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New Perspectives for Logistics Processes in the Energy Sector

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Abstract: The publication analyzes the logistic processes taking place in the energy sector. The impact of the analyzed logistic processes is crucial for the alternative energy sources industry. This article focuses on home photovoltaic installations. The bases for further research are the previously identified stages of logistic processes related to photovoltaic installations. Individual, selected logistics processes and their impact on the implementation of photovoltaic installations have been described in detail together with the results of the research. The basis of the research was to conduct a survey among randomly selected people who have been in possession of a photovoltaic installation since 2018 in Poland. This article is an introduction to further research on the analysis of logistic processes in other branches of energy.

Keywords: logistic process; photovoltaic installation; energy sector; logistic processes in the energy sector

1. Introduction

In recent years, both the Polish economy, and also the world economy have undergone a lot of changes. First the COVID-19 pandemic, and then the military conflicts in Eastern Europe, had a negative impact on the prices of raw materials in Poland and around the world. The drastic increase in electricity and gas prices forced households and entrepreneurs to look for alternative sources of electricity. Currently, the geopolitical situation in Europe has resulted in insufficient access to raw materials, mainly coal and gas, which translates into very high heating prices and an increase in electricity prices and concerns about the EU's ability to secure energy supplies. As a result of conflicts and the deepening of the energy crisis, energy prices in Europe continue to rise, which contributes to the development of green energy [1–3].

Based on the report from 26 May 2022, the installed capacity of photovoltaic panels in Poland at the end of 2021 is estimated at 7.67 GW. For comparison, at the turn of 2011/2012, the total capacity of PV installations was estimated at 7.9 MW, whereas the annual increase in installed capacity in this sector in 2021 was as high as 3.7 GW. According to data from other European countries, where the total installed capacity was 158 GW, this is an annual increase by 21.4 GW, translated into a 15% increase in the total installed capacity in PV compared with 2020. In 2021, Poland was second place in terms of increasing installed PV capacity in the EU. The forecasts for 2023–2030 show that Poland should remain at the forefront of Europe. The average capacity increases until 2030 at the level of 2 GW per year. The scenarios assume that the next milestone—20 GW installed in PV in Poland—will be achieved in 2025, and in 2030, the cumulative installed capacity may be as high as 28.5 GW [4–7].

The development of green energy is associated primarily with the reduction in exhaust emissions to the atmosphere, independence from solid raw materials and the growth of the economy in the field of energy and indirect branches of the economy. The entire process of implementing an individual order for solar panels is time-consuming and complicated. Not only companies operating in the energy sector are involved in this process, but also intermediaries and logistics operators. The entire process of building a home solar power plant consists of a number of processes and operations, including logistics processes,

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Citation: Kulińska, E.; Dendera-Gruszka, M. New Perspectives for Logistics Processes in the Energy Sector. *Energies* **2022**, *15*, 5708. https://doi.org/10.3390/en15155708

Academic Editor: Adel Mellit

Received: 31 May 2022
Accepted: 27 July 2022
Published: 5 August 2022

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without which the installation would not be possible. The following article describes the impact of logistic processes in solar energy in Poland. The research was conducted on Polish prosumers in May 2022, based on an anonymous questionnaire [8,9].

2. Characteristics of the Polish Energy Market

The production of electricity generated in Poland from coal has recorded a dynamic decline. Currently, the share of coal in the energy industry is below 70% of the entire energy market. There is a noticeable growth trend in renewable energy sources in Poland. An important issue in the development of renewable energy in Poland is home solar power plants. Private owners, for economic reasons, create favorable conditions for the development of this type of energy sector. There is also a growing public awareness about the environmentally unfavorable operation of the traditional power plant model. All of this translates into an increase in photovoltaic installations at private entities and business entities [4,10,11].

Due to the COVID-19 pandemic in the years 2020–2022, not only the Polish economy but also the global economy suffered. Actions carried out by governments are aimed at supplementing the world economy and giving a new growth momentum. In turn, the geopolitical situation initiated by military activities in Eastern Europe in 2022 contributed to further turmoil in the energy markets. The events related to Ukraine and Russia had a significant impact on the European energy system. Due to the fact that as much as 72% of the total demand for hard coal came from Russia, the current Polish energy market is in crisis. The situation in eastern Europe contributes directly to the growth of alternative energy sources. The blocking of coal imports from Russia in the first place translated into a dynamic increase in raw material prices on the local market for households. Due to this, companies dealing in the sale of photovoltaic panels experience a significant increase in their sales [12]. The energy transformation will require the sacrifice of many entities and large investment funds, which in the years 2021–2040 may even reach the amount of approximately PLN 1600 billion [13]. The energy balance in 2019–2020, i.e., before the pandemic and during the pandemic, confirms that there is less electricity produced than its consumption, which is associated with buying electricity from abroad. In 2020, a project for Poland's Energy Policy until 2040 entered into force, which set the share of coal at a level no greater than 56% by 2030; moreover, in the years 2030–2040, the presence of coal in energy production in Poland is set to be below 28% [1,11,14,15].

3. Materials and Methods

The research took into account the following aspects: supply, distribution, transport and storage of photovoltaic panels and other elements necessary to create a home solar power plant. Similarly, as it was noted at the beginning, the most investments in home solar power plants were implemented in 2021, and the second place was taken by 2020 (Figure 1). The development of green energy continues, because until May 2022, photovoltaic installations were installed in 19% of the surveyed companies [16]. The survey was conducted online (CAWI) is one of the forms of quantitative measurements, which involves conducting research with the use of online survey questionnaires. In total, 121 households represented by 90 men and 31 women participated in the study. The research was conducted in Poland. The questionnaire was modeled on logistic processes translated into renewable energy, in this case, home solar power plants. The questions in the survey correspond to the logistics processes. The procurement process, the transport process, the production process, the warehousing process, the distribution process and the customer service process from the perspective of the implementation of home solar power plants were described. The questionnaire also included questions such as the age or place of residence of the respondents, which do not correspond to logistics processes, but give an overview of the group of respondents participating in the study. Due to the extensive logistic undertaking, which is the assembly of photovoltaic panels, the article presents the decision-making process and the scheme of operation of the assembly of a home solar

power plant from the perspective of logistic processes. Based on the survey, it was realized that there would be a decision board that will still be available as part of the implementation of the new investment in renewable energy.

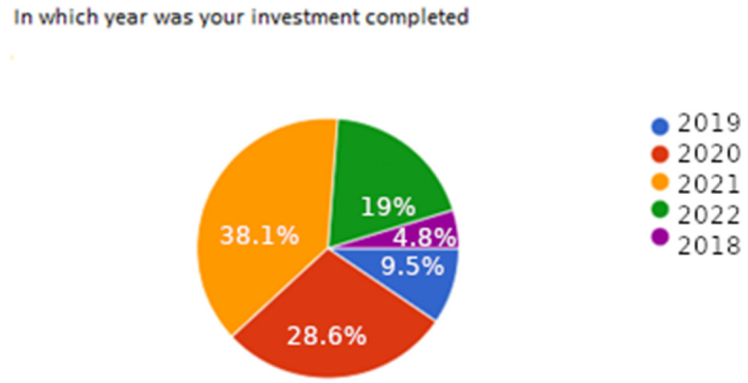

Figure 1. Year of establishment of the photovoltaic installation.

The most frequently installed power of photovoltaic installations was from 7 to 10 kWp (Figure 2).

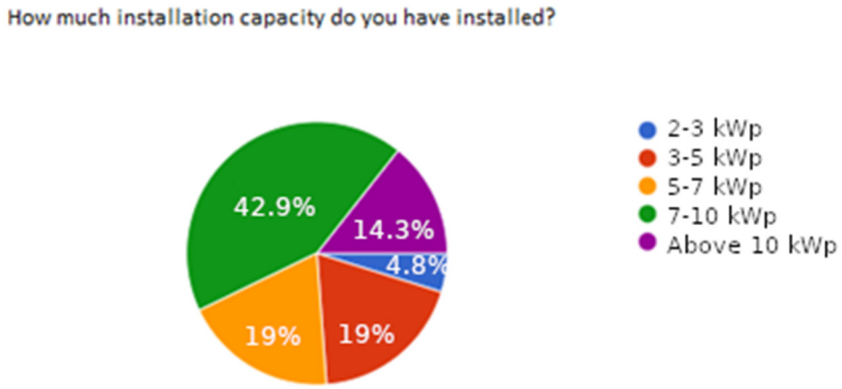

Figure 2. Power of the photovoltaic installation.

Before installing the photovoltaic panels, the monthly cost of electricity was between PLN 300 and PLN 600, and the second most frequently selected answer was between PLN 100 and PLN 300 (Figure 3).

