Towards practical typology of energy communities: main differentiating elements and examples of promising implementations

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Abstract

For developing energy communities, this paper provides a typology based on regulatory, contractual and commercial aspects. The main classification elements used in the paper are: use of the public grid, geographical proximity, property boundary crossing, individual/collective contracts and customer type (industrial/residential or commercial). These elements are used to distinguish six energy community types, which have different business model opportunities. With European examples, the typology helps to analyse the future pathways of energy communities by making their differences concrete and distinguishable.

1 Introduction

Energy communities (ECs) constitute a new type of energy system actor and have been a timely discussion and research topic during recent years. While enabling technologies, such as real-time IT and measurement systems are maturing, ECs aim to promote small-scale renewable generation and empower citizens to become active prosumers. ECs' widespread emergence means a paradigm shift both in energy system's technical operation and business models and in the role of customers. The challenge of the upcoming years is to create new business models and regulations that accommodate and incentivise ECs in a way that supports general energy policy targets: ecological sustainability, cost-efficiency and security of supply. The development is still in its infancy and there are no distinct models that could be seen as clearly the winners of the movement. ECs include many different activities: energy production, distribution, aggregation, energy sharing, energy storing, demand response, electric vehicle charging services or energy efficiency services. By combining these activities, ECs can help in enhancing energy efficiency through sector coupling.

In general, emerging fields hold space for exploration, innovation and creativity. However, a growth of a field requires mode of exploitation, efficiency and standardisation. Classification is a steppingstone towards business model standardisation, which enables efficiency gains and routinized tasks. Better theorization of various EC models helps in generalising different procedures, benefits and challenges related to them. A better understanding of different models and how they relate to each other would help all parties involved in EC diffusion: community developers and operators, regulators, technology providers, customers, network operators and energy market actors. For instance, community developers could more easily compare alternatives and start from more standardised options. The regulators could define more explicit rules and monitoring for different models. Distribution system operators (DSOs) could streamline and systematise their processes according to EC type instead of case-by-case arrangements. For the aim of creating a classification for different ECs, the research question of this paper is: *"What are the most important distinguishing properties of energy communities and how they could be categorised in a meaningful way?"*

1.1. Related European directives

Several directives from the clean energy package introduced by the European Commission in 2019 handle the different ECs. The new Renewables Directive 2018/2001 (REDII) defines renewable energy communities (RECs). They are non-profit legal entities for producing, storing, selling and sharing renewable energy. The new Directive for Internal market for electricity (IMDII) defines citizen energy communities (CECs), which are close to RECs but are not restricted to the use of renewable energy or location and can also operate grid infrastructure. Yet, CECs are limited to operating in the electricity sector. REDII also includes the directive of jointly acting renewables self-consumers, which refer to collective self-consumption within the same building or multi-apartment block.

1.2. Classification method

This paper is based on previous literature and argued properties that are found relevant. Typologies are reasoned by deduction and hold monothetic groupings, which means that members of the group must possess certain characteristics. Our steps (following [1]) when conducting the classification were:

- *Stating the objective*: categorising ECs with concrete and tangible characteristics. The concept of ECs is so vague that without precise conceptualisation, meaningful discussions are challenging. Partly the reason was internal to our cross-disciplinary ProCemPlus research project [2], which gained from having a common language and concepts.
- *Identify the necessary functions and characteristics*: literature on previous classifications, EC barriers, regulation (e.g. [3], [4]) was used.
- *Select classification philosophy*: abduction (i.e. comparing existing comparisons from literature to real-world examples)
- *Identify classification principles*: monothetic groups: only necessary characteristics of distinctive ECs. Regulation and relation to the existing role of the DSO and retailers were highlighted. Therefore, geographical aspects related to the grid, ownership structures and customer contracts were used as distinctive characteristics (e.g. resource control and internal ownership structures were not included in the categorisation since they are linked to all EC types).
- *Procedure consistent to principles*: we conducted a tree-diagram and went back-and-forth on the important elements by comparing them with real-world examples. Ideas were shared with industry actors and comments were asked on the relevance of the concepts.

