



When bits enter just transitions: data and energy justice in digitalised energy futures[☆]

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HIGHLIGHTS

- The transition towards digital energy systems raises numerous justice issues.
- Energy justice can evolve conceptually through engagement with data justice.
- Integrating data justice can help accounts for the nuances and complexities introduced by digitalisation in energy transitions.

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ABSTRACT

Energy systems worldwide are undergoing a profound transformation. Transitions to low-carbon pathways rely on digital technologies to decarbonise and decentralise energy infrastructure. However, this digitalisation raises critical questions around data and its fair use—referred to as ‘data justice’—which remained unexplored in energy research. While justice considerations have become central to energy transitions, the specific justice challenges introduced by digitalisation demand careful attention to ensure it does not exacerbate existing injustices or create new forms of exclusion and inequality. To date, little emphasis has been placed on how digitalisation influences justice outcomes through the data generated and required by smart energy systems, and how these data-related issues might prompt a rethinking of social justice in energy contexts. This paper argues that integrating energy and data justice perspectives offers a critical starting point for addressing these emerging challenges. The study identifies justice challenges related to the production, ownership, use, and governance of data within digital energy systems. The findings demonstrate how data justice perspectives can enrich energy justice scholarship and help navigate the nuanced social and ethical complexities introduced by digitalisation. The study offers recommendations for policymakers and energy stakeholders to embed justice principles into the design and implementation of digitalised energy systems, ensuring that future energy transitions are both inclusive and equitable.

1. Introduction

Justice issues are becoming increasingly important in energy systems discussions and energy transitions research [1–3]. Uninterrupted access to high quality, affordable energy has been the cornerstone of the development of modern economies. Over the twentieth century, modern energy systems became highly centralised, where production, distribution and transmission were often controlled by state-governed institutions or large-scale utility companies. This centralised system has

helped countries meet their rising energy needs. However, it has also created problems that have reached crisis points. An inability to provide universal energy access globally, excessive reliance on hydrocarbons, the consumption of finite resources, issues with energy poverty, greenhouse gas emissions and ensuring energy security are just some of the problems prompting efforts to transform and transition to new energy systems. However, the centralised nature of energy systems also implies that decision-making power has typically been restricted to a limited number of incumbent (and privileged) owners and regulators of the

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system. Other actors important for energy transitions, such as citizens, workers or local communities, have had relatively little influence on the system developments and transitions in which they are often implicated, because their role has primarily been that of a consumer or impacted stakeholder. This has led to debates over the extent to which energy transitions from fossil fuel systems to renewable and low-carbon energy systems can be made socially just, and what practical measures are required for transformations to be inclusive and fair to all members of society [4,5].

The concept of energy justice (EJ) was developed to understand the ethical dimensions of the energy system [6,7]. EJ strives to achieve transitions that fairly distribute the benefits and burdens of energy services and contribute to more representative and inclusive energy decision making [7]. EJ seeks to apply principles of social justice both across the energy lifecycle [8] and across local-to-global scales of governance and activity in energy systems transformation [9]. It offers a framework both for the analysis of the state of the energy sector and for providing guidelines and suggestions for improvement in order to humanise energy systems and place people and society and the heart of its functioning [10].

Transforming energy systems from centralised and hierarchical structures into more equitable and just forms of organisation, often accompanied by more horizontal structures, is enabled by new decentralised energy technologies and rooted in complex and multifarious political processes. Energy justice challenges the core institutions that underpin energy systems in society [10,11]. Seeking *just transitions*, therefore, fundamentally involves a questioning of the roles, responsibilities and practices of all institutions, actors and stakeholders involved in the energy value chain and across global energy supply chains.

Digitalisation—understood here as the deployment of digital technologies and the generation and use of digital data in energy systems [12]—is widely regarded by industry and policymakers as a vital enabler of energy transitions [13]. However, policies and investments towards so-called ‘smart’ energy systems have been conceived as proceeding largely through adaptations to existing liberalised energy governance arrangements, which are already subject to a multiplicity of challenges on justice grounds [13]. Curiously, a Special Issue of Applied Energy dedicated to digitalisation in 2021 made no mention of energy justice. With some notable exceptions [13–18], the digitalisation of energy transitions has not yet been analysed specifically from a social justice perspective. Moreover, these exceptions draw upon conventional energy justice frameworks and do not consider whether and how questions of *data justice* introduce new tensions.

An extensive body of data justice research, independent of energy studies, suggests a rethink is needed, particularly when we think about the digitalisation of energy systems and transitions, given the pivotal role of data in such processes [19–23]. Little emphasis has been paid to how digitalisation introduces new injustices and tensions through the data required and generated by smart energy systems, nor how measures for data justice might prompt a rethink of how best to understand social justice, specifically in digitalised energy systems. A combined energy-data justice approach is one place to start, bringing together insights from both energy and data justice research. The review and the analysis provided here identify the core justice issues in digitalised efforts to increase efficiency, modify grid balancing systems, optimise generation and facilitate the development and integration of new power storage facilities, trading platforms and demand flexibility. This is critical for energy scholars to analyse, as digitalisation will redraw social and technical relations between the production, distribution and consumption of energy services [24,25].

Our contribution to this special issue therefore centres on energy-data justice conceptually, and the tensions that emerge during the rollout of digitalised energy systems, offering recommendations for how these can be addressed through analysis, policy and practice. The method we use centres on a literature review of data justice (Section 2)

and energy justice research (Section 3), followed by a more focused exploration of how justice issues manifest in the context of digitalised energy systems (Section 4). We do not attempt an exhaustive review of these literatures and their differing principles and tenets. Rather, our aim in this paper is to use an appreciation of data justice to explore how empirical energy issues in the prominent energy justice tenets of distributive, procedural and recognitional justice in energy studies are both reframed and challenged by processes of digitalisation. In doing so, we identify several emerging challenges related to data privacy, data use, ownership, access rights, and equitable participation in energy system governance. Finally, building on this overriding goal, Section 5 discusses the implications of this analysis for policy and practice, before the conclusion is presented in Section 6.

