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Article

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THE STRATEGIC REPOSITIONING OF THE EUROPEAN UNION CONSUMERS IN THE CONTEXT OF THE ENERGY PARADIGM CHANGE. FROM THE TRADITIONAL SUPPLIER-USER RELATIONSHIP TO THE EMERGENCE OF THE PROSUMERS

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Abstract

The entire contemporary societal landscape, including the business environment, faces a complex kaleidoscope of challenges, fuelled by a greater than ever level of turbulence manifesting itself on all levels. In the new circumstances, opportunities and threats follow and multiply, interfere, and require a proactive approach and placed in synergistic logic. We are witnessing the emergence of times in which the most frequently used term is resilience. At the level of the European Union, resilience can be attached to all strategic or tactical vectors, the most interesting areas of manifestation of the need for resilience being those related to digitisation and the energy sector. Starting from the hypothesis that most of the geopolitical and geoeconomic conditions are changing at a very high speed, the authors of this article proposed to emphasise aspects related to the rediscovery of the advantages of energy autonomy. Aggregating the production curves for dispatchable photovoltaic energy in 2021, at the national level, the authors also highlighted a production model for prosumers. In this context, using the Cobb-Douglas production function, an attempt was made to diagnose the conditions in which the consumer can have a versatile role and become, in turn, an energy producer, contributing to the climate agenda.

Keywords: Prosumers, renewable energy, photovoltaic energy, prosumption, energy suppliers.

JEL Classification: D11, D24, 030

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Introduction

The linear growth model (based on consumption of resources that generate waste as a result of productive processes and built on the consideration of inexhaustible and widely available natural resources), still dominant on a global scale, is increasingly criticised (Denona Bogovic and Grdic, 2020). The externalisations of this model have led to an ecological and climate crisis, the depletion of conventional non-renewable resources and puts under danger the biodiversity.

Both at the level of European and national public strategies and policies, as well as at the level of the business plans of companies, respectively, the directions of action of the organisational structures of civil society, the referential strategic package is the European Ecological Pact, whose main thematic areas are: nature and biodiversity, economy circularity and quality of life, climate change mitigation and adaptation, clean energy.

Taking into account these basic elements of a redefined European societal picture is vital both when substantiating the development model centred on cohesion and when establishing the contour lines of a new development model at the level of the European Union, the one focused on more competitiveness. Energy resilience is increasingly organically connected with the digital one, this binomial of the future being subsumed under all the programmes and projects initiated at European and national level (especially the Recovery Assistance for Cohesion and European Territories (REACT EU) and the Recovery and Resilience Mechanism (MRR).

Within the economic recovery package of the European Union (Next Generation EU), the basic pillars are: Supporting the Member States in order to recover; Economic recovery and aid measures for private investment; Assimilation of lessons learnt from the crisis generated by the pandemic. For all these directions of action, the elements of the regulatory and institutional framework were outlined, important financial and relational resources were made available, and the process of configuring the partnership structures aimed at ensuring the achievement of the desired goals was started. As has been emphasised for a long time in the specialised literature (Kuhn, 1970), any paradigm shift means the simultaneous undertaking of three steps: the modification of the outline elements of the general societal picture, the adequacy of the regulatory and institutional framework, and the substantial transformation of the actors' behaviour participants in the economic and social game. The authors of this article proposed insisting more on transformations of an attitudinal and behavioural nature, with access to the stimulating factors and the generated effects.

The techno-industrial paradigm shift that we have been assisting for several years has caused, for the first time since the end of the preindustrial period, the transformation of the household from a space eminently intended for consumption, to one in which consumption is intertwined with energy production. Thus, the advantages of the virtual economy have become more and more visible, and the digitisation of social interaction has become the model engine of co-existence at a sustainable societal level, in which vulnerability is reduced in relation to the various societal threats, be they of an economic, health, energy, technological nature or otherwise.

In this context, access to uninterrupted flow of energy has turned into an essential priority, especially considering the package of turbulences that the international economy and, therefore, the European one has faced in the last decade. This accumulation of threats, which

can also be associated with numerous opportunities in terms of changing the development model, creates a favourable context for members of society to add to their energy consumption ability that of energy production.

The technology on which the energy produced from renewable resources (solar, wind, etc.) is based, which allows the production of energy at the point of consumption, has opened the chapter of a new paradigm in the energy sector, that of the emergence of prosumers.

1. Literature review

The concepts of prosumer and prosumption are not new. In the scientific literature, they can be found since the beginning of the 1980s, being anticipated by Alvin Toffler in the book *The Third Wave*. Some reflections on the role of prosumers in the economy can also be found in Philip Kotler's work (1986), who believed that the prosumer would generate profound changes in fundamental market mechanisms, determining at least four large categories of benefits for consumers: *large cost savings, minimal skills, little time and effort, high personal satisfaction*.

As the energy sector is conceptually and technologically redefined and this strategic reorientation is driven by the achievement of climate goals, the role of prosumers begins to become increasingly important. Prosumers could enable increasing the rate of energy electrification, democratising the energy sector, and reducing carbon emissions (Saleh, 2018). They can combine small, carbon-free energy production capacities with smart energy distribution and storage technologies such as solar photovoltaic panels, smart meters, electric cars, and storage batteries (Parag and Sovacool, 2016).

