a vital instrument in local energy projects where an inclusive mode of delivery is planned.

What makes an effective SLEET?

Effective SLEETs that match with users' requirement can encourage engagement amongst people, and people and technology, supporting replication of successful local energy projects. To achieve net-zero carbon emissions through a whole energy system transformation, digital energy tools need to be effective in enabling reductions in energy use, carbon and costs (Casals et al., 2020). SLEETs also need to enable behavioural change and learning by providing energy feedback and support to enhance user engagement (Vlaev and Dolan, 2015)., while empowering users to take control of energy services and interact with peer neighbours to exchange energy or engage in local energy markets (Morris et al., 2020).

SLEETs can be effective in a number of ways. They can mitigate grid constraint during peak hours by shifting energy demand (ECC, 2013) when combined with time-of-use (TOU) and dynamic pricing tariffs.. These tools can also support users in making cost savings by taking control of managing peak demand and making habitual changes in energy consumption to shift energy use from peak hours with high-energy rates to periods with cheap rates to reduce network pressure (Rosenow and Lowes, 2020).

SLEETs can also facilitate energy efficiency, which is the most cost-effective strategy to enable reductions in carbon emissions, energy use and energy costs, the governments' pillar to tackle fuel poverty (DECC, 2012). A study conducted by Dorahaki et al. (2018) on the coordination of energy efficiency and demand response in smart grid environments confirmed that effective energy management plans can shift energy load profiles and lead to energy use reduction and cheaper energy costs. SLEETs can support behavioural change to reduce energy use by providing advice and support or offering financial incentives through interactive SLEETs such as gamification-based tools. Energy saving apps as smart energy management systems have also been effective tools in enabling energy use reduction and behavioural change. They allow users to control home energy efficiency remotely and track real-time energy usage, identify patterns and obtain tips to save energy costs, as deployed in the Greenwich Energy Hero project in the UK (Greenwich Energy Hero, 2020).

What makes an inclusive SLEET?

To increase user engagement in local energy projects, it is vital to deploy inclusive SLEETs. This means considering the basic requirements of users to improve their quality of life (Francis et al., 2020), to construct fair and resilient communities and mitigate unjustified outcomes (Suboticki et al., 2019). User experiences and their requirements play a key role in the development of inclusive SLEETs. The needs of users should control the design of the tools by being reliable and providing valuable energy services that are tailored to their needs (Suboticki et al., 2019). This can support users to become active participants in managing and controlling energy services (Olivadese et al., 2021), while being inclusive for vulnerable users and those who are not digitally connected or on a low income (Hardy et al., 2020).

Inclusiveness means recognising broader diversity in the community, identifying different requirements, expectations and differing degrees of familiarity and technical expertise (DCLG, 2015). These range from addressing the needs of vulnerable users, including the elderly and people with a disability, those on fuel poverty, those who do not have access to digital technologies or those who do not want to take risks (Roberts, 2018). A research study on the impacts of user engagement in rolling-out smart meters in UK dwellings revealed elderly and lower social grade users were less engaged in the projects since they had difficulty in finding data, understanding new technology and required additional support to improve their knowledge (Darby et al., 2015). Brown and Markusson (2019) also revealed that although the elderly were more aware about the benefits of energy use reduction on energy costs and environmental impact, they had less confidence to engage because of their concern about losing comfort and convenience. However, a nationwide survey on acceptance of smart metering by the elderly in New Zealand confirmed that if the elderly can maintain a sense of control over personal expenses by using smart tools, they may switch to a smart metering system (Barnicoat and Danson, 2015). Additionally, digital voice assistant tools with automated systems have been found to promote energy efficiency by giving valuable capability to vulnerable users and linking energy systems to users through automated services, allowing them to monitor energy effortlessly (SCENe, 2018).

User engagement and SLEETs

User engagement, or involving local end-users in local energy projects to ensure their requirements are recognised and considered, is vital for the acceptance of SLEETs.

