INTEGRATION OF STORAGE INSTALLATIONS AT ACTIVE CONSUMER IN THE PRESENCE OF PHOTOVOLTAIC INSTALLATIONS

Niculae OPREA[1], Radu PORUMB[2]

The EU has offered new roles and responsibilities to the active consumer in order to control the generation and use of electrical energy, seeing it as an opportunity towards sustainable development for future generations. We investigated the operational characteristics of photovoltaic panels and storage installations for two users during the analyzed intervals and developed reasonable hypotheses considering the type of grid connection. The results provide interesting perspectives for decision-makers regarding the option to become active consumers. They once again demonstrate the feasibility of storage installations and the importance of optimizing consumption through various technologies.

Keywords: active consumers, storage installations, renewable sources, energy transition

1. Introduction

Fossil fuels have been the backbone of the industrial age, where nearly all of the world's electricity consumption was based on gas and coal. At some point, EU state representatives realized that this dependency could not continue, even though the industrial age brought significant progress to human society, it also harmed the environment. Human actions have a daily impact on the planet, which is why it is essential to identify various methods of producing electricity based on green energy sources.

The rapid progress of renewable energy sources (RES), such as wind and photovoltaic power plants, has generated increasing pressure for the development of energy storage infrastructures. With technological advancement, a considerable increase in storage capacities is expected to efficiently manage the fluctuations in energy production from renewable sources, including solar and wind.

There is a diverse range of storage technologies that will play a decisive role in the energy system transition by compensating for the variability of renewable energy sources. Currently, these storage installations have high costs, leading to

[1] PhD student, Faculty of Power Engineering, National University of Science and Technology POLITEHNICA Bucharest, Romania, e-mail: niculae.oprea@stud.energ.upb.ro

[2] Prof., Dept. of Power Engineering, National University of Science and Technology POLITEHNICA Bucharest, Romania, e-mail: radu.porumb@upb.ro

reluctance in their use. However, as their widespread adoption increases, they will become considerably more affordable.

The diversity of renewable electricity sources remains the best choice, along with storage installations, including at active consumer levels, which could be key to the stability of the energy system. Consumers are receptive to using renewable sources, especially photovoltaic panels, as well as modern energy storage technologies, due to the flexibility they offer and the cost benefits they bring to electricity consumption.

Photovoltaic panels and wind power plants are electric power generation equipment. Photovoltaic panels are made from different materials and come in various sizes and powers. The most common power ratings for photovoltaic panels at active consumers range between 30-80 W, and by connecting them in parallel, the power increases.

Residential consumer storage installations are found in the form of batteries that can store electricity during periods of low consumption when energy produced is in excess, and supply energy during peak demand when it is more expensive, thus also "smoothing out" the load curve peaks. The use of batteries, according to [1], represents the most suitable form of storage for consumers, but the biggest issue identified is the efficiency of repeated charge-discharge cycles, which varies between 40%-80%. The price for a stored kWh fluctuates between 60 and 3000 Euros, and the battery lifespan ranges from 90 to 120 charge-discharge cycles.

According to [2], other values are noted, namely battery efficiency fluctuates between 60-90%, the price per stored kWh varies between 45-1000 Euros, and the lifespan varies between 180 and 115 charge-discharge cycles.

This paper aims to analyze the optimization of electricity consumption for users with the help of storage installations, as well as the feasibility of investments in photovoltaic panels and storage installations at the level of active and residential consumers. Economic development of society necessitates the acquisition of different forms of energy at an affordable price for the final consumer, considering the environmental impact throughout the entire cycle, including the production, transport, and distribution of electricity.

The transition of the energy sector to clean energy should start with the active consumer; therefore, the EU, through the Clean Energy Package, places the active consumer at the center of the energy transition. Only big active consumers will play an active role in the electricity market.

The active consumer, is part of the energy transition that Europe hopes will lead to a cleaner environment and sustainable development.