Using this combination of equipment and technologies, the prosumers achieve two results. First, they optimise and manage their own energy consumption, making it easier for them to achieve cost reductions and use energy more efficiently (Morstyn et al., 2018). Second, they can produce and feed electricity into the grid, thus achieving the status of a power producer while reducing the load on the national grid (Borowski, 2020).

More and more analysts are considering that the exponential growth of the prosumers in the energy sector, especially in the European Union, is not related to an imminent exhaustion of conventional resources. Several epistemological constructions, but also empirical research highlight the fact that the emergence of this new category of users took place in a period of abundance, in which the energy markets were unbalanced due to an oversupply and a low demand for energy, amid the sanitary measures imposed during the first wave of the pandemic.

The correlations we identified during this research highlighted the fact that the number of prosumers started to increase during 2020 and 2021, at a time when power prices reached historic lows. Therefore, the exponential increase in power prices that emerged in 2021 was not the main motivation for these behavioural changes.

The growing number of prosumers is facilitated by the substantial reduction, by 82%, of the production costs for renewable energy capacities (European Commission, 2021), by technological improvements and thanks to the subsidy mechanisms made available by the Member States to promote green energy in order to achieve the climate objectives. In this context, prosumers become an essential link in the architecture of energy security and in the

efforts of the EU's climate agenda, while taking over a share of the labour costs that were originally borne by producers (Jakimowicz, 2022).

2. The role of prosumers in the context of the transition to the new paradigm of energy sustainability

Starting with Stanley Jevons (1865), one of the main figures of the Marginalist School, and continuing with other theorists, including Donella H. Meadows (1972), William D. Nordhaus, Hendrik Houthakker, Robert Solow (1973) or M.A. Adelman (1986), a concern of economic thought has been, for decades in a row, to draw attention to the danger of exhausting conventional energy resources and the effects on economic activity.

The identification of resources and technologies as varied as possible for the production and distribution of energy catalysed efforts toward the operationalisation of technological improvements and innovations that allowed the diversification of the energy mix. At the same time, the improvement of industrial applications has generated a vital need to access energy without interruptions, to ensure the continuity of productive activities, as well as societal activities in general.

The energy landscape has repositioned itself over time, migrating from demand to supply and from a status defined by scarcity to one defined by abundance. This transformation has been driven by successes, particularly in the US, in unconventional oil shale hydrocarbon production, and as cross-border trade transactions have become more intense, diversified, and complex.

In these redefined conditions of the general economic picture, it has become increasingly obvious that there is a robust correlation, from a statistical point of view and relevant, from an analytical point of view, between environmental degradation and the inefficient and intensive consumption of fossil resources. This fact was also highlighted in the 2015 report of the Intergovernmental Panel on Climate Change, which formed the basis for the consensus of the Paris Agreement. In this context, climate policies have begun to play an increasingly important role in the process of economic activity planning, especially the one administered by decision-making bodies in the European Union.

The assumption of increasingly ambitious objectives, one of their aims being to control climate change, has determined the orientation of innovations toward renewable energy production technologies and has allowed it to acquire a central position in the decarbonisation of the energy mix and consumption. In an era of abundant energy resources, part of the consumption began to decentralise and was included in a new development model, the one based on decentralisation or atomisation in terms of the generation and use of energy resources. These were the prerequisites that facilitated the advancement of prosumers toward the inner circle of the energy landscape, that is, those energy consumers who can ensure their own energy needs using renewable energy production technologies, inside or close to the place of consumption (Leal-Arcas, Lesniewska and Proedrou, 2018).

Prosumers have gradually recognised their increasingly important role within the package of strategies and public policies operationalised within the European Union. They have become core vectors of mechanisms aimed at the emergence of a complex, low-carbon, inclusive, and equitable energy system in which citizens actively interact with the energy market (Horstink,

Wittmayer and Ng, 2021). For this reason, non-household consumers, small or medium-sized economic operators, institutions or public authorities were not included in this category, the central element being individuals who consume and produce value, either for self-consumption or for consumption by others, and may receive direct or indirect incentives from the organisations involved in the exchange (Lang et al., 2021).

On the same line of conceptual reasoning and practical action is the text of the Directive of the European Parliament and of the Council on the promotion of renewable energy RED II (2018), but which does not use the term prosumer, but self-consumer. It can only be part of a renewable energy community if it has a production capacity of less than 10.3 kW and not more than 50 kW and does not involve water pumping systems. In Regulation 944 (European Parliament, 2019), additional elements were added regarding prosumers, stating that all customer groups, industrial, commercial, and households, should have access to electricity markets in order to market its flexibility and self-generated electricity.

In the new energy paradigm, consumers could have the opportunity to change their positioning in the value chain of energy distribution from a relatively passive one to an offensive (proactive) one, thanks to the technological possibilities to produce energy in various forms, electrical, by means of photovoltaic panels, or heat, using solar panels and heat pumps. Also, electricity can be stored in the short term with the help of specially designed batteries or using the batteries of electric cars as storage capacities. The goal is not just to ensure one's own consumption, but to participate in energy markets by selling or sharing energy, either individually or collectively, as part of an energy community (Horstink, Wittmayer and Ng, 2021).

