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New Clean Energy Communities in a Changing European Energy System (NEWCOMERS)

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Distributed energy resources and energy communities: Exploring a systems engineering view of an emerging phenomenon

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Abstract

This working paper is part of Work Package 4 of the NEWCOMERS project and explores the interface of two popular concepts in energy transition discourse: distributed energy resources (DERs) and energy communities (ECs). DERs are expected to play an increasingly prominent role in the creation and operation of decarbonised and decentralised energy systems. ECs have been proposed, by the European Commission amongst others, as holding the potential to empower energy consumers, making them active participants in energy systems who use, own and manage DERs. On the surface, ECs appear to be well positioned to develop DERs in the realisation of decentralised and decarbonised energy futures. This working paper examines and ultimately challenges this assumption. To take a closer look at contemporary EC activity, the paper first clarifies what DERs are conceptually, and then applies this understanding to the 10 NEWCOMER ECs to assess the extent to which they employ DERs within their current and potential future operation.

Based on a review of the literature, we suggest the concept of DERs is a system engineering view of energy systems. We define DERs as ***technologies and activities that contribute to establishing low-carbon, renewables-based energy systems; that can be drawn on when necessary to manage renewable energy systems; and that are located on the distribution network, often on the customer side of the meter.*** In doing so we highlight that what characterises DERs is their *capability* – rather than merely their potential – to support the management of renewables-based energy systems. This is an important distinction that is often overlooked in the literature.

Analysing our NEWCOMERS case studies through a DER lens reveals that distributed generation based on renewable sources is the most prominent type of DER delivered by our case studies. Their main contribution to power networks is increasing the amount of renewably generated electricity and reducing demand for grid-sourced electricity. Other services, such as storage and demand-side management, are offered by only a small number of cases.

Although the ECs we assessed use many of the technologies that have the potential to be a DER, they often do not exploit that potential. The difference is in the *purpose* of technologies ECs employ and the activities they undertake, which is usually not concerned with energy system operation. By implication, ECs are not configured in a way that makes their technologies or activities resources for system management.

A possible (partial) explanation for the limited development of DERs by ECs is that there are currently few incentives for ECs, or indeed other energy system actors, to contribute to system balancing at the level of distribution networks. If ECs are to support emerging decentralised, renewables-based energy systems through deploying technologies that can be drawn on when necessary to balance energy systems, then a variety of incentives will be required. This implies that in advancing the energy transition, it is important to consider both the value ECs may offer networks through the increased deployment of DERs, as well as the value energy systems may offer communities.

More broadly, our examination suggests that the DER and EC lenses are contrasting ways of thinking about energy systems, their intersection emphasising that energy systems must embody and deliver multiple values to a variety of system stakeholders.

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Glossary

DER(s) Distributed energy resource(s)

DES Distributed energy storage

DG Distributed generation

DR Demand response

DSM Demand-side management

EC(s) Energy community/ communities

ICT Information and communication technology

VPP(s) Virtual power plant(s)

1 Introduction

Energy systems are an important piece of the climate change mitigation puzzle. Driven by the urgent need to decarbonise, energy systems globally are undergoing a transition that is not limited to a mere change in power generation sources but affects every aspect of their organisation and management (Markard, 2018). A prominent theme in this transition is the scale at which power is produced and managed. Instead of fewer, large generation plants, emerging energy systems are characterised by many small, decentralised sources of generation (Judson et al., 2020). In this context, the term distributed energy resources (DERs) is commonly used, referring to resources at the level of the distribution network that are increasing viewed as vital to the creation of net zero energy systems (see for instance Pownall et al., 2021). Related phenomena of such transitions and increasingly decentralised energy systems are energy communities. Often driven by social and environmental objectives, energy communities, to varying extents, allow groups of people to use, own and/or manage DERs (Blasch et al., 2021). The development and growth of energy communities across Europe is viewed by the European Commission as holding the potential to create more equitable, and democratic energy systems with citizens at their centre (European Commission, 2020).

Against this backdrop, this working paper assesses the extent to which 10 contemporary energy communities (ECs) employ technologies and activities that can be considered distributed energy resources within their current operation, and their potential to deploy such technologies or develop such activities in the future. These ECs were selected as part of the EU Horizon 2020 NEWCOMERS project, as contemporary examples of new clean energy communities: "associations of actors engaged in energy system transformation for reduced environmental impact, through collective, participatory, and engaging processes and seeking collective outcomes" (van der Grijp et al., 2019). The working paper addresses task 4.4 of Work Package 4 of the NEWCOMERS project and is a partial contribution to task 4.6.

To that effect, it:

- introduces the concept of DERs as being a systems engineering view, concerned with managing future net zero energy systems and commonly based on three main categories of resource (section 1.1);
- reviews previous studies of DERs and ECs (section 1.2);
- sets out our approach to examining DERs in the context of the 10 case studies (section 2.1);
- presents each case study in terms of current and future (potential) utilisation of technologies and activities as DERs (section 2.2);
- and draws conclusions about current and future utilisation of DERs by ECs and about the application of a DER logic more broadly (section 3).