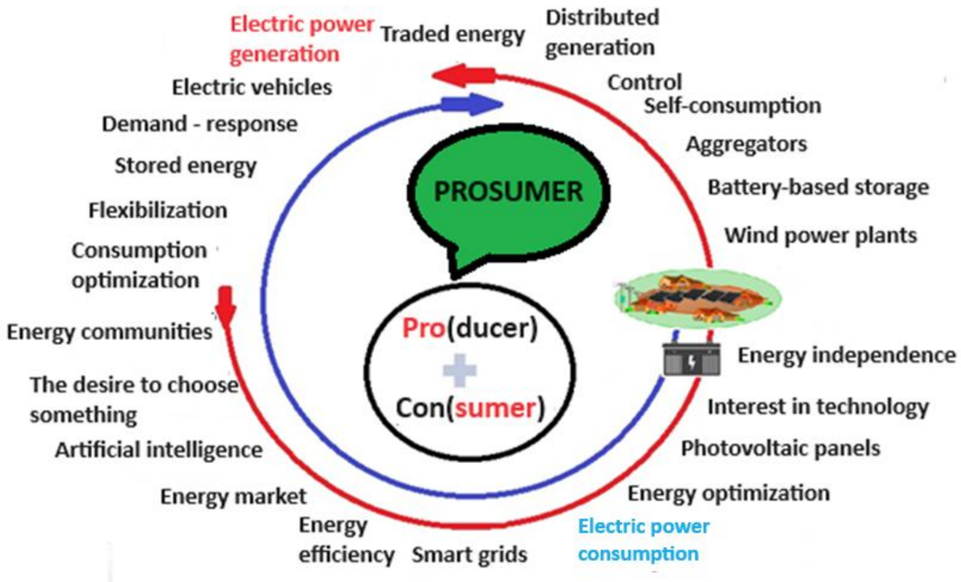

Fig 1 The active consumer at the center of the energy transition

The red and blue circular arrows in the diagram represent the flow of energy and the relationship between the active consumer and the energy grid. The red arrow labeled "Electric power generation" and "Electric power consumption" indicates the flow of energy being generated and consumed. It represents how active consumers (who both produce and consume electricity) interact with the grid by generating power (through sources like photovoltaic panels or wind power) and consuming electricity. The blue arrow is associated with the broader context of energy management and optimization. It suggests activities related to managing, storing, and optimizing energy usage, such as demand response, stored energy, consumption optimization, and interactions with smart grids.

The term "active consumer" was first used by Alvin Toffler in 1981, an American author recognized as one of the prominent and respected Figs. in the business world and intellectual circles. He described active consumers as individuals who produce some of the goods and services they use [3].

According to [4], the active consumer is identified as the end customer who generates electricity from renewable sources for their own consumption, provided that their main activity is not the generation of electricity. Directive [5] offers users who produce their own electricity the possibility to consume, store, or sell the energy they generate.

Active consumers will play an essential role in achieving the targets set by the European Union, which aim for a 30.7% level by 2030. Through various funding programs, Romania has increased the number of active consumers, Table 1, reaching 120,000 active consumers with an installed capacity of 1500 MW in 2024.

Table 1

The evolution of active consumers

An	Consumatori activi	Capacitate instalată (MW)
2018	0	0
2019	289	2,5
2020	1634	16,2
2021	13596	230
2022	40171	423
Iul 2023	87733	1063
Iul 2024	120000	1500

Even though few active consumers participate in the energy market, it has become much more dynamic with the emergence of these actors. At the national level, various funding programs are being implemented, such as the Green House Photovoltaic Program and Electric Up, aiming to guarantee consumption requirements and the distribution of excess electricity into the public grid.

These funding programs include various promotion systems for active consumers regarding the electricity produced and delivered, such as quantitative compensation and financial settlement. The compensation-settlement mechanisms are provided in [4]. If active consumers do not choose these mechanisms provided by law, they have the option to sell the generated and supplied energy into the grid through directly negotiated bilateral transactions.

Given the large number of active consumers, solutions are needed for the formation of local energy markets, energy communities, aggregators, and virtual power plants. These solutions, found in Poland's experience [6,7], will be made available to distribution operators.

Based on Poland's experience, Romania must ensure a growth framework for energy communities, encouraging the development of energy clusters with new regulations and energy models to avoid network congestion or the inability to connect new users to the distribution grid [6,7].

2. Purpose

The purpose of this paper is to analyze the production/consumption of electricity in two typical examples of photovoltaic installations with the following users: an active consumer with an on-grid connection and a consumer off the grid equipped with a battery-based storage system:

- An active consumer from the Bucharest area (active consumer, on-grid connection).
- A residential consumer from the Călărași area (consumer, off-grid connection). The residential consumer has, in addition to the photovoltaic installation, a battery-based storage system.

We investigated the operational characteristics of the photovoltaic panels and the storage installations for the two users during the analyzed intervals and made reasonable assumptions considering the type of grid connection.

3. Input Data Analysis

The paper is based on existing data obtained from personal households, inverter data, prices from various producers and suppliers, technical knowledge accumulated over time, and experience in the national electric energy sector, a sector in constant motion and development.

The consumer bears all the costs of the energy chain from generation, transportation, distribution, and supply, whereas the active consumer has the possibility to produce and consume electricity generated by photovoltaic panels and storage installations in their own household, achieving reduced energy bill, a better quality of life, and a cleaner environment.

The most important advantage of the active consumer is that they obtain a level of energy independence in their electricity consumption, as well as the possibility to sell the surplus energy produced to the electricity supplier.

The active consumer, located in the Bucharest area, with an on-grid connection

The daily load curve for the active consumer represents the variation in electricity consumption. In Fig. 2, we have illustrated the daily electricity consumption of the active consumer over a 24-hour period during autumn.