The main novelty brought by the presence of prosumers is that, within the electricity production process, one no longer obstinately pursues the first order productive optimum (economy of scale effects) in large-scale production capacities held by utility companies, but can also opt for a second best operationalised through smaller energy producing facilities. The second innovation is that prosumers, benefiting from their own energy produced under certain seasonal and climatic conditions, can disconnect from low-voltage transmission networks, no longer depending on a distributor for energy supply. If they choose to stay connected to the grid, the third innovation that the prosumer brings is that the flow of energy becomes bidirectional, with prosumers able to redirect amounts of electricity into the grid via low-voltage links.

Another novelty that the presence of prosumers brings to the fore is that the premises are created for new market relations, some of which contribute to the flexibility of energy production. Prosumers can provide a network balancing service for suppliers because they can benefit from the energy surplus produced by the prosumers. The additional power produced by the prosumers may be priced lower than the day - ahead marginal market price when the supplier needs to secure a larger amount of energy for its portfolio of customers that has not been contracted through bilateral contracts or the forward market.

An aspect less studied in the scientific literature and which has been put on the back burner by the authorities is the option to promote a local market where prosumers can trade energy among themselves, within a peer-to-peer-type system.

Also, another integration model of prosumers, this time of those living in apartments, is that since they can generate green energy from a location other than the point of consumption, they might redirect it to the grid and, through bilateral contracts with distributors, they shall

be supplied with green energy from the grid at the place of consumption. This can be done by prosumers as part of an energy community, as stated in Regulation 944 (European Parliament, 2019): *Citizen energy communities are considered to be a category of cooperation of citizens or local actors that should be the object of recognition and protection under Union law.*

3. Encouraging developments in the direction of prosumers position at the European level

In the first two years of the pandemic, the EU has visibly increased its capacity to produce solar energy by about 35%, from ~130 GW to about ~160 GW, installing a solar energy capacity of 19.5 GW in 2020, and a capacity of 26.7 GW in 2021, according to Figure 1. The pace during this period was much higher than that recorded in the pre-pandemic period, and *rooftops have been the place for most of the deployment of solar energy so far* (European Commission, 2022). We are justified in clarifying this by the fact that photovoltaic panels installed on the roofs of buildings have the advantage of making use of a normally unusable space, reducing the pressure on the conversion of agricultural land to be used by photovoltaic energy production facilities.

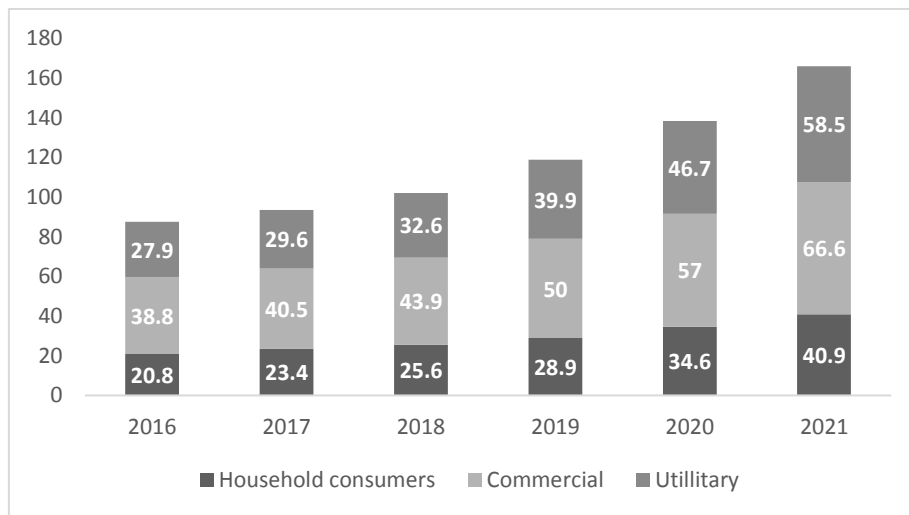


Figure no. 1. Annual solar energy production capacity (GW) installed at the level of the European Union in the period 2016-2021

Source: Data processed by authors using BloombergNEF

The substantial increase in solar power production capacity has come amid the European Union's post-pandemic economic recovery plans, orientated toward sustainability and increasing the degree of resilience of energy security. Thus, green energy represents the solution to reduce carbon emissions from energy consumption. Consequently, in 2021, the European Commission proposed the amendment of the Renewable Energy Directive, advancing more ambitious objectives regarding the share of renewable energy in the energy mix, which implies an increase from 32% to 40%. In 2022, in the context of strengthening

energy security, the European Parliament adopted the RePower EU plan in May. One of the targeted objectives is for EU member states to have a total capacity of 600 GW of solar energy in 2030 (European Parliament, 2022), with the aim of reducing the dependence on natural gas imported from Russian companies.

