NATIONAL UNIVERSITY OF SCIENCE AND T ECHNOLOGY
“POLITEHNICA” BUCHAREST

DOCTORAL SCHOOL OF ENTREPRENEURSHIP, ENGIEERING AND
BUSINESS MANAGEMENT

# SUMMARY

## Research on the participation of prosumers in the energy market and their aggregation

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# Contents

*Key words:power aggregators, prosumers, green energy transition, renewable technologies*

## THE TOPIC AND MAIN OBJECTIVE OF THE THESIS

The topic of the doctoral thesis explores the participation of prosumers in the energy system and the aggregation of distributed energy sources within the internal energy market. The field is new in Romania, so the development of the research required the use of recent experience of the European Union.

Among distributed energy sources, the aggregation of dispatchable consumption and electric vehicles are approached in a general manner. However, the aggregation of prosumers is the subject of a practical approach, with the aim of developing recommendations for new entities participating in the electricity market: prosumers and aggregators. This is the main objective of the doctoral thesis, the fulfillment of which required the development of a set of mathematical equations and the performance of technical-economic calculations focused on a well-defined time horizon. Prosumers represent a new field in Romania, which, unlike dispatchable consumption and electric vehicles, is developing at a rapid pace, with insufficiently anticipated consequences, including by policy makers, legislative initiators, and regulators.

To achieve the main objective, specific objectives were established, and to correctly place the main objective in the economic and social context of the energy transition, contextual objectives were defined.

The contextual objectives are:

- Selecting a technology for producing energy from renewable sources to study the establishment of an aggregation portfolio,
- Identifying the means of integrating renewable sources into the energy grid,
- Understanding the technical and commercial aspects that define the activity of aggregators.

The specific objectives are:

- Determining the prosumers potential,
- Determining the legislative and regulatory elements that condition the business of aggregating prosumers,
- Developing a set of mathematical equations to evaluate the cost avoided by prosumers through self-consumption and revenues from injection into the network, the latter with a breakdown into two scenarios: regulated (involves the supplier having to commercializthe energy produced by the prosumer) and competitive (aggregation);
- Determining a relevant time horizon for Romania for the application of mathematical equations,
- Performing technical and economic calculations, interpreting the results, and elaborating recommendations/conclusions.

# THE STRUCTURE OF THE THESIS

**The first chapter** of the paper presents the main technologies for generating electricity from renewable sources, their advantages, and disadvantages. The chapter concludes with reflections on quantifying the positive and negative effects of certain technologies in both the field of conventional energy sources and renewable ones.

**Chapter 2** addresses the fundamental concepts that accompany the integration of renewable energy sources: distributed energy sources, hybrid systems, and microgrids, aspects of the transition from a passive distribution network to an active one, and the new role of the distribution system operator in this context.

The role that the aggregator has in the energy market is addressed in **Chapter 3** of the work under the generic title "business models." Determining the services, it provides and the market/markets in which it operates are addressed under the generic title "operating models."

**Chapter 4** selects significant elements regarding the development of prosumers, both in the European Union and in Romania, and the European experience in aggregating the production of electricity injected into the network by them. The technical and economic potential, applicable legislation, and aggregation models are mentioned.

**Chapters 5-6** present the results of fulfilling the last three specific objectives, and contain the set of equations (primary data, formulas, and results) and the calculations performed, that lead to recommendations regarding the aggregator-prosumer negotiation and recommendations for portfolio construction.

Said chapters present the modeling of the interaction between prosumers and the electrical system and the electricity market, in a regulated or competitive manner (through the aggregator).

The modeling consists of:

- evaluating production, self-consumption, export to the distribution grid, extraction from the grid,
- evaluating revenues from injection and the cost avoided through self-consumption,
- evaluating the difference between injection revenues obtained in alternative scenarios (regulated/competitive), by using a negotiation margin between the aggregator and prosumers.

The set of equations developed was also used for the analysis on the 2020 horizon of the ways of capitalizing onsite production compared to the capitalization of photovoltaic energy production in two alternatives (opposite in principle and different in efficiency):

- increasing the injection into the network through offsite production (with virtual compensation) and
- increasing self-consumption to the detriment of injection, but with reduced extraction, by using storage systems.

The results of these simulations are presented in **Chapter 7**.

In the context where the theme of doctoral research is only at the beginning of a systematic approach in Romania, the innovation factor of the thesis is present in Chapters 4-7. These chapters present:

a) the prerequisites for developing a set of mathematical equations aimed at determining the conditions for the aggregator-prosumer negotiation (Chapter 4),

b) the elaborated set of mathematical equations: formulas, primary data, data resulting from calculation (Chapter 5),

c) the results of the calculations performed to determine the financial revenues for prosumers and aggregators in various scenarios (Chapters 6,7).

The results of the simulations were presented graphically and in tables. This was followed by their interpretation, a set of original conclusions and recommendations, regarding the objectives and strategies that aggregators can establish and the constraints they may face in the activity of aggregating prosumers.

## COMPARATIVE ANALYSIS OF TECHNOLOGIES FOR GENERATING ENERGY FROM RENEWABLE SOURCES

The purpose of the introductory part of the thesis is to provide an overview of the technologies used for producing energy from renewable sources and to identify indicators and criteria for selecting technologies.

The classification criteria for technologies are:

- the origin of energy (the source)
- the stage of technological development
    - mature,
    - still in the research and development phase.
- installed capacity
    - large scale
    - distributed production
- geographic criteria and type of human settlement
    - rural/urban
    - metropolitan areas
    - hard-to-reach communities

To date, measures to encourage electricity production technologies based on renewable sources have consisted of financial support mechanisms to ensure additional income for producers from renewable sources, various measures to discourage the production of electricity with carbon emissions and favoring producers from renewable sources (granting priority access to the transport grid).

The IEA anticipates an increase in renewable energy production capacities by 60% (425 GW) between 2022 and 2027, double the growth from 2016 - 2021.

The technology considered in the following chapters for the analysis of the formation of aggregation portfolios is the production from solar photovoltaic sources through rooftop solar panels. Photovoltaic technology was chosen to give the main path of the study of the effects produced by prosumers and their aggregation within the context of the energy market. The conditions offered by the Romanian market were chosen to provide the relevant legislative and regulatory framework necessary for a concrete analysis of these effects, both qualitatively and quantitatively. These choices are due to the fact that:

- Photovoltaic production has a significant technical potential in the European Union, and especially in Romania.
- Strategically, legislatively, normatively, and from the point of view of public involvement and acceptance, Romania has the necessary conditions to be able to accelerate the decarbonization process based on this technology.

However, the aggregation of photovoltaic production by specialized entities is necessary to move beyond the current stage based on incentives and enthusiasm, and to replace it with a framework based on professionalism, security, and efficiency, including financial efficiency.

## DISTRIBUTED ENERGY SOURCES AND THE INCREASING NEED FOR SYSTEM FLEXIBILITY

Renewable sources have contributed in the last decade to reducing the dependence on fossil fuels and to the decarbonization of the energy system. Worldwide, in 2022, developers installed 295 GW of renewable energy production capacity, increasing the cumulative global installed capacity by 9.6%, to 3,372 GW. It was a year of record growth, largely based on newly installed photovoltaic systems: an annual increase of 22.4%.

The increase in installed capacities globally from year to year by an average of 13% for wind farms and 27% for photovoltaic plants during the period 2016-2020 has made a positive contribution but has also led to an increased need for flexibility in the energy system.

The elements in the system that represent sources of variability, and which determine the demand for flexibility are fluctuations in consumption, technologies with a variable energy production profile, and system failures. It can be noted that on top of the traditional factors of variability in the system (failures and consumption variation), a new and constantly growing one has been added: intermittent production technologies.

However, the responsible actors (legislators, regulators, operators) must also recognize and take advantage of a great opportunity: the specific factors that contribute to consumption variation and the intermittency of production from renewable sources, which traditionally represent sources of variability, thus disturbance, can become stabilizing factors, offering flexibility services that balance the system. The participant that has a key role in this essential transformation is the active consumer (or "active client"), through the two main activities: dispatchable consumption and distributed production of electricity from renewable sources (respectively self-consumption). Aside from these, storage can be added. Facilitators within the energy system that influence the extent to which available sources of technical flexibility can be activated are markets, system operators, and the network.

The sources of flexibility in the system that respond to the demand for flexibility and contribute to balancing the system are flexible production units, dispatchable consumption (also called demand response), and storage systems.

a) Distributed production of electricity from renewable sources (mostly photovoltaic panels located at the residential level) is connected to the distribution network and contributes to reducing the need of drawing energy from the grid during the day.
b) Dispatchable consumption allows better control of consumption during peak hours, reducing demand, increasing system flexibility, and at the same time stabilizing the energy system and market prices.
c) Storage systems collect electricity locally for use during peak hours, thus flattening the consumption curve.

These three elements represent the object of the decentralization process, the sources of flexibility, and the subject of the aggregation effort carried out by specialized entities: aggregators.

## AGGREGATORS. BUSINESS MODELS AND OPERATING MODELS

Chapter 3 introduces the concept of aggregators. The term is present in European legislation through a two-step definition, reflecting the technical aspect, the combination of electricity consumption and/or production, and the commercial aspect, the sale/purchase of aggregated energy in the market.

Thus, according to Directive (EU) 2019/944 on common rules for the internal market in electricity, aggregation is " function performed by a natural or legal person who combines multiple customer loads or generated electricity for sale, purchase or auction in any electricity market”.

It can be observed that the definition does not impose restrictions on the size of the aggregated production capacities. Currently, in Europe, most existing aggregators include in their portfolios exclusively clients with large installed capacities, thus choosing to avoid including residential customers. Large capacities can be held by entities with the status of producer, but also by entities with the status of prosumers, depending on the declared business activity, in the case of legal persons. Many industrial customers could participate in the wholesale market due to their size, but prefer to collaborate with an aggregator.

The thesis distinctly presents the two mentioned steps by organizing the presentation into two sections. The first describes business models, detailing the two main categories of aggregators: those with a combined role and those with an independent one. The second describes the operating mode, trading energy on various markets.

The six types of aggregators either combine existing functions, fulfilled by existing entities: supplier, BRP (Balancing responsible party), service provider, prosumers, distribution operator with the new function of aggregator, or start as a new entity, without a history of activity in the market: the delegated (independent) aggregator. The latter represents approximately a quarter of all existing aggregators.

The main advantage of the combined role aggregator models is that no major changes are required in the existing legislative framework, their other functions being integrated into the energy system. In contrast, the business model of the independent aggregator represents an opportunity for increasing competitiveness.

