Energy Research & Social Science 115 (2024) 103608

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Review

The co-benefits and risks of smart local energy systems: A systematic review

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ARTICLE INFO

Keywords:
Co-benefits
Local energy
Smart energy
Energy communities
Process
Impacts
Distribution

ABSTRACT

A transition to 'smart' local energy systems (SLES) could provide an opportunity to deliver a range of social, economic, technical and place-based co-benefits for SLES communities, alongside CO_2 reduction. However, there could also be underlying factors that limit success.

In this paper we present the results of a systematic literature review to outline the potential co-benefits and risks of taking a SLES approach to energy system change. This review identifies multiple potential co-benefits, as well as a range of risk factors which could affect delivery. In addition, we identified that several co-benefits are interconnected, whereby certain co-benefits cannot occur until other co-benefits have first been achieved.

We propose three dimensions of SLES co-benefits and risks: *process*, *impact*, and *distribution* to aid understanding of how, where, why and when these co-benefits or risks could arise and who might be in receipt of them. However, we conclude that a more co-ordinated approach across a range of stakeholders is required to maximise beneficial outputs and to ameliorate risks.

1. Introduction

As the largest contributor to global greenhouse gas (GHG) emissions, international energy systems are undergoing major transformations to mitigate against the effects of climate change. Primarily this has included moving away from fossil fuel extraction to renewable energy sources and accompanying technologies [1]. Since these technologies tend to be less energy dense and more modular than fossil fuelled power stations, energy systems are becoming increasingly decentralised to the point where generation technologies are now available at the household level. This increasing number of distributed energy resources can also be seen through the emergence of new energy loads such as electric vehicles, heat pumps, and energy storage [2]. Alongside this decentralisation of energy there is also an uptake of digitalisation across the energy sector, enabled through the declining costs and increased performance of ICT technologies [3,4]. Energy system digitalisation and the uptake of 'smart' technologies complements decentralisation through increasing the utilisation of intermittent renewable and low carbon assets, altering demand and enabling new platforms and marketplaces [2,5,6]. However, this increase in decentralisation and digitalisation will impact upon how a previously centralised energy system will need to be designed, built, managed and regulated in future [2,7].

In addition, the increase in decentralised and digitalised systems is impacting on the remit of established energy stakeholders and introducing new stakeholders – for instance Distribution Network Operators (DNOs) are transitioning to become Distribution System Operators (DSOs) due to the need to more actively manage bi-directional flows on distribution networks [2,8] and local authorities (LAs) are increasingly expected to integrate energy systems planning within their remit, including through the development of Local Area Energy Plans. Meanwhile there has been a rise in community groups and grassroots organisations delivering a plethora of energy schemes at the neighbourhood level [2,9] while at the household level electricity consumers are now becoming 'prosumers' - generating, storing and utilising their own electricity and responding to demand side response (DSR) events to help alleviate network pressures [10]. Community renewable energy (CRE) has been the subject of much academic research over the last two decades, with currently over 2000 articles available on Scopus which

Abbreviations: CHP, combined heat and power; CO_2, carbon dioxide; CRE, community renewable energy; DSO, distribution system operator; DSR, demand-side response; EV, electric vehicle; ICT, information and communications technology; GHG, greenhouse gas; GVA, gross value added; LA, local authority; NHS, National Health Service; P2P, peer to peer; PV, photovoltaic; SLES, smart local energy systems.

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https://doi.org/10.1016/j.erss.2024.103608
Received 4 October 2023; Received in revised form 16 May 2024; Accepted 22 May 2024
Available online 8 June 2024
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include the exact term. While CRE can been described as an ambiguous concept, it is normatively associated with local ownership, collective benefit sharing, public participation and collective action [9,11]. In other words, CRE is often 'run by the community for the community'.

However, over the past decade there has been an uptake in 'smart, local energy systems' or SLES at the community level, which rather than being delivered by 'bottom-up' grassroots endeavours are more often delivered by 'top-down' enterprises led by collaborations which can include corporate entities, academic institutes, DNOs, LAs and energy providers (for instance [2,12–18]). While SLES can incorporate many of the same characteristics as CRE (e.g. technologies, ownership models, governance arrangements, sharing of benefits) the overarching aim of SLES is to better understand and manage the integration of community-scale energy systems into the wider energy system. To this effect SLES include demonstration projects designed and funded to specifically identify and test the challenges that decentralised and digitalised energy systems might face with integration, along with the challenges faced by both existing and new stakeholders in managing their new remits [2,16]. SLES projects are therefore focused more on *how* the energy system can be better managed, regulated and operated to achieve net zero ambitions, and *how* these systems can be scaled-up and integrated. Gupta & Zahiri (2020) observe that:

> "*Although there is no standardised definition of SLES, the UK Government considers SLES as energy initiatives at local scale that have elements of energy demand and supply, are integrated across demand side reduction and demand side response (DSR), include innovative use of data or digitalisation, and may involve local trading of energy and system balancing*".
>
> [16]

There is no standardised definition of SLES as each SLES project is unique, employing a diversity of technologies and approaches appropriate to their local context. Research, however, intimates that a transition to SLES could provide an opportunity to deliver a multitude of social, economic, technical and place-based co-benefits for communities alongside the anticipated environmental benefits of CO_2 reduction, through capitalising on the increasingly local and smart nature of the energy sector [2,6,16].

Conversely, there could be negative outcomes from these systems that need to be explored, as well as external factors that could limit potential co-benefits from being realised. As identified by Sovacool et al. "*with great transformation comes great opportunities – for a cleaner, fairer way of life. However, it also presents risks and we will only reap these rewards if we pre-empt problems and act to mitigate them*." [19] These considerations form the basis of this study's starting assumptions that:

- SLES could produce multiple benefits for multiple beneficiaries, at multiple scales.
- There could also be unintended consequences or negative impacts of taking a SLES approach to energy system change which need to be explored to ensure equity.

In this paper we present the results of a systematic review and content analysis of the published international academic literature on the co-benefits and negative impacts of taking a localised and smart approach to energy system change. Much of this literature adopts a project-specific lens, linking benefits to activities within the restraints of a given project. Furthermore, each project is unique: working with different technologies, different communities and stakeholders, with different governance structures, in different geographical and socio-economical landscapes. Therefore, while some beneficial outcomes could be consistent across a range of projects, some could be unique to the typology of an individual project. As a result, our findings cannot be viewed as a 'basket' of co-benefits that could be delivered in every SLES community. However, as the boundaries within and around the energy sector are blurred it is important to understand the scope of these co-benefits, and how these could be achieved on a local scale within a national context. It is also crucial to understand the trade-offs that might occur in certain circumstances, and how to mitigate against the negative impact of these.

The remainder of this paper is structured as follows. In Section 2 we discuss the academic context of the review, while in Section 3 we outline the methods used to collect the data and an overview analysis of the data. In Section 4 we outline the Findings and in Section 4.2.5.1.2 we discuss the relevance of the findings to future research along with further considerations.