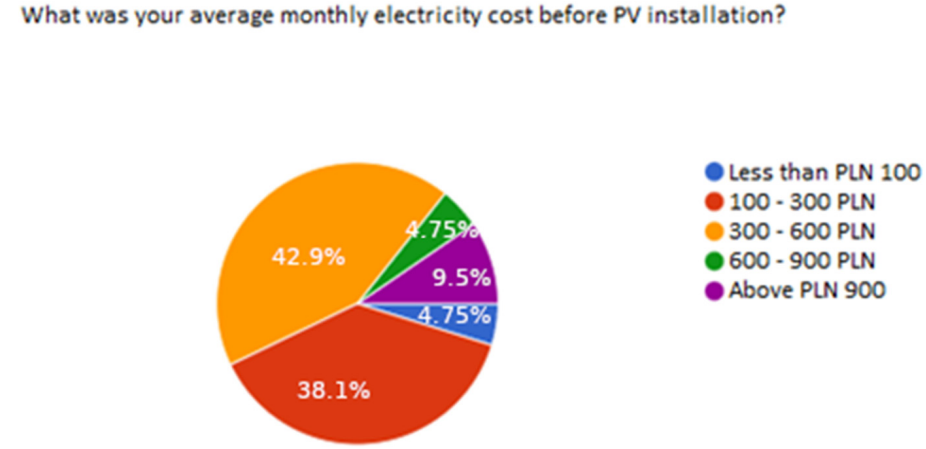

Figure 3. The monthly cost of electricity.

3.1. Procurement Process

The first process that was tested was the procurement process, which is defined as a component of the logistics system in which the necessary goods are supplied. The procurement process includes decision-making processes of what, in what quantity, where and when to buy. The task of the procurement process is to reduce costs, and thus prices, by selecting alternative suppliers. Successively, the supply process is responsible for independence from one supplier and focus on multiple sources of supply. The procurement process also includes elements such as [15,17]:

- Supply with minimal stocks;
- Lower inventory maintenance costs;
- Possibility to conclude long-term contracts on better terms;
- No need to constantly analyze purchasing markets.

Choosing an alternative energy source meets all the above-mentioned criteria of the procurement process. Investing in a renewable energy source, in this case from solar radiation, makes prosumers independent not only from one energy supplier, but also may contribute to a change in the source of heating a household or economic entity [18].

The factor that plays a key role in the procurement process is time, which can result in production downtime or unnecessary storage of raw materials. Therefore, the research focused first on the time of contract execution, from the first contact with the company's sales representative, through placing an order, to the installation of photovoltaic panels, to the acceptance of the installation by the energy company (Figure 4). The problems that arose at the very beginning of the logistics chain have a significant impact on the efficiency of the photovoltaic installation in the first year of its operation, which translates into the financial considerations of the project. Therefore, the time of order fulfillment is extremely important, because waiting too long may not bring the assumed financial result. It is directly related to the geographical location of Poland and the period of the greatest insolation. Therefore, if the order is placed in May, and the order is processed in August, the expected financial result will be disproportionately lower than initially expected, because the start-up of the installation will take place in the months where insolation is the lowest. When introducing external sources of financing to this stage, one should take into account not only the monthly installments for the installation, but also slightly reduced electricity and energy bills, which are added to the prosumer's portfolio. Based on the research, the order execution time was 1–3 months (Figure 5), whereas the decisions regarding the installation of photovoltaic panels are shown in the diagram below.

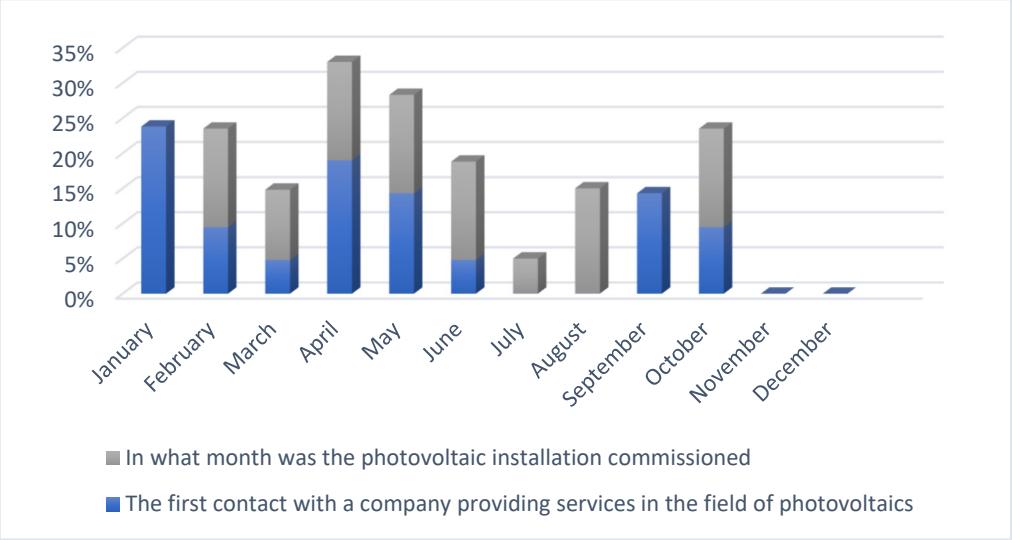

Figure 4. Time-decision process of purchasing a photovoltaic installation.

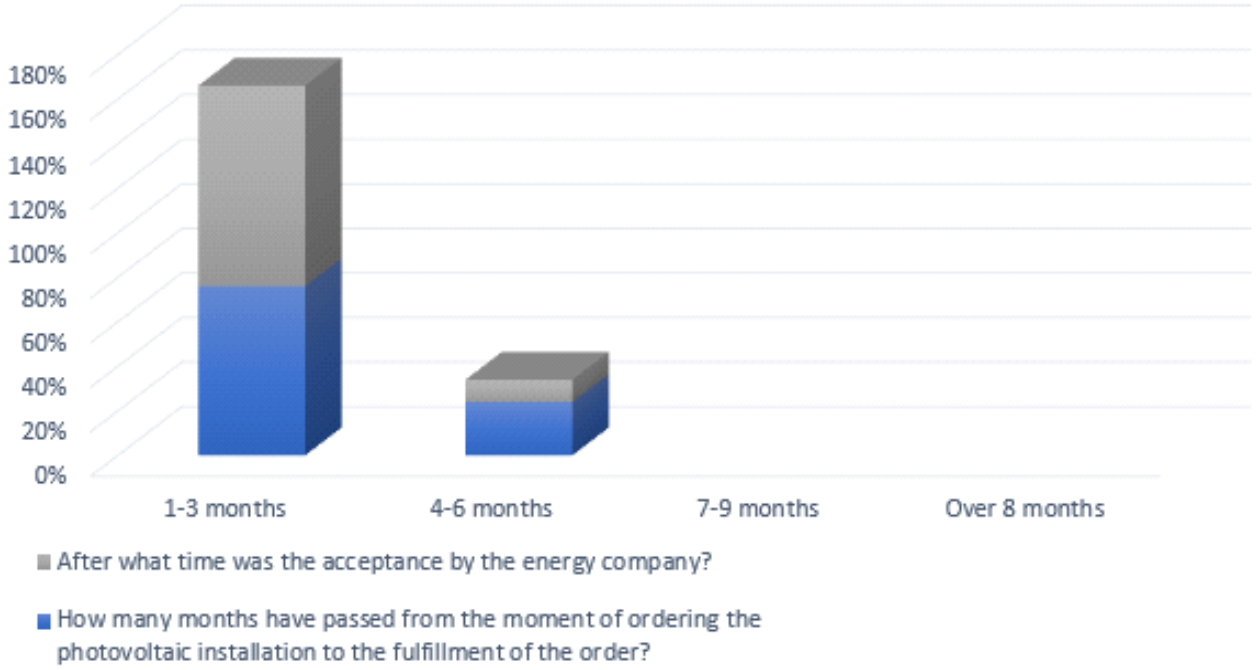

Figure 5. Duration of the decision-making process for purchasing a photovoltaic installation.

To confirm the above data, the questionnaire asked about the duration of the contract and the duration of commissioning the installation by the energy company. In both cases, this time was from 1 to 3 months, i.e., from the first contact of the sales representative, through the energy audit, presentation of the offer, signing and implementation of the order, notification and acceptance of the installation, approximately 6 months passed.

The assembly of photovoltaic panels itself is not a time-consuming process. On the basis of the tests carried out, it appears that the assembly amounted to 62% from one to two working days. Then, the most frequently selected answer was "2–4 days" (Figure 6).