2. Digitalisation and data justice

Digitalisation is becoming an increasingly important phenomenon that is disrupting the business operations, services and processes of industries worldwide. In our use of the concept, we follow Bukht and Heeks [12], who define digitisation as the technique of “conversion of data from analogue to digital form” and digitalisation as processes that apply “digitisation to organisational and social processes (including economic activity)”. In smart energy systems, digitalisation involves creating and using data throughout various supply chains, integrating it into processes such as energy generation, distribution and storage, as well as supporting retail operations and enhancing our understanding of points of consumption through more real-time information. However, as research in other sectors demonstrates, digitalisation is not only about the adoption of new technologies and techniques, as is often thought, but also involves a fundamental shift in organisational strategies and business processes in order to implement digitalised systems successfully [26,27]. Legner et al. [28] thus describe digitalisation as a socio-technical phenomenon whose processes reconfigure the broader individual, organisation and societal contexts into which they are introduced. The promise of new forms of profitable accumulation, managerial control and business efficiency has been a driving factor behind businesses’ desire to adopt and adapt to digitalisation [29].

The dominant discourse of digitalisation in society is geared towards highlighting benefits and opportunities. However, digitalisation also brings multifaceted justice issues and challenges that raise significant concerns, highlighting the need to adopt a more comprehensive and balanced approach to address them [29,30]. Among these, one of the most discussed and recognised relates to data [19]. Digitalisation generates and exploits a vast amount of (energy- and resource-consuming) data, whose ethical management becomes essential to avoiding any potential harm [31].

The field of ‘data justice’ analyses justice issues related to the production and use of data [31,32]. Data justice is held as the primary ethical standard by which data-related resources, processes and structures are evaluated [20]. It delves into what concepts and practices are needed to advance and strengthen equity and fairness in ‘datafied’ societies [19]. Its premise lies in the relations between the way data is generated and collected, what it is used for, and the wider social consequences that are bound up with social structures, prevailing practices, interests, and ideas [31]. Therefore, to achieve equity and fairness, the development and implementation of data-related systems, technologies, practices, and new business models should adhere to principles of social justice. A corollary of this sociological appreciation of the roots of data injustices and associated tension of digitalisation is that justice involves not only well-designed technologies but also changes to organisational structures and new governance approaches to digitalisation [12].

Contrasting conceptualisations of data justice have emerged based (sometimes implicitly, others explicitly) on different theories and frameworks of social justice [33]. Taylor [32], for example, sees data justice as consisting of: 1) visibility; 2) engagement with technology; and 3) non-discrimination, as core pillars of data justice. Information privacy

is at the centre of the visibility pillar, highlighting higher standards of privacy, but also attention to fair representation (especially whenever the data generated by people in the social margins are a core concern). Furthermore, this pillar considers an individual's autonomy and freedom to engage with data, or the ability to decide not to be included in databases. The second pillar, engagement with technology, is about the freedom to control the terms of one's engagement with "data markets". The pillar is concerned with how data is used, to whom data is resold, how it is profiled and what kind of interventions the data can enable. The third pillar, non-discrimination, highlights the freedom not to be discriminated against through data misrepresentation.

Others in data justice research make use of a tenets approach to social justice and apply it specifically to data generation, collection, storage and use [19–21]. Instrumental justice refers to fairness in the use of data with respect to outcomes. It emphasises that the use of data should lead to beneficial consequences, which may be in the form of new services and solutions, or as a means to mitigate injustices [20,21,34]. Procedural justice emphasises the fair handling of data by relevant organisations, as well as fairness in the decision-making processes that create ethical codes of conduct and other governance arrangements for data [20]. Distributive justice relates to the fair and equitable distribution of benefits, opportunities, and outcomes emerging from the use of data. It examines 'who gets what' as a result of the use of a variety of data systems.

Heeks and Shekhar [21] emphasise rights-based and structural data justice. Rights-based justice adheres to basic human rights such as representation, privacy, access and ownership over data and data representation. It stresses that individuals and communities shall have the right to be fairly represented in datasets, as well as the right to privacy, which includes the ability to withhold data under certain circumstances or for particular purposes, or to keep data private if they so choose. Additionally, rights-based justice encompasses the right to access and own data [21,35]. The structural dimension of data justice looks at prevailing hierarchies and critical power dynamics in society and considers their impact on data injustices [20]. It emphasises that wider socio-economic structures and power differences influence individuals and communities' differential and unequal ability to engage in data issues. These power structures often underlie the design and shape of data systems and operations in the information value chain. Structural justice recognises that economic, political and legal reforms may be necessary to these structures in order for other social justice measures to become more feasible [21]. For example, offering free access to online energy efficiency resources and advice can empower low-income households to participate in digital energy initiatives, helping to reduce structural inequalities in access to digital tools and services. Geographical and spatial conditions also play a significant role in shaping justice outcomes. The underdevelopment of critical infrastructure, for instance, broadband and internet infrastructure, creates unjust exclusions [36] and may prevent some spaces and places from gaining access to the potential benefits of digitalisation and the digital economy. Infrastructural unevenness perpetuates lasting privileges and advantages for some, whilst an absence of data-related infrastructure exacerbates inequalities across the digital divide.