2. Academic context

Several previous academic studies have sought to frame the co-benefits of taking a *localised* approach to energy transition, most notably the co-benefits to be gained from CRE schemes [20–24]. Of particular relevance to this review has been Walker & Devine-Wright (2008) [20] who identified two key dimensions that underlie the understanding of co-benefits from community renewables: *process* and *outcome*. In their article 'process' relates to who's involved in establishing, operating, and managing a CRE project; while 'outcome' relates to those factors which influence who the benefits are designed for and how they are distributed, both spatially and socially. Ten years on from Walker & Devine-Wright's review, Berka & Creamer [21] undertook a systematic review of the benefits of CRE initiatives in the UK, also framing their findings by way of process and outcome, while in 2021 Roberts et al. [22] drew on Berka & Creamer's research framework for their own study of CRE initiatives in New Zealand.

While our study has included outputs from CRE projects, we acknowledge that there are tensions between projects 'run by the community for the community' and those that work in partnership with host communities in the range of benefits that each can produce. We defer here to Devine-Wright's 2019 article "*Community versus local energy in a context of climate emergency*" [9] which discusses these tensions in detail, focusing on the enduring benefits of 'bottom-up' grassroots organisation rather than the sometimes transient benefits accrued from a 'top-down' imposition of a particular model on a host community.

However, several of the co-benefits identified across our own literature review require specific actions to be taken in a 'top-down' approach, such as at the LA level (e.g. spatial planning) or at the distribution network level (e.g. to reward flexibility provision) and are therefore outside the remit of what CRE can ultimately provide. Indeed, some of the co-benefits require joint actions from multiple stakeholders working together towards a co-ordinated end goal in a 'multi-level' approach. Therefore, to achieve the widest range of co-benefits, or to understand where negative issues may lie, it becomes necessary to consider implications across the energy system in a holistic fashion, rather than to focus on one sub-set of current action.

In addition, 'smart' systems could also deliver co-benefits. The Council of European Energy Regulators describe digitalisation as a "*means to deliver benefits for the energy system and ultimately for energy consumers*" through increasing productivity, altering demand and enabling new platforms and marketplaces [5]. Smart systems – and particularly the co-benefits of such systems – is an emergent topic, which can include the role of microgrids, distribution system operators (DSOs), tariffs, DSR and the ability to trade self-generated electricity or flexibility services. As an emergent topic, however, many of the perceived co-benefits that could be realised through digitalisation are yet to be fully achieved in practice.

Cross-cutting throughout many of the local and 'smart' energy publications has been the theme of social acceptance. Of particular relevance are von Wirth et al. (2018) [25] who conducted a systematic literature review of barriers and drivers to social acceptance in local energy schemes and Balest et al. (2018) [26] who similarly conducted a systematic literature review of local energy actors, specifically searching for the interaction between conflict-acceptance of renewable energy.

Von Wirth et al.'s review highlights that there are two forms of social acceptance – active and passive acceptance, depending on whether there is supporting behaviour displayed by participants or merely a 'tolerance' of change. There is a marked distinction to be made between these two forms of social acceptance as while communities may accept development they do not necessarily support it [27]. Von Wirth et al. highlight that the more local co-benefits that can be realised, the greater likelihood for supportive behaviour. Additionally, Balest et al.'s review focuses on the complex technological and social systems that influence local energy actors' actions and reactions to renewable energy projects. These systems can invoke trust through the building of relationships, the sharing of information and collaborative working. However, Balest et al. warn that these relationships can be fragile as they are based on opinions and the understanding of a common vision.

Leading on from social acceptance, the theme of energy justice has also been recurrent throughout the review, having been an expanding topic in the published academic literature over the past decade. Of particular relevance to this review are three 'tenets' of energy justice known as distributional justice (where injustices lie), recognition justice (who is affected) and procedural justice (how injustices can be overcome) [28,29]. As Devine-Wright acknowledges, "*justice considerations are central for appraising acceptable, fair and inclusive energy pathways*" [9]. However, justice is not always easy to determine – with potential 'winners' and 'losers' across transition scenarios [30,31]. It therefore becomes necessary to acknowledge potential negative or risk factors to frame the trade-off decisions to be made – while also considering who has the power to make these decisions.

Energy justice considerations can become apparent at any spatial scale, from international issues (macro scale) through to national considerations (meso-scale) and down to local communities and household implications (micro level) [31]. As the focus of this study has been on localised energy systems we have mainly drawn on the micro-scale justice arguments, acknowledging the meso-scale as required when considering national decision-making.

At this micro-scale, Sovacool et al (2019) [32] approach the co-benefits of household technological change from an energy justice lens. While acknowledging that a range of co-benefits could be achieved for households by technological transformation, their perspective focuses on the unintended consequences, vulnerabilities and trade-offs that could arise. In earlier papers Sovacool et al (2017) [30] and Delina & Sovacool (2018) [33] outline a range of energy justice principles to guide decision-making, four of which are analysed in more depth within the 2019 paper; those of affordability, sustainability, equity and respect. Although that study does not draw on Walker & Devine-Wright's framing there are parallels between affordability and equity (the accessibility of an innovation) and sustainability and respect (that an innovation does not impose burdens on particular demographic groups) with Walker & Devine-Wright's definitions.

Sovacool et al. introduce a further dimension for consideration, noting that outcomes are not only distributed spatially and socially, but also temporally. This raises the question of when co-benefits may appear – some may be immediate, while others are latent or dependent on other co-benefits being realised first. Sovacool et al additionally caution that today's conceived co-benefits should not negatively impact tomorrow's consumers [32].

Van Wee & Banister (2016) [34] contend that a literature review paper should add value to the existing published literature and that this should permeate the whole review, not just the conclusion. Our review aims to build upon the above dimensions and considerations and extend the literature in several ways. First, it builds on the process and outcome framework applied in CRE and extends this to include local energy systems which include both top-down and bottom-up approaches, as well as a focus on 'smart' approaches. Second, it widens the framework to introduce 'impacts' - those co-benefits or risks which have repercussions for the wider geographical community, not just project participants or stakeholders. Thirdly, it recognises and incorporates the temporal, that is the latent or co-dependent, nature of co-benefits. Finally, it aims to add relevance for real-world applications and recommends avenues for future research. Such an ambitious and broad review is necessary to gain a holistic understanding of the wider social, technical and economic effects of a smart and local approach to energy transition.

3. Methods and content analysis

Our starting assumptions were that:

- SLES could produce multiple benefits for multiple beneficiaries, at multiple scales.
- There could also be unintended consequences or negative impacts of taking a SLES approach to energy system change which need to be explored to ensure equity.

To test these assumptions, we conducted a systematic review and qualitative content analysis of the academic literature published in international peer-reviewed journals. In the first instance, the literature review was conducted through an online search of titles, abstracts and key words in Scopus using defined search terms derived from the multiple factors identified in the starting assumptions. Due to the multiplicity of factors explored in the search terms, Boolean Operators were introduced to some search terms to ensure that the retrieved articles were both focused on the subject material and manageable in terms of numbers of articles retrieved. This included adding quotation marks to search for exact phrases where the quantity of literature returned without the use of quotation marks was unmanageable or produced irrelevant results. The use of Boolean operators has been recognised as an efficient research search strategy technique that both saves time and produces more relevant search results [35]. Searches terms including any applied Boolean Operators are shown in Table 1.