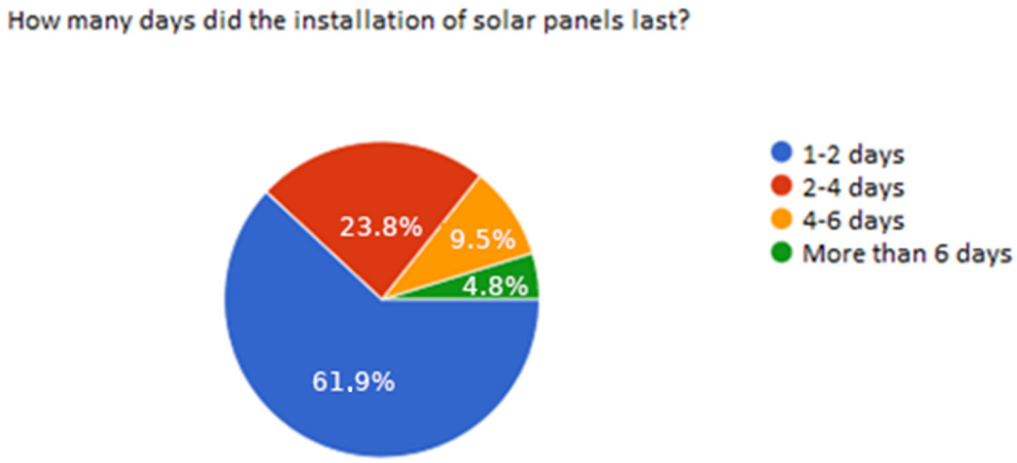

Figure 6. Duration of the installation assembly.

3.2. Transport Process

Another investigated element in renewable energy is transport. The transport process is the ability to move cargo, and people from point A to point B, using appropriate resources and appropriate infrastructure. The final goal of the transport process is to deliver the goods to the final recipient [19].

The role of the logistics process of transport in the energy sector is particularly visible during the transport of power plant components, and their loading and unloading. In the discussed case, the transport process refers to the movement of components of small solar power plants from the producer to the end customer. The research covered various forms of transport:

- Transport on the client's side;
- Transport on the side of the service provider;
- Transport provided by an external company;
- Collection at the service provider's premises;
- Receipt from the manufacturer of the photovoltaic panels.

It is extremely important to transport the entire photovoltaic installation safely, due to the fact that every slightest defect of the panels significantly affects their efficiency. The transport of the photovoltaic installation includes not only PV modules, but also an inverter, all assembly parts of the structure, warning signs, as well as cables and all necessary security measures. Elements of the photovoltaic installation should be properly secured, because it is of great importance for their future operation; bad transport of photovoltaic panels may reduce the efficiency of the installed panels. Photovoltaic panels are fragile and easy to damage elements of a photovoltaic installation, it is very easy for microcracks to form, which are not always visible, and the installation of damaged panels may work properly at first, but may cause problems later on. Correct transport of PV modules includes placing them in relation to their longer side or in a horizontal position, because when transporting the panels in this way, the pressure on a single panel is limited, which must additionally be separated from each other by special cardboard separators. Separating each module will guarantee the reduction in the risk of mutual contact of the transported modules and helps to dampen vibrations. Photovoltaic panels should be transported in transparent packaging so that any damage can be noticed; in addition, special protections should be applied to the sharp edges. One pallet should contain no more than 30 panels, and the pallet for transporting panels should be larger than them [11,18,20].

Based on the research, 90% of the panels were transported by the service provider, and in 5% of the cases equally by the ordering party and by an external company (Figure 7).

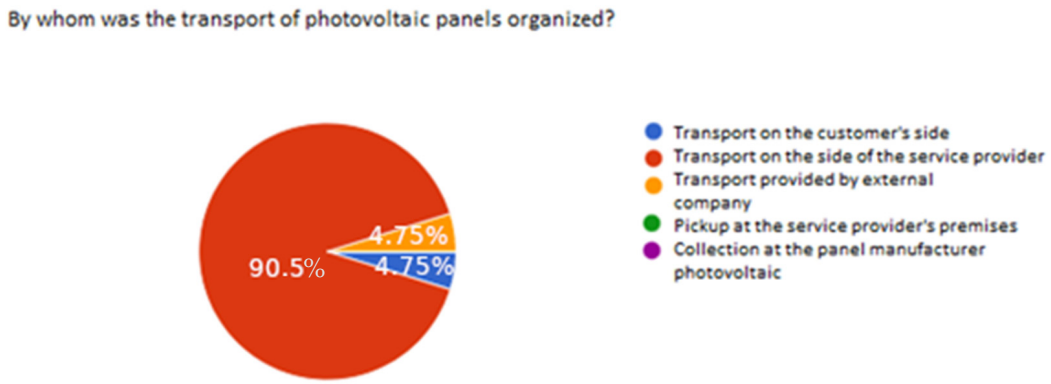

Figure 7. The process of transporting the photovoltaic installation.

More than 70% of the questions regarding the loading and unloading of solar panels correspond to the operations of the service provider (Figure 8). On the other hand, almost 20% of the respondents replied that the employees of the company producing solar panels were responsible for the loading. On the other hand, over 14% of the respondents were obliged to unload the panels themselves, 10% of cases were unloaded by a company producing photovoltaic panels, and 5% of cases were unloaded by an external company (Figure 9).

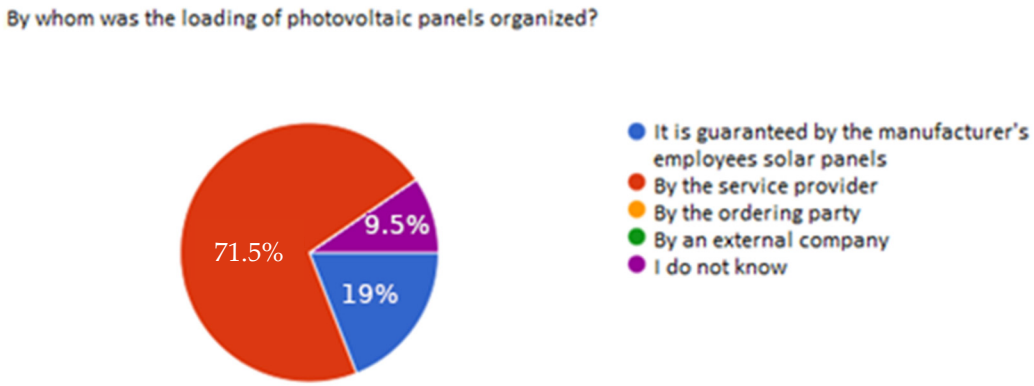

Figure 8. Loading process.

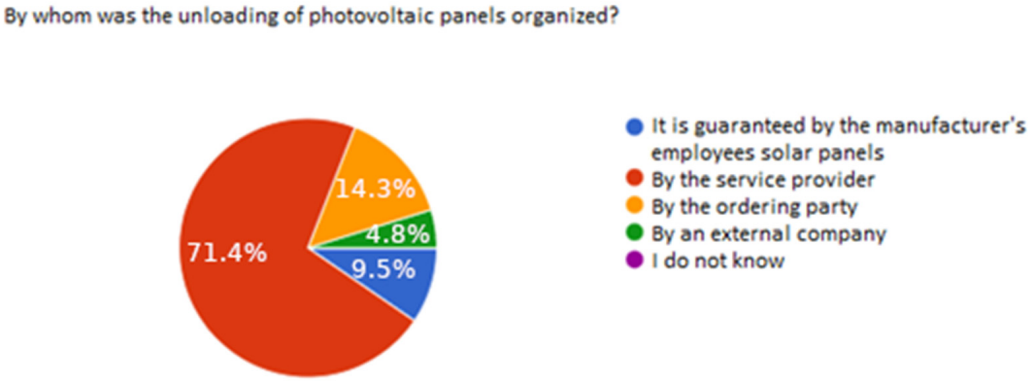

Figure 9. The unloading process.

Based on the research, it can be concluded that the panels were not damaged during transport (Figure 10).

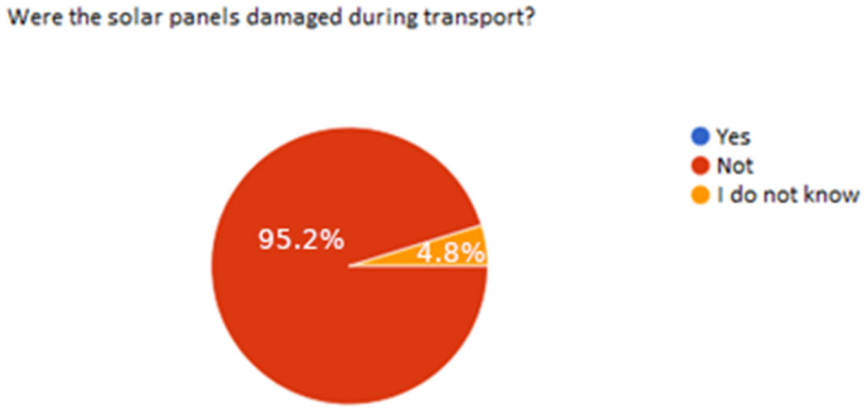

Figure 10. Damage to the photovoltaic system.

The vast majority of photovoltaic panels have been properly secured in the transport process (43%). Despite the fact that the recommendations correspond to the transport of the panels along the long side on pallets, separated by securing dividers, as much as 14% of the panels were packed in cardboard boxes. In turn, 14% of the panels were transported on the car without pallets (Figure 11). Despite this, the panels were not damaged, which may indicate the high quality of the purchased photovoltaic panels, or that the defects were not noticed at the right time.

