Civic Energy in an Orchard Farm–Prosumer and Energy Cooperative—A New Approach to Electricity Generation

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Abstract: In Poland, electricity production is based on nonrenewable energy sources. The energy market is dominated by corporations. Rising electricity prices and threats of power shortages have become, among others, prerequisites for the development of distributed sources based on renewable sources, primarily using photovoltaic panels. The development of the renewable energy market is slow due to the lack of legal solutions and insufficient state support. Polish farmers, especially fruit growers, whose electricity consumption costs are a significant item in production costs, may become part of the energy sector by building a local energy system. In 2022, Poland introduced two new legal regulations, which currently provide three options for obtaining electricity using renewable micro-installations. The conducted study aimed at indicating which of the legally permitted option is the most advantageous for fruit farms in Poland. Growers can produce energy by being a prosumer who settles accounts in the net-metering and net-billing system and by participating in an energy cooperative. The direction of changes was ascertained by conducting a pilot study among fruit growers. The study used real quantitative and valuable data on the consumption and costs of electricity in 2012–2022 and the production of photovoltaic panels in a fruit farm in 2021. The study consisted of comparing three models of settling accounts for electricity with two comparative models in two scenarios. The analysis of prosumers’ functioning showed that the situation in Poland is favorable for the development of civic energy. However, participation in an energy cooperative with new legal solutions will not always be the more advantageous solution in terms of economy and energy. In particular, the study showed that the support mechanism needs further changes. The results of the research confirm the existing potential of fruit farms, which can be developed in the area of securing energy needs. The results of this research can be used as the premise for introducing changes to the legal conditions for the establishment and operation of energy cooperatives in Poland.

Keywords: prosumer; energy cooperative; civic community; costs; electricity consumption; renewable energy sources

1. Introduction

Problems related to the conventional energy sector, including the depletion of conventional resources [1], an increase in the demand for electricity, and the need to reduce emissions of harmful substances into the atmosphere, have contributed to the concept of civic energy. It postulates the transformation of the energy system, which is to introduce changes in the structure of entities generating electricity. In 2015, the European Union, in its Energy Union Package [2], outlined a vision of an Energy Union in which citizens take responsibility for the energy transition, use new technologies, and actively participate in the market [3]. Instead of developing large system power plants or combined heat and power plants, a change is expected towards generation by a single citizen, a cooperative formed by a group of citizens, local authorities, local enterprises, or farms. For the first time, EU legislation also recognizes the role that community energy ownership can play in helping the EU meet its climate and energy goals [4] while fostering social innovation at
local level. In 2019, European Union institutions finalized the work on the Clean Energy for All Europeans package. The Clean Energy Package (CEP) defined two new terms: “Renewable Energy Communities” (RECs) and “Civic Communities” (CECs). The changes introduced in the directives contain provisions on community property. The Internal Electricity Market Regulation 2019/943 requires Member States to guarantee certain rights to energy communities and to create framework solutions to ensure a level playing field and promote their development. EU directives do not require specific legal forms of communities, leaving it to the Member States to decide what legal forms are to be accepted when establishing energy communities. Therefore, it should be possible for Member States to choose any form of entity for renewable energy communities, provided that such an entity may, acting in its own name, exercise rights and be subject to obligations.

Citizen energy communities may take any form of entity, such as an association, cooperative, partnership, nonprofit organization, or small- or medium-sized enterprise, provided that the entity is authorized to exercise rights and is subject to obligations in its own name. As Ceglia et al. emphasized, moreover, the main purpose of an REC is to provide environmental, economic, or social benefits to its shareholders, members, or to the local areas in which it operates, not financial gains.

Rural areas provide specific opportunities for the implementation of measures to mitigate the effects of climate change. They have the potential to significantly support efforts to move away from fossil fuels and help develop a circular economy. Farmers, including fruit growers, who have free roof areas on buildings, including cold stores and land, may become consumers and electricity producers—prosumers. Since 2019, there has been the legal possibility of establishing energy cooperatives in Poland. It is currently the only legally permitted form of collective action by prosumers. Although Poland has a long tradition of cooperative movements, as of 2022, only two such cooperatives have been registered. The developing social economy, which is a manifestation of civic activity, may restore the former meaning of the cooperative, previously associated only with socialism. The cooperation of electricity producers has developed around the world. Citizens are turning from passive consumers to prosumers, i.e., producers and consumers of electricity at the same time, connected by an intelligent network to which they sell or buy electricity.

Polish fruit growers (e.g., the largest blueberry producers or the third-largest apple producers in the world are historically associated in various forms) use energy to irrigate fields, sort fruits, load needle carts, and store fruit.

Will fruit growers, however, be interested in investing in renewable energy sources and setting-up cooperatives if so many of them negatively evaluate the cooperation within fruit and vegetable producer groups (originally classified as agricultural producer groups)? In the literature, attention has been drawn to the various reasons, including demographic, technological, organizational, and financial, for establishing cooperation but also the prosumers’ motivations for collective cooperation, pointing to their possible beneficial impact (e.g., the possibility of creating a sense of community). In turn, one of the four main factors hindering the development of joint initiatives are public policies and legislation in this area (e.g., unstable, inconsistent legislation, and nontransparent administrative procedures).

This article posed the research question of whether participation in an energy cooperative was a more economically and energetically beneficial solution for an orchard farm than individual production of electricity for a farm own’s needs, which was a prosumer. The main aim of this research was to indicate the possibilities of operating a fruit farm under the conditions of being a prosumer and a member of an energy cooperative in Poland and to identify the most beneficial solution. The specific goal was to examine how fruit growers view the possibility of creating energy communities. A pilot study among fruit growers was carried out to achieve this specific objective.

The necessary conditions for the implementation of the main objective of this research were the presentation of the principles of becoming a prosumer, conducting a legal analysis of establishing a cooperative, and a comparative analysis in terms of the effects achieved.
by a fruit farm under the situation of electricity production with a renewable energy installation (i.e., photovoltaic). This study compared three methods of settling electricity generation, i.e., by a prosumer settling in the net-metering system; a prosumer settling in the net-billing system; an energy cooperative. Eight variants of the achieved economic and energy effects were simulated under the three currently acceptable billing models and a comparative model (no RES production) in two scenarios.

This research fills a gap in the literature and methods in the following ways. Thus far, the possibility of establishing energy cooperatives by fruit farms has not been analyzed. This study presents the functioning of prosumers under the new conditions in force in Poland since July 2022 and the new rules for accounting for production and consumption by an energy cooperative and its members.

The contribution of this paper to the scientific literature is as follows. In connection with the introduction of detailed legal provisions for energy cooperatives and a new settlement system for new prosumers from 1 July 2022, three models of producers’ settlements with the electricity system operator and energy seller are presented. By using a real case, the limitations that occurred when creating and testing the effectiveness of the models are indicated, considering the principles of accounting for energy producers. They are related to a comparative model in which no electricity was produced. A comparative analysis of the effectiveness of the approaches used in each model were also carried out for the new conditions in 2022.

The article is structured as follows. Section 2 presents the importance of cooperatives in the world with an indication of the principles of operation that influenced their development. Against this background, the state of research in the field of energy cooperatives in Poland is presented. In Section 3, the source materials from which the research data were obtained and the approach adopted to the applied comparative analysis of two scenarios and four models for accounting for the consumed and produced electricity are described. They are used to obtain the results on the effectiveness of the models in Section 4, which are preceded by the results of the pilot studies on the willingness of fruit growers to cooperate and the formal conditions for the functioning of cooperatives in Poland. Section 5 presents the conclusions resulting from the research as well as recommendations as to the direction of further research towards developing the best solutions that allow members of the cooperative to account for the energy they produce or consume.

2. Background Review of Energy Cooperatives and Literature Review

2.1. The Importance of Cooperatives around the World

The importance and popularity of cooperatives around the world is evidenced by their number and diversity. In Europe, mainly in northwestern Europe, there are approximately 3500 [12] so-called renewable energy cooperatives. This number is even higher when other types of community energy initiatives are considered [13]. Currently, in the EU, at least 2 million people are involved in more than 7700 energy communities. These energy communities have contributed to up to 7% of the installed capacity in the EU, with an estimated total renewable capacity of at least 6.3 GW [14]. It is easier for those operating within the cooperative to conduct their activities using methods oriented towards environmental protection, take actions to limit the effects of climate change, and use alternative energy sources. Around the world, cooperative activity enjoys varying degrees of interest [15]. Especially in the European Union, apart from Poland, energy cooperatives play a significant role [16]. The tendency to set-up and operate them each time depends on the legal conditions of their functioning. The mismatch of the created laws, contradictions, or loopholes in the law contribute to limiting or even inhibiting their development [17].

