# The Use of Typical User Load Profiles to Energy Communities in Finland - Aspects on Distribution Tariff Design and Regulation

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***Abstract*—The recent developments in the energy sector have promoted the role of citizen as active actors in the energy market in the form of energy communities (ECs). However, it is not clear how ECs should be treated in the pricing of electricity distribution and the price regulation. This paper discusses the definitions and load profiles of typical users used in the electricity distribution price regulation in Finland. The definitions are compared to different combinations of small-scale customers who could form different types of ECs. The comparison shows that the typical user definitions of larger commercial and industrial users would be of the same size as the studied ECs. The conclusion is that the typical user definitions should be kept up to date and updated in the future to account for ECs to ensure that the legislative requirements are met, and accurate statistics can be provided to the public.**

***Index Terms*— Distribution tariff, distribution system operator, electricity distribution pricing, energy community, regulation**

## I. Introduction

The recent European Solar Rooftops Initiative states that the EU will make the installation of rooftop photovoltaics (PV) compulsory for new and existing public and commercial buildings by 2027 and for all new residential buildings by 2029 [1]. The role of renewable electricity production will thus be significant in the future and the change will affect the business of different stakeholders, e.g., the distribution system operators (DSOs) and the energy retailers. From a customer perspective, the issue related to the PV production is that it may not be always profitable to place PV panels on every rooftop regardless of the location. For instance, shading conditions can vary significantly, and the payback periods of the energy resources can be excessively long for some customers, although today, the resources might be profitable for some customers. Instead of individual customers having to invest in different energy resources, they could form energy communities (ECs) that acquire the resources collectively, place them in optimal locations, and share the costs and the benefits of the resources among the members. By forming ECs, the customers could take part in the electricity market more actively than today and investing in energy resources through ECs can be more profitable than at an individual customer level. Regarding ECs, there are still unanswered questions concerning certain topics that, e.g., relate to the pricing of electricity distribution in the presence of ECs and how the national regulatory agency (NRA) oversees the pricing of electricity distribution.

Because ECs can own different electrical energy resources that reduce the need to buy energy from the retailers and the excess energy can be sold to the grid, ECs will thus affect the revenues of both the energy retailers and the DSOs if those actors remain passive and no changes are made to the present pricing schemes. Additionally, the ECs, through smaller electricity bills, will have an impact on the state as to how much taxes are collected from the customers. In terms of regulation of the pricing of electricity distribution, NRAs will also face challenges in the case of ECs to ensure that the pricing executes the requirements set to it in the legislation related to the pricing of electricity distribution and to provide annual statistics about the industry to the public.

This paper investigates the impacts of the ECs on the pricing of electricity distribution and the regulation in Finland. The key focus is on the development aspects of the national typical user definitions and load profiles in the case of ECs. The definitions and load profiles (see, e.g., [2]) are investigated by comparing the information and load profiles of apartment houses and a group of detached houses as ECs. Herein, the goal is to study if development needs can be identified in the currently used typical user definitions.

The three key research questions, to which this paper answers, are as follows:

1. What the example load profile of an EC would look like in a situation where it is considered to consists, e.g., of an apartment house, multiple apartment houses, or a group of detached houses?
2. Do the typical user load profiles used in Finland match the load profiles of the studied ECs?
3. If development needs are identified, what are the potential implications of those needs related to, e.g., electricity distribution tariff design and regulation?

The paper is structured as follows. In Section II, different forms of ECs are discussed. After this, aspects on the electricity distribution pricing in Finland are provided in Section III. In Section IV, the regulation of electricity distribution pricing in Finland and the use of typical user load profiles are discussed. Section V provides input related to the development aspects of typical user load profiles in the price regulation in the presence of ECs. The last two sections, V and VI, provide the discussion, policy implications, and the conclusions.

