National University of Science and Technology
POLITEHNICA Bucharest
Faculty of Power Engineering
Electro energetic Systems Department

DOCTORAL THESIS
Influence of identifying end customers load profiles on electricity markets

-Summary-

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Introduction

Globally, the major challenges and interests are: Environmental conservation, increased electricity consumption and economic growth.

The transition to a low-carbon economy is currently being attempted, which means that renewables, higher energy efficiency and electrification of transport play an increasingly important role.

It also seeks to actively engage small end customers, allowing them to actively manage their demand, produce electricity for self-consumption and deliver excess to the grid. In this context, electricity markets, regulations and infrastructure need to be adapted to a world where large end customers no longer dominate the market.

For high-consumption end customers, TSOs or DSOs, on a case-by-case basis, have equipped the measurement points with measurement groups that meet the technical, operational and design code for measuring electricity. If the measuring group is not able to generate measured values for each dispatching interval, a load profile may be determined for the respective measuring group according to the provisions of the Electricity Measurement Code, by means of which, the measured values for each dispatching interval can be determined.

Electricity markets need to be redesigned to encourage investment in low-carbon technologies while safeguarding security of supply and keeping costs for household customers and industry under control.

The totality of the improved buying and selling transactions in a given space represents the economic concept of the electricity market. Correlation is the main function, completed with the signing of a sale-purchase agreement through the supply and demand. In addressing sudden changes in electricity prices, contract planning is considered a vital risk management instrument for stakeholders in a regulated energy market.

Spot electricity prices display cyclical patterns on different frequencies such as daily, weekly, and annual cycles. Disruptive effects such as unexpected power plant outages or uncertainty at transmission lines add complexity and reduce predictability. Extreme price changes caused by disruptive events can be modeled using cutting-edge processes.

In chapter three of the presented paper, potential risks for the near future are analyzed. There are two conceivable crises in the electricity market. Subsequently, cost-benefit analyzes are performed for possible measures to be implemented. First, the costs and benefits of increasing the reliability of electricity generation are analyzed, and the economic consequences of the increase in the tax on electricity are further assessed.

Battery energy storage systems (abbreviated BESS) analyzed under Chapter four are increasingly introduced into distribution networks. BESS projects, formerly considered "scientific experiments", are now considered to be active as equipment in distribution networks, which improve operational efficiency, postpone, or eliminate the need for large capital expenditure for network modernization and can also generate revenue from services provided.

The economic viability of the BESS is under constant debate, especially if only one or two cases of energy storage use are considered. In addition, the economic environments and financial factors of each distribution network vary greatly, so the relative value of BESS compared to alternatives is frequently perceived as circumstantial or opportunistic and can be expected to change over time.

Based on the different interface schemes of BESS in distribution networks, both local control levels and SMD in a hierarchical control framework are relevant for the efficient operation of storage units in active distribution networks.

The integration of renewable energy sources into distribution networks is one of the most urgent issues that needs to be addressed. The networks in Romania and beyond cannot absorb the quantities of energy produced by the production units from renewable sources without putting pressure on the entire system.

By comparing the characteristics of the Romanian supply system with a wide variety of solutions offered by demand management, improving the integration of electricity production from renewable photovoltaic sources by responding to demand seems a suitable solution.

In an ever-changing context, companies operating in the electricity sector must carefully follow the new opportunities that arise in the electricity market. The main focus in the last chapter will be on end-customers demand management, i.e., end-user participation in the electricity market. In the current situation, end-customers have a passive attitude toward their electricity consumption. The price structure only offers limited incentives to adapt its behavior to consume in a smarter way. The development of wireless communications networks and the installation of smart meters, which has become mandatory by law [1], has opened the way to OMR and AG; in other words, the end-customers would give consent to a third party that would change their consumption in an optimal way based on its main objectives and considering the comfort constraints imposed by each end-customer. AG and OMR would be capable to react to price and network signals and influence the entire production system in the long term. Instead of meeting demand peaks, reducing consumption in peak consumption intervals can be a much cheaper alternative if it is proven to be reliable on a large scale. The technical functionalities that an AG can fulfill for end-users, as well as the economic value of the services it can offer are analyzed.

In the first part of Chapter five, the scenario of a business model aimed at minimizing the losses due to the transmission of electricity by adapting the use of electricity to the production of electricity from renewable sources is analyzed. By conducting numerical simulations and evaluating technical and economic results as well as environmental benefits, the key parameters for the successful implementation of the proposed solution were determined.

In the second part of Chapter five, an industrial customer with a photovoltaic power plant was economically analyzed. In the beginning, the installation of the behind-the-meter photovoltaic power plant was analyzed, then the scenario in which the photovoltaic power plant is connected to the grid and part of an aggregate entity was analyzed.

Acknowledgements

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Keywords: Load profiles, electricity markets, electricity consumers, active electricity customers, electricity generation from renewable photovoltaic sources, PV, battery storage systems, BESS

1. End customers load profiles

In electrical engineering, a load profile is a graph of the variation of the electric charge for a given customer type over time. A load graph will vary depending on the type of customer (typical examples include residential, commercial, and industrial), temperature and seasonality.

2. Electricity Markets

In Europe, trading on electricity markets is initiated a period of time before actual delivery takes place and is carried out in real time.

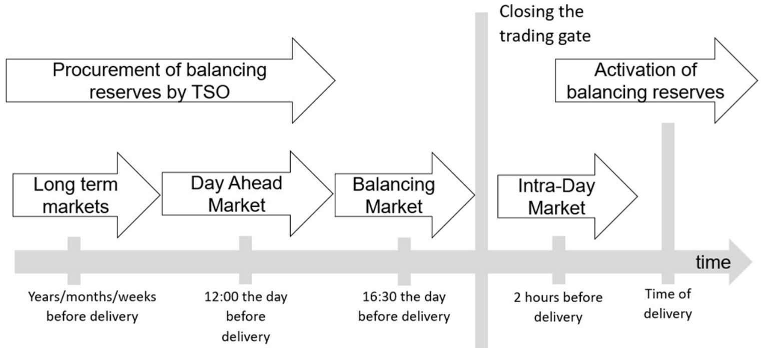


Fig. 12. Trading on electricity markets

3. Risks of interruption in electricity supply

3.2.1. Cost-benefit analysis for the reliability increase of electricity production

In the analysis from this section, a capacity availability crisis is simulated. To mimic the "Dutch cooling water crisis" outlined in Chapter 3.1, the availability of all generation capacity from renewable sources (about 74% of total generation capacity) is reduced from 74% to 55%.

In the event that the capacity is insufficient, and demand cannot respond to price signals in a timely manner, a decrease in the availability of operational capacity may induce a system failure, causing interruption in electricity supply to end customers.

3.2.1.4. Frequency of the profitability threshold

The results presented in this chapter expresses the frequency with which a predefined crisis should occur in order to equal the costs and benefits of the possible measures. The frequency of the profitability threshold is calculated as the ratio of the total benefits during a crisis to the annual average costs. According to the analysis, to reach the profitability threshold, a crisis should occur every 14-22 days. This is obviously very unlikely. Moreover, if this were to happen, price increases would be so frequent that producers would increase their capacities anyway. It can therefore be concluded that if the receptivity of the request is sufficient, none of the measures presented in this chapter will be implemented.

4. Electricity storage. Types of BESS systems

4.2.8. BESS influence on load profiles

With the help of BESS systems, stored energy can be used to reduce the load during periods when there is high demand, and the peak consumption of the system is reached. Shifting the load to other than peak consumption intervals mean transferring excess energy produced from renewable sources.