These entities operate in a legal form depending on a given legal system, and they have a diversified structure and objects of activity. Hence, the energy cooperatives described in the literature, operating in a legal order typical of Anglo-Saxon countries, are entities that differ significantly from those operating in countries based on a continental legal system [18].
The leaders in the concept of civic energy and energy cooperatives are Denmark, Germany, the Netherlands, Austria, and Belgium [11].

In Denmark, many different types of legal structures apply to energy and utilities companies, and partners in the energy community can be individuals, homeowners, cooperatives, public institutions, shops, and small businesses. This can be an inspiration in choosing the form of company law most suited to the tasks and decisions to be dealt with by the energy community. Usually, a distinction is made between nonprofit and for-profit organizations. The latter type of company provides its participants with a financial profit, for example, through lower energy prices or revenues from energy sales. The energy community’s partners can each contribute their energy installations, and they can invest in and operate energy installations under the umbrella of a joint venture. The latter kind of company is intended to provide a financial gain for its participants, for example, through lower energy prices or revenues from the sale of energy.

In Denmark, one of the recommended legal forms is a cooperative [19]. The second recommended legal form is an association. In these forms, it is essential that the association is established with limited liability. The statutes of the cooperative and the association can contain the provisions which the EU Directives require for energy communities. According to the assumptions of the EU, the statutes should specify the partners involved: citizens, housing societies, institutions, municipalities, and small businesses.

Associations have a less institutional character than a cooperative company. The association is organized based on the specific agreements among the members and is thus more open and flexible to be specifically adapted to the tasks of an energy community than a cooperative form. It is relevant that these commercial actors also have limited liability, meaning that no partner is personally liable.

The idea of cooperatives is one of the main reasons why energy cooperatives in Germany are so closely connected with the energy transition and locally generated energy [20]. Today, cooperatives are an important part of the German economic system [21]. Although the number of economic activities in the form of cooperatives has decreased, from approximately 26,000 in 1950 [21] to 6871 in 2021, the cooperative system has 22.7 million members [22]. Statistically, every fourth German citizen is a member of a cooperative [22], and 835 energy cooperatives constitute 12% of all cooperatives [22]. Of the 200,000 members, as many as 95% are natural persons, which is why they are often referred to as civic energy cooperatives. It is not a legal term, and there is no such term in German law. The remaining members of energy cooperatives are banks and enterprises (2%), farmers (2%), and municipalities (1%) [22]. The share of cooperatives in the production of electricity from RES is 3.5% [23]. In Germany, 95% of energy cooperatives operate in the field of energy production from RES, with the most common production of energy from photovoltaic cells (photovoltaic cooperatives accounted for 83% in 2019).

Energy cooperatives operate at all levels of the energy supply, except for the level of the transmission grid. Some cooperatives only buy and sell energy, others buy and distribute it [24].

A cooperative is a legally regulated form of economic activity that is driven, unlike other forms of business, by values that go beyond economic benefits [25]. This gives the cooperative a certain social dimension, which seems to be particularly valuable in the context of meeting social needs related to renewable energy technologies and, consequently, the implementation of the energy transformation [25]. From the outset, the cooperative’s activity is also aimed at mutual assistance without involving third parties such as the state or banks [26]. A cooperative aims to promote the common interests of its members, and these interests must be related to a specific activity. It is not an attractive form when it comes to maximizing the return on investment. An energy cooperative in Germany is not a separately defined legal entity, it operates based on legal norms applicable to cooperatives [27]. By being entered in the cooperative’s register, it becomes a legal person [27]. To establish a cooperative, three members are enough, which may be, as long as the statute of a given cooperative does not derogate from general legislative regulations, both natural and legal
persons, associations other than legal persons, as well as housing communities and heirs’ communities [27]. Legal persons under public law (i.e., communes and powiats) may also be members of a cooperative [27].

Commune citizens may become direct members of a cooperative by taking up cooperative shares. Minimum investment amounts make it possible to buy relatively low-risk shares for broad social groups [28].

The cooperative members are prosumers only in the economic sense of the word. From the point of view of German energy law, however, neither the members nor the cooperative—with the exception of only a few constellations—are perceived as prosumers.

Civic energy cooperatives operating as operators of photovoltaic systems produce electricity and then feed it into the grid, receiving, in return, a feed-in tariff under the German RES Act [29]. However, the model of energy cooperatives in Germany, the operator of photovoltaic systems, for an extended period of profitable business model, is losing its attractiveness due to the falling feed-in tariffs [29]. Although the profit of a cooperative is subject to corporate income tax on general principles, there is a so-called “compensation” payable by the cooperative to its members for the remittance of income to members from transactions with them. The compensation is treated as a tax-deductible cost and, thus, reduces the cooperative’s taxable income. However, if all of the cooperative’s income comes from transactions with its members and is distributed entirely on a “compensation” basis to its members, then the cooperative does not pay any income tax at all. Cooperatives offer an interesting socioeconomic business model that also helps to overcome institutional and systemic gaps including national policies, enterprises, organizations, and human capacity. Especially in isolated communities, managing the demand side, based on a combination of cooperative action plans, independent of load control equipment installation or user knowledge, minimizing energy production costs and community discomfort is important [30].

In the United States, in the 19th century, when only large cities were covered by the electrical grid and rural households did not have access to emerging central systems, it was energy cooperatives that allowed rural households to access electricity. Today in the United States, energy cooperatives serve 12% of the population and have over 40% of the power distribution networks. Moreover, due to the decentralized nature of rural electrification, 80% of electricity production comes from renewable sources [31]. In the USA, there are 63 production and transmission cooperatives supplying wholesale electricity from their own generation installations to 831 distribution cooperatives, which are the backbone of the network of electrical cooperatives [32].

In addition, in Great Britain, the generation of electricity has long dominated the community energy sector in terms of the size of implemented projects. Although the pace of production capacity growth is declining year by year, by 2.4% from 2017 to 2021, the steady increase in the last few years, despite the feed-in closure and the global pandemic, indicates the resilience of the sector and the involvement of people in working with them. Of the 495 identified community energy organizations, 57% were registered as social welfare societies (BenComs), cooperatives, or community service partnerships, and the remainder were mainly composed of limited liability companies, charitable groups, or unincorporated community groups involved in energy activity. Approximately 70% of the organizations operating in the sector were fully supported by volunteers. However, there is now strong support for legislative changes enabling the local supply of electricity produced by community-owned energy projects and calls for more help from local authorities including more supportive planning policies and constructive cooperation and incentives [33]. A multicriteria analysis by Francesco Demetrio Minuto et al. showed that the diffusion of condominium energy communities alone does not guarantee the pursuit of the European Union’s decarbonization roadmap. Suppose that the purpose of a condominium energy community is not well channeled to citizens by giving them other additional incentives such as economic ones. In this case, they may still opt for the economic benefits over the environmental one [34].
In the last three years, Greece has seen a sharp increase in renewable energy, mainly from solar energy, thanks to newly formed energy communities or cooperatives, mainly in areas where lignite mines and thermal power stations have been closed. Since the adoption of new regulations (i.e., since 2018) governing this area, 1036 energy communities have been established in Greece. The energy communities in Greece use a total of 466 MW in renewable energy and cogeneration units [35]. Until 2018, only 10% of farmers were associated with farmers’ cooperatives, but the provisions on energy communities adopted in Act 4513/2018 created the conditions for development. They define, among others, the subject of their activity, the minimum number of members, and the rules for acquiring shares and distributing the surplus. Natural persons, legal persons under private law, and legal persons under public law, including local government units, may become members of energy communities. An energy community may consist of five, three, or two members. The rules also establish the criteria for the location of members. Regarding capital formation, members have compulsory participation in the capital of the cooperative. However, they may also acquire one or more voluntary shares, which may not exceed 20% of the total capital of the cooperative. This limit is higher when local authorities purchase such voluntary contributions. Regarding the distribution of profit, Art. 6 L. 4513/2018 uses the term “surplus” to describe the economic result of a given year [36]. This article provides two different systems for distributing surpluses; thus, energy communities are divided into two categories: not-for-profit and profit oriented. Common to both categories is the requirement to allocate at least 10% of the surplus to reserve capital. In particular, the first system prohibits the remainder of the surplus from being distributed among the members. Instead, they create a reserve fund to meet the goals. In contrast, the second distribution system (i.e., for-profit) stipulates that the remainder of the surplus (after a deduction of 10% for the fund) may be paid to members, provided that the energy community is composed of at least 15 members or ten members in island regions with a population of fewer than 3100, and where 51% of the members are natural persons, not legal entities. Most of the organizations in the sector have been set-up for profit [35].