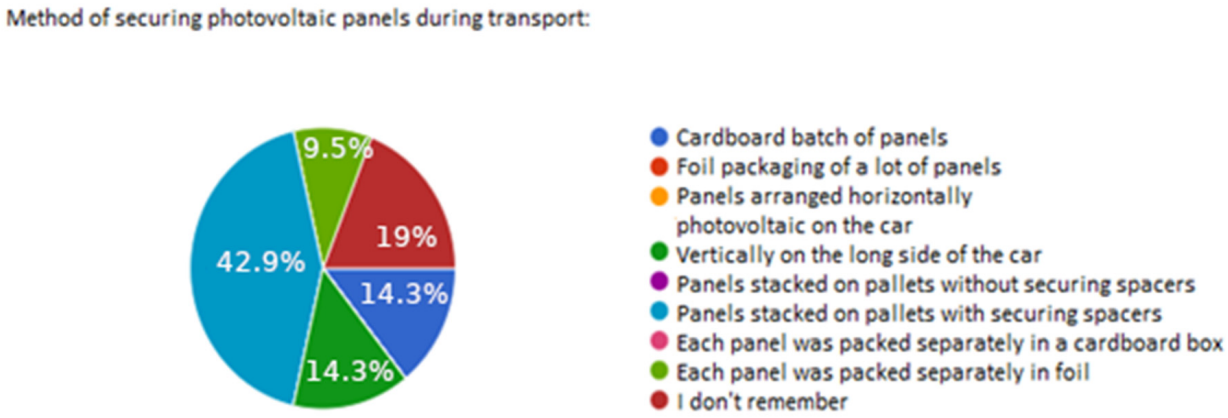

Figure 11. Packaging methods for photovoltaic panels.

3.3. Storage Process

The next considered logistic process was warehousing, which in the literature is defined as receiving and issuing goods from a warehouse, storing goods, order picking and administering warehouse space [21]. In the example we are discussing, the storage concerns mainly the storage of the generated energy by a home solar power plant and the cases of storage of the power plant components on the property of the contracting authority before their installation at their destination. In the first place, questions were asked about the place of installation of the panels, then about the information about the possibilities of energy storage and their choice by the respondents and about the method of storage of the panels before their installation [10] (Figure 12).

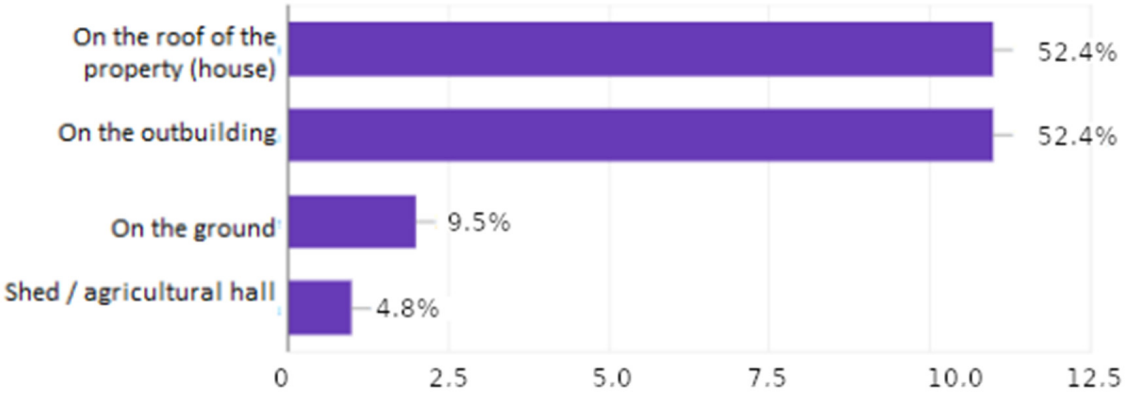

Figure 12. Place of installation of photovoltaic panels.

The vast majority of panels were installed immediately after their unloading. The next-most-common information related to the storage of panels for 2–3 days on the premises of the orderer (Figure 13).

The most common answer related to the question "why do you not store energy" was the too-high cost of additional installations, which is not profitable, which also answers the question why the respondents do not want to resell energy. In turn, 81% said that the installed photovoltaic installation fully covers their demand for electricity (Figure 14). Identical results were obtained for 9.5% of respondents—the installation is oversized, and the installation does not produce enough energy. The reasons why the respondents decided to install a photovoltaic installation was 60% of the lack of payment for electricity, 30% of environmental care, 5% of favorable subsidy systems, 2.5% of independence from fossil fuels and profitability of investments (Figure 15).

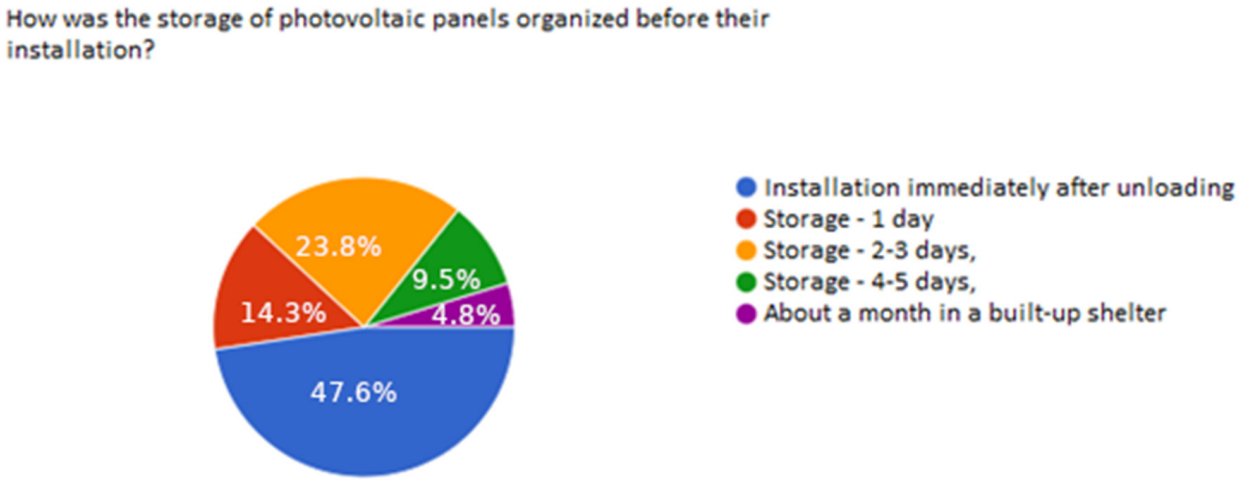

Figure 13. Duration of panel assembly.

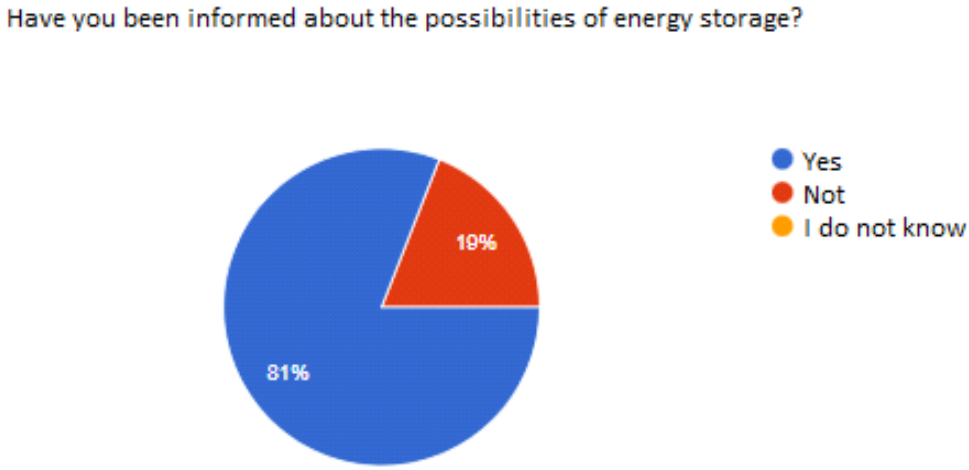

Figure 14. Energy storage.

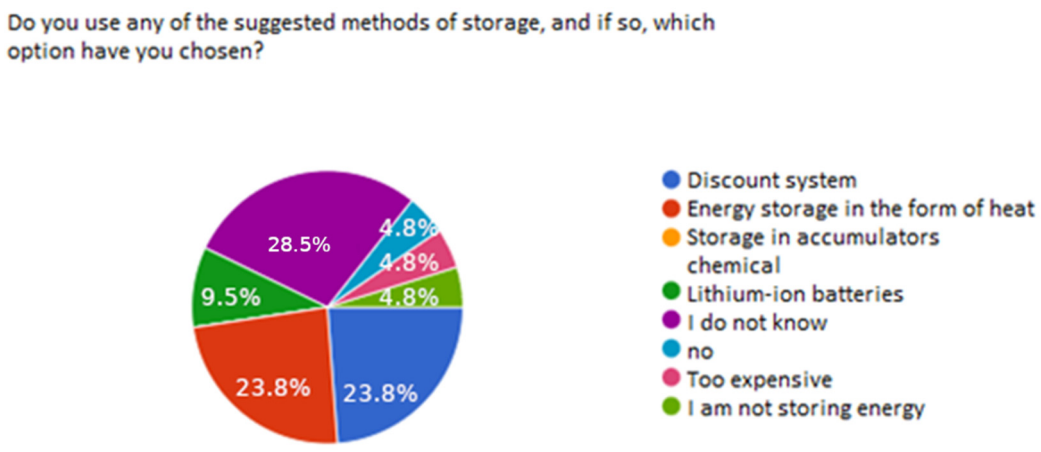

Figure 15. Reasons for giving up energy storage.

