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Coopetitive Nature of Energy Communities—The Energy Transition Context

Karolina Mucha-Kuś [1,*], Maciej Sołtysik [2], Krzysztof Zamasz [1] and Katarzyna Szczepańska-Woszczyna [1]

[1] Department of Management, WSB University, Cieplaka 1c, 41-300 Dąbrowa Górnicza, Poland; kzamasz@wsb.edu.pl (K.Z.); kszczepanska@wsb.edu.pl (K.S.-W.)
[2] Faculty of Electrical Engineering, Częstochowa University of Technology, Armii Krajowej 17, 42-200 Częstochowa, Poland; maciej.soltysik@pcz.pl
* Correspondence: kmucha-kus@wsb.edu.pl

Abstract: The decentralization of the large-scale energy sector, its replacement with pro-ecological, dispersed production sources and building a citizen dimension of the energy sector are the directional objectives of the energy transformation in the European Union. Building energy self-sufficiency at a local level is possible, based on the so-called Energy Communities, which include energy clusters and energy cooperatives. Several dozen pilot projects for energy clusters have been implemented in Poland, while energy cooperatives, despite being legally sanctioned and potentially a simpler formula of operation, have not functioned in practice. This article presents the coopetitive nature of Energy Communities. The authors analysed the principles and benefits of creating Energy Communities from a regulatory and practical side. An important element of the analysis is to indicate the managerial, coopetitive nature of the strategies implemented within the Energy Communities. Their members, while operating in a competitive environment, simultaneously cooperate to achieve common benefits. On the basis of the actual data of recipients and producers, the results of simulations of benefits in the economic dimension will be presented, proving the thesis of the legitimacy of creating coopetitive structures of Energy Communities.

Keywords: energy cooperatives; coopetition; renewable energy sources; Renewable Energy Communities; management

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1. Introduction

The decentralization of large-scale energy, its replacement with pro-ecological, distributed generation sources, and building a civic dimension of the energy sector are the directional objectives of the energy transformation in the European Union (Clean Energy Package—CEP). Community legislation does not impose a precise formula for achieving these goals, giving individual member states freedom of action. Building energy self-sufficiency at a local level is possible on the basis of formulas called Energy Community (EC). The first is the energy community defined in the Renewable Energy Directive REDII [1] and focusing on the area of renewable energy, including the Renewable Energy Community. Citizens Energy Community (CEC) [2], which is implemented within the so-called Market Directive, is the second form of activity. Both of these concepts serve the development of distributed energy in the local dimension, have legal personality and are characterised by voluntary and open participation. The main goal of their operation is to run activities that bring economic and environmental benefits in the local and regional dimension, which are aimed at building self-sufficiency and energy independence [3,4].

The EU direction of transformation of the energy market has also been reflected in Polish law, where, similarly to the Community regulations, two concepts were created that introduce the civic dimension of energy [5]. These include energy clusters and energy cooperatives—with the latter being the latest form of support for distributed civic energy are the subject of this article. Energy cooperatives are voluntary associations of energy consumers and producers, who jointly declare and implement the goals of building energy independence. Thanks to which we are able to achieve additional benefits together [3,6].

In practice, the realization of additional benefits is associated with the coopetitive interaction of players. Coopetition is a deliberate strategy of mixing cooperation and competition [7] at different stages and arenas in order to achieve better individual and collective results [8]. The term coopetition has been present in strategy literature for many years now, allowing for several threads of research to exploit or investigate it. Firstly, a theoretical view of coopetition has been developed as related fields theory extension. Game theory brought into light the need to deliberately transform inter-organizational market relations into a positive sum game or reshape competition structure [9]. The strategic behaviour perspective attracted attention to the rent appropriation issue, which is far more in a manager's scope than mere rent generation, and it has syncretic forms beyond those discussed in literature [10]. Inter-organizational dynamics in turn provided theoretical grounds for showing that coopetition is a dynamic process that emerges between cooperating parties and leads to intertwining rent maximization and rent appropriation behaviours [11]. Secondly, a growing body of empirical investigation has brought a substantial body of mainly case-study based evidence that provides rich insights into both coopetition's nature and its dynamics. Several industries have been under scrutiny, most notably: professional football [12], insurance [13], cultural institutions [14], information and communication technologies [15], transportation industry [16], banking [17], purchasing groups [18], and electro-mobility [19]. Another thread of research has a clearly theoretical inclination because it expects coopetition to appear between market players [13], or it suggests that this option is in their best interest [9]. Therefore, coopetition is seen as a collective and individual ideal strategy. Those actors that do not deliberately use it fall into a non-equilibrium or suboptimal option. Under-performing competitive strategies have the traits of individual rationality. which is not optimal in a multi-actor context typical to coopetition under scrutiny. Those claims remain broadly grounded in game theoretical applications to cooperative settings. Rational collective decision making models, such as the prisoner's dilemma repeated game, suggest that cooperation between competitors clearly yields best results for all players. Yet, empirical findings suggest that many managers choose to remain outside coopetitive strategies. The theoretical underpinnings of this thread of research rely heavily upon collective strategies models using game theoretical mathematics.

The aim of this paper is to advance coopetition empirical findings by addressing the case study of energy communities. The individual and innovative contribution of the authors to research in this area is the element of empirical research that clearly demonstrates the legitimacy of the application of coopetition strategies. Combining the context of energy communities with the analysis of the effects of coopetition (both joint and individual) has never been the subject of empirical analyses.

