Prosumer Aggregators in Romania

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Abstract. *The European Union has pledged to transform Europe into the first climate neutral continent by 2050, and the first step towards achieving this goal is to reduce greenhouse gas emissions by 55% by 2050, compared to levels recorded in 1990. The two main paths the EU has chosen to follow to ensure its climate neutrality goals are electrification and the increase of the integration of renewable energy technologies. If the 2010 period was characterized by the development and adoption of large-scale production of energy by using renewable sources, the 2020s seem to encompass a decentralization process, meant to bring energy production closer to the final consumer. In Romania, the past three years saw a rapid growth in the overall production of energy through distributed energy sources. Although this development is encouraging for achieving the broader environmental targets of the EU, at a local level there are several disadvantages that are starting to appear, such as issues in the distribution grid and confusion of both consumers and prosumers regarding the economic advantages of producing energy locally. The main goal of the research that has been conducted for a doctoral thesis was to develop a set of recommendations for aggregators regarding prosumers, based on mathematical model and calculations centered around a specific time frame. Research was spread into identifying and analyzing existing renewable technologies, detailing concepts such as decentralization, electrification, demand response and power aggregators, and the study of the main power aggregator business models. For these aspects to be covered, secondary research was used in the form of both academic and industry state-of-the-art papers. The main contributions of the research are the synthesizing of available information on aspects related to decentralized energy systems, and a set of recommendations aimed at aggregators, as a business, and existing and potential future prosumer.*

Keywords: prosumers, renewable technologies, decentralization, power aggregators, green energy

Introduction

In the past two decades, the leading factors that have fueled the technological development and commercial spread of renewable energy technologies were the apparent depletion of natural resources, the overall increase in energy consumption, and ongoing climate changes. The integration of renewable technologies in the energy mix started to accelerate in the 2010s with large scale capacities, such as wind turbine farms and ground photovoltaic panels. Although the establishment of a proper regulatory framework that incentivizes investments in such technologies was a road paved with legislative errors and frequent changes, large scale deployment can be seen nowadays as a success. Looking forward to 2030, the next decade will be characterized by the deployment of distributed energy resources (small-scale renewable technologies installed at the consumption site).

Seeing how the energy sector is responsible for 75% of greenhouse gas emissions in the European Union, in 2018 the European Parliament and the Council of the European Union set an

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ambitious target of having energy produced from renewable sources represent 32% of the total energy consumption by 2023. This target was increased to 40% in 2021, and a proposal to increase the target to 45% was made in 2023. These series of targets are a major undertaking, especially since the European Union is one of the main producers of greenhouse gas emissions, having situated as the second largest producer between 1850 and 2021. However, efforts in the past years contributed to the EU being situated as the fourth largest producer in 2021.

To reach carbon neutrality in the energy sector, the European Union is currently encouraging two processes within the larger context of decentralization:

1. firstly, the increase of the integration of renewable energy technologies, mainly through encouraging the deployment of distributed energy resources, and transformation of the distribution grid into a bidirectional grid;
2. secondly, the transformation of electricity into the main energy carrier (electrification in the transport and residential heating sectors), which in turn would increase the flexibility potential of consumers (demand response).

These two processes combined have the purpose of empowering consumers and allowing them to become active participants in the power sector.

Between 2020 and 2023, in Romania, the number of prosumers vastly increased, and once delays caused by regulations were solved, in 2023, an average number of 7.000-8.000 prosumers had their capacities integrated into the grid. In June 2023 a total number of 77.638 prosumers were recorded, with 973 MW installed.

However, this massive deployment of distributed energy resources comes with a series of challenges, starting with technical issues for the distribution system operator. Given the large number of prosumers, distribution system operators now must become familiar with concepts which were previously limited to transmission system operators, which are used for managing inverters, using smart meters, and connecting storage systems to the grid. In Romania, the desire of consumers to become prosumers (and in some cases the misguided intention of turning this activity into a source of revenue) caused increased pressure to the grid and to the distribution system operators. Beside a series of measures that can be taken by operators to adapt themselves to the current conditions (such as the upgrade of their information system in order to be better prepared for the large number of prosumers, and the consolidation of the distribution grid) a new participant in the power sector, in the form of the aggregator, can help with taking some pressure away.