The estimates made by experts from the European Commission show that, in this ideal scenario, natural gas imports would decrease, annually, by an amount of 9 billion cubic metres compared to the level of 2021. To achieve this objective, the annual growth rate in the newly installed solar energy capacity, in the period 2022-2030, should double compared to that recorded in 2021. Prosumers play an important role in this increase in the share of photovoltaic energy, but, as can be seen in Figure 2, the development of the prosumer sector was asymmetric at the European level.

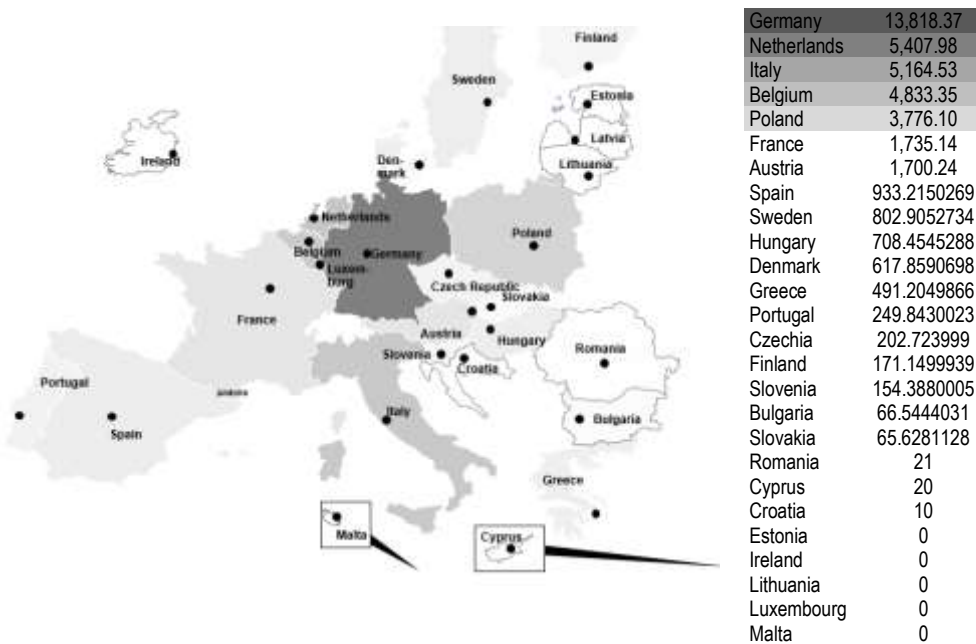


Figure no. 2. Annual solar energy production capacity (GW) installed by prosumers at the level of the European Union in the period 2018-2021

Source: Map processed by authors using BloombergNEF

At the end of 2021, in the European Union, the installed solar energy capacity in the residential sector reached 40 GW. The most developed prosumer sector is that of Germany, which has an installed capacity of 13 GW, i.e., more than a third of the European capacity. Other countries where the prosumer sector experienced significant expansion are the Netherlands – 5.4 GW, Italy – 5.1 GW, Belgium – 4.8 GW, Poland – 3.7 GW, France – 1.73 GW, Austria – 1.7 GW, Spain – 0.9 GW, Sweden – 0.8 GW, Hungary – 0.7 GW, Denmark – 0.6 GW and Greece – 0.5 GW. The asymmetric way in which the appetite for solar energy has developed in the European Union, in a way, runs counter to the natural potential correlated with the energy demand. Eastern European and South-East European countries, such as Cyprus, Romania, Estonia, Greece, and Bulgaria, although they have significant

potential for the development of photovoltaic energy capacities, have not been able to capitalise on it.

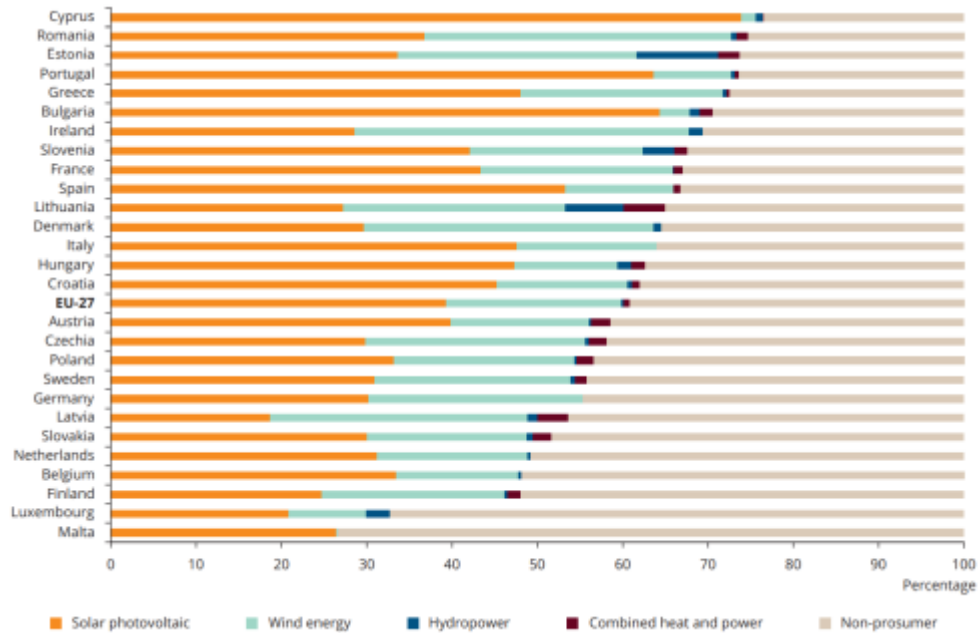


Figure no. 3. The technical production potential of photovoltaic energy in 2050, relative to the total electricity demand in the EU

Source: Europa.eu, 2021. Energy prosumers in Europe. Citizen participation in the energy transition, p.19.