4.4.Energy storage at the level of aggregated electricity entities

MR which include photovoltaic (PV) systems, small wind turbines and BESS systems are increasingly common in many residential units, but also in the industrial sector in general. MR installations in apartment-residential buildings are a more complex problem, especially in the context of ownership and distribution of benefits resulting from the quantification of the delivered electricity generation.

4.4.1.1.Diagram of the electrical circuit of the aggregator service

To analyze the aggregator service and to facilitate the understanding of the proposal from this chapter, in fig. 27 the diagram of the electrical circuit is presented.

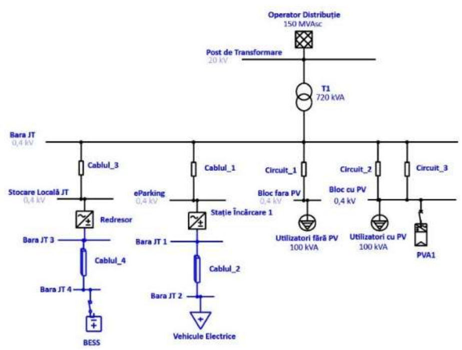


Fig. 27. Electrical circuit diagram with BESS and PV systems connected

4.4.1.4. The stimulation mechanism

Residents will not join any aggregation service unless they are rewarded with attractive benefits. As such, a set of incentive mechanisms for aggregation services is analyzed as follows:

- Minimum price guarantee;
- Rewards for participation;
- Programmed charging of electric vehicles.

4.4.2.1.Objective optimization function

The aggregator aims to minimize the costs of electricity extracted from the grid. The objective can be expressed by the following formulas:

$$Min \sum_{k=1}^{T} C^{ag} = \sum_{t=1}^{T} \left(B^{ag} - C_i^{ag}\right) \quad (17)$$

$$B^{ag} = q_i^{ag} \cdot p_i^{ag} \cdot \Delta t \ \left(dacă\ q_{e/i}^{ag} < 0\right) \quad (18)$$

$$C_i^{ag} = q_e^{ag} \cdot p_e^{ag} \cdot \Delta t \ \left(dacă\ q_{e/i}^{ag} < 0\right) \quad (19)$$

4.4.2.2. BESS and EV constrains

It should be mentioned that BESS is charging when $p_{i/d}^{BESS}$ is positive and discharges when $p_{i/d}^{BESS}$ is negative.

$$\sum_{m=1}^{N_{ap}} c_{ap,t}^{m} + \sum_{n=1}^{N_{VE}} c_{i,t}^{VE,n} + q_{i/d,t}^{BESS} - q_{v/c,t}^{ag} - q_t^{PV} = 0 \tag{20}$$

It is assumed that the BESS installed in the residential building is composed of used batteries. The operation of BESS should comply with the following constraints:

$$p_{min,i}^{Bat} \leq q_{i/d,t}^{Bat} \leq p_{max,i}^{Bat} \ \text{ when } \ q_{i/d,t}^{Bat} > 0 \tag{21}$$

$$p_{min,d}^{Bat} \leq q_{i/d,t}^{Bat} \leq p_{max,d}^{Bat} \ \text{ when } q_{i/d,t}^{Bat} > 0 \tag{22}$$

$$E_{t+\Delta t}^{Bat} = \begin{cases} E_t^{Bat} + q_{i/d,t}^{Bat} \cdot \eta_i^{Bat} \cdot \Delta t \ \text{ when } \ q_{i/d,t}^{Bat} \geq 0 \\ E_t^{Bat} + q_{i/d,t}^{Bat} \cdot \eta_d^{Bat} \cdot \Delta t \ \text{ when } q_{i/d,t}^{Bat} < 0 \end{cases} \tag{23}$$

For reused batteries in BESS, it is assumed that all batteries have the same degree of wear (GU) of the battery modules and that their capacity is initially the same. The battery modules within the BESS should comply with the following constraints:

$$E_{BESS} = N \cdot E_{Bat}^{original} \cdot GU \tag{24}$$

$$0 < SdI_t = \frac{E_t^{Bat}}{E_{BESS}} \leq 100 \tag{25}$$

The operation of charging stations should comply with the following:

$$\sum_{t=T_{VE}^{start,n}}^{t=T_{VE}^{final,n}} S_t^{VE,n} \cdot p^{VE} \cdot \Delta t = E_{VE}^{n} \tag{26}$$

$$T_{VE}^{start,n} \leq t \leq T_{VE}^{final,n} \tag{27}$$

$$S_t^{VE,n} = 0 \ sau \ 1 \tag{28}$$

4.4.3.1. Aggregator service input parameters

A five-level residential building with thirty apartments located in Bucharest is used for simulation. The production capacity of the photovoltaic power plant is assumed to be 100 kWp, which is estimated based on the roof surface. The production data for one day of the photovoltaic system is presented in fig. 33

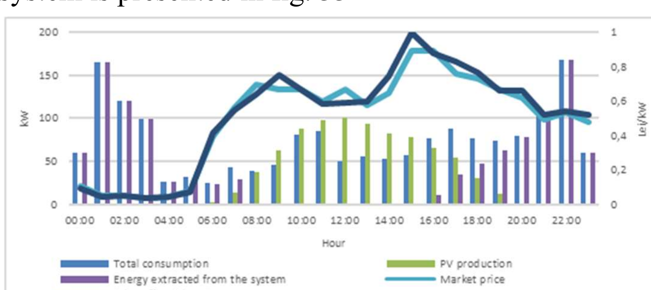


Figura 33. The performance of the aggregation service for a residential building with thirty apartments

4.4.3.2.1. Overall performance

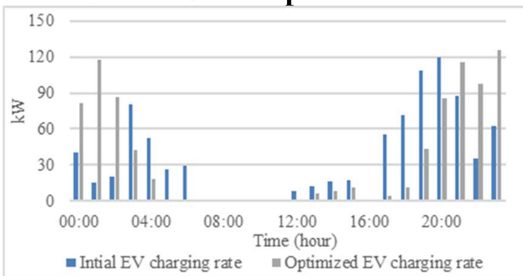


Fig. 34. EV load planning results

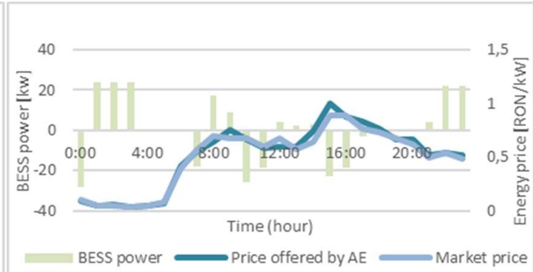


Fig. 35. BESS charging/discharging status

4.4.3.2.2. The performance of the aggregator when applying different prices

Invoicing information are calculated based on the data from the simulation results shown in table 26.

Table 26. Invoicing information [2]

[RON/kWh]	Fixed price	Price depending on the time of use	Real-time price
Extraction from the system	0,371	0,371	0,371
PV	0,253	0,268	0,334
BESS	0,067	0,063	0,102
Internal trading	0,259	0,183	0,715
Total	**0,951**	**0,885**	**0,879**

4.4.3.3. Comparison of the depreciation period

It is assumed that the residential building analyzed in this paper already has installed a photovoltaic system of 100 kWp and 150 kWh BESS using used car batteries, which are used in the calculation due to the low purchase cost. The calculation equations of the depreciation period are given below:

$$Depreciation\ period\ (years) = \frac{I_{BESS} + I_{PV}}{P_{agregator}^{anual}} \tag{29}$$

$$P_{agregator}^{anual} = \sum_{k=1}^{n} P_x \tag{30}$$

Table 27. The depreciation period of PV and BESS systems

	Fixed price	Price depending on the time of use	Real-time price
Cost of PV system [RON]	1.125.098,33		
Cost of BESS system [RON]	103.855,23		
Normal depreciation period [years]	12-20		
Depreciation period after using the aggregator service [years]	7,06	6,92	5,70

4.5. Energy storage at active end customers' level

Behind-the-meter electricity storage refers to the installation of electricity storage systems on customer-side.