1.3. Previous classifications

Besides the regulatory categories described in the directives of the Clean Energy Package, there are several different ways of categorising ECs. The pioneers of EC research, Walker and Devine-Wright divided ECs by their process and outcome dimensions [5]. The process can be either open & participatory or closed & institutional. Some papers make distinctions by ECs' business models. [6] divides ECs into local renewable energy generation and supply; innovative contracting and community-based products (including e-mobility; community energy storage; peer-to-peer energy trading platforms; community energy aggregator business models. [7] divides ECs by their activity to ones with self-consumption and ones for electricity export.

According to [8], communities can be place-based communities or non-place-based communities with one or multiple purposes. Gui and MacGill [9] divide EC types according to their governance model as centralised, distributed and decentralised models and Parag and Sovacool in a similar fashion to peer-to-peer model, prosumer-to-grid model and organised prosumer groups [10]. Many papers on community energy emphasise how local ownership increases acceptance of renewable energy and therefore the ownership model is also a classifying element of ECs. For instance, in the case of microgrids, where ownership is a challenging question, choices are: DSO model, hybrid model and customer or third-party ownership [11].

Some papers use several characteristics. A recent analysis on the European legislation divides the main elements of ECs into: types of energy; generation capacity limits; local electricity grid tariffs; organisational form; physical expansion, proximity and governance; and participation of vulnerable consumers [12]. Virtual power plants (VPPs) can be categorised by community's needs and motivations, DER portfolio, control architecture and role in the energy system [13].

2 Classification elements

This chapter describes the chosen elements that distinguish ECs from one to another. The elements are organised hierarchically in a decision tree (see Fig.1.) The hierarchy forms sub-groups which have different distinguishing elements between each other.

Public grid usage

Our principal distinction is between grid-owning ECs and virtual ECs. ECs with their own grid refer mainly to jointly acting renewable self-consumers, whose business model is similar to individual prosumers. In other words, they can save network tariffs and also taxes at a nationally specified level with self-consumption behind the DSO's main electricity energy meter. In essence, within a grid-owning community, prosumers have the right to consume, store and sell the electricity (e.g. via power purchase agreement) that has been produced in their premises. Also, grid-owning ECs may include also larger areas in some more exceptional cases, such as closed distribution networks (CDNs).

On the contrary, virtual ECs do not typically offer the opportunity to save network costs or taxes via collective self-consumption, even though it may be incentivised. In other words, virtual ECs' relationship with the DSO remains similar to the usual arrangement.