3.4. Distribution Process

Distribution from the perspective of the logistics process is defined as "activities related to the movement of materials, usually products and elements for the needs of the service, from the producer to the consumer. These activities include transport, warehousing,

inventory management, material manipulation, order processing, location analysis, packaging management, information processing and communication necessary for the effective coordination of all activities" [19]. The essence of distribution is the transfer of finished products from the place of their production to the final recipient at the right time. On the other hand, distribution of electricity is the transmission of electricity to the end customer via low, medium and high voltage lines [15,21]. A very important element of electricity distribution is to ensure continuity in its supply; the most important role in this respect is played by the National Power System of the Polish Power System, which deals with the generation, transport and distribution of electricity. A special part of the NPS is the distribution network, i.e., the network that supplies electricity to consumers. In Poland, OSD Distribution System Operators [10,11,22] exercise control over the National Power System. For 81% of those surveyed, the electricity supplier is Tauron Dystrybucja S.A (Figure 16).

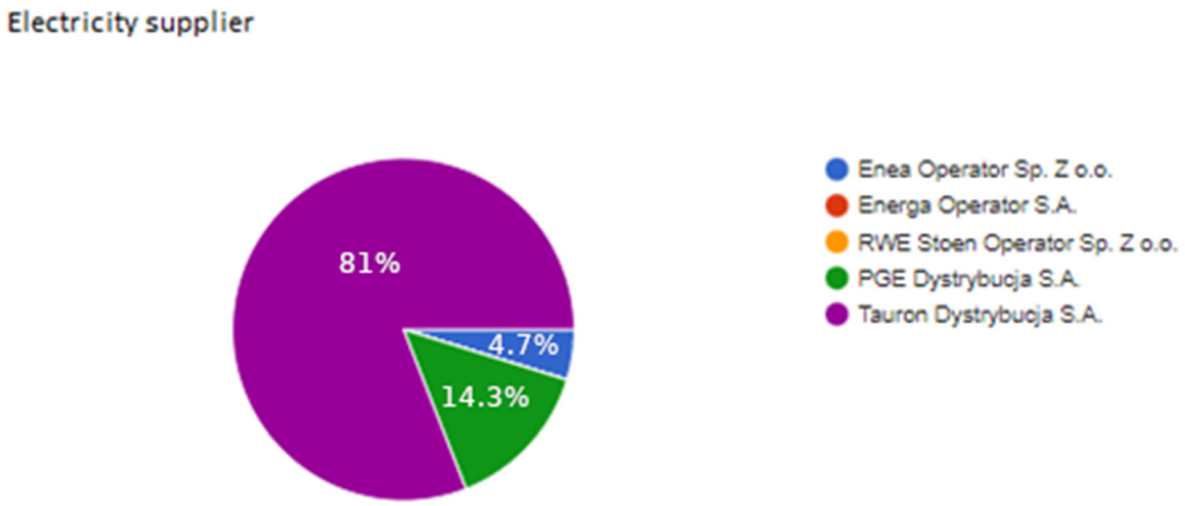

Figure 16. Energy distributors in Poland.

The power network distributor in Poland is subject to strict obligations, which are regulated by the energy law. These include [23,24]:

- Network traffic in the distribution network;
- Operation, maintenance and repair of the distribution network;
- Planning the development of the distribution network;
- Ensuring the expansion of the distribution network;
- Cooperation with other power system operators;
- Energy enterprises within the scope specified in the Energy Law;
- Managing the capacity of specific generating units connected to the distribution network;
- System balancing and management of system constraints;
- Providing network users and operators of other electricity systems with information defined by the Energy Law;
- Enabling the performance of electricity sales contracts by customers connected to the network by meeting the conditions set out in the Energy Law;
- Maintaining an appropriate level of security of the distribution network operation.

3.5. Customer Service Process

The last element tested was the customer service process. At this stage, questions were asked about the overall satisfaction with the services of the company selling photovoltaic panels, whether it was dictated by the choice of the service provider and what impression was made by the company's employees (Figure 17).

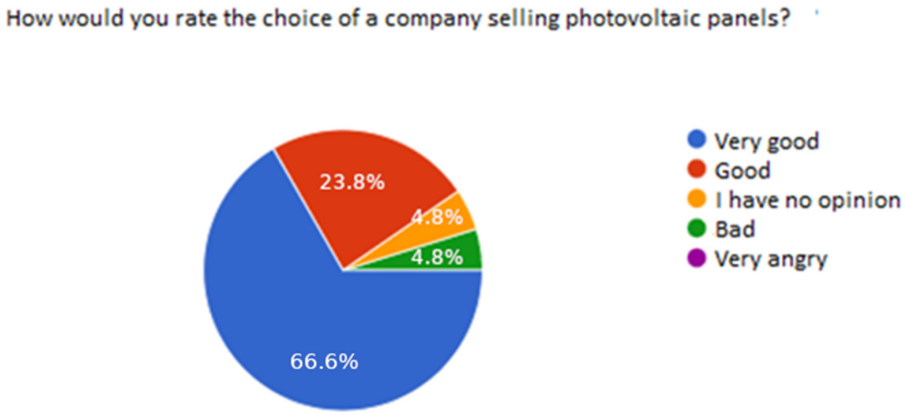

Figure 17. Opinion about the service provider.

Questions regarding the selection of the service provider focused on such issues as advertising in the media, opinions of friends, or the company made the first contact with the recipient. There were also questions whether customers checking opinions about companies on the Internet and whether they had an impact on the choice of service providers. Next, whether the clients, when choosing a company, also took into account such information as: earlier services, deadlines, contractual penalties, services or services and audit services by the company or company contacts (Figure 18). It was possible to use the questionnaire in relation to the application, which answers that the question for them when choosing a company was made by the company, in the case of selection for use for a given home appliance. Another thing are other implementations of a given company (Figure 19).

The customer service process also includes warranty service. In the given responses, as many as 43% of respondents have a warranty period of more than 10 years, whereas in 24% there were warranty services after the installation of photovoltaic panels (Figure 20).

Positive feedback on warranty service was ensured by the time of repairing the fault, which for 62% was completed in less than a week, and for 14% between 8 and 20 days from reporting the failure (Figure 21). However, it is disturbing that as many as 24% of respondents answered that the defect had not been repaired, and in 40% of the respondents no faults occurred. Further irregularities occurred with the settlement of energy supplied to the grid (19%), with the settlement of energy taken from the grid (19%), with the settlement of energy from the photovoltaic installation (9.5%), with the operation of photovoltaic panels (14%), and with energy storage and the price of electricity (5%) (Figure 22).

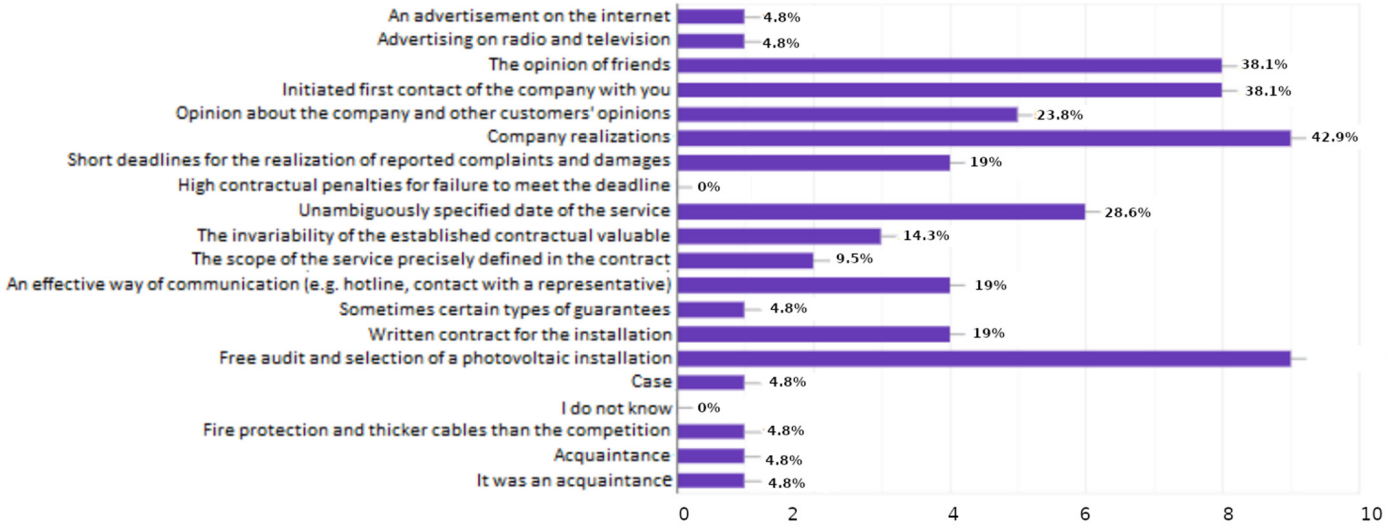

Figure 18. Elements influencing the choice of service provider.