Table 28. ”Behind-the-meter” storage – potential savings and the difference from the energy consumption from the system through an energy supplier

	2023
Price of active energy [RON/kWh]	1,300
Supply price excluding VAT and other charges associated with electricity [RON/kWh]	0,726
Saving per kWh by behind-the-meter storage [%]	100%
Energy saving by “behind-the-meter” storage for a consumption of 210 kWh/month [RON/year]	1.757,83
Difference from the energy consumption from the system via an energy supplier (amount of charges applicable to the energy consumed) [RON/year]	1.351,25

5. Comparative economic calculation for end customers with integrated power generation systems

5.1.1. Description of the proposed system

The studied service consists of the sale of electricity produced by AE members from intervals where the users’ electricity consumption is lower than the electricity produced from their own sources. One solution to this problem can be the transfer of the load from consumption intervals where production is at a minimum in consumption intervals where production is higher. The most important consumer of the end customers is the heating/cooling system, which uses electricity as the primary source.

5.1.1.1. Industrial end customers

In this analysis, the industrial end customers from the portfolio of the supplier, member of AG, were considered. The Supplier’s portfolio consists of 9 end customers, who have a total of 20 consumption points. The industrial end customers analyzed have an average annual consumption of between 67,000 and 112,000 MW, predictable due to the business program of the companies.

5.1.2. Proposed optimization model

AG must perform optimization services for the integration of electricity produced from renewable photovoltaic sources, using a set of constraints based on the availability of its resources, namely the heating/cooling systems of the analyzed end customers. AG receives revenue corresponding to the benefits it induces for the OMR, while it has to compensate for the discomfort it creates for industrial end customers.

5.1.2.2. Process description

In order to better understand the optimization algorithm, the description of the reasoning sequence for the AG business model is formulated. In particular, the role of the aggregator is to minimize the amount used for the OMR’s CPT. This is achieved by optimizing the load profile of the end customers, so that as much renewable electricity generation as possible is used. For this task to be carried out, AG can remotely control the heating of buildings.

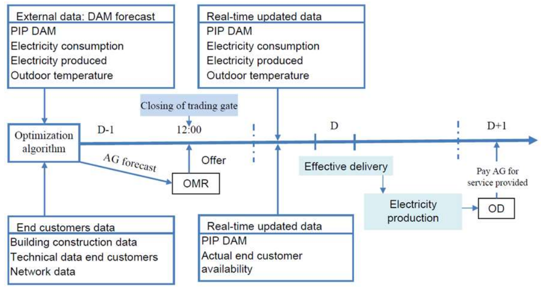


Fig. 38. Sequence of events in the process

5.1.2.2.3. Results

Upon completion of the optimization process, the total benefit obtained by AG during the 24-hour analysis period, as well as the forecast savings that AG generates indirectly for end customers, shall be calculated.

Additionally, a graph is generated showing the impact of the action of the aggregator on the load curve. A gross estimate of environmental benefits shall also be calculated as a result of the reduction in greenhouse gas emissions during the day (34).

$$Q_{CO_2} = (P_{import}^{baseload} - P_{import}^{AG}) * \Phi_{CO_2} \tag{34}$$

5.1.3.2. Optimization variables

The values of the optimization variables are calculated for each hour h and service provider k according to the equations below:

$$Q_{required} = P_{PV} - BL \tag{35}$$

$$P_{EA} = \begin{cases} P_{disp}, if\ P_{nec} > P_{disp} \\ P_{nec}, if - Q_{baseload} \le P_{nec} \le P_{disp} \\ Q_{baseload}, if\ P_{nec} < Q_{baseload} \end{cases} \tag{36}$$

$$Forecast_{AG} = BL + P_{EA} \tag{37}$$

5.1.3.3. Objection function

Following the assumptions formulated, AG's revenues correspond exactly to the reduction of additional energy costs that OMR no longer needs to purchase to cover transmission losses in/to the distribution network.

Mathematically, the objective function aimed at maximizing the profit π of the aggregator, calculated according to the equation:

$$\max \pi = \sum_{h=1}^{24} \left[\beta \cdot PIP_{PZU} \cdot \left[\left(P_{PV}(h) - BL(h)\right)^2 - \left(P_{PV}(h) - Forecast_{AG}(h)\right)^2 \right] - \sum_{k=1}^{k} P_{EA}(h) \cdot C_k(h) \right] \tag{38}$$

5.1.3.4. Constrains

AG's shares are subject to several constraints, both local and global. Specifically, each end customer sets their own temperature limits for each hour h, whereas the consumption generated by AG must not exceed the initial forecast.

$$T_{int}^{min} \leq T \leq T_{int}^{max} \tag{39}$$

$$\sum_{h=1}^{24} P_{EA}(h) \leq \sum_{h=1}^{24} Q_{baseload}(h) \tag{40}$$

5.1.4.1. The simulation strategy

If there is a surplus in the production of electricity from renewable photovoltaic sources, AG sends a signal to end customers to increase their consumption – compared to – P_{EA} – to the required level or to the maximum capacity they can use. Otherwise, it is a consumption reduction command that is sent to end customers: The thermostat adapts the thermal load in buildings to a new, lower reference temperature T^{ref}.

The estimation of the temperature in buildings for h is shown in the equation (42).

$$\begin{cases} T(h=1) = T^{ref} \\ (\forall h \in \mathbb{N} \cap [1;23]) \begin{cases} T^{aux}(h) = T_{ext}(h) + \dfrac{Q_{baseload}(h) + P_{EA}}{\lambda} \\ T(h+1) = T_{ext}(h) - (T_{ext}(h) - T(h)) \cdot exp\left(-\dfrac{1}{\Delta t}\right) \end{cases} \end{cases} \tag{42}$$

If one or more constraints are not met, then the program tries another solution until it finds the best answer that satisfies all the constraints. This "trial and error" approach is repeated for each time interval in the time horizon considered.

5.1.5. Results of the optimization algorithm

The simulation is repeated several times, each time, with an increased level of difficulty. First, a simple scenario is designed to assess the overall outcome of an AG's activity in the current situation, as well as to determine what the decisive parameters are. In the second stage a more sophisticated model was developed, considering several categories of users and stochastic phenomena.

5.1.5.1.Reference cases

The first simulations aimed to determine whether it would have been profitable to implement AG in Romania in 2023. All simulations were compiled based on historical data from 2023, published by the electricity market operator in Romania [3], but also general assumptions about market and user characteristics.

In order to calculate the savings that participation as a service provider for AG could offer end customers, the variable electricity tariff was estimated at 5 RON /MWh. Only 61% of the invoiced electricity price represents the equivalent of the active electricity consumed, the difference of 39% is consisting of taxes and tariffs applicable to the electricity consumed and invoiced.

5.1.5.1.1. Analyzed scenarios

Since the first version of the program simulates only one day, specific circumstances have been favored. Two extreme scenarios and a normal scenario were selected for a better understanding of what AG is able to achieve and the quality of service provided, as well as the revenues for each type of scenario.

5.1.5.1.2. Results

The first conclusion resulting from the simulations is that the service appears to work under all circumstances and always allows for higher levels of electricity production, also during periods of low production, as long as the optimization horizon does not exceed one day.