The success of independent aggregators is conditioned by the existence of clear price signals in the wholesale market that guides their activity because the basis of the aggregators' business is price differences, and price variations which determine the size of risks/revenues.

The legislative framework must allow aggregators to participate both in the electricity trading markets and in the ancillary services market (adjustment, reserves).

The presentation of the operating models details the aggregator's interaction with wholesale and retail markets. The aggregator takes and aggregates energy from the retail market, which it sells in the wholesale market represented by the day-ahead market, the intraday market, and the balancing market.

In the aggregation process, energy manifests either as production, in the case of producers or prosumers, or as consumption, in the case of dispatchable consumption. The aggregator will therefore sell not only production surpluses (in the case of energy producers) but also ordered reductions in consumption in the case of dispatchable consumption (explicit flexibility). In the case of the aggregator who also acts as a supplier, balancing their own portfolio can be an objective of aggregation: surplus energy or ordered consumption reductions are no longer traded in the market but are used to balance opposite trends within their own portfolio, which represents a service to their own customers.

The paper presents the aggregation of dispatchable consumption and electric vehicles in a purely theoretical approach, since these aspects are not part of the practical application field of the thesis.

Following this theoretical introduction, the paper presents the current state in the aggregation of distributed energy resources, reviewing aggregators from European markets, from the point of view of the practical activity of aggregators, the way of constituting the portfolio, services offered.

## ENERGY AGGREGATORS IN ROMANIA

In Romania, the definition of aggregation is in line with EU legislation, and the activity is carried out based on a license. After obtaining an aggregation license issued by the National Regulatory Authority for Energy, aggregators can provide balancing services for the National Energy System. For this, they use the flexibility of production units, storage systems, or consumption within the aggregated unit they manage.

The aggregator qualifies for providing balancing reserves (system services) either through the production units, controllable consumption sites, or storage facilities belonging to the aggregation, or at the level of the aggregated unit by using their capabilities and IoT.

The characteristics of the activities carried out by an aggregator are given by the conditions of the aggregation license:

- The purpose of the activity is to generate income, in exchange for financial remuneration for the owners of the aggregated resources,
- Aggregators have the right:

    - to purchase electricity from the supplier/suppliers of their customers,
    - to acquire flexibility services from their customers, participants in the Aggregated Entity (EA),
    - to participate in the day-ahead market,
    - to participate in the intraday market,
    - to participate in the balancing market;
    - to participate in the system services market and to bid the available electric power for increase, reduction, or interruption.

- Aggregators are not allowed to carry out the activity of supplying electricity to end customers,
- The aggregation activity towards customers is carried out only after signing an aggregation contract.
- Aggregators are obliged to ensure the response for the dispatch instructions for their aggregated units.

## CATEGORIES OF PROSUMERS AND MEANS OF CAPITALIZING ENERGY

The term "prosumer" refers to an individual electricity consumer or a group of consumers who produce part of their electricity needs from their production capacity and use the distribution network to inject excess production and to extract electricity when production is not sufficient to meet their own consumption needs.

At the same time, the prosumer offers energy services for flexibility and storage.

Regarding the incentivization of the use of energy from renewable sources, EU legislation recognizes three categories of customers generically known as "prosumers", although it does not use this term.

The three categories are:

- Self-consumer of renewable energy, who is a single final customer and can be an individual residential consumer or a small enterprise, for example, public institutions (schools, hospitals, government buildings, etc.).
- Self-consumers of renewable energy who act collectively, for example, owners and tenants in a flat or apartment block who use the building's roof to install solar panels.

- Renewable energy community, which is essentially a legal entity, with shareholders being less geographically grouped, ranging from a local community to one with national reach. Shareholders are individuals, SMEs, or local authorities.

Depending on the entities involved and the methods of energy transfer, the following policies are defined, which differ in the way of valorizing excess production.

a) SINGLE ENTITY
b) "INTER PARES"
c) SHARING PRODUCTION
d) AGGREGATOR

The production capacities and consumption sites may belong to a single entity (a), to third-party entities (b), to energy communities (c), or represent participants in a trading platform/ the clients of an aggregator. While the "single entity" (a) represents an autarchic model, in which the prosumer does not interact with other entities and (virtually) does not alienate excess energy, the other three methods of valorization imply interaction with other entities, including with other prosumers (b), sharing energy with them (c), and direct trading or through an intermediary (aggregator) (d).

## EXPLOITING THE PHOTOVOLTAIC POTENTIAL ON ROOFTOPS IN ROMANIA.

An EU-funded analysis (2021) of the potential of prosumers to contribute to covering the electricity consumption establishes the size of this contribution along three separate time horizons: 2015, 2030, 2050, with the last two horizons being approached in three hypotheses:

- Reference scenario ("business as usual");
- The scenario with maximum use of the technical potential of renewables, but without storage; social and financial constraints are not considered;
- The self-sufficiency scenario (similar to the previous one, but also considering storage).

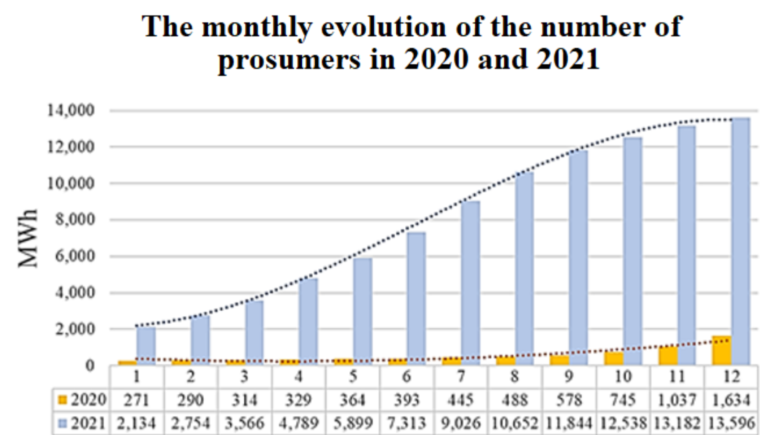
The last two scenarios highlight the role of prosumers (individuals and in energy communities) at a global level, in the residential sector (where in 2050 prosumers can cover 89% of their own consumption) and the tertiary sector (where prosumers can cover 20% of their own consumption). In the scenarios of maximum renewable/maximum self-sufficiency 2050, the solar source represents 59% of the prosumers' potential.

For each member state, the stock of residential and utility buildings and the demand for electricity in 2015, projections of the evolution of the residential housing stock and electricity demand were considered. The production of photovoltaic solar electricity in 2015 and the forecast for 2030 and 2050 are those used and calculated by PRIMES for the EU 2016 reference scenario.

In assessing the contribution of prosumers to meeting demand, the entire potential is considered as exploited if it is less than the demand, and if it is greater, exploitation is prioritized by technologies in the following order: a) cogeneration, b) solar - rooftop photovoltaic (PV) panels, c) hydroelectricity, d) solar - ground-mounted PV, and e) wind. Of these, the last three technologies are associated only with energy communities, as prosumers.

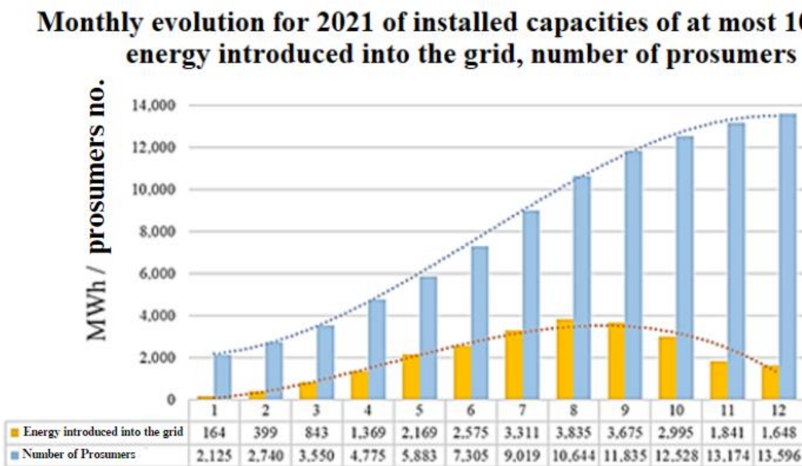
## ROMANIA – EXPLOITING THE POTENTIAL

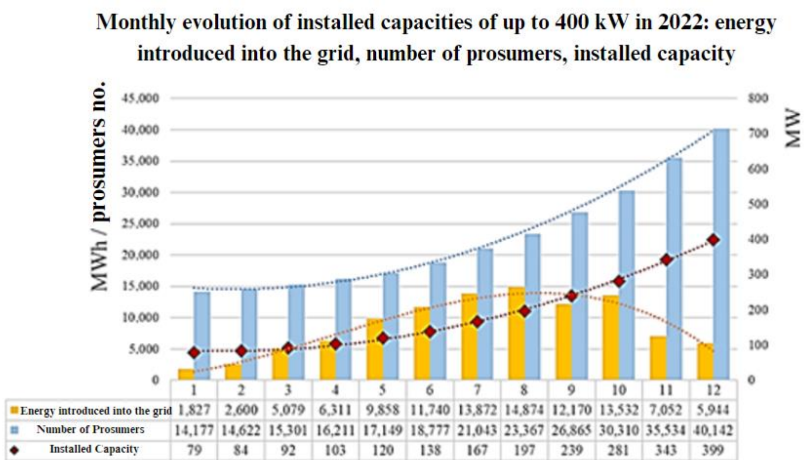
The term prosumer was introduced into legislation by Law no. 184/18.07.2018, which amended Law no. 220/2008 for establishing the system of promoting the production of energy from renewable energy sources. The same legislative framework allows prosumers to exploit excess electricity by delivering it to the electrical grid and remuneration according to the legislation in force.




In December 2022, prosumers owning capacities of up to 400 kW in total had a capacity of 399 MW. The total installed power of prosumers was 417 MW. The total number of prosumers at the end of 2022, including prosumers with powers greater than 400 kW, was 40,159.

The monthly evolution of the quantity of electricity exported by prosumers to the grid in 2023 has a similar profile to that of 2022, but the total quantity is 478,530 MWh compared to 104,860 MWh in the previous year, thus an increase of 356% year over year.