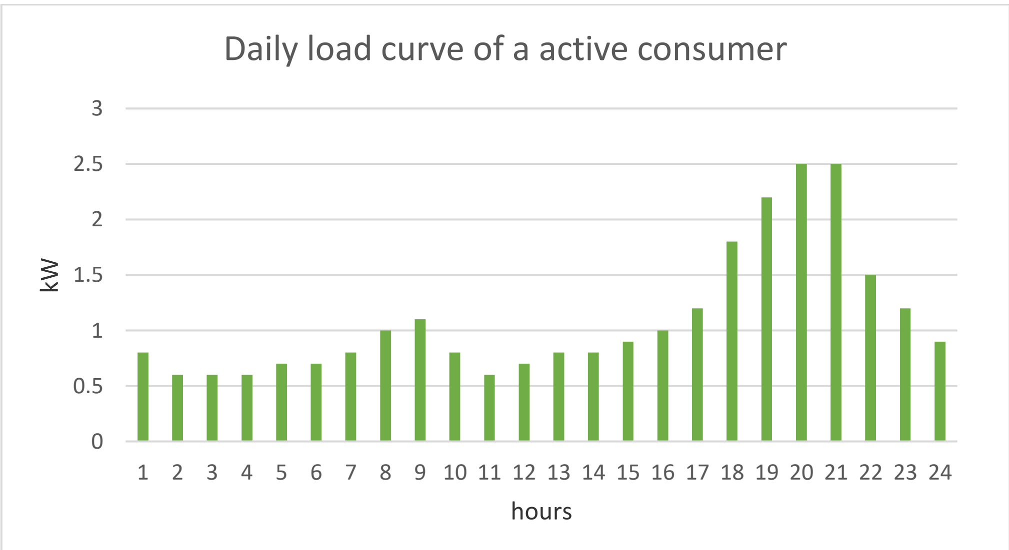

Fig. 2 Daily load curve of an active consumer on an autumn day

This variation in consumption can differ from day to day and is influenced by several factors: weekdays vs. weekends, summer vs. winter, urban vs. rural consumer. The main electrical appliances in the active consumer's household, table 2, based on their importance, critical vs. non-critical consumers, as well as their estimated consumption, are:

Table 2

Electrical appliances for the active consumer

Essential consumers	Estimated daily consumption Wh	Non-essential consumers	Estimated daily consumption Wh
LED bulbs - lighting	150	Washing machine	2600
TV	650	Vacuum cleaner	1500
Microwave oven - electric oven	300	Dishwasher	1500
Refrigerator	860	Lawn mower	2000
Coffee maker	100	Hair dryer	600
Range hood	150	Air conditioner	850
Home alarm system	240	Boiler	1000
Cameras + NVR + router	690	Garden watering system	500
Electric stove	1200	Tablets	300
Heating system	4000	Laptop	800
		External batteries	50
		Phones	100

On the electricity generation side for the active consumer, the load curve follows solar irradiance, depending on the day, hour, and season. During the summer, solar energy production is very high, while in the winter, production is very low, almost nonexistent on some days. Electricity production starts to increase in the spring, peaks during the summer months, and decreases again in the fall. The orientation of the panels towards the light also plays an important role.

The electricity production of the active consumer can be observed in Fig. 3, where we have added the corresponding consumption mentioned above over a 24-hour period.

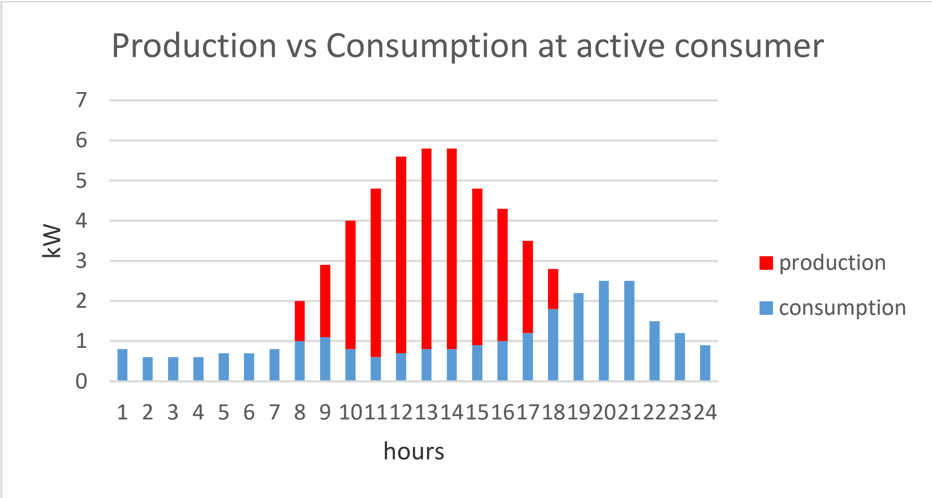

Fig. 3 Production and consumption of the active consumer

It can be observed that the peak energy consumption is in the evening, which does not coincide with the peak production, hence the need for storage installations.

In the summer months, the active consumer covers their own household electricity consumption and also has a surplus of energy that can be sold to the energy supplier.

Residential consumer, located in the Călărași area, off-grid connection, and battery-based storage system

The energy surplus for a user is unutilized; therefore, for both active consumers and residential consumers, battery storage installations help optimize the production and consumption of electricity within the household, in Fig. 4.