For the scenarios mentioned in chapter 5.1.3.1.1 specific curves describing: Volume of transport losses, temperature profile of users and finally load profiles for Romania were drawn. The baseline scenario is shown in blue, the influence of AG appears in green, and the energy production is represented in red.

5.1.5.1.2.1. Peak day of energy production from photovoltaic sources

The objective is to transfer the heating load from peak intervals to off-peak intervals when the price is lower. The load profile is modified as shown in figures 42 and 43, where the modified profile is presented when a new constraint is added to the simulation program. The interior temperature must comply with the criterion $T_{start} \cong T_{end}$.

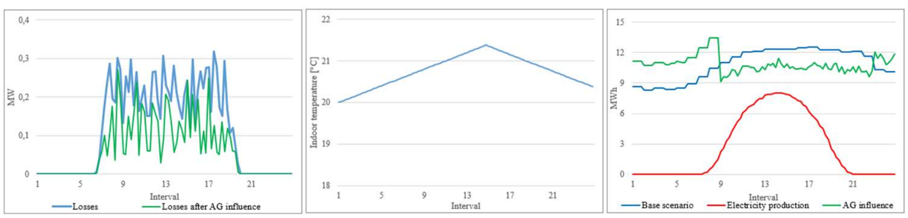


Fig. 42. The scenario in which users set the interior temperature without a limitation

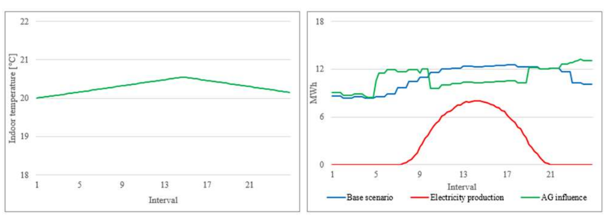


Fig. 43. The scenario in which the criterion $T_{început} \cong T_{final}$ is met

As can be observed by comparing the two curves, the additional limitation reduces the possibilities of AG and considerably limits its ability to correctly track the profile of electricity productions from renewable photovoltaic sources.

5.1.5.1.2.2. Peak day of the DAM price

The interest of AE is to reduce the heating load during price peaks to reach the minimum threshold of energy acquisition costs. Optimized curves are presented in fig. 44.

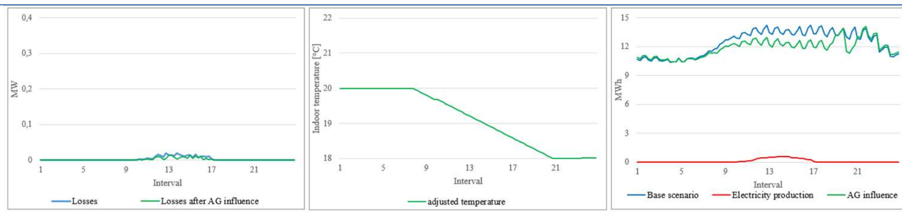


Fig. 44. Scenario peak price day and temperature optimization

5.1.5.1.2.3. Average day

An average day during the heating season, which usually lasts from September 24 to April 4, is analyzed further. It should be noted that the economic result obtained for this day cannot be multiplied by 192 (heating days) to obtain the total revenue throughout the season, because the final temperature is not the same as the original.

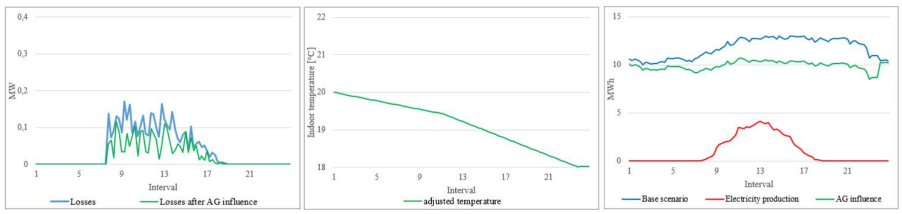


Fig. 45. Scenario for an average day during the heating season

In table 35 the effects of AG are presented in the 3 cases analyzed, the economic benefits of the end customers involved, as well as the technical impact of AG actions are included.

Table 35. Results of the analysis

	U.M.	Peak day of energy production	Peak day of the DAM price	Average day	Average
The benefits of AG	RON	101.226,17	177.567,04	193.271,48	157.354,90
Reduction of network fees	%	16%	16%	32%	20%
Net benefit of AG	RON	236.114,19	187.262,57	230.616,69	217.997,82
Savings of end customers	RON/ MWh	96,98	148,73	171,25	140,23
Increase in the rate of nebulosity	%	24%	11%	6%	17%
Power limitation	%	-	-	-9%	-16%
Reduction of greenhouse gases	%	-33%	-12%	-26%	-23%

5.1.5.1.3. Data analysis

In the first place, regarding the technical quality of the “nebulosity monitoring service”, it is very high. The results are positive when the aggregator has to act and modify the consumption profile to adapt it to the electricity production from renewable photovoltaic sources.

5.1.5.1.3.1.Peak day of energy production from photovoltaic sources

As can be observed from fig. 42, fig. 43 and from table 35, the penetration of energy production throughout the day increases significantly, while spending on network charges and greenhouse gas emissions experiences a significant reduction.

Even though it clearly appears to be the most promising technical service that AG is able to offer, profits for both AG and the end customers are limited as no reduction in consumption is achieved as price variations do not allow for considerable savings.

5.1.5.1.3.2.Peak day of the DAM price

In a period of extremely high prices related to maximum nebulosity, as presented in fig. 44, the benefits for the aggregator and especially for a supplier with a business model that is sensitive to price increases are at a low level due to low consumption during periods with increased DAM prices. End customers also reduce their electricity invoice value, but this is closely related to the loss of thermal comfort as they must accept lower temperatures at the end of the day.

5.1.5.1.3.3.Average day

The above-mentioned results should be compared with the third case analyzed or the average day of heating shown in Fig. 45. It is in many ways similar to the "peak day of the DAM price", except that the market prices do not reach the same high levels. What makes the difference between an average day and a peak day of the DAM price is the final economic result, directly proportional to the market prices.

5.2. Economical calculation for and end customer with installed PV system

At the moment, the analyzed industrial end customer has a meter with integrated smart-metering system installed. The analysis and calculation are performed for the active energy consumed in 2023. The calculation also includes the tariffs paid by the end customer, in order to further highlight the savings achieved by installing PV systems. The tariffs used in this calculation are approved and published by ANRE.

5.2.1. End customer analysis

The end customer owns a shopping center in Iasi County. The operating hours are between 9-22, Monday to Sunday. The annual consumption of this end customer is about 112,000 MWh/year.

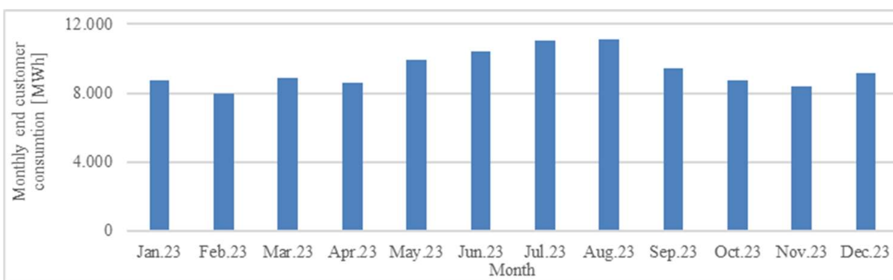


Fig. 47. End customer's consumption for 2023

As can be observed from Fig. 47, the peak consumption months are in the summer period, and the increase in consumption is due to the air conditioning systems installed in the shopping center.

5.2.1.1. Analysis of end customer's monthly invoices

Active energy price for the analyzed end customer is PIP DAM, calculated for each interval, plus the top-up per MWh of the supplier.