The hypothesis reflects the statement that coopetition seems to be favourable for all the actors involved, while functioning on ones' own gives worse results both the individual and collective level. The paper is organized into four sections. First, the characteristics of the functioning of an energy cooperative are being presented in order to identify their background and identify the benefits. Second, simulation assumptions for research on cooperatives are listed, showing the details of the empirical analysis background. Third, an economic analysis focusing on the main findings is shown. The fourth one presents the results and conclusions also stressing the limitations of the paper and a further research agenda.

2. Background—Characteristics of the Functioning of an Energy Cooperative with the Identification of Benefits

2.1. Energy Cooperative as a Response to REC and CEC

Poland is a country where the energy sector is still dominated by worn-out system units fuelled by hard coal and lignite. On the other hand, there is strong legislative pressure as well as pressure formulated in terms of social expectations to carry out difficult but necessary energy transformation processes. One of the three pillars of the strategic direction document—Poland's Energy Policy until 2040, concerns the issue of a zero-emission energy system. This area assumes the need for a strong development of local and civic energy, and the measure of the goal is to increase the share of recipients that are actively participating in the market. It is assumed that 300 energy sustainable areas and a million prosumers will be created by 2030 [20].

One of the solutions enabling the acceleration of Poland's green transformation is the popularization of local energy communities and the consequent decentralization of the energy sector. The definition of an energy cooperative appeared in Polish law in 2019 during the amendment to the Act on Renewable Energy Sources [21]. According to this legal act, an energy cooperative is a cooperative within the meaning of the provisions of the Cooperative Law [22] and the Act on farmers' cooperatives [23] (in the case of agricultural cooperatives), the subject of which is the production of electricity, heat, or biogas only for the own needs of an energy cooperative and its members.

Energy cooperatives:

- may be established in the area of a rural or urban-rural commune or in the area of not more than three adjacent communes of this type,
- they can operate in the area of operation of a single distribution system operator supplying electricity to producers and customers who are members of this cooperative, whose installations are connected to the network of a given operator. The area of operation of an energy cooperative is determined on the basis of the places of connection of producers and customers who are members of this cooperative to the distribution network,
- operate within low and medium voltage networks,
- may have from three to 999 members inclusive,
- where their object of activity is the production of:
    - electricity, total installed electrical capacity of all renewable energy installations:
        - makes it possible to cover not less than 70% of the own needs of an energy cooperative and its members during the year,
        - does not exceed 10 MW,
    - heat, the total achievable thermal power does not exceed 30 MW, and
    - biogas, the annual capacity of all installations does not exceed 40 million m^3.
- may be created only by natural or legal persons.

The main goals of establishing energy cooperatives include:

- building local energy self-sufficiency,
- increasing the energy independence of mainly rural areas and small towns,
- improving the living conditions and running a business in rural areas, including increasing the competitiveness of the agro-food sector, achieved thanks to cheaper energy media, and
- increasing the use of locally occurring renewable resources.

2.2. Principles of Operation and Settlement in an Energy Cooperative

Energy cooperatives operate on the basis of a prosumer system that consists of an energy settlement that is based on the so-called discounts. An energy seller only settles accounts with an energy cooperative for the difference between the amount of electricity that is introduced to the electricity distribution network and the amount of electricity collected from this network for its own needs by the cooperative (its members) in the ratio of the corrected quantitative factor of 1 to 0.6 (in the case of prosumers, depending on the power of the installation, the coefficients 1 to 0.8 or 1 to 0.7 apply) [24,25]. In other words, for 1 MWh of energy produced by the cooperative and not used at the moment by the members of the cooperative, i.e., fed into the distribution network (the network in this situation acts as a storage for energy not used by the cooperative), 0.6 MWh of energy can be obtained from it. This can happen at any time within the billing period when the cooperative's generation sources do not meet the current demand. This settlement applies to electricity that is introduced and taken from the distribution network by all electricity producers and consumers who are members of an energy cooperative. The same principle applies if the subject of the cooperative's activity is heat or biogas. Therefore, it should be assumed that the more it is possible to "synchronize" the amount of energy that is produced with its receipt at a given moment within the cooperative entities, so as not to discharge the surplus energy production into the grid, the greater the economic effects of the energy cooperative will be. It can be said that the distribution network will, in such a situation, only "secure" the internal energy economy of the cooperative.

As a prosumer, an energy cooperative functions in the power system under a comprehensive agreement that is signed with an external energy supplier. This agreement regulates the issues of both distribution and sale of possible energy shortages to the cooperative. For an energy seller, an energy cooperative is one collective end-user subject to a single settlement. For the needs of internal settlements of an energy co-operative between its individual members, the seller provides the amount of energy that is introduced and taken from the grid by individual members of the co-operative. The cooperative settles them in accordance with internally adopted rules. The amount of unused energy remains to be collected (compensated) within the given 12-month billing period. The functioning of an energy cooperative is associated with specific benefits at the cooperative level, which can then be cascaded onto its members. The seller carries out the settlement of the energy cooperative, in the discount model, on the basis of measurement data that are provided by the distribution system operator (DSO). The first of the benefits is:

- maximization of energy self-consumption—achieved thanks to the daily-hourly balancing of the amount of electricity that is introduced to and taken from the distribution network by all producers and consumers belonging to an energy cooperative after prior summary balancing of the amount of energy introduced and taken from the distribution network from all installation phases.