1.1 What are DERs?

1.1.1 What's a resource?

The Oxford English dictionary defines a resource as "stocks or reserves of money, materials, people, or some other asset, which can be drawn on when necessary"[1], whilst the Cambridge dictionary defines a resource as "a useful or valuable possession or quality of a country, organization, or person"[2]. What unites these definitions is the idea of a resource as being something that has value, and which can be directed at a particular use. The wide range of values and uses that 'resources' might entail, opens up a malleability within the term, which is reflected in its contemporary use

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[1] https://www.oed.com/view/Entry/163768?rskey=nE6UEu&result=1&isAdvanced=false#eid

[2] https://dictionary.cambridge.org/dictionary/english/resource accessed 02/08/2021, accessed August 2, 2021

within energy systems research. To understand its meaning in this context, it is necessary to briefly trace the evolution of the term.

Historically, 'energy resources' such as oil, gas and coal were the basis of energy systems. Energy was generated by using technologies to convert these resources into useful end products (electricity or heat), a process that involved consuming, i.e., using up, the resource. While these technologies and processes are still in use today, global efforts to reduce carbon emissions and mitigate dangerous climate change are seeing them become replaced by a new energy generation paradigm: one based on renewable energy resources.

These emerging, new energy systems still use technologies to convert an input into useable energy. Unlike conventional generation systems, however, renewable ones – as the name implies – do not rely on using up a finite resource in this process. Solar PV technology, for instance, converts sunlight into electrical current, but does not reduce the amount of sunlight available thereafter. While this is an advantage in many ways, a downside of renewable sources of energy like the sun or wind is that they are not as readily available as fossil fuels, and their supply is much less constant. As a result, energy system management is becoming increasingly occupied with the task of balancing demand and supply, whilst growing the share of variable renewables in the system.

This shift in focus has come with a shift in how the term 'resource' is used in the context of energy systems. **In renewable energy systems, resource no longer refers exclusively to the input** – the source of power, if you will – **or to physical or material entities, but the technologies and activities that make the input useable and useful in energy system operation**.

1.1.2 Types of DERs

Interest in 'distributed energy resources' took off around the turn of the 20th century. Largely resigned to scholars interested in microgrids, DERs were thought of as disruptive technologies, with the "potential to radically change the electric utility system" (Early, 2001). Subsequent attempts sought to clarify and define DERs, in relation to distributed generation and combined heat and power. The perceived aim of DERs was "to increase the quality and reliability of the power supply to a customer at a competitive price and to reduce overall environmental emissions" (Scheer et al, 2001, 2006).

In one of the earliest definitions of DERs Ackermann et al. (2001) quote Moskovitz (2000), defining distributed resources as

> *"demand- and supply-side resources that can be deployed throughout an electric distribution system (as distinguished from the transmission system) to meet the energy and reliability needs of the customers served by that system. Distributed resources can be installed on either the customer side or the utility side of the meter".*

Ackermann et al. (2001), like Scheer et al. (2001), go on to differentiate between distributed generation and demand-side measures, where the latter referred to load management and energy efficiency measures, including those that would influence the supply of electricity from the distribution network (Ackermann et al., 2001).

Over time, more distributed resources have been identified and discussed. In 2011, the European Commission (2011) set out an understanding of DERs as encompassing distributed generation (DG), distributed energy storage (DES) and demand side management (DSM). For the most part, contemporary use of the term focuses on these three categories. Because these categories are so widely shared, and often form the detailed discussion of DERs, it is worth introducing them in more detail.

1. **Distributed Generation (DG):** While no internationally accepted definition of (DG) exists, it is generally understood as power generation (technology) that is small-scale, and in close proximity to the load it feeds (Mehigan et al., 2018). A widely cited definition of DG is that it refers to an electric power source that is "connected directly to the distribution network or on the customer side of the meter" (Ackermann et al., 2001, p.201; cited in e.g., Mehigan et al., 2018; Nguyen et al., 2018). This is a general framing that draws on the legal definition to distinguish between distribution and transmission networks; and does not define parameters such as area of delivery, ownership, or the rating of the generation source as these may vary widely (locally as well as internationally) (Ackermann et a., 2001).

   The types of technologies and activities often referred to under DG include variable renewable energy sources, such as solar PV (SWECO 2015) but may also include fossil-fuel generators (Banerjee, 2006). The promotion of higher penetration of renewable generation is an often-cited benefit of DG, directly linked to reducing greenhouse gas emissions (Mehigan et al., 2018; Nguyen et al., 2018). As such it is also considered a more sustainable option than centralised generation based of fossil-fuels (Mehigan et al., 2018; Nguyen et al., 2018). In addition, DG may enable flexible demand response management (Nguyen et al. 2018).