Table 36. Applicable monthly prices for the analyzed end customer

[RON/ MWh]	**Price$_{EA}$**	**Top-up$_{EA}$**	**T$_L$** [4, 5]	**T$_{SS}$** [6, 7]	**TD$_{MT}$** [8, 9]	**P$_{CV}$** [10, 11]	**Tax on energy** [12]	**COG** [13, 14, 15]	**VAT** [16]
Total	529,92	10,00	26,97	7,09	91,17	71,68	3,03	2,38	141,03

The contractual price of the end customer is calculated according to the following equation:

$$P_{EA} = \frac{\sum_{i=1}^{n} PIP_{DAM} \cdot VM_{15\,min}}{\sum_{i=1}^{n} VM_{15\,min}} \tag{43}$$

VAT rate presented in table 36 is calculated according to the equation:

$$VAT = (Preț_{EA} + Top-up_{EA} + TL + SS + TD_{MT} + P_{CV} + Tax\ on\ Energy + COG) * 0{,}19 \tag{45}$$

Table 37. Value of end customers invoices for 2023

	EA consumption	EA value	Tax value	Total invoice value
UM	[MWh]	[RON]	[RON]	[RON]
Total	**112.459,862**	**58.911.356,78**	**39.652.213,14**	**98.563.569,92**

The value of the active energy consumed by the end customer from table 37 it is calculated according to the equation:

$$EA\ value = \sum_{i=1}^{n} EA\ consumption \cdot Price_{EA}\ [RON] \tag{46}$$

The value of the taxes from table 37 is calculated according to the equation:

$$Tax\ value = EA\ consumption \cdot (Top-up_{EA} + TL + SS + TD_{MT} + P_{CV} + Tax\ on\ energy + COG + VAT)\ [RON] \tag{47}$$

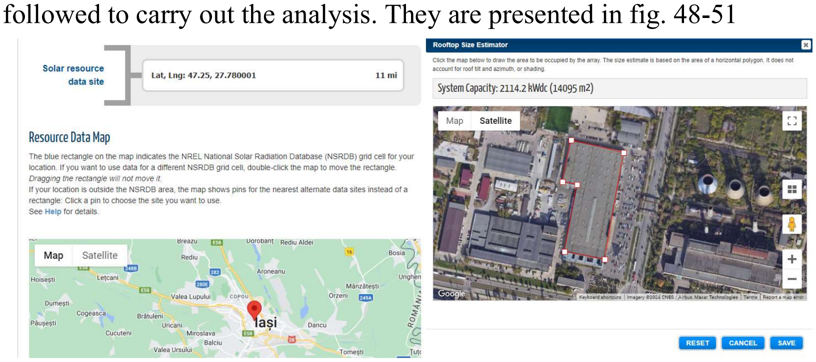
5.3. Dimensioning the off-grid PV system installed at the analyzed end customer

Using the online simulator [17], a simulation is performed for the installation of a PV system on the roof of the building owned by the end customer.

5.3.1. Dimensioning PV system of the analyzed end customer

It is assumed that the end customer owns a shopping center in Iasi Couny, with a total usable PV area of approx. 14.000 m^2.

In the simulator used [17**Error! Bookmark not defined.**], there are several steps that need to be followed to carry out the analysis. They are presented in fig. 48-51



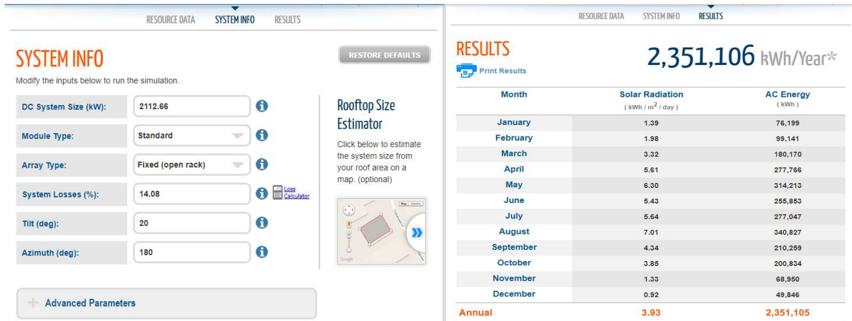


Fig. 48-51. PV system dimensioning

According to [18], the value of the photovoltaic system is calculated on the basis of the average daily production, measured in kWh, multiplied by approx. 5 Euro (25 RON - at an average exchange rate of 5 RON/Euro), plus the value of photovoltaic panels.

In order to calculate the number of PV panels, the following calculation formula is used [17]:

$$Number\ of\ panels = \frac{Installed\ system\ power}{Nominal\ panel\ power} \tag{48}$$

The nominal power of the panel is 605 Wp. For installation, Trina panels of Vertex N type were considered [19].

$$Number\ of\ panels = \frac{2{,}1126\ kWp * 1000}{605\ Wp} = 3.491{,}90 \tag{49}$$

It is considered a number of 3,492 panels at a price per panel of 2,500.00 RON.

The analyzed system has an installed power of 2112,66 kWp, and the panels proposed to be installed which are produced by the company Trina have a power of 605 Wp [19].

The total system cost for the analyzed end customer is calculated according to the following equation:

$$\begin{aligned} &Total\ system\ cost \\ &\quad = Number\ of\ panels * Price\ per\ panel \\ &\quad + Daily\ production\ in\ [V] * System\ Price \end{aligned} \tag{50}$$

$$Total\ system\ cost = 3.492 \cdot 2.500 + 63.088{,}75 * 25 = \mathbf{10.307.218{,}75\ RON} \tag{51}$$

The price of the system also includes the interface for the PC, which acts as electrical insulation between the inverter and the computer.

5.3.2. Economical calculation of the analyzed end customer

In table 38 the quantities of electricity consumed, the total amount of electricity produced by the PV system, but also the difference that is required to be purchased from the electricity market are presented.

Table 38. Electricity quantities consumed and produced

MWh	EA consumption	Quantity produced by PV system	Difference in the amount of energy purchased from the market
Total	**112.459,862**	**2.302,739**	**110.157,123**

In table 39 the new value of the active electricity extracted and used from the system is calculated.

Table 39. Comparative analysis of the active energy value

	EA initial value*	**EA purchased after PV installation**	**EA savings value due to PV installation**
U.M.	[RON]	[MWh]	[RON]
Total	**58.911.356,78**	**57.942.188,10**	**969.168,67**

*value retrieved from table 37

Economy from EA value from table 39 is calculated using the following formula:

$$Economy\ from\ EA\ value = EA\ intial\ value - value\ of\ EA\ purchased\ after\ PV\ installation \quad (52)$$

$$Economy\ from\ EA\ value = 58.911.356{,}78 - 57.942.188{,}10 = \mathbf{969.168,67} \quad (53)$$

In addition to the savings from the use of active energy produced for own consumption, the economy achieved due to non-application of tariffs and taxes associated with electricity extracted from the system must also be taken into account.

