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The (in)justices of smart local energy systems: A systematic review, integrated framework, and future research agenda

Abstract

Smart technology alongside local energy systems are regularly considered critical for a low-carbon transition. More recently, a growing body of literature has started to examine the (in)justices that exist within energy systems and the impact this has on all people having equal access to safe, affordable, and sustainable energy. To date, little research has sought to synthesise the evidence base around whether smart local energy systems are an effective means of promoting energy justice. This paper presents a systematic literature review of 105 peer-reviewed articles, with a focus on understanding the antecedents of energy justice in local energy systems and the role smart technology can play in mitigating these (in)justices. We propose an integrated framework outlining our findings and discuss the implications for a future research agenda.

Keywords: energy justice, smart local energy systems, local energy, smart technology, systematic review

1. Introduction

The costs and benefits associated with satisfying our energy needs are unevenly distributed across society [1,2]. These injustices are widespread across the energy system and take a variety of forms [3,4]. They include, for example, high levels of energy poverty in wealthy countries that are net exporters [5], or lower income households paying proportionally more towards government policy costs through their energy bills [6]. Injustices have become deeply entrenched in our energy system and will require radical action if they are to be resolved. Within policy circles the notion of energy justice is embedded within official guidelines to promote decarbonisation and mitigate climate change [7,8]. As such, there is a need to evaluate how the energy system embodies the principles of energy justice by recognising: (a) where the injustices are; (b) who in society is ignored; and (c) whether there are fair processes in place to distribute the costs and benefits across society [1,5,9–12].

To realise a new net-zero and just economy, energy decentralisation has emerged as an important element underpinning the transition towards a sustainable and equitable energy system [13–16]. While there is no formal definition of energy decentralisation, it can include localisation of energy hardware, network management, asset ownership, planning, decision-making authority, market structure, public participation and so on [17]. Local, ‘place-based’ energy solutions offer a number of potential advantages over centralised, ‘one size fits all’ solutions. These include: (1) directly connecting local energy action with community benefit; (2) tailoring solutions to the needs of local communities; and (3) economic growth, job creation, skills and infrastructure improvements [16,18,19].

Energy system digitalisation is regarded as key to unlocking the benefits of local energy systems [17]. ‘Smart’ technologies, which self-report, analyse, monitor, and automate, often go hand in hand with decentralisation because the majority of local energy systems rely on intermittent renewables like onshore wind or solar PV [17]. Consequently, smart systems can help to better align peaks in energy supply and demand on the grid, for instance, through demand load management and local system balancing. Smart technology is “layered into energy systems by collecting and using more and different forms of data” to facilitate a wide-range of process improvements that can yield efficiency gains and cost reductions [20]. This intelligent use of system data can also enable users to actively make more informed decisions about the timing and level of their energy use [17].

The role of both smart technology and local energy systems in obtaining net-zero and justice goals are at the heart of many flagship policy and industry reports [21–24]. Considering the importance placed on smart local energy systems (SLES), we know relatively little about what might make these systems (in)just. There are a potential myriad of antecedents – i.e. preceding events, conditions, barriers or causes - that drive these energy (in)justices [3,4] - yet efforts to integrate both smart and local energy system literature have been slow to emerge [17].

To address this gap in our understanding, this paper presents a systematic literature review (SLR) to examine smart local energy systems against the three tenets of energy justice: *distributive*, *recognition* and *procedural* [1,2]. The aim is to uncover the factors associated with local energy systems and smart technology (in)justices by developing an integrative framework. The end goal is to help researchers, policy makers and practitioners develop SLES in such a way as to promote energy justice. To do this, we ask:

- 1) *What are the main antecedents that make a local energy system (un)just?*
- 2) *How does smart technology influence the (in)justice of local energy systems?*

2. Systematic review methods and approach

To understand the factors that shape the (in)justice of SLES, we utilised an interpretive qualitative synthesis SLR approach. This approach is particularly relevant in emerging fields when research questions are concerned with the development and integration of concepts [25]. Since we integrate three bodies of literature (local energy, smart technology and energy justice) this was considered appropriate [26]. For this review, we followed existing protocols for conducting a transparent, reliable and rigorous SLR [27–29].

2.1 Article selection

To identify a valid sample of articles dealing with the energy justice of SLES, we used criteria sampling based on keyword searches (summarised in *Table 1*) [25]. After defining our key concepts, we used a wide number of search combinations to cover the breadth of terms used to describe similar phenomenon. We first used search terms for ‘energy justice’ in combination with ‘local energy’ and then ‘smart technology’. As we read abstracts and reviewed articles we refined and added to our search terms. We applied our search terms to the Elsevier’s Scopus® database and Thomson Reuter’s Web of Science™ Core Collection in August 2020.

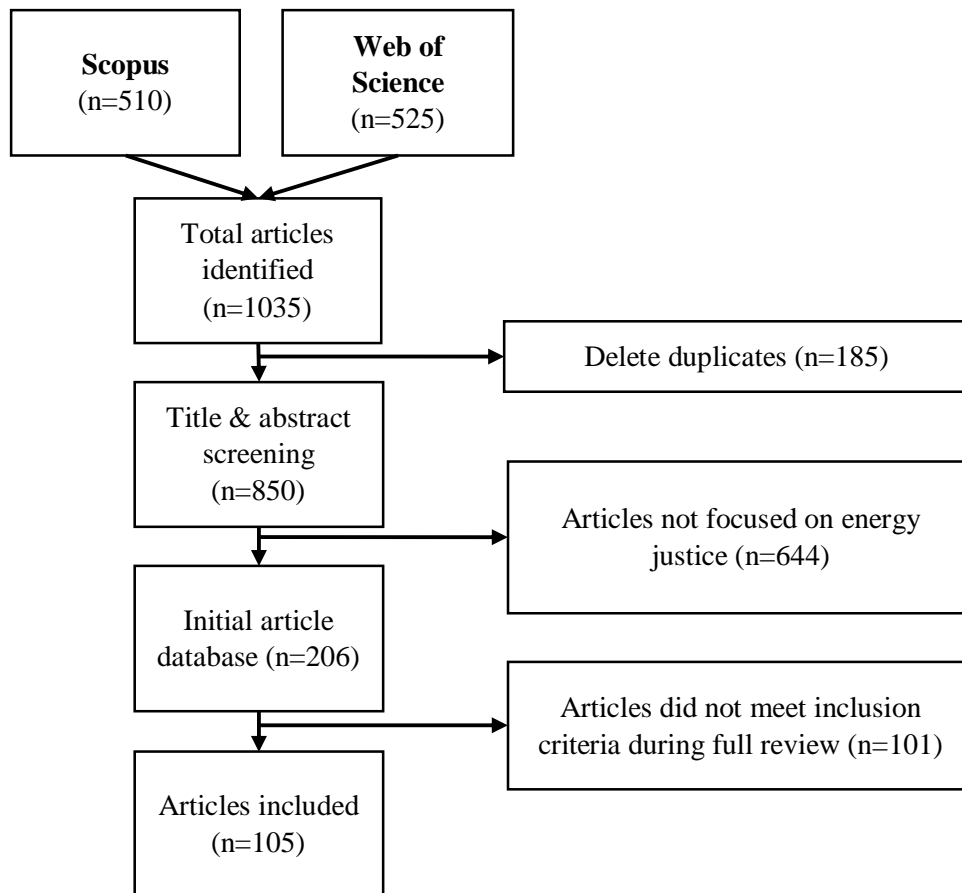
Table 1: Summary of search strings

Concept	Definition	Search terms
<i>Energy justice</i>	“Evaluates (a) where injustices emerge, (b) which affected sections of society are ignored, (c) which processes exist for their remediation in order to (i) reveal, and (ii) reduce such injustices” [1].	“energy justice” “just transition” “social equity” “social justice”
<i>Local energy*</i>	“Energy arrangements led by (or for the benefit of) a local group and for the benefit of local consumers. A local group is a collection of people and organisations with shared interests in local energy outcomes within a common geographical area” [24]	“city” “community energy” “decentralised energy” “dispersed generation” “distributed generation” “embedded generation” “local authority” “local council” “local energy” “local government” “municipal energy”
<i>Smart technology</i>	“Ability to acquire information from the surrounding environment and react accordingly” [30].	“artificial intelligence” “autonomous management” “data and learning” “energy storage” “flexibility markets” “machine learning” “smart” “smartness” “smart meter” “smart grid” “vehicle-to-grid services” “user input”

* The inclusion of “community energy” as a search term, although not commensurate with local energy, was because some papers using this term fit with our definition of local energy.