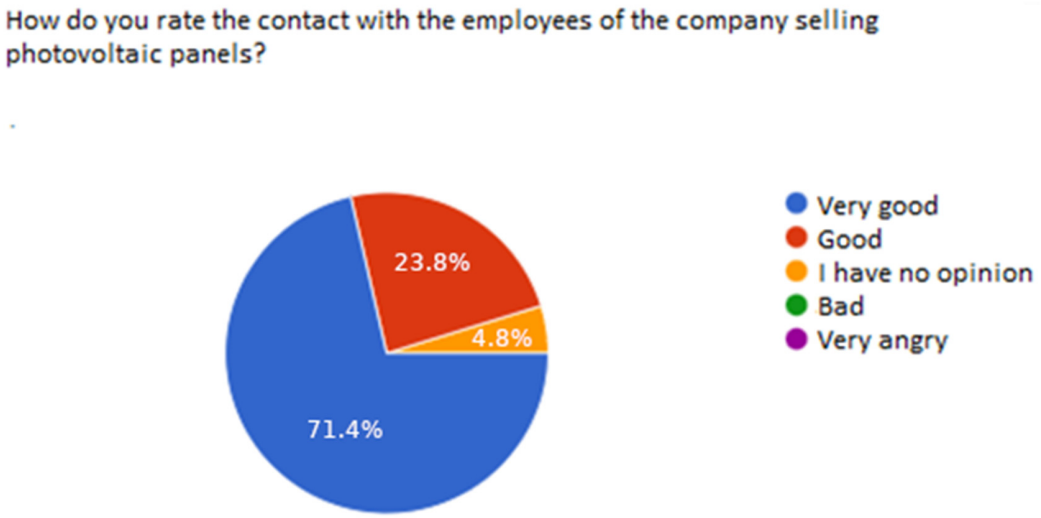

Figure 19. Contact with the service provider's employees.

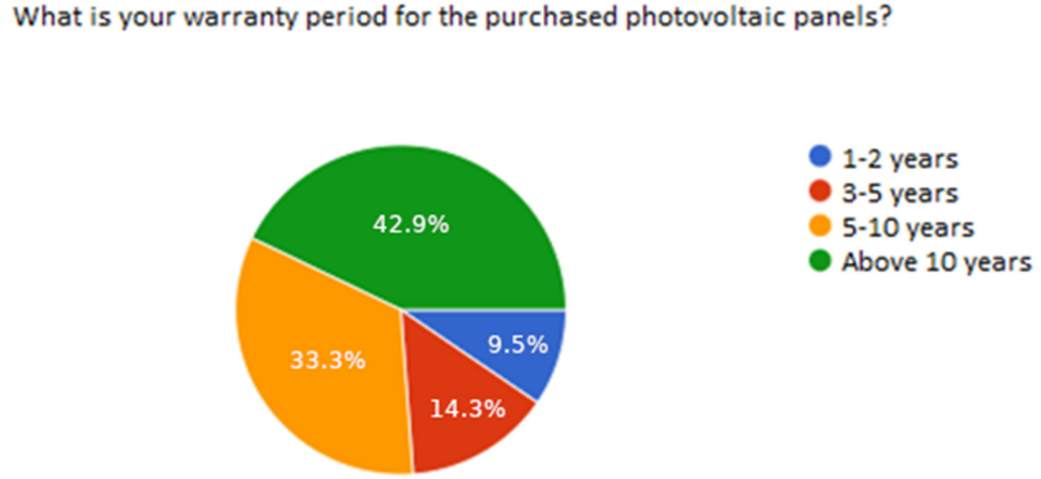

Figure 20. Guarantee period.

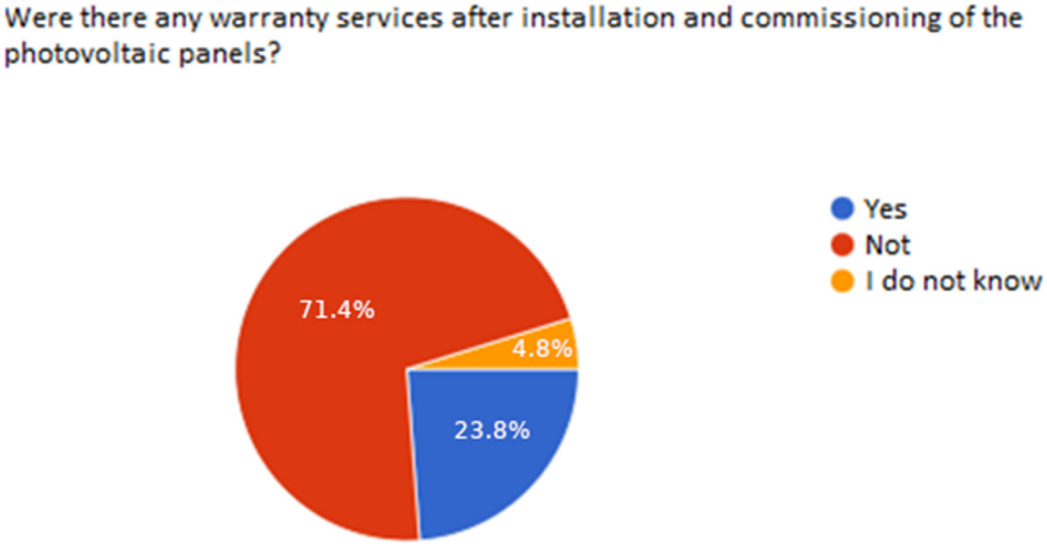

Figure 21. Warranty services.

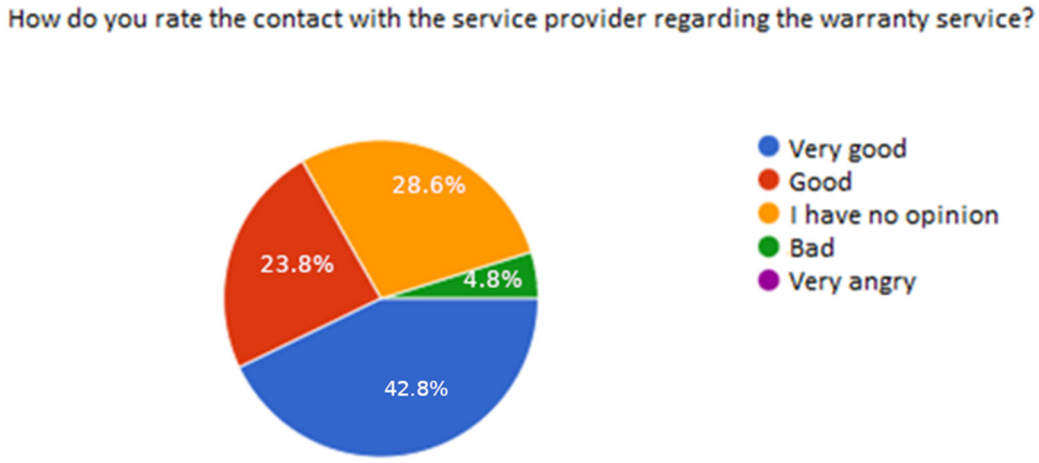

Figure 22. Warranty service.

4. Discussion

Electricity is the basis for the functioning of every household and business entity. The research concerned those entities that decided to change the current conditions from traditional access to electricity to energy obtained from the sun. Due to the cost of photovoltaic installations, this is the fastest growing energy division. In Poland, there are very favorable conditions for photovoltaic installations [1].