The issues and principles within data justice have evolved through engagement with other sectors beyond energy, such as telecommunications, education, healthcare, and urban planning. Nevertheless, they are highly relevant for energy transitions and smart energy systems, offering a valuable lens through which to examine emerging tensions in energy digitalisation. Whilst data justice issues and principles can be conceived within a similar tenets-oriented framework to energy justice, their underlying causes and problems and the potential solutions to them may not be adequately addressed or considered in energy justice frameworks. The next section considers energy justice as conventionally developed and understood in the literature, before Section 4 explores the implications of data justice for digitalised energy transitions more specifically.

3. Energy justice: Core principles, tenets and critiques

The field of energy justice responds critically to the dominance of techno-economic and engineering-oriented thinking in energy policy and energy transitions. In doing so, energy justice tries to embed a more ethical and socially conscious approach into the technicalities of transforming energy systems. Since its inception over a decade ago [4,6], which borrowed heavily from tenets and approaches within environmental justice scholarship (see Schlosberg [37]), energy justice has evolved considerably through application across the globe, in multiple locations and in relation to a diverse range of energy technologies and systems. We review the core approaches, principles and tenets, so that we have a baseline from which to consider energy-data justice issues.

Energy justice is largely underpinned by a commitment to two dominant frameworks: the "three tenets" of energy justice and the "eight principles" for decision-making and policy. The three tenets refer to procedural, distributional and recognition justice [6]. Whilst the eight principles consider: availability; affordability; due process; transparency and accountability; sustainability; intra-generational equity; inter-generational equity; and responsibility [3]. These principles, in essence, cover (a) whether energy is sufficiently available to people at affordable prices, (b) if the due process and principles of good governance are observed during the decision-making processes, (c) whether due consideration is paid to ensure that consumption patterns consider future generation's needs, (d) if everyone has a right to access energy, and that it is (e) everyone's responsibility to protect nature and minimise energy related threats. Sovacool et al. [7] later reimagined these principles and extended them by adding two more: resistance and intersectionality. The resistance principle highlights the need to actively and deliberately oppose injustice, whilst intersectionality emphasises the extent to which the realisation of energy justice is linked to other forms of justice, such as socio-economic, political, and environmental. It is this last principle which is especially pertinent to the analysis of energy digitalisation here, and the injustices brought in (or exacerbated) by datafication and data justice remedies.

The tenets-based approach is also widely used in energy justice [38]. McCauley et al. [6] propose three tenets, namely, distributive justice, procedural justice and recognition-based justice to assess energy justice within energy systems. The distributive justice tenet concerns the distribution of benefits, burdens, costs and responsibilities among the actors and stakeholders in energy systems. It suggests that benefits and costs should be fairly distributed among the stakeholders involved. Procedural justice refers to equitable access and participation opportunities for everyone in the decision-making processes that govern energy systems. It focuses on whether decision-making employs fair participation and transparent engagement strategies [2,39]. Justice as recognition considers the equitable appreciation of different social groups that are historically marginalised and disenfranchised. It emphasises inclusiveness to ensure that relevant sections of society are represented, and no social group is ignored or misrepresented, especially the most vulnerable ones [40]. Revision of these core tenets have emerged, including but not limited to the suggestion of additional tenets such as "cosmopolitan justice" – understanding the global implications of energy systems and how they affect the rights and lives of global citizens [41] - and "restorative justice" [1,42], a process of remediation in response to a historic energy injustice. McCauley and Heffron [43] suggest that a just energy system should also ensure that it aims to repair the damages that have been done to individuals and society.

Energy justice scholars have also begun to question *where* exactly energy system injustices take place. For example, Yenneti et al. [44] detail the importance of geography in energy justice. Emphasising socio-economic or demographic features in energy justice can overlook important spatial aspects. The field has, because of work directed towards attending to issues of space, place and geography in energy justice, sought to incorporate spatial justice considerations [45]. Certain areas and regions may be more vulnerable than others in energy

transitions, particularly those that are historically dependent on fossil fuels and/or historically marginalised, both socially and geographically. This requires that the concept of spatial justice be incorporated into energy justice [46]. Paying greater attention to the geographical dimension of inequality and inequity can further help address these energy-related injustices. Heffron [8] and McCauley et al. [47] emphasise the significance of cosmopolitan justice because it considers how energy systems and global supply chains transcend boundaries and regions.

The tenets-based and principle-oriented approaches remain the most prevalent in energy studies [5,38,46]. The three tenets have the advantage of parsimony and usefully connect and relate to one another conceptually and empirically. As noted by Gillard et al. [48], for example, facilitating recognition and procedural justice can give rise to the realisation of distributional justice. This interrelatedness strengthens their use in energy justice research, unearthing interconnected aspects of issues of social justice, equity and inequality in energy systems.