Through its services the power aggregator acts as an intermediary between prosumers and the other participants from the power sector by establishing a portfolio of small-scale production sites and selling their excess production while providing monetary value to prosumers and stability to the system.

Given the numerous changes and developments that have taken place in the power sector in the past years, as well as the characteristics that set the energy sector aside from other industries and the fact that these topics aren't extensively covered in academic papers in Romania, the author set to explore in his thesis the challenges implied by the decentralization process by using state of the art literature and to develop a set of recommendations for prosumers and aggregators, based on mathematical model calculations made for several scenarios.

The paper is divided into seven chapters, which cover theoretical aspects relevant to the study and the applicative side of the research.

The first chapter of the thesis presents the main renewable energy technologies, their advantages, and disadvantages. Both the positive aspects associated to the integration of said

technologies in the energy production mix (technological maturity, economic competitiveness, social acceptance) and the negative effects that may occur in the energy grid and environment due to improper deployment. The chapter concludes with a comparison of both renewable energy technologies and conventional technologies and the solar photovoltaic technology is selected as the technology that will be further used for the mathematical model due to its technological and economic maturity and extended applicability at residential level, which brings relevant contributions to the decentralization process.

The second chapter details the main elements associated with the integration of renewable energy technologies in the energy sector. Concepts and trends such as distributed energy sources, hybrid systems and microgrids, the transition from a passive grid to an active one and the new role of the distribution system operator are explored extensively.

In the third chapter, the role of the power aggregator in the energy market is described, based on the existing business models of aggregators and the services which can be provided.

The following three chapters highlight aspects and data related to the evolution of prosumers both in the EU and in Romania, the expansion of aggregators in the EU, the technical and economic potential of photovoltaic systems. Following the transition chapter (4), the mathematical model is presented in the fifth chapter, and several scenarios based on it are presented in the sixth chapter.

The hypothesis of the thesis is that the emerging services of power aggregators will prove invaluable in the following years to both prosumers, by allowing for a better mechanism of rewarding the commercialization of excess production, and access to markets that are inaccessible to individual prosumers (balancing market), and distribution system operators.

Literature review

In order to gain a better understanding of the power sector in terms of the theoretical aspects related to renewable energy technologies, power production, the transmission and distribution grid, the trending technologies that enable and facilitate decentralization and the services provided by aggregators, state of the art academic papers were analyzed, filtered and referenced. Furthermore, industry articles and reports were examined to establish the current state of deployment of distributed energy resources and determine projections and forecasts for the following years. Finally, European Union and local legislation papers were used to define a clear regulatory framework to determine what limitations are currently in place and to anticipate future changes accordingly.

In the first three chapter of the thesis predominantly theoretical aspects were covered in order to:

- Classify energy types (Bahman et al., 2022);
- Identify the main problems caused by greenhouse gas emissions (European Commission, 2023);
- Determine projections for the following years (International Energy Agency, 2023) ;
- Detail existing renewable energy technologies (Azadani. L., N., 2023), (Marsh, J., 2023), (Lee & Kwon, 2020), (Al-Ezzi & Ansari, 2022);
- Define concepts related to the decentralization process (Martin et al., 2017), (Frost & Sullivan, 2020), (Cummins, 2022);
- Classify aggregator business models (Juffermans, J., K., 2018) and their business flows (Zacanella et al., 2017), (Ghose et al., 2019)

The fourth chapter represents a transition to the applicative segment of the thesis by presenting data related to prosumer and aggregator deployment in the EU and in Romania (Bodis et al., 2019) , (Naber et al., 2021), (European Environment Agency, 2022).