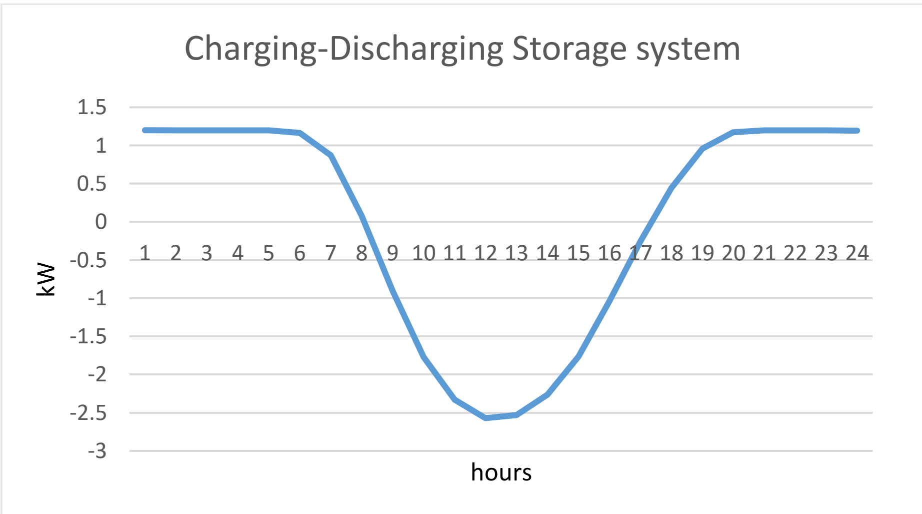

Fig. 4 Storage requirements for the residential consumer

Considering the production/consumption of electricity by the residential consumer, i have overlaid the generation and consumption with the storage requirements in Fig. 5.

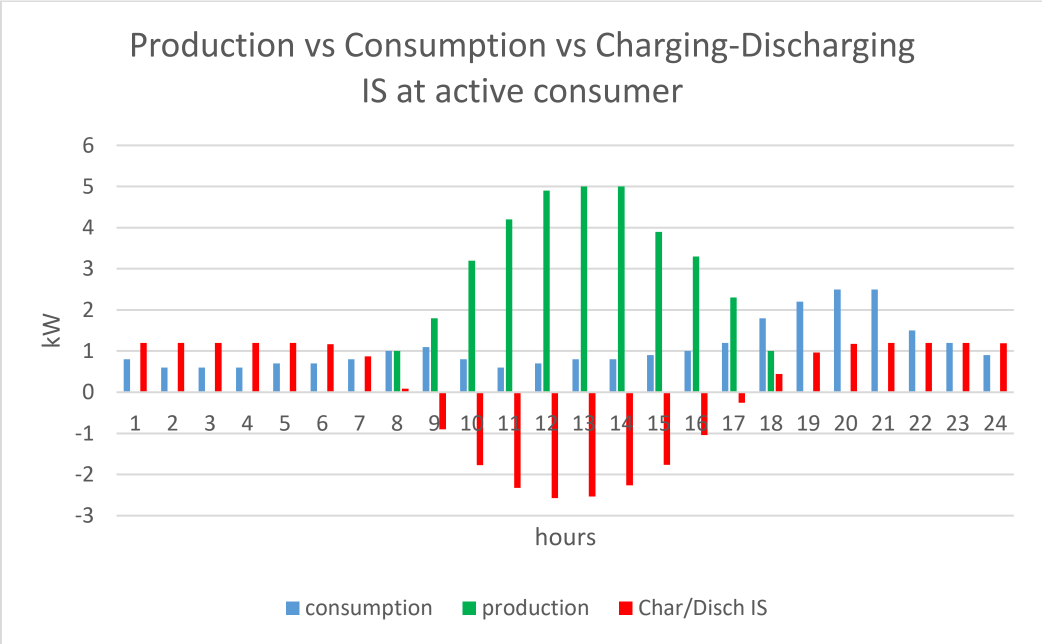

Fig. 5 Evolution of production, consumption, and energy storage for the residential consumer

From Fig. 5, it can be observed that the residential consumer can smooth out the evening and morning consumption peaks with the help of the storage installation and optimize energy consumption using intelligent systems.

The optimization of production/consumption should start from the summer/winter variation, including different times of the day, in terms of how the photovoltaic panels are installed and power management.

It has been observed that active consumers purchase electricity from suppliers at a negotiated price and sell surplus energy to the same supplier at a fixed price set by OPCOM. This scenario is disadvantageous for active consumers because the price per kW sold to the grid is significantly lower than the price consumed from the grid. For example, in the 2023 Enel Simplu Anual Rez offer, for 100 kWh consumed from the grid, the active consumer pays 68 lei, while for 100 kWh supplied to the grid, they receive only 24 lei from the same supplier.

Currently, there are discussions about the losses and imbalances caused by active consumers, highlighting the need for technical solutions to address these issues. One solution could be for the distribution operator to have storage installations or for each active consumer to have a certain percentage of battery-based storage installations upon connection.

Stored electricity production can be used in the evening to power consumer devices, even overnight, for non-critical household loads. Storage installations are essential for users, especially active consumers, as they provide the ability to store renewable energy without wasting it and use it when needed, even during frequent power outages.

Battery storage systems are highly effective for rural areas experiencing frequent power outages in all seasons. It is evident that a residential consumer with a photovoltaic installation can manage consumption by optimizing the production of generated electricity. Active or residential consumers have various methods available to optimize their consumption, such as smart systems like Wi-Fi-enabled smart plugs and various smartphone applications. With the help of these smart devices and communication technologies, consumers or active consumers can flatten their evening consumption peak. This means that some devices can follow the generation load curve and be shifted away from the evening peak consumption period.