  From the settled amount of electricity, an energy cooperative:

- does not pay settlement fees to the seller and
- does not pay distribution service fees, the amount of which depends on the amount of electricity consumed by all producers and consumers of the cooperative (variable distribution component).

  For the amount of electricity that is generated in all renewable energy installations of an energy cooperative and then consumed by all electricity consumers of the energy cooperative:

- is not charged and charged:
  - RES charges referred to in Art. 95 paragraph. 1 of the Act on Renewable Energy Sources,
  - capacity fee, as defined in the provisions of the Act of 8 December 2017 on the capacity market,
  - cogeneration fee within the meaning of the provisions of the Act of 14 December 2018 on the promotion of electricity from high-efficiency cogeneration,
  - excise duty, provided that the total installed electric capacity of all renewable energy installations of the energy cooperative does not exceed 1 MW, and
- the obligations to redeem the certificates of origin or to pay the substitution fee referred to in Art. 52 sec. 1 (green and blue certificates), nor those resulting from Art. 10 of the Energy Efficiency Act (white certificates).

  The model of internal settlements of produced and consumed electricity can be carried out for any time horizon—e.g., for an hour.

3. Materials and Methods

The basic methodological approach presented in this article is a case study analysis of energy communities and it was based on an economic analysis of real market data.

A case study includes:

- background introduction—characteristics of the functioning of an energy cooperative with the identification of benefits,
- defining the simulation assumptions for research on cooperatives,
- economic analysis, and
- effects of coopetition within the energy communities.

3.1. Simulation Assumptions for Research on Cooperatives

It was necessary to prepare simulation scenarios reflecting the energy cooperative that could function in reality and the relations between its members in order to simulate and test the hypothesis. Actual data on producers and consumers of energy in rural areas were adopted for analytical and simulation activities due to the definition indicating that an energy cooperative is a solution aimed, in particular, at stimulating the construction of energy communities in rural areas. An energy cooperative was created for simulation purposes, reflecting various: (i) location character, (ii) level of demand for electricity, (iii) nature of economic activity of cooperative members, (iv) electricity consumption profile for each member of the cooperative, (v) production potential among cooperative members, and (vi) the level of voltage supplying cooperative members. The construction of an energy cooperative also takes the formal and legal aspects resulting from the applicable regulations into account. In particular, the location criterion regarding the allocation of members in the area of up to three adjacent rural or rural urban communes was maintained, as well as the need to balance at least 70% of the demand from own generation sources.

The simulation process was carried out in several stages in order to thoroughly examine the effects of establishing an energy cooperative:

1. In the first stage, 11 farms meeting the criteria described above were selected and the actual costs of purchasing electricity along with the distribution service were calculated, taking the current tariff rates into account. The obtained results constituted a reference for the results of further simulations.
2. The second stage assumed that each farm would build its own power source, adjusted to the demand profile with the generation profile. For the prosumers created in this way, the calculation of the costs of purchasing the missing energy along with the distribution service was carried out in the same way as for the first stage. The obtained results illustrate the benefit of becoming an individual prosumer. The selection of generation sources, i.e., generation technology and source power, was optimized in terms of the target combination of receiving and generating facilities into a cooperative. The objective function was to minimize the sum of energy that is drawn from the grid from outside the grid storage and the state of the energy storage at the end of the billing period.
3. The third stage assumed the consolidation of farms–prosumers within the framework of an energy cooperative, and the calculation of the effects of self-balancing, an increase in self-consumption, and the costs of purchasing missing energy. The result of simulations and calculations was to be the cost seen from the perspective of the entire cooperative, which was ultimately to be decomposed for each of its members. The results of the decomposition were to make it possible to evaluate the profitability of joining the cooperative for all of its members.

3.1.1. Assumptions for Stage 1

The purpose of the selection of farms was to reflect:

- location character—the simulation was made for entities located in the Silesia Voivodeship, and the selection additionally took different locations of communes in the voivodeship into account. The choice of this voivodeship was also aimed at reproducing the level of insolation typical for the country, and thus the generation efficiency,
- different levels of demand for electricity—under this criterion, participants were selected taking into account the diversity of individual energy demand of each of them.

The cooperative was composed of participants with low consumption of 52 MWh/year, up to the level of 3574 MWh/year,

- the nature of the economic (agricultural) activity—the selection of participants reflected the division in force in Polish law by the so-called PKD (Polish Classification of Activities) codes that are appropriate for typical agricultural activities, i.e., agricultural crops, vegetable cultivation, cereal cultivation, poultry, pig, and cattle breeding, as well as services for the agricultural sector. The full classification is included in the commentary to Table 1,
- electricity consumption profile for each member of the cooperative—the tariff diversity in force in Poland, and which may occur among members of energy cooperatives, was taken into account. Entities belonging to one, two, or three zone tariffs were selected, thanks to which the diverse nature of energy consumption was reproduced,
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- different levels of supply voltage for farms—consumers supplied at the medium (MV) and low (LV) voltage level, and
- production potential among cooperative members—the selection of municipalities took into account the possibility of building renewable energy sources in each of the technologies: wind, photovoltaic, biogas, biomass, and water.

Table 1. Characteristics of the selection of farms.