4. The evolution of prosumers in Romania

As far as Romania is concerned, the figures regarding the installed capacity of the solar energy by the prosumers vary. BloombergNEF estimated that, in the year 2021, non-household prosumers in Romania installed a photovoltaic energy generation capacity of 30.5MW, while household consumers had an installed capacity of 21MW.

Instead, the National Energy Authority, NARE mentions in the annual Report on Monitoring the Activity of Prosumers a total capacity of 85MW, without distinguishing between domestic and non-domestic consumers. The reason is that in the Energy and Natural Gas Law, prosumers are considered to be consumers, natural persons, legal entities, and public authorities that own electricity production units from renewable sources with an installed power of no more than 100 kW (ANRE, 2022).

According to NARE data, at the end of 2021, there were 13596 prosumers in Romania, of which 13109 were natural persons and 492 legal persons. The counties in Romania with the highest installed photovoltaic energy power for the prosum are Ilfov – 13,921 kW, Bucharest – 5,658 kW, Timiș – 4,337 kW, Arad – 3,612 kW, and Harghita – 2,622 kW.

The prosumers, natural persons, accumulated a total installed power of 55,672 kW, while the prosumers, legal persons, benefited from an installed power of 29,275 kW. It follows that the average installed power for natural person prosumers is 4.24 kW, while, in the case of non-household consumers, the average installed power per user was 59.5 kW.

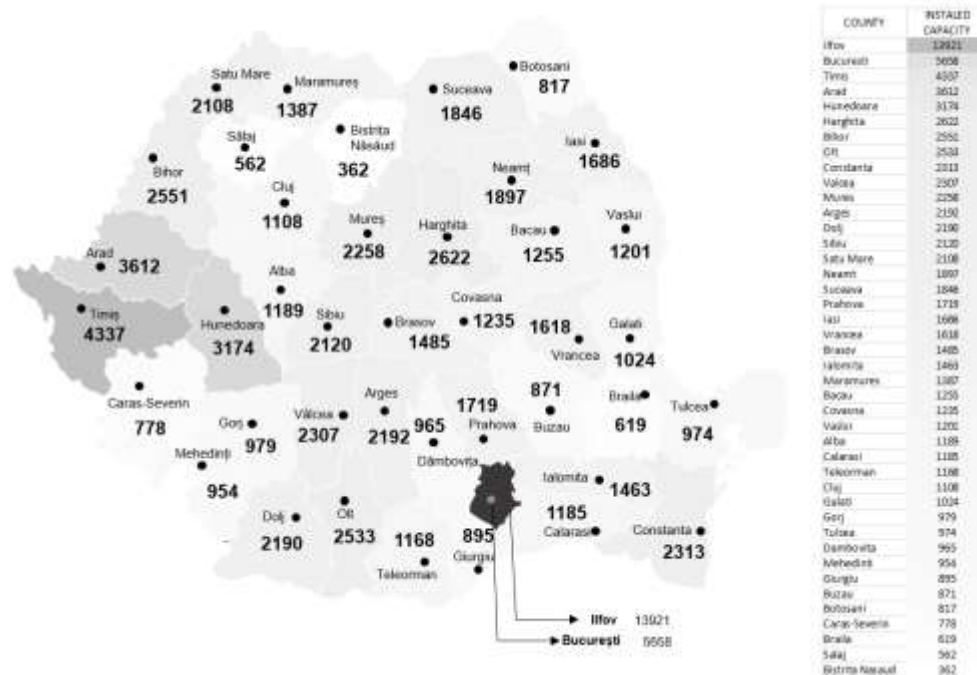


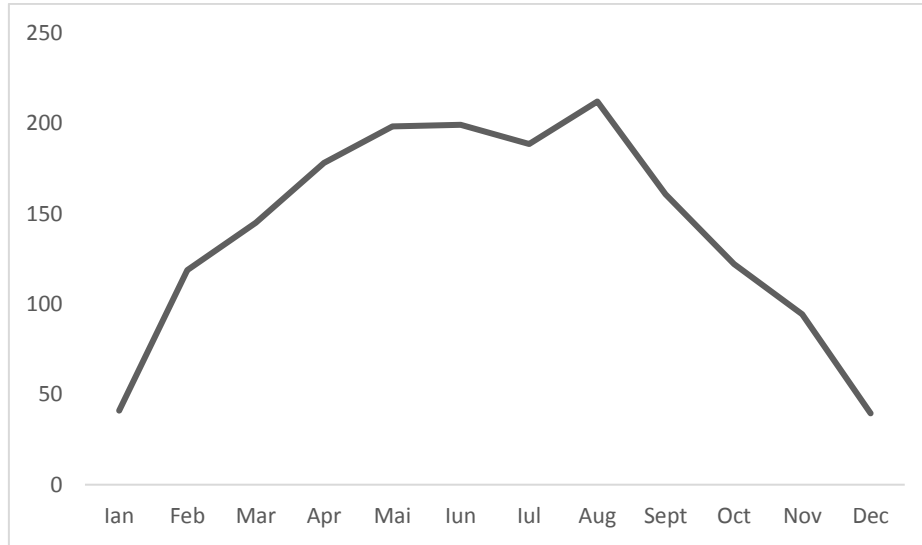
Figure no. 4. Distribution of the installed power of prosumers in Romania, by county, in 2021