2. **Distributed energy storage (DES):** involves technologies that "demand electricity and supply electricity at a later point in time" (SWECO, 2015), such as batteries, flywheels, or electric vehicles (ibid.). Storage resources may be thermal or electrical (Burger & Luke, 2017). In line with the above definitions, DES has also been described as energy storage systems within the electricity distribution network that are located near the end consumer (Aktaş, 2021).

3. **Demand side management (DSM)**: refers to activities aimed at involving the demand side more actively in power system operation (Paterakis et al., 2017). These activities may focus on energy efficiency, energy savings, self-production (offering supply from storage or behind-the meter generation at times of high demand) or load management (Paterakis et al., 2017). A major approach within DSM is demand response (DR) which is defined in the European Commission's recast Electricity Directive (Art. 2.20) as follows:

   > *"'demand response' means the change of electricity load by final customers from their normal or current consumption patterns in response to market signals, including in response to time-variable electricity prices or incentive payments, or in response to the acceptance of the final customer's bid to sell demand reduction or increase at a price in an organised market as defined in point (4) of Article 2 of Commission Implementing Regulation (EU) No 1348/2014 (17), whether alone or through aggregation".*

   It has also been described as time-shifting of electricity demand (McKenna et al., 2018), or a change in electricity consumption by end-users (SWECO, 2015) that occurs in response to variable price signals or incentive payments (McKenna at al., 2018; Paterakis et al., 2017; SWECO, 2015). DR may be implicit or explicit, where the former refers to voluntary changes in consumption patterns in response to market signals (dynamic pricing that reflects real-time price of electricity); and explicit DR refers to aggregators offering rewards for consumers' willingness to be flexible (Willems & Zhou, 2020; Lavrijssen & Parra, 2017).

1.1.3 What defines a DER?

The above discussion shows that there are two principal defining features associated with DERs. First, **they share a common position within the system, located on the low-voltage distribution network, often on the customer side of the meter**. This is in contrast to incumbent energy systems that have been organised around the burning of fossil or nuclear fuels in large, centralised power stations. Alluding to this shift and the renewable nature of many DERs, their role in establishing a low-carbon, renewables-based energy system is the primary benefit associated with DERs (Mehigan et al., 2018; Nguyen et al., 2018; Pownall et al., 2021). An important implication of the shift from centralised to decentralised power generation is the way systems are kept in balance. Traditionally, carbon-based generation plants provided a flexible means of balancing supply with demand. Through their reliance on fossil fuel resources that were relatively easy to store, supply could be ramped up rapidly as needed to meet demand: the system was said to be demand-led.

Renewable sources, however, (notably wind and solar) are a lot more variable and less predictable in when and how much they generate. This increases the risk of over- or under-supply at any point in time. As such, there is now a need to foster alternative means to balance systems in real time (Grunewald & Diakonova, 2018). This leads to the second, and arguably more important, defining feature of DERs: **they are thought valuable in managing decentralised, renewables-based energy systems.** The three types of DERs outlined in the preceding section – DG, DES, DSM – all comprise technologies and activities that may be employed to control this balance between demand and supply. In addition, DERs are thought to have the potential to avoid costly upgrades to or replacements of ageing and capacity constrained distribution infrastructure (Pownall et al., 2021).

Linking back to our dictionary definitions of resources, we thus suggest that **distributed energy resources are technologies and activities that contribute to establishing low-carbon, renewables-based energy systems; that can be drawn on when necessary to manage renewable energy systems; and that are located on the distribution network, often on the customer side of the meter.**

1.1.4 DERs and value

Although this helps clarify what DERs are, it still leaves one issue: the growing range and number of things that might qualify as a DER. As illustrated by the definitions and examples provided in section 1.1.2, each category of DERs contains a long list of technologies and activities. The list is so long in fact, that without additional qualifying attributes, the term DER is at risk of becoming but a shorthand for 'energy-related kit at the grid edge'.

We argue that the underlying issue is a lack of appreciation of the difference between a technology and its various uses. Further, we suggest that this issue may be resolved if, building on the preceding section, **we emphasise the value DERs provide to energy system operation as a qualifying criterion. This means differentiating between a technology's *potential* to be valuable and its *actual capability* to do so**, which is linked to the social, material, and institutional contexts within which it is set to work. For those technologies and activities that result in distributed generation or storage, value is self-evident because it is their primary purpose. For technologies and activities that contribute to system balancing, this is less clear because they typically fulfil a different primary purpose, such as heating, cooling or transport. This is often where confusion arises.