We limited our search to the field of social science as the energy justice concept has emerged as an important research agenda within the field [1], and is where the vast majority of work is located [31]. We then screened articles by reading abstracts and applying a number of exclusion criteria to ensure that they would inform our research questions [32]. We excluded articles if they were not peer-reviewed; did not have empirical analysis; were based in developing countries not located in Europe, North America, or Australasia; and did not provide indication for energy justice impact. We excluded theoretical and review papers in line with our research aim to identify factors that have empirical evidence of contributing to any (in)justices. We limited studies to developed countries to (a) acknowledge the conceptual differences with how the concept is applied [33]; (b) align with our research aim to understand the shift from centralised to decentralised energy provision which is relevant to the developed country context; and (c) make the search manageable in size. This procedure led to an initial database of 206 articles which was further reduced to 105 articles during full review. The selection process is presented in *Figure 1*.

Figure 1: Flow chart of our selection process



2.2 Analytical procedure

To ensure reliability and reduce bias, two of the research team were responsible for the coding of papers [27]. To ensure the consistency of our analytical approach we developed an initial coding schema to act as a reading template for capturing information from our sample of articles, similar to those used in other systematic reviews in energy research [31,33]. This protocol had five main categories aimed to capture bibliographic, contextual, theoretical, methodological, and empirical details. To address our research questions, we analysed the findings from each paper looking to capture information on the antecedents for (in)justices and the impact of smart technology on local energy system (in)justices. Under each category we had a number of mainly open-ended coding fields for the coder to input information. In total we had 22 coding fields, detailed in *Table 2*.

Table 2: Data coding schema

Category	Details
Bibliographic information	Authors, year, journal, and article title.
Study context and focus	Level of analysis (individual/household, organisation/community, socio-economic landscape), energy/technology type, smart technology details, and country of research origin.
Theoretical background	Research gaps and aims, main theoretical perspective(s), conceptualisation of energy justice, and conceptualisation of level of analysis.
Methodological details	Approach, quantitative/qualitative/mixed, and unit of analysis.
Findings	Summary of findings, antecedents/facilitating factors, consequences and outputs, beneficiaries, and policy-recommendations.

After reviewing our 105 articles using this coding schema, we analysed our resultant data using thematic analysis [34]. Since our review spans a variety of academic fields, a thematic synthesis approach was deemed suitable as it allowed for iterative and flexible analysis across our different topics [35,36]. Our approach to analysis is best described as both inductive and deductive, similar to Jenkins et al. [31]. We used, as a starting point, pre-established notions and categories from the wider energy justice and local energy literature (e.g. *procedural*, *distributional* and *recognition* justice – Table 3). We categorised data from all articles, in a deductive manner, into these overall categories. We then conducted a more in-depth thematic analysis to identify the main antecedents of energy (in)justice within these categories. To understand the impact of smart technology on the (in)justices of local energy, we used a more grounded approach, inducing codes as we analysed the antecedents.

Table 3: Tenets of Energy Justice

Justice tenet	Description	Manifestation of injustice
<i>Distributive</i>	The distribution of energy costs and benefits across society.	One or more sections of society are subjected to an uneven distribution of costs and/or benefits, in terms of geography, demographic etc.
<i>Recognition</i>	The recognition of different sections of society in relation to energy matters.	One or more sections of society are ignored or misrepresented.
<i>Procedural</i>	The extent stakeholders are meaningfully included in decision-making processes that govern distribution of energy costs and benefits.	One or more sections of society are excluded from key decision-making processes.

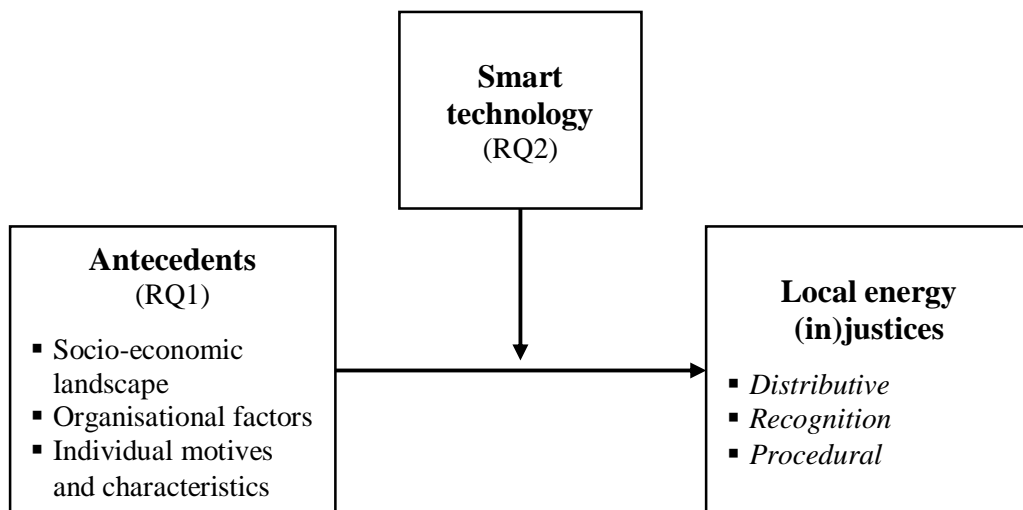
Source: Adapted from Jenkins et al. [1]; McCauley et al. [37]; Sovacool and Dworkin [38]

Figure 2 presents a guiding framework for our SLR. Using the tenets outlined in Table 3 as our theoretical underpinning, our first phase of analysis investigates energy justice antecedents (RQ1). Antecedents can, depending on the specific local energy context, be either drivers or barriers to energy justice at three analytical levels:

- 1) The *socio-economic landscape*, which refers to broader developments such as policies and market dynamics.
- 2) The *organisational factors*, which concern the structures and practices of local energy organisations (e.g. business models, resources).
- 3) The *individual motives and characteristics*, which refer to the individuals and households that participate and benefit from local energy.

Our second phase of analysis considers how smart technology can impact and potentially mitigate the (in)justice of local energy systems (RQ2).

