# The Impact of Energy Communities on Electricity Distribution Business – Aspects on Seasonal Turnover Risks for the Distribution System Operator

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***Abstract*—This paper discusses electricity distribution network pricing in the case of multi-apartment buildings as energy communities (ECs) in the Finnish electricity market environment. Electricity distribution network tariffs for ECs have been a topic of interest as the EU legislation steers the members states to both further the emergence of ECs and ensure that they contribute to the sharing of the system costs. A case study is presented in which data from a multi-apartment building and tariffs of 3 Finnish distribution system operators (DSOs) are used to study the impacts of an EC on the DSO turnover at a monthly level. The results show that, with present tariffs of the studied DSOs, the turnover risk for the DSO increases when different electrical energy resources are included. Ways to develop the DSO pricing to mitigate the turnover risks and simultaneously comply with the goals set in the EU legislation should be pursued.**

***Index Terms*— Distributed energy resource, electricity distribution business, electricity distribution pricing, energy community, network tariff**

## I. INTRODUCTION

The role of the customers, or more inclusively, the citizens, in the electricity sector is changing as they are becoming more active than before. For instance, the amount of distributed energy production, e.g., by solar photovoltaic (PV) systems, on the customer side has increased in the past years, and battery energy storage systems (BESSs) will surely follow as they become more affordable. In the case of small-scale customers, such as those living in multi-apartment buildings, the possibilities to acquire and reap the benefits of different electrical energy resources (ERs) are limited due to practical issues such as lack of space. Additionally, the payback periods of those investments may not be economically sensible for individual small-scale customers. Energy communities (ECs) can provide a solution for small-scale customers to acquire different ERs collectively and share the benefits among the community members. In the case of multi-apartment buildings, the EC could include all the apartments and the common loads of the building, and they could be treated as a single customer, as a behind-the-meter EC type (see, e.g., [1]) from a distribution system operator (DSO), electricity retailer, and the state points of views.

In this paper, the key focus is on the DSO aspects in the case of multi-apartment buildings as ECs. The main issue of the study is on the electricity distribution network tariffs, and how a multi-apartment building as an EC would affect the annual turnover of the DSO with different combinations of electrical ERs. A central item for the DSO is the electricity use profile of an EC and how it changes due to the impact of different electrical ERs. For instance, if the EC has a solar PV system and it decreases the need to buy electrical energy from the energy system, then it might have an impact on the DSO turnover.

To study the impacts of a multi-apartment building as an EC on the DSO turnover, different cases are investigated in Section 4. In the studied cases, the turnover of a DSO is investigated at a monthly level with different combinations of electrical ERs. The electrical ERs of the case study include a shared solar PV system and a BESS. The case study is based on hourly energy readings from a multi-apartment building that is situated in Finland, and the impacts on the DSO revenue were studied over a one-year period (i.e., 2018). As for the price data, electricity distribution network tariffs of three Finnish DSOs were used.

This paper provides answers for the following key research questions that focus on the DSO turnover aspect:

1. How would different electrical ERs, e.g., solar PV systems and BESSs affect the electricity use profile of an EC that is formed by a multi-apartment building?
2. What would the potential impacts of different electrical ERs be on the turnover of a DSO?
3. If the impacts on the electricity use profiles or the DSO turnover are significant, then what solutions, in terms of electricity distribution pricing, could be used to mitigate the potential turnover risk for the DSO?

The first two questions are answered in Sections 4 and 5 that present a case study and its results, in which data of one multi-apartment building from Finland and distribution tariffs of 3 Finnish DSOs are used to study the impacts of forming an EC that includes different electrical ERs. The third question is answered in Section 6, in which a potential approach to develop electricity distribution tariff for an EC is discussed briefly. It must be noted that the results presented in this paper are based on the Finnish electricity market environment that closely follows the principles of EU legislation (e.g., [2] and [3]), although the results can be applied in countries with similar electricity market environments.

This paper is structured as follows. In Section 2, a brief introduction to ECs is provided. In Section 3, electricity distribution network tariffs are discussed focusing mainly on the Finnish unbundled electricity market setting. Section 4 presents a case study, in which hourly energy readings from one multi-apartment building from Finland was used to study the impacts of an EC on the DSO turnover with different combinations of electrical ERs, and the results of the study are presented and analyzed in Sections 4 and 5. The last two Sections, 6 and 7, provide the discussion and the conclusions.