The analysis of the principles of the functioning of cooperatives around the world shows that they have become an attractive form of cooperation for obtaining energy; if the number of founders is small, which facilitates cooperation, the legal form guarantees the personal liability of its members and guarantees profits, and investments do not require significant expenditure on the part of its members.

2.2. Prosumers and Energy Cooperatives in Poland

Rightly noted by Wróbel J., Soltysik M., and Rogus R. [37], one of the solutions consistent with community recommendations, which at the same time does not constitute an excessive burden for the national economy and legal order, is to use the potential of micronetworks of local communities striving for energy independence based on their own energy sources and regulations enabling neighborly energy exchange.

In Poland, even though the cooperative movement [15] boasts over 200 years of tradition and has been associated with agriculture from the very beginning [38], only two energy cooperatives have been registered as of 2022 [39]. After the political transformation after 1989, there was a period of aversion to entities associated with socialism. Its essence is incomprehensible on a mass scale, just as it is in the case of creating producer groups [17]. Despite this, Polish citizens have taken over the responsibility for the energy transformation. At the end of 2021, the number of prosumer micro-installations amounted to 854 thousand, with a total capacity of 6071 GW. At the end of May 2022, all micro-installations connected to the DSO distribution network amounted to over 1 million 104 thousand, and their power exceeded 8.1 GW [40]. The increase in newly installed prosumer capacities were related to subsidies, personal income tax allowances, or agricultural tax allowances, and the change in the net-metering settlement system [41] to net-billing [42]. In the net-metering system, from the date of connection to the power grid for 15 years, the prosumer may account for the energy produced and not consumed by them in twelve-month periods, using the principle
that 70% or 80% of the amount of energy fed into the grid will be obtained from 10 MW and above. After six years of the described rule being in force, the rules were changed. The prosumer billing system was replaced by “net-billing”. In this billing model, the value of electricity introduced by the prosumer to the electricity distribution network will be settled against the value of electricity collected from this network to use for their own needs. The energy fed into the grid will be billed at the monthly market price of electricity.

Frequent changes to the legal provisions, their ambiguity, or their lack, as was the case in the absence of rules for settling cooperatives [43], inhibit the development of cooperatives in Poland. The research shows that despite the benefits of the net-metering mechanism [44], the Polish RES Act was amended. This mechanism does not allow surplus energy to be resold to the market and to generate revenue, but it is not completely free. It requires investment in renewable sources and, in the event of energy overproduction, 20% or 30% is taken over by the seller who settles accounts with the distribution system operator to cover their operating costs.

Jasiński, Kozakiewicz and Soltysik [45] attempted to answer the question regarding the structure of electricity production and consumption and the number of members at which the operation of an energy cooperative would be economically justified, considering the limitations and conditions arising directly from Polish law for individual prosumers and cooperatives energy. The subject of the analysis was the economic benefits of the operation of energy cooperatives, and the results led to a conclusion regarding the possible profitability of establishing and operating a cooperative. However, in the construction of a cooperative model and the subsequent economic analysis, investment outlays, which are crucial in the investment profitability analysis, was not considered. Due to the method of accounting for the surplus of energy produced as of the day of the research, it was justified to assume that more members in the cooperative to “synchronize” the amount of energy produced and consumed at a given moment in order not to discharge the surplus energy into the grid, the greater will be the economic effects of the energy cooperative [45].

The conclusions from this study indicated that to maximize the profit of small cooperatives, members should be selected with a similar aggregate energy demand, whose daily or weekly profiles are negatively correlated to the greatest possible extent. In the case of larger cooperatives, the aggregate energy demand may vary significantly, but the correlation of trends in annual demand should be as close as possible to 1. In each case, one should strive to diversify generation sources, and optimal results were obtained for cooperatives that had a small hydroelectric power plant and a wind power plant but with a production share not exceeding 30%. The proposed arrangement of devices, including water use, will not be conducive to developing cooperatives in Poland. The research cited by the authors also did not indicate what the number of cooperative members should be to achieve the maximum profit from its activities. The audit did not cover the financial aspects, i.e., capital expenditure and operating costs. The simulations did not consider the market conditions including the current prices of electricity, transmission and distribution fees, energy storage, and e-mobility chargers.

M. Wrocławski [46] aimed to look at the internal settlements of the cooperative to determine the average cost of energy achieved in the process of cooperative operation and the benefits for cooperative members. The researcher presented a case study of the settlement of an energy cooperative that was established within the previously established energy cluster. The cooperative consisted of producers with a diversified profile of generation sources: three wind turbines, two PV farms, and prosumers. Unfortunately, in the presented case study, the formal conditions for the functioning of the cooperative was not maintained. Pursuant to Polish law, energy cooperatives cannot sell electricity to entities other than its members.

In Poland, 80% of prosumers use photovoltaics [40]; therefore, the results of the research by Wójcicki [47] seem to be important, as he drew attention to the essence of dimensioning photovoltaic installations and their appropriate adjustment to the annual demand for electricity. The results of the author’s research show that it is possible to
increase the power of the installation, but it was associated with a reduction in the yield per kW of installed power or it was necessary to use additional areas (elevation, roofed car parks, garages, etc.). However, 20 kW PV was enough to generate electricity an amount corresponding to approximately one-third of the annual demand of consumers. Along with the further increase in the power of PV installations, the ratio of energy used for self-consumption to the energy fed into the grid decreased; thus, for larger installations, it becomes increasingly important to adjust the consumption profile to the source generation profile (i.e., use of IoT technology).

Popczyk and Bodzek [48] indicated the directions of change and the resulting need to create a new investment allocation strategy in the energy sector. The authors analyzed the confirmation of the importance of energy cooperatives in the process of the country’s energy transformation. Modern low- and medium-voltage networks in rural areas should be transformed into prosumer networks (within the population and local government segment), cooperative, and cluster networks; large cities (i.e., 100–500 thousand inhabitants) into prosumer and cooperative networks. In rural areas, fruit growers can become energy producers with significant power requirements.

3. Materials and Methods

The conducted research was a continuation of the considerations of reducing the costs of orchard activities. Therefore, references were made to the research results on the structure of costs of orcharding activities and the impact of installed photovoltaic panels on their amount [49]. In 2018, energy costs accounted for over 6.4% of the cost of an orchard.

The costs of fruit production depend on many factors such as weather conditions, unfavorable weather phenomena, and the severity of diseases or pests used for producing varieties with different rootstocks and on different types of soil. The cost level depends on the farm’s performance. Difficulties in maintaining the comparability of the conditions of incurring costs between farms and the lack of data on the number and power of cooling devices in Poland influenced the applied research methods and the appropriate research approach.

The study included an entity classified as large in Poland, with an area of 33 ha. It was an exemplary and representative object in its group. In Poland, 73% of the cultivated area of fruit trees and shrubs are apple trees and, therefore, in terms of the type of fruit cultivation, an orchard farm is a typical orchard. However, 12.7% of large farms in Poland cultivate fruits with an area of more than 30 ha [50]. This study used information on the annual electricity consumption of an orchard farm broken down into individual accounting periods. The data came from ten full years of operation, i.e., 2012–2021. The first settlement period of each calendar year covered approximately 3 weeks, while the last settlement period of the calendar year was longer than a month. Thus, until October 2020, the billing period did not coincide with a full calendar month. From November 2020 (i.e., from the moment when the farm became a prosumer), the settlement period was one month. The farm had 29.92 kW photovoltaic devices installed; the tariff was C12a. The study used the actual amounts of electricity obtained in 2021 from the installed devices and the actual consumption and costs incurred in connection with energy consumption in 2012–2021.