3.1. Screening process: applying inclusion and exclusion criteria

All papers retrieved through the online search were initially screened for relevance to the study by two reviewers who applied the inclusion and exclusion criteria below to the titles and abstracts.

Where the title and abstract proved insufficient, the full paper was assessed, and the inclusion and exclusion criteria reapplied. Those that did not meet the inclusion criteria after initial screening were excluded from the study, although have been counted as excluded for completeness. All remaining studies were added to the Zotero reference management system and held under the initial search term, although any duplicate articles retrieved across more than one search term have been deducted from the final total of included articles as shown in Table 2.

3.2. Inclusion criteria

All documents were assessed for inclusion based on the following criteria:

- Published in English
- Substantive description of perceived benefit **or** negative impact that can arise from taking a localised **or** smart energy system approach
- Substantive description of perceived benefit **or** negative impact that can arise from energy transition
- Studies with a focus on energy to be prioritised for inclusion, with studies in other areas (e.g. public health) included on the basis of theoretical and practical relevance to the research
- Study must present clear methods for their research
- Is applicable to the UK energy context (but not limited to publications from the UK)

Table 1
Search terms including Boolean operators where applicable.

Benefits OR Impacts of…
benefits OR impacts AND "local energy"
benefits OR impacts AND "community energy"
benefits OR impacts AND "renewable energy"
benefits OR impacts AND "distributed energy"
benefits OR impacts AND microgrids
benefits OR impacts AND "smart energy"
Energy transitions
justice AND "energy transitions"
"social equity" AND "energy transitions"
"smart technologies" AND "energy transitions"
smart energy transitions
local energy transitions
"local energy systems"
Engagement
"community engagement" AND "energy systems"
"local engagement" AND "energy systems"

Table 2
Data collection and screening.

Scopus search results	Exported to Zotero after initial screening (inclusion and exclusion criteria applied)	Duplicates removed	Removed from study during full content analysis	Total included in study
2823	282	27	48	207

3.3. Exclusion criteria

Since the scope of the review was concerned with the potential co-benefits and impacts of a local and smart approach to energy transition we excluded documents which met any of the following exclusion criteria:

- Are not applicable to a localised and smart energy approach (e.g. documents which are mainly concerned with nuclear or fossil fuels, or in taking a highly centralised energy approach)
- Are not applicable to a decarbonised energy transition (e.g. diesel generators)
- No relevant or transferable benefit or negative impact is identified
- Documents based on technical calculations rather than concepts

Once all screened articles were exported to Zotero (and 27 duplicates removed) two reviewers undertook a qualitative content analysis of the remaining 255 articles to map the emerging themes. During this analysis a further 48 articles were removed from the study as on full inspection they were found to contain at least one of the exclusion criteria which hadn't been apparent from the initial screening of titles and abstracts. This left us with 207 articles which were analysed against the starting assumptions.

3.4. Qualitative content analysis

Qualitative content analysis is a recognised method for analysing text data such as journal articles [36]. The process is non-linear and characterised by de-contextualisation and re-contextualisation of the data through a process of intuitive coding which divides the data down into units or themes (de-contextualisation) and then returns these themes to their context (re-contextualisation) to enable a deeper understanding of the area of interest [37].

Through the de-contextualisation process we identified multiple potential co-benefits of a localised and smart approach to energy transition. We also identified a range of negative factors which had the potential to stop the co-benefit from occurring, limit its impact, or cause other unintended consequences. We have termed these negative factors as 'risks' throughout the remainder of the paper as they provide cautionary warnings for SLES communities to consider when embarking on energy projects.

In addition, we identified that several of the potential co-benefits are interconnected, whereby one cannot be realised without another being achieved first (for example, reduction in air pollution could lead to better public health which could lead to reduced NHS cost). The coding analysis therefore had to identify not just the potential co-benefits but who/what received them/didn't receive them, by what mechanism they received them/didn't receive them and any other mitigating factors or risks to delivery.

Through the re-contextualisation process we iteratively arranged the identified co-benefits and risks into three separate dimensions for observation: *process*, *impact*, and *distribution*. These three dimensions arose inductively from our interpretation of the cross-cutting themes analysed and enabled us to better articulate how, where, why and when these themes occur.

While we recognise the merits of Walker and Devine-Wright's original framing of process and outcome we have not directly replicated it within our own analysis for several reasons. Firstly, the scope of our research focus is much wider (as detailed in Section 2) which blurred the boundaries between identified impacts and the ability to directly distribute the effects of those impacts. For example, better air quality and additional job creation are applicable to everyone, not just project participants. In addition, by including 'smart' into our analysis this opened discussion on in-home systems, flexibility trading and wider network system considerations which again are beyond the direct jurisdiction of an energy project to determine. For instance, in-home systems enable personal agency in household energy use, while changes in supply and demand profiles have wider repercussions on the management of electricity networks.

Therefore, while our understanding of 'process' aligns with Walker & Devine-Wright's definition, we have rephrased 'outcome' as 'distribution' and limited it to the decision-making elements that can be determined by an individual project, such as the distribution of direct project costs and benefits and any trade-off decisions to be negotiated. We also identified the additional definition of 'impact' to discuss those factors which could be attributable to the operation of local and smart energy projects within a place, but which can be beyond the decision-making powers of the project organisers to determine their distribution.

For clarity, the literature analysed does not necessarily align itself directly to a local and smart approach to energy transition in most cases, but rather discusses individual components and factors which could be replicable if such an approach were taken. For example, the literature discusses different technologies and hardware typically found in a localised approach such as CHP, solar PV, battery storage, EVs, building retrofit, energy efficiency, wind turbines, heat networks and small-scale community hydroelectric. The literature also discusses different software typically employed in a smart approach such as home energy management, automation and DSR. It should be noted that individual papers may only focus on one or two of these solutions.

The literature looks at the potential co-benefits or risks from different scales. These range from the individual household scale and individual prosumers through to prosumer communities, community energy groups and local energy co-operatives and further through to 'smart' cities and distribution networks. Again, individual papers mostly focused on only one of these scales. While we consider scale in the Discussion, wider considerations between the scale of project and the scale of the potential co-benefit is beyond the scope of this review.

The literature also discusses schemes led by different providers, such as community-led projects, local authority-led, industry-led and joint ventures. As SLES can be, and are being, developed by a range of different providers these are all appropriate for inclusion within the study and we have not placed any value on one type of provider over another within the Findings.

In addition, it should be noted that some of the papers discuss *potential* co-benefits or negative impacts which could be experienced by taking a particular energy pathway; while other papers discuss *experienced* co-benefits or negative impacts arising from primary data such as observed case studies. Through the Findings section we have sought to be clear on what is proven and what is assumed, as well as any factors which could limit the identified outcome.

Several of the papers included were themselves the product of a full thematic literature review on their given topic (e.g. social acceptance) for example [21,25,26,38–47]. These papers have been particularly helpful to this review as their weight of evidence spans beyond that of an individual project or case study.

4. Findings

As discussed in Section 3 we have arranged the identified co-benefits and risks into three separate dimensions for observation: *process*, *impact*, and *distribution* (see Table 3).

Process: Several of the co-benefits and risks identified relate to the processes involved in establishing, operating, and managing a project, rather than to the ultimate project outcomes. While these processes can be deemed as co-benefits in their own right, they can lead to increased potential of securing beneficial project outcomes (such as skills development, better data and increased sustainability). They

Table 3
Overview of potential co-benefits and risks.