## II. Energy Communities

Energy community is a collective that may consist of citizens operating together to be a more active participant in the electricity market than today. From a practical viewpoint, the definition, such as that presented in the EU Directive [2], of an EC is broad, and, in fact, several different types of ECs have been identified (see, e.g., [1]), and the types range from local to distributed, and from physical to virtual ECs.

From the viewpoint of this paper, citizens who live in multi-apartment buildings are in the key focus. The first reason for this is that, in Finland, multi-apartment buildings cover approximately 47% of all dwellings. The second reason for multi-apartment buildings being of an interest is that, from a distributed electrical energy viewpoint, through ECs, ways to incentivize the citizen to acquire electrical ERs to produce clean energy can be pursued. The challenge at present is that, for individual citizens, different ERs may be expensive to acquire, and the payback periods of the investments might be long. In the case of multi-apartment buildings, the citizens typically are small-scale customers, and there are practical challenges present such as those pointed out earlier in the introduction. However, if the multi-apartment building would form an EC, then the members could invest together in different ERs through democratic decisions and install the electrical ERs in best possible locations considering the local circumstances.

In the recent academic literature, a study that would show a cost-based way to determine electricity distribution network tariffs for different types of ECs seems to be lacking. However, as the EU Directive states, it should be ensured that ECs participate in the cost sharing of the system in a balanced way, there is clearly a need for a thorough research in that area [2]. A methodology that is based on costs and accurate cost allocation might ensure that the requirements, as those stated, e.g., in the EU Directive, are met.

## III. Electricity Distribution Network Tariffs

For the DSO, which is the local monopoly actor that provides the electricity distribution network services, the annual turnover to recover its costs results from the income produced by electricity distribution network tariffs, connection charges, and other service charges. From those items. in terms of annual turnover, the first is the most significant, and electricity distribution network tariffs are used to bill the customers each month based on the connection, demand, and distributed energy volume. In countries, where electricity tariffs are unbundled, the customers receive more detailed information about what the individual elements in their electricity bill are compared to countries, where the DSO tariffs might be bundled to the tariffs of the electricity suppliers.

Distribution tariffs may have different formats and prices for different customer groups, which often depend on the size of the customer (e.g., different tariff formats and unit prices are used for small-scale customers and larger customers.) For instance, in Finland, there are different electricity distribution network tariffs for low voltage, medium voltage, and high voltage customers. Additionally, there are 77 different DSOs in Finland, who can determine the price levels of their electricity distribution network tariffs independently, albeit they must follow the overall principles of distribution network business regulation set by the national regulatory authority (NRA), which leads to differences in tariff prices and billing parameters between DSOs. The electricity distribution network tariffs used for small-scale customers consist of two components; a fixed charge and a volumetric charge that, for certain customer groups includes a Time-of-Use feature. At present, four DSO use a demand charge for a portion of their small-scale customers. For larger customers connected to the low-voltage network, the electricity distribution network tariff includes three components; a fixed charge, a volumetric charge that may have a TOU feature depending on a DSO, and a demand charge. The billing parameter regarding demand depends on the DSO, and, at present, there are over 20 different ways of billing demand. The state of smart metering in Finland is good, and practically the electricity use of all customers is being measured by a smart meter that can be seen as a precondition to use more advanced electricity distribution network tariffs.

At present, there are no specific tariffs in place for ECs in Finland, mainly because they are yet to emerge. Additionally, as the concept of ECs is novel, there are some unanswered questions, e.g., regarding what the electricity distribution network tariffs used for different types of ECs should be. Additionally, in the earlier research, it has been studied whether the present tariffs used for larger customers could be used for ECs formed by multi-apartment buildings as such, but the results seem to indicate that they might not be the best options for those ECs from a DSO perspective [4].

In principle, it could be possible to determine distribution network tariffs that could be used specifically for ECs. For instance, in Finland, the NRA has stated that a DSO could determine distribution network tariffs that would be used only for energy storage customers (i.e., no other loads or production elements are allowed.) However, if the DSO would determine a tariff that is that is limited to be used for certain customer groups, then that tariff should be public and available for all similar customers to choose from inside the responsibility area of the DSO.

