First things first: laying the foundations for smart energy communities by exploring concepts and realities in European case studies

Paula Hansen
Environmental Change Institute, University of Oxford
OUCE, South Parks Road
Oxford OX1 3QY
Email: paula.hansen@ouce.ox.ac.uk

Jake Barnes
Environmental Change Institute, University of Oxford
OUCE, South Parks Road
Oxford OX1 3QY
Email: jacob.barnes@ouce.ox.ac.uk

Sarah Darby
Environmental Change Institute, University of Oxford
OUCE, South Parks Road
Oxford OX1 3QY
Email: sarah.darby@ouce.ox.ac.uk

Abstract

Smartness has become a central theme in practical and theoretical discussions of energy system decarbonisation. Smart technology is widely regarded as critical to the effective operation of a system based predominantly on distributed, renewable sources. This paper examines the concept and reality of smartness with regards to another prominent feature of emerging energy systems: energy communities. Both phenomena are seen as highly significant in the EU Clean Energy Package, yet the interface between them has received little explicit attention. In this study, we explore the meaning of 'smart' in the context of energy communities, to contribute to building a solid foundation for future research on smart energy communities. A rapid review was conducted to gain an understanding of how 'smartness' is mobilised in the literature. The resulting insights were applied to six case studies in five European countries. In doing so we answer the question, what does 'smart' mean in the context of energy communities? Our findings suggest while there appears to be agreement that smartness is based on information and communication technology, the plethora of technologies and community configurations this entails is often neglected. To address this lack of specificity, we propose that smartness may be thought of as a sociotechnical concept and issue, and outline some of its dimensions, including types of technology interactions, degrees of sophistication and its relation to the concept of community.

Introduction

The term 'smart' is applied very widely to energy systems and to elements of those systems: smart appliances, buildings, neighbourhoods or cities, for example. Yet there is no generally accepted definition of 'smart'. Instead, a gradual development of the concept can be witnessed over the past century from two strands of thinking and intention. One relates to comfort and convenience: for example, the idea of the automated home began to take root in the early 20th century, before evolving into the concept of the smart home with a web of interconnected devices (Strengers, 2013). The other strand of thinking about 'smart', more relevant to this paper, relates to a wider set of functions: those needed to operate an electrical network or grid as efficiently as possible by managing supply, demand and storage in real time. Computer-enabled controls were introduced to assist with the management of high-voltage grids by the middle of the last century. From then onwards, as information and communications technology (ICT) became less costly and less bulky, the process of 'smarting' percolated into smaller-scale applications: industrial energy use, lower-voltage distribution networks and, eventually, small businesses and homes. Storage heating, where the heaters are charged automatically in order to use off-peak electricity, can be seen as an early example of automation/ smart control in buildings designed to improve system efficiency and to offer a service to customers. It is also an early example of a shift in the relationship between supplier and customer in which the customer, in effect, offers a service to the system operator (demand response) as well as receiving one (relatively affordable electric heating) (Darby, 2017).

Along with 'smarting', the last few decades have also seen an increase in the general complexity of energy systems, especially where electricity is concerned. New forms of demand have emerged, variously related to new ICT applications, electric vehicles and heat pumps, and have percolated across energy systems to varying extents; supply is increasingly small-scale and decentralised. These trends have necessitated and driven numerous changes to the organisation of energy systems. On the one hand, the situation poses a major challenge to network operators, who can face a choice between costly network reinforcement or the development of 'smarter' systems, with some control over demand, capable of balancing it with available supply in real time and at the appropriate scale (Pudjianto et al., 2013). The deployment of smart metering is often viewed as a critical step towards achieving the latter. It connects customers and suppliers via a device with two-way communications that can measure, store and transmit information on both demand and supply when required, and which can enable more flexible control of each.

On the other hand, these changes, and in particular distributed, small-scale generation, have presented an opportunity for new actors to become involved in energy system operation and governance. Energy communities are one such actor, who has garnered strong interest and support over recent years as a potential means of delivering benefits to citizens and wider energy systems. Energy communities are often defined as entailing participatory processes and collective outcomes, whilst being driven by environmental, social or political, rather than purely financial, motives. Ordinary citizens typically play a strong role although they may also involve an association of actors (Seyfang et al 2013; Walker and Devine-Wright, 2008). In theory, at least, energy communities offer economies of scale by aggregating and balancing local supply and demand, easing the strain on networks, and contributing to general welfare by doing so. They can also offer new services to their members by retaining some of the wealth from locally-produced energy within a community. At the same time, they can be small enough to operate as trust-based, flexible and locally governed bodies that 'learn by doing'.