By shifting these devices from the evening peak, active consumers have the opportunity to utilize the entire amount of renewable energy produced, resulting in a significantly lower energy bill, as the amount of energy purchased from the supplier will be much reduced. It is clear that there is a correlation between the energy purchased from the supplier for consumption and the load curve of the active consumer.

4. Results

In this paper, we investigated the operational characteristics of photovoltaic panels and battery storage systems for an active consumer and a residential consumer who also owns a battery storage system.

We should mention that the data analyzed in this paper, especially regarding the production and consumption of electricity, comes from my own household. I chose to become an active consumer because I was interested in reducing electricity bill, decreasing greenhouse gas emissions, and particularly, capitalizing on the surplus energy injected into the grid. I have had a positive attitude towards green technologies, especially storage systems, as I am aware of the long-term benefits for active consumers.

From the analysis conducted by [8] and Fig. 6, it is evident that Romania's solar potential, particularly in the southeast of the country, is very high, with the country benefiting from 210 sunny days per year. Solar energy can be collected and converted into electricity, giving consumers the opportunity to become active consumers and utilize the entire amount of renewable energy produced by a photovoltaic system, which in turn contributes to the generation of electricity with reduced greenhouse gas emissions.

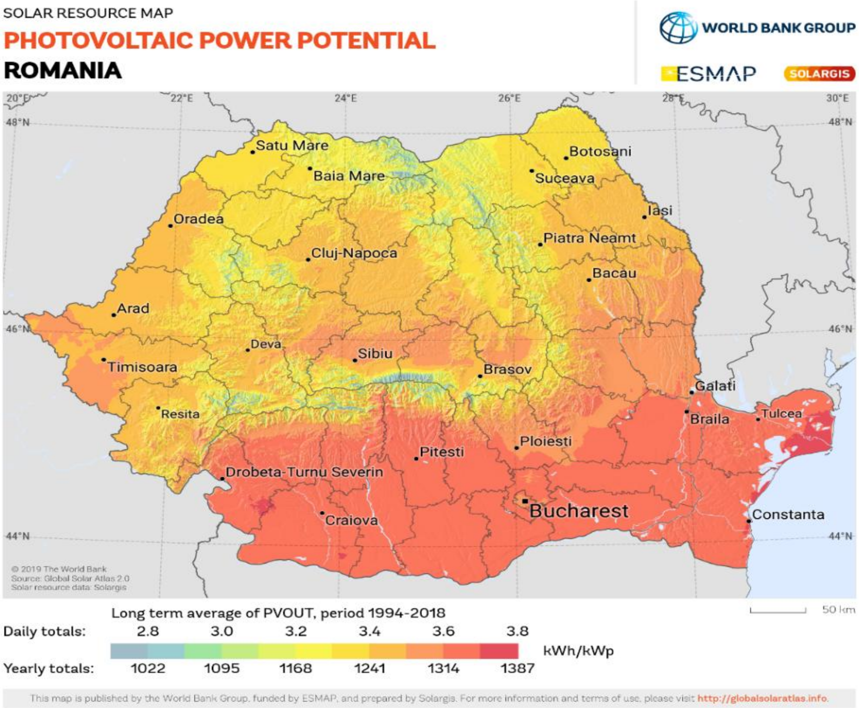

Fig. 6 Photoelectric potential in Romania source [8]

The active consumer is located in the București area, while the residential consumer who owns a photovoltaic installation is located in Călărași county. Both users have the same equipment but are situated in different areas.

Additional information was requested from distribution operators in the analyzed areas for both users. We analyzed their consumption profiles and identified the main household appliances. From the distribution operators, we also requested network parameters such as voltage levels, number of active consumers in the area, number of interruptions, and the network's capacity to handle surplus electricity produced. Based on the technical data received from the distribution operators, we determined that the residential consumer located in the Călărași area should also have a battery storage installation alongside the photovoltaic system, due to the high number of interruptions.

We chose a battery-based storage system for the residential consumer because the location frequently experiences power interruptions and to smooth out the evening consumption peaks.