To achieve the aim of the research, which was to indicate which of the possibilities of generating energy was the most advantageous for the grower, the solutions proposed in the law concerning the settlement of cooperative members were used. The mechanism of supporting producers was analyzed, and the impact of the changes in the rules for prosumers’ settlement and the newly introduced rules for cooperatives on the levels of consumption and costs of electricity for a farm were presented. The study’s approach was as follows.

The following were adopted for the simulation of the possible benefits:

- Four models;
- Two billing scenarios with a different approach to electricity purchase prices.
To compare the changes in the rules for settling prosumers, a division of entities was introduced for those prosumers who settled accounts using the previous act on renewable energy sources and for those who were billed under the new rules, introduced under the new act. The first entity was marked as “old prosumer” and the second as “new prosumer”. From 1 July 2022, the old prosumer may resign from the current rules for settling accounts with the seller and switch to the new net-metering system.

Electricity consumption and production were settled with the seller and the distribution network operator in the model:

- A prosumer settling accounts with the seller in the net-metering system, the so-called old prosumer;
- A prosumer settling accounts with the seller in the net-billing system, the so-called new prosumer;
- Energy cooperatives;
- Comparative in the absence of energy production for their own needs (no RES installations).

Two billing scenarios with a different approach to electricity purchase prices presents Table 1 with a schematic approach to the study.

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Source: Own study.

Electricity generated in a given renewable energy source installation benefits from settlements constituting a support mechanism when the old prosumer and an energy cooperative produced it. Prosumers’ support for producing energy from renewable energy sources using the so-called discount mechanism was based on noncash (quantitative) settlement of surplus electricity generated in a micro-installation and fed into the power grid and energy consumed by a prosumer. In the case of a prosumer, the energy billing depended on the power of their installation and was carried out at a proportion of 1:0.7 in the case of micro-installations greater than 10 kWp (model 1). In the case of cooperatives, settlement with the use of the discount mechanism took place at a quantitative ratio of 1:0.6 (model 3).

There were three parties involved in the mechanism of supporting the production of electricity from renewable energy sources in an energy cooperative or its members: an energy cooperative; seller; operator of the distribution system (Figure 1).

For an energy cooperative, the amount of electricity introduced into the electricity distribution network by an orchard farm was accounted for as if it were introduced by all producers in relation to the amount of electricity taken by electricity recipients from this network in order to use it for their own needs and its members—after prior summary balancing of the amount of energy introduced and taken from the distribution network from all phases for three-phase installations or micro-installations at prosumers. Unused electricity in a given billing period was transferred to subsequent billing periods but for no longer than the next 12 months from the date of introduction of this energy into the grid.

For the old prosumer, the amount of electricity introduced by them into the electricity distribution network would be settled against the amount collected for consumption for their own needs. For a new prosumer, the calculated amounts would be used to calculate the settled value.
In all three models of settlements between the seller and the parties (i.e., old, new, and cooperative prosumer), they would be carried out on the basis of the total balanced amount of energy, which was determined for a given hour using the vector method, according to the following formula:

\[ Eb(t) = Ep(t) - Ew(t) \]  \hspace{1cm} (1)

where:
- \( Eb(t) \) — Total amount of energy balanced in hour \( t \), expressed in kWh, billed in a given billing period;
- \( (+) \) — Positive value means the amount of electricity consumed in a given hour \( t \) from the electricity distribution network;
- \( (-) \) — A negative value indicates the amount of electricity introduced at a given hour \( t \) to this network;
- \( Ep(t) \) — The sum of all phases of the amount of electricity consumed in an hour \( t \) from the power distribution network, expressed in kWh;
- \( Ew(t) \) — The sum of all phases of the amount of electricity introduced in hour \( t \) to the power distribution network, expressed in kWh.

In scenarios 1 and 3, in the billing period, the amount of electricity introduced and taken from the grid was billed in accordance with the following formula:

\[ Er(o) = Ebp + (Eb_w \times Wi) + Er(o-1) \]  \hspace{1cm} (2)

where:
- \( Er(o) \) — The amount of energy billed as fed into the grid or taken from the electricity distribution grid in a given billing period, expressed in kWh;
- \( Ebp \) — The sum of the amount of summarily balanced energy from all hours \( t \) of the billing period for which the result of the summary balancing is positive, marked with the symbol \( Eb(t) \) in Formula (1), expressed in kWh;
- \( Ebw \) — The sum of the amount of summarily balanced energy from all hours \( t \) of the billing period for which the result of the summary balancing is negative, marked with the symbol \( Eb(t) \) in Formula (1), expressed in kWh;
- **Er(o−1)**—The amount of electricity not used by the prosumer in previous billing periods, settled in the current billing period for which the billing value is negative, expressed in kWh;
- **Wi**—Quantitative ratio, equal to 0.7 for installations, with a total power greater than 10 kW.

The new prosumer was billed based on the total amount of energy balanced in terms of the difference between the value of electricity fed into the grid and the value of electricity taken from it for consumption.

The value of the introduced energy was determined for each month and was the product of the sum of electricity introduced in individual imbalance periods (t) making up a given calendar month, marked with the symbol Eb (t), assuming negative values, and the monthly market price of electricity determined for a given month. This was the average of the market prices of electricity, i.e., the volume-weighted average of electricity prices specified for the Polish market area for all trading sessions of a given day in the single-price auction system on the day-ahead markets.

The old prosumer and the energy cooperative did not pay on the billed amount of electricity:
- To the seller, fees for its settlement;
- Charges for the distribution service, the amount of which depended on the amount of electricity consumed.

The new prosumer paid fees to the seller in connection with the conclusion of a comprehensive contract with him, the amount of which depended on the amount of electricity consumed in accordance with the DSO tariff.

Regarding the amount of electricity generated in all installations of renewable energy sources of an energy cooperative and then consumed by all electricity recipients of an energy cooperative, including the amount of billed electricity, the following was not calculated and collected:
- RES fees;
- Power fee;
- The cogeneration fee.

For each billing model, two analytical price scenarios were built, covering the annual billing periods. For both scenarios, actual quantitative data on production, consumption, and electricity fed into and off the grid for 2021 were assumed.

For the first scenario, the energy purchase prices and distribution fees applicable in 2021 according to the tariff in accordance with the comprehensive agreement for the holding and the average monthly energy prices of the day-ahead market (DAM) on TGE were applied in 2021.

In the second scenario for the first 6 months of the billing period, energy purchase prices and distribution fees according to the tariff in accordance with the comprehensive farm agreement in force in the first half of 2022 and the average monthly energy prices on the TGE DAM in the same period were applied. On the other hand, for the second half of the annual settlement period in the second scenario, the level of prices and rates for the purchase of electricity and distribution fees was adopted in line with the changes introduced by the energy supplier to the tariffs [51–53] and forecast by CA [54] DAM energy price level.

The results of the three models in the first and second scenarios were compared to the fourth comparative model in which electricity was not produced.

The assumptions for building the models in the individual scenarios are presented in Table 2. Table 2 presents the four billing models in the two price scenarios; in total, eight possible were adopted for comparative analysis, including six models of electricity production for their own needs and two comparative ones.
The analytical study was preceded by a survey which aimed at identifying the tendency of fruit growers to cooperate within the cooperative. It was interesting to know if farm producers would want to cooperate in the future.

Table 2. The modeling approaches.

<table>
<thead>
<tr>
<th>Model</th>
<th>no RES installation comparative model</th>
<th>Prosumer net-metering model</th>
<th>Prosumer net-billing model</th>
<th>Energy cooperative member model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy consumption (demand) reference data</td>
<td>2021 actual energy purchase + RES production actual</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy production</td>
<td>Y2021 RES production actual</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy purchase prices references</td>
<td>2021 actual + changes applicable</td>
<td>2022 actual + changes applicable</td>
<td>2021 actual + changes applicable</td>
<td>2022 actual + changes applicable</td>
</tr>
<tr>
<td>Energy sale prices references</td>
<td>2022 WAP D-AM actual + forecasted</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Own study.

To determine whether fruit growers would be interested in establishing and participating in a cooperative, at the turn of 2020/2021, a pilot study was carried out among fruit growers. From November 2020 to March 2020, a pilot study was conducted among fruit growers using social media.