Figure 2: Guiding framework for systematic review



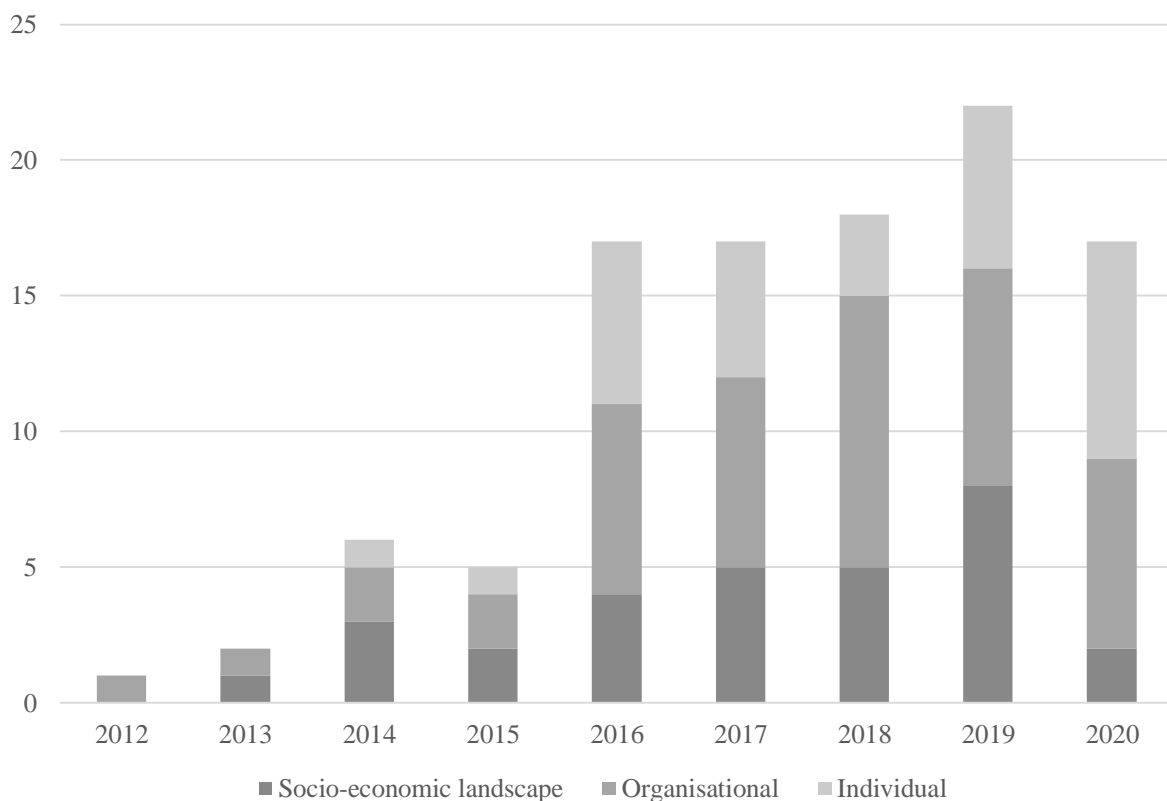
3. Findings

Our presentation of findings has three sub-sections. First, we briefly present the characteristics of our data. Following this we turn to a deeper analysis of the antecedents for energy (in)justice in local energy systems. Finally, we present our findings from the analysis of how smart technology can impact the relationship between energy (in)justice and local energy systems.

3.1 Characteristics of the data

Journal articles investigating the energy justice of smart technology and local energy are a recent trend, first appearing in 2012 (*Figure 3*). Articles that met our inclusion criteria came from a number of fields, including energy, geography, planning and development, business management and political science. However, the majority of articles were published in predominately energy related (n=66) or geography, planning and development (n=31) journals. Energy Policy was the most productive journal to publish on the topic (n=26), with Energy Research & Social Science the next most productive (n=19).

Figure 3: Research articles over time by level of analysis



The majority of articles were qualitative studies (n=68), which were typically case studies of local energy projects. Quantitative studies (n=21) and mixed method studies (n=16) were less frequently utilised. With regards to the level of analysis in our sample of articles (*Figure 3*) most focused on organisational factors that influenced energy justice (n=45). Studies focusing on the socio-economic landscape (n=30), or the justice impacts of individuals and households within local energy systems (n=30) were less prevalent.

Solar (n=50) and wind (n=29) were the most common types of energy generation to be studied. Over half of the articles explored the impacts of smart technology on energy justice (n=53), emphasising that smart technology and local energy systems go hand in hand [17]. The majority of these focused on integrated smart systems containing multiple technologies such as smart meters, battery storage and automated appliances. Research into local and smart energy were dominated by studies including evidence from UK energy systems (n=56), with Germany (n=24), Netherlands (n=13) and United States (n=10) the next most frequently studied countries. Just under a quarter of studies (n=23) provided cross-country evidence.

3.2 Local energy justice antecedents

In this section, we explore the antecedents for local energy (in)justice, across three levels of analysis: Socio-economic landscape, organisational factors and individual level motives and characteristics. Antecedents can, depending on the specific local energy context, be either drivers or barriers to energy justice. In the sub-sections that follow, we explore what the commonly identified drivers and barriers for energy justice are in local energy systems.

3.2.1 Socio-economic landscape

Antecedents related to the socio-economic landscape were linked to the specific context in which local energy systems operated. This underlines the importance attached in the local energy literature to the local contexts and institutional settings in which systems and organisations are embedded [39–41]. A summary of the main antecedents is presented in *Table 4*.

Table 4: Summary of socio-economic landscape antecedents

Theme	Description	Energy justice outcomes (<i>tenets</i>)	% of sample and references
Policy and regulation	Articles exploring policies and regulations that facilitate or restrict local energy, including FiTs and planning policies.	<ul style="list-style-type: none"> ▪ Generous FiT and favourable planning policies help local communities to participate in energy projects (<i>procedural</i>). ▪ Generous FiT policies increase the viability of decentralised energy projects, affording financial benefits to local energy participants (<i>distributive</i>). ▪ Poorer households pay proportionally more of their income towards FiT policy costs through their bills, where policy costs are not graduated*, meaning wealthier communities receive benefits (<i>recognition</i>). 	30% [3,42,51–60,43,61–70,44,71,45–50]
Market dynamics	Articles exploring the impact of local energy on market dynamics of energy generation, supply, and consumption.	<ul style="list-style-type: none"> ▪ Local public ownership of energy can reduce citizens’ energy choices, reducing participation in wider energy markets and the distribution of any benefits this may bring (<i>procedural, distributive</i>). ▪ Smaller energy generators are less able to afford transaction costs, leading to poorer distribution of benefits (<i>distributive</i>). 	10% [3,54,58,59,72–77]
Banking and finance	Articles exploring the various finance options for local energy development.	<ul style="list-style-type: none"> ▪ Banking and finance systems favour large energy projects versus smaller scale projects, thus reducing community participation and distribution of benefits (<i>procedural, distributive</i>). ▪ Alternative finance (e.g. community shares) can increase local community participation (<i>procedural</i>). 	7% [45,46,55,58,61,64,78]
Social networks	Articles exploring the importance of networks.	<ul style="list-style-type: none"> ▪ Collaborations, including intermediary support, can facilitate participation and distribution of benefits (<i>procedural</i>). 	6% [42,49,50,62,73,79]

*Any tax in which the rate increases as the amount subject to taxation increases, such as income tax in the UK.

3.2.1.1 Policy and regulation

Understanding both the policy and regulatory context that either supports or undermines the development of local energy projects was a key research focus (30% of sample). Policy and regulation shape the environment in which the market operates and have a significant influence over the number and type of local energy projects that operate. This in turn has important implications for the energy justice effects that local energy projects exhibit. This body of work focused on the impact various policy mechanisms had on the ability of communities to participate in the generation and distribution of energy. Feed in tariffs (FiT)ⁱ are acknowledged as key for stimulating investments into community energy projects [42]. Successive reductions in the level of subsidy provided by FiT policies in some European countries discouraged community initiatives and reduced the development of local energy projects [51]. Hillman, Axon and Morrissey [50], for example, highlight that a decrease from 43p per kWh to 4p per kWh for small scale solar energy FiT reduced the potential financial sustainability for many local initiatives.