Table 3

The energy balance in August 2023 for the residential consumer

POWER_LOA	POWER_GE	POWER_BA	SD_CAPACI	LOAD_PE	VPV	IPV	TIMESTAMP_	E_GEN	E_LOAD	E_GRID	E_BAT_CHA	E_BAT_DIS
(W)	(W)	(W)	%	(%)	(V)	(A)	date-hours	kWh	kWh	kWh	kWh	kWh
108	0	109	87	2	0	0	01.08.2023 00:03	7264,5	6311,3	567,4	7273,5	1618,9
226	0	213	79	5	79,1	0	02.08.2023 05:23	7268,7	6314,2	567,4	7277,7	1620,4
103	734	-622	74	2	307,2	14,5	03.08.2023 08:28	7273,2	6317,2	567,4	7282,2	1621,6
160	1459	-1306	86	3	254,6	28,6	04.08.2023 09:18	7278,3	6319,8	567,4	7287,3	1622,6
65	71	-20	99	1	333,1	1,4	05.08.2023 10:08	7283,8	6322,7	567,4	7292,8	1623,6
884	2083	-1081	90	19	228,8	40,8	06.08.2023 10:18	7290	6327,5	567,4	7299	1624,7
1123	1160	-15	99	23	331,9	22,6	07.08.2023 10:33	7302,4	6337,8	567,4	7311,4	1628,2
154	306	-138	60	3	270,8	6,1	08.08.2023 10:38	7312,8	6349,6	567,4	7321,8	1630,7
1010	1076	14	97	22	318,8	21,5	09.08.2023 11:48	7329,4	6361,1	567,4	7338,4	1632,9
994	1050	-25	98	22	326,8	20,5	10.08.2023 10:38	7342,7	6372,5	567,4	7351,7	1635,5
985	992	5	98	21	321,9	19,7	11.08.2023 11:03	7359,3	6387,3	567,4	7368,3	1638,2
234	254	0	97	5	320,8	5	12.08.2023 13:03	7378,8	6404,8	567,4	7387,8	1641,2
1883	1165	787	94	38	254,4	23,5	13.08.2023 13:44	7396,8	6421,1	567,4	7405,8	1643,8
2029	2029	0	98	41	304	40,6	14.08.2023 12:42	7411	6433,3	567,4	7420	1645,9
264	265	0	98	5	330,1	5,3	15.08.2023 13:01	7427,6	6448	567,4	7436,6	1648,3
1956	758	1289	90	39	283,9	15,3	16.08.2023 14:03	7443	6462,1	567,4	7452	1651,7
153	151	-24	96	3	327,1	3	17.08.2023 14:28	7455	6471,7	567,4	7464	1655,4
72	69	-24	97	1	326	1,3	18.08.2023 15:03	7459,2	6474,3	567,4	7468,2	1656,4
74	79	-24	96	1	321,2	1,5	19.08.2023 15:19	7463,5	6477	567,4	7472,5	1657,5
75	83	-24	96	2	318	1,6	20.08.2023 16:24	7468,4	6480,4	567,4	7477,4	1658,6
70	77	-29	96	1	319,2	1,5	21.08.2023 16:04	7472,6	6483	567,4	7481,6	1659,7
161	182	-29	96	3	313,4	3,6	22.08.2023 16:09	7476,9	6485,8	567,4	7485,9	1661
157	149	0	96	3	295	2,9	23.08.2023 16:04	7484	6491,4	567,4	7493	1662,1
64	71	0	95	1	310,9	1,4	24.08.2023 17:04	7493,3	6499,1	567,4	7502,3	1663,3
1148	403	783	95	23	259,5	8,1	25.08.2023 18:04	7506,8	6510,8	567,4	7515,8	1664,9
1229	757	504	99	25	249,2	14,6	26.08.2023 18:04	7526,1	6527,8	567,4	7535,1	1669,2
1951	1658	337	96	40	267,5	33,3	27.08.2023 18:04	7544,8	6544,7	567,4	7553,8	1672
122	162	0	95	2	304,9	3,2	28.08.2023 18:34	7561,4	6559,3	567,4	7570,4	1674,8
133	337	-200	88	3	268,3	6,4	29.08.2023 18:30	7576,4	6572,4	567,4	7585,4	1677,9
167	168	34	92	3	269,6	3,3	30.08.2023 19:20	7589,4	6583,9	567,4	7598,4	1680,1
196	179	29	92	4	233,9	3,5	30.08.2023 19:25	7589,5	6583,9	567,4	7598,5	1680,1
119	1	124 %		2	108,8	0	31.08.2023 20:25	7602,3	6594,8	567,4	7611,3	1683,6

Table 4

The energy balance in August 2023 for the active consumer

Period	Total consumption	Own consumption	Grid supply	PV production	Surplus to grid
	[kWh]	[kWh]	[kWh]	[kWh]	[kWh]
01.08.2023	4,83	3,23	1,60	27,10	23,87
02.08.2023	4,29	3,11	1,18	21,13	18,02
03.08.2023	4,78	3,62	1,16	20,53	16,91