In total, 121 people took part in the study, including 90 men and 31 women. The age of the respondents is (Figure 23):

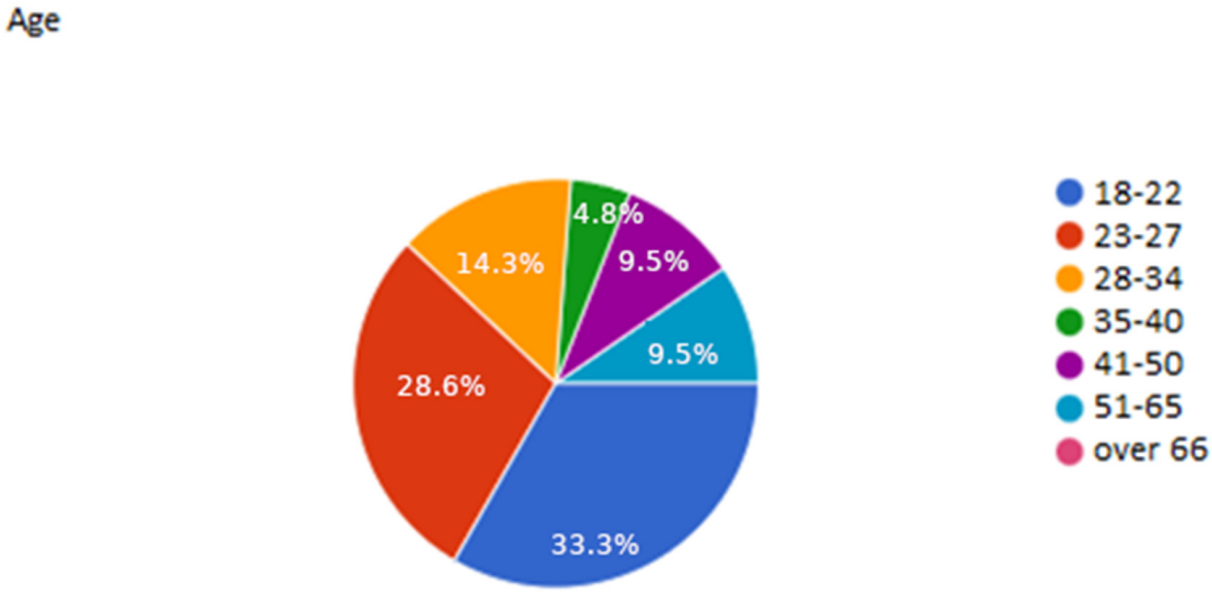

Figure 23. Age of respondents.

In total, 76% of the locations of the photovoltaic investment are villages (Figure 24).

In total, 90% of the photovoltaic installation was introduced in the household (Figure 25).

The great interest in photovoltaic panels is dictated primarily by the increase in the prices of raw materials, i.e., coal or gas, which leads to an increase in electricity prices. The photovoltaic installation itself is not so expensive to implement compared with other alternative energy sources.

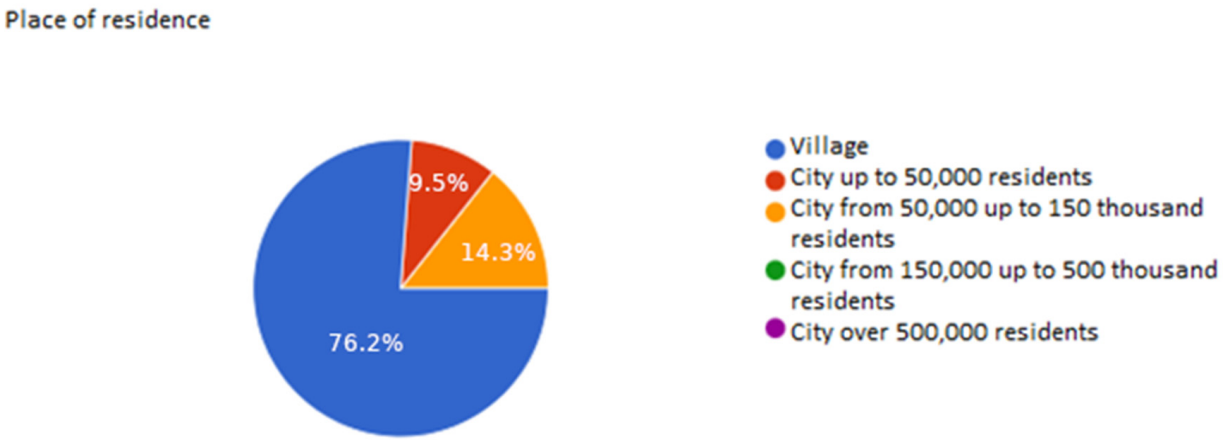

Figure 24. Place of residence of the respondents.

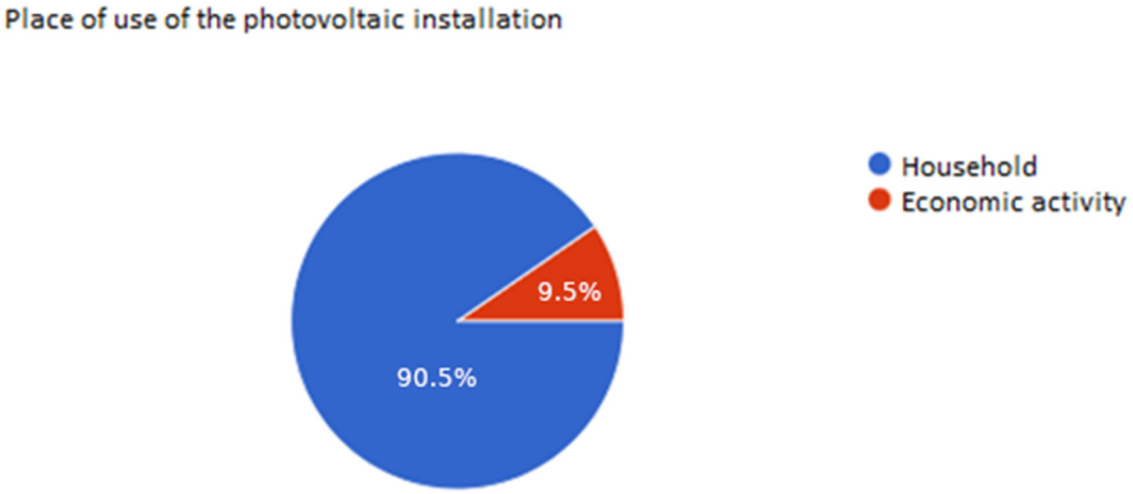

Figure 25. Place of use of the photovoltaic installation.

The data from the surveys were collected in the form of a decision table, which made it possible to accurately trace the respondents' decision-making process. The research presents the conditions and activities that correspond to the questions asked in the survey. On the other hand, the rules are the individual responses of the respondents. Due to the extensive data in the publication, it is possible to issue a table with 10 possible deliveries (Table 1). The questions collected from the survey were divided between a set (first part of the table) and a set of activities (second part of the table). The questions are grouped according to the best function, i.e., does the question normally use activities. The board is the basis that provides the greatest number of methods to solve problems and make decisions. The decision counter can be in a concise board, affecting the state of affairs that falls upon the fulfillment of a predetermined bank that had an impact on management. The board Decides the decision-making structure for jewelery. The conditions in the decision column correspond to the conditions for the decision. DETERMINATION OF IMPLEMENTED COOPERATIONS ON THE STUDY. Actions to initiate, initiate all steps to perform actions that can be performed to fulfill the assumption to use the first field of the array. The choice is determined by all of the rules. Symbol in this field indicating whether the data have been configured to be configured or not entered by the user. Action fault—identifying symbols (usually the actions of a systemic action of actions are the symbols "X"—the action is to be taken, "-" action of the functional actions) [25].

Table 1. Decision table with the analysis of the respondents' decision-making process.