Some scholars argue that energy justice retains a global North bias owing to its geographical and institutional origins [49,50], and that the ‘three tenets’ deserve more critical reflection and might not always be suitable or applicable to different energy contexts [51]. In addition, other scholars have noted that the continuing trend towards distributed and decentralised energy systems will create new and unforeseen forms of social and spatial injustice [46,52] and that technological advancements and digitalisation will force a rethink of core aspects of energy systems and thus the ethical dimensions of energy justice scholarship [16,18]. Importantly, we have begun to see different scholars engaging with the digitalisation of energy systems through both a justice-led and energy justice lens. Powells & Fell [53] introduced the concepts of ‘flexibility capital’ and ‘flexibility justice’ to respond to potential injustices in the capacity and ability of different individuals, households and communities to engage in smart energy systems that require considerable lifestyle adjustments, adaptive behaviours and access to modern technologies that are primarily afforded to more privileged social groups. Fjellså et al. [14] and Milchram et al. [39] consider how smart grid experiments and smart energy systems may reproduce or worsen existing social injustices, with the former study noting that only certain households possess ‘flexibility capital’ and the latter study urging for more fairness in data governance as smart grids continue to expand. Other recent studies consider the potentially paradoxical role of new digital systems in advancing energy justice and democracy; Judson et al. [54] note that the rise of ‘digital energy democracy’ could democratise public engagement with energy systems whilst also locking-in new material-software dependencies, whilst Noorman et al. [18] recognise that the introduction of Artificial Intelligence into energy systems governance may empower consumers on the one hand whilst also infringing on privacy and increasing discrimination on the other. An appreciation of data justice concepts and approaches can help address these ongoing debates by not only uncovering emerging forms of exclusion and inequality within digitalised energy systems but also by prompting a more critical reflection on how such developments challenge and potentially reshape the foundational assumptions underlying energy justice thinking.

4. Energy and data justice: Interactions in digitalised energy systems

The previous two sections have provided an overview of how energy research and data studies address questions of social justice separately, outlining the various approaches, principles and tenets used to identify injustices and conceive just remedies. In this section, we examine how data-related issues influence and shape energy justice in the digitalised energy system. By adopting a three-tenet framework of energy justice—distributive, procedural, and recognitional justice—we explore how data dynamics intersect with and influence energy justice considerations. Integrating insights from data justice deepens our understanding

of emerging challenges and opportunities for a just energy transition in increasingly digitalised contexts.

4.1. Distributive justice

Digitalisation has significant implications for distributive energy justice. As technologies advance and smart energy systems become central to energy system transformation, questions around who benefits and who bears the costs become increasingly salient. While digitalisation can lead to greater efficiencies and new value creation, the distribution of benefits and burdens remains uneven and increasingly complex. This complexity manifests in multiple justice challenges, including unequal benefit sharing, the monetisation and misuse of data, the amplification of existing inequalities linked to systemic and infrastructural disparities, and the erosion of consumer autonomy.

Balta-Ozkan et al. [55] and Goulden et al. [56] find, for example, that companies are not always open and transparent in how they transfer digital efficiency benefits to consumers. The use of digital and smart devices generates vast amounts of data, offering detailed insights into consumption behaviours and enabling the development of new and personalised services, as well as the monetisation of this data. While consumers are both the source and object of the data, companies can profit from it without necessarily redistributing the value it creates, raising concerns about fairness and equity in the distribution of gains [57]. Even when benefits are shared, they can be redistributed inequitably [58] across different consumer groups, raising further concerns around distributional justice. In practice, benefits tend to accrue to specific segments, such as an engaged middle class with the capacity to adopt smart energy technologies and take advantage of new services, or to groups with the technical skills to access, interpret and respond to new energy datasets. Meanwhile, the associated costs and burdens fall more heavily on those who cannot, leaving these groups increasingly vulnerable and marginalised [59]. To avoid deepening further inequalities, it is important that new energy services are not just beneficial to the privileged class but are accessible and advantageous for all [2].

Milchram et al. [17] and Raimi and Carrico [60] emphasise distributional justice issues associated with privacy, data storage and data governance. As smart technologies collect increasingly granular data, they can reveal sensitive information about consumers’ private lives—such as daily routines, occupancy patterns, or socio-economic status—potentially making specific groups particularly susceptible to discrimination [61]. Gutwirth et al. [62] further warn of the risks and harms associated with potential cyberattacks, security breaches and data leaks, which can disrupt vital energy services and could disproportionately affect those with limited means of redress.

Moreover, the ways in which data is used can deepen existing divides and inequalities. While data analytics offer valuable insights for system optimisation and value creation, they can also be employed in ways that can disproportionately impact certain consumer groups. For example, Yusonov & Torriti [63,64] analyse the distributional impact of Time-of-Use (ToU) tariffs on different income groups in the UK. Using smart meter data, these tariffs enable energy consumers to adapt their consumption and energy use patterns to off-peak times when electricity is cheapest. Their findings show that higher-income groups who have greater flexibility over when they consume electricity gain the most from these tariffs, whilst low-income groups with reduced time availability benefit less [64]. They also identify significant regional variations in the application of ToU tariffs across the UK, calling for modelling of the distributional impacts of ToU tariffs at multiple spatial scales [63].

Similarly, data-intensive practices such as surveillance [65], algorithmic profiling [66], or what has been termed as data violence [67] can distribute risks and negative outcomes unequally. The exploitation of personal data without adequate safeguards compromises individuals’ privacy [68] and risks reinforcing entrenched racial, gender, and socio-economic divides [19,20,69,70]. Preventing such discriminatory or

harmful uses of data is therefore essential to realising equitable outcomes in digital energy transitions.

Geographic and spatial inequalities further complicate how digitalisation shapes distributive justice outcomes. Access to critical infrastructure such as broadband networks, internet connectivity, data centres and energy data services varies widely across regions. These spatial disparities influence who can benefit from emerging energy services and who remains excluded [45,71,72]. In areas lacking such infrastructure, or among groups that cannot afford to connect, communities may be excluded from new services entirely, reinforcing existing socioeconomic and digital divides [36].

However, efforts to expand digital infrastructure must be approached with caution to avoid creating new injustices. For instance, the development of data centres often involves land acquisition and resource allocation processes that can impose disproportionate environmental and social burdens on already disadvantaged communities (e.g., water used for cooling, pollution and waste generation, and pressure on land and housing markets). Therefore, to avoid replicating patterns of exclusion and harm, infrastructure expansion must be guided by principles of equity and justice, ensuring that development processes do not themselves perpetuate or exacerbate existing injustice [44].