The issue can be illustrated with a few simple examples. Take, for instance, the fridge: a common household object since the 1960s, its value is usually limited to ability to store and preserve food and drink. However, some models now allow their cooling cycle to be externally controlled. Under certain circumstances – typically where lots of small loads are bundled together, are controlled by an

external aggregating actor and are collectively turned on/off in response to grid needs – fridges can provide a valuable service to electricity grids. Fridges can be considered DERs: but, as the example illustrates, only if enabling social, material and institutional contexts are present that create a means for the fridge to provide such a service. As another example, electric vehicles are now also commonly described as a DER owing to their *potential* to provide demand-side flexibility (e.g., IEA, 2021). EVs, and the coupling of electricity and transportation systems more broadly, is an exciting system development. However, in our view, EVs can only be considered a resource once their capacity to provide a service is established within a socio-material arrangement that supports this functionality. System managers or operators, whoever they might be and wherever they might be located, require visibility and control over these resources if they are to be of value. These simple examples open up a world of everyday artefacts that might be considered DERs if the qualifying criterion is merely their potential usefulness.

The issue also relates to more conventional renewable generation technologies. As the International Energy Agency has pointed out, renewable power plants drive the need for more system flexibility, while at the same time offering potential flexibility services. Technically it is possible to control the output from renewable power plants (at least downwards), by curtailing it (Grunewald and Diakonova, 2018). However, as the IEA points out, this is only possible where the full range of technical capabilities are present and adequate market incentives exist[3].

What this illustrates is that technologies are adopted for a variety of reasons, and often not with network management in mind (see also e.g., Lau et al., 2020). Even when it comes to energy-related technologies such as solar PV panels, their potential to contribute to system management can only be exploited if they are configured and managed in a way that allows for this. As such, **we argue that DERs should be defined by the value they offer energy systems – rather than their *potential* to offer value if used or configured in a certain way.** Emphasising the value that a given technology or activity offers means that it qualifies as a DER only if this value can be realised by the energy system. Placing emphasis on value also positions the term firmly within a managerial understanding of power systems. We identify two core values associated with DERs: generating (renewable) electricity and contributing to system balancing. In practice, DERs need to be visible and controllable if their value for system balancing is to be realised.

1.2 DERs and energy communities

Reviewing existing literature on "distributed energy resource(s)" and "energy community / communities" suggests these terms are representative of two contrasting approaches to energy systems research (Moroni et al., 2019): one techno-economic, drawing on engineering and computer sciences, and one social scientific. A quick search of Google Scholar illustrates that the term DER is frequently used by studies concerned with technical and economic optimisation and design problems[4]. In this context, energy communities tend to be defined in technical terms: for example, community may be used to refer to the aggregation of resources owned by a group of neighbours (Hansen et al., 2021).

On the other hand, studies considering energy communities from a social scientific perspective do not commonly employ the DER terminology or framing. If the term is used, this is usually not part of the study's main focus, i.e., it is used as a catch-all term for technologies on the distribution network

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[3] https://www.iea.org/reports/introduction-to-system-integration-of-renewables/technology-options

[4] A search for "*distributed energy resource*" *AND community AND energy* in Google Scholar seemingly did not uncover any social scientific studies, or studies focused on the community element. (Based on scanning of titles). This was the same for "*distributed energy resource*" *AND "energy community"*.

(illustrating the issue outlined in the preceding section). Where categories of DERs, like distributed generation or distributed energy storage, are employed within studies, analysis is normally limited to discussion of the primary purpose of a technology. For example, the term distributed generation may be used to refer to renewable generation technologies but without reference to how these technologies relate to the (management of the) energy system. As such, considering DERs in relation to energy communities raises a similar issue to that of the fridge and car: energy communities can only offer DERs if configured accordingly.

Although communities are not an explicit element of the DER concept, they can support the development of integrated systems, which can help optimise network operation (locally) (Moroni et al., 2019; Koirala et al., 2016). The concept (and practice) of energy communities may therefore enhance considerations of DERs (Moroni et al., 2019). An example is the idea of community Virtual Power Plants (VPPs) which in theory allows communities to explore alternative ways of organising energy systems in their community, according to community values (Mourik et al., 2019). In one recent study, van Summeren et al. (2020) draw on the concept of DERs to define VPPs as ICT-based applications that "[aggregate] DERs in a coordinated portfolio" (p.2). They conceptualise community VPPs as

> *"a portfolio of DER aggregated and coordinated by an ICT-based control system, adopted by a (place- and/or interest- based) network of people who collectively perform a certain role in the energy system. What makes it community based is not only the involvement of a community, but also the community-logic under which it operates".*

In line with the discussion in the previous section, the DER framing foregrounds the community's role in (managing) the energy system. Conversely, one may argue that the DER framing only becomes relevant here, in a minority of EC business models, because the primary purpose of technologies/ activities in the community VPP model is concerned with the management of the wider energy system (Barnes and Hansen, forthcoming). Building on this fruitful application of the DER lens to the study of ECs, this paper explores the general usefulness of combining the two concepts.