4. Results
4.1. The Willingness of Fruit Growers to Cooperate

The data showed that in the 2021, there were only 132 fruit groups, and in the year 2007, there were 321 [55]. There are also fewer fruit and beekeeping cooperatives, but the number of producers declaring fruit crops in 2019 was 68,815 thousand [49]. The bulleted lists looked like this:

- Are you currently a part of a producer group?
- Please indicate at least three reasons why you are not a part of a group production.
- Would you become a member of a cooperative if membership provided benefits to the farm in the form of cost reduction or other economic or social benefits?
- Do you think fruit growers can cooperate with each other?

Eighty-eight answers were obtained from the questions asked. The results of the pilot studies showed that most of the fruit growers did not belong to a group of producers: thirty respondents confirmed that they belonged to a producer’s group (34.09%), and fifty-eight did not belong to a producer’s group (65.91%).

The respondents indicated the reasons why they did not belong to a group of producers. Most often, the respondents indicated that you did not have to belong to one to cooperate with it (37.5%). The second most frequently chosen answer was that they provided sales on their own (29.55%). The third reason producers did not sell fruit to producer groups was an unfavorable way of sorting fruit (26.14%). Bad experiences with cooperation indicated nearly twenty-four percent (23.86%), and, at almost the same, was too low of a price offered by the producer’s group (22.73%). Approximately twenty-two percent (21.59%) of respondents also indicated concerns regarding nonpayment. In addition, producer groups offered too long of payment terms for the products sold to them (11.36%).

Figure 2 shows the answers to the third question (Q3): Would fruit growers want to become members of a cooperative if membership provided benefits for the farm in the form of cost reduction or other economic and social benefits?
Figure 2. Answers to the survey question Q3.

The results obtained indicated that 75% of fruit growers could become members of the cooperative if it would bring them benefits, 49% stated probably. According to the respondents, 37.5% of fruit growers were rather not able to cooperate, and one-fourth of respondents were definitely not capable. When asked about the ability of fruit growers to cooperate (Q4: Are fruit growers able to cooperate with each other?), 72 people in total chose a negative answer, and only 16 people (18.18%) chose a positive answer (Figure 3).

Figure 3. Answers to the survey question Q4.

The obtained results of the questionnaires were not satisfactory if it is planned to develop the cooperation of fruit growers within the framework of energy cooperation. Most of fruit growers have cold storage buildings, and some already have solar panels installed (14%).

4.2. Formal Conditions for the Functioning of a Cooperative in Poland

4.2.1. Types of Cooperatives

Currently, the end-user producing electricity only from renewable energy sources for their own needs using a micro-installation may become a prosumer of renewable energy. It is an installation with a total installed electrical capacity of no more than 50 kW, provided that in the case of a final customer who is not a household electricity consumer, it is not the subject of the predominant economic activity [36]. The issues raised in the definition
require clarification. Such a formulation, such as constituting of the predominant activity, is not unambiguous. The rules determining the predominant activity have not been specified in the legal regulations. The criterion for determining this advantage has not been specified, whether it is to be determined on the basis of revenue, cost, income, or otherwise, e.g., not in a quantitative manner.

Farmers, including fruit growers, can therefore produce electricity in micro-installations. An energy cooperative can also become a prosumer. An energy cooperative may operate in accordance with the provisions of the Cooperative Law Act or in accordance with the provisions of the Act on Farmers’ Cooperatives.

An analysis of the legal provisions shows that cooperatives can be divided into four types, including three operating in accordance with the provisions of the Cooperative Law Act—on general or specific principles provided for with agricultural production cooperative [50] and one type operating in accordance with the Act on Farmers’ Cooperatives [51] (Figure 4).

**Figure 4.** Classification of cooperatives due to the presence of legal regulations.

The type of cooperative influences the way it is established and operates including the subject of activity and the number of founders.

### 4.2.2. Founders and Members of the Cooperative

If an energy cooperative operates in accordance with the provisions of the Cooperative Law [56], the number of founders may not be less than:

- Ten natural persons;
- Three legal persons;
- Five natural persons in agricultural production cooperatives;
- Five natural persons and legal persons running a farm within the meaning of the provisions on agricultural tax or conducting agricultural activity in the field of special departments of agricultural production solely for the purpose of organizing themselves into groups of agricultural producers or in preliminary recognized groups of fruit and vegetables producers and recognized fruit producer organizations and vegetables (Article 6 § 2 and § 2a of the Cooperative Law Act).

Only farmers, the number of which may no fewer than ten, can be founders of a cooperative of farmers [57]. The founders of the cooperative who signed the statute become members of the cooperative upon its registration, upon their acceptance by the cooperative.

The number of members in each cooperative is at least the same as that of the founders, unless the statutes require more members to be farmers. For members, the situation is slightly different than for the founders.

The members of an agricultural production cooperative may be farmers who are owners or independent holders of agricultural land, tenants, users, or other dependent
holders of agricultural land. They can also be other people with qualifications useful for working in the cooperative.

In addition, in a farmers’ cooperative, members may be farmers or nonfarmers. Farmers operate a farm within the meaning of the provisions on agricultural tax or conduct agricultural activity in the field of special departments of agricultural production. Farmers are producers of agricultural products or groups of these products.

Entities that are not farmers conduct activities in the field of storage, warehousing, sorting, packaging, or processing of agricultural products, groups of these products, produced by farmers, or service activities supporting agriculture, including the provision of services to farmers with the use of machines, tools, or devices for the production of by these farmers of agricultural products or groups of these products.

A farmers’ cooperative is established due to the fact of agricultural products and groups of these products including fruit [58].

4.2.3. The Object of Activity of an Energy Cooperative

The subject of activity of energy cooperatives is the production of electricity in renewable energy source installations and balancing the electricity demand, including for the own needs of an energy cooperative and its members, connected to an area-defined power distribution network.

Each type of cooperative conducts an economic activity based on an economic calculation with benefits for the members of the cooperative.

The predominant activity of an agricultural production cooperative (agricultural production cooperative) is running a joint farm and activities for the benefit of individual farms of the members, but the cooperative may also carry out other economic activities. Apart from an agricultural production cooperative, other cooperatives may be established, the basic subject of which is running a joint farm (Art. 178 § 1) [56].

On the other hand, the subject of an activity of a farmers’ cooperative [57] is to conduct business activities for members of the cooperative in the following areas:

- Production planning carried out by farmers and adapting it to market conditions;
- Concentration of supply and organizing the sale of products produced by farmers;
- Concentration of demand and organizing the acquisition of the means of production necessary for farmers.

A farmers’ cooperative may conduct business activities related to storage, packaging, standardization, processing, and marketing of products produced by farmers. A farmers’ cooperative may provide farmers with services related to the production and sale of their products and may disseminate among its members environmentally beneficial cultivation methods, production technologies or waste management methods. A farmers’ cooperative may also provide other services to its members, but the revenues from conducting this other activity may not, in total, exceed 25% of the farmers’ cooperative’s revenues obtained in a given financial year. For the provision of other services, billing with members as part of their or their generation of electricity may qualify.

A comparison of the subject of activity of a farmers’ cooperative and an agricultural production cooperative show that their scopes are not the same. A farmers’ cooperative does not have to run a farm, it does not have to produce agricultural products, but its founders must be farmers. A farmers’ cooperative conducts activities supporting the production, storage, and sale processes of agricultural products of the cooperative’s members. On the other hand, an agricultural production cooperative carries out activities with the use of a farm. There may also be other economic activity. However, if the subject of the activity of an energy cooperative is only the production of electricity, Polish law does not allow the establishment of an agricultural production cooperative. An energy cooperative would have to be established by five farmers and would have to run a joint farm. If there are at least ten founders, an energy cooperative may operate on general principles according to the cooperative law. Moreover, if the founders of an energy cooperative are ten farmers, they can set-up a cooperative according to the law provided for farmers’ cooperatives.
4.2.4. Types of Cooperative Capitals

A comparison of the equity of individual cooperatives shows that they differ in terms of the type and method of formation. The basic own funds created in each cooperative are the share fund and the resource fund (art. 78 § 1, art. 167 § 1) [56]. The farmers’ cooperative also creates a third basic own fund—the mutual fund. The value of the created fund is the cash accumulated on the account of the mutual fund, which is allocated to the development and promotion of farmers’ cooperatives. Each cooperative also creates other own funds provided for in separate regulations and in its statute.