To encourage user engagement, different engagement pathways are available to be delivered by project partners or intermediaries. As identified by Nobles et al. (2018), an engagement pathway defines key concepts (e.g. recruitment) and their relationships in an energy intervention. Social and technical aspects of SLEETs can be delivered through the five engagement pathways of informing, communicating, involving, empowering and technical, with the associated methods as identified by Gupta and Zahiri (2020). The social engagement methods are outlined in Table 4.

Table 4: Engagement pathways and methods (Gupta and Zahiri, 2020)

Engagement pathway		Engagement methods
Social	**Informing**	Media, newsletter, video, mail shot, leaflet, brochure, notice boards and social media
	Communicating	Presentation, seminar, conference, exhibition, fair and open days, workshop, events, meetings
	Involving	Consultation, drop-in sessions, tele-service, training, webinar, offers (e.g. free smart meter)
	Empowering	Empower to effectively manage energy load and balance energy demand and supply, generate / store energy, create energy market to trade surplus of energy
Technical		In-home display (IHD), gamification, spatial mapping, digital energy platform (DEP), thermal imaging and energy management systems

The technical methods are in-home display (IHD), gamification, spatial mapping, digital energy platform (DEP), thermal imaging and energy management systems. Integrating social aspects of engagement with technical aspects of SLEETs can improve user knowledge and awareness by delivering tailored guidance, advice and learning materials. This improves trust and supports long-term user engagement if delivered through trustworthy intermediaries (Suboticki et al., 2019). Through interviews with key stakeholders in the Energy-SHIFTS project, Suboticki et al. (2019) found that to make the projects successful, inclusive engagement with users needs to be presented at all stages of the projects, alongside continual feedback loops that allow for mutual learning and continual interaction over time. Such an approach confirms that continuous engagement, with follow up, is a key in building trust, getting wider communities interested, and validating the project socially at the local level.

Despite the growing interest in SLEETs, there is a lack of comprehensive study investigating the various types of SLEETs deployed in local energy projects., and examining how effective and inclusive they are in engaging users by setting out standard criteria that can confirm if the projects' objectives were met by providing equal opportunities to vulnerable users, those on fuel poverty, and those who are not digitally connected (Roberts, 2018).

Appendix 1: Meta-data search

The search process started with local energy projects undertaken in the UK from 2008 to 2018 using major funding programmes. To identify the demonstrator projects, the websites of likely funding bodies were searched as an initial source of information. These included EU Cordis, Gateway-to-Research (Gtr) and UK Research and Innovation (UKRI)/ InnovateUK. To identify projects that were not recorded in these data sources, literature was explored using the search engines including Web of Science, Science Direct, Scopus, Google Scholar and Google using specific terms under the main key research area, namely 'energy projects', 'user engagement' and 'smart energy tool'. The search also provided information about the projects from the following sources:

- Individual project / university / energy supplier / distribution network operator (DNO) / private sector or National Government websites
- Energy Systems Catapult
- Community Energy Hub
- Community Energy Scotland
- UK Energy Research Centre

A range of keywords were used to explore the extent of the study in terms of local energy projects, smart energy tools and user engagement, namely 'community energy', 'local energy', 'smart local energy system', 'trial', 'initiative', 'project', 'smart', 'grid', 'renewable', 'energy management', 'demand response', 'demand management', 'smart control', 'storage', 'district heating', 'distributed generation', 'electric vehicles', 'EV charging', 'microgrid', 'smart energy technology', 'smart energy tool', 'user engagement', 'user participation'. The meta-study brings together data from major funding programmes including the Low Carbon Communities Challenge (LCCC) and Localised Energy Systems funded by the UK government, Network Innovation Allowance (NIA) funded by regulators, the Energy and Communities programme funded by UK Research Councils, Horizon 2020 funded by the EU and the Local Energy Assessment Fund (LEAF) funded by the UK Government. The systematic literature data flow is presented in Fig. 11.