Source: Map created by the authors based on: ANRE, 2022. Report on monitoring the activity of prosumers for the year 2021, p. 26.

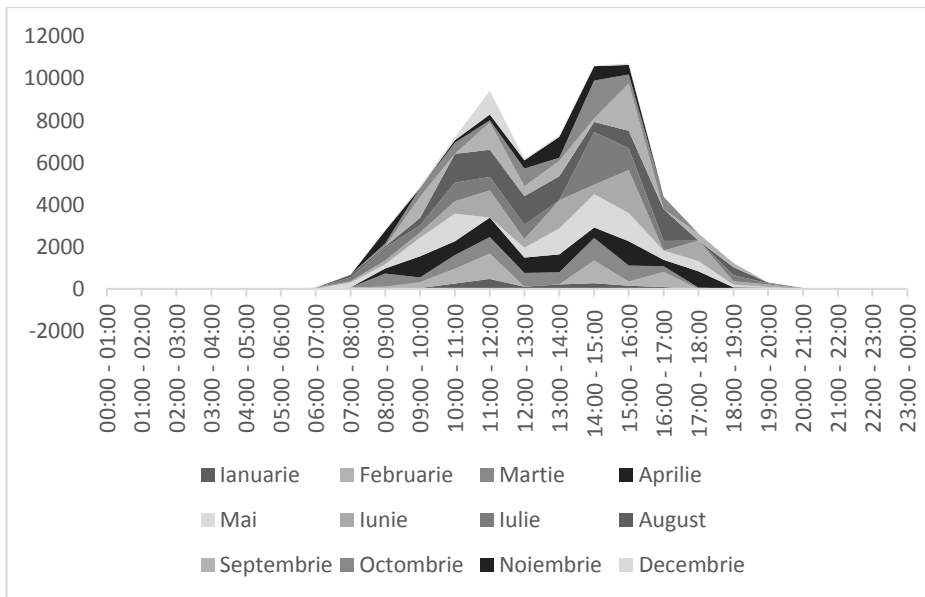
5. Identifying the photovoltaic energy yield for prosumers based on the Cobb-Douglas function, revised

In Romania, in 2021, according to the National Institute of Statistics, photovoltaic energy had a contribution of 2.9% to the national energy mix. Aggregating the national photovoltaic energy production from the year 2021, on a monthly and hourly basis, it was noticed that the most unfavourable calendar intervals for photovoltaic energy production were the months of December - January, with 40MW and 39.5MW, respectively, while production peaks were recorded between March and October, with the highest volume in August of 213 MWh.

This can be seen better in Graph no. 2, when the monthly data is aggregated and broken down into hourly bins. In this way, the seasonality of photovoltaic energy production, and also the hourly thresholds favourable for this type of green energy stand out.



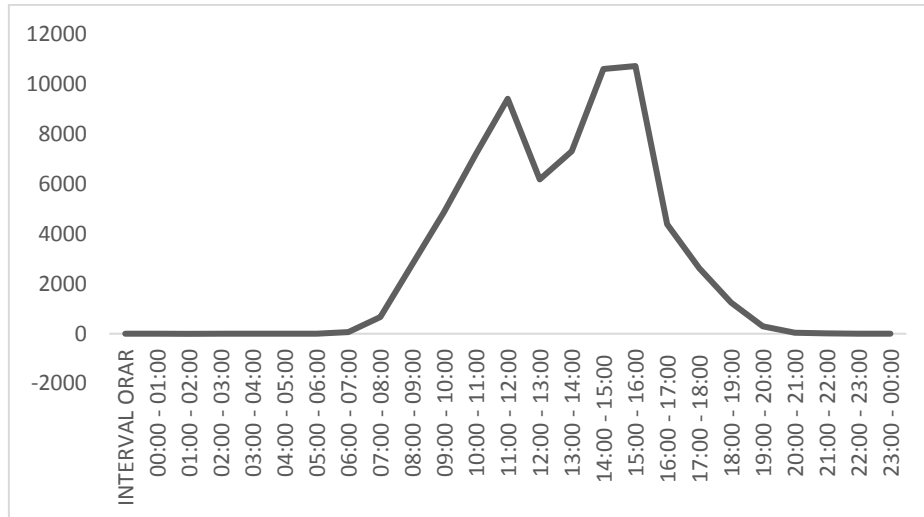
Graph no. 1. Photovoltaic power output in MWh, in 2021, in Romania, at a monthly level
 Source: Transelectrica, data processed by the authors



Graph no. 2. Production of photovoltaic electricity at hourly and monthly intervals, in 2021, in MWh

Source: Transelectrica, data aggregated and processed by the authors

On an hourly basis, in 2021, there were two peaks in the production of photovoltaic electricity dispatched by Transelectrica on the national grid, according to graph no. 3. The first slot was 11:00 - 12:00 and the second was 13:00 - 16:00. Seasonality has an important impact, as production peaks were recorded between March and October. This pattern is also valid in the case of prosumers, because it indicates the hourly interval and the period of the year in which they can exploit the potential of photovoltaic energy.