The challenge with respect to electricity distribution network tariffs is that, as discussed in Section 2, the goal should be on ensuring that ECs contribute to the cost sharing of the system appropriately. To achieve that goal, electricity distribution network tariffs should be investigated to see whether the present pricing schemes could be used as such or if development needs can be identified. Additionally, in tariff design, the fundamental principles include items related, e.g., to efficiency, cost-reflectivity, cost-recovery, non-discrimination, and simplicity [5]. In this paper, in which the focus is on the potential turnover risks of ECs for the DSO, cost-reflectivity and cost-recovery principles play a key role as they relate to the item highlighted in Regulation (EU) 2018/943 and Directive (EU) 2019/944 regarding the participation of ECs in the cost sharing of the system [2]-[3].

Lastly, it should be noted that, in tariff design, the end results (i.e., tariff formats and unit prices of different tariff components) are the results of a compromise, in which several pricing principles and practical issues, e.g., the state of smart metering, are accounted for appropriately. This often means that, in practice, the pricing schemes might not be optimal in the theoretical sense. The key challenge is to determine tariffs that further the progress of forming ECs and enable the internal electrical energy transfers that occur between the members inside the EC interface, and still allocate enough costs to ECs for them to participate in the cost sharing of the system in a balanced way.

## IV. Case Study

To study the impacts of different ERs on the DSO turnover in a situation, in which the EC is formed by a multi-apartment building, the energy readings from one building that is situated in Finland was used. The hourly energy readings are from 2018, and they cover that entire year. The multi-apartment building of the case study was situated inside 3 different responsibility areas that are operated by different Finnish DSOs. The reason for this selection is that electricity distribution tariffs vary between DSOs, and accounting for multiple DSOs provides a broader view of the potential impacts of ECs on the DSO turnover. The electricity distribution tariffs (VAT 0%) used in the calculation are shown in Table 1. The three DSOs of the study were selected so that they would represent three different emphases in terms of the ratios of tariff components, which means that the income produced by the tariff depends more on either the fixed, demand, or volumetric charges. The billing basis of the demand charges was harmonized for the study so that it would correspond to the recommendation made by the Finnish regulator (see, e.g., [6]) regarding the tariff structure and the billing bases of the tariffs used for larger low-voltage customers. The price levels of the harmonized demand charges were determined to generate the same turnover than what the present DSO tariffs do when no changes are assumed to take place (i.e., Case 1) in the electricity use. Four different situations were investigated in a setting, where the EC would

Table 1. Electricity distribution network tariffs used for larger customers connected to the low voltage network by three Finnish DSOs.

| DSO | 1 | 2 | 3 |
|---|---|---|---|
| Fixed charge (€/month) | 171.92 | 42.50 | 26.00 |
| Demand charge (€/kW) | 2.43* | 2.81* | 4.45* |
| Volumetric charge (c/kWh) | 0.95/1.39** | 2.02 | 0.88/1.66*** |

* Demand charge (harmonized billing basis) is billed based on the peak demand of the month.

** Time-of-Use. Higher rate is used during nighttime (07:00-22:00).

*** Time-of-Use feature. Higher rate is used during winter workdays (Dec.-Feb., Mon.-Fri., 07:00-21:00.

Table 2. Descriptions of the studied cases.

| Case | Electrical ERs | Description |
|---|---|---|
| Case 1 | - | No Electrical ERs. |
| Case 2 | 30 kWp shared solar PV system | Solar PV system size is the same under the pricing of each studied DSO. |
| Case 3a | 30 kWp shared solar PV system<br>20 kWh shared BESS | The electrical ERs are used to maximize the self-consumption rate. |
| Case 3b | 30 kWp shared solar PV system<br>20 kWh shared BESS | The electrical ERs are used to maximize the self-consumption rate and shave the demand peaks. |

consist of the common consumption of the multi-apartment building and the apartment loads. The descriptions of the studied cases are shown in Table 2. The electricity use profiles in the four cases described above are presented in Fig. 1. In the figure, Case 1 is based on the actual hourly