Energy communities are about owning, operating and participating in energy systems in new ways that leverage the benefits of collective action. The DER framing, on the other hand, is concerned with the optimal management of energy systems. However, as discussed in this paper, the term is often applied indiscriminately to a very broad range of scenarios and lacks a clear definition. Use of the term often obfuscates rather than clarifies or enhances understanding. As a result, its utility in the context of emergent activity by energy communities remains unclear. Addressing this knowledge gap, in the remainder of this paper, we explore if or how the notion of DERs can be usefully applied to ECs.

2 Applying the DER lens to NEWCOMERS case studies

2.1 Approach to understanding DERs in the context of our case studies

Building on the above, the following approach was taken to assessing the current and future utilisation of DERs in the NEWCOMERS case studies. In this working paper, **DERs are conceived as combinations of energy technologies and activities, located on or below distribution network levels, that are used to provide core operational services to energy systems such as generation or flexibility**. DERs may involve generation (DG), storage (DES) or demand side management (DSM). This, we suggest, is a system engineering or system operator view of energy systems and their operation, that may or may not be shared by EC practitioners.

The benefit of employing this view is twofold. First, it highlights the role and value of different EC business models to the operation of energy systems. Second, it provides a system engineering view of how existing EC business models may be extended, to provide additional services to energy systems. This viewpoint also has clear limitations. For instance, it reveals little about the social and economic viability of such extensions.

To assess the current and future (utilisation of) technologies and activities as DERs in NEWCOMERS case studies, we draw on our understanding of the case studies, i.e., their activities, technologies etc. (based on D4.2 and D4.4) as well as input from partners regarding DERs in the vicinity of case studies and/or communities' plans. Based on this, we outline current and potential future DERs offered by the case study communities, using the differentiation between DG, DES and DR as a point of reference.

2.2 DERs in NEWCOMERS case studies

2.2.1 Project Z, Germany

This energy community is a pilot project developed by a multi-national energy company based in Germany. It trials the use of peer-to-peer energy trading in two neighbourhoods in North Rhine Westphalia in Germany using blockchain technology to facilitate trading (and thereby retain locally generated electricity). Households are connected via the public distribution network (within a virtual private network). The trial currently comprises about 30 households, and a total of 12 solar PV installations (60 kW) and six battery storage systems (30 kWh). Because the trial uses these to facilitate peer-to-peer trading, the project can be said to feature DG and DES. The resource Project Z offers is the activity (not an asset) of managing demand and supply more effectively through trading. The generation assets were already installed, they would exist even if the Project Z system did not. Project Z participants have access to an online platform that tracks energy usage within the community. Although not presently intended for this purpose, the platform could be used to incentivise participants to shift their electricity use to peak generation times, i.e., for DR. In the future, parent utility hopes to double the capacity of solar generation and battery storage systems in the trial. This would also expand the resource the EC can provide for the system, i.e., increased flexibility.

2.2.2 sonnenCommunity, Germany

Sonnen is a battery manufacturer and energy services company. The sonnenCommunity comprises all owners of sonnen storage products and generation assets (solar PV), as well as people without renewable assets of their own but subscribed to a sonnen tariff. Information on the cumulative capacity of these resources is not currently available. The community has over 40,000 members. The community provides a means for sonnen to facilitate the sharing of energy amongst members.

Sonnen use these DG and DES resources to form a VPP and provide flexibility services to network operators. Sonnen are licensed to offer and supply balancing energy (= control reserve) to network operators. Specifically, they participate in the market for frequency containment reserves (= primary control reserve, "Primärregelenergie"). In addition, they offer redispatch services (in collaboration with TenneT, a transmission system operator, and IBM) using community members' storage resources and blockchain technology. Sonnen also provide additional storage resources by offering an EV car share service to members of the sonnenCommunity. The Sonnen community therefore provides a variety of services to the grid including renewable generation (through DG) and system balancing (via DES and DSM), and is exploring ways to advance the services it offers.

2.2.3 Zuiderlicht, The Netherlands

Zuiderlicht aims to connect Amsterdam residents who do not have access to roof space for solar PV with available roof space on large (public) buildings, such as schools. The cooperative facilitates DG projects in Amsterdam with the primary objective of making renewable generation available to everyone. While most projects focus on solar PV, the cooperative's project page currently also lists two wind energy projects (as of July 2021). Zuiderlicht promotes and facilitates the uptake of renewable generation assets and thereby enables increased self-consumption onsite and behind the meter, and – in a limited number of cases supported by the Dutch reduced tax scheme – in front of the meter. Their business model relies on virtual net metering which, in effect, uses the public grid for storage of electricity not consumed at the time of generation. Arrangements with the licensed supplier for net metering and management of (surplus) electricity are also essential.