04.08.2023	5,86	3,16	2,70	23,78	20,62
05.08.2023	8,35	4,45	3,90	23,14	18,69
06.08.2023	8,83	4,90	3,93	25,92	21,02
07.08.2023	9,66	6,12	3,54	24,23	18,11
08.08.2023	9,24	5,90	3,34	26,32	20,42
09.08.2023	8,36	5,30	3,06	24,65	19,35
10.08.2023	7,62	4,73	2,89	28,23	23,50
11.08.2023	7,53	4,53	3,00	22,53	18,00
12.08.2023	7,30	4,53	2,77	26,32	21,79
13.08.2023	7,80	4,89	2,91	27,15	22,26
14.08.2023	9,80	5,90	3,90	25,54	19,64
15.08.2023	8,69	5,91	2,78	26,29	20,38
16.08.2023	8,81	5,80	3,01	25,65	19,85
17.08.2023	9,70	6,69	3,01	26,35	19,66
18.08.2023	8,81	5,79	3,02	26,48	20,69
19.08.2023	8,09	5,09	3,00	16,28	11,19
20.08.2023	7,60	5,01	2,59	21,36	16,35
21.08.2023	8,53	5,46	3,07	19,76	14,30
22.08.2023	7,65	4,40	3,25	18,83	14,43
23.08.2023	9,82	6,83	2,99	22,25	15,42
24.08.2023	7,87	4,79	3,08	19,32	14,53
25.08.2023	8,62	6,10	2,52	24,29	18,19
26.08.2023	11,40	7,60	3,80	24,35	16,75
27.08.2023	10,60	7,74	2,86	23,76	16,02
28.08.2023	11,72	8,93	2,79	23,39	14,46
29.08.2023	13,07	9,17	3,90	23,29	14,12
30.08.2023	12,70	7,74	4,96	21,63	13,89
31.08.2023	13,78	9,35	4,43	22,35	13,00
TOTAL	271,71	176,77	94,94	732,20	555,43

The active consumer, due to the connection to the grid, benefited from the support scheme through the government program Casa Verde. The investment cost for the active consumer was 26,000 lei, of which they paid 6,000 lei. The residential consumer bore the entire investment cost, plus the cost of the battery storage system, which amounted to 15,000 lei for the three batteries mounted on a special rack. According to the analyzed data, the photovoltaic panels generated 733 kWh in August 2023, while the total consumption of the active consumer was 271.71 kWh. From the readings obtained from the inverter, it was found that 176.77 kWh were consumed from their own production, and 94.94 kWh were consumed from the public grid.

The surplus energy generated by the active consumer was sold to the supplier with whom they have a supply contract, at a price of 0.24 lei/kWh. For the energy consumed from the grid, the consumer paid the supplier a price of 0.68 lei/kWh, which includes taxes, energy excise duties, green certificates, and VAT. This represents a disadvantage for the active consumer. Based on this disadvantage in favor of the active consumer, we have prepared the energy balance for August 2023, where we can observe the difference between a user as a active consumer and a classic consumer, as shown in Figs. 7 and 8.

The energy balance for consumer	**kWh**	**Price kWh**	**Total Lei**
Total consumption	271,71	0,68	184,76
Self-consumption from the PV	176,77	0	0
Grid consumption	94,94	0,68	64,55

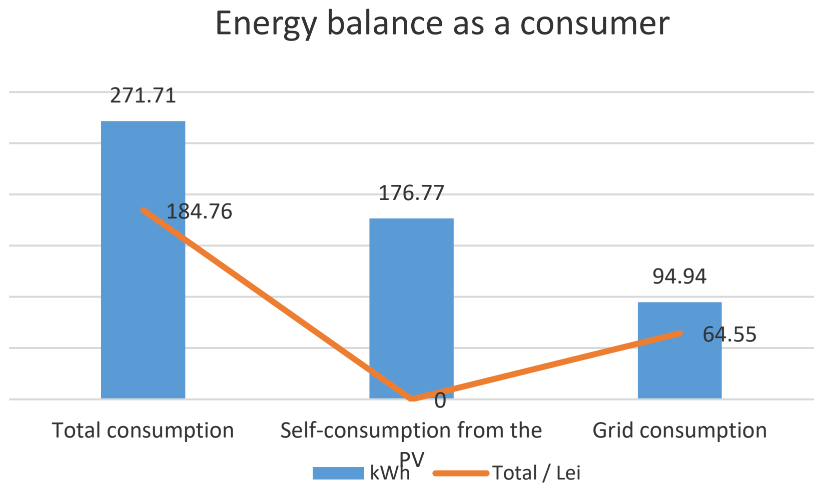

Fig. 7 Energy balance viewed as a conventional consumer

Energy balance as active consumer	**kWh**	**Price kWh**	**Total Lei**	**Diffe rence**
Production from the PV	732,20	0,24	175,72	
Self-consumption from the PV	176,77	0	0	
Electricity consumption from the grid	94,94	0,68	64,55	
Surplus energy delivered to the grid	555,43	0,24	133,30	-68,75

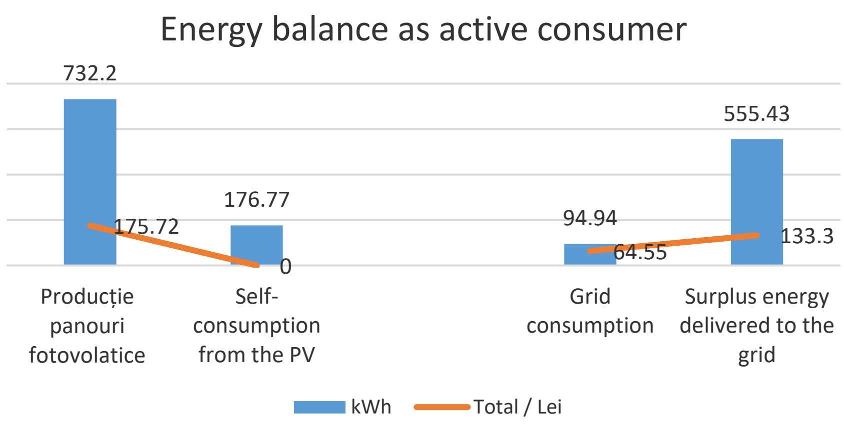

Fig. 8 Energy balance viewed as an active consumer

From the data analyzed above, Fig. 7 and 8, and table 3, 4 it is observed that the user as an active consumer, compared to a classic consumer who is entirely dependent on the grid, still requires some energy from the grid, but in a significantly reduced proportion. This variable dependence on the grid can be minimized by using battery storage systems for active consumers.