Less attractive FiT subsidies fail to de-risk local energy projects and, in turn, reduce the appeal for investment and undermine the ability of local energy initiatives to deploy and scale [43,44]. Brauholtz-Speight *et al.* [68] highlight that over 90% of projects they sampled make a financial surplus, but this falls to just 20% if income from price guarantee mechanisms such as FiT schemes are removed. Several papers recognise that FiTs represent a regressive policy in both how costs are raised via energy bills, with poorer communities paying proportionally more towards policy costs on their bills. Further, wealthier communities are able to access the policy benefits more readily than poorer communities as they have access to capital to participate in local energy projects and subsequently capture FiTs [52,69–71]. A lack of attractive FiTs, therefore, can restrict participatory and distributive justice as local communities are less able to secure the necessary funds to deliver their own energy initiatives and, in turn, generate any benefits from this.

Multiple studies identify how city and regional planners need to re-think their wider policies in order to scale local energy development, by shifting away from traditional, centralised production [3,59,65]. Nolden [45], for example, highlighted that in the UK planning permission was typically granted to local communities with small wind farm initiatives with <50 kW scale. Low success rates for wind farm planning were attributed to how renewable local energy projects are positioned within the UK's planning framework. A lack of grid connectivity, excessive requirements for community engagement and environmental impact,

designed for larger commercial scale projects, were highlighted as impediments to local energy projects [39,45]. These political barriers act to deter the participation in local energy and the generation of any benefits from this.

3.2.1.2 Market dynamics

Several studies highlight that the emergence of decentralised energy is disrupting current market dynamics, undermining regional monopolies, and increasing the political complexity of energy generation, distribution and consumption [58]. Emelianoff and Wernert [72] highlight how local actors compete to take the place of centralised energy providers. They find that the power and benefits conferred by the control of energy production to be a central dimension to energy justice, with local public ownership of energy infrastructure no guarantee of a democratization of energy choices. In some cases, public ownership of energy can create ‘lock-ins’ that restrict the options and choices of citizens [2,73].

However, in advanced economies, current market dynamics restrict the ability of local energy initiatives to develop. Large providers generally control energy markets as they are able to bear the transaction costs of trading on wholesale markets. Smaller generators, with lower power outputs, are unable to bear these costs, leading them into unfavourable Power Purchase Agreements with major suppliers. Smaller producers also struggle to secure favourable agreements due to their preference for generation from intermittent renewables, which are not normally as attractive to major suppliers who value predictability of supply [64].

3.2.1.3 Banking and finance

Several studies highlighted that banking and finance systems, generally, do not support smaller scale community initiatives and instead mainly favour large installations of more than 20 MW, and demanding more than £20m capital [45,64]. This affects the ability of communities, who do not have access to abundant resources, from participating in local energy initiatives [46]. In some countries alternative finance facilitates the development of community energy initiatives, for example via crowd-sourced community shares or loans from ethical lenders [45,64,68]. In Germany, for example, the civic ownership of generation assets and municipal ownership creates access to finance from co-operative, state-owned and local banks, while this infrastructure is missing in the UK [64].

3.2.1.4 Social networks

The strength of a region's social network is another facilitating factor for the energy justice of local energy. Intermediate support provided by governments to community initiatives are key for development as they can advise on business models and structures, which can enhance participation and distribution [49,62]. Additionally, strong community initiative networks allow for business model innovation and help leverage resources from wider areas [50,79]. Collaborative strategies amongst multiple community initiatives, for example, is an effective approach to mitigate changing institutional structures and to scale energy movements, while also maintaining local participation [42].

A strong social network will allow some community organisations to access resources not currently within their control [80]. Bauwens et al. [42], for example, highlight how combining resources of multiple cooperative groups to meet the changing institutional landscape in Denmark, Germany and Belgium offered an effective strategy to compete at a larger scale. Likewise, Goddard and Farrelly [73] highlight how key partnerships and relationships with external stakeholders - particularly with intermediaries - helps to draw in the resources needed to develop local energy initiatives. Coordinating actions also helps to reduce transaction costs, thus improving economies of scale and profitability. This enables communities to participate and benefit in local energy projects.

3.2.2 Organisational factors

Many articles within our review focus on the level of the organisation and the factors that make-up the structure and actions of local energy systems, which has consequences for energy (in)justice. The main antecedents covered in our SLR are presented in *Table 5*.

Table 5: Summary of organisational antecedents

Theme	Description	Energy justice outcomes (<i>tenets</i>)	% of sample and references
Business models, legal structures, and practices	Articles that explore legal structure, business operations and local stakeholder engagement.	<ul style="list-style-type: none"> ▪ Shared ownership affords greater involvement in management versus commercial arrangements (<i>procedural</i>). ▪ Community involvement and communication increases participation (<i>procedural</i>). 	23% [41,48,81–90,49,91,55–57,63,65,66,80]
Resource availability	Articles that explore the access to various resources needed to operate local energy.	<ul style="list-style-type: none"> ▪ Communities and individuals with greater capital are afforded greater participation and benefits (<i>procedural, recognition</i>). 	12% [4,40,93–95,43,56,57,68,80,83,84,92]
Organisation aims and motives	Articles that explore the various reasons for operating local energy organisations.	<ul style="list-style-type: none"> ▪ Organisations aiming for community inclusion afford greater procedural justice than those with commercial impetus (<i>procedural</i>). 	10% [39,40,100,41,48,89,93,96–99]

3.2.2.1 Business models, legal structures, and practices

At the organisational level, both trust and equality in decision-making are important for equity outcomes [41,48]. Participatory practices are important for community initiatives as they help to create infrastructure, build relationships and distribute social equity [80,86,87,99]. Different business models and legal structures have different impacts on participation in local energy initiatives and the distribution of their benefits. Cooperative legal structures and shared ownership arrangements for instance afford the greatest procedural justice versus commercial partnerships, especially with a low-cost membership criteria which supports inclusivity (e.g. one shareholder, one vote) [48,82]. Walsh [91], for example, highlights how larger shareholders, with substantial land ownership, maintained control over a local community wind farm in Ireland. The control exerted by a few individuals subsequently excluded wider community members from involvement in policy agenda, planning and support.

Regardless of the type of business model community initiatives adopt, there are two main practices highlighted that seem to be important for procedural justice. First, community involvement in the early stages of larger projects through meaningful engagement and deliberative participation [65,89,90]. Indeed, participation of community organisations in larger local energy initiatives is reportedly low [59,77]. While some communities can effectively lobby to ensure involvement and community benefit, the majority are excluded from participation [66]. Different legal structures denote different means of participation, for example, a charity with a board of trustees has power concentrated in just a few people, whereas a cooperative has greater distribution and more inclusive decision-making processes. Second, access to information and communication is key for community participation [57,61]. This can reduce tensions in communities and increase the perceived legitimacy of initiatives [84].

3.2.2.2 Resource availability

The energy justice of local energy projects is impacted by the resources available to organisations. For some citizen-led initiatives, particularly in less wealthy communities, the ability to raise finance is a key barrier [56,83]. Considering the institutional challenges small community initiatives often face in raising finance from banks and lending institutions, there is a reliance on community shares. For example, Brauholtz-Speight et al. [68] find that “community shares account for almost all the finance raised by projects with a CAPEX of less than £200,000 (the majority of projects), but a much smaller proportion of the total finance raised by projects costing over £1.5 million” (p.172). This has clear implications for the distribution and recognition of local energy benefits (greater benefits to places where individuals are able to invest more). It also implicates procedural injustices for those that cannot participate financially, such as the fuel poor. This impacts ability to participate in democratic processes like shareholder voting, which could otherwise improve their levels of recognition and distributional justice.

Unsurprisingly, it is generally wealthier communities and landowners that benefit the most from local energy projects, as they can afford upfront costs, investments and have land for installation [43,92,93]. However, incentives like reserved shares that are set-aside for the general public allow even relatively low-income citizens to benefit financially from participating in local energy projects [84].