Process	Impacts					Distribution
	Place-based	Health & wellbeing	Energy supply & demand	Electricity network considerations	Employment & skills	
Inclusion/equitable participation in decision making	Community empowerment/ community pride	Better indoor air quality (which leads to better health outcomes)	Increased energy independence/self-sufficiency	Reduced system operation costs	Employment opportunities	Increased social equity
Transparent decision making	Social cohesion	Better outdoor air quality (which leads to better health outcomes & wellbeing)	Reduced energy demand/consumption	Reduced network stress (through deployment of flexibility/demand-side response)	Local investment	Local ownership models
Community support for project & tech (social acceptance)	More coordinated local planning	Warmer homes = increased comfort/ wellbeing	Reduced reliance on imported oil and gas	Grid optimisation (through taking an integrated approach)	Skills development	Achieving joint goals
Trust in the process	Regeneration of place	Warmer homes = reduced winter mortality/better health outcomes	Reduced household bills (from energy reduction and opportunities for demand-side response)	Higher quality data (can lead to improved efficiencies and grid optimisation)	Knowledge exchange	Distribution of power from monopolies
Collaborative governance and accountability	Increased sustainability	Reduced NHS cost (e.g. from reduced respiratory issues & depression)	Reduced fuel poverty (plus knock-on effects for reducing inequalities)			
Stronger partner/ stakeholder relationships (can lead on to other joint working)			New market models & opportunities			
Risks						
Requires skilled leaders & local responsibility	Attachment to place and landscape are important factors to be considered	Poor quality installations can reduce ventilation (need appropriate workforce skills)	Behaviour change may be required	New local loads added without the deployment of flexibility will increase network congestion	Difficult to measure affects across a community/lack of quantifiable metrics	Potential for some areas to benefit over others (inequalities between SLES and non-SLES localities)
Tendency for projects to occur in affluent areas	Impact of infrastructure on landscape and biodiversity		Elderly & vulnerable may struggle with smart technologies	Vulnerability to cyber-attack (through increased integration of smart technologies)	Projects more likely to occur where skills are already in place	Infrastructure may benefit communities elsewhere to where it is sited
Acceptance may be 'bought' through project sweeteners			Current regulation limits market models and innovation			Potential for new monopolies
Participative decision-making is very time-consuming and can't be rushed if people are to make informed choices			Impact on socialised network costs			

can also increase participants' levels of trust and involvement in the project, and ensure that local challenges, constraints and desired outcomes are considered at the early stages of project development.

Impact: We define impacts as the co-benefits or risks that can be attributable to the actual operation of the energy project. These impacts are wide ranging and can extend beyond the geographical or distributional boundaries of the project – for instance through (dis) benefitting the wider energy system or through contribution towards national targets.

Distribution: These considerations relate to how benefits and risks are distributed between project participants, stakeholders, and the wider geographical community. This includes the distribution of costs and profits, managing conflict and trade-offs and the distribution of political power.

4.1. Process

Many of the process related benefits stem from ensuring that the wider local community have opportunity to be involved in the project planning process from an early stage and that engagement with them continues throughout project delivery. Martiskainen [48] advocates for immersing established community leaders into project development from the start as these actors, being embedded into their social networks, bring with them a wealth of local knowledge, are better aware of their communities' priorities and needs, and can nurture the relationships needed to foster ongoing engagement throughout project delivery.

Much of the 'Energy Justice' literature analysed discusses process related benefits by way of the 'tenets' of energy justice, such as via 'recognition justice' (understanding who is affected by decision-making and acknowledging social inequalities); 'procedural justice' (participation in decision-making) and 'distributional justice' (where injustices lie either spatially or societally) [43]. These narratives focus on including all people affected by decision-making outcomes in the actual decision-making processes and enabling their engagement and participation in non-discriminatory ways throughout project design and delivery.

Several authors highlight that the direct involvement of communities in local energy systems aids social acceptance of new energy projects and develops trust [20,21,27,38,49–52]. There is also evidence that community approaches that are open, participatory, and collective can lead to a greater acceptance of renewable energy technologies per se and a decrease in opposition based on issues regarding costs and returns on investment [53]. Others remark that without social acceptance the energy transition will be slower, increase disparities between communities and ultimately be more costly [53,54]. Participation in community energy activities has been linked to a higher awareness of issues around energy generation and consumption, which can help to induce positive changes in behaviours and societal norms [12,38,55]. While Batel (2018) [52] remarks that if we engage people in ways that enable them to be politically active they are more likely to engage in other forms of public life such as planning and policymaking. In addition, trust has been highlighted as an important factor for local acceptance [50]. Interestingly, while the 'community trust factor' has been cited as the most statistically significant predictor of willingness to participate in community energy projects [56], involvement in these types of projects then leads to increased trust in renewable technologies themselves [38,56].

However, management of local energy projects can be complex due to the involvement of many stakeholders (from home owners, LAs, DSOs, funders, technology suppliers etc.) who all enter the project with different priorities, means, and scopes of action [57]. Coordination between these stakeholders is therefore complicated. One study on community acceptance identified that peoples' attitudes could be negatively affected between project planning and delivery stages if the co-benefits envisioned at the start of a project were not actually realised in project delivery [58]. However, participants were more likely to agree that project outcomes were fair and reasonable if they considered that transparent and equitable processes had been employed throughout the project development and management stages [58,59]. All of this takes time, therefore project timescales should allow for the time required by communities to make informed decisions [60]. Research also shows that collaborative governance and decision-making on projects can strengthen existing relationships between stakeholders and that this can then lead on to further joint working on additional projects [12].

4.1.1. Risks

Martiskainen, while advocating for the essential role of community leadership in project planning and delivery, additionally observes that these leaders need to be skilled for the role and well equipped to undertake it [48]. Likewise, Tricario [61] warns that with local decision-making comes the need for local responsibility and the ability to make difficult choices where necessary.

Research also shows that communities who invest in energy generation projects tend to be those that are already economically advantaged, with limited examples of community-owned projects in disadvantaged communities [62]. Additionally, where projects are developer-led, rather than community-led, there are examples of private developers offering community benefit 'pots' or an overemphasis of co-benefits, as a way to gain social acceptance for schemes that wouldn't otherwise gain community support [11,63]. Ryder et al. (2023) [51] contend therefore that community engagement can often be perceived as disingenuous and tokenistic by those being engaged. To remedy this, they propose that community engagement should be designed to incorporate multiple-actor perspectives which combine scientific rationale with local knowledge and which gives additional power in decision-making to community members. In addition, Batel et al. (2013) [27] consider that to gain a more nuanced picture of public opinion, qualitative data collection should include reflection on the themes of opposition and resistance, to move beyond passive acceptance that is merely a form of tolerance instead of active support.

4.2. Impacts

As the Impacts section is the most wide-ranging we have arranged these considerations under five thematic sub-headings – place-based impacts, health and wellbeing, energy supply and demand, electricity network considerations and employment and educational impacts to add clarity.