Whilst the right of communities to generate, consume, store and distribute energy has only recently been enshrined within the EU's Clean Energy Package (CEP)[1], agreed in 2019, community-based action on energy is not new. It has a long lineage (Smith, 2012), and is by no means immune from the smarting trends discussed above or the broader digitalisation of energy systems practices. However, the incorporation of smart energy into the processes of energy communities appears to be a work in progress. What smart energy communities (may) look like, what the integration of smart technologies into their operation may involve, is unclear. This leads to the central question guiding this paper: What does 'smart' mean in the context of energy communities?

To answer this question, the paper proceeds by introducing a rapid review methodology, adopted to examine use of the term smart within research on energy communities. A brief introduction to six European energy communities, later discussed in light of the rapid review, concludes the research design section. The results of the rapid review are then presented and discussed in relation to conceptualisations of 'smartness', interpretations of 'community' and 'smart communities'. These themes are then discussed in relation to the six case studies to develop a better understanding of what constitutes smartness in the context of energy communities. A discussion follows, with proposals to further develop smartness as a sociotechnical concept in relation to energy communities.

Research design

To address how the concept of smart has been used in the context of energy communities, a rapid review of prior research was conducted. Our aim is not to offer exhaustive or definite answers to what smart energy communities could or should mean, but to establish a basis for reflecting on contemporary activity and provoke discussion.

Rapid review methodology

No formal or universal definition of what constitutes a rapid review currently exists (Hamel et al., 2021; Featherstone et al., 2015; Khangura et al., 2012). Rapid reviews are commonly described as knowledge syntheses or evidence summaries that are conducted in a shorter timeframe than comprehensive systematic

[1] https://ec.europa.eu/energy/topics/energy-strategy/clean-energy-all-europeans_en

reviews, typically with the aim of informing evidence-based decision- and policy-making (Hamel et al., 2021; VCU Libraries, 2018; Khangura et al., 2012). They may also serve “as a scoping mechanism for deciding when a full review is needed” (Featherstone et al., 2015, p.4). To accelerate or simplify the review process, rapid reviews employ streamlined, modified or restricted methods such as limiting the databases used or the scope of questions (Hamel et al., 2021). Questions are generally narrowly focused (Dobbins, 2017; Featherstone et al., 2015; Grant and Booth, 2009). The question that guided our review was: How have researchers defined and used the term ‘smart’ in the context of energy communities?

Figure 1 illustrates the review process. The search used Scopus after a preliminary consultation of literature on database comparisons (Gusenbauer & Haddaway, 2020; Martín-Martín et al., 2018). Scopus was chosen because it features bulk download options and preliminary analysis functionalities, and because of the authors’ familiarity with the database. While Scopus is a curated database (in contrast to Google Scholar), it is one of the largest, and fares slightly better than Web of Science (of similar size) in terms of coverage (Martín-Martín et al., 2018). Papers indexed in Scopus are peer-reviewed. Acknowledging the limitations of using a single database, this choice may be regarded as a first restricting criterion in the rapid review process.

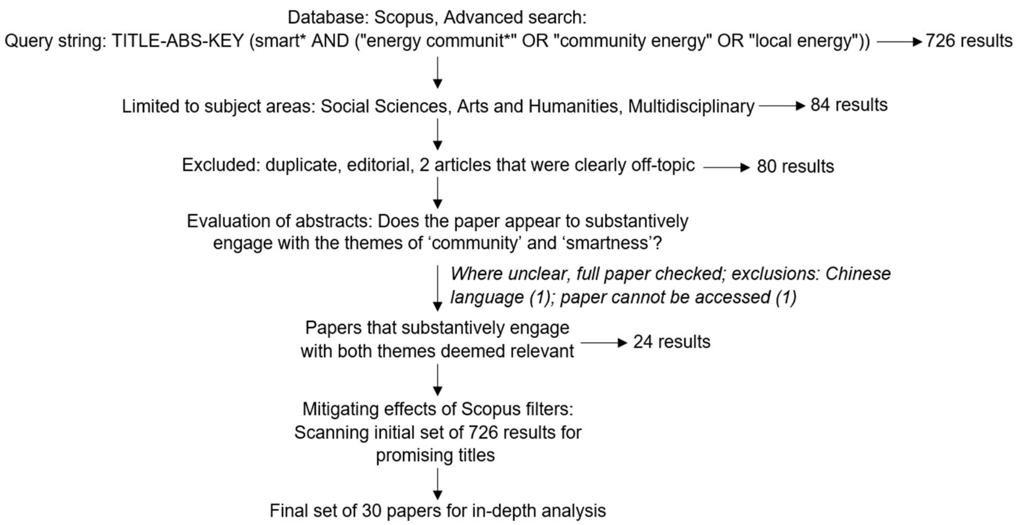

Figure 1: Rapid review process to select papers for analysis.