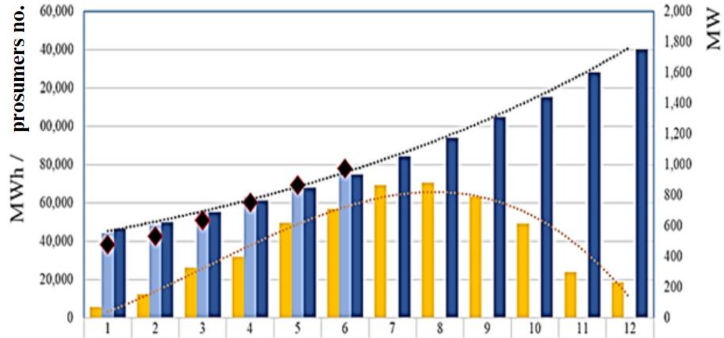



## ROMANIA - FORECASTS

In Romania, the contribution of domestic and tertiary prosumers together to covering their own consumption is expected to evolve from 39% in 2030 to 75% in 2050, of which approximately 35% is photovoltaic solar.

The ANRE forecast for the evolution of the total number of prosumers over the period 2023-2030 anticipates a number of 140,338 prosumers by the end of 2023, 236,000 by the end of 2025, and 350,331 prosumers in 2030. A more cautious forecast, with extrapolation based on a linear trend, based on the evolution in the first 6 months, would have anticipated a number of 120,000 prosumers in December 2023.




| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Energy introduced into the grid | 5,640 | 12,390 | 26,230 | 31,870 | 49,770 | 57,140 | 69,390 | 70,790 | 63,300 | 49,250 | 24,140 | 18,620 |
| Number of Prosumers | 44,415 | 48,453 | 55,244 | 63,162 | 70,840 | 77,638 | | | | | | |
| ANRE prosumer no. Forecast | 46,500 | 49,838 | 55,338 | 61,338 | 67,838 | 74,838 | 84,338 | 93,838 | 104,838 | 115,338 | 128,338 | 140,338 |
| Installed Capacity | 479 | 535 | 636 | 753 | 867 | 973 | | | | | | |

**2023**

- **54.258 GWh** SEN Internal Consumption
- **478 GWh** Prosumer injection
- (only) **0,9 %** from consumption
- **110.000** prosumers
- **1,5 GW** installed by prosumers

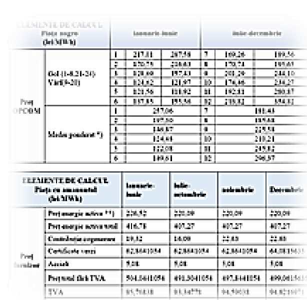
This seems closer to reality considering the latest data published by the Ministry of Energy, which estimated 101000 prosumers and 1.298 MW installed as of November 1, 2023. According to the latest statements by ANRE representatives in December 2023, the most likely final number of prosumers in 2023 was 110000 and the installed capacity was 1.500 MW.

## CALCULATION ALGORITHM

The set of mathematical equations developed for performing technical-economic calculations is based on a simple algorithm for managing a large volume of processed data, which is reduced through hourly averaging, to ensure control of the calculations, detection of possible errors, maneuverability of the results, and to facilitate their presentation and interpretation.

### Primary Data

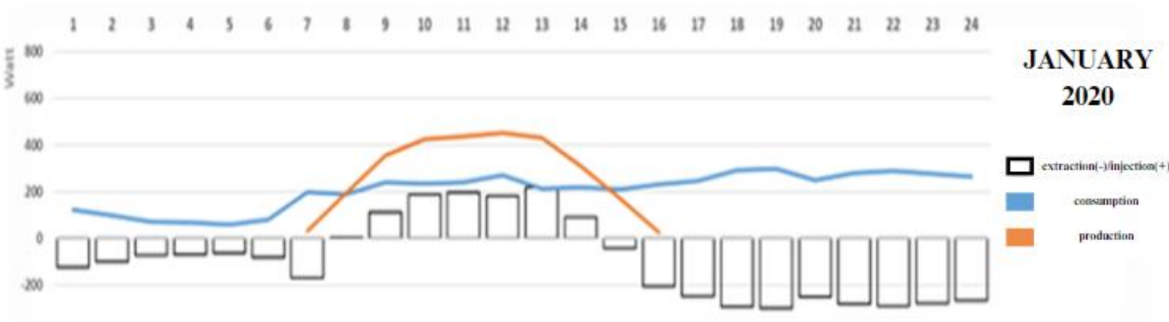
- ❑ Consumption 12 months x (29, 30,31) days x 24 hours = 8784
- ❑ Production 12 months x (29, 30,31) days x 24 hours = 8784
- ❑ Wholesale prices 3 x 2 years x 12 months = 72
- ❑ Retail prices (active energy, total price) 2 x 2 years x 12 months = 48



### Hourly averages of consumption/production are calculated monthly.

- ❑ Consumption 12 months x 24 hours = 288
- ❑ Production 12 months x 24 hours = 288

**Hourly averages of self-consumption/injection/extraction are calculated monthly for 2020**




**Hourly averages and monthly values of negotiation margins are calculated for 2020/2021**

- ❑ Absolute Margin — 2 years x 12 months x 24 hours = 576; 2 x 12 = 24
- ❑ Unit Margin (per kW) — 2 years x 12 months x 24 hours = 576; 2 x 12 = 24
- ❑ Marja procentuală (%) — 2 years x 12 months x 24 hours = 576; 2 x 12 = 24

## CONSTRUCTION OF THE ANALYZED CASES

Two distinct cases were built, for 2020 and 2021.

- CASE 1 ("2020") - built on actual quantitative data (energy needed/production) from 2020 and actual wholesale/retail prices from the year 2020;
- CASE 2 ("2021") - built on the quantitative data of case 1 and on the actual price data from the year 2021.

Together, the calculations performed fully address the two years, 2020 and 2021, thus 24 consecutive months. Different price data are used, but for both cases, the same quantitative data (those from 2020) are used.

These data are relevant for:

- the influence of the seasonality of production and consumption at the hourly level throughout a day and at the monthly level throughout a year on the regulated revenue or through aggregation of the prosumer;
- the influence of price variations in the wholesale market, determined by trends (continuously ascending in 2021-2022) and seasonality (winter-summer) on the revenue obtained through aggregation.

The reasons for choosing the two years are the following:

- The year 2020 is the most recent year for which actual production data is available, the last year of price stability in the wholesale market in the European Union and Romania, and the last year before the liberalization process in the retail market in Romania;

- The year 2021 is the first year of continuously ascending price evolution in the wholesale market, the first year of complete liberalization of the retail market in Romania, and the last year in which the electricity market was not affected by the energy crisis generated by causes external to the energy system.
- Starting with the year 2022, the data from the wholesale and retail markets are affected by the quasi-regulated nature of the retail market, with a strong impact on the formation of prices in the wholesale market.

The data collected for the application of the algorithm highlight:

- Seasonality (diurnal and annual) of production and energy needed, the hourly correlation of production and energy needed determining self-consumption, extraction, and injection.
- The trends of price evolution in the wholesale market, which correlated with the retail market price determine the aggregator's gain or loss.

The size of the gain or loss is also determined correlating production with the energy needed. (For example, there are periods when the price correlation is favorable, but the correlation of production and energy needed does not result in injection, so the gain is 0).

Calculations were performed to determine the conditions of aggregator-prosumer negotiation using:

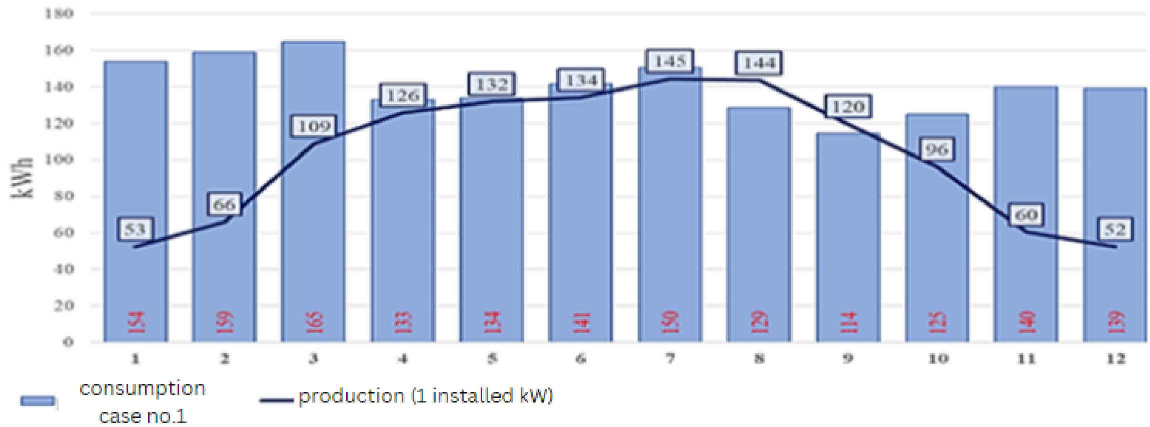
- The prosumer's electricity consumption profile (based on hourly data measured in 2020 by a smart meter installed by the distribution operator at a consumption site; average consumption of 139 kWh/month),
- The profile of average hourly photovoltaic energy production; an installed capacity of 1 kW in the location of Bucharest (data provided by a public software program from the European Union, developed based on statistical meteorological measurements from the last 15 years).
- Market data regarding energy prices and tariffs. The active energy price, the total contract price, and the average monthly off-peak and peak prices were taken from ANRE and OPCOM reports and from invoices issued by the electricity supplier. (The necessary calculation elements not identified in these documents were deduced by calculation from the existing ones and from data derived from ANRE regulations).

The PVGIS web interface was configured with the characteristics:

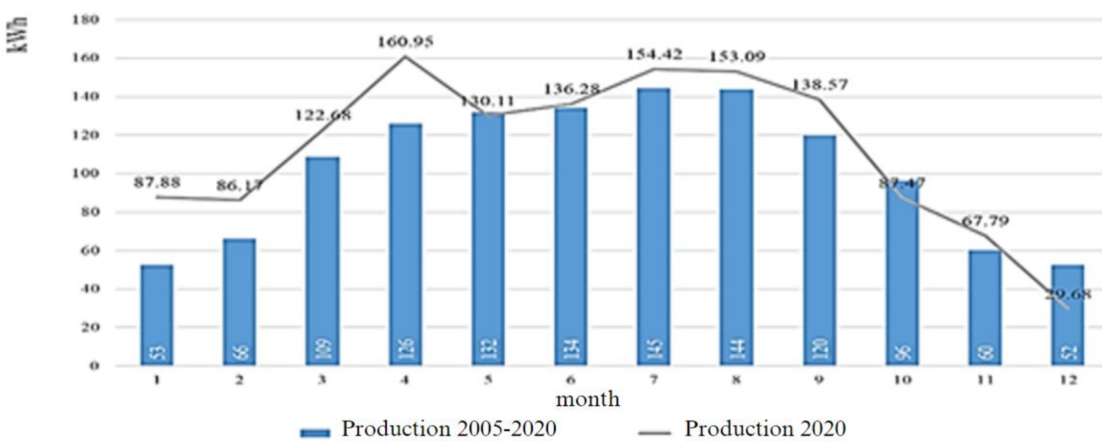
- Bucharest (latitude 44.43, longitude 26.09);
- Photovoltaic technology;
- Losses 14%;
- Tilt angle 35% (optimal);
- South orientation.