4.2.1. Place-based impacts

An improved sense of 'community' and community empowerment can lead directly from the Process related benefits outlined in Section 4.1. While hard to measure and quantify, several studies have found that citizens involved in community energy activities have reported feeling a greater sense of community pride, empowerment, and strength from doing so [21,38,58,64].

Closely linked to this increased sense of community is the positive impact on social cohesion which comes from taking a local and holistic approach to planning and delivering of energy services [38,58,65]. De Pascali & Bagaini [41] highlight that there is a strong and direct connection between physical and geographical characteristics of place and the energy systems that serve them. However, over the past 50 years there has been an increasing trend to disconnect energy planning from spatial planning, causing disintegration. This can be overcome through bottom-up local planning which fosters regeneration of place, hand-in-hand with decentralised energy systems, local energy communities, and concepts such as energy districts. Increased energy efficiency and reduced energy demand could also minimise the impacts on land demand for energy infrastructure; while sustainable planning of infrastructure coordinated through site-specific measures could limit impacts on species and habitats [66] which are key to enabling regeneration of place co-benefits [23].

Van der Schoor & Scholtens consider the prioritisation of community co-benefits as a defining characteristic of community energy initiatives, and suggest that local energy production can often appear to be a "*means to the end of improving social coherence*" [50]. The Scottish Government cite social cohesion as a desired benefit of their goal to reach 1GW of community and locally-owned renewable energy by 2020 [65]. For example, on the island of Shapinsay, Scotland, revenue generated from community-owned renewables partly funded local transport services which connected members of the island community who were otherwise isolated, thus improving the island's social cohesion [65]. Embedding community engagement into the project was also linked to improved social cohesion across the island.

4.2.1.1. Risks. Süsser et al. show how people's place-based attachments and attitudes towards change are important considerations that can affect the adoption or rejection of renewable energy projects within their locale [67]. Consequently, greater consideration is required of "*the relationship between landscapes and the people who occupy and value them*" [68].

In addition, although renewable technologies can bring significant environmental advantages in terms of carbon emissions, increased ambition is required to ensure human activity upon ecosystems and the natural world is minimised and to preserve biological diversity [66,69].

4.2.2. Health & wellbeing

According to the latest UK government statistics, in 2022 the percentage of households in fuel poverty in the UK had reached 13 % in England, 14 % in Wales, 24 % in Northern Ireland and 25 % in Scotland [70]. However, the national fuel poverty charity, National Energy Action, estimate that as of January 2024 the total number of UK-wide households in energy poverty had reached 6.5 million, with a typical annual energy bill at £1928 [71,72]. With UK households struggling to sufficiently heat their homes and provide enough food for their families, these impacts can have knock-on effects on nutrition, educational performance, health and household relationships.

The negative health impacts associated with living in cold homes include an increased risk of respiratory issues including asthma and bronchitis (especially in children), and an increased likelihood of developing depression and anxiety, while the impact of cold homes on physical and mental health has been estimated to cost the NHS alone £2.5 billion a year (equivalent to 1.7 % of annual spending between 2016 and 2017) [73]. Data from the Office of National Statistics suggests that in the winter period between 2017 and 2018, there were almost 17,000 excess winter deaths that could be attributed to living in cold homes [73,74]. Improving the energy efficiency of homes (see Section 4.2.3) is one policy response which could therefore lead to significant improvements in public health [12,75]. Jennings et al. estimate that investing just £1 in energy efficiency could lead to a saving of £0.42 to the NHS in direct healthcare costs [73], while Kerr et al. note that improved energy efficiency through retrofitting could achieve multiple co-benefits such as a reduction in carbon emissions, improved health, reduced fuel poverty and improved energy security [75].

In addition, tackling indoor and outdoor air pollution has the potential to deliver a wide variety of co-benefits [76]. For instance, reducing the burning of fossil fuels will lead to a reduction in local air pollutants, including sulphur oxides, nitrogen oxides and particulate matter. These pollutants are linked to health issues including cardiovascular and respiratory diseases, lung cancer, dementia, diabetes and mental health disorders which contribute to around 40,000 premature deaths per year in the UK [12,73]. Decarbonisation goals can therefore positively impact levels of indoor air pollution, increasing health of residents [77,78].

Furthermore, tackling outdoor air quality through the electrification of transport or via increasing the share of journeys taken by public and active travel modes can have a 'multiplier effect,' as it both reduces local air pollution and can improve physical and mental health and well-being [32,73]. The cost to the wider UK economy of premature deaths from traffic related air pollution is estimated at £54 billion a year [73]. The health costs of fossil fuel pollution has been evidenced in other international studies, such as Mathiesen et al. whom showed that on enumerated lost workdays, hospital admissions, health damage, deaths, etc. the combined health costs of air pollution amounted to approximately 14–15 billion DKK/year on the Danish economy [79].

Investment in initiatives which aim to reduce carbon emissions can also offer a wealth of opportunities which can boost economic growth and create jobs within the low carbon economy [80] as shown in Section 4.2.5. These can include additional outputs such as ecosystem performance, social equity, economic development and regeneration [81]. Particularly within the context of Covid recovery, this multiplicity of outcomes offers a route to tackle several negative impacts caused by the pandemic, including social isolation and economic decline for instance.

4.2.2.1. Risks. Poor-quality installations of energy efficiency could reduce ventilation and lead to detrimental impacts on indoor air quality and cause overheating [73,82]. An appropriately skilled workforce is therefore critical to enabling effective deployment of sustainable construction and building performance and renewable technologies. At present, there are notable skills gaps and regional variations in both the type and quality of skills across the workforce leading to calls for a nationwide training programme to upskill the existing workforce, with appropriate accreditation schemes to be implemented, to ensure a co-ordinated response [78,80].

4.2.3. Energy supply & demand

As stated in Section 4.2.2. above, improving the energy efficiency of housing through retrofitting is one way of reducing fuel poverty and helping to improve the equality of opportunities for people from low-income groups [73]. Improving energy efficiency can reduce overall energy demand, which in turn reduces the reliance on imports of oil and gas, thus reducing vulnerability to volatile international markets and geopolitical events [73].

While reduced energy demand through retrofitting will have a beneficial impact on household bills, taking an integrated approach can further reduce overall energy demand through the application of several mechanisms. These include the use of onsite microgeneration technologies (e.g. solar PV, wind turbines, heat pumps etc.) which can reduce the volume of imported generation required and the use of energy monitoring equipment and smart controls which can deliver short-term demand reduction [83]. As well as reducing costs through reducing demand, householders are able to sell any excess generation back to the grid through the feed-in-tariff, or its replacement the smart export guarantee. However, further savings could be made by storing electricity in a battery or hot water tank to use when needed [32].

Additionally, involvement in citizen-led initiatives, such as energy co-operatives, has been linked to reduced energy demand. One study, of over 10,000 households, reported an average reduction in electricity consumption of over 29 % based on actual energy use [84]. Importantly, this was sustained over a period between 2012 and 2016, suggesting that the demand reduction is sustainable.

Housing regeneration and smart city developments have also been found to reduce energy expenses, particularly for low-income households, in eight EU projects [12]. Moroni & Tricarico [85] highlighted that a more holistic approach to energy management that utilises smart technologies could allow for the integration of local services (such as power, water treatment and supply, waste management, and communications) into one system, reducing costs and freeing up public resource. This could support households on poor incomes to take advantage of new technologies to reduce their energy costs.

