Forming Collective Self-Consumption Models: How the end user sees them?

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Abstract

The collective self-consumption model has significant potential to diffuse and some pilots already exist, yet the models on value sharing are not widely researched. This paper compares three different value sharing methods in energy communities and what kind of customer proposition they represent: static model, which provides a simple, cost-efficient model for communities with a modest amount of DERs; a dynamic model that incentivises customers to engage in demand response; and local energy markets (LEMs) that enable customer choice, creation of local synergies between community members and make the community open and compatible for 3rd party service providers with whom the customers may want to make own contracts.

1. Introduction

The profitability of collective self-consumption models depends on the self-consumption ratio and value sharing methods can be used to incentivise actions that increase it. Demand-side distributed energy resources (DERs) such as electric boilers, air-conditioners and electric vehicles (EVs) can be used to match the production of solar panels or micro-CHP (combined heat and power) plants. Also energy storages can be used to balance production and consumption. There are different possibilities for the technical and financial arrangements for collective self-consumption depending on the institutional environment [1]. In this paper, the assumption is that all loads and all households and small businesses in an multi-apartment block participate in self-consumption.

Collective self-consumption models are not only technical innovations but also social innovations, which brings new challenges for community decision-making and governance [2]. There is a need for a more detailed analysis on how the benefits of shared DERs are divided between owner-occupiers, landlords, and tenants of the apartments [1]. Whereas simple cost-benefit allocation methods such as equal investments and benefits sound compelling, they have limits and do not consider community members' different resources, engagement levels or efforts in creating value with the community-owned assets [3].

2. Value sharing methods in collective self-consumption

In the new Renewable Energy Directive (REDII) from 2019, collective self-consumption refers to "jointly acting renewables self-consumers". They are prosumers who are located in the same building or multi-apartment block. Member states have to define more clearly the boundaries of the area where self-consumption is possible. Prosumers are allowed to "generate renewable energy, including for their own consumption, store and sell their excess production of renewable electricity, including through renewables power purchase agreements, electricity suppliers and peer-to-peer trading arrangements".

The European directives give some preconditions for energy communities, as well as collective self-consumption models. An important priority is that participation in an energy community is open and voluntary. For this, the model has to be scalable, modular and flexible in the sense that it may accept new members and allow members also to leave the community. The directive also states that the energy communities are not profit-driven but can make social, environmental and economic value. In essence, the model encourages large participation and democratic decision-making.

The financial value formation mechanism depends on the type of electricity contract. Traditionally the prices have been fixed and electricity bills have composed of three parts: energy price, network tariff and taxes. These all have been priced by every kWh. In many collective self-consumption schemes, the economic value is based on the agreement that its members do not pay network tariffs or taxes of the self-consumed and -produced electricity. This earning can be thought of as apparent as it is based on release of normally paid fees. Here load scheduling to achieve high self-consumption is essential. Still, the agreement benefits society as the self-produced energy is normally renewable energy. Besides, there are real savings in the energy part for decreased amount of bought electricity and earnings from the production feed into the grid and sold to a retailer. In the future, there will be changes in the form of tariff structures and tax levels, which will also affect the economic value of collective self-consumption schemes.

In addition to the value formation mechanism of fixed-price contracts, an hourly changing spot or day-night price contract gives other opportunities that both benefit the prosumers and the society. Here load scheduling not only to high self-production times but also to cheap electricity price times is essential. Utilisation of electricity during low prices not only gives consumer savings but also benefits society as low electricity prices correlate with low carbon dioxide in the energy system. Besides the benefits and cost-saving opportunities above, the prosumers and energy communities can earn additional income by offering flexibility to local DSO, TSO's reserve markets or electricity market actors.

2.1. Static allocation

In its simplest form, collective production is divided to consumers equally or by a fixed coefficient. For instance, tenants buy an equal share and have equal benefits. This may be the shares owned of the housing company, investment size in the system unit, number of people living in the household, the surface area of the apartment or the power capacity allocation. Naturally, the members can also earn an equal share of the production. In the Finnish collective self-consumption scheme, the default implementation divides production that is not used in common property areas to households by their in ownership proportions of the housing company stocks.