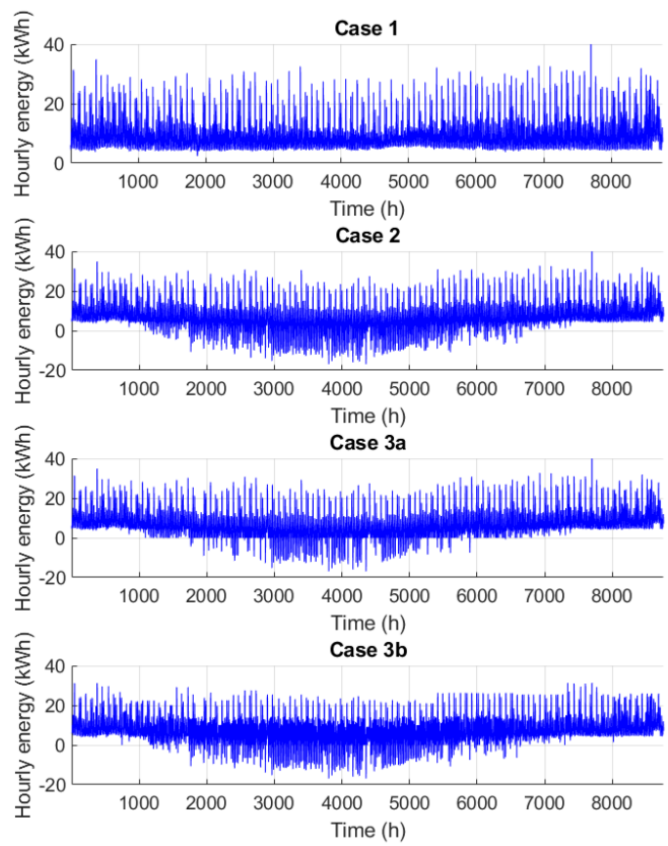


Figure 1. Hourly electricity use profile of the EC in all three studied cases (1, 2, 3a, and 3b) over a one-year period.

energy readings of the multi-apartment building. In the other three cases, 2, 3a, and 3b, the original electricity use profile is modified due to the impacts of different electrical ERs. It is observed from the figure that in cases 2, 3a, and 3b, the electrical energy produced by the solar PV system occasionally exceeds the consumption of the multi-apartment building, and the excess energy is fed into the public electricity network. In this study, no electricity distribution network tariffs were assumed to be carried out for the injection. However, some Finnish DSOs do charge a small volumetric rate (0.07 c/kWh VAT 0% price cap set by the current Finnish legislation) for the injection. The solar PV system for each related multi-apartment building were sized by using methods described in more detail in [7], and, for the studied cases, a 30 kWp size system was included. In addition to the solar PV system, in cases 3a and 3b, a 20 kWh BESS was used in the simulations.

## V. Results

To investigate the impacts of an EC that is formed by a multi-apartment building with and without electrical ERs on the DSO turnover, the monthly turnovers of different cases are shown in Fig. 2. In addition, the relative differences in the DSO turnovers when compared to Case 1 are shown in Fig. 3.

It is observed from Figs. 2 and 3 that when different electrical ERs are added, the annual DSO turnover decreases especially during the spring and summer (i.e., March-August.) In addition, as it is observed from Fig. 2., the level of the decrease in turnover is dependent on the ratios of different tariff components. Because the income produced by the electricity distribution network tariff in the case of DSO 1 depends significantly on the fixed charge, the impact of ERs on the turnover is smaller (i.e., less than 10% decrease in the total annual turnover in Case 3b) when compared to the other two studied DSOs. The income from the tariff used by DSO 2 depends more on the demand charge, and the overall impact of ERs on the DSO turnover is higher than in the case of DSO 1 (i.e., approximately 13.7% decrease at an annual level in Case 3b.) The electricity distribution network tariff of DSO 3 has a higher emphasis on the volumetric charge that, together with the demand charge, led up to a maximum annual decrease of approximately 19.3% in Case 3b.

An important observation made from Figs. 2 and 3 is that the DSO might face a seasonal turnover risk if, and when, different electrical ERs become widespread, and the number of ECs increases. From a DSO viewpoint, the costs of a DSO depend more on the capacity of the electricity network, and on the short-term, a large portion of the costs is fixed. Thus, the monthly expenses for the DSO remain steady across the year, but the income used to recover those costs might become more dependent on the season. Additionally, as it is observed from Fig. 1., the locally produced electrical energy exceeds the consumption during summer months, and that excess electrical energy is injected into the public electrical energy system. Since in Finland, there is a price cap in place for the injection, and, if the number of ECs as studied herein increases, then the practices regarding how injection should be billed by the DSO must be investigated in the future to ensure that the distribution pricing is cost reflective.