Characteristics	Cooperative 1
Voivodeship	Silesia
Number of members	11
Agricultural activity profile and number of members	01.46.Z; ż (3) 01.13.Z; (3) 01.47.Z; (5)
Voltage level (LV/MV) and number of members	LV (4) MV (7)
Tariff group and number of members	C11 (2) C12a (1) C22b (1) B21 (1) B23 (6)
Electricity demand [MWh/year]	9 757
Minimum, average and maximum energy consumption by a cooperative member [MWh/year]	min: 52 mean: 887 max: 3 574

Where:

Agricultural activity profile:

- 01.13.Z—Growing vegetables, including melons, and growing root crops and tubers,
- 01.46.Z—Pig rearing and breeding, and
- 01.47.Z—Poultry Farming and Breeding

For economic analyses, the tariff rates for both the sale of electricity as a commodity and distribution were used. The rates of DSO—Tauron Distribution and Tauron Sales for 2020 were taken into account, being additionally increased by the capacity fee related to the introduction of the capacity market in Poland from 1 January 2021. Tables 2 and 3 present the individual price components.

Table 2. Distribution tariffs included in the calculation [26].

Tariff Group	All Day	Day/ Peak	Night/ Offpeak	1st Peak	2nd Peak	Rest of the Day	Qualitative Rate	Capacity Fee
	PLN/MWh						PLN/MWh	PLN/MWh
B11	67.27						13.33	76.2
B21	55.26						13.33	76.2
B22		53.48	53.48				13.33	76.2
B23				35.13	35.13	35.13	13.33	76.2
Tariff Group	PLN/kWh						PLN/kWh	PLN/kWh
C21	0.1422						0.0133	0.0762
C22a		0.1422	0.1422				0.0133	0.0762
C22b		0.1422	0.1422				0.0133	0.0762
C23				0.1564	0.2274	0.1138	0.0133	0.0762
C11	0.1401						0.0133	0.0762
C12a		0.1315	0.1315				0.0133	0.0762
C12b		0.1315	0.1315				0.0133	0.0762

Table 3. Sales tariffs included in the calculations [27].

Tariff Group	All Day	Peak	Offpeak	Day	Night	1st Peak	2nd Peak	Rest of the Day
	PLN/MWh							
B11	447.00							
B21	437.00							
B22		506.00	390.00					
B23						500.00	586.00	359.00
Tariff Group	PLN/kWh							
C21	0.471							
C22a		0.585	0.425					
C22b				0.541	0.365			
C23						0.602	0.644	0.380
C11	0.489							
C12a		0.600	0.422					
C12b				0.591	0.364			

3.1.2. Assumptions for Stage 2

The purpose of the selection of farms was to reflect:

- the selection of generation sources, both in terms of generation technology and capacity, was aimed at achieving the effect of minimizing the sum of energy that is purchased from the grid outside the grid storage and the stock at the end of the billing period. For the purposes of the simulation, it was assumed that the total annual energy production in each farm cannot exceed 120% of the annual energy demand. This level guarantees the full balance of each farm in the annual settlement period, while not guaranteeing an hourly balance,
- Poland has moderately favourable sun exposure conditions, however, the prosumer energy industry is almost 100% based on photovoltaic sources. For the purposes of the simulations, it was assumed that at least 25% of energy production in all farms comes from solar energy. Additionally, the power limitations for a single PV farm were adopted from 0 to 1000 kW with increments of 50 kW,
- due to unfavourable hydrological conditions, it was assumed that ultimately a maximum of one hydroelectric power plant may operate within an energy cooperative. An assumption was made, which is reflected in practice, that a small hydropower plant is characterised by a low power of several dozen to several hundred kW. Therefore, the simulation takes the power limitations of a single source from 0 to 500 kW in increments of 50 kW into account, and it was assumed that it would be only in one farm,
- rural and rural-urban areas are very often undeveloped or low-built areas. This location is favourable for the construction of low-mast, low, and medium power wind

sources. For the needs of analytical and simulation works, it was assumed that the participants of the cooperative could build sources with a capacity from 0 to 1000 kW with an increment of 250 kW,

- agricultural land is also a space for the construction of biogas and biomass sources, guaranteeing high generation efficiency and stability of the production profile. For the simulation, for both biomass and biogas, power limitations of the sources from 0 to 600 kW with increments of 200 kW were assumed, and
- due to the fact that the installation of new sources is associated with significant costs, it was assumed that one farm has at most two sources of energy production when selecting production sources to optimally balance the demand.

For the assumptions that are indicated for stages 1 and 2, an optimization process was carried out in order to select the type and capacity of generating sources based on a dedicated mathematical model using the mixed integer programming technique. GLPK software was used for modelling, in particular, the GMPL high-level language made available. The presentation of the mathematical model and the detailed analysis of the results are not the subject of this work and constitute separate publication material [28]. The results presented in Table 4 were obtained as a result of the optimization.

Table 4. Characteristics of the sources and obtained results of generation simulation.