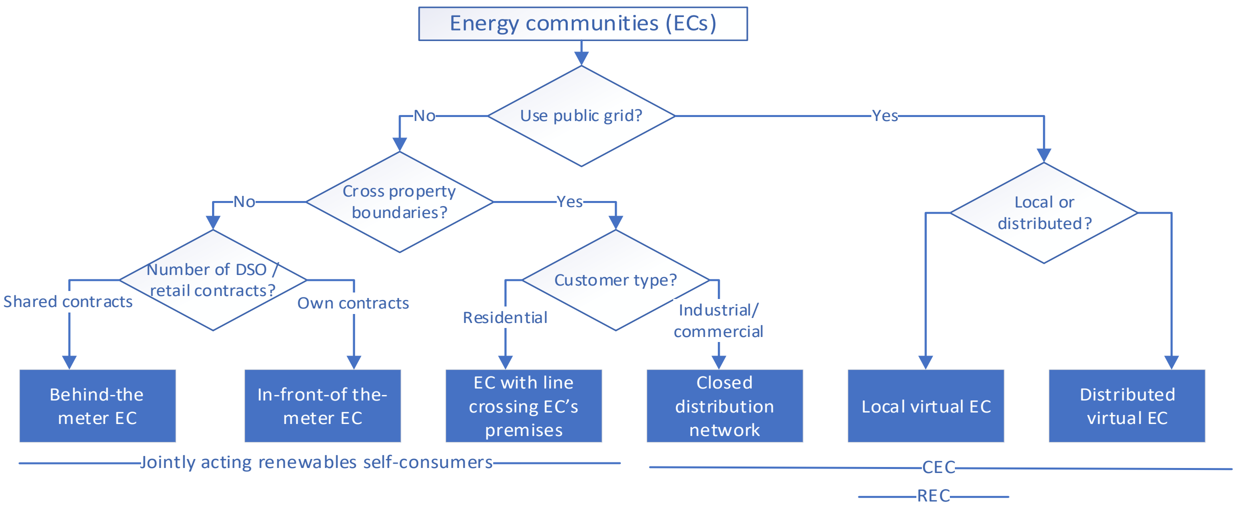

Figure 1. Decision-tree on the EC typology and related EU directives

Local vs. distributed virtual EC

Virtual ECs can be dispersed to various locations, yet, they can also be local. In the EU directives, these ECs refer to CECs and RECs, of which the latter ones are considered local. In local virtual ECs, self-consumption happens in a broader area than an apartment building and is typically less remunerated than in grid-owning ECs. Besides collective self-consumption, local virtual communities can include various business models ranging from offering flexibility services to the grid or energy markets to collectively owned power production. The distributed virtual ECs can be compared to VPPs and can be dispersed nation-wide. In general, local ECs are built around social cohesion and community values, whereas VPPs are based on acquiring resources and scaling the business model as widespread as possible.

Inside vs. crossing property boundaries

This distinction is required for clarifying the differences within grid-owning ECs. Usually, property boundaries come from distinctions in the land ownership and affect how connection points to the public grid are located. For maintaining the monopoly of DSOs, there needs to be a limitation on the area of collective self-consumption. The REDII directive notes "same building or multi-apartment blocks" as the area of collective self-consumption. There may be national differences in how multi-apartment blocks are defined.

There is some flexibility on this property boundary restriction. There may become a contradiction with the requirement of having a production plant within one's own property area. There may be a better spot for a solar plant or micro-CHP (combined heat & power) plant nearby the property or a road crosses the condominium. Similarly, the consumption (e.g. electric vehicles) may situate next to the property boundaries. Therefore, the regulator may allow a power line across property boundaries in some cases.

In general, building parallel private networks is considered unfavourable [4], yet, grid-owning ECs including several different property owners may be possible CECs according to the IMDII as it states that member states are allowed to grant CECs the right to manage distribution networks. They may become DSOs under the general rules concerning DSOs or as CDNs. There are several requirements for CDNs, most notably that they are composed of industrial customers, commercial customers or shared services, but not households ("Customer type" in Fig. 1). Essentially, these ECs may form microgrids that can operate in island-mode as well as part of the public grid.

Single/multiple contracts with DSO and retailers

With the upcoming regulations on jointly acting renewable self-consumers, ECs can be formed either behind or in-front-of the meter. The behind-the-meter model has been possible also before, but due to increasingly affordable metering, solar plants and battery technologies, that model is also gaining ground. In behind-the-meter systems, the EC members share a common retail contract and distribution network contract. The local self-consumption is allocated with sub-meters provided by a third-party service provider. An EC (e.g. housing company) can also benefit from better bargaining power when negotiating their shared electricity contract with a retailer.

The challenge in forming a behind-the-meter community is related to collective decision-making: for instance, in a Finnish housing company, there needs to be a uniform willingness among the community to create a behind-the-meter community. Besides, leaving the EC should be possible. The Citiworks case (European Court of Justice: Case C-439/06) proved that customers' freedom of choice to choose a retailer. In that case, the DSO installs their meter and costs are burdened to the customer. The customer should also be well-informed and able to know the price of electricity.

3 Energy community types, business models and country examples

3.1. In-front-of-the-meter EC within property boundaries

This EC is the most typical model for enabling collective self-consumption in an apartment building complex. It can also be a campus, shopping centre, an office building if it is located within one property. The EC informs the DSO the value division model used to divide the production and storage outputs to each EC member. Billing is conducted by the DSO and the retailer(s). DSOs have a significant role in handling data.

Customers keep their retail contracts and own DSO contracts and meters but can join in an EC as well. In this way, they also maintain their rights as customers to change their retailer. The benefit of self-consumption is often savings on the electricity taxes and network tariffs. Yet, there may be a difference in whether they are saved completely by the customers or only partly. Germany's Mieterstrom model and Finland's collective self-consumption model are examples of this arrangement [12].

3.2. Behind-the-meter EC within property boundaries

In this model, the EC has one contract with an energy retailer and DSO. The end-customers do not have DSO's smart meters, yet they can have sub-meters provided by a service company. The EC organises customers' billing according to a chosen allocation method. As end-customers give up their personal retail contracts, this model contradicts the customer's freedom of choice. Yet, it is a used model in rental agreements, for example. An EC (e.g. housing company) can, on the other hand, benefit from better bargaining power when negotiating their shared electricity contract with a retailer.