After analyzing the existing literature, the apparent consensus at an academic level indicates that, moving forward, prosumers and aggregators will be the leading factor in decentralization of production and consumption, and a determining factor in the increase of flexibility. However, industry reports do not appear to be as positive and caution that renewable energy integration is not happening at a rate that will ensure that EU targets are met by their respective deadlines. Furthermore, industry reports urge regulatory bodies to make changes that facilitate proper infrastructure developments and encourage consumers to play a more active part in the energy sector.

Methodology

As part of the research methods used by the author in establishing the flow of the doctoral research, the following aspects were considered:

- Defining the overarching objective of the thesis and setting up several subtasks designed to help achieve it;
- Establishing the research methods and tools used during the research.
  The second aspect can be broken down into the following steps:
  - Selecting and critically analyzing information related to the field which is the subject of the research (descriptive research, as a preliminary form of study meant to identify and filter relevant information;
  - Centralizing, synthetizing and interpreting information in order to elaborate a mathematical model;
  - Elaborating a mathematical model and presenting the results of economic calculations in order to determine the negotiation margins between prosumers and aggregators and coming up with a set of comprehensive recommendations for both parties.

In order to achieve the overarching objective, secondary research of both academic and industry papers was used. The first type of literature was explored in order to gain a better understanding of the theoretical concepts related to aggregation, while the second type was used to determine the current state of deployment of the aggregator business models in the world. Finally, the regulatory framework of the power sector was defined by analyzing reports of the European Union and other endorsed entities. Since in Romania there is currently only one aggregator that performs services meant for prosumers, secondary state of the art literature sources were mainly used during the research.

Based on the data resulted from the secondary research, the following personal contributions and results were brought:

- The comparative analysis of the existing renewable energy technologies by determining the main advantages and disadvantages;
- The synthetization of the building blocks of power aggregator business models;
- The elaboration of a mathematical model meant to highlight the negotiation conditions between prosumers and aggregators;
- Deifying a set of recommendations for both aggregators and prosumers.

The main tools used for the previously mentioned calculations are the PVGIS web interface (European Commision, 2022), which were used to gather data related to solar radiation and the energy production for an installed photovoltaic solar capacity of 1 kW, and Microsoft Excel which

was used to centralize the input data and perform calculations of the production profile of a Romanian prosumer.

The seventh chapter of the thesis contains the results of the simulations which were run for the four scenarios in the previous chapter.

The four scenarios begin from a consumption profile from 2020 for an apartment in Bucharest, Romania. The data regarding consumption is available for every hour and was recorded by a smart meter. To determine a production profile (Figure 1), statistical data from the PVGIS web interface was used. The database of the interface includes hourly data for every year between 2003 and 2020, and the interface allows the user to select the location (Bucharest, latitude 44,43, longitude 26.09), the type of photovoltaic system that would produce the energy (crystalline silicon), losses, angle, and orientation of the panel.