Graph no. 3. Photovoltaic energy curve produced and distributed by Transelectrica on the national grid, in 2021, expressed in MWh

Source: Transelectrica, data aggregated and processed by the authors

A special feature of the energy prosumers is that their activity is orientated both on the basis of the utility function, a specific feature of consumers, and on the basis of the production function. They basically interact with three sources of electricity: the one from the low-voltage distribution network, the solar one produced by the photovoltaic panels and the one stored in different types of energy storage batteries, including here, as the case may be, the battery of an electric vehicle. However, in order to consume, prosumers must produce, which means that their objective is to maximise their utility by producing and consuming energy as efficiently as possible with the goal of using as little energy as possible from the distribution network, provided that the price of the energy produced and consumed from the network is regulated.

The utility of production in the case of a prosumer actively interacting with the distribution network can be measured by the Cobb-Douglas function. This function measures the amount of electricity output with the help of photovoltaic panels that ensure enough both for the prosumer's own consumption, including during load gaps (time intervals 20:00 - 07:00) and for storage or distribution in the low voltage network.

In the classical model, the Cobb-Douglas function was expressed by the formula:

$$Q = PC^\alpha M^\beta \tag{1}$$

Where:

- Q represents production;
- P represents the productivity of the production factors as a measure of their efficiency;
- C represents the capital factor;
- M represents the labour factor;
- α represents the elasticity of the capital factor;
- β represents the elasticity of the labour factor.

In the energy production model of a prosumer, the Cobb-Douglas function can be expressed as follows:

$$Q = PEp^{\alpha} Eb^{\beta} \quad (2)$$

where:

- Q = energy consumed by the prosumer;
- Ep = energy produced by the prosumer;
- Eb = energy used by the prosumer from a storage battery;
- α represents the elasticity of electricity produced by the prosumer;
- β represents the power elasticity of the battery storage system.

If $\alpha + \beta < 1$, it means that the prosumer experiences diminishing scale returns and the production factors used are insufficient to meet its own consumption needs. In these circumstances, the prosumer can choose between meeting its consumption requirements by using electricity from the grid or, option two, reduce its consumption to the point where the electricity available from its own resources becomes sufficient, meaning that it starts recording constant returns to scale.

This situation arises under the conditions where $\alpha + \beta = 1$. In this case, the prosumer records constant returns to scale, i.e. it has reached the point where it provides its own consumption needs with the energy produced from the photovoltaic panels. On the other hand, when the returns to scale are constant, it means that the prosumer does not actively interact with the distribution network, which for some energy suppliers could be a drawback. It is the case of those energy suppliers who have incorporated into their business strategy the provision of services for energy consumers through which they become prosumers – sale of photovoltaic panels and maintenance services for them, storage batteries, etc. This category of suppliers aims to capitalise on the potential of the prosumer in two major ways. On the other hand, the prosumer is seen as a balancing source for its own customer portfolio, providing green energy in return. In this way, suppliers complete their palette of support means for those non-household customers who have targets to reduce emissions from the electricity they constantly consume. At the same time, providers ensure their access, through prosumers, to a source of cheap energy produced at a regulated price, below the market price, which they can trade at the market price.

When $\alpha + \beta > 1$, then the prosumer can actively interact with the distribution network and the surplus energy produced can be directed to the supplier. In this scenario, both the

prosumer and the provider are in a win – win situation. In the case of the prosumer, he has two alternatives at his disposal. It either redirects the surplus energy produced to the distribution network or redirects it to its own energy storage sources. In the case of electric vehicle users, the battery of this type of vehicle can be powered by excess electricity produced and reused when the prosumer no longer experiences increasing returns to scale. As for the supplier, as mentioned above, he benefits from access to green energy produced with minimal resources at a low price.

When seasonal conditions allow, the prosumer will be motivated to produce excess electricity influenced not only by seasonal factors, but also based on the following formula:

$$P_{ef} - P_{ep} > LCOE \tag{3}$$

where:

- P_{ef} = Price of electricity in the supply contract;
- P_{ep} = Price of electricity produced by the prosumer;
- LCOE = levelised cost of energy.

In 2021, the price at which prosumers in Romania sold their solar energy surplus was 0.19 lei/kWh, while, according to Eurostat, the wholesale price of electricity was, on average, 0.76 lei/kWh. The price difference of 0.57 lei / kWh represents the savings achieved by the prosumer when he ensured his consumption with his own electricity production.