Table 40. The economy achieved for the active electricity produced and used for their own consumption

	Tax value*	**Value of the taxes after PV installation**	**Cost saving due to PV installation**
U.M.	[RON]	[RON]	[RON]
Total	**39.652.213,14**	**38.848.942,08**	**803.271,06**

* value retrieved from table 37

The cost saving due to PV installation from table 40 is calculated using the formula:

$$Cost\ saving\ taxes = Initial\ tax\ value - Value\ of\ the\ taxes\ after\ PV\ installation \quad (54)$$

$$Cost\ saving\ taxes = 39.652.213{,}14 - 38.848.942{,}08 = \mathbf{803.271,06\ RON} \quad (55)$$

The total saving due to the installation of the PV system is calculated as the sum of the savings achieved from the value of the active energy and the savings achieved from the value of the taxes due to the installation of PV.

$$Total\ saving = EA\ saving\ value + Cost\ saving\ taxes \quad (56)$$

$$Total\ saving = 969.168{,}67 + 803.271{,}06 = \mathbf{1.772.439,73\ RON} \quad (57)$$

The costs for the maintenance of the photovoltaic system were not taken into consideration because they are insured by the photovoltaic panel manufacturer during the first 5 years Due to the complexity of the BESS system, but also to the higher consumption compared to electricity production, the installation of such a system was not taken into consideration.

The end-user sends the consumption forecast to the supplier and the supplier pays for the imbalances generated by the forecast.

5.3.3. Calculation of the depreciation period of the investment

The total cost of the system calculated in the chapter 5.3.1. it is used to calculate the period of depreciation of the investment in the photovoltaic system.

$$Depreciation\ period(years) = \frac{I_{PV}}{Total\ saving} = \frac{10.307.218,75}{1.772.493,73} = 5,8\ ani \qquad (58)$$

The usual period of depreciation is communicated by the Ministry of Environment and is between 12 and 20 years [20]. According to the calculation from the equation (58), the initial investment in the system will be recovered in 5.8 years, a period reduced considerably due to the high level of tariffs applicable to the electricity consumed.

5.4. Aggregate entity consisting of a supplier with end-users and production units

In this chapter it is considered an aggregate entity consisting of three producers of electricity from renewable sources (wind with an installed capacity of 50 MW and two electricity producers with photovoltaic panels installed with an installed capacity of 10 MW and 2,1126 MW respectively), and a supplier with a portfolio of 9 end customers (20 consumption points), registered as AE under a BRP. Is analyzed the comparative difference in balancing costs for each of the AE members and balancing costs if they are registered as individual entities in the BRP register.

5.4.1. Forecasted and metered values of AE members

5.4.1.1. Physical notifications of AE

Each AE within the BRP is required to send physical notifications to BRP by the agreed time, and BRP is required to send physical notifications to the OPE by 16:30 on the day before the delivery day [21].The net contractual position of an AE is calculated according to the equation described in [13]:

$$PN_{contr} = \left(\sum SB_{livr} - \sum SB_{prim}\right) + \left(\sum EX - \sum IM\right) + \left(\sum E_{ech}^{cres} - \sum E_{ech}^{red}\right) \qquad (59)$$

All contracted quantities for each hour are expressed in MWh, to three decimal places. Sales, exports and quantities contracted at power reduction are expressed with "-", being considered as "outputs" from the AE contour.

In the analyzed AE, the net contractual position for a settlement range can be calculated using the following equation:

$$PN_{contr}^{PRE} = \left(\sum SB_{livr} - \sum SB_{prim}\right) \qquad (60)$$

The analyzed AE members do not export or import energy, nor are they registered in the balancing market to respond to power increase/decrease orders. Purchases and sales transactions are for DAM only.

Also, block exchanges are made only with OPEEGN OPCOM, as AE participants do not have bilateral electricity procurement contracts, all the energy is purchased/sold through DAM.

The energy balance a PRE is calculated according to the following equation:

$$NF_{consumption} + NF_{production} + SB_{V_{DAM}} + SB_{A_{DAM}} = D_{NF}^{PRE} \qquad (61)$$

Table 41. Physical notifications of AE for 01.01.2023

NF	NF consumption	NF production	$SB_{V_{PZU}}$	$SB_{A_{PZU}}$	D_{NF}^{AE}
U.M.	[MWh]	[MWh]	[MWh]	[MWh]	[MWh]
Total	**315,808**	**-142,721**	**-184,4**	**11,2**	**-0,113**

5.4.1.2. Metered values of AE members

The metered values (VM) of the production units shall be recorded and transmitted with the sign '-'. The AE receives from the BRP metered values related to the participants and confirms them with them, subsequently confirming their correctness to BRP.

In Table 42 the metered values of the AE members for 01.01.2023 are partially presented.

For the measured values at AE level, the following calculation formula has been applied:

$$VM_{AE} = VM_{Furnizor} + \sum_{i=1}^{n} VM_{Producător} \tag{62}$$

Table 42. Metered values of AE members

Date	VM_F	VM_{P_1}	VM_{P_2}	VM_{P_3}	VM_{AE}
U.M.	MWh	MWh	MWh	MWh	MWh
….	...	...	...	...	...
03.01.2023 16:15	10,586	-0,200	-0,382	0,000	10,004
03.01.2023 16:30	12,381	-0,244	-0,446	0,000	11,691
03.01.2023 16:45	13,185	-0,381	-0,475	0,000	12,328
….	...	...	...	...	...

5.4.1.3. Imbalances of AE members

The regulation and methodology for calculating imbalances, but also for BRP settlements are published by OPE on its website and approved by ANRE.

For the determination of the AE imbalance for a settlement range it is necessary to calculate the imbalances of each member using the following equation:

$$Dez_{AE} = \sum_{i=1}^{n} Dez_{member} \tag{63}$$

$$Dez_{member} = PN_{contr}^{member} - VM_{member} \tag{64}$$

After determining the AE imbalance for each interval of the month of analysis, the direction of the imbalance is determined according to the equation (65).

$$\begin{gathered} if\ Dez_{AE} < 0\ then\ Dez_{AE} = Dez_{positive} \\ if\ Dez_{AE} > 0\ then\ Dez_{AE} = Dez_{pozitive} \\ if\ Dez_{AE} = 0\ then\ Dez_{AE}\ is\ null \end{gathered} \tag{65}$$

In table 43 the imbalances of each member are partially presented, but also the imbalances at AE level.

Table 43. Example of imbalances of AE members

Date	Dez_F	Dez_{P_1}	Dez_{P_2}	Dez_{P_3}	Dez_{AE}
U.M.	MWh	MWh	MWh	MWh	MWh
03.01.2023 16:15	-0,688	-0,815	0,279	0,000	-1,224
03.01.2023 16:30	-1,634	-0,770	0,228	0,000	-2,177
03.01.2023 16:45	-1,384	-0,634	-0,124	0,000	-2,142

In intervals where the imbalances for all members are in the same direction, the AE effect cannot be applied, but in intervals where the imbalances are in opposite direction, the AE effect is applied, decreasing the exceedance/deficit by the opposite amount of the other participant.

5.4.2. Method of calculation for BRP prices

After calculating the imbalance prices, the OPE is publishing them. Using the imbalances calculated for BRP based on the metered and forecasted data and imbalance prices, each AE recalculates the exceedance and deficit prices for each settlement interval, applying the portfolio effect and improving the surplus and deficit prices within AE. For settlement intervals where the surplus price is equal to the deficit price, the portfolio effect cannot be applied.

Based on the exceedance and deficit prices published by OPE, the average balancing price (P_{med}^{ech}) is determined using the following equation:

$$P_{med}^{ech} = \frac{P_{exc_{BRP}} + P_{def_{BRP}}}{2} \tag{66}$$

Table 44. Example for the imbalance prices calculated by BRP

Date	$P_{exc_{BRP}}$	$P_{def_{BRP}}$	P_{med}^{ech}
U.M.	RON/MWh	RON/MWh	RON/MWh
03.01.2023 16:15	-2.487,85	4.587,85	3.537,85
03.01.2023 16:30	201,00	1.892,45	845,73
03.01.2023 16:45	660,18	1.900,00	1.280,09

The value of imbalances for each AE member is calculated using the imbalance prices published by the OPE, being considered as 'unallocated' imbalances (NA), as the BRP effect is not applied at this stage.

$$\begin{aligned} if\ Dez_{member} < 0;\ V_{NA}^{dez} = Dez_{negative} \cdot P_{def_{BRP}} \\ if\ Dez_{membru} > 0;\ V_{NA}^{dez} = Dez_{positive} \cdot P_{exc_{BRP}} \end{aligned} \tag{67}$$

$$V_{AE}^{dez} = \sum_{i=1}^{n} Dez_{AE} \cdot \frac{P_{def_{BRP}}}{P_{exc_{BRP}}} \tag{68}$$

In table 45 the values of unallocated imbalances of BRP-members are partially presented.