The chosen search string will not cover all terms that have been used by others to describe energy communities and related notions such as energy cooperatives, or collective action initiatives. The extent of multiple, often overlapping, concepts used to describe and explain contemporary activity was a critical challenge in designing a suitable search strategy. The term ‘local energy’ was included to mitigate against focussing too narrowly on ‘community’ activity. Several test searches were conducted using different combinations of search terms and restricting criteria to find the best strategy for the present paper. While the selected search strategy did not yield an exhaustive set of articles, it yielded a manageable number of results[2], in line with the purpose of rapid reviews outlined above, and appropriate for the scoping exercise here described.

The initial search yielded 726 results. Around three quarters of results was indexed in Engineering, Mathematics, Computer Sciences and related topic areas. With the aim of maintaining a focus on the social scientific literature, a second step in the selection was limiting the Scopus search results to the subject areas Social Sciences, Arts and Humanities, and Multidisciplinary. After exclusion of duplicates, an editorial and two papers stood out as being off-topic, the remaining 80 abstracts were evaluated in terms of their engagement with the two themes ‘smartness’ and ‘community’. All abstracts were evaluated by at least two of the authors to reduce bias. To mitigate some of the potential bias introduced by the Scopus subject are filters, titles in the initial set of 726 were scanned. Six additional papers were thus identified. The final set comprised 30 papers that were read in-depth and evaluated with regards to the research question.

Application to case studies

[2] To illustrate the need to restrict search terms, using ‘community’ and ‘energy’ separately rather than as compound terms (TITLE-ABS-KEY (energy AND smart AND (community OR local))) yielded nearly 10 times as many results (7,167).

To further explore the meaning and realities of smartness, findings from the rapid review were examined in the context of six case studies. The communities were selected to cover a range of countries, motivations (reducing costs, accessing renewable energy etc.) and ways of operating (collective self-consumption, peer-to-peer, virtual power plant). Because energy communities cover a wide range of processes and applications, we do not claim a representative sample of activity. The six energy communities are introduced in Table 1. Detailed analysis of these case studies has been undertaken as part of the NEWCOMERS project[3] drawing on interviews with project managers, practitioners, partners and participants, as well as document analysis and workshops. The final case study report – covering their emergence, operation, interaction with energy systems and potential for growth or replication – is due for publication at the end of 2021.

Table 1: Case studies employed in the research.

Case study	Description
Energy Local *(United Kingdom)*	A Community Interest Company (CIC) established in 2016, in partnership with a licensed supplier, to link local renewable generators with local consumers so that both receive fairer prices for the electricity they produce or consume locally, through the creation of Energy Local Clubs.
GEN-I Jesenice *(Slovenia)*	A collective self-consumption initiative, established in 2019 within an apartment building comprised of 23 households, who share electricity and heat generated from two roof-mounted solar PV installations and a heat pump, with the support of a Slovenian energy company.
Power Zone *(Germany)*	A peer-to-peer trial, initiated in 2019, trading locally produced electricity within two neighbourhoods. The trial is premised on retaining electricity generated within a defined geographical area using blockchain technologies and a 'virtual private network' to connect households.
Solidarity & Energy Social Housing (SO_EN) *(Italy)*	A transdisciplinary pilot project developing an energy service company to manage onsite generation and storage assets to maximise collective self-consumption through a private microgrid on a new built social housing estate. The pilot is expected to launch in 2021.
sonnenCommunity *(Germany)*	A virtual power plant established in 2016, linking decentralised and privately-owned generation and storage units (principally solar PV and batteries) through cloud-based software, centrally controlled, to enable prosumers to cover 100% of their electricity needs through a combination of self-consumption and excess generation from fellow community members.
Zuiderlicht *(The Netherlands)*	An Amsterdam-based cooperative of approximately 900 members, who collectively own and manage 18 roof-mounted PV installations. Under the Dutch 'postcoderoos' regulations, some members receive electricity with reduced tax rates from two projects.

Results of literature search

The review included a total of 30 publications: 20 journal articles, seven conference papers and three book chapters. All were published within the past 10 years (2011-2021), with the majority (23) published since 2018 (ten in 2019). The set included two comprehensive review articles (Ford et al., 2021; Ceglia et al., 2020). Despite the intended focus on social scientific contributions on the topic of smart energy communities, the selected papers were found to cover a range of disciplines, including studies focused on modelling techno-economic issues associated with energy technologies. Eleven papers were based on case studies covering five European countries (Pallesen & Jacobsen, 2021; Parks & Wallsten, 2020; Rodrigues et al., 2020; Ghiani et al., 2019; Snape, 2019; Walnum et al., 2019; Fladvad Nielsen et al., 2018), Australia (Hansen et al., 2020), Chile (Alvial-Palavicino et al., 2011), Korea (Leem et al., 2019), and the United States (Sarfi et al., 2016). The following two sections describe how the notions of 'smartness' and 'community' were addressed in the reviewed literature. We then discuss the interface – smart communities – before reflecting on the findings in the context of the six case studies. The aim of the exercise is not to generate new definitions, but to review what smartness in the context of energy communities may entail.