To identify the opportunities that solar photovoltaic technology installed on rooftops offers to prosumers and for the optimal use of this type of resource for the development of a prosumer aggregation business in Romania, hourly production and energy needed data were used.

## QUANTITATIVE DATA (2020)



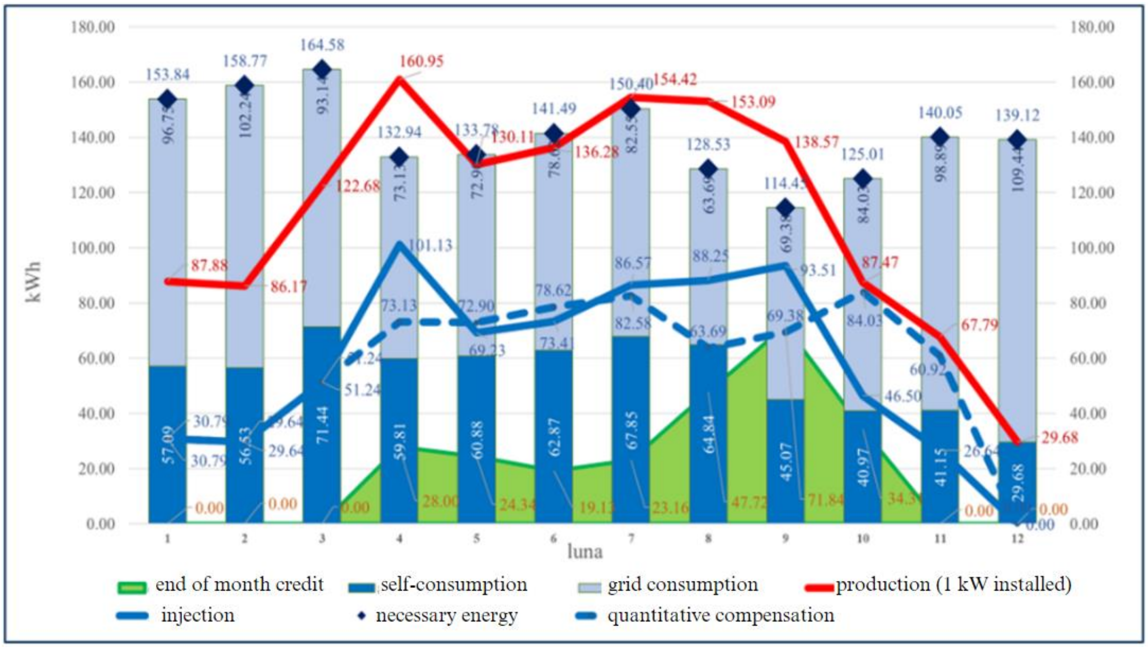

The figure above comparatively presents the average monthly consumption in the year 2020 for cases 1 and 2 constructed and the monthly production averages for 1 kW installed in the Bucharest location over 16 years: 2005-2020. However, there is a significant dispersion from year to year between the annual production data illustrated by the following figure:




The figure above shows the differences between the averages of monthly production over 16 years and the monthly production in 2020. Based on the average data of hourly consumption and production, the following are calculated monthly:

- the energy needed, broken down into self-consumption and extraction from the grid,
- production, injection into the grid.

From this data, the quantity credited from month-to-month results from the application of the quantitative compensation method legislated in Romania.




## REFERENCE PRICES (2020/2021)

The operator of the electricity and natural gas markets determines the price of electricity for each hourly interval of the following day.

The average base/off-peak (1-8, 21-24) / peak (9-20) prices, as well as the weighted average price, are published in the operator's monthly monitoring reports.

| **CALCULATION ELEMENTS Wholesale market (RON/MWh)** | | **January-June 2020** | | | **July-December 2020** | | |
|---|---|---|---|---|---|---|---|
| **OPCOM price** | Off-peak (1-8,21-24) Peak (9-20) | 1 | 217,01 | 287,58 | 7 | 169,26 | 189,56 |
| | | 2 | 170,75 | 216,63 | 8 | 170,74 | 195,65 |
| | | 3 | 128,69 | 157,43 | 9 | 201,29 | 244,10 |
| | | 4 | 124,62 | 121,97 | 10 | 174,46 | 234,27 |
| | | 5 | 121,56 | 118,92 | 11 | 192,81 | 280,87 |
| | | 6 | 137,85 | 155,56 | 12 | 213,82 | 354,82 |
| | Weighted Average | 1 | 257,06 | | 7 | 181,43 | |
| | | 2 | 197,30 | | 8 | 185,68 | |
| | | 3 | 146,87 | | 9 | 225,58 | |
| | | 4 | 124,48 | | 10 | 210,21 | |
| | | 5 | 122,08 | | 11 | 245,82 | |
| | | 6 | 149,61 | | 12 | 296,37 | |

| **CALCULATION ELEMENTS Wholesale market (RON/MWh)** | **January-June 2021** | **July-December 2021** |
|---|---|---|

<table>
<tr><td rowspan="12">OPCOM price</td><td rowspan="6">Off-peak (1-8,21-24)<br>Peak (9-20)</td><td>1</td><td>223,39</td><td>319,19</td><td>7</td><td>433,36</td><td>491,07</td></tr>
<tr><td>2</td><td>194,97</td><td>273,84</td><td>8</td><td>505,08</td><td>604,23</td></tr>
<tr><td>3</td><td>251,04</td><td>280,95</td><td>9</td><td>615,41</td><td>708,89</td></tr>
<tr><td>4</td><td>305,16</td><td>313,00</td><td>10</td><td>845,72</td><td>1056,99</td></tr>
<tr><td>5</td><td>292,81</td><td>285,81</td><td>11</td><td>857,35</td><td>1246,34</td></tr>
<tr><td>6</td><td>371,22</td><td>386,43</td><td>12</td><td>854,45</td><td>1424,15</td></tr>
<tr><td rowspan="6">Weighted Average</td><td>1</td><td colspan="2">281,25</td><td colspan="2">7</td><td>470,98</td></tr>
<tr><td>2</td><td colspan="2">241,61</td><td colspan="2">8</td><td>565,35</td></tr>
<tr><td>3</td><td colspan="2">269,66</td><td colspan="2">9</td><td>668,31</td></tr>
<tr><td>4</td><td colspan="2">314,04</td><td colspan="2">10</td><td>977,77</td></tr>
<tr><td>5</td><td colspan="2">294,50</td><td colspan="2">11</td><td>1086,81</td></tr>
<tr><td>6</td><td colspan="2">377,59</td><td colspan="2">12</td><td>1303,45</td></tr>
</table>

The reference prices (active energy and total energy from ANRE reports in 2020 and respectively from the supplier's invoices in 2021 (the tables below) are necessary for the calculations performed.

| CALCULATION ELEMENTS Retail Market (Universal Service - US) (RON/MWh) | | January-June 2020 | July-October 2020 | November 2020 | December 2020 |
|---|---|---|---|---|---|
| Supplier price | Active Energy Price | 226,52 | 220,09 | 220,09 | 220,09 |
| | Total Active Energy Price | 416,78 | 407,27 | 407,27 | 407,27 |
| | Cogeneration Contribution | 19,32 | 16,09 | 22,63 | 22,63 |
| | Green Certificates | 62,8641054 | 62,8641054 | 62,8641054 | 64,0815635 |
| | Excise Duty | 5,08 | 5,08 | 5,08 | 5,08 |
| | Total Price without VAT | 504,0441054 | 491,3041054 | 497,8441054 | 499,0615635 |
| | VAT | 95,76838 | 93,34778 | 94,59038 | 94,8216971 |
| | Total Supply Price | 599,8124854 | 584,6518854 | 592,4344854 | 593,8832606 |

| CALCULATION ELEMENTS Retail Market (RON/MWh) | | January-February 2021 (US) | March-May 2021 (US) | June-December 2021 (concurential) |
|---|---|---|---|---|
| Supplier price | Active Energy Price | 339,30 | 339,30 | 284 |
| | Distribution Tariff | 157,18 | 157,18 | 157,18 |
| | Grid Extraction Tariff (TL) | 19,22 | 19,22 | 19,22 |
| | Grid Injection Tariff (TG) | 1,30 | 1,30 | 1,30 |
| | System Services | 11,96 | 10,82 | 10,82 |
| | Total Active Energy Price | 528,96 | 527,82 | 472,52 |
| | Cogeneration Contribution | 17,12 | 17,12 | 17,12 |
| | Green Certificates | 64,0659204 | 64,0659204 | 64,0659204 |
| | Excise Duty | 5,23 | 5,23 | 5,23 |
| | Total Price without VAT | 615,3759204 | 614,2359204 | 558,9359204 |
| | VAT | 116,9214249 | 116,7048249 | 106,1978249 |
| | Total Supply Price | 732,2973453 | 730,9407453 | 665,1337453 |

Even from these tables, by comparing the relevant wholesale prices (OPCOM peak price) and retail prices (active energy price), it is possible to see which months the aggregated sale will record losses (orange cells in the wholesale price tables) compared to the regulated one and which months it will record revenues (yellow cells in the wholesale price tables).

It can be noted (green cells) that while the variation in the wholesale price between the lowest and highest value throughout the year 2020 was relatively small (174 RON), in 2021 it was quite exceptional (1062 RON).