A 2020 report estimated that there were

- approximately 60-70 MW of solar PV capacity, the majority of which were small-scale installations;
- and 38 wind turbines with a combined capacity of 66 MW (128 GWh)

installed in Amsterdam in 2019[5]. The same report estimates about 400 MW (380 GWh) of solar and 127 MW (283 GWh) of wind energy will have been realized by 2030. With its current model, Zuiderlicht could/will contribute to this uptake. Smart metering and half-hourly settlement could further advance the model and create the basis for providing DSM to the Dutch energy system. Zuiderlicht has an active community of participants. This could be leveraged to expand to DES or to promote energy efficiency as a form of DSM. Lastly, the community may be able to expand and adapt its model of shared investment to include energy storage (e.g., a community/ neighbourhood battery).

2.2.4 Buurtmolen Herbaijum and Buurtmolen Tzum, The Netherlands

Buurtmolen (Dutch for neighbourhood mill) Herbaijum and Buurtmolen Tzum are two wind energy communities in the Dutch province of Frysland. Both centre around the generation of wind energy and its collective consumption by the local communities. The Herbaijum turbine has a capacity of 900 KW and is 35m high[6]. The Tzum turbine will be slightly larger, with a capacity of 1,000 kW (to produce on average 2,800,000 kWh annually) and a height of 46m[7]. The primary resource provided by each Buurtmolen project to the energy system is thus distributed generation.

The collective consumption of electricity generated by these turbines is enabled by regulation that promotes the uptake of renewables via a tax rebate. In addition, the communities rely on their cooperation with a licensed supplier, turbine developers, and landowners. The Buurtmolen models do not lend themselves to integration of other DERs. The main mechanism by which these projects may contribute to energy system operation is by serving as demonstration projects of wind energy generation (DG) in a community setting, thereby enabling other communities to set up similar schemes.

2.2.5 GEN-I Jesenice, Slovenia

This case study energy community was created with the aim of reducing utility bills for residents of an apartment building, and empowering residents by giving them more control over their energy-related choices and decision-making. The building has two rooftop solar systems with a combined total capacity of 37 kW. The larger system (21.6 KWp) supplies electricity to individual apartments, while the smaller one (15.1 kWp) supplies electricity to communal areas and a heat pump. The apartment building achieves about 50% self-sufficiency over the year. The primary resource provided by GEN-I Jesenice to the energy system is DG. The model uses net metering, meaning the public grid

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[5] https://energieregionhz.nl/app/uploads/2020/02/DEF-Concept-RES-Amsterdam_mail.pdf
[6] https://www.duurzaaminvesteren.nl/Projecten/Propositiedetail/PropositionID/61/Title/qurrent-buurtmolen-herbaijum
[7] https://buurtmolentzum.nl/zo-werkt-het/

serves as storage. The involvement of GEN-I and its solar subsidiary GEN-I Sonce are essential to the operation of the model.

According to the building manager, a 30kW upgrade of the EC's PV system was planned in spring 2020 but has been postponed due to the Covid-19 pandemic. EV charging points are also planned for the EC, as well as for another nearby apartment building. Installation has been delayed by the Covid-19 pandemic. A 60-70 kW solar PV system is planned for a neighbouring apartment building (200m away), that will follow the GEN-I Jesenice model. This means that the EC is having an impact by serving as demonstrator. Having proved viable, the model now allows more DG to be installed in the area. If residents are interested in investing, integration of battery storage into the existing system could serve as an additional resource (DES) for the distribution system. Depending on the extent to which residents are engaged and interested, energy efficiency could be promoted through education and/or smart use of appliances, generating further benefits (DSM).

2.2.6 ERiC, Italy

The ERiC project is concerned with increasing the uptake of solar PV by guiding homeowners through the process of purchasing, installing and operating rooftop PV. Practically, the team provide expert advice and education, and facilitate purchasing groups. In this way, the project has enabled approximately 600 households in Sicily to install rooftop solar PV systems. ERiC's impact on the local energy system is increased distributed generation. Given sufficient demand, the model could be expanded to include household battery storage. This would likely require additional educational and administrative efforts, to inform people of the advantages of home energy storage systems, as well as additional agreements with suppliers to enable discounts through purchasing groups.

2.2.7 SO_EN Social Housing, Italy

Solidarity & Energy Social Housing aims to provide an equitable means of accessing electricity from renewable sources of generation to socially disadvantaged tenants. The transdisciplinary pilot project is integrating a solar PV and battery storage system into a newly built apartment building. The primary DERs offered by the EC are DG and DES. The model relies on a 'social algorithm' for equitable accounting that utilises information on residents' socio-economic background. If the model is shown to be viable, it may be applied elsewhere. Given the experimental set-up, there may also be scope to test a range of DSM measures. The EC could also expand its resource offering by increasing the capacity of its solar PV and/or battery storage installations or adding an EV charging point.