Smartness

Mirroring the range of subject areas covered, smartness was treated in various ways across the reviewed literature. One commonality was that definitions were generally provided not for the term 'smart' itself but for compound terms or concepts used to frame studies, such as smart city (Deguchi, 2020), smart consumers (Lynch et al., 2016) or smart grid. 'Smart grid' was by far the most frequently cited concept, though one that is missing a

[3] New clean energy communities in a changing European energy system (NEWCOMERS) project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 837752. More information is available at https://www.newcomersh2020.eu/

clear definition of its own (e.g., Wolsink, 2012; Alvial-Palavicino et al.; 2011). These compound terms suggest a nested hierarchy, with the concept of a smart city at its top encompassing districts, microgrids and buildings.

Irrespective of terms used, the most common way of defining ‘smartness’ was by referring to ICT as a defining feature. Related to this are the notions of bidirectional communication or flows of information (Ashouri et al., 2016; Alvial-Palavicino et al., 2011); and/or notions of monitoring and control (e.g. Alvial-Palavicino et al., 2011; Good et al., 2017). No clear definitions of ICT were found in the reviewed literature.

Largely implicitly, an important feature of smartness appeared to be the digital nature of the technologies or processes of interest. The term ‘smart’ was also interpreted as synonymous with digital (e.g. Ford et al., 2021; Hansen et al., 2020). Ford et al. (2021, p.2) described “the introduction of smart meters, greater prevalence of “Internet of Things” devices in homes and businesses, and increasing sophistication of automation (e.g., artificial intelligence) used to provide system services” both as ‘smartness’, and as exemplifying the trend of increasing digitalisation. In addition to ICT, digitalism thus emerges as a second dimension of smartness.

Digitalisation and the associated smartening of systems were framed as responses to a range of problems within the reviewed literature. At the broadest level, smartness may be seen as a response to increased penetration of renewables (e.g., van Summeren et al., 2020; Čaušević et al., 2019), or the “energy quadrilemma of affordability, sustainability, security and social acceptance" (Good et al., 2017). Smartness may help address these challenges by, for instance, making energy systems more efficient overall (e.g., Parks & Wallsten, 2020; Ashouri et al., 2016; Prinsloo et al., 2016); automating the balancing of demand and supply (Lammers & Heldeweg, 2019); improving resilience by facilitating a shift towards decentralised coordination (Čaušević et al., 2019); or maintaining reliability in a cost-effective way by improving monitoring and control of, and communication between, devices and infrastructures (Good et al., 2017). Framed more narrowly, ICT may be viewed as enabling specific functions, such as peer-to-peer trading (Yahaya et al., 2020).

Moreover, smartness in the reviewed literature was associated with use of the terms ‘intelligent’ or ‘intelligence’. These concepts were not clearly differentiated from ‘smart’. While some authors appeared to use the terms ‘smart’ and ‘intelligent’ interchangeably (e.g. Ceglia et al., 2020; Deguchi, 2020; Ghiani et al., 2019; Massey et al., 2019), others seemed to imply a differentiation between the two, for example “new information and communication technologies as well as automation and self-regulation operating paradigm” (Ford et al., 2021, p.9), “added intelligence and ICT enabled communication” (van Summeren, 2020, p.2). The term covers a range of processes and mechanisms such as machine-learning, automation and artificial intelligence that marks it out from the deployment of ICT for monitoring or the remote control of assets. Intelligence thus appears to be a possible, advanced facet of smartness.

Differences in levels of specificity reflect how central the concept of smartness was in different studies. In many cases smartness was part of the study’s framing and not the main subject of interest. This may be particularly true for studies using a smart grid framing to contextualise their research problem, referring to the concept to describe trends in energy systems. In addition, the research problems addressed by the reviewed literature were rarely linked directly to implications or challenges of smartness, such as increasing amounts and types of data (Ford et al., 2021). Studies where smartness was relatively central included an examination of how digitalism affects sociotechnical dynamics in shared renewable energy systems (Hansen et al., 2020); discussions of platforms (e.g. Rodriguez et al., 2020; Kloppenburg & Boekelo, 2019); a study on virtual power plants (van Summeren et al., 2019); and the two review articles (Ford et al., 2021; Ceglia et al., 2020).