LCOE represents *the price at which the electricity produced would have to be traded for the system to break even at the end of its life cycle* (Papapetrou and Kosmadakis, 2022).

The calculation formula can be expressed by:

$$LCOE = \frac{\sum_{t=0}^n \frac{I_t + M_t}{(1+r)^t}}{\sum_{t=0}^n \frac{E_t}{(1+r)^t}} \tag{4}$$

where:

- t = year x ;
- t = represents the year in which the photovoltaic production capacity was put into production;
- I_t = Investment;
- M_t = Operating costs;
- E_t = Electrical energy expressed in kwh.

To maximise its utility function, the prosumer depends on the fulfilment of three main conditions:

1. the difference between the supply price and the prosumer price to be greater than the LCOE
2. to achieve constant reductions in energy consumption at the prosumer site

3. to produce an amount of energy that ensures not only its own consumption needs, but also a surplus of energy greater than the amount of energy received from the supplier in the time intervals in which the prosumer does not produce enough photovoltaic energy.

To mitigate the impact of the LCOE, the prosumer will need to follow the Cobb-Douglas function. In the time slots 11:00-12:00 and 13:00-16:00, which are favourable for a surplus of solar energy production, he will have to produce as much electricity as possible to redirect it to the grid and, at the same time, to reduce its own consumption during the hours when it is not producing solar energy. Taking into account that, on the day ahead market (PZU), according to OPCOM data, the annual average price for electricity traded in 2021 between 9:00 and 20:00 was 0.39 lei / kwh, it follows that prosumers have had a competitive advantage in relation to the energy produced by utility companies, as they benefited from the possibility of producing electricity at a price 50% lower than that achieved by centralised energy production. A higher number of prosumers present in the national energy system would have assumed a reduction in the contribution of those inefficient electricity production capacities and with high production costs.

Conclusions

On the basis of the revised Cobb-Douglas function, we were able to obtain results that prove to be methodologically relevant and interpretatively robust in terms of new type energy mix analysis.

The shift of an energy user from consumer to prosumer must, by itself, lead to a behavioural change, a fact that is explained by the Cobb-Douglas function. This reveals the prosumer with the entire scope of the prosumption, from the choice and sizing of the photovoltaic system to how it must be used and the energy consumed. In the classic consumer position, the energy user ensures his energy security by relying on a single source that is, in theory, uninterrupted, and this service is quantifiable through the monthly tariff paid for energy consumption. In the position of prosumer, the energy user not only benefits from a new option for his own energy security, but, by being able to interact bidirectionally with the distribution network, he can also ensure the energy security of other energy users. The latter represents a common goal for both prosumers and suppliers that is only achieved when the Cobb-Douglas function indicates that the prosumer experiences increasing returns to scale.

The use and interpretation of the Cobb-Douglas function in the case of the energy prosum can also provide valuable clues to those non-domestic users who have the possibility to install photovoltaic systems with higher installed powers. Unlike household customers, who are more concerned with meeting their own consumption needs, non - household customers may be more motivated to experience increasing returns to scale.

It might be noticed that this function was used in another study by Fikru and Canfield (2020), which attempted to demonstrate how prosumers interact with distribution systems by providing them with energy at reduced prices.

The photovoltaic production curves highlighted in this research can also be a production model for prosumers, as they reflect the nationwide dispatch of this type of energy. It was underlined that the intervals 11:00 - 12:00 and 14:00 - 16:00 are the most favourable to produce photovoltaic energy. Paradoxically, this production pattern benefits the prosumers involved in a professional activity that is carried out in a hybrid regime, because, during that time slot, they can be away from home and redirect all their solar energy to the grid.

In a market context in which the price of electricity based on coal and natural gas increases exponentially because of the turbulence generated by the uncertainty of some sources of supply from imports and against the background of the increase in the taxation of CO₂ emissions, both prosumers and distributors of energy reach the situation of having a common objective.

Decentralised energy production can become a tool for energy autonomy for prosumers, while, for distribution companies, surplus electricity obtained from prosumers can be an additional source of income, as it facilitates their access to a low-cost energy source which can be traded to other consumers at a different market price. In addition, electricity purchased from prosumers helps distribution companies reduce their carbon footprint in Goal 3 and, since distributed energy is carbon-free, it can facilitate the decarbonisation of energy consumed by other users who want to meet their climate goals.

Incentives offered by public administrations from funds where the money obtained from the taxation of inefficient and CO₂ – emitting production capacities is accumulated, can contribute substantially to the reduction of the LCOE. In this way, the foundations are laid for a pole of electricity production without carbon emissions and at a lower price than the market price compared to that practised by the utility companies.

They can have much higher marginal costs per unit of electricity produced compared to a prosumer, and this is reflected in the prices charged on DAM when the demand for additional electricity increases.

To stimulate the growth of the number of prosumers, an extension of the market mechanisms is necessary to include the possibility to trade photovoltaic energy within an energy community, the possibility to enter into PPA (Power Purchased Agreements) type contracts with distribution operators, and the introduction of a net billing type mechanism, which allows the prosumer to trade his surplus electricity at market price. In this way, the prosumer market, which is at the beginning in Romania, can reap the full potential of solar energy in our country in the future.

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