A member of a cooperative is obliged to declare one share, if the statute does not oblige to declare a larger number of shares (Article 20. § 1 of the Cooperative Law Act) and to make payments for the shares. The statute may provide for members to make contributions to the ownership of the cooperative or to be used by the cooperative based on another legal relationship, e.g., lending, lease, rental, leasing. In this case, the statute should specify the nature and scope of the cooperative’s right to contributions, the number of contributions and their type, if they are in-kind contributions, the deadlines for their payment, the principles of valuation and return in the event of liquidation of the cooperative, withdrawal of a member or termination of membership for other reasons, and also in other cases provided for in the statute (Article 20 § 2) [56].

Specific provisions for agricultural production cooperatives stipulate that the statutes of a cooperative may provide that a member who owns land is obliged to contribute it in whole or in part as a contribution to the cooperative (Art. 141 § 1 of the Cooperative Law Act). The ground contribution may be the ground, buildings or their parts and other devices permanently connected with the ground, located on the land at the time of their bringing in, i.e., biogas plants or photovoltaic panels or other devices to produce renewable energy. The use of land contributions by the cooperative is payable, i.e., the cooperative should pay the remuneration due for the equipment contributed by the member. The articles of association define the principles of remunerating for the use of these contributions.

The statute of an agricultural production cooperative may oblige its members to make a specific financial contribution. Because of this contribution, the cooperative may accept the means of production, such as seed, equipment, machines, and tools useful for the common farm. These funds are assessed according to the condition and prices on the day of payment. The cash contribution as well as the means of production contributed to it are converted according to the rules set out in the statute. This contribution bears interest in the amount specified in the statute, and the payment of interest on the cash contribution takes place once a year on the date also specified in the statute. The interest due for a given year may be counted towards increasing the member’s financial contribution (Art. 152). In the event of termination of membership, the cash contribution is returned.

In accordance with the general part of the Cooperative Law Act [56] and the Act on Farmers’ Cooperatives [57], a cooperative member has the right, inter alia, to participate in the balance sheet surplus (i.e., the cooperative’s net profit (gross profit less income tax and other obligatory charges resulting from separate statutory provisions)) and to the benefits of the cooperative in the scope of its statutory activity.

The balance sheet surplus is subject to division based on a resolution of the general meeting. At least 5% of the balance sheet surplus should be allocated to increasing the resource fund if this fund does not reach the amount of the contributed obligatory shares. Part of the balance sheet surplus, remaining after the write-off, is allocated for the purposes specified in the resolution of the general meeting.

The rules for the distribution of the balance sheet surplus among the members of the cooperative are set out in the statutes. If the shares declared by the member have not been fully paid in, the amounts due to the member in respect of the distribution of the balance sheet surplus shall be credited to its incomplete shares.

If a part of the balance sheet surplus is to be distributed among the members in the form of interest on shares, this division includes former members (their heirs) who have claims for the payment of shares.
In the farmers’ cooperative, the balance surplus is allocated to the resource and mutual funds, and the remaining part, after these write-offs are made, is allocated for the purposes indicated in the resolution of the general meeting. The general meeting of farmers’ cooperatives may allocate part of the balance surplus of the farmers’ cooperative to interest on contributed shares (Article 14 of the Act on Farmers’ Cooperatives) [57].

A member of a farmers’ cooperative who is the owner of the in-kind contribution made to the farmers’ cooperative may dispose of it, however, of the intention to sell such a contribution, he is obliged to notify the farmers’ cooperative in writing, at least 12 months before the intention to perform this activity, unless the statute specifies an earlier date to do so [57].

Specific provisions for agricultural production cooperatives are set out in Art. 154a [56] that the statutes of the cooperative may provide for an increase in cash contributions from general income. In such a case, the statute also specifies the rights of the members to withdraw part of the contribution from the write-offs during the term of membership.

When considering the establishment of this type of cooperative, it should be remembered that a member of the cooperative who is able to work has the right and obligation to work in the cooperative in the amount determined annually by the management board, according to the needs resulting from the cooperative’s business plan. Members are remunerated for their work in the form of a share of divisible income according to their contribution to the work.

General income is subject to distribution based on a resolution of the general meeting. The cooperative allocates at least 3% of its total income to the resource fund, if this fund does not reach the amount of the obligatory shares contributed [56]. Part of the general income, created after deductions for increasing contributions, the share and resource fund, is divisible income to be divided between members and household members due to the performance of work.

The cooperative law provides that a member of a cooperative participates in covering its losses up to the amount of the declared shares [56]. The balance sheet losses of the cooperative are covered in the first place from the resource fund, and in the part exceeding the resource fund from the share fund and other own funds of the cooperative according to the order established by the articles of association. Should own funds be insufficient to cover the losses, members may be required to pay up the shares earlier than provided for in the articles of association.

Balance losses incurred in the farmers’ cooperative are also covered from the resource fund, and in part exceeding the resource fund from other own funds of the farmers’ cooperatives, except for the mutual fund, in the manner and under the conditions specified in the statute. If the losses incurred during the financial year could not be covered in this way, they may be covered in the following five financial years consecutively.

Table 3 presents the types of funds of the three cooperatives and their sources of supply.

4.2.5. An Energy Cooperative Is a Prosumer

One possibility of ensuring the supply of electricity to the farm is to obtain the title of a prosumer, and the other option is the participation of a farmer—a grower—in an energy cooperative. Who can get the status of an energy cooperative? It can be obtained by the cooperative which will function according to the general rules provided for one of the four discussed types of cooperatives. To obtain the status of an energy cooperative, each cooperative must meet the relevant criteria (Art. 38e. 1) [41]. The first criterion for considering a cooperative to be an energy cooperative is that it conducts activity in a rural or urban–rural commune or in the area of no more than three such communes directly adjacent to each other. The second condition for obtaining the status of a cooperative is the number of members, which has been limited to 1000, even though the cooperative law applies to an unlimited number of members.
Table 3. Distribution of own funds and the source of their formation in an energy cooperative.

<table>
<thead>
<tr>
<th>Funds</th>
<th>Cooperative</th>
<th>Agricultural Production Cooperative</th>
<th>Farmers’ Cooperative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share capital</td>
<td>Payments of members’ shares</td>
<td>Payments of members’ shares</td>
<td>Payments of membership shares</td>
</tr>
<tr>
<td></td>
<td>Write-offs for shares from the balance sheet surplus</td>
<td>Write-offs for members’ shares from the distribution of general income</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other sources specified in separate regulations</td>
<td>Other sources specified in separate regulations</td>
<td></td>
</tr>
<tr>
<td>Resource capital</td>
<td>(a) Payment of the entry fee</td>
<td>(a) Payment of the entry fee</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(b) Part of the balance sheet surplus, at least 5% of the balance sheet surplus up to the number of obligatory shares contributed</td>
<td>(b) Part of the general income—at least 3% of the general income, if it does not reach the amount of the obligatory shares contributed, property values received free of charge</td>
<td>(a) Entry fees</td>
</tr>
<tr>
<td></td>
<td>(c) Other sources specified in separate regulations</td>
<td>(c) Other sources specified in separate regulations</td>
<td>(b) 10% of the balance sheet surplus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(d) Reduced by losses on liquidation of fixed assets and random losses</td>
<td></td>
</tr>
<tr>
<td>Mutual capital</td>
<td></td>
<td>At least 3% of the balance sheet surplus</td>
<td></td>
</tr>
<tr>
<td>Net profit (balance sheet loss)</td>
<td>Balances sheet surplus</td>
<td>General income</td>
<td>Balance sheet surplus</td>
</tr>
<tr>
<td>Other own funds</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Own acts study.

The analysis of the formal conditions for the functioning of prosumers and energy cooperatives shows that an agricultural production cooperative or a cooperative of farmers may become a prosumer if it produces energy in an installation with an installed capacity of up to 50 kW for its own needs. However, there is one more condition to be met.

4.2.6. Balancing the Electricity Demand of an Energy Cooperative and Its Members

In the case of an energy cooperative producing electricity, the total installed electrical capacity of all renewable energy installations must cover no less than 70% of the energy cooperative’s and its members’ own needs during the year and may not exceed 10 MW. How should an energy cooperative secure 70% of electricity demand? In the fruit farm accepted for this study, the annual electricity consumption was between 50,000 and 92,000 KWh (Figure 5).