Id	Production		Consumption		Capacity [kW]				
	Total [GWh/Year]	Average Daily [kWh/Day]	Total [GWh/Year]	Average Daily [kWh/Day]	PVPP	SWPP	WPP	BMPP	BGPP
Total	8.760	997	9.757	1111	3810	200	3750	400	600
Farm1	0.175	44	0.190	22	175				
Farm2	0.105	27	0.104	12	105				
Farm3	0.270	31	0.255	29	70	200			
Farm4	1.245	149	1.102	125	495		750		
Farm5	0.540	62	0.501	57	140			400	
Farm6	2.000	239	3.574	407	1000		1000		
Farm7	1.960	234	1.809	206	960		1000		
Farm8	1.370	164	1.124	128	370		1000		
Farm9	0.905	105	0.900	102	305				600
Farm10	0.140	35	0.146	17	140				
Farm11	0.050	13	0.052	6	50				

Where: PVPP—Photovoltaic power plant; SWPP—Small hydro power plant; WPP—Wind power plant; BMPP—Biomass power plant; BGPP—Biogas power plant.

4. Economic Analysis

Based on the above-mentioned assumptions, an analysis of the costs of energy purchase was carried out along with the distribution service for each of the three stages. In the first stage, in which each farm purchased all electricity from the seller—Tauron Sales GZE on the basis of a comprehensive contract (energy and distribution), it was possible to observe the level of personalized annual costs from PLN 35,000 to over PLN 1.85 million. The total cost for all farms exceeded 5.14 million PLN/year, of which 4.28 million PLN (85%) is the cost of energy as a commodity, and the remaining 0.87 million PLN (15%) is the cost of distribution and power fee. The calculations were made while taking the actual number of hours and energy for each hour zone in each of the tariff groups into account. Table 5 presents the detailed calculation results. The second stage included the settlement of each farm that is equipped with its own source or generation sources with the power and generation technology that is presented in Table 4. Having a separate generation of each farm allowed for obtaining the status of a prosumer and reducing the amount of energy that is purchased from the seller. Depending on the effectiveness of the source selection, the total level of self-consumption obtained for all prosumers amounted to 5.84 GWh, which, in relation to the total level of demand of 9.76 GWh, constituted nearly 60%. This energy and the energy collected in the discount model from the network storage are both not subject to distribution and sales fees. Full payment for energy and distribution only occurs in the event of an imbalance of each prosumer. The total amount of energy purchased from the seller for balance purposes by all prosumers amounted to 2.14 GWh. This purchase was associated with a cost of PLN 1.12 m, of which PLN 0.94 m (84%) was the cost of energy, and PLN 0.18 m was the cost of distribution and power charges.

Table 5. Economic calculations results.

Stage	Users [1]	Self-Consumption	Collection from the Network Storage	Loss on the Network Storage	Consumption from the Network (Outside the Storage)	Energy Cost	Distribution Cost	Capacity Market	Total
		kWh/Year				PLN			
1	F1	-	-	-	-	88,669	27,552	6721	122,941
	F2	-	-	-	-	49,043	16,191	3255	68,489
	F3	-	-	-	-	111,380	17,482	10,091	138,953
	F4	-	-	-	-	480,833	53,400	38,133	572,366
	F5	-	-	-	-	218,677	24,286	17,342	260,305
	F6	-	-	-	-	1,559,584	173,204	123,684	1,856,472
	F7	-	-	-	-	789,190	87,645	62,587	939,423
	F8	-	-	-	-	490,443	54,467	38,895	583,806
	F9	-	-	-	-	392,840	43,628	31,155	467,622
	F10	-	-	-	-	71,262	22,355	4866	98,484
	F11	-	-	-	-	25,392	7966	1734	35,091
	T(1)	-	-	-	-	4,277,313	528,175	338,464	5,143,952
2	P1	65,555	76,611	0	48,109	22,910	6966	1406	31,282
	P2	32,634	47,963	2693	23,527	10,682	3658	541	14,881
	P3	188,672	42,922	14,008	23,280	10,173	1597	1078	12,848
	P4	731,788	303,503	55,756	66,651	29,633	3230	2562	35,425
	P5	421,531	55,368	27,568	24,250	11,185	1175	819	13,179
	P6	1,701,672	208,830	0	1,663,653	723,439	80,621	47,803	851,862
	P7	1,155,359	504,022	59,235	149,234	66,120	7232	5124	78,475
	P8	777,016	318,016	97,093	28,934	12,694	1402	1014	15,110
	P9	703,174	126,986	14,302	70,125	31,827	3398	2118	37,343
	P10	49,230	63,539	0	32,961	16,118	5056	894	22,068
	P11	17,551	22,714	0	11,661	5702	1789	318	7809
	T(2)	5,844,183	1,770,474	270,655	2,142,384	940,483	116,124	63676	1,120,283
3	M1	-	-	-	-	18,147	5481	1220	24,848
	M2	-	-	-	-	8446	2872	474	11,793
	M3	-	-	-	-	9208	1445	1031	11,685
	M4	-	-	-	-	29,930	3385	2673	35,989
	M5	-	-	-	-	10,228	1045	750	12,023
	M6	-	-	-	-	594,082	78,209	46,298	718,589
	M7	-	-	-	-	67,245	7578	5389	80,211
	M8	-	-	-	-	11,875	1460	1020	14,354
	M9	-	-	-	-	25,970	2809	1887	30,666
	M10	-	-	-	-	12,262	3847	738	16,847
	M11	-	-	-	-	4366	1370	263	5998
	C (3)	6,237,022	1,446,487	67,317	2,073,532	791,760	109,500	61,744	963,004
	(2)–(1)	-	-	-	-	−3,336,830	−412,051	−274,788	−4,023,669
	(3)–(1)	-	-	-	-	−3,485,553	−418,676	−276,720	−4,180,948
	(3)–(2)	392,839	−323,988	−203,338	−68,851	−148,722	−6625	−1932	−157,279

[1] Where: F—Farm; P—Prosumer; M—Member of cooperative; T—Total; C—Cooperative.