In addition to these structural considerations, individual-level disparities also shape distributive outcomes in the digitalised energy systems. Distributive justice concerns not only fair allocation of material benefits and costs but also equitable distribution of informational sources, such as access to information, advice, and knowledge, which enable individuals to benefit from digital technologies. Milchram et al. [17] emphasise that the lack of knowledge and understanding regarding how digital technologies and data operate fosters fear, mistrust, and uncertainty among consumers. Ransan-Cooper et al. [73] and Fell et al. [74] similarly highlight that individuals often experience limited autonomy, choice, and control in digitalised energy systems. Opaque algorithmic decision-making and preconfigured service models constrain user agency and restrict how individuals can interact with and benefit from digital services.

4.2. Procedural justice

Conventional energy systems have long been characterised by centralised, top-down governance structures where key decision-making was concentrated among a limited number of institutional actors. The model has historically excluded consumers and other stakeholders, limiting their ability to influence energy policy, market design, or infrastructure planning. However, as energy systems undergo rapid digitalisation, there is a growing recognition of the need to make governance more participatory and inclusive. Jenkins et al. [2] and Miller et al. [10] argue that inclusiveness and consumers' engagement in decision making are not only desirable on normative democratic grounds, but also essential for creating more effective and socially responsible energy systems. This necessitates appropriate legislative and institutional frameworks that support consumer and citizens' involvement, particularly in data governance, where questions of transparency, ownership, use and accountability are increasingly critical [17].

In practice, however, participation and engagement frequently fall short of the principles of equity and inclusiveness [13]. The engagement mechanisms are often voluntary and tend to attract 'first movers' who generally have interest, resources or knowledge on the topic [17,48]. Such relative selectivity results in biased representation, undermining diversity and reinforcing pre-existing inequities. Consequently, the perspectives of less resourced or marginalised groups are often underrepresented or entirely absent, raising critical questions about equitable representation and procedural justice. Ensuring a genuinely inclusive process requires robust and inclusive selection procedures that ensure a meaningful diversity of experiences and perspectives, thereby avoiding participatory efforts from becoming merely performative.

Walker and Day [75] emphasise the importance of providing

participants with early access to information, noting that delayed or incomplete disclosures can significantly limit participation possibilities. Likewise, a clear understanding of data management and governance processes is critical in fostering engagement. Well-defined procedures, standards and practices not only instil confidence but also signal a commitment to fairness and accountability in the digitalised energy landscape. Milchram et al. [17] further stress that, in addition to establishing best practices and procedures, it is essential to ensure that companies and other actors adhere to fair practices and agreed-upon rules and norms regarding data and information handling.

Companies that purposefully obfuscate the process, bypass regulations, or misuse data must be held accountable [8]. Achieving procedural justice, therefore, requires clearly defined mechanisms for addressing misconduct, including protocols for compensation, redress, and corrective action, to ensure that the concerns of affected parties are adequately addressed. In particular, growing concerns over privacy violations, cyberattacks and data leaks further reinforce the urgency of establishing robust procedures to ensure transparency and accountability. The responsible actors should have binding obligations to rectify errors, mitigate harms and compensate for negligence. Companies and system operators must also outline and implement clear protocols detailing how they will respond to and rectify any potential breaches or negligence. These measures are vital for fostering confidence that affected individuals will be treated fairly and their concerns will not be overlooked.

Beyond reactive measures, achieving procedural justice entails proactive transparency about potential risks. The possibility of cyber threats, data breaches, or misuse of information should be openly communicated. Such transparency is critical for building trust, enabling informed stakeholder collaboration, as well as establishing the foundation for both preventive and restorative measures. Risk communication must be embedded with inclusive and responsive engagement practices. Energy system operators and companies should ensure that all stakeholders have the opportunity to voice their concerns and that these concerns are acknowledged openly, rather than being dismissed as uninformed or driven by personal motives [2]. This inclusive approach reinforces procedural legitimacy by ensuring uncertainties are addressed in an equitable and transparent manner.

Procedural justice also extends to data governance, requiring greater attention to data management and protection of participants' and communities' rights regarding the ownership, access, and use of their data [21]. The processes through which data is generated, collected, analysed and used are not the product of the actions of a single entity; rather, they are shaped by an amalgamation of different actors, interests, and social forces that influence the terms on which these processes are handled [19]. A clear system of procedures, to which all actors adhere, is essential to prevent dominance by a few stakeholders. Instead, individuals whose data is collected must be empowered to assert ownership, ensure fair representation in data sets, participate in decisions about data-sharing, and have the liberty to withhold data or keep it private from specific parties for particular purposes [20,34,35,76,77]. This includes having control over who can access their data, the ability to remain anonymous, and the capacity to limit the sharing of sensitive information. Such control over access and use is fundamental to strengthening procedural justice in digital governance, reinforcing the principles of transparency, autonomy, and equity.

Translating these rights and normative principles into real-world applications, however, presents significant practical challenges—especially as digitalisation efforts move beyond pilot phases. Calver et al. [78] highlight the complexities involved in scaling from innovative technical pilots to full-scale commercial implementation. The transition requires the careful institutionalisation of practices and procedures concerning participation, data management, governance, accountability, and stakeholder engagement. Continuous re-evaluation and adaptation are essential to ensure a smooth progression from experimental initiatives to fully operational commercial systems.