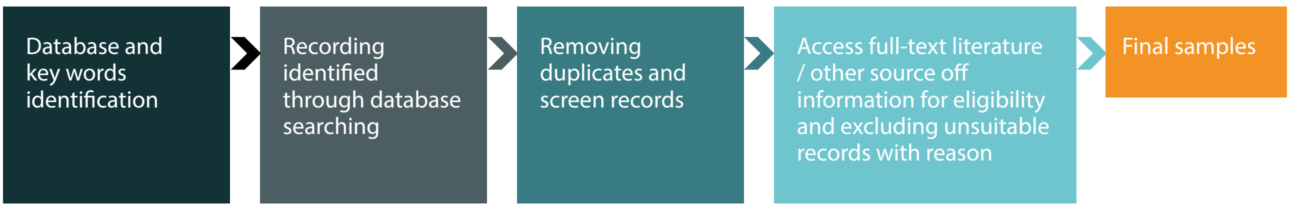


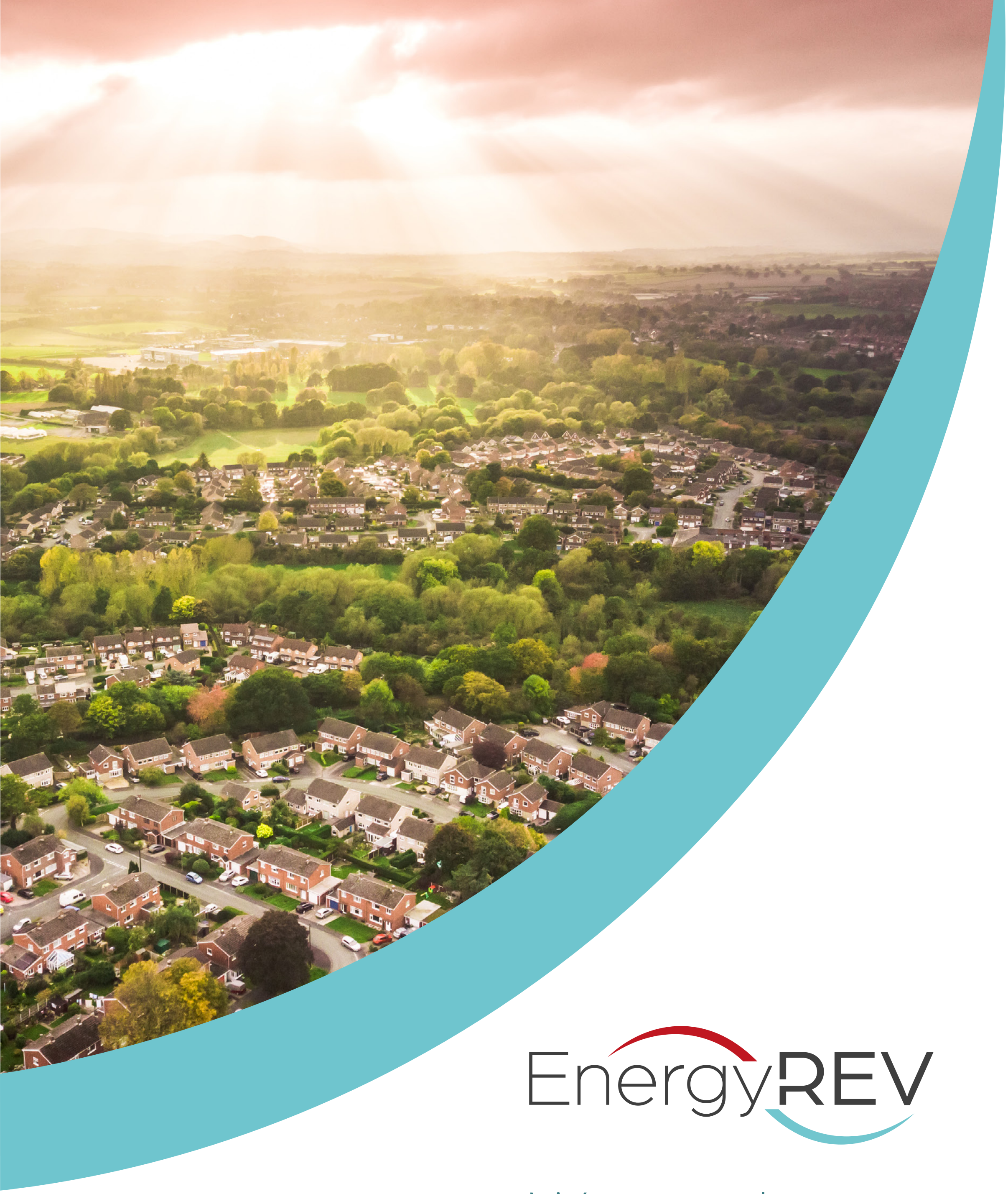
Figure 11: Information flow of systematic review