In addition, increasing households energy independence and self-sufficiency through the use of microgeneration technologies is often considered a benefit in its own right [46,50,73]. The perceived benefit of energy independence has been cited as a key factor for determining individuals' willingness to participate in community energy systems [56] and peer-to-peer (P2P) energy trading communities [86], while an important notion of community energy in Germany is a higher level of independence from external markets [38].

Consumers who produce part of their own electricity demand through the use of generation technologies at their property are termed 'prosumers' as they produce as well as consume electricity [87]. Prosumers have been shown to be more autonomous than traditional energy consumers and can participate in more active and diverse ways in energy markets [88]. This has opened up opportunities for innovative new market models which can enable prosumers to trade their locally generated energy (e.g. through P2P trading, DSR and local energy markets) [88–90].

In addition to energy autonomy, new business models for trading microgeneration could increase civic empowerment and other social goals [91,92]. For instance Hoppe & De Vries [93] outline several key ways in which business models could provide these wider social benefits, particularly the generation of social innovation development, new governance structures and activities, community empowerment and new routes for participation, along with subsequent behaviour change.

4.2.3.1. Risks. Where 'smart' approaches require changes in behaviours and practices, there may be challenges with user uptake [93]. For example, increasing digitalisation and the introduction of new technologies could cause difficulties for some users, such as older adults, who are unable to effectively utilise smart technologies, causing them to disengage [94].

Consumers generally have a lack of understanding of real-time price information, different energy tariffs (e.g. Time of Use Tariffs) and optimisation of renewable technologies [95]. Consumers can also be resistant to comfort changes and increased automation [83,96]. One study additionally suggests that 'smart homes' where all equipment is automated could be less energy efficient rather than more so, due to consumers having less consideration of the impacts of their energy usage and behaviours [97].

New market models are currently unclear and may be provided by new actors from those customers are currently familiar with (e.g. DSOs or aggregators) [83]. Although we introduced the notion of P2P trading and local markets these models currently face significant difficulty in the UK due to existing market, policy and regulatory structures [10,15]. There are therefore very few examples of local energy projects supplying electricity directly to their local community (with the exception being through private wires or in partnership with commercial organisations that are able to meet UK licensing requirements) [21].

An additional issue is that if communities increase their energy self-sufficiency, they also reduce their imports from electricity networks, thereby contributing less to overall network costs which could have a knock-on financial impact to those network users who have limited capacity to reduce their own electricity imports [98].

4.2.4. Electricity network considerations

An increasing uptake of SLES could have a major impact on the cost of balancing the electricity networks. National Grid's costs of balancing the electricity system has increased rapidly in recent years, to over £1.19 billion in 2017/18 [74]. However, analysis undertaken by Imperial College [99] suggests that reduced system operation costs of between 25 % and 40 % could be achieved through the deployment of new, cheaper, flexibility sources connected at the distribution level rather than by conventional generation. Increased flexibility can improve system efficiency, increase utilisation of renewable generation as well as reducing overall system costs [83]. Deploying flexibility assets at the local level is a key component of emerging energy systems and could include any action taken in response to network conditions in real time. This includes customers shifting their demand at peak hours to reduce network stress, deployment of storage as either demand or supply, and coupling local generation supply with demand to absorb excess generation locally.

Modelling from the EnergyREV consortium [13] shows similar results to the analysis undertaken by Imperial College in that deployment of local flexibility assets leads to cost savings elsewhere in the wider electricity network, with the potential of reaching £8.7bn per year in a high take-up scenario.

Increasing the share of intermittent renewable electricity generation raises new challenges in ensuring frequency and voltage stability of the grid. Addressing these challenges as an isolated 'power system' issue is likely to result in inefficiencies. However, adopting an integrated approach which considers the full 'smart energy system' – i.e. integrating power, heat supply, transport and DSR – could be a more efficient way of ensuring grid stabilisation while offering other co-benefits [14,100]. A Danish study illustrated that small-scale generation can provide valuable grid stabilisation at low additional investment and operating costs when co-ordinated with heat storage and flexible assets [101].

Integrating smart elements including digitalisation, smart meters and smart grids provides opportunity to collect higher quality data which can be used to improve efficiencies and grid optimisation [83,102]. Smarter systems can also help to unlock DSR, which can increase utilisation of renewable energy sources, reduce costs, improve utilisation of the transmission grid and distribution network assets, and enhance balancing capability in the context of high penetration of intermittent renewable energy generation [83,103].

4.2.4.1. Risks. While the increasing penetration of new energy loads at the distribution network level could achieve the benefits outlined above if deployed flexibly and 'smartly' in accordance with network operational needs, their deployment without taking network needs into consideration will increase the likelihood of stress events occurring, leading to voltage limit violations and line congestions [104–106].

In addition, the increasing integration of smart elements could make energy systems more vulnerable to cyber-attacks and exploitation. Ahmed & Dow (2016) warn that high levels of interconnectedness, for example of sensors, actuators, and devices, increases risk, and that security threats can be particularly damaging when devices, for example smart EVs, connect to the internet and to intelligent transportation system infrastructure. They warn that under these circumstances, computing systems can no longer be considered a closed network, and there are opportunities for malicious attacks, including cyberterrorism, which could severely impact the security and safety of energy systems [107].

4.2.5. Employment & skills

Since 2009, the annual growth of the green economy in the UK has consistently grown faster than the rest of the economy. By 2017, the low-carbon and renewable energy sector in the UK was worth £44.5 billion and accounted for 209,500 full-time equivalent jobs, or around 400,000 UK jobs when the wider supply chain is accounted for [73].

A transition to SLES could therefore provide a key opportunity for the creation of related jobs and business ventures - thereby increasing local earning potential. While some of these new roles could be performed by external specialists (e.g. manufacturing and installation) there will be an increased need for ongoing activities (such as contracting, supervision and maintenance) which can be performed locally, adding to local employment opportunities [38]. Thus contributing to the growth of regional gross value added (GVA), while reducing the amount of GVA that leaks out of the local economy through energy spend [80].

A Scottish study by Callaghan & Williams shows that communities generating revenue from energy projects generally use this revenue to stimulate local investment in a variety of ways such as crosssubsidisation of affordable housing, tackling fuel poverty, building business space and wider economic activity [108]. The presence of a local renewable energy scheme can also help to raise that locality's national and international reputation, which can in turn lead to further employment opportunities [64]. For example, a survey of community energy projects in Germany found that new businesses were consciously moving into these areas due to the expanded business potential that such schemes created [69]. In addition, three of the studies researched in this review found that the presence of renewable energy schemes increased tourism potential, adding wider economic opportunities [69,108,109].

4.2.5.1. Skills development. There are several different angles to skills development – skills gained from involvement in project design and delivery (as per Section 4.1) the skills needed for related employment and the skills required by participants (e.g. consumers and prosumers) to operate and optimise renewable energy technologies within their homes and workplaces.