3.3. EC crossing property boundaries

The business models of this model are similar to previous EC models, the only difference is that the generation units exist on another property and possible security issues have to be taken care of. This solution follows the article on Direct lines in IMDII.

3.3. Closed Distribution Network

In principle, residential ECs with own distribution networks are rare. Islands and other remote locations have such systems, as well as some municipalities like Schönau in Germany. In Switzerland (a non-EU member), a neighbourhood (i.e. houses next to each other with no public land between them, behind one point of common coupling) can form a consortium that can operate behind one DSO meter [12]. For their rarity in the EU, this paper classifies CDN as another boundary-crossing EC. CDNs are for industrial and commercial businesses and potentially, they can include all business models that other ECs have.

3.4. Local virtual EC

Some countries have decided to implement collective self-consumption so that it does not have restrictions related to property boundaries. Also, the effect on network tariffs and taxes is less significant compared to jointly acting renewables self-consumers. In many cases, the financial benefits are cost-reflective to the benefits that the EC can produce for the DSO [12] (e.g. by reducing peak demand). Local virtual ECs can include a variety of business models, ranging from local flexibility markets to guaranteeing security of supply with island mode capability.

In France, the perimeter of collective self-consumption is 2 km and there are specific tariffs that incentivise collective self-consumption with slightly cheaper network tariffs; in Italy, the area is limited to the same MV/LV cabin; in Spain, it is set to 500 m and the local network tariff is under preparation; in the Netherlands, the perimeter is the postal code area and self-consumer electricity is remunerated with a 0,11 €/kWh tax refund; and in Wallonia, it is a "technically, socially environmentally and economically optimal" area, which will be specified later on [12], [14]. Alternatively, the geographical proximity requirement may be set by the grid topology.

3.5. Distributed virtual EC

In this kind of EC, distribution fees and taxes are typically paid even if the production is small-scale. Yet, it is possible to create trading between entities via a digital platform provided by an energy retailer. It is used, for example, by Powerpeers in the Netherlands and Sonnen Community in Germany. Finland plans a model that enables end-users' energy consumption netting from a distant production plant [12]. It can also be a VPP that aggregates different production and demand-side resources and participates in different energy and flexibility markets. As they are formed of distributed customers, there is no possibility to offer local grid services.

4 Discussion & Conclusions

The aim of this paper was to answer to the research question *"What are the most important distinguishing properties of energy communities and how they could be categorised in a meaningful way?"* The paper made distinctions between EC types by mirroring them to existing energy regime and how ECs change its prevailing rules. The most geographically proximate model is constructed within property boundaries under the directive of jointly acting renewables self-consumers. Here, a behind-the-meter EC has often been possible also before, but new directives ensure that collective self-consumption also in-front-of the meter is possible. Implementation of ECs crossing property boundaries requires more discussion with the local DSOs. ECs with their own grid represent more significant changes to the existing regime as they shift DSOs' tasks to the EC. Local virtual ECs are close to ECs in-front-of the-meter, yet the benefits of self-consumption are typically less significant. Virtual distributed ECs include VPPs and peer-to-peer markets backed by an energy supplier.

The proposed typology helps to analyse future pathways of different types of ECs in a more structured manner. One promising perspective is the one of transaction cost economics [15]. Transaction costs can be divided into search and information costs, bargaining and decision costs, and policing and enforcement costs [16]. The search and information costs refer to the customer determining the availability of the chosen product, the best price for it, whereas bargaining and decision costs are related to the drawing up of the contract and settling on a price with the provider. Policing and enforcement costs are related to the laws governing both parties of the agreement that ensure the rights of the parties involved [16]. Individual customers experience different transaction costs depending on the EC type. The bargaining and decision costs can be relatively high especially in the CDN model as the contracts and prices have to be drawn interdependences between EC members in mind (e.g. risk of customers leaving the EC). However, flexibility in contracts can simplify demand response and the selection and switching between energy forms. This could enable better sharing of resources and creation of synergies via sector coupling.

The analysis of transaction costs economics from the perspective of ECs and their effects on the formation of ECs would offer a fruitful avenue for future research. Implications would be seen especially in policy planning, which has different effects on ECs depending on the policy level and EC type. As a cross-sectoral entity, ECs affect many policy areas ranging from land use planning to transportation policies.

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