To categorise the local energy projects under community energy (CE), local energy (LE) and Smart Local Energy System (SLES) initiatives, key characteristics were established drawing upon the study by (Devine-Wright, 2019) and these are listed in Table 5.

Table 5: Characteristics to select CE, LE and SLES initiatives in this study			
Characteristics of local energy projects	**CE**	**LE**	**SLES**
Participating actors / stakeholders	• Community groups / third parties • Local authorities may be involved • Individuals acting collectively	• Local authorities & LEPs • Community groups and third parties are involved • Institutions working in partnership with strong focus on investment	• Institutions (e.g. DNO, energy suppliers, universities and private sector – working individually or in a partnership collaboration • Local authorities or community groups may be involved
Positioning of individuals	• Active energy users led by a range of motivations	• Active energy consumers or prosumers – with an aim to maximise personal utility and choice	• Active energy consumers or prosumers – with an aim to maximise personal utility and choice
Spatial focus	• Communities of locality • Yet also communities of interest	• Networks of organisations spanning local and non-local areas	• Networks or organisations spanning local and non-local areas
Goals	• Addressing local, social, economic and environmental needs • Contributing to broader environmental challenges	• Economic growth and prosperity • Specifically job creation and skills training, delivered by investments in 'clean' energy systems	• Political, economic, social, environmental and technological dimensions are included in the energy chain • Delivering energy services tailored to the local areas • Using digital and data-based solutions
Technologies	• Energy feedback • Energy generation • Energy efficiency	• Energy feedback • Energy generation • Energy efficiency • Energy storage • Electricity and heat distribution • EV charging	• Having elements of demand and supply • Local balancing of supply and demand across multiple domains • Having element of 'smart' • Grid balancing and management
Scalability and replicability	• Predominantly a local focus to address specific needs ad requirements	• Predominantly identifying locally beneficial solutions that are replicable elsewhere	• The boundary can vary from a single street or estate up to a county of region • Accounting for local priorities to meet local needs • Wider value-based needs (e.g. reducing global environmental impacts)

The association of user engagement methods with SLEETs in the identified projects was also assessed in the meta study. To encourage users to become involved in local energy projects or to enhance engagement, different engagement methods were deployed in local energy projects. These were categorised into different groups (social pathways and the associated methods) based on examination of academic and grey literature and meta study of local energy projects in the UK that was carried out by Gupta and Zahiri (2020). These pathways included informing, communicating, involving and empowering, as detailed in Table 4 in Annex1.

A pool of 384 initiatives (CE (176), LE (86), and SLES (123)) were identified from an extensive review of literature. However, only 72 projects deployed smart energy tools to engage users and these were used for meta-data analysis. 84 SLEETs were found to be deployed across the 72 projects with some projects deploying multiple SLEETs. An analysis framework was also developed to characterise SLEETs through meta-data gathered to study how prevalent, effective and inclusive SLEETs have become across the UK in the last few years.



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