## SET OF MATHEMATICAL EQUATIONS. APPLICATION IN CASE 1.

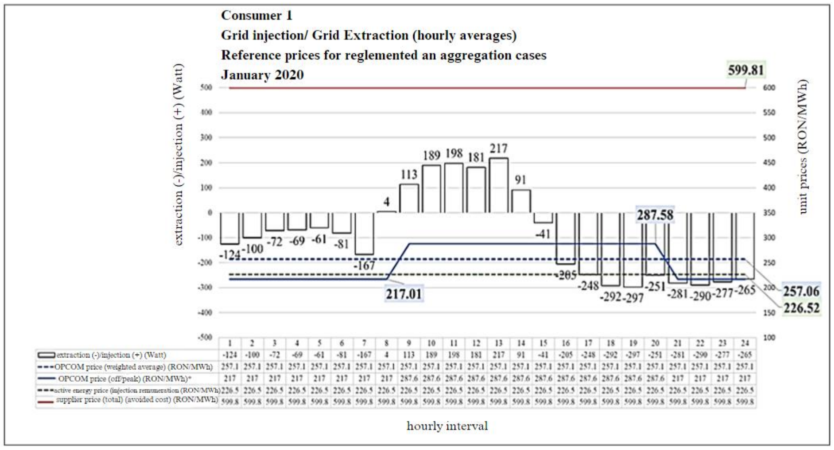
All evaluations are made monthly, at the level of hourly averages, with the monthly data to be evaluated by multiplying by the number of days in the respective month.

| 1. PRELIMINARY DATA |
|---|
| a) Extraction from the grid<br>b) Injection into the grid<br>c) OPCOM Price (weighted average)<br>d) OPCOM Price (off-peak/peak)<br>e) Active Energy Price (injection remuneration)<br>f) Total Supplier Price |

| 2. RESULTS | |
|---|---|
| g) Self-consumption<br>h) The cost avoided by the prosumer through self-consumption:<br>i) The prosumer's income from injection, through regulated quantitative compensation:<br>j) The total revenue of the prosumer, through self-consumption and regulated quantitative compensation of the injection into the grid:<br>k) The gross income of the aggregator by including the prosumer's injection in aggregation:<br>l) The maximum revenue of the prosumer from self-consumption and by including the injection in aggregation (aggregator gain=0):<br>m) The negotiation margin between prosumer and aggregator: | f x g<br>b x e<br>h + i<br><br>b x d<br><br>h + k<br>l – j = k – i |

The graph below presents the primary data for January 2020:

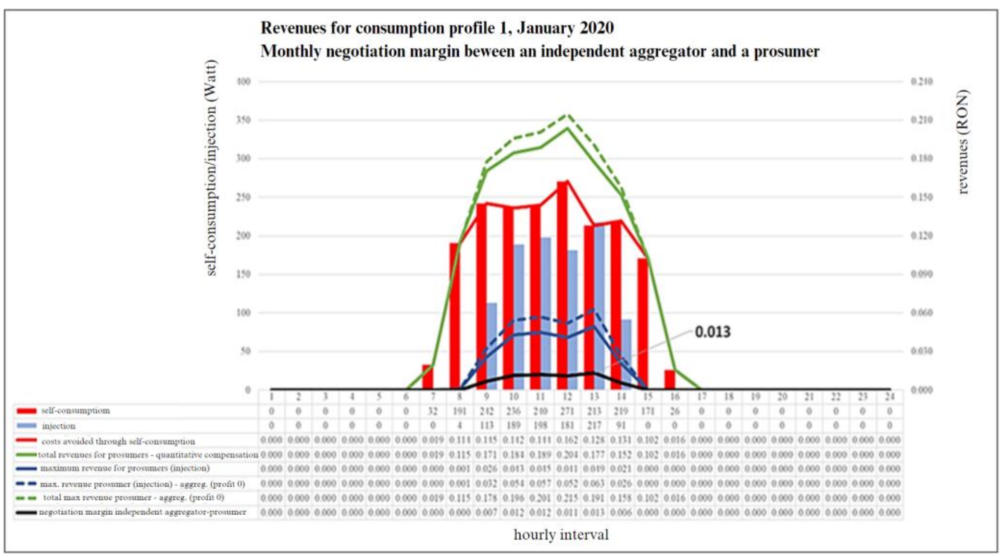
- The average hourly profiles of extraction and injection, at the monthly level, generated by the hourly profiles of consumption and production at the monthly level;
- PZU (Day-Ahead Market) prices: off-peak/peak/weighted average;
- The total contract price and the active energy price.




The following graph presents the financial evaluation results for January 2020:

- The average hourly cost avoided by the prosumer through self-consumption, independent of the valorization alternative (regulated/aggregation): red color
- Average hourly income from injection remuneration, through aggregation, compared to the regulated revenue: blue color. Aggregation: dashed line.
- Average hourly financial revenues through aggregation, compared to the regulated revenue of the prosumer: green color. Aggregation: dashed line.

Additionally, the bar graph represents the average hourly self-consumption and injection.




The aggregator-prosumer negotiation margin is the monthly difference between the gross income of the aggregator by including the prosumer's injection in aggregation, and the prosumer's income from injection, through regulated quantitative compensation: black color.

In January 2020, the margin is positive or 0 for all hourly intervals. It is a month in which aggregation is profitable.

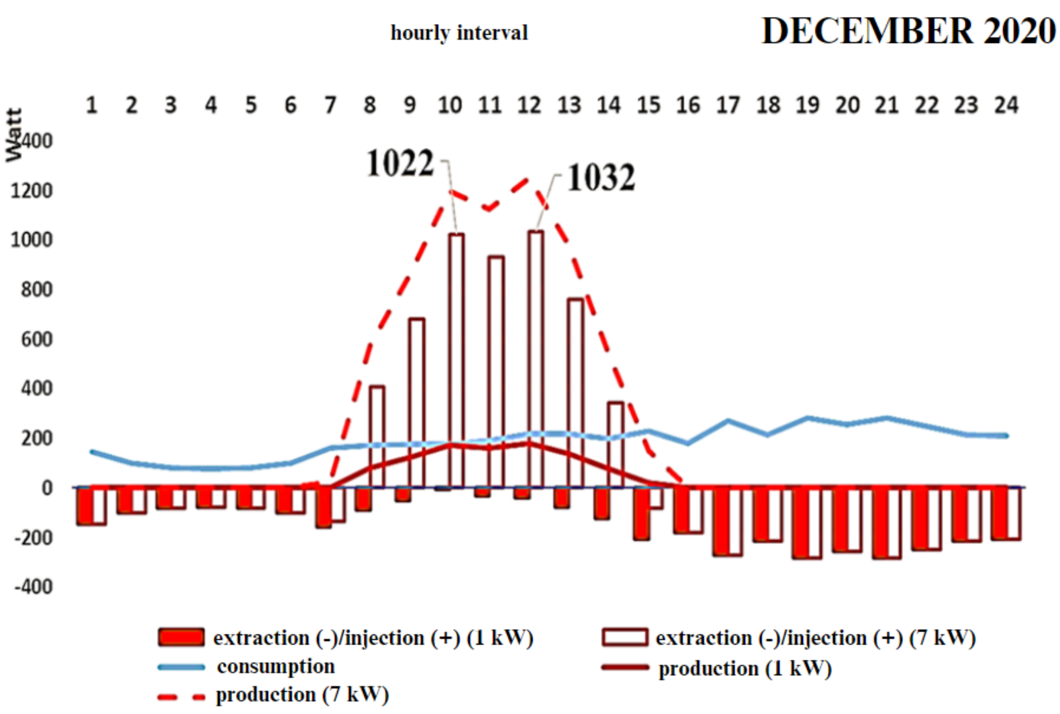
Additionally, the following are calculated:

- Unit negotiation margin. It is the negotiation margin per kWh injected into the grid.
- Percentage negotiation margin. It is the unit negotiation margin expressed as a percentage, relative to the price of active energy from the supply contract that remunerates the injection into the grid.

## THE NEED FOR AGGREGATION AND THE SIZE OF THE MINIMUM PORTFOLIO

In Poland, the average installed capacity per consumption site was 10.3 kW at the end of 2022. In Romania at the same date, it was 9.9 kW, so a very close average, but by the end of the second quarter of 2023, the average power installed per consumption site in Romania became 12.5 kW (0.973 GW/77,638 prosumers), an increase of 25%, which denotes an increased interest in grid injection, with negative consequences for distribution operators.

However, these prosumers are not representative, and the average installed by individuals within the perimeter of Distribuție Energie Oltenia, namely 6.4 kW, can still be considered a reasonable reference. Given the production data used and the consumption profile used in the calculations performed, an installed power of 7 kW could inject at least 1 kW on average into the grid in at least one hourly interval every day of the year, with the minimum reached in December, according to the graph.



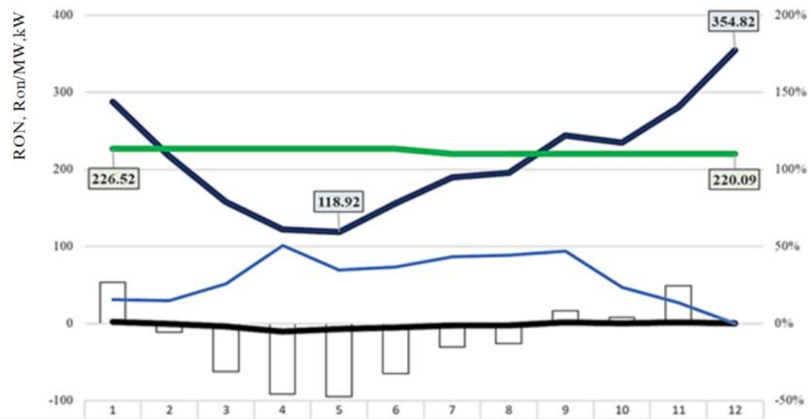
In EU legislation, on day-ahead and intraday markets, the minimum bid is 500 kW or less, to allow for the effective participation of dispatchable consumption. The minimum power that can be offered on OPCOM markets is only 100 kW. However, to accumulate this power, at least 100 prosumers, with the consumption used for constructing the presented cases, and with an average installed power of about 7 kW, close to the previously mentioned average, would need to be aggregated to bid in at least one hourly interval every day of the year.

## BENEFITS OF AGGREGATION IN THE YEAR 2020

**CASE 1** is based on actual quantitative production and consumption (energy needed) data from 2020 and actual wholesale and retail prices from 2020.

As noted from the previous price tables, in 2020 the months of February-August were unfavorable for trading on the day-ahead market, with its peak price being lower than the price of active energy. This can be seen in the graph below, comparing the two prices.