As shown in Figure 5, the consumption of electricity in the analyzed period was different in each year, even though the conditions of the activity conducted (i.e., the total area of the farm, the object, and place of business and their types) did not change (Figure 5). How, then, in the case of the presented characteristics, to ensure 70% of the demand for electricity, if it were the demand of the cooperative? The demand for electricity in a fruit farm is highly variable not only in the individual years of the period under examination, but also in the individual accounting periods of a given year. Figure 6 presents the consumption of electricity in the ten analyzed years, broken down into individual accounting periods.
Figure 5. Electricity consumption on the farm in 2012–2021.

Figure 6. Demand for electricity in the individual months of the surveyed years.

The electricity consumption presented in Figure 6 shows that it had a different level in each year and in each settlement period. It only indicated a tendency for electricity consumption. The repeatability of wear is also confirmed in Figure 7.
A detailed analysis of electricity consumption (Figure 7) shows that the highest consumption was recorded in the periods when the orchards were irrigated (from April to September) and the fruit was harvested in the cold store (from July to October/November).

Electricity consumption below the average for the year fell in the months from the end of October and lasted until the second decade of April (2015–2019) or even May (2012–2014 and 2021). In the period of the lowest demand for electricity, it was used to drive machines and devices (sorters, forklifts) and for lighting.

Higher electricity consumption in warm periods of the year and lower consumption in colder periods coincide with the production capacity of photovoltaic panels, which was related to insolation during the year.

In the analyzed period of 2012–2021, the lowest demand for electricity occurred in 2013 at the level of 58 MWh, and the highest in 2018, with the consumption of over 92 MWh. Thus, the level of 70% of the own needs of the cooperative and its members in one year can be maintained at the level of 41 MWh and in another at 65 MWh. The historical daily–hourly measurement data for the period of the last full 12 months, if any, provided by the electricity distribution system operator, preceding the date of submitting the cooperative’s application for registration of its status, is not sufficient to correctly determine 70% of its own and members’ needs. If the cooperative were to be registered in 2022, it would provide 82 MWh, 57 MWh for consumption in 2021. Therefore, it is recommended that this condition for obtaining the status of an energy cooperative be specified in the provisions of law in such a way as to consider the specificity of activities that are performed by members and the cooperative. Otherwise, cooperatives will be at risk of being deprived of their rights to the support mechanism.

4.3. Electricity Generation in Micro-Installations from RES and the Support Mechanism

The analysis of the costs of electricity generation in micro-installations was carried out for the prosumer:

(a) According to the current accounting rules in a quantitative ratio of 1 to 0.7;
(b) According to the new settlement rules, in force from July 2022;
(c) Being a cooperative.

The demand for electricity in the year in question was 81.57 MWh, and the production of energy from this source was 27.58 MW. The consumption (demand) and production of energy on the farm in 2021 in monthly granulation are presented in Table 4.
Table 4. RES energy production and electricity demand in fruit farm in 2021 (in kWh).

<table>
<thead>
<tr>
<th>Months</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>IX</th>
<th>X</th>
<th>XI</th>
<th>XII</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>353</td>
<td>852</td>
<td>2018</td>
<td>2842</td>
<td>3859</td>
<td>4896</td>
<td>4162</td>
<td>3195</td>
<td>2631</td>
<td>1865</td>
<td>645</td>
<td>264</td>
<td>27,582</td>
</tr>
<tr>
<td>Consumption</td>
<td>2696</td>
<td>2843</td>
<td>3505</td>
<td>4673</td>
<td>4258</td>
<td>8438</td>
<td>6407</td>
<td>9599</td>
<td>9729</td>
<td>13,223</td>
<td>10,230</td>
<td>5966</td>
<td>81,567</td>
</tr>
</tbody>
</table>

Source: own analysis of energy invoicing and PV installation supplier reports for year 2021.

The production of electricity from RES on the farm (Table 4) covered 33.82% of its annual energy demand in 2021. The monthly, highest share of produced energy in relation to the needs was recorded in May (96%) and the lowest in December (4%).

The analysis of energy purchase documents made it possible to determine the amount of electricity introduced to the grid in relation to the amount of energy taken from the grid, considering the quantitative factor of 0.7, in line with the statutory support model (net-metering) applicable to prosumers in 2021 for installations with a capacity of less than 10 MW. Detailed monthly data on energy fed into and received from the grid in 2021 are presented in Table 5.

Table 5. RES energy production fed into and picked up from the grid in 2021 (in kWh).

<table>
<thead>
<tr>
<th>Months</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>IX</th>
<th>X</th>
<th>XI</th>
<th>XII</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy fed into the grid</td>
<td>62</td>
<td>297</td>
<td>852</td>
<td>1293</td>
<td>1937</td>
<td>1316</td>
<td>1484</td>
<td>670</td>
<td>477</td>
<td>69</td>
<td>14</td>
<td>17</td>
<td>8488</td>
</tr>
<tr>
<td>Energy picked up from the grid (0.7) *</td>
<td>43</td>
<td>208</td>
<td>596</td>
<td>905</td>
<td>1356</td>
<td>921</td>
<td>1039</td>
<td>469</td>
<td>334</td>
<td>48</td>
<td>10</td>
<td>12</td>
<td>5942</td>
</tr>
<tr>
<td>Energy picked up from the grid (0.6) **</td>
<td>37</td>
<td>178</td>
<td>511</td>
<td>776</td>
<td>1162</td>
<td>790</td>
<td>890</td>
<td>402</td>
<td>286</td>
<td>41</td>
<td>8</td>
<td>10</td>
<td>5093</td>
</tr>
</tbody>
</table>

* As per the net-metering model. ** As per energy the cooperative model. Source: own analysis of the farm energy invoicing for the year 2021.

According to the data from Table 5, in 2021 the prosumer led 8.488 MW of electricity to the grid, which constituted 30.77% of the annual production from the installation and collected 5.942 MW (21.54% of the energy produced during the year).

The volume of production and consumption (Table 4) and the settlement of energy fed into the grid and received from it (Table 5) show that the prosumer consumed 25.036 MW of energy from own production during the year, which accounts for 36.59% of the farm’s annual energy demand. This means that in 2021, 2.546 MW, i.e., 9.23% of the energy produced in the installation, was made available to the seller, in accordance with the provisions of the prosumer support model in force in the RES Act (0.3 of energy fed into the grid).

Based on the information on the amount of energy introduced by the prosumer to the grid in 2021, the annual amount of energy introduced and received from the grid (in the energy cooperative model) and the amount of energy fed into the grid—for deposit valuation (in the net-billing model) were determined. The structure of these data for all the tested models is presented in Table 6.
Table 6. Demand and energy supply sources for the fruit farm in different models for the year 2021 in kWh.

<table>
<thead>
<tr>
<th>Energy consumption/demand</th>
<th>No RES Installation Approach</th>
<th>Prosumer Net-Metering Model</th>
<th>Prosumer Net-Billing Model</th>
<th>Energy Cooperative Member Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy consumption/demand</td>
<td>81,567</td>
<td>81,567</td>
<td>81,567</td>
<td>81,567</td>
</tr>
<tr>
<td>RES energy production</td>
<td>-</td>
<td>27,582</td>
<td>27,582</td>
<td>27,582</td>
</tr>
<tr>
<td>RES energy temporarily fed into the electricity grid</td>
<td>-</td>
<td>8488</td>
<td>-</td>
<td>8488</td>
</tr>
<tr>
<td>RES energy (for deposit)</td>
<td>-</td>
<td>8488</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RES energy picked up</td>
<td>-</td>
<td>5942</td>
<td>-</td>
<td>5093</td>
</tr>
<tr>
<td>Energy remained to be purchased under overall contract conditions</td>
<td>81,567</td>
<td>56,531</td>
<td>62,473</td>
<td>57,380</td>
</tr>
</tbody>
</table>

Source: own analysis of energy invoicing and PV reports for the year 2021.

Data on the amount of energy transferred to the grid and received or transferred to the deposit as well as energy demand on the farm allowed to determine the amount of energy to be purchased to cover the full annual demand of the farm (Table 6) row: energy remained to be purchased under overall contract conditions) in each of the analyzed models. In both scenarios, and the amount of energy produced on the farm and sold in the net-billing model. As it results from the analysis of these values when producing its own RES energy using the net-metering, net-billing, and energy cooperative model, the farm must purchase 56.531 MW, 62.473 MW, and 57.380 MW of electricity from the obligated seller, respectively, to secure annual consumption, which was 69.31%, 76.59%, and 70.35% of its energy needs in each of the models, respectively. The farm would have to purchase the largest amount of energy when using the net-billing model—5.942 MW—more than in the net-metering model (10.51%) and 5.093 MW more than in the energy cooperative model (8.88%).