2.2.8 Energy Local, United Kingdom

The Energy Local model links renewable energy generators and consumers with the aim of creating fairer prices for the local production and consumption of renewable-based electricity. Energy Local Clubs may be based on purpose-built renewable generation plants or existing ones. Through this, and the matching of local demand and supply, it helps support the efficiency of networks locally.

Energy Local offers DSM, plus increased DG if more renewable capacity is added. Using smart meters, consumer access devices that link smart meter data with in-home displays or other devices, and a 'match tariff', the model helps shift demand to match times of local (renewable) generation. The model relies on the relationship with a licensed supplier who supplies additional electricity needed and manages billing; and the legal structure of a cooperative formed by local generators and households (Energy Local Clubs).

Energy Local is continuously growing the resources it offers the energy system by developing more Energy Local Clubs. Additional DG capacity could be developed by increasing the capacity of existing plants, or by adding plants, privately or collectively (e.g., individual households installing solar PV).

2.2.9 Dalby Solby, Sweden

Dalby Solby is a sustainability-driven community and housing association. A solar PV system provides electricity for common spaces. In both 2018 and 2019, Dalby Solby's solar PV system generated 36 470 kWh (2019) of electricity. About 53.5% (19,527 kWh) of this was sold, and the remainder utilized by the community. In addition, the community procures wind energy from a nearby wind power plant (Vindela power plant, located between Lund and Dalby). The community owns 30 shares in this plant which corresponds to about 28,300 kWh of electricity annually. Some residents had heat pumps installed in their dwellings. As such, the community's main DER is DG, with the potential to use the heat pumps to provide some flexibility service to the network via automated load control.

In terms of DES, there is one EV charging point in the village. The community is developing further charging points and associated infrastructure as part of an EU project, with additional solar cells on their carports. The planned system also includes battery storage (size to be determined), which represents an additional resource the community could offer the energy system in the future.

3 Discussion

Having applied the DER framing to our 10 NEWCOMERS case studies, we now discuss the results before turning to reflect on the utility of the approach more broadly.

3.1 DERs in our case studies

In terms of the three commonly referenced categories of DERs (DG, DES, DSM), evaluation of the case studies yields a fairly simple picture. Distributed generation based on renewable sources is the most prominent DER currently provided to energy systems. The largest contribution to power networks that our case studies make is thus in increasing the amount of renewably generated electricity from distributed sources and reducing demand for grid-sourced electricity. None of the case study communities are yet employing DG for the purposes of system balancing.

DES is part of only a few case studies (SO_EN, sonnenCommunity, Project Z). In terms of our communities' business models, DES could be integrated in others as well. For example, in the case of ERiC or GEN-I Jesenice, the general operational model could be expanded to include storage applications. Whether to include DES in these cases in the future appears to be less a question of whether the system would value it than a question of available funding and the estimated return on investment.

It also appears that DSM remains an under-exploited resource, with Energy Local and sonnenCommunity the only case studies explicitly offering this kind of DER to system management. One reason for this may be that DSM requires advanced metering infrastructure and further user engagement. It may be more difficult to understand, develop and implement. Another reason may be that there appear to be no markets for it: ECs have few incentives (e.g., financial) for offering demand-side resources (Mourik et al., 2019; Pownell et al., 2021). One example to the contrary is the case of Energy Local, where DSM is rewarded by reduced imbalance costs for the licensed incumbent supplier (a vital partner). The Energy Local model was designed by practitioners with strong knowledge about what was good for the system overall.

3.2 Reflection on the DER approach

Another explanation for the lack of DSM in the case studies is the misalignment of the DER and EC logics. **While the DER logic is primarily interested in the value certain assets or activities create for energy systems, the logic behind many ECs typically focusses on creating value for a community.** The kinds of DERs identified in the case studies highlight this. The most prominent DER identified in the case studies is DG which has the perceived direct benefit of

supplying communities with cleaner, renewably sourced, often cheaper electricity. DES is a means for individuals or communities to consume larger portions of their renewably generated electricity. In the case of DSM however, it is difficult to discern any benefits from a community perspective. One may argue that benefits for the energy system outweigh those to the community. Similarly, one may argue that most ECs do not aim to replace existing systems of provision (Barnes and Hansen, forthcoming; Nolden et al., 2020), and therefore do not have to deal with questions pertaining to network management. From a regulatory standpoint, too, there are currently few, if any, financial incentives for ECs to optimise their operational models from a systems point of view.

There are exceptions to this: cases where the EC was developed by actors with expertise and/or interest in energy system operation. Energy Local and the sonnenCommunity (where DSM is used), and Project Z engage to some extent with the distribution network and, in the case of sonnenCommunity, with the transmission grid. Project Z, for example, is run by a local network operator and therefore has an interest in improving network operations. Sonnen explicitly want to drive system change and have set up their virtual community for this purpose.