As well as tangible assets, human resources are also critical to the development of local energy projects, thus having an indirect effect on energy justice. Knowledge and skills are

prerequisites for successful local energy projects and the more successful a project, the more the community benefits from it. Having entrepreneurial skills and capabilities, such as resourcefulness, opportunity-pursuit, creativity, innovation and networking are also key for starting and scaling community enterprises [40,57,94]. Local access to finance, skills and knowledge is key to achieving local benefit through energy projects but given the unequal spatial and societal distribution of these resources, some local communities will naturally benefit, whilst others will not.

3.2.2.3 Organisation aims and motives

The aims and motives of local energy initiatives also impact energy justice. Community energy projects are started with different goals, such as environmental impact, financial saving, energy autonomy or energy poverty alleviation. Hoffman et al. [100] highlight that an organisation's founding values impact how and if justice objectives are achieved. For example, some initiatives place greater value on inclusive processes and decision-making (*procedural justice*), while others will prefer a more technocratic, cost-effective approach – sacrificing *procedural justice* for increased financial benefits. Lacey-Barnacle [101], for example, highlights how deprived communities are not primarily concerned with lowering their carbon emissions, but rather financial benefits and local regeneration.

Becker et al. [98] highlight how the notion of empowering citizens to address climate change is strongly related to procedural justice, regardless of organisational structure (public utility, cooperative, informal association). High levels of trust, respect and communication between cooperative members are generally found in organisations that aim for community and environmental benefit [41,48]. In some situations, where financial benefit and organisational efficiency are primary motives, organisations' leaders do not follow democratic decision-making procedures allowing them to make quicker decisions [99].

3.2.3 Individual-level motives and characteristics

We found a number of motives and characteristics that influenced how individuals and households were able to participate in and benefit from local energy systems. The main antecedents covered in our SLR are presented in *Table 6*.

Table 6: Summary of individual level antecedents

Theme	Description	Energy justice outcomes (tenets)	% of sample and references
Financial motives	Articles that explore the potential for energy savings as a motivating factor.	<ul style="list-style-type: none"> ▪ Up-front financial costs adversely affect vulnerable and low-income groups (<i>recognition</i>). 	10% [4,63,109,76,102–108]
Energy autonomy motives	Articles that explore energy autonomy as a motivating factor.	<ul style="list-style-type: none"> ▪ The ability to have control over energy decision making can lead to cost benefits (<i>procedural, distributive</i>). ▪ Lower energy choices can lead to higher potential costs which adversely effects low-income households (<i>procedural, recognition</i>). 	9% [102,104–106,110–113]
Knowledge and information	Articles that explore the importance of information dissemination about energy use and generation.	<ul style="list-style-type: none"> ▪ Education levels prevent citizen participation in local energy (<i>procedural, recognition</i>). 	8% [54,95,102,113–117]
Community identification and social motives	Articles that explore the social dynamics of local energy participation.	<ul style="list-style-type: none"> ▪ Strong community identification increases participation (<i>procedural</i>). 	5% [93,105,106,110,118]

3.2.3.1 Financial motives

The potential for energy savings and financial benefits was cited as a driver for individual household participation in local energy projects [109]. Likewise, a lack of finance, time and resources were found to be key deterrents for participation in local energy projects [106,109]. Considering the justice implications, these studies point to how participation in local energy projects generally requires people to have up-front finance and knowledge, adversely affecting vulnerable and lower income groups [104,108].

3.2.3.2 *Energy autonomy motives*

Energy autonomy and control over production and consumption are also motivating factors for individual participation in local projects [110]. This includes the ability to control whether they opt-in or opt-out of participation in energy initiatives, such as the roll-out of smart meters [102,111]. Having the ability to make decisions over energy participation is key for *procedural justice*. Buchanan et al. [102] when looking at smart automation highlight how UK users want to (a) be able to opt-in to using technology and (b) be able to override automation systems to maintain their need for autonomy. Without choice, consumers can experience potentially higher inconveniences, which could prove largely unjust [104].

However, energy autonomy appears to be a privilege for wealthier households. Lower income households are typically more focused on financial savings over autonomy. Generally, higher-income households have more resources to afford participation in local energy initiatives, can afford smart appliances, battery storage and electric vehicles. This affords them the privilege of choice, creating a basis for injustice between higher and lower income households and communities [112]. Adoption is purely based on individual means and the choices this affords [4].

3.2.3.3 *Knowledge and information*

A number of articles explore the important role that information regarding energy supply and distribution has on the ability of individuals to participate and benefit from local energy. Many of the most vulnerable in society do not respond positively to having autonomy over their energy system, which can lead to adverse feelings particularly if they are not educated on system use [113]. A lack of understanding and access to information were key themes highlighted for the uptake of smart technology and participation in local energy initiatives. Education levels were regarded as barriers preventing citizen participation, particularly in low-income and rural communities [114]. This is in part because understanding the economic benefits that are available through local energy projects is crucial to expanding engagement and the subsequent distribution of benefits [63,109].

3.2.3.4 *Community identification and social motives*

For individuals, strong identification and affiliation with their community facilitated participation in local energy initiatives [105,106]. Individuals that are motivated by community well-being are more likely to perceive outcomes positively than those who look for economic

returns from participation in local energy projects [93]. Koirala et al. [106] highlight that a ‘sense of community’ was a strong factor for determining participation in local energy initiatives. They report 79% of their respondents who viewed participation in community energy as positive were willing to work with their neighbours in energy projects.

Participation in local energy projects does not just lead to financial benefits and autonomy but can create socio-emotional well-being. However, community members that are unable to participate within these projects can experience adverse emotions. Likewise, participating community members can experience adverse emotions for non-participating members, detracting from the positive socio-emotive experience of participation [118].

3.3 The impact of smart technology on local energy (in)justices

The second aim of this review is to explore how smart technology can impact and potentially mitigate the (in)justices of local energy systems. Our analysis revealed four overall themes in which integrating smart technology into the design, organisation and operation of local energy systems can influence energy justice.

- 1) *Increased grid connectivity* between consumers, organisations, and the wider socio-technical system to increase financial feasibility, aid participation and distribute benefits.
- 2) *Disrupt centralised market dynamics* by increasing the autonomy and control of consumers.
- 3) *Enhance learning capabilities*, both for systems and individuals which can alleviate education and knowledge as a barrier to participation.
- 4) *Extend the spatial boundaries* of local energy systems, increasing potential for local energy participation and distribution.

These factors and the key technologies linked to them are detailed in the sub-sections which follow and summarised in *Table 7*.

Table 7: Summary of smart technology impacts

Theme	Description	Key technologies	Energy justice outcomes (tenant)	% of sample (References)
Increasing grid connectivity	Articles that explore the potential of smart technology to improve connectivity and grid integration.	Battery storage, demand-response management technology, supply management system	<ul style="list-style-type: none"> ▪ Smart grids facilitate access to local energy, affecting participation (<i>procedural</i>) ▪ Ability to afford smart technology means smart grids offer greater utility to wealthier consumers (<i>recognition</i>). 	14% [59,63,120–124,64,75,83,88,103,105,107,119]
Disrupting power dynamics	Articles that explore the potential of smart technology to disrupt energy market dynamics.	Battery storage, demand-response management technology, smart meters, peer-to-peer trading platforms	<ul style="list-style-type: none"> ▪ Greater consumer control of energy supply and demand can increase household decision-making power and capture additional cost savings (<i>procedural, distributive</i>). ▪ Smart city agendas are dominated by multinationals which restricts smaller local energy initiatives access to market (<i>procedural</i>). 	11% [53,77,127,85,105,110,111,113,117,125,126]
Enhancing learning capabilities	Articles that focus on the ability of smart technology to increase knowledge of users.	Smart meters, energy monitors, energy displays, smart appliances wearable tech, smart phone	<ul style="list-style-type: none"> ▪ Improved understanding of energy consumption can enable consumers to make informed energy choices, affecting their participation and the subsequent benefits (<i>procedural, distributive</i>). ▪ Autonomous appliances can distribute energy savings but can also cause a loss of control (<i>procedural, distributive</i>). ▪ Costs can be prohibitive to low income households (<i>procedural, recognition</i>) ▪ Inconsistent media messages complicate information and decision-making for consumers (<i>procedural</i>). 	9% [102,103,114,115,118,122,128–130]
Extending spatial boundaries of ‘local’	Articles that focus on how smart technology can increase energy distribution.	Virtual power plant, virtual net metering, digital platforms, smart meters	<ul style="list-style-type: none"> ▪ Virtual trading can increase reach of localised projects (<i>procedural</i>). ▪ Can exclude participation for parts of society without reliable internet access (<i>recognition</i>) 	6% [39,88,105,108,125,131]