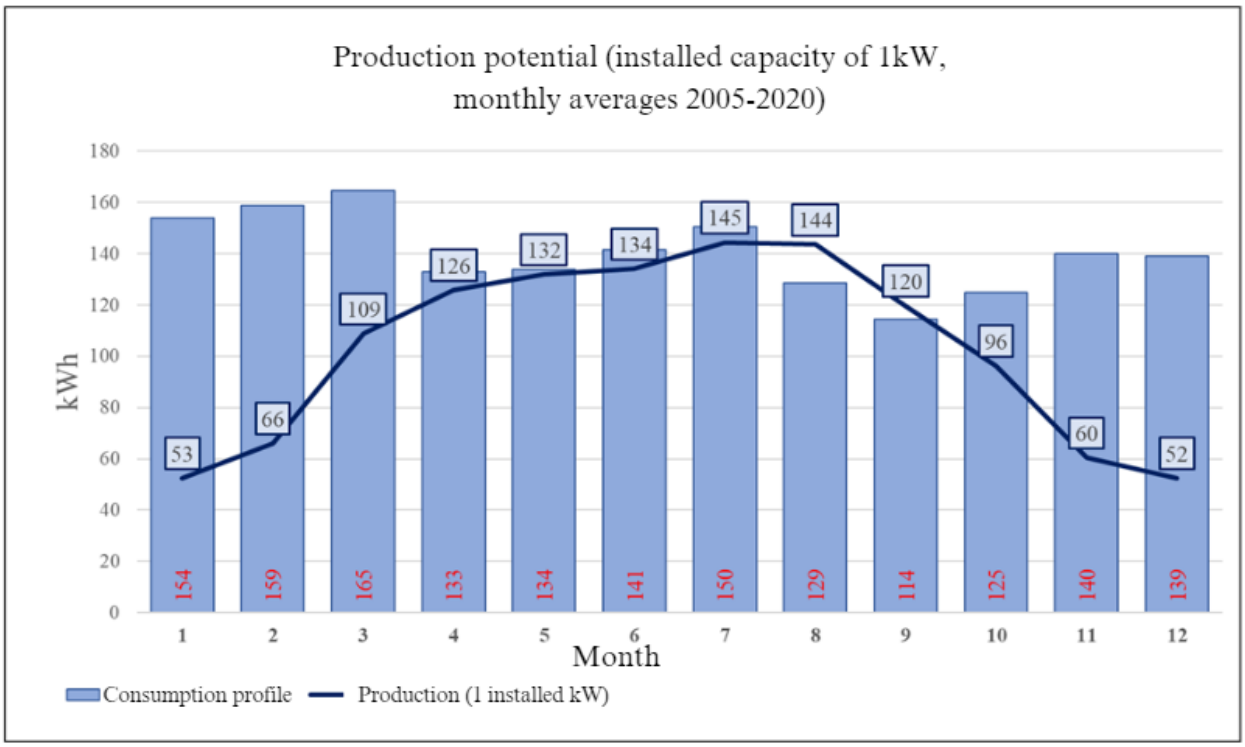

Figure 1. Monthly consumption and production for an installed capacity of 1 kW

Source: Author's own research).

Starting from these inputs, the author defined four scenarios as follows:

1. input data for 2020 and reference prices (contract and market) from 2020;
2. input data for 2020 and reference prices from 2021;
3. offsite production;
4. maximization of self-consumption through the installation of storage systems.

Results and discussion

Based on the results of the calculations and the current and foreseeable legislation, prosumers with installed capacities that are less than 200 kW, the attractiveness of a potential aggregator contract is influenced by the difference between the price of energy defined through the regulatory framework from the price from the competitive market is positive or negative and by the value of

said difference. If the price from the competitive market is higher, then aggregators are able to offer their clients (the prosumers) a higher price than that with which the prosumer would normally be rewarded by the regulatory framework. Throughout the time frame analyzed in the previously presented cases, both situations can be seen.

A prosumer segment that may find aggregator services attractive is represented by prosumers with installed capacities that exceed 400 kW, due to the fact that the current regulatory framework is not rewarding said prosumers, since they are regarded as actual producers.

For the prosumer segment with installed capacities between 200 and 400 kW it is more challenging for aggregators to make attractive offers since these prosumers are rewarded through the regulatory framework with the base price represented by the weighted average price from the day ahead market, for every hour in which they inject energy into the grid. This price is similar to the price that an aggregator may normally offer its clients, thus making this segment difficult to include in its portfolio.

The cases also highlight that while the number of prosumers in Romania from 2023 is nearing 100.000 (80.000 at the middle of 2023, which indicates a high aggregating potential for small prosumers), establishing a relevant portfolio of prosumers is a difficult undertaking. The difficulty comes from the fact that there's a minimum quantity of at least 100 kW which must be bid for an hour in the day ahead market. This threshold can be reached only after establishing a portfolio that includes prosumers with installed capacities that exceed 400 kW, such as businesses from the hospitality sector and smaller producers (wind and solar parks).