Examining ECs as providing resources for system management raises an important political question: to what extent should ECs be expected to engage with system management? Certainly, any expectation that ECs should take on a new mindset and purpose – system management – is a 'big ask'. This is particularly the case when we consider that balancing responsibility typically resides with a very limited number of actors within any system at present. The primary motivation for small ECs, whose BM operates behind the meter, to employ the system management thinking encouraged within the DER lens, would likely be to reduce energy costs. Optimal reductions of EC costs at the individual level may however not result in optimal solutions at distribution network or grid level. For instance, the incorporation of small onsite batteries to reduce grid spillage and make ECs more independent may be of little benefit to the transmission system operator at a time when it is useful to the network operator, and vice versa. For most ECs then, it makes sense to think about a variety of new services that they might be able to deliver to energy systems in the future, in dialogue with their network operator as this is likely to be the primary actor with responsibility for managing decentralised energy systems.

Applying the DER framing to our case studies presented a practical challenge, namely identifying the kind of information needed for the qualitative assessment and communicating this to partners. Available information varied across cases. While this may partly be due to the roles/positions of contact persons within projects and confidentiality issues (e.g., asking a retailer or a community member for data), it also suggests, once again, that the DER framing is not in line with how ECs tend to think about what they do, and what their value is. The information is not readily available because it has not been considered (from this angle).

Another issue in qualitatively assessing DERs in the context of energy communities is how to treat individual versus collective resource contributions. For example, Project Z features solar PV which existed prior to the community, already serving as a resource for renewable generation. One may therefore argue that DG in this case is not offered by the community as a collective, nor is it the result of a community effort (the resource would still exist even if the community did not). On the other hand, its existence does affect the overall resource the community offers – system flexibility – by affecting amounts of electricity traded. As energy communities continue to develop, their capacity to provide collective system offerings is likely to gain in importance. Knowing how and under what conditions collective resource contributions can be developed is likely to be a fruitful and important line of future inquiry.

Our evaluation also revealed that assessing future resources is a difficult undertaking. A resource is only viable or capable in certain circumstances; system and resource need to be in alignment for one to benefit the other. Quantitative details on technical performance of individual technologies and strategies are very difficult to obtain (often even for the community itself) and would only be useful in the context of a comprehensive quantitative assessment. In the end, the question of how models may be expanded to deliver more services to energy systems is not so much a question of how to incorporate more DERs but more one of business model design and development. A more suitable question may be: what additional services might ECs provide to energy systems with relatively minor modifications? To advance understanding, future research should examine the interplay between common system needs and the types of (system) value ECs can easily provide, and the means through which needs and propositions can be vocalised and actioned.

While the DER and EC lenses are contrasting ways of thinking about energy systems, they are not mutually exclusive and may even be complementary. Both are concerned with lower carbon and decentralised (or even polycentric) energy systems. While one addresses views this issue in terms of systems engineering, the other focusses on collective action people can take in energy systems. Examining the intersection of DERs and ECs highlights that energy systems create and require multiple types of value, including for networks and people. One might argue that in addressing the low carbon transition, it would be useful to encourage a middle ground view that recognises the potential contributions of community-based activities as a resource for energy system management in its own right (there are capabilities and possibilities at the collective level that do not exist at the individual level); and at the same time, recognises that to unlock this potential, benefits must also accrue to the community. Vice versa, there may be some ground in more actively educating and incentivising communities to consider energy system benefits.

3.3 Conclusion

'Distributed energy resource' is a popular concept in discussions of energy system change: Having emerged from historical understanding of fuel resources like coal and oil, the term DER has been broadened to include a variety of technologies and activities that both generate power and help balance contemporary energy systems. Building on existing discourse, we defined DERs as technologies and activities that are located on the distribution network, and that contribute to establishing and/or managing low-carbon, renewables-based energy systems. We have further argued that the concept is only useful if another critical qualification is made: a DER must have the *capability* to contribute to energy system operation. This sets our definition apart from the majority of existing applications which confound *actual capability* with *theoretical potential*. Failing to make this distinction renders the DER concept futile, making its meaning synonymous with 'energy-related kit at the grid edge'.

In this working paper we applied this revised understanding of DERs lens to the 10 NEWCOMERS case studies. This exploration showed that qualitative applications of the concept yield very little practical insight; and that the DER framing does not align with how ECs think about their activities. This may be because ECs typically do not actively engage with networks and have no responsibility for balancing or operating energy systems. They lack incentives to take on a whole-system view of their own operations.

Conceptually, the DER and EC perspectives represent contrasting ways of thinking about energy systems. The greatest value of combining them may lie in the way it balances the scale: considering what energy communities do through a DER lens reintroduces the possibility of non-technical value being created by energy technologies and activities. For those advocating the importance of ECs in operating future energy systems, it indicates that the way this may occur from an engineering point of

view requires further consideration. Based on our exploration of the DER concept in this paper, it is however questionable if a DER lens is the right one to advance such endeavours.

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