3.3.1 Increasing grid connectivity

One body of research focuses on the integration of local energy initiatives with current electricity grids and markets [105]. This work shows that new ICT and technologies are required in local and regional distribution networks to achieve widespread integration between local energy generation and national supply [64]. Smart technology has the ability to meet some of the major challenges of decentralised low-carbon energy production, such as better balancing energy supply and demand. This can help to facilitate the integration of typically intermittent renewable energy onto national grids. This can yield benefits, such as reducing the need for additional network investment costs that enable connections to local energy [103], such as bolstering network capacity. These cost savings can then be passed onto all consumers, as a form of distributional justice.

Battery storage is key for the integration of decentralised power generation with wider electricity market, as it allows battery owners to exploit market volatility by temporarily halting, capturing and releasing energy at different times [105]. Using a combination of demand-response management technologies, storage and smart grid software affords greater control over supply and demand. This allows larger numbers of renewable energy resources to connect onto and supply the grid [63,119,122]. However, as Milchram et al. [122] highlight, smart grids also have the potential to reinforce local energy injustices by being more accessible to wealthier consumers who can afford capital costs.

3.3.2 Disrupting power dynamics

Whilst smart technology in general is putting more control and decision-making capabilities in the hands of consumers [110,111], the combination of certain smart technologies has the potential to further disrupt current energy dynamics. A combination of active demand management and energy storage for example, can help to capture energy surplus, which can then be sold back to the grid in times of greatest demand [53]. This opens up new opportunities for export [85], further bolstering financial performance and improving the feasibility of decentralised energy generation [105]. This can be further facilitated by peer-to-peer trading platforms which can offer local energy initiatives a route to market [105,127].

In this context, smart technologies have the potential to afford prosumers more influence, giving them choice and control over supply and demand. McLean et al. [127], for example, highlight that Austin Energy in Austin, US, are reducing their own role as energy provider, aiming to transition to an intermediary facilitating transactions in a smart

marketplace. This marketplace will allow business to develop hardware and software which they sell directly to consumers with little utility involvement. The marketplace, offering residents demand response systems, decentralised renewable energy technology and small-scale storage devices, aims to enable residents to become responsible for their own generation and consumption. This effectively allows them to become ‘players in the market’ by affording them greater choice over energy transaction and reducing the power of energy utility companies. By transferring greater control over both the level and timing of energy supply and demand to consumers, smart technology can bolster *procedural justice* by transferring decision making power to households. It can, by extension, improve *distributional justice* by helping some consumers to capture additional value (e.g. cost savings).

It is important to offer an alternative perspective. Despite the potential of smart technologies to disrupt current market dynamics, several studies highlight current smart technology policies are doing little to change neoliberal market dynamics. March and Ribera-Fumaz [126] state “the (urban) environment, mediated through infrastructure and ICT, under the label of the Smart City, is increasingly being seen as a frontier for capital accumulation and circulation”, emphasising that the control of energy agendas remains in the hands of large energy utilities and technology corporations [75,77].

Viitanen and Kingston [77] emphasise that smart city agendas are being ‘handed’ to multinational organisations, which diminishes the ability and participation of smaller local energy initiatives, further reinforcing procedural inequalities. Similarly, Taylor Buck and White [75], for example, highlight how the UK government’s ‘TSB Future Cities Demonstrator Competition’ saw the same technology consultancy companies bidding for funds, including: Siemens, IBM, Microsoft, Intel and Cisco. This resulted in a lack of innovation, diversity and competition between cities and providers, crowding out engagement with local community-led initiatives and organisations.

3.3.3 Enhancing learning capabilities

Education and knowledge about smart technology and energy providers are an antecedent for participation in smart local energy projects [114]. Household integration with smart meters, energy monitors, displays, wearable tech and smart phone compatibility can improve consumers’ understanding of the factors that determine the level and timing of their energy consumption. Autonomous smart appliances have the ability to create energy savings without behavioural change, which can provide benefits to citizens who are unwilling or unaware of

how to change [122]. However, automated ‘passive’ technology which involves minimal decision making from consumers has been reported to have a negative impact on socio-emotional well-being, due to feelings of loss of control [118]. Having flexible systems that allows control can enable behavioural change and facilitate energy savings, thus allowing for procedural and distributive justice [128].

Smart metering and visual displays are seen as advantageous for less affluent consumers because they can help inform decision making to target actions that reduce energy consumption and bills [122]. The visual cues that smart monitors provide seem to be particularly effective at reaching people vulnerable to fuel poverty and helps empower them to manage their energy use more effectively [103,115]. Considering education levels and wealth is distributed unevenly across communities, lower income and education households are less likely to know how to access and benefit from smart meters [117]. This is largely due to the preventive cost of equipment, a lack of knowledge on how to use it, and unawareness of the benefits. This is exacerbated at a wider level, where media discourse creates contested, complex and inconsistent messages for consumers into the benefits of smart technology systems, which ultimately reduces participation in smart technology initiatives [74].

3.3.4 Extending spatial boundaries of ‘local’

Smart technologies such as virtual power plants can extend the geographical reach of local energy projects by allowing monitoring and exchange through virtual trading platforms. Van Summeren et al. [131] argue that instead of focusing on community energy as a concept with fixed local boundaries, community virtual power plants have the potential to expand the horizons of communities and the markets they can access through ICT-based controlled networks of virtual communities [108,131].

On one hand, digital platforms for peer-to-peer trading, can increase participation in local energy projects and energy transitions. Thus, they can improve energy justice by increasing the reach of localised projects to wider groups and spread the benefits of participation to wider parts of society. Virtual communities enhance the prospect of reaching consumers in places where there is limited renewable energy capacity or an absence of local energy projects. On the other hand, they can exclude participation for certain members of society who do not have access to reliable internet, knowledge, and information on how to participate in these initiatives. Hansen et al. [125] summarises this trade-off, finding that digital interfaces can increase connections and enable the sharing economy to increase scope, outputs,

benefits (*distribution*), whilst also increasing complexity (*procedural*) particularly for the disadvantaged and uneducated (*recognition*).

Considering that wealthy households are able to afford and utilise smart technology, ensuring wider access to these opportunities is key for energy justice. Shaw-Williams and Susilawati [88] highlight how virtual net metering (innovative technology for monitoring, billing and settlement software) can enable the sharing and generation of storage for citizens in social housing. This can increase the connectivity and viability of smart energy projects for less affluent households, thus allowing vulnerable groups to participate in and enjoy the benefits of smart local energy projects.