These studies also highlighted a final theme: smartness, albeit characterised by the use of ICT, is not a purely technical concern. Smartness may be mobilised to increase management of energy systems or can be mobilised for social purposes. For example, an online platform may be understood as a digital space “where users can communicate and interact with each other and get temporary or permanent access to products, services, or more broadly ‘resources’” (Kloppenburg and Boekelo, 2019, p.68), or as a “tool to build ‘community’ linked to shared behavioural drivers” (Rodriguez et al., 2020, p.5). Such descriptions point to social purposes and to the inevitably social nature of innovation: however much automation and machine learning may be involved, the design, operation and development of a smart system will be socially guided and will have social inputs and impacts (e.g., Hansen et al., 2020).

Community in relation to smartness

Like smart, the term ‘community’ was mobilised within the reviewed literature in multiple ways. Community was commonly mobilised through geography and by network infrastructure, with authors citing, for example, geographic co-location (e.g., Bourazeri & Pitt, 2018), an island (Pallesen & Jacobsen, 2021), an area of buildings (Walnum et al., 2019, Fladvad Nielsen, 2018), or the interconnection and aggregation of microgrids (Tian et al., 2019) to define their boundaries. As such, interpretations of community were often linked to the notions of place and to notions of scale, as outlined in the previous section, e.g., smart city (e.g. Leem et al., 2019), or smart microgrids (e.g., Parks & Wallsten, 2020; Prinsloo et al., 2016). Collectively, these works point towards an understanding of *communities of place* and to *community as scale*, intimately linked to energy infrastructure.

Fewer studies explicitly included people in their conceptualisations of community. For example, discussing features of cooperative microgrids, Wolsink (2012, p.828) pointed not only to close physical distance, but also "closer 'social distance' when users become the owners/managers of the production units and the microgrid". In addition to ownership and related notions such as self-organisation (e.g., Čaušević et al., 2019; Bourazeri & Pitt, 2018), an emphasis on more active engagement and participation of users (Alvial-Palavicino, 2011), citizens (Massey et al., 2019), or consumers (e.g., Pallesen & Jacobsen, 2021) emerged as a feature of communities in the context of the review. In this sense smarter energy systems seem to have increased capacity to engage end-users and mobilise or create new communities.

The increased engagement potential of smarter energy systems may also enable communities to break out of geographical or infrastructural constraints, to exist across such boundaries. In their study of community Virtual Power Plants van Summeren et al. (2020) presented an understanding of community not just in terms of co-located involvement but also in terms of dispersed ownership and governance. In doing so they mobilised an understanding of communities of interest also employed by Kloppenburg and Boekelo (2019) who distinguished community platforms from 'transactive' platforms as serving a predefined common interest or purpose.

A further interpretation of community within the reviewed studies is that of *community as an actor*, with varying degrees of agency (e.g., Hansen et al., 2020; Lynch et al, 2016). Common across this conceptualisation is an understanding of community united through collective action over a common problem (e.g., Bourazeri & Pitt, 2018). For instance, the work of van Summeren, et al. (2020, p.20) demonstrates how communities may increasingly play an active role in managing electricity systems through the use of intelligent technologies and ICT. Their work poignantly highlights how smartness can extend prior agency. It also demonstrates how smartness can become, in effect, an extension of previous community activity.

Smart communities

The rapid review highlights the multiplicity of ways in which smart and community have been mobilised within existing literature. Table 2 summarises the key themes. Principally, the rapid review suggests that a defining feature of 'smart communities' may be their use of ICT, and potentially intelligent technologies, in order to manage energy activities within a defined place, at a particular infrastructural scale or within a community of interest. The brief exploration also highlights how smartness goes hand in hand with the increased digitalisation of energy system activities. Though implicit in most cases, smartness is generally linked to digital technologies.

The review also highlights how smartness takes on different meanings depending on how community is mobilised, each mobilisation entailing slightly different smart qualities: community as place or scale intimately linked to smarter energy infrastructure and its management, whilst community mobilised as an actor seemingly implying that increased smart capacities correspond to increased community agency. Individually reviewing notions of smart and community within this single body of literature highlights a variety of important technical elements and social implications and possibilities contained within. This suggests, at the very least, that smartness needs to be understood in the context of energy communities as a sociotechnical phenomenon and investigated with equal weight given to social and technical elements.

These preliminary findings point to two central questions that may help solidify our understanding of smartness in the context of energy communities. Importantly, the findings call for examination of the types of ICT mobilised within energy communities, and of what functions they serve. Differentiating between types and/or uses of technologies may help open up smart as a black box and allow for differentiation within. The findings also point towards investigation of the different mobilisations of community and qualities of smartness associated with each. These questions subsequently form the basis on which examination of six contemporary, European energy communities is undertaken below.

Table 2: The meaning of smart in the context of energy communities: Themes identified in the reviewed literature.