4.3. *Recognitional justice*

As digitalisation reshapes energy systems, it brings not only new opportunities but also a growing risk that existing social hierarchies and inequities become embedded in system design and data practices. Recognitional justice emphasises the urgent need to acknowledge and value a broader and more diverse range of actors and social groups, not only a normative ideal but a necessary condition for legitimacy and equity in the governance of digitalised energy systems. The practices surrounding digital data—its collection, processing, and deployment—carry intricacies and complexities that can privilege dominant social groups while overlooking or dismissing the knowledge and lived realities of others.

Recognitional justice centres on the imperative that no relevant actors, social groups are excluded, ignored or misrepresented in the development and governance of digitalised energy systems [8,15,79]. This includes fair and respectful representation of social, cultural, ethnic, racial, gender and class differences in ways that adhere to the principles of inclusivity and non-discrimination [16,48,80]. Under the tenet of recognitional justice, particular attention must be given to recognising vulnerable and marginalised groups—such as low-income households, individuals with limited education, and those lacking digital literacy [81,82]. The everyday realities, priorities, and constraints of these groups are often overlooked or treated as less legitimate in system design, reflecting deeper patterns of social misrecognition rather than a mere question of access or participation. For example, a smart energy application requiring constant internet access, ‘flexibility capital’ or financial flexibility may inadvertently exclude users who cannot meet these implicit expectations, thereby reinforcing digital and energy inequalities.

Moreover, achieving recognitional justice requires critically examining the extent to which existing power structures and socioeconomic configurations determine whose identities and perspectives are recognised and whose are normalised, marginalised or silenced in digitalised energy systems [20,21]. The constructed nature of data allows injustices to be embedded within it, as the process of its generation, categorisation and interpretation is shaped by prevailing social values, structures, privileges and social hierarchies [61]. For example, algorithmic classifications — the automated process through which systems categorise and rank energy users based on consumption data and predicted behaviours — can inadvertently prioritise high-consumption households deemed more valuable for demand response. These households are often scored favourably on metrics such as load flexibility, consumption consistency, and revenue potential. In contrast, lower-consumption users whose energy needs are more constrained or shaped by precarity risk being marginalised. Such algorithms effectively create hierarchies of ‘desirable’ versus ‘undesirable’ customers, reinforcing existing socioeconomic inequalities within energy systems and limiting equitable access to energy innovations. Such biases, misrepresentations, and discriminatory outcomes, however, should not be dismissed as mere technical flaws or ‘bugs’ in the system, but rather understood as manifestations of more profound structural inequalities that reinforce stereotypes and systemic inequalities [23]. In this way, injustices embedded in data practices often reflect and reproduce inequalities deeply rooted in broader social and economic structures through which digitalisation is advanced and proceeds [81].

Recognitional justice also emphasises the fundamental need to respect, acknowledge and include the diverse identities, experiences and voices of communities, including those who may be indirectly or temporally affected by digitalisation [8]. For instance, the material infrastructure underpinning digitalisation raises critical justice concerns. Decisions about where and how such infrastructure is developed can have lasting consequences for local communities, particularly regarding land use, energy consumption, and environmental degradation. These developments should be guided by the principles of sustainability and intergenerational responsibility, ensuring that planning

and implementation processes are attentive to local contexts, respectful of culturally and socially distinct communities and sensitive to broader social and environmental implications that may arise [16].

In addition, it is essential to ensure that data and digital technologies are beneficial to all socio-economic groups, not just the digitally literate or economically privileged. Insights derived from data should inform the development of inclusive products, services and solutions that improve accessibility, affordability and wellbeing across the broader community. For example, energy management platforms can be designed with multilingual interfaces, low-bandwidth functionality, or simplified dashboards to accommodate different user needs. In this way, digitalisation becomes a tool for recognition and social inclusion rather than deepening existing divides.

The discussions above highlight potential data justice issues that arise as energy systems become increasingly digitalised. Table 1 presents the key justice issues and their manifestation in digitalised energy systems.

5. Discussion

Our paper offers one of the first in-depth insights into the intersection of energy justice and data justice within digitised energy systems by drawing extensively on data justice literature. It offers novel perspectives on how smart and digitalised energy systems introduce new and complex justice challenges that extend beyond traditional concerns, highlighting the crucial role of data-related issues in energy transitions. Developing a clear understanding of these issues is essential for examining how digitalisation shapes the pursuit of just energy transitions, a core focus of this special issue. Below, we discuss the key tensions emerging at the nexus of data justice and energy justice in digitalised energy transitions and outline brief policy recommendations for addressing them in future just transitions.

5.1. *Tensions in digitalised energy transitions*

The increasing digitalisation of energy systems brings unique opportunities for greater efficiency, enhanced flexibility, expanded consumer participation and accelerated low-carbon transitions. However, it also generates profound challenges that arise at the intersection of data justice and energy justice. These tensions reflect persistent dilemmas around technological innovation, social equity and governance, with digitalisation risking the reproduction or deepening of existing inequalities as well as introducing new forms of exclusion.

A core tension stems from the distinctive nature of data as a resource. Much like energy, data is generated, distributed and consumed across vast networks of complex infrastructures. However, data systems tend to be more decentralised and distributed, with individuals, households, and communities continuously feeding data into a global system of devices, platforms and networks. Today, over half of the world’s population owns or engages with some sort of smart device, transforming people into active producers of data in addition to being consumers of energy services [83]. This constant and active data production raises profound procedural justice questions regarding who owns, accesses, uses and controls energy-related data. These concerns intersect directly with distributional justice. Many benefits of digitalisation in the energy sector stem from data-driven technologies and services, such as demand response, peer-to-peer trading, and vehicle-to-grid solutions, which rely on individuals’ ability to manage the digital data infrastructure underpinning these services. This requires not only technology and connectivity but also digital literacy and economic resources. To date, the rise of the “prosumer” has largely been confined to more affluent communities in the Global North, creating a risk that digitalisation could deepen existing socio-economic divides and potentially lock out already disadvantaged groups from the benefits of new energy systems, rather than bridging them [84].