## II. Energy Communities

Energy communities are a set of new actors in the electrical energy market, however, the exact definitions for various kinds of ECs, at a practical level, are still broad. Different types of ECs have been identified and discussed in the Finnish electricity market environment, e.g., in [3]. ECs can be categorized into different groups based on different characteristics. Herein, we discuss different types of ECs that differ in terms of location and whether the EC is considered physical or virtual.

In terms of location, the EC can either be local or distributed. Local ECs operate inside a specific area, such as inside the property boundaries or a specific location in the electricity network (e.g., the members are situated in the same low voltage network behind a single secondary substation.) In the first option, the EC owns the electricity network inside the property boundaries, and among the members, there is a common point of connection to the DSO network. In the second option, the EC operates over the DSO network, and it is characterized as a distributed local EC. A practical example of a local EC is an apartment house, and an example of a distributed local EC is a group of detached houses or multiple apartment houses situated in the same quarter albeit on different properties. Distributed ECs operate primarily over the DSO network because the EC members, and the energy resources that are connected to the EC, can be situated in different locations that fall either inside the responsibility area of a single DSO or they might also be distributed so that the EC operates over several DSO networks.

In terms of the ECs being either physical or virtual, the nature of a local EC is more that of a physical because its members are situated either close to each other either inside the same property boundaries, inside the responsibility area of a single DSO, or in a specific location in the electricity network. The distributed EC can be considered primarily as virtual because its members can be situated far from another (e.g., in different DSO networks), and there is not a clear electrical path to follow the exact electrical energy transfers that occur between the members.

In this paper, the key focus is on the local ECs that own their network and local distributed ECs that operate over the DSO network. The reason for this decision is that, in terms of the electricity distribution pricing and the regulation, there are unsolved issues regarding, e.g., what the pricing schemes applied to the ECs should be, how the electricity distribution tariffs should be determined, and how the NRAs should assess those pricing schemes and their impacts. Thus, the ECs are viewed in this paper through the lenses of the DSOs and the NRA. It is apparent that ECs will impose challenges on the present practices of the DSOs and NRAs, because the small-scale customers have been traditionally considered primarily as passive consumers. The emergence of different types of ECs thus create pressure for both the DSOs and the NRA to account for these new actors in the electricity market. It is central to investigate beforehand if there are needs to review and develop the practices related to the electricity distribution pricing and regulation.

## III. Electricty Distribution Pricing in Finland

In this section, the pricing of electricity distribution is discussed in the context of the Finnish electricity market environment.

### A. *Present state of the electricity distribution pricing in Finland*

Today, there are 77 different DSOs that determine the prices of their electricity distribution tariffs with a high level of independence compared, e.g., to some European countries where the NRA has a significant role in setting the electricity distribution tariff formats and prices. The tariff structures and the billing bases of different electricity distribution tariff components used for customer groups of different sizes in Finland vary. For instance, the fixed charges used for small-scale customers are either uniform inside a single customer group, or they can be tiered based on the connection size. The volumetric charges are either single-rate volumetric charges or, for customer groups that consist of larger small-scale customers (e.g., customers with electrical heating), the volumetric charges have two-rates that are based on the Time-of-Use (i.e., a time-of-day or a seasonal variation). In the demand charges that are used mainly in the electricity distribution tariffs of larger users, the billing bases have a large spectrum of different options between the DSOs [4]. For small-scale customers, today, 4 DSOs have included demand charges to the electricity distribution tariffs that primarily concern only a fraction of the small-scale customers of those DSOs.

The DSOs in Finland have a monopoly over specific geographical areas. The responsibility areas of the DSOs do not necessarily follow, e.g., the boundaries of cities or municipalities. This means that there are situations where the customers situated on both sides of the same street must acquire the distribution network services from different DSOs, and the electricity distribution tariffs, i.e., the tariff structures and the price levels, might be significantly different depending on the DSO.