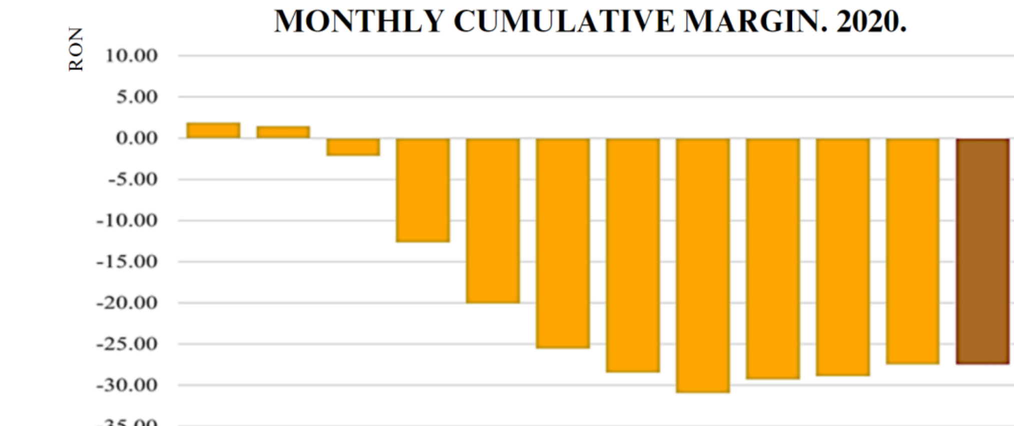
Furthermore, among these months, the months of April-August are months with high injection (blue curve), which will amplify losses. Once again, December, which records the most favorable price ratio, is a month with zero injection, so this favorable ratio does not contribute to revenue.




| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| percentage margin | 26.84% | -5.92% | -31.10% | -45.98% | -47.38% | -32.72% | -15.23% | -12.94% | 8.13% | 3.88% | 24.39% | 0.00% |
| margin | 1.872 | -0.397 | -3.610 | -10.532 | -7.430 | -5.441 | -2.902 | -2.513 | 1.674 | 0.397 | 1.430 | 0.000 |
| OPCOM weighted average price | 287.58 | 216.63 | 157.43 | 121.97 | 118.92 | 155.56 | 189.56 | 195.65 | 244.10 | 234.27 | 280.87 | 354.82 |
| active energy price (injection remuneration; quant. comp) | 226.52 | 226.52 | 226.52 | 226.52 | 226.52 | 226.52 | 220.09 | 220.09 | 220.09 | 220.09 | 220.09 | 220.09 |
| injection | 30.79 | 29.64 | 51.24 | 101.13 | 69.23 | 73.41 | 86.57 | 88.25 | 93.51 | 46.50 | 26.64 | 0.00 |

While the graph above shows the month-by-month evolution of the negotiation margin (black curve) and the percentage margin (bar chart), the graph below shows the evolution of the cumulative margin. By the end of the year (November-December), a loss of at least 27.45 RON accumulates if the aggregator has guaranteed the prosumer at least the regulated price.

**CONCLUSION**: The year 2020 is entirely unfavorable for a prosumer aggregation business with the valorization of energy injected into the grid on the Day-Ahead Market (PZU).



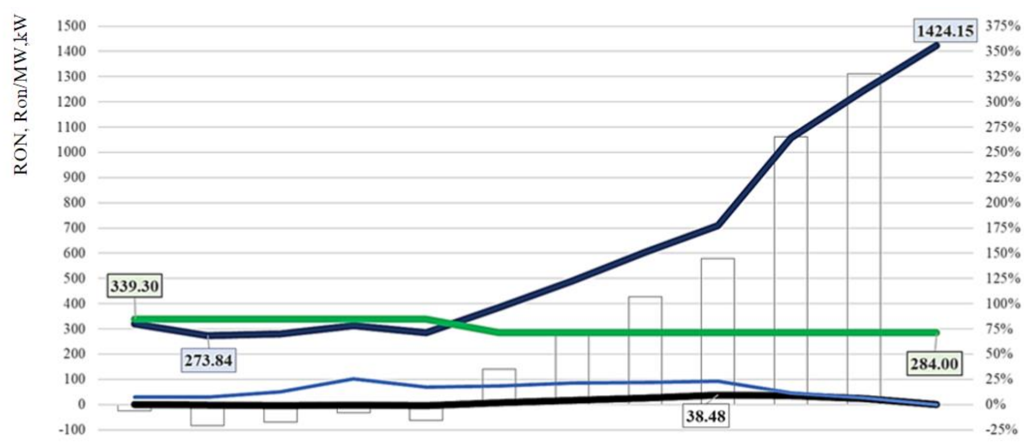

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| cumulative margin | 1.87 | 1.47 | -2.14 | -12.6 | -20.1 | -25.5 | -28.4 | -30.9 | -29.2 | -28.8 | -27.4 | -27.4 |

## BENEFITS OF AGGREGATION IN THE YEAR 2021

**CASE 2** is based on actual quantitative production and consumption data from 2020 and actual wholesale and retail prices from 2021.

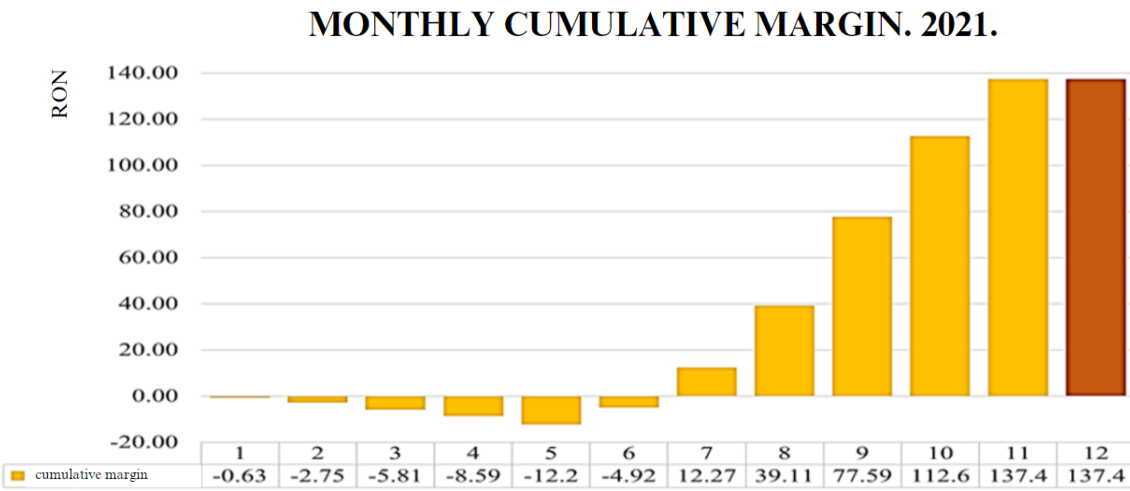
As noted from the previous price tables, in 2021 the months of January-May were unfavorable for trading on the day-ahead market, with its peak price being lower than the price of active energy from the supply contract. This can also be seen in the graph below, comparing the two prices. Among these months, April and May are months with high injection (blue curve), while the other months with high injection, June-August, are months with a price ratio favorable to aggregation.

The months of September-December, which record an extremely favorable price ratio, are months with low injection, and December, when the ratio is most favorable, is a month with zero injection, so this ratio does not contribute to the aggregator's revenue.




| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| percentage margin (%) | -6.03% | -21.08% | -17.62% | -8.10% | -15.55% | 35.11% | 69.92% | 107.11% | 144.91% | 265.17% | 327.81% | 0.00% |
| margin (RON) | -0.63 | -2.12 | -3.06 | -2.78 | -3.65 | 7.32 | 17.19 | 26.85 | 38.48 | 35.01 | 24.80 | 0.00 |
| OPCOM peak price (RON/MWh) | 319.19 | 273.84 | 280.95 | 313.00 | 285.81 | 386.43 | 491.07 | 604.23 | 708.89 | 1056.99 | 1246.34 | 1424.15 |
| active energy price (RON/MWh) | 339.30 | 339.30 | 339.30 | 339.30 | 339.30 | 284.00 | 284.00 | 284.00 | 284.00 | 284.00 | 284.00 | 284.00 |
| injection (kWh) | 30.79 | 29.64 | 51.24 | 101.13 | 69.23 | 73.41 | 86.57 | 88.25 | 93.51 | 46.50 | 26.64 | 0.00 |

While the previous graph shows the month-by-month evolution of the negotiation margin (black curve) and the percentage margin (bar chart), the following graph shows the evolution of the cumulative margin. By the end of the year (November-December), a revenue from aggregation of 137.41 RON is accumulated, which will be shared between the aggregator and the prosumers according to the contractual clauses.




**CONCLUSION**: The year 2021 is very favorable for an aggregation business with capitalization on the Day-Ahead Market of the energy injected into the grid. The revenue of 137 RON represents no less than 64.35% of the income following a contract with the supplier.

## RECOMMENDATIONS FOR AGGREGATORS

Aggregators are legal entities that aggregate and optimize consumption, production, and energy storage. Through aggregation, consumers, prosumers, and producers can be included in a portfolio that can become an active player in the electricity markets.

- **The general strategy recommended for the aggregator is a diversification of the customer portfolio:**
  - The first recommendable target for future aggregators to form a portfolio, given the risk highlighted by cases 1 and 2, is the segment of prosumers with installed capacities over 400 kW, to whom the regulatory framework does not guarantee purchase and a fixed purchase price (the energy price within the contract price).
  - The second target is represented by the segment of prosumers with installed powers under 200 kW, but negotiation should be approached cautiously considering the risk of losses, a risk widely highlighted by the two cases presented.
  - The third target, is represented by the segment of prosumers between 200 kW and 400 kW, is practically impossible to approach at present because the regulated framework guarantees them the market price, but they may be approached in the future as they gradually become responsible for balancing.

- **Finally, these customer segments should be added to other pre-existing segments (large producers and dispatchable consumption).**

Experience in the European Union confirms this strategy. The most profitable measure for the system and the market, which increases the revenue from the sale of aggregated prosumer injection, is ensuring a transparent and efficient regulatory framework in Romania for the participation of aggregators in other markets besides the day-ahead and intraday markets, namely the balancing and reserve markets. Legislatively this is possible, but regulatory provisions are needed in this regard.