The analysis shows that the active consumer sells surplus energy to the public grid while simultaneously reducing their electricity costs.

According to the ANRE 2012 report, 1 kWh of conventional energy, especially from coal, generates 0.346 kg of carbon. Therefore, by becoming a active consumer, I have helped the environment by approximately 253.34 kg of carbon during the analysis period, namely August 2023.

5. Feasibility of user-installed storage system

The residential consumer did not benefit from the support scheme offered by the government program, as they are not considered an active consumer, thus bearing the full investment cost of 22,600 lei. This consumer also owns a battery storage system, costing 13,500 lei for the three batteries installed in a special rack.

The purchase of the battery storage system was necessary due to frequent power interruptions in the location. For the analysis of data obtained from the inverter, I considered a longer period starting from 2021 when I became an active consumer until now. The period analyzed in both cases of grid connection, active consumer vs residential consumer with a battery storage system, provided several perspectives in my approach, which is why data from August-September were particularly interesting for a more detailed analysis.

Each appliance within the household was individually analyzed to determine its corresponding consumption, taking into account:

-The type and nature of the energy source
-The electrical capacity of the device
-The quantity of identical devices
-The average daily operating time under standard conditions

Therefore, according to table 4, the maximum load capacity that the electrical system can handle has been established. The installed power is determined by summing up all the nominal powers of the connected devices:

$$Pi = \sum Pn = 13.355\ kWh$$

To this sum, the estimated household heating requirement of 5000-6000 Wh/day is added. Taking into account the simultaneity factor ks and the maximum utilization factor ku, the power estimation was:

$$Pc = Pi \times ks \times ku = 13\ kWh$$

where

$$ks = 0.9$$

$$ku = 0.78$$

Due to the fact that the total cost of the investment was borne by the residential consumer, it was necessary to size the production installation as close as possible to the electricity consumption to avoid unnecessary expenses. As indicated above, the estimated daily consumption was 13 kWh, and the average monthly electricity consumption for the consumer was 400.65 kWh.

Table 5

Breakdown of investments related to the off-grid consumer

Components	Pi (W)	Number of units (Nr)	Pi total (W)	Operating hours (h)	Production (Wh)	Price/unit (RON)	Total price (RON)
Photovoltaic panels	5.5	11	60.5	3.5	211.75	600	6600
Inverter	5000	1	5000			5000	5000
Batteries	2x2400 1x3500	3	8300			4500	13500
Installation, permits, etc.							11000
						Total	36100

In recent years, the price of energy in the Romanian market has increased and it is estimated to continue rising due to the gradual phase-out of coal and the increase in CO_2 certificate prices. Currently, there is a real incentive for distributed generation sources and user storage installations due to government programs.

Therefore, we analyzed the hypothesis assuming a stable electricity price until 2025 and a 10% increase thereafter until 2035, table 6. The hypothesis also took into account the annual degradation indicated by the photovoltaic panel manufacturer, which is 0.01.

Table 6

The evolution of photovoltaic system production and the price obtained from 2020 to 2035

Period analyzed	Apr-Dec 2020	2021	2022	….	2034	2035
Annual generation (kWh)	4791	6388	6388	….	6388	6388
Annual generation with indicated degradation (kWh)	4743	6324	6324	….	6324	6324
Average obtained price (Lei)	6165,9	8221,2	8221,2	….	9043,32	9043,32

Demonstrating the feasibility of the photovoltaic system with battery storage involved evaluating aspects related to technical, economic, and environmental factors.

Annually, the solar panels produce 6000 kWh, and at an average price of 1.3 lei/kWh, this results in an annual energy bill savings of 7800 lei.

The initial investment of 36,100 lei, table 5, will be recovered in approximately 5 years, which is an acceptable timeframe considering that photovoltaic panels have a lifespan of 15 to 20 years.

6. Conclusions

The purpose of this study is to analyze the production/consumption of electricity and the storage needs in two typical examples of photovoltaic installations: one with an active consumer connected to the grid and another with a consumer off-grid equipped with a battery storage system.

The study analyzed the management of electricity production, consumption, and storage for these two consumers with photovoltaic installations but with different grid connections: on-grid and off-grid. The analysis focused on the month of August to compare the two types of grid connections.

For the active consumer with grid connection, it was found that the selling price of surplus energy is considerably lower compared to the cost of purchased energy from the grid. This represents a disadvantage for the active consumer.

It would be beneficial for active consumers, through government programs promoting renewable energy, to have a battery storage system to manage energy production that can be used in the afternoon and throughout the evening and night.

The results offer interesting perspectives for decision-makers considering becoming active consumers.

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