In some countries, the regulations set the local tariffs for energy communities. In principle, the local tariff is lower for each kWh self-consumed. In France, the benefit also varies seasonally [4]. This creates the incentive for optimising collective self-consumption but also sets narrower possibilities for service providers to design their own value allocation methods. This is a model often used by energy service companies (ESCOs) in their service contracts.

2.2. Dynamic allocation

Dynamic models encourage members of collective self-consumption to adjust their electricity consumption according to the production. This could be done by allocating a larger share of the production to households that change their consumption patterns.

If there are different types of households or companies in the energy community, their different load profiles increase the self-consumption rate and, therefore, the value of the whole community. Differences in load profiles would be recognized better in a dynamic value sharing method compared to the fixed allocation. For instance, a storekeeper would consume electricity during the day, whereas a working couple consumes electricity during the mornings and the evenings.

Tounquet et al. [3] proposed models of marginal value allocation, where each member's value to the community would be evaluated regularly and coefficients would be set accordingly. The Shapley method from Game Theory is another way of doing dynamic allocation [3]. Also the grid aspect can be taken into account in the more dynamic models, yet in this paper, we concentrate in the electricity production allocation.

2.3. Local energy market (LEM)

LEMs are market platforms that enable trading locally generated energy in a geographically and socially close community. These customers are connected to the national grid for security of supply and still have a contract with a licensed supplier who provides balancing and settlement services. Whereas community energy and energy sharing mean a broader set of activities, including joint investments in renewable energy, LEMs are a market mechanism for short-term trading [5].

Some energy communities are using bilateral peer-to-peer contracts, where users are allowed to choose with whom they buy and sell electricity. The RED II, Art 2 defines peer-to-peer trading as "the sale of energy between market participants by means of a contract with pre-determined conditions governing the automated execution and settlement of the transaction". These models are mostly pilots like the Quartierstrom in Switzerland, but some companies like Powerpeers in the Netherlands have also commercialised the model to a more widespread audience.[6]

Local energy markets can include different market designs [7]. In centralised markets, there is a service provider controlling the trade. Typical blockchain-based solutions aim to create fully decentralised market models where the middleman would be replaced by distributed ledger technology and smart contracts and enable members trading directly with each other. LEM can be also coordinated by a central community market manager. For instance, an iterative double auction mechanism can be used, in which members can set their preferences [8].

3. Functional customer value related to collective self-consumption

Literature does not have an explicit framework for addressing the value of an energy community that engages in collective self-consumption. In this paper, we look at the customer value from the perspective of the functional value. Smith and Colgate [9] define functional customer value as "concerned with the extent to which a product (good or a service) has desired characteristics, is useful, or performs a desired function".

Customer value can be divided into five different types: functional, conditional, social, epistemic and emotional value. Yet, the relative importance of each of these varies contextually.[10] In the case of collective self-consumption and energy communities, the customer value depends especially on the socio-technical context [11]. It may answer, for example, to high energy prices and energy poverty, lowering the initial investment costs by collective investments, issues in security of supply, or the desire to increase the use of renewable energy locally. In principle, here we discuss a case of a typical apartment building in a developed country, which does not have significant security of supply issues. Furthermore, collective self-consumption offerings include various business models, which include a different set of activities such as planning, installing, owning and maintaining the system. In this paper, we concentrate solely on the value sharing methods and exclude the wider customer offering.

We reviewed relevant literature on collective self-consumption and especially solar PV energy sharing [1]–[3], [5], [12], [13]. From this literature, we categorised the functional customer value stemming from two configurations: (1.) the desired financial allocation philosophy and its relation to complexity, transparency and simplicity and (2.) ownership of the DER assets and share of collective consumption in the energy community.

3.1. Financial allocation philosophy

The functional value that is most commonly stated as important is the *financial benefit* of the solution. Customers used heuristics such as the payback time to evaluate their willingness to pay or participate in an investment. For such evaluations, self-consumption business models are more uncertain than schemes like feed-in tariffs and net metering, which offered a guaranteed stable price without adjusting own energy consumption patterns. In a static model, the whole community's demand pattern affects the benefits as an aggregate, and therefore there is less incentive to adjust demand individually. Adjusting own demand patterns could be seen as solidarity for the community rather than capturing value to one's self. The dynamic and LEM models take individual demand into account and change the evaluation of financial benefits more complex.