- **Aggregators must contribute concrete proposals to this development.**

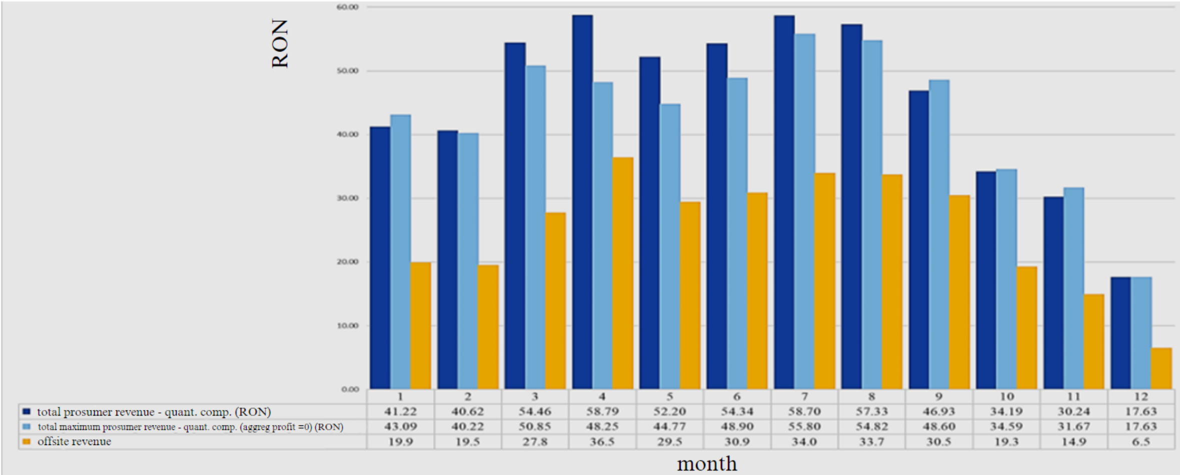
## INCONVENIENCES AND ADVANTAGES OF OFF-SITE PRODUCTION

In April 2023 in Romania, an important amendment to the order of the president of ANRE no. 15/2022 was discussed, to detail the method of settlement of electricity produced off-site, a facility that was introduced by GEO no. 163/2022 but has not yet been implemented at the regulatory level.

Case 3 analyzed simulates the prosumer's revenues in the situation of production at one location (without consumption) and the compensation of the entire production with consumption from another/other locations. The graph below comparatively presents the monthly revenues in 2020 of the prosumers with the consumption profile used in cases 1 and 2:

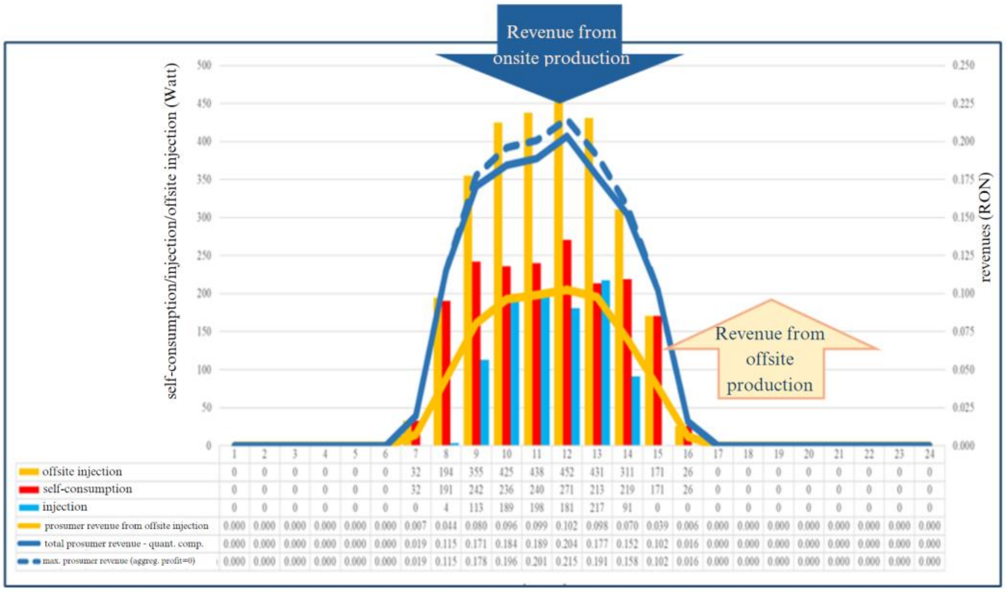
a) from the production of one kW installed in the situation where they produce and consume in a single location, injecting the surplus into the grid, which is quantitatively compensated by the supplier, and
b) produce at a location where they have no consumption and inject the entire production into the grid, following which the financial compensation by the supplier with consumption from another location/other locations will be carried out.

It can be noted that under the conditions of production and consumption used for simulation in case 1 (data from 2020), the prosumer revenues in the situation of virtual compensation of the entire quantity of energy produced only 55.4% of the reveneus made through quantitative compensation and 58.3% of those through aggregation in the situation of production and consumption at the same location. The graph below presents the results in all 12 months, and the annual values are indicated in the following table.




| | |
|---|---|
| total revenue (cost avoided + injection remuneration through quantitative compensation) | 547 RON/year |
| total revenue (cost avoided + injection remuneration through aggregation) | 519 RON/year |
| total revenue (offsite injection remuneration through quantitative compensation) | 303 RON/year |
| offsite revenue / onsite gain through quantitative compensation | 55,4 % |
| offsite revenue / onsite gain through aggregation | 58,3 % |

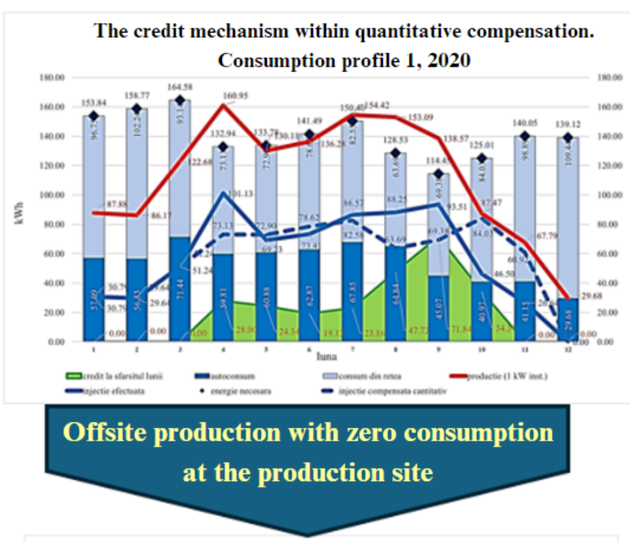
The value of the revenue in intermediate situations between these two extreme cases (i.e., for various consumptions at the production site ranging from 0 to the consumption value at the location(s) where there is no production) can be determined by scaling from maximum to 0 of the 'offsite injection' quantity, and from 0 to maximum of the 'self-consumption + injection' quantity. The curves of the average hourly evolution would be placed in these situations between the orange curve and the blue curves in the following figure.

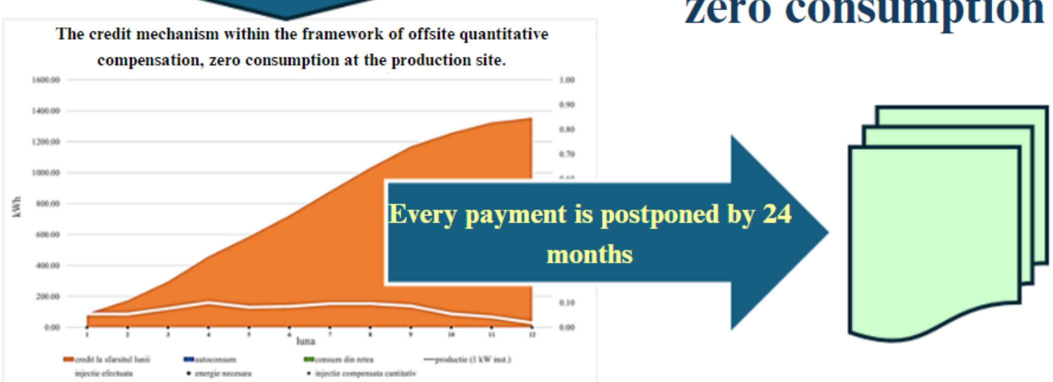



| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| offsite injection | 0 | 0 | 0 | 0 | 0 | 0 | 32 | 194 | 355 | 425 | 438 | 452 | 431 | 311 | 171 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| self-consumption | 0 | 0 | 0 | 0 | 0 | 0 | 32 | 191 | 242 | 236 | 240 | 271 | 213 | 219 | 171 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| injection | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 113 | 189 | 198 | 181 | 217 | 91 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| prosumer revenue from offsite injection | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.007 | 0.044 | 0.080 | 0.096 | 0.099 | 0.102 | 0.098 | 0.070 | 0.039 | 0.006 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| total prosumer revenue - quant. comp. | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.019 | 0.115 | 0.171 | 0.184 | 0.189 | 0.204 | 0.177 | 0.152 | 0.102 | 0.016 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| max. prosumer revenue (aggreg. profit=0) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.019 | 0.115 | 0.178 | 0.196 | 0.201 | 0.215 | 0.191 | 0.158 | 0.102 | 0.016 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

Offsite production is convenient for retail networks or the hospitality sector, however, it does not represent an advantageous solution for the prosumer in terms of the value of the remuneration received in the case of residential consumers unless for one reason or another there are no conditions for installing photovoltaic panels at the place of consumption.

**The effect of the credit mechanism characteristic of quantitative compensation in the case of offsite production with zero consumption**



However, in terms of collecting remuneration, applying quantitative compensation in the case of production at a location with much lower consumption, in the absence of virtual compensation of offsite production at another consumption site, would result in the postponement from month to month of significant payments, and most of the bill with a 24-month due date would be paid at 24 months. Virtual compensation would expedite this payment.

Like any other situation where injection increases at the expense of self-consumption, the advantages of the latter are lost from the point of view of the distribution operator: reduction of network losses, avoidance of congestion, and decrease in investments.

## BENEFITS OF STORAGE

The construction of **case 4** aimed to simulate the revenues in the scenario when a storage system is used for gathering the excess production and transforming said production in its entirety into self-consumption at a later time, instead of injecting the excess into the grid.

The objectives and results of production accompanied by storage presented in this case are entirely opposite to those characterizing offsite production presented in the previous case (case 3). While the previous case maximizes the injection into the grid, case 4 maximizes self-consumption.