Moreover, digitalisation creates significant recognitional justice

Table 1
Potential data justice issues in digitalised energy systems.

Justice Dimension	Justice Considerations	Manifestation in the digitalised energy systems
Distributive Justice <u>Injustice issues:</u> Unequal distribution of benefits, costs, and risks among the stakeholders <u>Justice aim:</u> Promote fair distribution of benefits and burdens across all social groups	Fairness and transparency in benefits sharing	Companies may not be fair or transparent in how data-driven efficiency gains are distributed to consumers.
	Monetisation and unequal value sharing	Commercial actors profit from consumer generated data without redistributing the value to users (e.g., data monetisation and introduction of new services and solutions). Benefits often accrue to certain socioeconomic classes (e.g. digitally skilled or affluent users) while disadvantaged groups face higher costs or exclusion.
	Unequal access to benefits for all classes and groups	Cyberattacks, security breaches, and data leaks can make users susceptible to varying degrees of harm.
	Cybersecurity risks and vulnerabilities	Unfair data practices (e.g. data analytics and algorithmic profiling) can be used as an instrument of harm on users.
Procedural justice <u>Injustice issues:</u> Unequal access to decision-making processes, resulting in exclusion and limited influence for certain stakeholders <u>Justice aim:</u> Ensure equitable access to participation, transparency and accountability in governance processes	Transparent and equitable participation	Participation procedures often favour actors with more resources, knowledge or influence, leading to biased representation.
	Transparency in data governance	Data collection, storage, and sharing procedures are often unclear, with limited understanding regarding governance standards and responsibilities.
	Accountability and redress mechanisms	Mechanisms to challenge unfair data practices (e.g., data misuse, regulatory evasion or governance failures) are often weak or non-existent.
	Proactive risk communication and prevention	Risks related to cyber-attacks, data misuse and breaches are rarely communicated transparently, and companies often fail to implement adequate preventive safeguards.
	Data ownership and control rights	Users often lack meaningful control over how their personal data is accessed, processed and shared.
	Continuous procedural adaptation	Governance processes often remain static even as systems scale and evolve (e.g., from pilot to commercial stages), which limits their

Table 1 (continued)

Justice Dimension	Justice Considerations	Manifestation in the digitalised energy systems
	Early and accessible information sharing	relevance, fairness and effectiveness. Stakeholders often receive late or incomplete information, limiting their ability to engage meaningfully.
Recognitional justice <u>Injustice issues:</u> Misrepresentation, marginalisation or neglect of certain social groups <u>Justice aim:</u> Acknowledge and respect the needs, rights and experiences of diverse and marginalised groups	Exclusion of vulnerable and marginalised groups	Low-income households, digitally limited users, and socio-economically disadvantaged groups are often overlooked or excluded in data governance processes. Social groups differentiated by gender, ethnicity, class, or disability are often underrepresented in datasets and decision-making, resulting in biased outcomes.
	Misrepresentation or underrepresentation of groups and perspectives	Algorithmic models privilege high-consumption or commercially attractive users, while low-income or irregular consumption households are under-served.
	Embedded bias in data and algorithms	Data infrastructure development (e.g., data centres or communication networks) often imposes social and environmental burdens on local communities who are rarely consulted or recognised in planning and decision-making processes.
	Neglect of the community impacts from digital infrastructure	

challenges, highlighting tensions between technological innovation and social inclusion. Digital systems often reflect dominant norms and assumptions that usually fail to account for the needs, practices, or experiences of the marginalised groups whose realities do not align with prevailing digital models or algorithmic assumptions, further risking their exclusion and marginalisation. Research on injustices in Smart Local Energy Systems (SLES), for example, shows how advantaged groups capture policy benefits more readily, while those living in underprivileged circumstances remain excluded from such opportunities [15]. This reflects the ways in which recognitional injustice becomes embedded in system design: advantaged groups are treated as the ‘default’ energy user for SLES pilots, typically homeowners with stable income, digital access and the capacity to invest in new technologies. Their lifestyles, capabilities, and preferences are made visible and built into the system architecture. By contrast, marginalised groups, such as low-income renters, people with insecure housing or limited connectivity are rendered invisible in design and implementation processes, with their needs deemed irrelevant or largely ignored. Furthermore, the ways data is used to create services and solutions can inadvertently entrench and deepen existing inequalities. Data analytics and algorithmic decision-making often prioritise profitable or easier-to-serve users, potentially sidelining individuals or communities in vulnerable situations. Consequently, those already facing social or economic disadvantages may receive fewer benefits or be excluded entirely, thereby

embedding lasting injustice in the foundations of future energy systems.

Another significant tension emerges around data governance and the commodification of personal consumption data. Data-driven energy services create economic value and operational efficiencies, but simultaneously raise serious concerns about privacy, surveillance and individual autonomy. Energy data can reveal deeply personal details about people's lives, behaviours and routines. The monetisation of such data by private actors may unlock new business models and revenue streams, but this also heightens serious concerns related to privacy, surveillance, discrimination, and the erosion of public trust. This shift of control over data and its benefits from users to commercial entities exacerbates existing power asymmetries and challenges fundamental justice principles.