Trust is regarded as an important value for the prosumer., User's trust related to value sharing can be divided into trust towards other community members and the service provider. The static model is simple and the allocation is easy to understand and mistrust on service provider can be avoided [13]. In dynamic and especially the LEM models, there is less need for trust between members of the community to contribute to self-consumption. Instead, the members have to trust the companies (e.g. aggregators) and algorithms that operate the community [14]. *Simplicity* may give community members also a sense of *convenience and comfort* as the solution is aimed to be an install-and-forget type of solution that does not require frequent inputs by the consumer [5]. Presumably, most customers are not willing to make many transactions for getting cheaper energy prices, therefore systems that run autonomously and without need for adjustment increase the *convenience* of the system. In addition, a more complex value allocation mechanism may increase administrative costs, which should be considered in the planning phase of the project.

In communities where there are smaller and larger consumers (incl. residential apartments and companies) that contribute differently to self-consumption rates, there may be a desire to remunerate its members differently. Here, the *fairness* and *stability* of the value sharing method become a question [3]. Stability means that the value sharing is done in a way that community members do not have an incentive to initiate a sub-community or leave the community. If a member leaves the community, the remaining members have to cover the investment shares. Also, the aggregate consumption patterns of the community change. In landlord-owned communities, stability is important from the landlord's perspective, whereas in privately owned shares, the risk is borne by all households.

3.2. Resource ownership

In existing multi-apartment buildings, the resources that can offer flexibility for energy demand include electric vehicles, air conditioners, etc. If members own and pay such resources collectively, there is less incentive for dynamic value sharing methods. For instance, some apartment buildings have collective laundry machines [2]. Yet, the more customers own and control these resources individually, more incentives there are for dynamic and LEM value sharing models.

Information provision can motivate and help prosumers to make more informed decisions with their resources. This naturally requires individual smart metering and even devices that are connected to an energy management system. Real-time data availability is also a precondition for autonomous control of resources and devices that self-learn user preferences. In all value sharing models, customers have an incentive to gain more data on the system functioning, but in the dynamic and LEM models, there is a direct financial motivation to do so. The LEM model poses the largest incentive for information sharing between members of the community.

Real-time data enables designing and capturing ways to capture synergies between different load patterns [13]. Complementing loads can increase self-consumption rates. Individual metering of the loads allows monetising the value by individuals. Increased controllability leads to a transactive energy concept, for which a LEM is an integral part.

DERs' system integration is still a challenge as there are many different standards and protocols that are not compatible with each other. *Compatibility* of the value sharing method with customers' existing and potential resources and their software and APIs is important for minimising switching costs and full use of their existing resources. Interoperability of different DERs can also introduce 3rd party services (e.g. EV charging station operators) and customer choice in ways to participate in the energy community. [14] The complexity of the information is linked to the aims that the community has with the larger energy system. For example, do the customers have their own electricity retailers, does the community or participants have fixed electricity contracts or dynamic ones.

4. Value propositions of different value sharing methods

Customer value proposition emphasises customer's perspective of the product/service and has a strategic role in creating organisation's competitive advantage. The value proposition refers to articulating the value that the chosen customer segment receives from a service. The different value sharing methods influence the customer's value proposition. The challenge is that there are different kinds of customers involved in the same community, and the value proposition for each of them may be different. Whereas some value simplicity, there may be larger customers like offices or small businesses that value more exact value allocation. Others may have resources like electric vehicles that could benefit from value sharing that encourages customer engagement and flexibility. Table 1 summarises the value propositions of different value sharing methods from the customer's perspective.