4.2.5.1.1. Involvement in project delivery. Berka & Creamer, 2018 state that active involvement in community energy projects can:

> "*facilitate the development of knowledge and skills across a range of areas, including organisational management and leadership, project management, problem-solving, teamwork, community consultation and engagement, marketing and communication, business development, project finance and fundraising, law, as well as technical capacity around renewable energy technology and energy efficiency*".
>
> [21]

In addition, Brummer's research states that engagement in community energy projects can lead to increased social skills of participants; better technical understanding of renewable technologies and the generation system as a whole; more awareness of climate change and the role of energy consumption within that - including the need for behaviour change to optimise energy efficiency outcomes [38].

Local energy projects and particularly community energy projects, have also been recognised for fostering knowledge sharing [38,58,62,110]. In the UK this knowledge sharing is seen as an educational benefit for other communities to gain first-hand information [38] and considered crucial inspiration for future initiatives [62].

4.2.5.1.2. Skills for employment. With regard to employment, workers require a broad range of skills across every stage of the technology life-cycle and supply chain, such as skills related to supervisory, technical or crafting roles, as well as skills such as operation and transportation. In this respect, some regions in the UK have introduced Skills Advisory Panels to produce evidence-based skills and labour market analysis to identify local skills requirements. In addition, some regions are incorporating energy education into school and college curricula to promote energy awareness from a young age which could help encourage more apprenticeship applications or involvement in further and higher education [80].

4.2.5.1.3. Skills for participants. Participants require skills to optimise their equipment, read smart meters and adapt their energy behaviour in line with achieving net-zero. In this respect some areas have created 'one stop shop' advice centres and skills workshops to equip consumers with the skills required to engage with these new technologies and processes [80].

4.2.5.2. Risks. While research shows that the presence of a local energy scheme can stimulate the economy, the net effects are difficult to measure and depend on local conditions [98]. In addition, when looking at a complete range of co-benefits associated with an energy project it becomes even more complex in defining net gains, as co-benefits can range across many different aspects of community life. Furthermore, studies show that local energy projects are more likely to occur in places where the prerequisite skill-sets are already in place and a lack of these skills can hinder project success [21].

With disruptive impacts such as the COVID-19 crisis, ensuring employment generation in parallel with green economic recovery, is vital. However, there is also a need to understand the impacts of the growth of local energy generation on other industries. Firstly, this will mean a shift in investment away from more traditional fossil fuel reliant energy production methods which could accelerate job losses in these industries, along with the existing workforce needing upskilling or reskilling to enable entry into alternative employment [98].

4.3. Distribution

Social equity has been defined as the balance between economic development, environmental protection and social justice [111]. In the context of local energy, it includes establishing a fair distribution of the costs and benefits of energy systems and the trade-offs to be made between these through inclusive decision-making [112]. Süsser & Kannen [69] describe these related trade-offs as "*sunshine and shade*" – while there are many economic, environmental and social benefits to be gained, there can also be challenges and negative impacts which need to be accurately portrayed to participants in order to make informed decisions and to keep social acceptance high [69].

In the Processes section (4.1) we outlined how instilling participatory processes at the start on any project can help shape the distribution of co-benefits and beneficial outcomes. Research by Becker et al. highlights that there needs to be a fair distribution of both costs and benefits in order to gain trust and increase social acceptance but that with profits comes a responsibility to 'give back' to society [113].

Community owned energy projects open up new financial opportunities, create wider public support and can help to increase participation and contribution [46]. Callaghan & Williams show that communities that own their own renewable energy projects can make much more substantial profits than community projects funded by commercial developers [108]and that the impact of this is will be magnified depending on the degree to which this revenue is spent locally.

A strong driving force for starting community energy projects is the personal interests of the people involved to 'tackle things for themselves' rather than rely on LAs or energy companies to solve environmental, economic and social issues [62]. In addition, Gjorgievski et al. [114] show that while individuals will have their own priorities for joining energy communities there are a number of co-benefits to pursuing those goals collectively rather than individually. These co-benefits include economies of scale, greater bargaining power and greater revenue generation.

Furthermore, Gjorgievski et al. state that energy communities can help to achieve joint goals for external stakeholders such as policy makers and DSOs. For policy makers there is the contribution towards national targets in relation to energy and emissions reductions, while for DSOs there is reduction in violations of voltage and capacity limits through flexibility procurement.

Lacey-Barnacle contends that deprived communities are not primarily concerned with lowering their carbon emissions but that combining local energy projects with other socioeconomic co-benefits increases interest [115]. Research also shows that communities are more likely to engage with local entities rather than national entities in the provision of schemes [116], although people are not necessarily concerned by which local entity, as long as those projects directly benefitted the local community by way of, for example, the provision of employment opportunities, local regeneration and educational benefits, alongside the environmental benefits brought about through carbon reduction [20]. Therefore:

> "*Those that benefit and how they benefit becomes relevant for each project's definitions and boundaries*".
>
> [20]

Meanwhile, Brisbois (2019) [117] contends that community energy leaders are now challenging incumbent energy producers for political influence, through developing their own political networks and lobbying capacity. This brings potential for reshaping energy narratives and altering policy outcomes in favour of new practices, albeit not easily [117,118].

4.3.1. Risks

There is potential for SLES communities to benefit at the expense of non-SLES communities, creating inequalities between areas. Given that many SLES projects occur in locations that have the resources to deliver them there is a need to ensure that less well-resourced areas are not left behind [2]. Conversely, although local generation projects may start with the aim to benefit the immediate geographical community, it has been observed that benefits could be received by those many miles from where the actual infrastructure is sited, if membership isn't linked to locality [62]. This can exacerbate any underlying community tensions between landscape change and the generation project.

In addition, Emelianoff & Wernert [119] warn of the potential for new monopolies to arise at the local level creating path dependence and energy choice lock-in for local residents. Their study in Metz, France observed that a local initiative had not led to wider democratisation of energy choices and that the power and benefits gained at the local level had been no better shared with the community than in previous hierarchical structures. Instead, renewable power had become a source of political power for the local administration.

5. Discussion and conclusion

Our review has analysed and contextualised the published international literature regarding the benefits and negative impacts of taking a local and smart approach to energy transition. We arranged our Findings under three discrete dimensions to aid clarity as to how, where, and why these benefits or impacts might occur: Process, Impact and Distribution.

5.1. Process

Research shows that early and continuous engagement with local communities, along with meaningful participation, is a crucial factor for project success. This can enable greater awareness of why renewable technologies are important in the transition to net zero, greater acceptance of CRE and other local energy projects and ultimately more trust in both technologies themselves and in the specific project. However, community engagement is complex – it involves recognising who will be affected by decision-making - who could potentially 'win' or 'lose' - and tailoring participation accordingly [69]. Project leaders therefore need to demonstrate understanding of community structures, priorities and values and ensure transparency in decision-making processes and the distribution of outcomes. While we have categorised 'distribution' as a separate dimension for analysis, distribution needs to be fully considered early in project development and any arising tensions, trade-offs and unintended consequences dealt with transparently throughout project delivery to create and maintain trust. Robust community engagement can lead to our first identified Impacts - community empowerment and cohesion, as well as to other direct impacts such as skills development, thus emphasising the necessity of early engagement to maximise the co-benefits and mitigate the risks.