### B. *Upcoming changes in the electricity distribution tariffs in Finland*

As previously mentioned, 4 DSOs in Finland have already made reforms to their electricity distribution tariffs used for small-scale customers. Additionally, several Finnish DSOs have investigated the potential of using demand charges for their small-scale customers, and it is expected that some of those DSOs will eventually reform their electricity distribution tariff structures to include demand charges for small-scale customers in the future. The ongoing change may increase, e.g., the level of complexity of the calculations that assess the profitability of the ECs from a customer viewpoint. However, because the structures of the electricity distribution tariffs are going to be harmonized in the future, it can make it easier for the future service providers to develop and offer new products and services to the ECs. Currently, there are no specific tariffs in place for ECs. As stated in [5], the tariffs used for ECs should ensure that the ECs participate in the cost sharing of the system in a balanced way. Thus, it must be investigated if the present tariffs are suitable for different types of ECs and, if not, then new tariffs that meet the requirements must be developed.

## IV. Regulation of Electricity Distribution Pricing in Finland

In this section, the regulatory aspects of electricity distribution pricing that are currently in place in Finland are discussed. The first part of this section discusses the present requirements set in the legislation for the pricing of electricity distribution, and the second part focuses on how the cap in place for the annual price changes is assessed in the Finnish regulation using the typical electricity user definitions.

### *A. Regulatory aspects related to the electricity distribution pricing in Finland*

The electricity distribution business is operated by the DSOs as monopolies, so that unnecessary and expensive duplication of the network assets required to deliver the energy to the end customers may be avoided. Due to the monopoly statuses of the DSOs, there is no natural competition that would pressure the DSOs to keep their prices at a reasonable level, and because of that, the pricing of electricity distribution is a subject to legislation and regulation. The prevailing practices aim to protect the customers from excessively high prices and simultaneously ensure that the costs faced by the DSOs, and a reasonable return, can be recovered with the electricity distribution tariffs. According to the Finnish legislation, the DSOs must offer their services to the customers in a fair and non-discriminatory manner [6]. Additionally, the electricity network must be designed, built, and maintained cost-effectively. The law also states that, as a whole, the pricing of electricity distribution must be reasonable, and the terms of the tariffs, such as the billing bases of tariff components and their determinations, must be presented to the customers in a clear and intelligible way. Within the responsibility area of a DSO, the distribution tariffs are uniform for different customer categories (i.e., the unit prices of the tariffs do not depend on the location of the customer in the DSO network [6].)

In the current regulation, the NRA focuses on the total allowed turnover of an DSO that consists of appropriate costs, reasonable return for the invested capital, and different incentives, which steer the DSOs toward efficient economic operation. The NRA in Finland oversees the overall pricing of an DSO to ensure that the requirements set in the legislation are met, but as discussed in Section III, the DSOs can determine the electricity distribution tariffs independently. This means that individual tariffs are not assessed, and there are significant differences in the prices of structurally similar electricity distribution tariffs between different DSOs.

A recent development in the Finnish legislation that is related to the electricity distribution pricing concerns changes the DSOs are allowed to make to the tariff prices. In 2017, the EMA was revised to include a section that states that the price changes can lead up to a maximum of 15% (including taxes) changes in the distribution bills of the customers over a 12-month period. That cap for price increases was then lowered further down to 8% in 2021, setting an even stricter limit for the DSOs [6]. The price changes are monitored by using the typical electricity user definitions and their corresponding load profiles that are applied at a national level. This means that individual customers can face changes in their electricity distribution bills that exceed the 8% limit, but the overall impacts of the price changes, observed through the typical user profiles, fall under the allowed limit at a DSO level. The DSO thus faces two main limiting economic factors to consider regarding the pricing of electricity distribution, the revenue cap (i.e., the combination of appropriate costs, a reasonable rate-of-return, and other incentives determined by the NRA), and the price increase cap.