The net value of purchased energy and energy settled in value in two scenarios for each of the models calculated based on quantitative data (Table 6) and prices (according to the description of the model structure) are presented in Table 7.

Data presented in Table 7 clearly indicate similar levels of energy purchase costs and costs of distribution services for each of the models in scenario 1. The cost of energy purchase ranges from 50.37% in the net-billing model (after the settlement of funds for energy introduced to the network in the amount of PLN 2833) to 56.73% in a farm not equipped with a RES installation, and in the net-metering and energy cooperative model, it amounted to slightly over 50%.

The situation was different in scenario 2, when the costs of purchasing energy significantly exceeded the distribution fees. In the case of models assuming energy production from RES, they accounted for almost 81% of the annual electricity expenditure (in the net-billing model after the settlement of funds from the sale of energy to the seller); in the farm model without RES energy production, they amounted to over 83% of the total energy expenditure. This means an over three-fold increase in expenditure on securing the quantitative needs of electricity year on year (scenario 1 vs. scenario 2), while the value
of distribution service charges in scenario 1 increased by approximately 7% in each of the analyzed models compared to the scenario 2 for each model.

Table 7. Energy purchased and deposited by the fruit farm—all models in scenario 1 and in scenario 2 (net values in pln).

<table>
<thead>
<tr>
<th>No RES Installation Approach</th>
<th>Prosumer Net-Metering Model</th>
<th>Prosumer Net-Billing Model</th>
<th>Energy Cooperative Member Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scenario 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purchase of energy</td>
<td>33,192</td>
<td>23,761</td>
<td>25,895</td>
</tr>
<tr>
<td>Distribution services</td>
<td>25,316</td>
<td>21,928</td>
<td>22,728</td>
</tr>
<tr>
<td>Prosumer deposit *</td>
<td>-</td>
<td>(2833)</td>
<td>-</td>
</tr>
<tr>
<td><strong>Scenario 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purchase of energy</td>
<td>134,560</td>
<td>98,947</td>
<td>106,572</td>
</tr>
<tr>
<td>Distribution services</td>
<td>27,262</td>
<td>23,637</td>
<td>24,348</td>
</tr>
<tr>
<td>Prosumer deposit *</td>
<td>(6168)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* Value of electricity fed into the grid. Source: own study.

A comparative analysis of the settlement results of all models in both scenarios is presented in Table 8, respectively.

Table 8. Comparative analysis of the energy costs in fruit farm settlement according to the considered models—scenario 1 and scenario 2.

<table>
<thead>
<tr>
<th>No RES Installation Approach</th>
<th>Prosumer Net-Metering Model</th>
<th>Prosumer Net-Billing Model</th>
<th>Energy Cooperative Member Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scenario 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy purchased under overall contract conditions including distribution fees</td>
<td>58,508</td>
<td>45,689</td>
<td>48,623</td>
</tr>
<tr>
<td>Energy sold (collected on prosumer account)</td>
<td>(2833)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Energy costs overall</td>
<td>58,508</td>
<td>45,689</td>
<td>45,790</td>
</tr>
</tbody>
</table>

| **Scenario 2**              |                            |                            |                               |
| Energy purchased under overall contract conditions including distribution fees | 161,822                    | 122,584                    | 130,920                       | 123,650                       |
| Energy sold (collected on prosumer account) | (6168) | -                          | -                             | -                             |
| Energy costs overall        | 161,822                    | 122,584                    | 124,752                       | 123,650                       |

| **Savings on each model**   |                            |                            |                               |
| Energy cooperative member model | 21.91%                    | 21.74%                     | 21.19%                        |                               |
| Prosumer net-metering model | 0.22%                      | 0.92%                      |                               |                               |
| Prosumer net-billing model  | 0.69%                      | 0.88%                      |                               |                               |

| **Savings on each model**   |                            |                            |                               |
| Energy cooperative member model | 24.25%                    | 22.91%                     | 23.59%                        |                               |

Source: own study.
The analysis of the level of expenditure on energy purchase and distribution fees in the settlement models in scenario 1 (data according to Table 8, scenario 1) indicates a slight differentiation in the effectiveness of model solutions for a farm producing energy for its own needs. Accounting for the surplus from energy production in the net-metering and net-billing models, the farm would achieve an almost equal value of savings compared to the model without energy production from renewable energy sources—nearly 22%, while in the case of an energy cooperative it would be slightly over 21%. The differences in the effectiveness between the support models reached the level of less than 1%; thus, they can be considered equally effective.

A comparison of the total annual purchase costs and distribution fees in a fruit farm in scenario 2 (data according to Table 8, scenario 2) led to the conclusion that the effectiveness of the analyzed support models was slightly greater than that observed in scenario 1. In this scenario, the net-metering model turned out to be the most effective (it was almost 2% more effective than the net-billing model and less than 1% of the cooperative), and the cooperative model lost its effectiveness in relation to the net-billing model by almost 1%. Savings with the use of renewable energy sources by the farm and the use of the net-billing model or participation in the cooperative would amount to approximately 23%. The cooperative model, on the other hand, became more attractive compared to the net-billing model.

5. Conclusions

Growers need electricity at the lowest possible cost. They can produce electricity in micro-installations. This is an installation with a total installed electrical capacity of no more than 50 kW. Due to the introduction of detailed legal provisions for energy cooperatives in Poland for the first time and a new settlement system for new prosumers, starting production from 1 July 2022, legally permissible options have been indicated as the most advantageous for fruit farms in Poland. Growers can produce energy by:

(a) A prosumer settling in the net-metering system, if they were prosumers before 1 July 2022;
(b) A prosumer who settles in the net-billing system, if they start generating electricity after 1 July 2022, or if they have already generated electricity and wish to change the rules of accounting;
(c) A member of an energy cooperative.

Analyzing the mechanisms supporting electricity production in renewable energy installations has shown that participation in an energy cooperative is the most beneficial and economical solution for new prosumers. Support for the new direction of energy production was expressed in the survey of the farmers’ willingness to cooperate. The study’s conclusions are unclear in the case of prosumers who have acquired the right to settle according to the net-metering model. Staying in the current net-metering model seems to be more advantageous than changing the model to net-billing or even membership in an energy cooperative. Limitations were revealed when creating models and testing their effectiveness. These limitations include:

- The need to analyze electricity production in a micro-installation, because it cannot be the subject of the principal economic activity of a grower—there are no conditions determining what measure to measure the activity by, for example, by the amount of revenues or some other measure;
- The multitude of types of cooperatives—it is possible to establish four types: cooperatives on general terms; agricultural production cooperatives; farmers’ cooperatives; other cooperatives, which may be granted the status of an energy cooperative;
- Numerous conditions to be met when choosing the legal form for an energy cooperative require maintaining an appropriate number of founders and members per the regulations; additionally, the subject of activity of an energy cooperative being a prosumer is not arbitrary;
Meeting the condition of ensuring that members of the cooperative have 70% of the electricity demand—orchard production and the volume of the electricity demand are not predictable.

When selecting the direction of further research, attention is drawn to the fact that the development of cooperatives in the world took place as a result of introducing as few conditions as possible limiting their functioning, e.g., in terms of the number of members and investment outlays with institutional and financial support. Thus far, no attention has been paid to the fact that the energy cooperatives in the world are not obliged to deal with other activities. They can sell outside, thanks to which their chance for profits are not prohibited in running this legal form, which as a cooperative, increases. There are collective and virtual prosumers worldwide, and in Poland, by the provisions of the RES Act, new players will appear in the prosumer market in 2024 including collective and virtual prosumers.

The uncertainty generated by new conditions for the functioning of individual and collective producers of renewable energy sources on the market indicates the need to continue research on the effectiveness of energy cooperatives. The problem of fair settlement between the cooperative members remains unsolved. Such possibilities have not been identified at present. Solutions are expected to settle cooperative members with the cooperative and the cooperative itself with the distribution system operator. The critical issue is to find a solution that will integrate local civil society.

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**Conflicts of Interest:** The author declares no conflict of interest.

**References and Note**