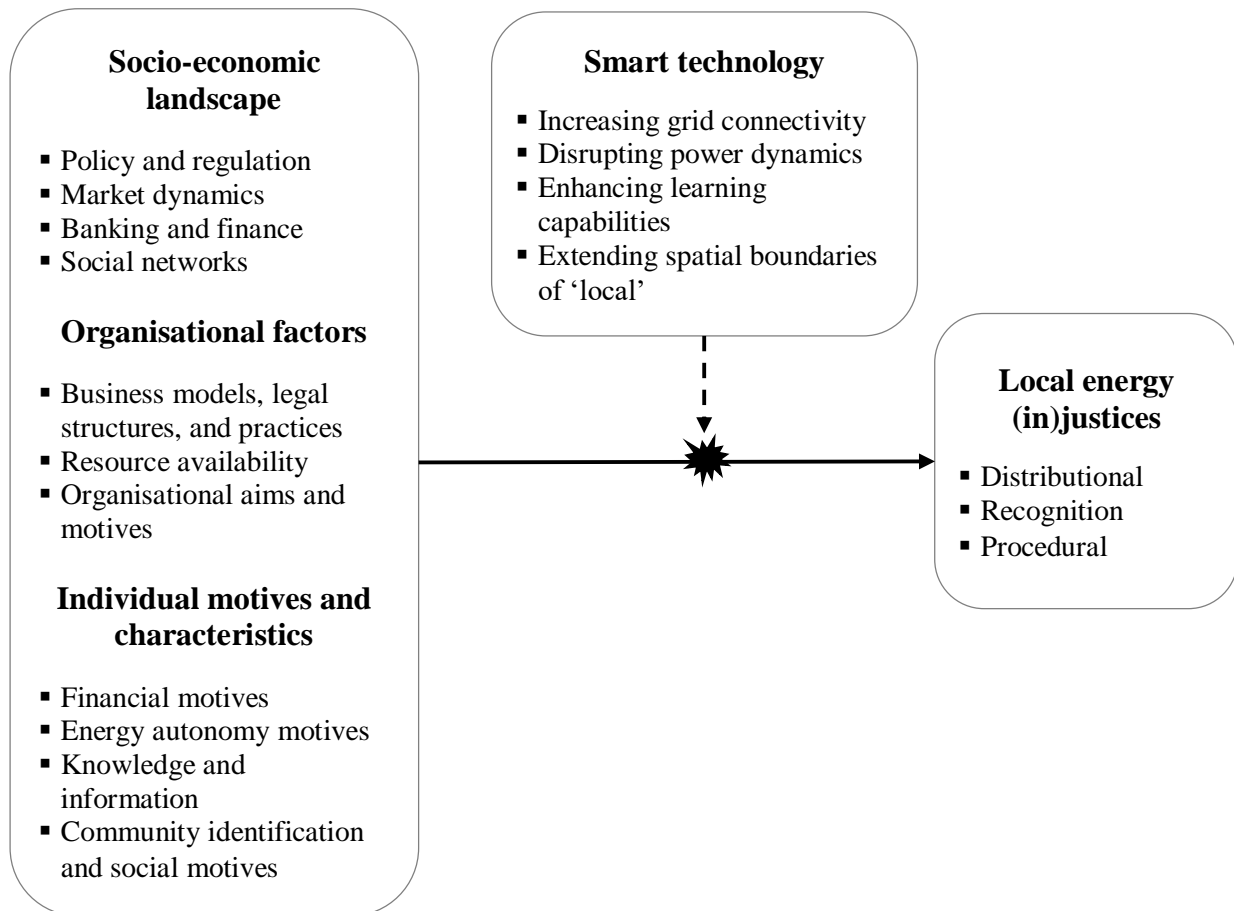
4. Discussion, implications, and conclusion

The aim of this review and integrative framework have been to uncover the processes by which local and smart energy technology can support or undermine social equity in the energy system. This has made it possible for us to identify the multi-level factors that shape (in)justices in local energy systems and the impact of smart technology on these (in)justices. We are also able to consider our findings on a broader scale and point towards areas of future potential within SLES research.

4.1 An integrative framework for examining the social equity impacts of SLES

Figure 4 presents the framework that we derived from our synthesis of empirical articles. It is intended as a blueprint for academics, practitioners and policymakers when considering the various aspects that contribute to the (in)justices of local energy systems. While the components of the framework do not represent a comprehensive list of all antecedents for just local energy systems, or potential mitigating factors of smart technology, they do offer a detailed multi-level perspective on the factors associated with the (in)justices of smart, local energy.

Figure 4: Framework for smart local energy system (in)justice



Our framework has a potentially much wider application beyond local energy. First, its multi-level perspective on the antecedents can help analysts determine the factors responsible for shaping the (in)justices associated with any project or intervention (in our case local energy projects), specifically against the three pillars of *distributive*, *recognition* and *procedural* justice. Second, our framework can offer insight into how changing the characteristics of these projects to incorporate a common feature may serve to impact these (in)justices (in our case integrating smart technology into local energy projects). From our analysis, we find that the impact of smart technology on energy justice is varied. On one hand, it may be positive in the sense that smart energy was able to mitigate injustices or bolster justices. On the other hand, smart energy can have the opposite effect, by undermining justices or making existing injustices worse. The framework offers a balanced view of the impacts an intervention may have on social justice, such as integrating smart energy into local energy projects.

4.2 Limitations

Our study is not without limitations. First, to keep the total number of articles manageable, we only searched for academic literature. We excluded grey literature, such as policy reports, briefings and white papers which could provide valuable future insights into the (in)justices of SLES. Evaluation synthesis of various policies, incentives and initiatives could provide more detailed insight into the impact of SLES on energy justice. An obvious next step for future research would be to examine the grey literature to complement this study.

Second, we focused only on studies in the context of developed country. This excluded a lot of articles written about local energy systems in developing countries [132,133]. Considering that local context and institutional settings are important for how SLES are organised, a similar review of the developing world literature could provide a blueprint more relevant for academics, policymakers and practitioners focused on activities in these settings.

Third, our review synthesises energy justice impacts of local energy and smart energy. Expanding the energy justice impacts beyond the local level can enhance wider energy justice debates. For example, Martiskainen et al., [4] highlight that the production of solar PV and lithium batteries which fuel many local energy initiatives creates inequalities in the countries where minerals are mined and technologies manufactured.

Finally, our study is not sensitive to social equity impacts in the context of time and space; a critical component of the socio-technical transitions literature and the basis of energy justice. Future studies would do well to consider the temporal nature of the influences these SLES have on social equity. For instance, do these potentially have short- or long-term impacts on social equity? Space is also important, and future studies should be sensitive to the geographical nature of these social equity impacts, i.e. not just who (distributive) but where (geographical) and how extensively these impacts are felt.

4.3 Future research agenda

In bringing this diverse literature together, we were able to offer several avenues for future research to advance ‘energy justice’ agendas. This framework provides a useful overview of antecedents, which could be examined and extended in future empirical studies. We highlight the following research avenues that we believe could be particularly fruitful, derived by some of the most striking findings from our analysis.

4.2.1 Socio-technical transitions and institutions

SLES are socio-technical systems whose performance depends on the complex interaction between technologies, institutions, and social actors [122]. Considering the production, distribution, and consumption of energy spans social, economic, political and environmental dimensions across multiple scales, the equity challenges that SLES face are not solely bound to local spaces [2,134]. We found from our analysis, SLES currently face a double institutional bind. Typically, local initiatives only get planning permission for small installations, but financial institutions favour the financing of larger projects. Furthermore, a lack of or unfavourable FiT policies also make it hard to de-risk projects and present attractive returns to community investors, critical to scaling initiatives. SLES therefore, are operating in ‘niche’ spaces and need to disrupt the current status quo in order to scale [18,135,136].