### *B. Typical electricity user load profiles used in the electriciy distribution price regulation in Finland*

The Finnish regulator uses typical user definitions and load profiles to assess the pricing of an DSO and provide general statistics related to the electricity distribution pricing to the public. The typical user definitions, and the load information related to each user category, were updated in 2018-2019 to reflect the prevailing situation better compared to the old typical user definitions and load profiles [2]. For instance, before the update, the peak demands of larger customers were represented with fixed values that did not account for the differences in the billing practices of different DSOs. The load information provided by the update offers a broader perspective on different combinations of peak demands. As pointed out in Section III, there are several different billing bases used by the Finnish DSOs, which can now be assessed with the updated typical user definitions and load profiles. In total, there are now definitions for 14 different typical users that include both the small-scale customers and the larger customers [7].

There are at least two recognizable challenges in how the typical user definitions and the load profiles are used. Firstly, the typical user definitions were made for load customers, and thus, there are no typical user definitions or load profiles available for active customers, who own different energy resources, such as PV systems, electric vehicle charging, or electrical energy storage systems. Secondly, in all geographical areas, the customer mix is not homogenic, and there might not be customers in the customer base of the DSO that would include all the 14 typical user groups. However, the price increase cap concerns all DSOs, even if the customer mix would not include, e.g., summer houses or some other specific typical user groups, or there are just a few of those customers inside the whole responsibility area of the DSO.

## V. Aspects on the Future Development Needs of Electricity Distribution Pricing and Regulation

As previously discussed in Section II, ECs can consist of different combinations of customers of various sizes. In the context of this paper, the focus is on small-scale customers, and in Table I, examples are provided from 6 apartment buildings and 16 small-scale customers that are situated in Finland. The studied ECs are considered as local ECs and distributed local ECs. The hourly load measurements for the apartment buildings are from the year 2018, and the measurements for the detached houses are from the year 2015.

For comparison, the relevant typical user definitions are presented in Table II to investigate, which of them would match the best the annual energy volumes and monthly peak demands of the different ECs shown in Table I. By comparing Tables I and II, it is observed that the matching typical user definitions for the ECs of the study would be those used for larger business or industrial customers. In the case where the 6 apartment buildings would form a larger EC, the most suitable typical user definition would be somewhere in between the last two typical user groups shown in Table II, and it is important to note that the last typical user definition shown in that table is for a customer with a medium voltage level connection. For an EC

TABLE I. Key information of the studied ECs

| EC case | Annual energy volume (kWh/a) | Range of monthly peak demands (kW) | Number of individual customers |
|---|---|---|---|
| Apartment house #1 | 38 124 | 7.32–12.36 | 24 |
| Apartment house #2 | 80 901 | 21.95–27.99 | 24 |
| Apartment house #3 | 261 496 | 49.65–59.89 | 59 |
| Apartment house #4 | 187 060 | 31.21–55.50 | 43 |
| Apartment house #5 | 119 773 | 23.61–33.40 | 49 |
| Apartment house #6 | 81 638 | 28.32–40.56 | 29 |
| A group of six apartment houses | 768 992 | 126.84–167.32 | 228 |
| A group of 16 detached houses | 135 056 | 24.63–44.48 | 16 |

TABLE II. Key information of the relevant typical user groups that are currently used by the Finnish NRA in the price regulation of electricity distribution (The information shown in the table is based on [7])

| Typical user group | Description | Annual energy volume (kWh/a) | Range of monthly peak demands (kW) | Connection size |
|---|---|---|---|---|
| 10 | Business (Mon.-Fri.) | 50 000 | 11.39–17.59 | 3x63 A |
| 11 | Small-scale industry (1 shift) | 180 000 | 51.64–78.96 | 3x160 A |
| 12 | Business (Mon.-Sun.) | 600 000 | 105.56–116.40 | 3x400 A |
| 13 | Large industrial customer (1 shift) | 1 000 000 | 309.25–383.81 | Medium voltage connection |