During time spans when the price from the market is rising or during times with lower trading on the spot markets, aggregators are advantaged by the fact that the price in the spot market influences the price from the supply contract to a lesser extent. On the other hand, as highlighted in the first case, during time spans with intensive trading on spot markets, when the energy price from the prosumer's supply contract exceeds the price from the spot market, losses on the aggregator's site should be expected. Losses can be higher if the contract between the prosumer and the aggregator is based on set prices instead of a percentage split of the aggregator's revenue between the two parties.

The study also includes two other cases which highlight two opposing cases: offsite production and the maximization of storage. The first case represents a suboptimal choice from the prosumer's side since the revenue in this case would represent only 55% of the revenue of the prosumer in the case in which consumption and production took place at the same location. The only scenario in which this solution would be viable is applicable for supermarket stores, or similar businesses that have multiple locations spread through the country and decide to invest in production in areas with constant sunlight or wind, however, this option is not recommended for residential prosumers. The second case, in which storage is maximized, highlights the fact that for prosumers, the main revenue stream from renewable energy is represented by the savings associated with self-consumption. In this case, the revenues of prosumers are 50% higher than the ones recorded in the first two cases.

Given the previously presented results, the main recommendations for prosumers would be to carefully plan the capacity of their production capacities, since starting with 2030, prosumers with installed capacities which exceed 250 kW will be charged for balancing issues caused to the system and to target increasing their self-consumption by installing storage units.

For prosumers, the main recommendations have to do with planning their portfolio and its expansion by attempting to start their business with prosumers or small producers with capacities which exceed 400 kW, then to expand their portfolios by attracting prosumers with installed

capacities which are less than 200 kW and then to diversify their business in other markets (balancing market) and other services, such as electric vehicle aggregating and demand response services.

Conclusion

In the larger context of decentralization, which entails the gradual transition from energy systems based on centralized production of electricity and large consumption sites to decentralized production and consumption, prosumers will be essential. The decentralization process is fueled by governments' targets for decarbonization and a strong shift towards electrification, with the progressive elimination of coal and natural gas as sources of electricity production.

In the years to come aggregators will play an increasingly important role in the power sector, due to their potential of offering valuable services for prosumers and contribution to the system's overall stability.

The perspective over the technical and economic potential for the prosumer activity is a positive one, both in the EU and in Romania. In 2019, the EU estimated that Romania has a potential situated between 25.000 GWh/year and 50.000 GWh/year. At a political level this potential must be valued through careful planning and attractive incentives which offer potential prosumers reliability, transparency, and predictability.

While the aggregator activity greatly relies on prosumers, the interests of the two parties are not common. Through its production, the prosumer has two main forms of revenue, which come from avoided costs through self-consumption, and the revenue coming from the injection of excess energy into the grid. The mathematical model which was used determined that for prosumers self-consumption should be maximized, however, as self-consumption of the prosumer is increased, the activity of the aggregator becomes limited.

In Romania, the past few years saw a gradual increase in the number of prosumers, specifically 2023, which saw an exponential increase compared to 2022. This was due in part to a regulatory framework that both incentivized investments in renewable energy sources at a residential level and rewarded the injection of excess energy through guaranteed prices. While these years were intended to help Romania reach its environmental targets, the aggregator's activity was somewhat discouraged.

As previously detailed, aggregators should carefully plan the establishment and development of their portfolios. The diversification of the portfolio is also subjected to some limitations of a legislative nature for example, the contribution of the prosumers from the portfolio to the balancing of the entire portfolio of the aggregator would normally be an important component of revenues, however this is not possible in Romania, as the aggregator cannot be affiliated with the supplier.

Even if the current regulatory framework is not encouraging the aggregator's activity, it must be noted that in the past, the primary goal of the legislation was to increase the number of prosumers. However, prospects for the development of the role of aggregators exist. This development is anticipated by the current tendency of the regulations to limit the incentives for the prosumer (elimination of net metering and fixed tariffs, orientation towards a fair participation of the prosumer in the costs of network development, etc.).

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