The third stage involved the settlement of an energy cooperative that consists of 11 farms with the status of a prosumer. The illustration of the synthetic model showing the calculation method is as follows:

$$Cost_T = \sum_{n=1}^{c}\left(\sum_{d=1}^{365}\left(\sum_{t=1}^{k}(V_{Et}\times(P_{Et}+P_{Dt})) + \sum_{h=7}^{22}(V_{Eh}\times P_{CM})\right)_d\right)_n \quad (1)$$

where:

$Cost_T$—total cost of electricity purchase
t—number of tariff zones
h—hours 7:00 a.m.–10:00 p.m.
c—number of customers (1—for individual or prosumer, 11—for cooperative)
V_{Et}—volume of electricity consumption in each of scenarios (discount model for prosumer: 1/0.8 or 1/0.7; for cooperative 1/0.6)

V_{Eh}—volume of electricity consumption in peak hours in working days
P_{Et}—electricity price in tariff zone 't'; $t_{max} = 4$
P_{Dt}—price of electricity distribution in tariff zone 't'
P_{CM}—Settlement price on capacity market 76.20 PLN/MWhv [29].

A detailed model of settlements for energy cooperatives is described in the draft of legal regulation [30]. The financial results broken down into cost streams: energy purchase, distribution, and capacity market are presented in Table 5.

The merging of the demand–supply profiles of prosumers allowed for self-consumption at the level of 64%, i.e., 393 MWh more than in the case of individual prosumer settlement (Stage 2). The amount of electricity charged and subject to charges has also decreased, from 2.142 GWh (Stage 2) to 2.073 GWh. The above elements contributed to the reduction of the total cost of energy purchase and distribution services, which, for the entire energy cooperative, amounted to 0.963 million PLN/year, of which nearly 0.792 million PLN (82%) was the cost of energy. It is also worth emphasizing that the optimization of the selection of generation sources for individual participants was aimed at minimizing the sum of the volume purchased from the seller and the stock of network storage at the end of the settlement period. For this reason, energy losses that could not be used within the 12-month billing period were minimized. The reduction was achieved from 270 MWh for stage 2 to 67 MWh for stage 3.

5. Results and Discussion

The conducted profitability analysis of an energy cooperative, the results of which are presented in Table 5, allows for concluding that the creation of an energy cooperative on the basis of farms with the prosumer status additionally affects the emergence of benefits in the form of over 157 kPLN per year. Such a good result is obtained, despite a worse discount rate. In the case of a farm–a prosumer, this ratio is 1/0.7 and, for a cooperative, it is 1/0.6 (introduced to the 1 MWh network results in the possibility of free collection of 0.7 or 0.6 MWh). The financial effect that is obtained by the cooperative should be transferred to its individual members. In order to simulate such a separation, a key was used, depending on the share of each member of the cooperative in generating savings. The greater the daily-hourly profile of a cooperative member was correlated with the instantaneous generation of electricity and condition of the network warehouse, the greater its share in the profit distribution was obtained. Table 6 presents the results of such a division and they correspond to the model specified in the draft of legal regulation [30]. It shows that two members of the cooperative achieved a deterioration of the financial result in relation to the scenario, when they were only farms with a prosumer status. It is worth emphasizing that this happened, despite the fact that the financial result obtained by the entire cooperative was in favour of the cooperative.

Table 6. Economic effect for an energy cooperative.

Users	Total Cost for Stage 2	Total Cost for Stage 3	Stage 3–Stage 2
	PLN		
Member1	31,282	24,848	−6434
Member2	14,881	11,793	−3088
Member3	12,848	11,685	−1163
Member4	35,425	35,989	564
Member5	13,179	12,023	−1156
Member6	851,862	718,589	−133,272
Member7	78,475	80,211	1736
Member8	15,110	14,354	−756
Member9	37,343	30,666	−6678
Member10	22,068	16,847	−5221
Member11	7809	5998	−1811
Total	1,120,283	963,004	−157,279

In the context of the results obtained, one can ask whether if the cooperative did not include four and seven members, the obtained result for the entire cooperative and for its other members would still be favourable. For this purpose, the same profitability analysis was carried out for the entire cooperative with nine members (excluding farms with the prosumer status marked with numbers 4 and 7). Table 7 presents the results that were obtained for the original scenario of the cooperative (stage 3a) and for the cooperative with a reduced number of members (stage 3b).

Table 7. Decomposition of the cooperative's result into its members.