However, ECs should not be perceived only as a threat for the DSO. As it can be observed from Fig. 1, in Case 3b, by adding a BESS, and operating the electrical ERs also to shave the demand peaks, the largest peaks could then be lower than at present (i.e., Case 1 shown in Fig. 1.) If the demand at the network level could be lowered by using electrical ERs, then the present network could fit more customers, and the DSO

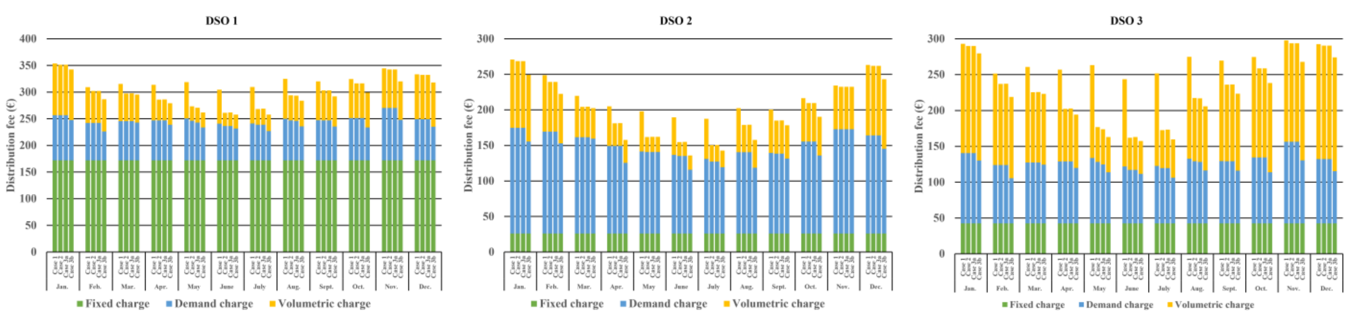


Figure 2. Monthly electricity distribution network fees over a one-year period for the studied EC in different cases (1, 2, 3a, and 3b) respectively that are calculated using the electricity distribution network tariffs of 3 Finnish DSOs shown in Table 1.

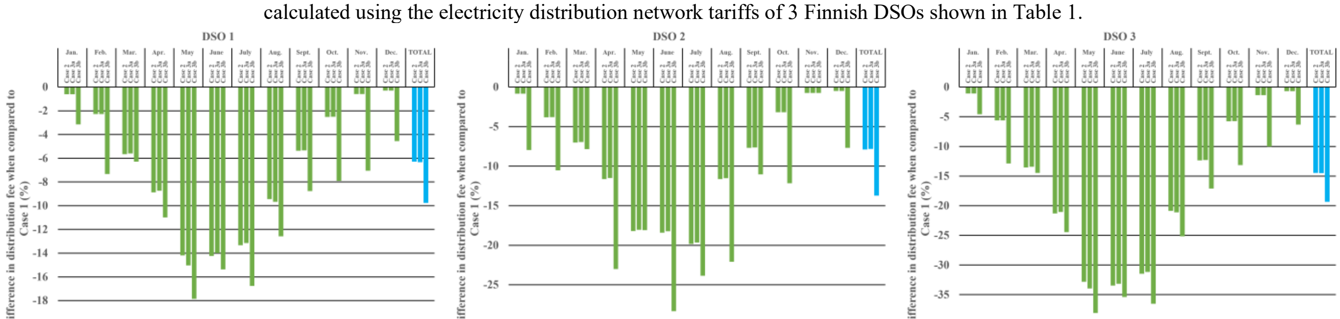


Figure 3. Monthly relative differences (green bars) between turnovers in different cases (2, 3a, and 3b) when compared to Case 1, which represents a situation where the EC has no electrical ERs. The light blue bars on the right side depict the total relative differences in the annual turnovers in different cases (2, 3a, and 3b) when compared to Case 1.

could save in costs in the long term, consequently benefitting the customers in the form of lower electricity distribution network fees. The evaluation of potential cost savings and their link to tariff design requires further research that would include larger electricity networks. However, that aspect is ruled outside the scope of this paper.