Table 1. Customer value propositions of different value sharing methods

	Customer Value Proposition
Static (Fixed proportion or price)	Simplicity, environmental and social benefits emphasised over economic value. Low admin costs.
Dynamic allocation	Increased customer engagement: economic value emphasised, incentivising demand response (e.g. smart charging)
LEM	Customer choice and engagement; co-creation of value (incl. V2G and batteries); scalability and interoperability

The static method delivers the customers a relatively certain and risk-free economic benefit. As the monetary values in collective self-consumption schemes are currently counted in tens rather than in hundreds of euros per household, the simplicity of the scheme can be well-argued. From the economic perspective, the proposition does not encourage customer engagement as the benefits of changing behaviour are distributed within the whole community. The dynamic value allocation methods require and enable more active participation from the members of the community. Heterogenous communities can harness the dynamic method for more significant benefits of self-consumption. Real-time pricing models can be complemented with in-home pricing displays or other ways to monitor the pricing [15]. The LEM-model has a more complex value proposition, which is rather created by the community than the service provider: members have the ability to create synergies between each other and there are fewer restrictions on what resources are taken into the community. Members can, for example, bring batteries into the system and in that way start offering new kinds of services for other members and themselves. Encouraging members to participate in energy and flexibility sharing requires data provision and a high level of engagement. Such flexibilities clear the pathway for sector coupling as heating sources and electric vehicles are linked more closely with traditional electricity consumption.

The value sharing methods can be categorised into a 4x4 table (see Fig. 1) according to the customer and community types. If there is a sense of community and solidarity, the amount of production that is shared is low or a low number of metered DERs, a fixed proportion is a suitable method. If there is mistrust or will to allocate the benefits individually among community members, a dynamic ex-post allocation is suitable. With increasing amount of DERs, real-time load control can reduce the need for grid enforcements and in that way reduce costs for whole community. When the number of individually owned DERs increase, the value of these resources can be allocated directly to their owners in a LEM model.

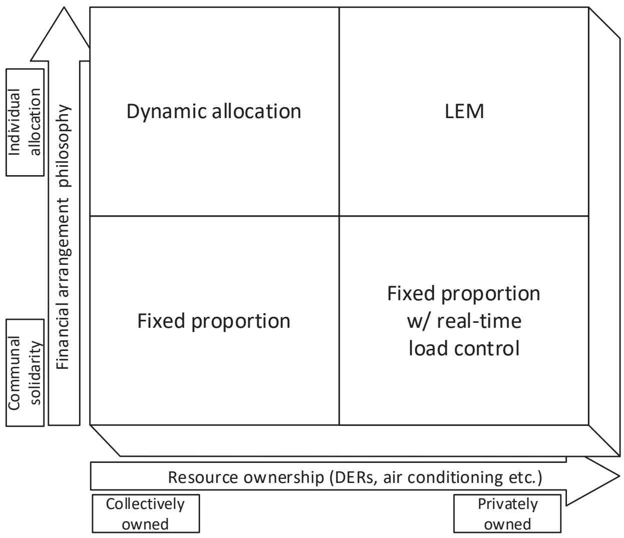

Figure 1. Selecting value sharing methods

5. Conclusions

This paper has explored the different value sharing methods in collective self-consumption models and derived the functional customer value propositions. Although the paper makes a clear distinction between the different models, the practical life may prove more nuanced models. For example, a hybrid model of methods of fixed proportion and dynamic allocation may provide benefits for usual consumers not interested in energy and those who own DERs, such as EVs. In addition, this paper did not consider other aspects related to the value sharing mechanisms, such as, organisational model or community members' different level of interest, time and effort put into building the community. When moving towards the more sophisticated value sharing methods, privacy issues and data protection become more important as individual data is required.

The overall picture of collective self-consumption includes many different services and value streams. In the future, stacking different value streams will become increasingly popular and energy communities enable harnessing certain level of economies-of-scale in DER adoption. For instance, community storage is more cost-efficient than individual residential batteries, supporting community-level solutions instead of individual investments. Frequency regulation, especially in grids with high wind and solar penetrations, and arbitrage in the wholesale market are other value streams that could be captured via the energy community, especially via battery storage assets. Distribution system operators may use energy communities to solve congestions in the grid.

For energy community service providers, the framework in this paper gives a structured view on values that different value sharing methods offer. Energy communities develop as their members acquire DERs and their members' profiles change, and the suitability of the initial method should be considered again after such changes. For policymakers, the framework shows how energy communities' different value sharing methods can impact various policy goals, such as privacy, renewable energy integration, and interoperability of smart grid technologies.

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