	Identified themes
General observations	- No common definition: Variety of interpretations & terms employed - Frequent use of compound terms (e.g., 'smart grid') - Implied nested hierarchy in term usage (e.g., from smart microgrids to smart cities) with 'community' mobilised across all levels - Smartness often part of general framing of papers but rarely the central topic of research

Meaning of smartness	- Definitions usually implicit - Definitions usually refer to ICT - ICT understood as digital ICT - There may be differing degrees of sophistication (e.g., from dumb to intelligent)
Smartness in relation to community	- Smartness has social dimensions - Smartness may enable/ support more active engagement of users/ citizens/ consumers, and enables transcendence of geographic or infrastructural boundaries - Smartness may give communities (improved) agency (as active actors in the energy system) - Smart takes on different meanings and qualities depending on the understanding of community mobilised, e.g., in relation to communities of place or scale, smartness refers primarily to the optimisation of resources at a given place/ scale, whilst in the case of community as actor, smartness appears to extend agency

Smartness in six European case studies

Types and functions of ICT

To begin with, all of the examined case study communities use ICT in their operation. At a minimum, digital technology is used for general communication or accounting activities. For example, may communities maintain a website to convey information to (potential) stakeholders. It is also safe to assume that billing is typically done by a machine, and not by hand. Beyond this, the most common type of ICT is advanced metering technology: smart meters are employed by Energy Local, GEN-I Jesenice, SO_EN and the sonnenCommunity, whilst Power Zone use a simpler 'plug and play', magnet connected device to collect and transmit consumption data. This advanced metering works as a vital, enabling technology in all but one of these cases (GEN-I Jesenice), as discussed below. Three of the cases (Energy Local, Power Zone and the sonnenCommunity) use 'front-end' consumer focused ICT, including web portals, apps and consumer access devices. Power Zone and sonnen operate specific ICT-based 'platforms' for managing their operations, whilst the sonnenCommunity is the only one to have enrolled a home energy management system into its operations: Power Zone intends to incorporate this functionality in the future once issues of data acquisition and the core operation of their community are resolved.

To understand why and how different types of ICT are employed requires looking at the functions they provide. At Gen-I Jesenice, smart metering is used for monitoring purposes only. Smart meters enable the community's licensed supplier to better understand self-consumption and manage its imbalance risk. However, data gathered by smart meters is not used (or needed) to operate the community. Allocation and billing of electricity is instead done using distribution keys based on historic data and apartment size, within national net metering regulation. In practice, these regulations, also present in the Netherlands and utilised by Zuiderlicht, negate the need for 'smarter' ICT-based solutions which would be needed to balance supply and demand in real time. Instead of unique distribution keys, Zuiderlicht uses ownership shares as a contractual tool to allocate generation to their stakeholders.

In addition to monitoring, ICT are also used to enable the core functionality of some of the case studies. For instance, in SO_EN the allocation and distribution of renewable energy is facilitated by smart technology. A 'social algorithm', developed to equitably distribute and price electricity, based on socioeconomic characteristics of residents, is seen as one of the community's core features. ICT is also essential to the core functionality of Energy Local, Power Zone and the sonnenCommunity. In these cases, ICT (including metering technology) is used to monitor generation and consumption at diverse sites at regular time intervals (or in real time), which is subsequently used to allocate generation to demand within the community. In these cases, ICT are used to enable core functionality. Energy Local uses its own 'fair share' algorithm to allocate local generation to consumption and measure net imports and exports to the community. The sonnenCommunity employs 'cloud-based software' to optimise operation of its virtual power plant, and intelligent algorithms optimise the use of individual community member batteries. Power Zone uses distributed ledger technology (blockchain) to create 'a chain of trust linking individual sensors/smart meters to the Power Zone platform and to E.ON's billing software'. Here, ICT adds specific functionalities.

ICT is also used in the case studies to convey information to members. Energy Local, Power Zone and sonnenCommunity all have ICT-enabled devices that members can access. These serve as the 'front-end' of the energy communities and a means of engaging with members. Unlike the 'back-end' functions, which are enabled by ICT, the extent to which communities rely on these front-end ICT varies. For Energy Local, engaging members through new technologies is seen as central to the initiative, assisting members in making 'better decisions' about when they consume energy and thereby facilitating better utilisation of local generation. For this purpose, a web portal – conveying predicted local generation information – was used initially whilst more advanced consumer access devices – which combine actual generation and consumption within the community in real-time – are now being rolled out. In contrast to Energy Local, Power Zone describe their approach as a 'digital service' and "a special electricity tariff that can be tracked in real time via a front-end [app] to see how self-sufficient a neighbourhood can actually be". They emphasise that they do not aim to actively engage with community members, but rather to provide information in an engaging way, if sought out by the user. In a similar fashion, sonnenCommunity members can access an app to learn about their systems' performance. While this may eventually lead to more energy conscious behaviour, neither Power Zone nor the sonnenCommunity rely on the functionality these ICT provide for the operation of the energy community.