Finally, a temporal tension exists between the urgency to deploy digital solutions and the imperative to ensure justice and inclusivity. Designing systems that are inclusive, responsive to diverse needs, and capable of preventing the exacerbation of inequalities often requires extensive engagement, tailored design approaches, additional resources and careful regulatory coordination. These necessary processes can increase costs, prolong development timelines, and introduce management, governance and regulatory complexities—potentially delaying the rollout of digital solutions that could improve affordability, reliability, or access to cleaner energy. This creates a complex paradox: efforts to embed justice and equity into digitalised energy systems are essential to ensure inclusive and fair energy systems. Yet, if these efforts significantly slow implementation, they risk postponing or locking out the very improvements that marginalised and vulnerable groups urgently need.

In sum, digitalised energy transitions embody complex tensions among technological advancement, social equity, and governance structures. Addressing these tensions requires integrated policy approaches that promote equitable access, protect data rights, ensure inclusive participation, and recognise diverse user needs. Only by confronting these multifaceted justice challenges can digitalisation truly contribute to fair and equitable energy systems. The following section outlines brief policy recommendations to help navigate some of the challenges discussed above.

5.2. Policy implications: Mitigating potential tensions and building ground for just transitions

Data injustices in digitalised energy systems extend beyond privacy concerns to include the fair and equitable use of data. It is crucial to define how benefits derived from increasingly granular data on energy generation, consumption, and storage can be shared among all stakeholders. Without careful attention and transparency, there is a risk of creating systems and structures that primarily serve for-profit actors or benefit users only in narrow terms, such as providing an extensive selection of services or greater convenience. Ideally, data utilisation should bring financial and other benefits for those actively participating in the system, while also ensuring vulnerable and marginalised groups are not left behind. Transparency is essential on several fronts, including the type of data collected and stored, where data is held, the security measures in place, who has access rights, and how data is processed and used. Cybersecurity, data privacy, and data protection are concurrent challenges that must be mitigated. A proactive approach is needed to avoid any potential harm that may result from the misuse of data. This implies regulations on data management and guidelines for the anonymisation of data.

These measures are crucial as the absence of data governance in energy system transformations risks allowing digitalisation to exacerbate or deepen energy injustices. Digitalisation often entails the emergence of platformisation and platform-based business models. While these models can establish an intermediary layer and facilitate two-sided markets, they often lead to lock-ins and uncompetitive market structures. Platformisation developments should be closely monitored and

carefully regulated to prevent anti-competitive practices, such as exclusive contracts. Moreover, regulatory attention is essential to promote interoperability and data portability, helping to lower barriers for new entrants in the market. Without such safeguards, platformisation and oligopolisation of energy and data markets risk consolidating power in the hands of dominant digital market actors, mainly based in the Global North. This concentration of power can steer digitalised energy domains towards anti-competitive structures and produce weak distributive justice outcomes.

Digitalisation in the energy system has the potential to redress some of the injustices that have previously plagued the conventional energy system. However, without sound governance, digitalisation is likely to introduce new forms of energy injustices. Robust governance structures and processes are therefore needed to manage the tensions arising from digitalising energy systems. Strengthening democratic participation in these complex change processes is crucial to ensure that energy data justice is embedded in the governance of energy systems. Digital technologies themselves can serve as platforms for more direct and inclusive democratic processes [85]. Here, we see promising, yet largely untapped, opportunities to use digital technologies to shape future visions and the practical deployment of energy systems that include diverse societal perspectives. Digital technologies can facilitate broader participation and gather diverse perspectives from a wide range of stakeholder groups, including women, ethnic minorities, and other marginalised communities. However, digitalisation should only be seen as a complement to some of the existing participatory processes and methods [85]. Beyond the energy or information and communication technology sectors, digitalisation has already demonstrated its value in domains like land use planning, where it enables more frequent and detailed public feedback to improve how land use plans are created and updated. Similar participatory approaches can be utilised in the twin transitions of energy and digitalisation. Moreover, participation and engagement around data-related issues should not be a static affair. Terms and conditions should be revisited and renegotiated whenever there are significant changes in data processes.

6. Conclusion

Justice issues have become vitally important for energy transitions, making just transitions to net-zero energy systems a central focus in future energy policy discussions. Transitions towards clean energy systems will increasingly rely on the integration of advanced digital technologies and solutions. While digitalisation offers transformative potential for operational efficiencies, it also introduces new justice challenges that require careful consideration. Our paper highlights the critical intersection of energy justice and data justice in these digitalising transitions. By drawing on the scholarship from both domains, we identify potential justice challenges arising from the production and use of data generated by digital energy systems. Our analysis highlights that energy justice scholarship can be enriched by integrating insights from data justice to better account for the nuances and complexities introduced by digitalisation. This provides a strong starting point for future research aiming to place justice at the heart of the evolving interface between energy and data systems.

Transitions to net-zero energy systems are becoming increasingly divisive issues in politics, economics and society. One vital way for policymakers to combat this divisiveness is to ensure a just transition that is both fair and attentive to broader social inequalities. Digital energy systems risk reproducing and enhancing social inequalities without robust attempts to broaden their inclusivity and justice impacts. If digitalised energy transitions are to meaningfully contribute to just energy transitions, principles of justice must be embedded from the outset in their design and implementation. This study offers suggestions for policymakers and energy system stakeholders to develop strategies that address these justice challenges effectively, ensuring an inclusive and equitable digitalised energy future.

CRedit authorship contribution statement

Shah Rukh Shakeel: Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Max Lacey-Barnacle:** Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Jouni K. Juntunen:** Writing – original draft, Supervision, Methodology, Formal analysis, Data curation, Conceptualization. **Adrian Smith:** Writing – original draft, Supervision, Project administration, Formal analysis, Data curation, Conceptualization.

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.

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Data availability

No data was used for the research described in the article.

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