Stage	Users	Energy Cost	Distribution Cost	Capacity Market	Total	Advantage	Loss
		PLN					
3a	Member1	−4762	−1485	−186	−6434	−6434	
	Member2	−2235	−786	−67	−3088	−3088	
	Member3	−965	−151	−47	−1163	−1163	
	Member4	297	155	111	564		564
	Member5	−957	−130	−69	−1156	−1156	
	Member6	−129,357	−2412	−1504	−133,272	−133,272	
	Member7	1125	346	265	1736		1736
	Member8	−819	58	6	−756	−756	
	Member9	−5857	−590	−231	−6678	−6678	
	Member10	−3856	−1210	−156	−5221	−5221	
	Member11	−1336	−419	−55	−1811	−1811	
	Cooperative (3)	−148,722	−6625	−1932	−157,279	−159,579	2300
3b	Member1	−3911	−1222	−149	−5281	−5281	
	Member2	−1819	−660	−51	−2529	−2529	
	Member3	−310	−49	38	−321	−321	
	Member4	-	-	-	-	-	
	Member5	−441	−82	−32	−555	−555	
	Member6	−130,791	−3435	−731	−134,957	−134,957	
	Member7	-	-	-	-	-	
	Member8	−934	15	−10	−929	−929	
	Member9	−4459	−444	−133	−5037	−5037	
	Member10	−3242	−1017	−123	−4382	−4382	
	Member11	−1120	−351	−44	−1515	−1515	
	Cooperative (3)	−147,027	−7245	−1235	−155,506	−155,506	

6. Conclusions

- Eliminating members of cooperatives 4 and 7 does not have a positive effect on the final benefit for the whole cooperative.
- For step 3b, the distribution of benefits indicates that only members numbered 6 and 8 gain as compared to scenario 3a. The remaining seven members have a worse financial result.
- The financial effect that is obtained in stage 3b is PLN 4,073 worse than in stage 3a. Therefore, it can be concluded that the departure of two members of the cooperative, for whom it was unprofitable to participate in it, deteriorates, as a rule, the results of other members. At this point, it becomes reasonable to leave members 4 and 7 in the coopetitive actions aimed at financing the loss recorded by them, by other members. Such an approach, apart from covering the loss, allows for the generation of benefits of PLN 1773 (as compared to scenario 3b), which can be distributed with the appropriate key to all members of the cooperative.

The results of the conducted research and simulations, which constitute an individual and pioneering contribution of members of the authors' team, very faithfully reflecting the specificity of the operation of energy cooperatives and based on actual data, confirm that the profitability of energy cooperatives is very dependent on the nature and supply-demand profile of its members. The profitability of the energy cooperative is additionally lowered, due to the less favourable discount rate when compared to the standard prosumer scenario. However, the analyses that were carried out clearly indicate that it is possible to obtain benefits within the cooperative both on the global and individual level. This statement confirms the realization of article's goal as well as positively tests the hypotheses.

It is worth emphasizing that not all energy consumers may become owners of their own generation sources and be prosumers. This is the case, for example, due to location limitations, a lack of space to develop the source, or high investment costs. The model of an energy cooperative guarantees very tangible benefits in each of such cases for each of the members. Additionally, within the energy community, it becomes possible to build ties and relationships that aimed at searching for the best financial effect, as seen from the perspective of the community and translating into individual benefits.

Many empirical papers clearly demonstrate that competitors either purposefully use cooperative behaviours to generate and capture rents, or should behave so. The founding achievement of coopetition research community is much more than coining a term for a complex phenomenon. This brings attention to attitudes, behaviours that prevent actors from coopetition strategy implementation.

This paper limitations may be attributed to selective case study presentation. This study does not have exhaustive ambitions, but, in turn, it might be biased by the omission of many theoretical and empirical works. Theoretical sampling satisfies for listing empirical case studies analysed by other coopetition researchers, but it does not provide representative results. Instead, it creates a sharp picture of the research community's current efforts. Moreover, the analysis case study is also selective. While those reasons suggest a prudent use of findings, their formulation remains straightforward. Yet, whether coopetition is a theory or just another dynamic capability as well their positive impact on individual and collective results remains to be tested.

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References

1. Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the Promotion of the Use of Energy from Renewable Sources; European Union: (OJ L 328). 21 December 2018. Available online: http://data.europa.eu/eli/dir/2018/2001/oj (accessed on 9 January 2021).
2. Citizens Energy Communities: Recommendations for a Successful Contribution to Decarbonisation; Eurelectric Position Paper—Dépôt Légal: D/2019/12.105/13. 2019. Available online: https://www.apren.pt/contents/publicationsothers/eurelectric--citizens-energy-communities.pdf (accessed on 9 January 2021).
3. Ghiani, E.; Giordano, A.; Nieddu, A.; Rosetti, L.; Pilo, F. Planning of a Smart Local Energy Community: The Case of Berchidda Municipality (Italy). *Energies* **2019**, *12*, 4629. [CrossRef]
4. Hussain, H.I.; Slusarczyk, B.; Kamarudin, F.; Thaker, H.M.T.; Szczepańska-Woszczyna, K. An investigation of an adaptive neuro-fuzzy inference system to predict the relationship among energy intensity, globalization, and financial development in major ASEAN economies. *Energies* **2020**, *13*, 850. [CrossRef]