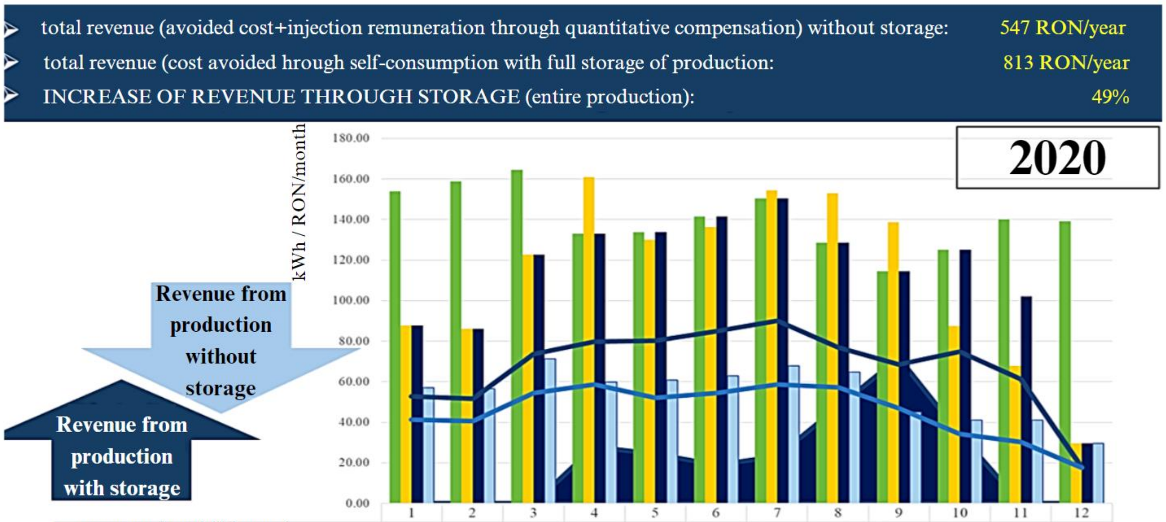
In general, storage allows for an increase in self-consumption at the expense of injection. Production combined with storage represents a better fulfillment of the theoretical advantages of distributed production (reducing the use of the grid and implicitly reducing network losses).

At the same time, storage reduces the problems faced by the distribution operator with the installation of photovoltaic panels on rooftops. It is perceived as the most efficient solution for overcoming network congestion that causes injection limitations that have already started to appear in the most populated areas and in those where consumers demonstrate a higher appetite for becoming active consumers.

On the other hand, from the prosumer's point of view, under the conditions of quantitative compensation legislated in Romania (net metering being excluded), maximum revenues are obtained through storage.

In the simulation whose results are presented in the following figure, the same quantitative data were used as those used in the previous case 3, but it was considered that a storage battery is used and that it is sized sufficiently to store the entire excess of production compared to the amount of energy required.

The difference between the financial results from case 1 and case 4 is significant. The annual increase in financial revenues through storage in the situation of the considered quantitative and price data is almost 50%, with variations from 1% (December) to 119% in October.




| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| storage at the end of the month | 0.00 | 0.00 | 0.00 | 28.00 | 24.34 | 19.13 | 23.16 | 47.72 | 71.84 | 34.31 | 0.00 | 0.00 |
| necessary energy | 153.84 | 158.77 | 164.58 | 132.94 | 133.78 | 141.49 | 150.40 | 128.53 | 114.45 | 125.01 | 140.05 | 139.12 |
| production (1 kW installed) | 87.88 | 86.17 | 122.68 | 160.95 | 130.11 | 136.28 | 154.42 | 153.09 | 138.57 | 87.47 | 67.79 | 29.68 |
| self-consumption with storage | 87.88 | 86.17 | 122.68 | 132.94 | 133.78 | 141.49 | 150.40 | 128.53 | 114.45 | 125.01 | 102.10 | 29.68 |
| self-consumption without storage | 57.09 | 56.53 | 71.44 | 59.81 | 60.88 | 62.87 | 67.85 | 64.84 | 45.07 | 40.97 | 41.15 | 29.68 |
| revenue from avoided cost (self-consumption with storage) | 52.71 | 51.69 | 73.58 | 79.74 | 80.24 | 84.86 | 90.21 | 77.09 | 68.64 | 74.98 | 61.24 | 17.80 |
| revenue from quantitative compensation without storage | 41.22 | 40.62 | 54.46 | 58.79 | 52.20 | 54.34 | 58.70 | 57.33 | 46.93 | 34.19 | 30.24 | 17.63 |

## RECOMMENDATIONS FOR PROSUMERS

Although optimistic about the development of technologies based on renewable sources, consultants from EY state that the current integration model based on the "**connect and consolidate**" model is unsustainable. How would this "**connect and consolidate**" translate and why is the model not sustainable?

- This paradigm resides in a strategically passive role of the distribution system operator exactly at a time when, in theory, it should become active from a technical point of view.
- The initiative, therefore, the active role, would belong to the prosumer who requests the connection, the operator complies and then, faced with the consequences, is forced to consolidate.
- However, this situation cannot last indefinitely: the length of the networks cannot be continuously halved, nor can the cross-section of the cables be continuously doubled.

The solution lies in adapting the legislative framework to the challenges of long-term development, which can only stop once the technical potential limits are reached, and this adaptation must be made by returning prosumers to the purpose recognized by the term used by European legislation, that of "self-consumer of energy from renewable sources," a meaning currently distorted, with consequences which are already visible. Lately, there has been a tendency to pay attention to injection and not self-consumption. This results in the following problems:

- instead of being aided by the practice of self-consumption, the network is burdened by excessive injection,
- some prosumers unfairly compete trying to create advantageous positions compared to other entities from the position of producers,

- financially, the revenues obtained through injection are suboptimal.

The sizing of the installed capacity by the prosumer determines the ratio between self-consumption, injection, and extraction in/from the network. The intention to install larger capacities is justified, as greater self-consumption leads to a larger bill reduction, and greater injection leads to greater additional income. However, sometimes the excess becomes counterproductive, not only the large number of prosumers but also the excessive injection of some prosumers causing the activation of the regulation that blocks the injection. It is expected that the authorities will decide in the near future to limit the facilities or even increase responsibilities, such as reducing the threshold of installed capacity over which the prosumer has the financial responsibility of imbalances.

Specifically, through legislation:

- the installed capacity of prosumers should be limited so that they become self-consumers again, and
- mandatory local storage should be established to allow the technical possibility of maximizing self-consumption.

Prosumers should anticipate these legislative changes by correctly sizing their installed capacities and coupling them with storage systems. These actions would visibly increase flexibility, reduce network losses, reduce the probability of congestion, and reduce network investment costs.

- ➢ **Therefore, prosumers are recommended to size their installed capacities prudently and responsibly.**

Offsite production is beneficial for a certain scale of consumption and a certain territorial distribution of production/consumption sites, namely commercial chains, the hospitality sector consumers, public institutions. The true significance of the interest shown in offsite production lies not in the model of the individual domestic prosumer with at least two properties, but in the importance of this type of production and net virtual billing for a relevant-sized business (such as supermarket chains) and for energy communities. Supermarket chains want to avoid the costs of installing and managing decentralized production capacities, and energy communities would like to produce including with ground-mounted photovoltaic panels (or wind turbines) outside the urban area. Virtual compensation for offsite production allows the use of the existing network and thus avoids costly and unnecessary investments in an ad-hoc distribution network that would connect production sites to consumption sites. For residential prosumers, offsite injection for compensating consumption at another location is not beneficial in terms of value, the compensation rate being reduced, but it is beneficial in terms of the speed of collection. However, it is advantageous in any situation to reduce the injection into the network in favor of increasing self-consumption.

- ➢ **Therefore, the use of storage is recommended.**

At the same time,

- **The storage battery must be sized so that self-consumption is maximized; implicitly, the injection into the network will be minimized.**

# FINAL CONCLUSIONS

## Prosumers potential

The paper presents a positive perspective on the potential of prosumer activity both in the European Union and in Romania. For Romania, it is profitable and promising that an economic resource for which it holds significant potential is also of interest to the European Union as a whole. Thus, the national policies necessary for exploiting this potential (including funding programs) currently have a consistent basis in community guidelines and even in community funding. At the same time, the strategic perspective of these community guidelines represents a guarantee of predictability for the future development at the national level.

## Evolution of policies and legislation

In recent years (starting with 2014-2016), the main attention of legislators and regulators in the European Union has initially focused on prosumers, first for them to exist (introduction of net metering, fixed tariffs), then for their number to increase (increasing the threshold of installed power for the obligation of purchase by the supplier at a guaranteed price, in Romania). During this time, the role of the aggregator, fundamentally competitive, could not be favored. However, the prospects for the development of the role of aggregators exist. These prospects for essential development in the future are anticipated by the current trend of regulations to limit incentives for prosumers (elimination of net metering and fixed tariffs, orientation towards a fair participation of the prosumer in the costs of network development, etc.).

## Relationships of interest between aggregator and prosumer

The set of equations developed highlights the two sources of revenue for the prosumer as an active consumer:

The cost avoided by replacing part of the necessary energy that would have been extracted by the passive consumer from the network with a quantity produced at the place of consumption (or at another place of consumption), this part of the necessary energy becoming "self-consumption",

Income from injection into the network, which can be valorized either in a regulated regime or in an aggregation regime. In Romania, for a small prosumer, the unit value of a kWh of avoided consumption contains all the components highlighted in the invoice, while the value of a kWh injected into the network is limited to the value of active energy either from the supply contract or by selling in the wholesale market. This results in a compensation rate of about 40-50% in the compensation of extraction from the network with injection into the network. Self-consumption and storage of excess production to later transform it into self-consumption are beneficial both for the prosumer and for the energy system; but not entirely for the aggregator. A change in the ratio between self-consumption and export to the network in favor of the former strengthens the comfort of the prosumer and restricts injection, thus the field of action of the aggregator. The potential for injection exists, especially when the installed production capacity is oversized compared to the level of necessary energy. In the case of installed capacities whose production significantly exceeds consumption, thus maximizing self-consumption can easily reach its limits, the same storage facility can give the prosumer, through the aggregator, the freedom to choose the moment of injection into the network, orienting towards time intervals with high prices and towards providing flexibility services in the reserve market and in the system services market. This is a beneficial approach for collaboration with the aggregator. Policies so far The paradox of this initial stage for prosumers and aggregation in Romania is that retrospectively, the evolution of the regulatory framework has increased from year to year the threshold of installed capacity for which the purchase by the supplier and the purchase price are guaranteed (from 27 kW to 100 kW and currently 400 kW), which has encouraged the increase in the number of prosumers, as demonstrated by the graphs in the paper but at the same time has significantly narrowed the segment of profitable types of prosumers for aggregators. Best practices in the European Union: diversification of portfolio and markets A careful analysis of the business model of a number of aggregators from member states (Germany, France, Belgium, Italy, Austria) and the United Kingdom, including the orientation of actions to improve it, shows two characteristics:

the growing importance of aggregating dispatchable consumption, complementary to the aggregation of distributed production, thus a tendency to diversify, and

valorization of injection into the network on reserve and balancing markets (Next Kraftwerke Germany – Germany), respectively balancing (Next Kraftwerke Germany – Italy), thus a tendency for dynamic approach. Aggregators in Romania should follow the good practices formed in developed markets in developing the portfolio and in defining services and orientation on existing markets.

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