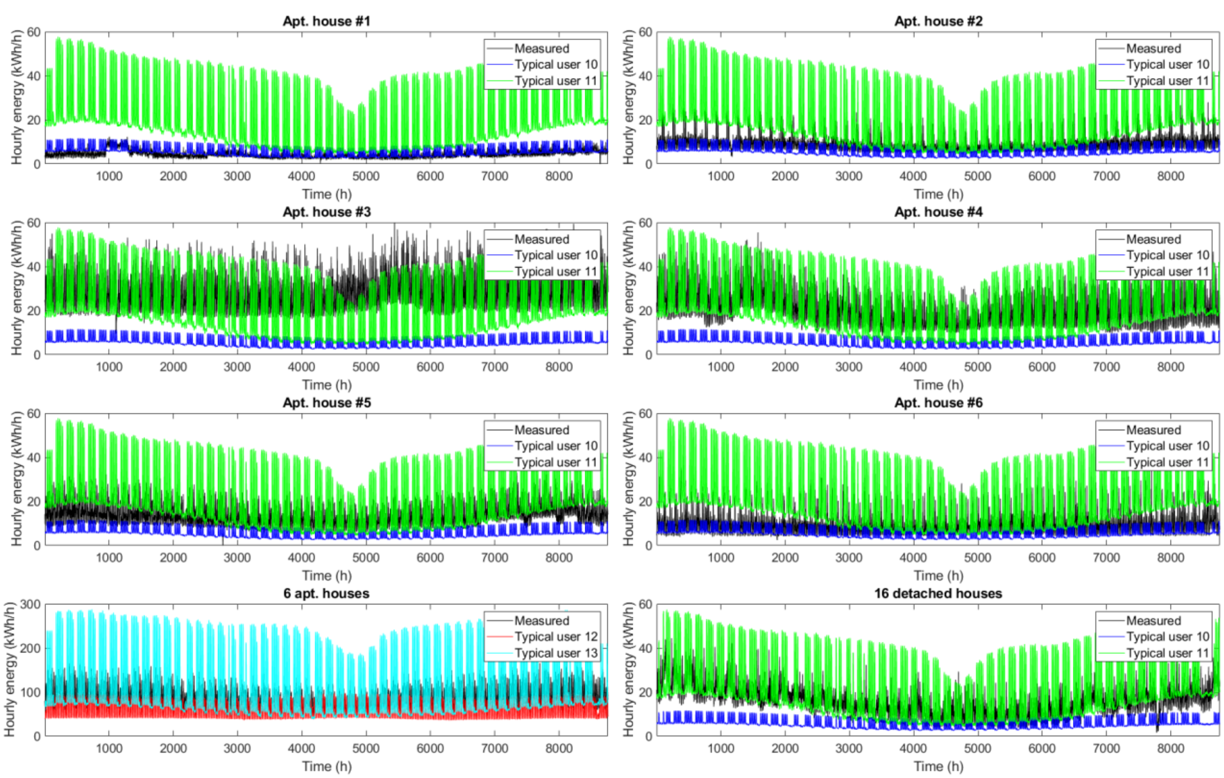


Figure 1. EC load profiles and typical user load profiles used by the Finnish NRA (Calendar year 2018 was used for the apartment houses and calendar year 2015 for the detached houses)

that is formed either by individual apartment houses or the 16 detached houses, the typical user definition used for smaller business or industrial customers, 10 and 11, would be the best match.

The load profiles of different ECs and the typical user load profiles (i.e., the expectation values) are presented in Fig. 1 for one year. It is observed from the figure that the actual load profiles of different ECs vary, and it is case-specific how well the load profile of the typical user matches the EC load profile. Because the studied typical user definitions used here were primarily selected based on the annual energy volumes and monthly peak demands, the profiles of larger users were used. In the future, it should be investigated more thoroughly to study if a combination of typical user definitions and load profiles of different small-scale customers could be an option to consider in these kinds of comparisons.