5.2. Impact

The analysed research shows that taking a local and smart approach to energy transition can lead to a multiplicity of beneficial impacts (e.g. social, economic, technical and place-based benefits) that reach beyond the remit of energy per se. Many of the identified co-benefits lie within the 'social' realm and as such are not easy to validate as they either lack quantifiable metrics, or the current metrics used are more normally associated with other sectors e.g. health or the economy rather than with climate or net-zero accounting. In addition, some co-benefits are interconnected and can have a cumulative or knock-on effect depending on how each is developed. For instance, we have shown that both improving air quality and reducing fuel poverty can improve health and wellbeing, which in turn reduces NHS costs for the management of associated illnesses. However, how fossil fuels are reduced, for example by focusing on public and active travel, can bring wider benefits. Therefore decision-makers need to act and think holistically, rather than within siloed departments.

Many of these decisions are inherently political and require deliberate choice from either project leaders or political leaders to prioritise social outcomes that may not see an immediate or direct financial saving and which are normally accounted for outside of the energy arena.

That is not to say that there aren't any easily identifiable economic co-benefits to be achieved. The most directly attributable economic co-benefit is on household bills, especially through the combined effect of increased energy efficiency (reduced demand) and the increase in onsite microgeneration (reduced supply) which in turn reduces reliance on volatile energy markets. Depending on ownership model, local renewables can additionally create local funding mechanisms that enable further investment in other community priorities.

Energy independence can also be viewed as a co-benefit in its own right. While we have shown that involvement in local energy projects can increase trust in both the project and the technologies employed, research shows that consumers distrust large energy companies and view energy autonomy and local trading options, such as P2P, as a way to reduce reliance on incumbent industries [120]. The uptake in household low-carbon and smart technologies brings the energy system much closer to people and the communities in which they live, opening scope for a range of new business and service models and direct engagement with energy markets, enabled by the uptake of digitalisation. These integrated approaches, if combined or bundled with other services (e.g. water, telecoms) could also reduce demand and cost to households, freeing up local budgets.

Data is key to unlocking the potential of flexibility assets in supporting the distribution network and delivering on service requirements, and as such new forms of measurement and monitoring are actively being utilised across the energy system at multiple levels [121]. However, at present, UK energy policy is not conducive to direct local energy trading schemes such as P2P, other than DSR [10,15,122]. In addition local energy projects have found that scalability and replicability is difficult in the current policy environment [11] and that ongoing support is needed for project participants, which can be costly and time consuming [123].

5.3. Distribution

Who benefits and how they benefit are important factors for any project to define. For some, this will enable them to reap the benefits associated with owning low-carbon or smart technologies, such as the ability to engage in DSR activities, charging their EVs at a time that takes advantage of preferential time-of-use tariffs etc. However, others will be locked out from these benefits due to lack of finance to purchase technology, lack of digital literacy to optimise technology or through a housing tenure which is unconducive to technology purchase (e.g. privately rented accommodation) [80]. Some of the distributional effects will be beyond the remit of what any one project can mitigate against, belonging in the realm of national policy-making. Therefore, those projects financed to identify and test the challenges of SLES need to consider inequalities in their feedback reporting.

5.4. Research limitations and future research

The approach taken to select papers for this review has resulted in the assessment of a very wide range of papers – from community energy projects to city-scale projects; from projects run by volunteers to projects funded by international organisations. The issue of scale therefore has been one which has been difficult to distinguish between, especially whether increase in scale (be that geographical scale or financial scale) has any direct bearing on the scale of the impact. This in turn raises questions around distribution – does a wider geographical scale equate to a wider distribution of impacts or might distribution be geographically wider but less targeted? What are the trade-offs between scale and participant involvement? Is there an optimal scale for SLES? These are interesting questions that cannot be answered through this literature review, but are nonetheless valid for future research.

In addition, some of the papers discuss *experienced* impacts, while others discuss *potential* impacts, or impacts that can only be realised given a change in external factors (e.g. a change in regulation). For clarity, we identified in the Findings which impacts we considered to be experienced and which are theoretical at this point. However, caution should be made in correlating impacts across different geographical or regulatory contexts. The intention of this paper was to review the co-benefits and risks of taking a SLES approach as identified by the published academic energy transition literature. We strongly recommend future researchers also review grey literature on this topic which may reveal alternative results and the wider climate change mitigation literature for comparisons and contrasts. In addition, we deliberately excluded papers from this review which focused entirely on modelling, which has bounded our review to qualitative research rather than quantitative. This therefore means that this review does not attempt to quantify the potential co-benefits.

From our starting assumptions we aimed to achieve a balanced response between co-benefits and risks. However, we found more emphasis on the co-benefits to be gained, whereas the risks focused more on taking a precautionary approach to project implementation to avoid unintended consequences. This needs to be better understood as perhaps due to commercial confidentiality or funding obligations, project reporting often majors on project 'success' and solutionism rather than the negative learnings. Unless these learnings are made explicit, future SLES projects will unwittingly come up against the same risks or barriers to delivery.

5.5. Conclusion

The co-benefits framework provided in this paper can be used by future SLES stakeholders as a starting point for discussion surrounding which co-benefits are most desired by the community, how to achieve them and how to mitigate against unintended consequences. The framework should not be viewed as a 'basket' of co-benefits that can be delivered by every SLES community, but as a deliberate choice as to which co-benefits should be pursued within the context of each project. In addition, while our review has identified many social, economic, technical and place-based co-benefits to be gained from taking a SLES approach to energy transition, for these co-benefits to be maximised (and for risks to be minimised) there needs to be a process to identify and account for them other than through financial value. This means that what 'success' looks like will vary on a project by project basis. For some it could be the number of jobs created, while for others it could be the increase in digital literacy in a given section of society, or the volume of energy traded locally.

What is therefore crucial to project success is that participants have the opportunity to define success for themselves at the start of the project and that any project tensions, trade-offs and unintended consequences are dealt with transparently throughout the course of project delivery and in end of project reporting [51,58] In addition, project outcomes have to be distributed fairly and equitably. Project leaders therefore need to be transparent surrounding what can or cannot be delivered, and what can be done to mitigate risks [48]. While several of the co-benefits can be delivered through bottom-up community action what is apparent from this review is that a more joined-up approach is needed from government, regulators and institutions to be able to co-ordinate and deliver the policy, regulatory and financial environment for more co-benefits to be achieved. Indeed, some of the co-benefits require joint actions from multiple stakeholders working together towards a co-ordinated end goal in a 'multi-level' approach. Although this research paper is essentially about energy systems, given the interrelated nature of the co-benefits a more holistic and strategic approach therefore needs to be taken to deliver positive outcomes across not just energy but also health, transport, education, skills development, planning, infrastructure delivery and financing. This should include the development of new metrics for analysing the impacts of co-benefits across different services and ensuring that any arising distributional inequalities are mitigated against.

Funding

This work is funded by the UK EPSRC EnergyREV (EP/S031863/1) grant.

CRediT authorship contribution statement

Rachel Bray: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Rebecca Ford:** Writing – review & editing, Validation, Supervision, Project administration, Funding acquisition, Conceptualization. **Madeleine Morris:** Writing – original draft, Investigation, Data curation. **Jeff Hardy:** Writing – review & editing, Validation, Conceptualization. **Luke Gooding:** Writing – original draft, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.erss.2024.103608.

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