It should be noted that the electricity distribution network tariffs used in this study are used for larger customers connected to the low-voltage network. Simply put, this means that the tariffs used herein are at present used for load customers, and there are no specific electricity distribution network tariffs in place for different types of ECs in Finland.

## VI. Discussion

As one potential solution for the possible risk the ECs could impose on the DSO, the pricing could be developed, e.g., by introducing different rates that could account for different electrical ERs. For instance, it should be investigated if a basis could be located for the DSO to use different price levels for ECs that have different electrical ERs. If the EC has only a shared solar PV system, then the unit price of the demand charge could be different when compared to a situation, where the EC also has energy storage, which could be used to shave the peak demands at the connection level as shown in Fig. 1. Demand charge plays a key role here because peak demand is a central cost driver in distribution business.

The case study presented in Section 4 was based on the present electricity distribution tariffs of 3 DSOs in Finland. The main weakness of the study is that the tariffs used are those currently used for larger customers connected to the low-voltage network. From a tariff design viewpoint, the present tariffs have been determined for the current set of customer groups. Thus, to determine tariffs for ECs that generate the turnover which would reflect the costs the customers cause, cost allocation should be done accounting for all customer groups. For instance, if several ECs were to be expected to form, then the number of regular load customers would decrease, e.g., those situated in multi-apartment buildings, which affects the cost allocation results.

As for the further work related to electricity distribution pricing in the case of ECs, several topics that require further research can be identified as follows.

- Ways to determine cost-based electricity distribution network tariffs ECs accounting for both the present and new (i.e., ECs) customer groups should be investigated.
- Different electricity distribution network pricing schemes should be explored that both further the progress of ECs to emerge and ensure the collection of adequate turnovers from EC customer groups.
- A broader study that includes several consecutive years should be done to gain a wider view of economic impacts of ECs on the DSO turnover.
- The integration of electrical ERs should be studied more widely, e.g., to seek ways to increase the size of the solar PV system as the policy targets aim toward producing more clean energy in the future [8].

## VII. Conclusion

This paper discussed the role of electricity distribution network tariffs in the case of an energy community (EC) that could be formed by a multi-apartment building in the Finnish electricity market environment. As ECs can be categorized based on where the members, i.e., the electricity points of use, are located, multi-apartment buildings as local behind-the-meter ECs are just one example of the many. The distribution system operator (DSO) aspect should be considered in the case of ECs, because, as shown in the case study presented in this paper, different mixes of electrical energy resources (ERs) might have a significant impact on the DSO turnover. The results of the case study show that, with the present electricity distribution network tariffs that are used by 3 Finnish DSOs, might result in a seasonal risk in terms of the DSO turnover. However, a combination of a solar photovoltaic (PV) system and a battery energy storage system (BESS) together can be used to shave the peak demands, which can provide long term cost savings for the DSO that also benefit other customers. The turnover risk for the DSO could be mitigated by using alternative pricing schemes that apply for different kinds of ECs, and those should be determined based on costs accounting for that ECs might have to be classified as separate new customer groups in tariff design. Further research should include investigating the use of alternative electricity distribution network tariffs and to quantify the potential cost savings for the DSO.

## References


[1] J. Valta, K. Lummi, T. Vanhanen, P. Järventausta, "Value streams in different energy community types – Review and Implications", in *Proc. 2023 EEM Conf.*

[2] 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.

[3] Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity.

[4] K. Lummi, J. Koskela, P. Järventausta, "Development possibilities of distribution network service charges of low-voltage customers - Apartment houses as energy communities", in *Proc. 2023 CIRED Conf.*

[5] European Union Agency for the Cooperation of Energy Regulators (ACER), "Report on distribution tariff methodologies in Europe", Report, Feb. 2021.

[6] Energy Authority, "Recommendations of the Energy Authority regarding the harmonization of network service charge structures" (In Finnish: "Energiaviraston suosituksia verkkopalvelumaksujen harmonisoiduksi rakenteeksi"), [Online] Available: https://energiavirasto.fi/-/suositukset-sahkon-verkkopalvelumaksujen-harmonisoinnista.

[7] J. Koskela, A. Rautiainen, P. Järventausta, "Using electrical energy storage in residential buildings – Sizing of battery and photovoltaic panels based on electricity cost optimization", Applied Energy, Vol. 239 (1), pp. 1175-1189, 2019.

[8] 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 (COM/2022/221 final).