Table 45. The unallocated imbalances of EA members

Date	$V_{NA_F}^{dez}$	$V_{NA_{P_1}}^{dez}$	$V_{NA_{P_2}}^{dez}$	$V_{NA_{P_3}}^{dez}$	$\sum_{i=1}^{n} V_{NA}^{dez}$	V_{AE}^{dez}
U.M.	RON	RON	RON	RON	RON	RON
03.01.2023 16:15	-3.156,72	-3.739,04	-693,24	0,00	-7.589,00	-5.617,35
03.01.2023 16:30	-3.092,90	-1.457,82	45,77	0,00	-4.504,95	-4.119,81
03.01.2023 16:45	-2.630,35	-1.204,09	-234,87	0,00	-4.069,30	-4.069,30

As can be observed from tables 43 and 45, in interval between 16:45 and 17:00 on 03.01.2023, all AE participants had negative imbalances. In this case, the AE effect could not be applied.

The calculation of absolute quantitative imbalances is performed, which is the basis for determining the amount by which exceedance and deficit prices can be optimized.

The equation applied to calculate absolute quantitative imbalances is as follows:

$$\sum_{i=1}^{n} Dez_{AE}^{abs} = \sum_{i=1}^{n} Dez_{F}^{abs} + \sum_{i=1}^{n} Dez_{P_1}^{abs} + \sum_{i=1}^{n} Dez_{P_2}^{abs} + \sum_{i=1}^{n} Dez_{P_3}^{abs} \tag{69}$$

Table 46. Absolute imbalances of AE members

Date	Dez_F^{abs}	$Dez_{P_1}^{abs}$	$Dez_{P_2}^{abs}$	$Dez_{P_3}^{abs}$	Dez_{AE}^{abs}
U.M.	MWh	MWh	MWh	MWh	MWh
03.01.2023 16:15	0,688	0,815	0,279	0,000	1,782
03.01.2023 16:30	1,634	0,770	0,228	0,000	2,632
03.01.2023 16:45	1,384	0,634	0,124	0,000	2,142

Based on absolute imbalances of AE members, the absolute benefit of AE, the amount by which exceedance and deficit prices can be optimized, and the percentual performance of AE shall be calculated. Values presented in table 47.

The value of absolute benefit due to AE participation ($V_b^{abs_{AE}}$) is determined based on the equation:

$$V_b^{abs_{AE}} = \sum_{i=1}^{n} V_{NA}^{dez} - V_{AE}^{dez} [RON] \tag{70}$$

The value by which AE prices are optimized due to the portfolio effect is calculated using the following equation:

$$V_{preț}^{opt} = \frac{V_b^{abs_{AE}}}{Dez_{AE}^{abs}} \tag{71}$$

The following equations is used for determining the optimized exceedance and deficit prices:

$$P_{exc}^{opt} = P_{exc_{BRP}} + V_{preț}^{opt} \tag{72}$$

$$P_{def}^{opt} = P_{def_{BRP}} - V_{preț}^{opt} \tag{73}$$

The percentual performance of AE in the intervals where dual prices have been published by the OPE is determined using the following equation:

$$P_{AE} = \frac{P_{exc_{BRP}} - P_{exc}^{opt}}{P_{med}^{ech}} \tag{74}$$

Table 47. Recalculated prices for analyzed AE

Date	$V_b^{abs_{BRP}}$	$V_{preț}^{opt}$	P_{exc}^{opt}	P_{def}^{opt}	P_{AE}
U.M.	RON	RON/MWh	RON/MWh	RON/MWh	%
03.01.2023 16:15	1.971,66	1.106,615	-1.381,23	3.481,24	31,3%
03.01.2023 16:30	385,14	146,310	347,31	1.746,14	17,3%
03.01.2023 16:45	0,00	0,000	660,18	1.900,00	0,0%

The AE performance is calculated using the following formula:

$$P_{AE} = \frac{P_{exc_{OPE}} - P_{exc}^{opt}}{P_{med}^{ech}} \tag{75}$$

Using the recalculated prices for the analyzed AE, the values of the imbalances of the AE participants are calculated using the following equation:

$$\begin{aligned} &if\ Dez_{member} < 0;\ V_{member}^{dez} = Dez_{negative} \cdot P_{def}^{opt} \\ &if\ Dez_{member} > 0;\ V_{member}^{dez} = Dez_{positive} \cdot P_{exc}^{opt} \end{aligned} \tag{76}$$

Table 48. Value of reallocated imbalances for AE members

Date	V_F^{dez}	$V_{P_1}^{dez}$	$V_{P_2}^{dez}$	$V_{P_3}^{dez}$	V_{AE}^{dez}*
U.M.	RON	RON	RON	RON	RON
03.01.2023 16:15	-2.395,31	-2.837,16	-384,88	0,00	-5.617,35
03.01.2023 16:30	-2.853,78	-1.345,11	79,08	0,00	-4.119,81
03.01.2023 16:45	-2.630,35	-1.204,09	-234,87	0,00	-4.069,30

* value retrieved from table 45

5.4.3. BRP data analysis for a period of 12 months

Extrapolating the calculation for a period of 12 months, further evaluation is considered for a energy producer with an installed capacity of 2.1126 MWh, the feasibility of obtaining a energy producer's license and registering in the energy markets, compared with the calculation from chapter 5.3 to determine which is the economically optimal solution.

In table 49 the imbalances of AE members are centralized for a period of 12 months.

Table 49. Imbalances of AE members

	Dez_F	Dez_{P_1}	Dez_{P_2}	Dez_{P_3}	Dez_{AE}
U.M.	MWh	MWh	MWh	MWh	**MWh**
Total	**-1.818,76**	**2.065,76**	**211,08**	**40,29**	**498,37**

As it can be observed from table 49, the portfolio effect applied by the AE, diminishes the members' imbalances in the intervals where another member registers an imbalance with an opposite sign.

Furthermore, in table 50 the value of unallocated imbalances and value of imbalances calculated using recalculated prices are analyzed.

Table 50. Imbalance value of AE members

	$V_{NA_F}^{dez}$	V_F^{dez}	$V_{NA_{P_1}}^{dez}$	$V_{P_1}^{dez}$	$V_{NA_{P_2}}^{dez}$	$V_{P_2}^{dez}$	$V_{NA_{P_3}}^{dez}$	$V_{P_3}^{dez}$
U.M.	RON	RON	RON	RON	RON	RON	RON	RON
Total	**-2.570.516**	**-1.939.357**	**-11.825.025**	**-11.119.999**	**-800**	**16.887**	**865**	**2.695**

In table 51, based on the values presented in table 45, the equivalent of the optimization (C_{F,P_1,P_2,P_3}^{opt}), is calculated, considered as the difference between the value of unallocated imbalances and the value of recalculated imbalances based on BRP prices for the year 2023, presented in the equation (77).

$$C_{F,P_1,P_2,P_3}^{opt} = V_{F,P_1,P_2,P_3}^{dez} - V_{NA_{F,P_1,P_2,P_3}}^{dez} \quad (77)$$

Table 51. Optimization of the value of imbalances

	C_F^{opt}	$C_{P_1}^{opt}$	$C_{P_2}^{opt}$	$C_{P_3}^{opt}$
U.M.	RON	RON	RON	RON
Total	**631.160**	**705.026**	**17.687**	**1.830**

5.5. Comparative calculation for an off-grid producer versus on-grid producer

The analysis is a comparative calculation based on the results from chapters 5.3 and 5.4.