Several papers in our review call for research to explore how local initiatives are able to transcend local scale to have greater impact at national and global levels [42,47,50,62,63,73,79]. Many socially equitable SLES are ultimately at odds with the utility-scale, centralised, for-profit regime that pervades the energy systems, thus confining SLES to their niche status. In order to achieve a more widespread diffusion, SLES will need to transition from niche to regime [18,137]. This may for instance revolve around advocates making a stronger case for how SLES can benefit the wider energy system and the companies that govern it. Offering flexibility services that better balance supply and demand, for example, could mitigate the need for grid reinforcements or additional generation capacity.

Here however lies the threat that as SLES look to gain traction, and make inroads to dominant energy regime institutions, they face a pressure to recalibrate the principles on which they were originally founded [18,138,139]. Failure to do so may see resistance from incumbent actors (e.g. multi-national companies, national government) and serve to ‘lock-out’ local initiatives looking to generate local value. Therefore, exploring the different facilitating factors, practices, and strategies to safeguard the energy justice credentials of SLES during their transition from niche to regime could help inform energy strategies. At the socio-economic landscape level, for example, future research could usefully examine what combination of policies might provide the necessary institutional support to scale-up socially equitable SLES [140–142].

4.2.2 Scale and consistency of justice implications

There are broader questions about the scale of SLES deployment needed to achieve a meaningful change on energy justice levels across the energy system. Niche applications may have small-scale positive impacts on justice but taken ‘in the round’ these impacts are peripheral. There is also a broader question about trade-offs between (in)justices by location and group. A singular SLES project may support energy justice in a specific locality by promoting public engagement and fuel poverty measures but could be funded by a regressive subsidy (e.g. the FiT which is raised on energy bills as opposed to general taxation). This can have the unintended consequence of shifting funds from the poorest sections of society, to the richest. The question is therefore, how do we avoid improving energy justice in one location, only to undermine it in another?

4.2.3 The role of local government and public ownership

A number of scholars have highlighted the important role that local authorities can play in the transition to sustainable energy systems [143–145]. In the UK, for example, this derives from the ‘opening-up’ of the energy market and policy support for localism which has given local governments a more prominent role in energy governance [146]. However, the justice implications of local government involvement is often neglected, particularly with how benefits are distributed and the recognition of population groups that are poorly positioned to take advantage of any opportunities [147]. Considering the promotion of local energy solutions by national and super-national governments (e.g. ILO [7]), we found relatively limited attention to the role of local authorities in both delivering and supporting SLES. Despite this limited attention, our analysis revealed several situations in which government intervention neglected energy justice.

First, Emelianoff and Wernert [72] highlight how municipal energy has been used primarily to advance political careers and generate local finances, with a focus on creating a technocracy versus democratising energy choices. Second, the distribution of benefits from municipal energy are not equal and are usually centrally managed by one local government authority. This does not necessarily involve deeper community engagement, but typically benefits city centres and promotes gentrification [66,72]. Third, the entrance of public authorities and growing local initiatives into the energy market has prompted regulatory changes. This has increased institutional complexity which to navigate typically favours larger more resource-rich organisations [45,62,64]. Finally, whilst the involvement of public

authorities in the roll out of SLES initiatives can have distributional advantages [40,124], this does not necessarily give the public choice to participate in energy decision making [3,72,73]. Furthermore, their presence can crowd-out smaller community-led initiatives and even force lock-ins to the supply of energy, as is the case with nuclear power provision in France [2,3].

A more comprehensive examination of government intervention and their impact on the energy justice of SLES is required and represent a couple of important avenues for researchers. First, an examination of the role that local governments play in the context of SLES development is important to inform policies and strategies going forward. This was called for by a few papers in our sample [72,124], and is a long standing agenda in technology and innovation research [148]. Second, investigation of different government energy interventions with regard to energy justice dimensions (distributional, procedural, recognition) can shed light into the efficacy of various governments actions. Utilising new research methods in the fields of energy justice and SLES can help facilitate this, such as evidence synthesis methods previously used in other social science research [149]. Large scale evidence synthesis can fuse large bodies of evidence to understand “what works” in a particular policy area [26].

4.2.4 Community innovations and entrepreneurship

Community-led enterprises and innovations are widely considered as providing solutions for many social, economic, and environmental issues [150,151]. Community innovations are thought to have greater potential to contribute to sustainability than market innovations [152]. They also encompass cooperative, community and employee-based ownership models which are thought to provide fairer participation and benefits to members [153–155]. Our SLR emphasises that SLES delivered by community-based enterprises (in their various guises) generally provide greater democratic participation and distribute benefits equally versus other market based business models [41,48,82,93].

The shape that many SLES take is dependent on the local and institutional contexts where they are located [57], with access to finance and resources a major barrier for their development [61,109]. This causes injustice, as poorer communities without access to land are at a disadvantage [48,60]. More research focused on the organisational strategies used to design and implement SLES in more disadvantaged geographies. This can shed light on the variety of different community energy business, legal and finance models available, and how they influence the equitable distribution of costs and benefits.

As well as focusing on business models, future research could focus on specific business practices that contribute to energy justice. Several studies in our sample identified entrepreneurial skills and capabilities as important for starting and scaling community enterprises [40,57,80,94]. Understanding the contexts, practices, and process where communities developing SLES “act as entrepreneurs” can provide fruitful insight into how SLES start and scale. This is particularly pertinent considering that many SLES are community enterprises which require members to act as “owners, managers, and employees, [to] collaboratively create or identify a market opportunity and organise themselves in order to respond to it” [156]. Exploring the entrepreneurial behaviours of organisations and individuals participating in SLES by engaging with social innovation and entrepreneurship literature can provide new insights into opportunities presented by SLES agendas.

5. Conclusions

At its heart energy justice is about: a) the balanced distribution of costs and benefits across society [157]; b) recognising individuals and treating them fairly [37]; and c) inclusive decision making processes that are open to all relevant stakeholders [158]. Whilst a large number of studies aimed at better understanding the (in)justices that exist within current energy systems [3,4], we do not fully understand the energy justice impacts of smart local energy systems, which are becoming increasingly common. Furthermore, whilst many governments advocate SLES as a means to reach their decarbonisation goals [7,21], much remains unknown about the wider changes necessary to ensure these projects support energy justice.

To help fill this gap this paper asks two main questions. The first is what are the main antecedents that make a local energy system (un)just? The second is how can smart technology mitigate the (in)justice of local energy systems? Answers to these questions offer insights to energy transition scholars, policy makers and practitioners alike about the role SLES can play in delivering a just energy system. It also offers insight to how best they can support these projects to promote justice, be it through business model design or policy making.

We make an important contribution to this discourse by developing an integrated framework that considers the antecedents, at multiple analytical levels, that highlights whether a local energy system supports or undermines energy justice. This is important because SLES are not ‘just’ by default, but their justice credentials are instead shaped by multiple factors, operating across different levels [1,2,38]. The same framework also allows examination of how

smart technology can influence these (in)justices, either mitigating injustices or fortifying justices.

Researchers need to engage with the socio-technical transition literature to understand how SLES can move from niche to regime while ensuring energy justice. Further investigation is also needed into the role of public authorities in developing and distributing SLES as their participation does not necessarily necessitate justice. Finally, research investigating the community innovation and entrepreneurial behaviour of SLES initiatives can advance our understanding of how socially equitable SLES can diffuse, thrive, and grow. These research avenues can collectively address: *how do SLES scale, how can we ensure they promote energy justice, and what are the roles of key actors to achieve this?*

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ⁱ FiTs vary by nation but taking the UK as a focus, “FiT payments are made quarterly (at least) for the [renewable] electricity your installation has generated and exported...[and] FiT payments are made by your energy supplier from the date you become eligible for the scheme.” The subsidy typically lasts for 20 years, is levied on consumers’ bills and the rate of subsidy differs by technology type and scale of deployment.