This vignette into the types of ICT employed in the case studies confirms the variety ICT observed in the review. It also extends our understanding by illustrating some of the different roles ICT may fulfil. In the review of six case studies, we identify three broad functions: monitoring, operation and engagement. It also suggests that technologies may be differentiated by degree of sophistication of their function: from metering for monitoring purposes to distributed ledger technologies for core functions. Examination of the case studies also suggests that smartness is not a pregiven outcome of a particular application of technology, such as an advanced ('smart') meter, or indeed any other digital ICT. Rather, smartness emerges as a characteristic of the way in which technologies are mobilised in practice, that is, a characteristic of socio-technical configurations. Conceptually, this suggests that to critically engage with smartness in the context of energy communities, we need to differentiate more clearly between types and uses of technologies in our analyses.

Primary notions of community and associated qualities of smartness

Across the case studies a common way of mobilising community drew on geographical notions. Within GEN-I Jesenice and SO_EN, community is demarcated by building occupation. In Zuiderlicht community is defined by urban population, expressed in the slogan 'Open to all Amsterdamers'. Energy Local clubs are named based on the towns they serve. This mobilisation of communities of place was also overlayed throughout many of the case studies with an understanding of community defined in relation to energy infrastructure. This is the case for example with Energy Local or Power Zone, where more efficient management of renewable energy generation and consumption is achieved through the establishment of a locally defined 'community'. Community boundaries are based on substation area (Energy Local), a specified 4.5 km radius (Power Zone) or, as in another case, in relation to a single meter point (SO_EN). Mobilised in relation to infrastructure, community boundaries seem to result from functional decisions about optimal operation, largely concerned with aggregation and the use of local generation.

In contrast, community is mobilised at best and exclusively as 'interest-based' within the sonnenCommunity: geographically dispersed members are linked, loosely, through product ownership or as recipients of a sonnen service. For sonnen, the notion of community is a deliberate strategy, deployed for its various connotations, yet left deliberately empty, an open vessel to be filled by participants. Whilst the sonnenCommunity is an extreme example, the idea of communities of interest is infused throughout many other cases too: in Energy Local, Zuiderlicht or Power Zone, members are united in common interests, generating renewable energy locally, and/or consuming locally generated electricity. In some instances, the case studies were formed by actively tapping into existing social networks (e.g., around a church or school), to engage and inspire participation in the new energy community, thus simultaneously seeking to ferment new communities of practice around energy. This relation to community can be illustrated through the contrasting use of consumer facing ICT in two cases. Whilst considered an essential component of the communities' use of local generation in Energy Local, consumer facing ICT-backed interfaces are deployed in Power Zone as a means of conveying information 'so they can reach their goals, via the app'.

Despite multiple, at times overlapping, mobilisations of community used across the case studies, we might infer two foundational notions, which can be associated with different ways in which smartness is introduced. In some case studies (e.g., Power Zone) community is mobilised as the optimal *scale* at which smarter ways of operating energy systems exist. This mobilisation views community in particular geographic localities and as a particular scale. Geographic boundaries may be implied by the primary constituting group or may emerge as a consequence of technical and/or legal requirements, as in the case of Zuiderlicht and GEN-I Jesenice. In contrast, where community is mobilised with people front and centre - within the relations and networks of people which may or may not share geographic boundaries and which may or may not result in new community agencies - smart solutions seem to follow the (conceptual and/or formal) establishment of the community. Here, existing or emerging community entanglements with energy appear to seek out 'less smart' ways of achieving collective goals.

Towards smart(er) energy communities?

This paper posed the question: What does smart mean in the context of energy communities? Having reviewed the literature and case studies, in this section, we focus on what shapes the concept of smartness in the context of energy communities to provide a foundation for efforts to develop it further. One important overarching observation is that both concepts – smartness and community – are highly ambiguous. The reviewed literature suggests that smartness is primarily associated with technology, and typically with the use of (digital) ICT. Often, these notions are not linked clearly or exclusively to smartness but to concepts, systems or artefacts using compound terms such as ‘smart microgrid’. Descriptions of these notions often lack specificity. Moreover, the technologies associated with smartness are not always clearly differentiated from other technologies. The confounding of ‘smart’ and ‘intelligent’ is another example of imprecision in term usage. Using the umbrella term ICT may be sufficient when smartness is of no relevance to the study in question but is likely to be insufficient moving forwards.

The need for greater precision is even more pressing given the pervasiveness of ICT in modern life. Some ICT used for billing and/or communication for example, have been embedded to such a degree that they no longer appear ‘smart’ but normal practice. This indicates that smartness in the context of energy communities is a relative characteristic, the attainment of which is progressively advanced. Ascertaining where this boundary lies and how it shifts over time is an important line of future inquiry.