According to the equation (51), the total cost of the system is 10.307.218,75 RON.

For the scenario presented in the chapter 5.3, the expense that the end customer with the behind-the-meter PV system (off-grid) registers is the initial expense for commissioning the system.

Because the system described in the chapter 5.3 it is not connected to the network, with its help, the end customer reduces the amount from the invoices that he should pay to his electricity supplier.

The monthly expenses for the end customer with behind-the-meter PV system (C_{BtM}^{p}) are equal to 0, due to the use of energy produced for its own consumption.

The amount of expenses reduction with the energy consumed (rC_{BtM}^{p}) (value for EA and taxes) is considered a revenue and was calculated using the following equation:

$$rC_{BtM}^{p} = EA\ value\ saving\ due\ to\ PV\ installation\ + \\ Taxes\ value\ saving\ due\ to\ PV\ installation \quad (78)$$

According to [22], for obtaining the license for exploitation of electricity generation capacity with installed power less than 5 MW, the tariff is 500 lei. Additionally, the annual tariff $\left(t_{license}^{ANRE}\right)$ which represents 0,01% from turnover is applicable.

AE is registered for trading on the day-ahead market, the tariffs related to trading PZU are fully borne by AE as the net position shown in table 41 the as forecast.

The tariffs applied by AE for representation in the balancing market are as follows: monthly fixed tariff (t_F^{BRP}) of 5.000 RON/month + variable fee (t_V^{BRP}), representing 5% of the imbalance optimization value.

$$C_{licensed}^{p} = \frac{t_{license}^{ANRE}}{12} + t_F^{BRP} + t_V^{BRP} \tag{79}$$

The revenues generated by the analyzed producer are analyzed according to the following equation:

$$V_{licensed}^{p} = V_{DAM}^{p} + V_{Exc}^{p} - C_{Def}^{p} \tag{80}$$

The total benefit of the producer in the two analyzed cases from chapter 5.3 and 5.4 is calculated using the following equation:

$$B_{BtM}^{t_p} = rC_{BtM}^{p} - C_{BtM}^{p} \tag{81}$$

$$B_{licensed}^{t_p} = V_{licensed}^{p} - C_{licensed}^{p} \tag{82}$$

In table 52 the producer's revenues and expenses reductions with the behind-the-meter system are presented:

Table 52. Comparative analysis of producer's benefits

	rC_{BtM}^{p}	C_{BtM}^{p}	$B_{BtM}^{t_p}$	$V_{licensed}^{p}$	$C_{licensed}^{p}$	$B_{licensed}^{t_p}$
U.M.	RON	RON	**RON**	RON	RON	**RON**
Total	**1.772.439,73**	**0**	**1.772.439,73**	**922.583,32**	199.689,42	**722.893,90**

The calculations performed in chapters 5.3, 5.4 and 5.5 demonstrates that the deduction of costs of purchasing energy from a supplier is approximately 150% higher than the registration of the production unit in the electricity markets and its trading on the wholesale market via AE. The calculation did not take into consideration the costs of the return on investment, the costs of operation and maintenance or the personnel costs.

Conclusions

From this research can observe the importance of load curves and load profiles in the electricity market.

In Chapter three, a new global energy system modeling framework is presented, combining traditional elements of systems engineering modeling approaches with essential characteristics of a risk management perspective. The use of optimization techniques in modern portfolio theory with a representation of uncertain costs and associated risks along the energy chain, including extraction and conversion technologies, as well as demand management costs, it has enabled the identification of future development paths that are cost-effective not only from the current perspective and expectations, but also consider the risk posed by future uncertainties.

Through a series of sensitivity analyzes, the characteristics of hedging strategies which are adapted to considerably reduce future risks and are therefore robust against a wide range of future uncertainties.

Energy storage can balance the production of centralized and distributed electricity, while contributing to energy security. Energy storage will supplement demand response, flexible production and provide another option in network development. It can also contribute to the decarbonization of other economic sectors and support the integration of improved shares of electricity from variable renewable sources, buildings, or industry.

In chapter 4, a new aggregation service for residential apartment buildings with PV and BESS is proposed based on three differentiated price types, internal trading and low-price guarantee. Both the physical and communication structures of the aggregator are developed to support the implementation of the aggregation system in the building. The business model, including the invoicing system and incentive mechanisms introduced by the aggregator, are also analyzed. The guarantee of the reduced price and the reward of the participation promised by the aggregator can effectively attract users to participate in the proposed service.

In order to validate the efficiency of the aggregator, three prices that can be offered to end customers and are compared in the case studies: the fixed price, the price according to the time of use and the real-time price. The results show that the proposed aggregation system can achieve considerable profits while providing low-priced electricity for residents. According to the general depreciation periods, the aggregator can reduce the depreciation period up to 5.72 years, which is 64.3% shorter than the general depreciation period.

End customers with behind-the-meter power generation and storage solutions can adapt their electricity consumption to price signals. This method helps them reduce the value of electricity invoices and avoid unplanned network interruptions if their positioning is in a problematic area.

In the last chapter it was attempted to demonstrate that the establishment of an AG providing load transfer for the integration of electricity from renewable sources is technically feasible and advisable but would not be sustainable from an economic perspective. The financial result of such a service would not cover investment costs due to variations in the electricity market and the involvement of end customers in this new solution model is difficult to predict.

The low benefits for AG are partly due to the specific conditions of Romania. Given that there are distribution networks that cannot support the transition from conventional heating using natural gas to electricity-based heating systems, the proposed solution is not feasible.

In the last part of Chapter five, the scenario in which an industrial user would have a PV power plant installed for producing behind-the-meter electricity was analyzed. An online simulator was used for dimensioning of the system that can be mounted, and for comparability were used the quantities consumed and the closing prices of the market in 2023.

In the last part of the paper was analyzed the creation of an AE for the comparability between mounting the PV system behind-the-meter, versus the grid connection of the production unit and its inclusion in the contour of an AE. It should be noted that the values presented under Chapter five may be subject to change if, within the AE contour, other entities are included whose consumption/production profile differs from those used.

Any of the scenarios analyzed would be implemented, it is clear that they would aid in the decongestion of the electricity grid and reduce consumption in peak consumption intervals, which would lead to savings for the end customers involved.

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[7] Ord 67/25.05.2023
[8] Ord 27/23.03.2022
[9] Ord 25/29.03.2023
[10] Ord 141/21.12.2021
[11] Ord 9/24.02.2023
[12] Regim accize Ministerul Finanțelor https://mfinante.gov.ro/domenii/fiscalitate/ impozite-si-taxe/regim-accize
[13] 142/21.12.2022
[14] Ord 75/28.06.2023
[15] Ord 97/25.10.2023
[16] Ghidul privind taxa pe valoarea adăugată (TVA) - https://www.mfinante.gov.ro/static/10/Mfp/legislatie/GhidTVA_I.pdf
[17] https://pvwatts.nrel.gov/pvwatts.php
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[20] Hotărârea nr. 2139 din 30 noiembrie 2004 actualizată
[21] Clauzele și condițiile pentru Părțile Responsabile cu Echilibrarea, CNTEE Transelectrica
[22] Ordinul ANRE nr. 118/2023