5. Sokołowski, M.M. Renewable and Citizen Energy Communities in the European Union: How (Not) to Regulate Community Energy in National Laws and Policies. *J. Energy Nat. Resour. Law* **2020**, *38*, 289–304. [CrossRef]
6. Neagu, B.-C.; Ivanov, O.; Grigoras, G.; Gavrilas, M.; Istrate, D.-M. New Market Model with Social and Commercial Tiers for Improved Prosumer Trading in Microgrids. *Sustainability* **2020**, *12*, 7265. [CrossRef]
7. Czakon, W.; Mucha-Kuś, K.; Rogalski, M. Coopetition Research Landscape—A Systematic Literature Review 1997–2010. *J. Econ. Manag.* **2014**, *17*, 121–150.
8. Czakon, W.; Mucha-Kuś, K.; Sołtysik, M. Coopetition strategy—What is it in for all? *Int. Stud. Manag. Organ.* **2016**, *46*, 80–93. [CrossRef]
9. Brandenburger, A.M.; Nalebuff, B.J. *Co-Opetition*; Doubleday Currency: New York, NY, USA, 1996.
10. Lado, A.; Boyd, N.; Hanlon, S. Competition, Cooperation and the Search for Economic Rents: A Syncretic Model. *Acad. Manag. Rev.* **1997**, *22*, 110–141. [CrossRef]
11. Tidström, A. Perspectives on Coopetition on Actor and Operational Levels. *Manag. Res.* **2008**, *6*, 207–218. [CrossRef]
12. Robert, F.; Marques, P.; Le Roy, F. Coopetition between SMEs: An empirical study of French professional football. *Int. J. Entrep. Small Bus.* **2009**, *8*, 23–43. [CrossRef]
13. Okura, M. Coopetitive Strategies of Japanese Insurance Firms—A Game Theory Approach. *Int. Stud. Manag. Organ.* **2007**, *37*, 53–69. [CrossRef]
14. Mariani, M. Coopetition as an Emergent Strategy. Empirical Evidence from an Italian Consortium of Opera Houses. *Int. Stud. Manag. Organ.* **2007**, *37*, 97–126. [CrossRef]
15. Ritala, P.; Hallikas, J.; Sissonen, H. Coopetitive Networks in ICT Sectors. *Int. J. Bus. Environ.* **2008**, *2*, 1–16. [CrossRef]
16. Tidström, A. Causes of Conflict in Intercompetitor Cooperation. *J. Bus. Ind. Mark.* **2009**, *24*, 506–518. [CrossRef]
17. Czakon, W. Power Asymmetries, Flexibility and the Propensity to Coopete: An Empirical Investigation of SME's Relationships with Franchisors. *Int. J. Entrep. Small Bus.* **2009**, *8*, 23–43. [CrossRef]
18. Mucha-Kuś, K. Measurable Effects of Metropolitan Gas Purchasing Group in the Light of Gas Market Functioning in Poland. *Resources* **2020**, *9*, 36. [CrossRef]
19. Mucha-Kuś, K.; Stęchły, J.; Zamasz, K. The role of coopetition in development of electromobility. *Zesz. Nauk. Politech. Śląskiej Organ. Zarządzanie* **2018**, *21*, 357–369. [CrossRef]
20. Polish Energy Policy until 2040. Available online: https://www.gov.pl/attachment/e585942a-af9a-45f6-a580-dc607b4c0d22 (accessed on 29 December 2020).
21. Act on Renewable Energy Sources 'Ustawa z Dnia 20 Lutego 2015 r. o Odnawialnych Źródłach Energii, Dz. U. 2015 poz. 478 z Późn. Zm. Available online: http://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=wdu20150000478 (accessed on 9 January 2021).
22. The Cooperative Law Act 'Ustawa z Dnia 16 Września 1982 r. Prawo Spółdzielcze, Dz. U. 1982 nr 30 Poz. 210 z Późn. Zm.'. Available online: https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU19820300210 (accessed on 9 January 2021).
23. Act on Farmers' Cooperatives 'Ustawa z Dnia 4 Października 2018 r. o Spółdzielniach Rolników, Dz. U. 2018 Poz. 2073 z Późn. Zm.'. Available online: https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20180002073 (accessed on 9 January 2021).
24. Wróbel, J.; Sołtysik, M.; Rogus, R. Selected elements of the Neighborly Exchange of Energy—Profitability evaluation of the functional model. *Energy Policy J.* **2019**, *22*, 53–64.
25. Saługa, P.W.; Szczepańska-Woszczyna, K.; Miśkiewicz, R.; Chłąd, M. Cost of Equity of Coal-Fired Power Generation Projects in Poland: Its Importance for the Management of Decision-Making Process. *Energies* **2020**, *13*, 4833. [CrossRef]
26. Tariff for Electricity Tauron Dystrybucja S.A. for 2020. Available online: https://www.tauron.pl/-/media/offer-documents/firma/taryfa-msp/gze-podstawowe/taryfa_dystrybucyjna.ashx (accessed on 17 December 2020).
27. Tariff for Electricity Tauron Sprzedaż GZE Sp. Z o.o. Available online: https://www.tauron.pl/-/media/offer-documents/firma/taryfa-msp/gze-podstawowe/01022020-gze-taryfa-sprzedaz-gze-taryfy-abcor-pdf-k.ashx (accessed on 17 December 2020).
28. Jasiński, J.; Kozakiewicz, M.; Sołtysik, M. Determinants of Energy Cooperatives' Development in Rural Areas—Evidence from Poland. *Energies* **2021**, *14*, 319. [CrossRef]
29. Energy Reulatory Ofiice. Available online: https://www.ure.gov.pl/pl/energia-elektryczna/rynek-mocy/informcjepure/9164,Informacja-nr-632020.html (accessed on 30 January 2021).
30. Draft Regulation of the Minister of Climate and Environment of 9/12/2020 on the Registration, Balancing and Sharing of Measurement Data and Settlements of Energy Cooperatives. Available online: https://legislacja.rcl.gov.pl/projekt/12333808/katalog/12687355#12687355 (accessed on 30 January 2021).