## VI. Discussion

The comparison shown in Section V was made by using the data of 6 apartment houses and 16 detached houses that, from a sample size perspective, is not large. Thus, the EC types therein do not provide general descriptions of all EC types, and a comprehensive study should be done in the future to investigate what the average EC, or ECs, would be in terms of the typical user definitions and load profiles. The key challenge in developing those definitions for different EC types is that they are yet to emerge, and thus, the definitions and the load profiles cannot be made based on the existing data. In addition, different electrical energy resources affect the load profiles, and the mix of different resources can vary between the ECs. The definitions and load profiles for ECs that account for different electrical energy resources would have to be generated by simulations that may have different targets that, e.g., maximize the economic benefits of the ECs or the size of the PV system.

Another topic in the present electricity distribution pricing and the related regulation is how small-scale energy production injected to the energy system is treated. The present price cap set in the Finnish legislation limits the average price to 0.07 c/kWh (excluding VAT). If the amount of renewable energy production increases rapidly, then it should be investigated if there is a need to use cost-based and cost-reflective electricity distribution tariffs for the injection. The economic impacts of injection should be studied more precisely, and the policies should be reviewed if other efficient means to boost the distributed electricity production can be identified.

### *A. Policy implications*

The policy implications for the electricity distribution price regulation in Finland are twofold. Firstly, the typical user definitions and the load profiles should be kept up to date. If the situation, e.g., related to the customer mix through the emergence of different types of ECs, changes, then new typical user definitions should be added to the list to ensure that the price regulation can be done accurately. Secondly, as the ECs can make the investment into different energy resources more profitable for small-scale customers by common ownership among the EC members, it can boost, e.g., the amount of distributed energy production in the electricity distribution network. If the increasing amount of generation imposes costs on the DSO (e.g., additional grid reinforcement costs), those costs should be directed to the customers in a cost-reflective way. Thus, in the future, it should be discussed if, instead of, e.g., price cap set for the injection in the electricity distribution tariffs in Finland, there are other efficient means to promote distributed electricity production.

## VII. Conclusion

This paper discussed energy communities from the electricity distribution pricing and regulation perspectives in the Finnish electricity market environment. As small-scale customers may form different types of ECs in the future, it is central for the distribution system operators and regulators to have proper tools to address the challenges imposed by the ECs on the electricity distribution pricing and the price regulation. The comparison, shown in the paper, which is based on a small sample size, indicates that the national typical user profiles used for larger commercial and industrial customers would be the best match in terms of annual energy volumes and monthly peak demands for the studied ECs. However, ECs can be a collective of small-scale users with different electrical energy resources, and that aspect should be considered in making these kinds of comparisons in the future. Additionally, in the future, the typical user definitions and load profiles may have to be updated to account for different types of ECs to provide accurate statistics about the pricing of electricity distribution to the public. Lastly, it should be investigated if new distribution tariffs should be determined for different kinds of ECs.

## References


[1] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS EU Solar Energy Strategy

[2] A. Mutanen, K. Lummi, P. Järventausta, ”Load models for electricity distribution price regulation,” in *Proc. 2019 The 25th International Conference on Electricity Distribution*

[3] J. Valta et al., ”Towards practical typology of energy communities: main differentiating elements and examples of promising implementations,” in *Proc. 2021 The 26th International Conference on Electricity Distribution*

[4] K. Lummi, A. Mutanen, P. Järventausta, ”Upcoming changes in distribution network tariffs – Potential harmonization needs for demand charges,” in *Proc. 2019 The 25th International Conference on Electricity Distribution*

[5] Directive (EU) 2019/944 of the European parliament and of the council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU

[6] Finnish law, “Electricity Market Act 588/2013” (In Finnish: “Sähkömarkkinalaki 588/2013”)

[7] Energy Authority, “Price increase cap regulation” (In Finnish: "Korotuskattovalvonta"), (Available at: https://energiavirasto.fi/hinnoittelun-valvonta)