Supporting a call for greater scrutiny in describing the technologies associated with smartness is the observation that communities may employ a wide range of different technologies, and for a variety of different reasons. Examination of the case studies suggests that ICT is being employed in three principal areas: monitoring, core purpose, engagement. The exploration further suggests that there may be varying degrees of sophistication in the technologies used. On the one hand, sophistication may vary with regards to technology type, ranging from analogue devices, via simple digital communication, to applications of machine-learning and automation – or what some have labelled ‘intelligent’. On the other hand, sophistication may vary with regards to technology function, from basic tasks such as monitoring, to facilitating a community’s core motivation.

Considering these different functions highlights that while ‘smart’ is often used with reference to technologies, smartness in the context of energy communities is a sociotechnical concept. This was also highlighted by several studies in the review (e.g., Ceglia et al., 2020; Hansen et al., 2020; Lammers & Heldeweg, 2019; Ashouri et al., 2016), and confirmed by the case studies. Online platforms, for example, open up new activities to members that would otherwise not be available (Kloppenburg & Boekelo, 2019), and can serve as tools for engagement, consultation and community-building (Rodriguez et al., 2020), offering an opportunity for more active involvement of users in the energy system and in communities (e.g., van Summeren et al., 2020; Massey et al., 2019). As such, another way of looking at the different functions ICT may fulfil is that they may serve to connect different types of technologies (e.g., Power Zone’s use of distributed ledger technology); to connect humans (see for example, the concept of community platforms, Kloppenburg & Boekelo, 2019); or to transmit information to actors (e.g., the sonnenCommunity app).

Given these observations, we propose to conceptualise smartness as a characteristic of a sociotechnical configuration. This helps to set smartness as a feature of energy communities apart from the ill-defined notion of smart technologies. It thereby helps highlight, firstly, the need for greater specificity in talking about technologies in the context of energy communities; and secondly, positions smartness as a relative concept, and one dependent on technology as well as humans.

The review of the literature suggests that any kind of digital ICT may be considered smart, while examination of the case studies shows that all communities use some kind of digital ICT in one way or another. Labelling something as ‘smart’ purely in the technological sense thus becomes futile. Thinking about smartness instead as a characteristic of sociotechnical configurations, underscores that it is not the technology but the way that it is used that may make a community smart. This brings the term ‘smart’ closer to the notion of ‘innovative’. The question is not whether a community uses digital ICT, but how effectively it uses it to meet its aims. Smartness is thus a relative concept, influenced by both, the type and function of technology, and the chosen mobilisation of ‘community’.

While it is beyond the scope of this paper to discern the exact ways in which types of communities and technologies may interact in shaping smartness, we point to two potential ways of thinking about these interactions. The case study communities suggest a possible link between the degree of sophistication of ICT and the actors involved in different operational models. Communities started by local community actors tend not to use the most sophisticated technologies. On the other hand, those using more sophisticated technology were not started by local community actors but rather, commercially oriented businesses. This would suggest that ICT, in type and purpose, follows a community´s guiding principle.

Lastly, the analysis of how notions of community and smartness may be mobilised suggests that one may broadly differentiate two types of *smart energy communities*. On the one hand, it may denote local. Interpretations of ‘community’ based on infrastructure or geography may be used in cases where the primary focus is on the efficiency gains that can be achieved by using ICT at the local scale. On the other hand, community may denote a focus on people (community as actor and process). In these cases, the focus is on maximising benefits to the community, and this may be done using ICT, for instance by providing platforms for online engagement with other members, or for learning.

Conclusion

This study explored the meaning of ‘smart’ in the context of energy communities by reviewing 30 papers from the academic literature and applying emerging themes to six European case studies. While the review and case study analysis were not comprehensive, they served the aim of this study to take a first step towards a better understanding of smartness. A comprehensive systematic review on the same topic is a recommendation for future research, using additional databases and a larger set of studies. This exploratory study of smartness in the context of energy communities has identified a number of dimensions that offer possible foundations for the development of a robust conceptualisation of smartness.

By building on what is already known about the nature of ‘smart’ and ‘community’, and about emerging practices in energy communities, we can avoid having to rediscover again and again, often painfully, the need to develop smart energy as a sociotechnical process. Having put first things first, we argue that future research can concentrate profitably on topics such as in-depth analyses of ICT used in communities, and what the implications of their different types and functions are for the involved actors – and vice versa. Conceptually, it will be useful to differentiate (more) systematically between potentially different shades of smartness we are beginning to see, not least to allow for researchers and other stakeholder to communicate findings more effectively. This will involve asking a number of questions, including: Are some communities smarter than others?

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