U	1	2	3	4	5	6	7	8	9	10
Is the entry element to be the completion of the investment in 2019?	N	Y	N	N	N	N	Y	N	N	N
Is the entry element the completion of the investment in 2020?	Y	N	N	N	Y	N	N	Y	N	N
Is the input element the completion of the investment in 2021?	N	N	Y	Y	N	Y	N	N	Y	Y
Is the starting point for the commissioning of the photovoltaic installation in February?	N	N	Y	N	N	N	N	N	N	N
Is the starting point for the commissioning of the photovoltaic installation in March?	N	N	N	N	N	N	Y	N	N	N
Is the starting point for the commissioning of the photovoltaic installation in April?	N	Y	N	N	N	N	N	Y	N	N
Is the starting point for the commissioning of the photovoltaic installation in May?	N	N	N	N	N	N	N	N	Y	Y
Is the starting point for the commissioning of the photovoltaic installation in July?	N	N	N	N	N	Y	N	N	N	N
Is the starting point for the commissioning of the photovoltaic installation in August?	N	N	N	Y	Y	N	N	N	N	N
Is the starting point for the commissioning of the photovoltaic installation in October?	Y	N	N	N	N	N	N	N	N	N
Is the implementation of the contract from 1 to 3 months as the starting point?	N	Y	Y	Y	Y	Y	Y	N		Y
Is the implementation of the contract from 4 to 6 months as the starting element?	Y	N	N	N	N	N	N	Y	Y	N
Is the starting point for the transport of photovoltaic panels?	Y	N	N	N	N	N	N	N	N	N
Whether the input is transport on the service provider's side	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Whether the input is collection at the service provider's premises	N	Y	Y	N	N	N	N	N	N	N
Whether storage is input—1 day	Y	Y	Y	Y	Y	Y	N	N	Y	Y
Is the input element storage—2–3 days,	N	N	N	N	N	N	N	Y	N	N
Is storage as input—4–5 days,	N	N	N	N	N	N	Y	N	N	N
Is the input element the cardboard packaging of the panel lot?	N	Y	N	N	N	N	N	N	Y	N
Is the input element stacked vertically along the long side on the car	Y	N	N	Y	N	N	N	N	N	N
Is the input element panels stacked on pallets with securing dividers?	N	N	N	N	Y	Y	Y	Y	N	N
Whether the input element is each panel was packed separately in a cardboard box	N	N	N	N	N	N	N	N	N	Y
Is each panel an input element? Was it individually wrapped in foil	N	N	Y	N	N	N	N	N	N	N
Is the input element assembly of photovoltaic panels in 1–2 days	N	Y	N	Y	N	Y	N	N	N	Y
Is the input element to install photovoltaic panels in 2–4 days	Y	N	Y	N	Y	N	N	Y	N	N
Is the input element assembly of photovoltaic panels in 4–6 days	N	N	N	N	N	N	N	N	Y	N
Is the input element the installation of photovoltaic panels over 6 days	N	N	N	N	N	N	Y	N	N	N
Is the input element the location of photovoltaic panels on the roof of the property (house)	Y	Y	Y	Y	N	Y	N	N	Y	N
Is the location of the photovoltaic panels on the farm building the input element?	Y	N	N	Y	N	Y	Y	Y	N	N
Is the input element the location of the photovoltaic panels on the ground	N	N	N	N	Y	N	N	N	N	Y
Is the entry element to use the Clean Air program?	N	Y	N	N	N	Y	N	N	N	Y
Is the entry element to use the My Electricity program?	N	N	Y	N	Y	Y	N	Y	Y	Y
Is the entry element to use the program—Thermo-modernization relief?	N	N	N	Y	Y	N	Y	N	N	Y
Is the input element to install photovoltaic panels with a capacity of 2–3 kWp	N	Y	N	N	N	N	N	N	N	N
Is the input element to install photovoltaic panels with a power of 5–7 kWp	N	N	Y	N	N	Y	N	N	N	N
Is the input element to install photovoltaic panels with a capacity of 7–10 kWp	Y	N	N	Y	Y	N	Y	Y	Y	Y
Is the input element a monthly energy cost of less than PLN 100	N	Y	N	N	N	N	N	N	N	N

Table 1. *Cont.*

U	1	2	3	4	5	6	7	8	9	10
Is the input element a monthly energy cost between PLN 100–300?	N	N	Y	N	N	Y	Y	N	N	N
Is the input element a monthly energy cost between PLN 300–600	N	N	N	N	Y	N	N	Y	Y	Y
Is the input element the monthly energy cost between 600–900 PLN	Y	N	N	N	N	N	N	N	N	N
Is the input element the monthly energy cost above PLN 900?	N	N	N	Y	N	N	N	N	N	N
Is the input element the electricity tariff G11—24 h	Y	Y	Y	Y	Y	N	Y	N	N	Y
Is the input element the electricity tariff G12—different energy rates during the day and during the night	N	N	N	N	N	Y	N	N	N	N
Is the input element the electricity tariff G12w—different energy rates during the day, night, weekend, holidays and at specific times	N	N	N	N	N	N	N	Y	Y	N
Is the operation in the net-billing system the input element?	Y	Y	N	N	Y	Y	Y	N	N	Y
Is online advertising the input to the selection of a solar PV company?	N	Y	N	N	N	N	N	N	N	N
Is radio and TV advertising the input to the selection of a solar PV company?	Y	N	N	N	N	N	N	N	N	N
Is the opinion of friends the input to the selection of a PV company?	N	N	N	N	N	Y	N	N	N	Y
Is the initial contact of the company with the respondent at the input of the selection of a photovoltaic company?	Y	N	Y	N	N	N	Y	Y	N	N
Is the opinion about the company and the ratings of other customers the input element for choosing a PV company?	N	N	Y	Y	N	Y	N	N	N	N
Are the company's realizations the input element in the choice of a photovoltaic company?	N	N	N	Y	N	Y	N	Y	N	N
Is the unambiguously defined date of service implementation the input element of the selection of a photovoltaic company?	N	N	N	Y	N	N	Y	N	N	N
Is the invariability of the agreed contractual value the input element of the choice of a photovoltaic company?	N	N	N		N	N	Y	N	N	N
Is the input element of the selection of a photovoltaic company precisely defined in the contract with the scope of the service?	N	N	N	Y	N	N	N	N	N	N
Is an effective method of communication the input element for choosing a PV company (e.g., hotline, contact with a representative)	N	N	N	N	Y	N	N	N	N	N
Is a written installation contract an input to the selection of a PV company?	Y	N	Y	N	Y	N	N	N	N	N
Is the entry element in the selection of a photovoltaic company a free audit and selection of a photovoltaic installation	Y	N	Y	N	Y	N	Y	N	Y	N
Is the input element a warranty period of 1–2 years	Y	Y	N	N	N	N	N	N	N	N
Is the input element a warranty period of 3–5 years	N	N	N	N	N	N	N	Y	N	N
Is the entry element a warranty period of 5–10 years	N	N	N	N	N	Y	Y	N	N	Y
Is the input element a warranty period of over 10 years	N	N	Y	Y	Y	N	N	N	Y	N
Is the input element a fault repair time of less than a week	N	N	Y	Y	N	Y	N	N	Y	N
Is the input element a defect repair time between 8 and 20 days	Y	N	N	N	N	N	Y	N	N	N
Whether the input is not to repair a fault	N	N	N	N	Y	N	N	N	N	N
First contact with a service company providing services in the field of sales of photovoltaic panels—January		X	X							X
The first contact with a service company providing services in the field of sales of photovoltaic panels—February									X	
First contact with a service company providing services in the field of sales of photovoltaic panels—May	X			X	X					
First contact with a service company providing services in the field of sales of photovoltaic panels—June						X				

Table 1. *Cont.*

U	1	2	3	4	5	6	7	8	9	10
First contact with a service company providing services in the field of sales of photovoltaic panels—October							X	X		
Acceptance of the photovoltaic installation by an energy company within 1–3 months	X	X	X	X	X	X	X	X	X	X
Loading of photovoltaic panels by the service provider	X	X	X	X	X	X	X	X	X	X
Transport of photovoltaic panels on the side of the service provider	X	X	X	X	X	X	X	X	X	X
Percentage of damaged solar panels 0–10%			X	X						
Electricity storage option—Discount system		X			X			X		
Electricity storage option—Energy storage in the form of heat				X		X			X	X
Electricity resale			X			X				
Not for resale of energy—Procedures too complicated		X								
Not for resale of energy—Not profitable				X	X					
Not for reselling energy—Not knowing how to do it	X						X			
Not for resale of energy—Additional installation costs								X		X
Coverage of the annual electricity demand by a photovoltaic installation		X	X	X	X				X	
Planned increase in electricity consumption	X					X	X	X		
Protection against the future			X							
Installation that does not fully cover the energy consumed—Insufficient funds		X						X		X
Installation that does not cover the energy consumed in full—Carrying out a larger installation would rule out a subsidy						X	X		X	
The most important reason why a photovoltaic installation was installed—care for the environment		X	X				X	X		
The most important reason why a photovoltaic installation was installed—favorable subsidy systems								X		
The most important reason why a photovoltaic installation was installed—no payment for energy (net-metering)	X				X		X	X	X	X
Assessment of the selection of a company selling photovoltaic panels—Very good			X	X	X			X	X	
Assessment of the choice of a company selling photovoltaic panels—Good	X					X				X
Assessment of the choice of a company selling solar panels—I have no opinion		X								
Assessment of the choice of a company selling solar panels—Bad							X			
Assessment of the selection of a company selling solar panels—Very bad										
Assessment of contact with employees of a company selling photovoltaic panels—Very good			X	X	X			X	X	X
Assessment of contact with employees of a company selling photovoltaic panels—Good		X				X	X			
Assessment of contact with employees of a company selling solar panels—I have no opinion	X									
Warranty services after installation and commissioning of photovoltaic panels	X					X	X			
Assessment of contact with employees of a company selling photovoltaic panels regarding the repair of a defect—Very good			X					X	X	
Assessment of contact with employees of a company selling photovoltaic panels regarding the repair of a defect—Good		X				X	X			
Assessment of contact with employees of a company selling photovoltaic panels regarding the repair of a defect—I have no opinion				X	X					X

Table 1. *Cont.*

U	1	2	3	4	5	6	7	8	9	10
Assessment of contact with employees of a company selling photovoltaic panels regarding the repair of a defect—Bad	X									
Irregularities with the billing of energy fed into the grid	X									
Irregularities with the billing of energy consumed from the grid	X	X						X		
Irregularities with the billing of energy from photovoltaic panels	X									
Irregularities with the functioning of photovoltaic panels						X	X			
Irregularities with the storage of electricity	X									
Woman	X					X		X		
Man		X	X	X	X		X		X	X
Age 18–22					X	X		X		
Age 23–27				X			X			
Age 28–34	X	X							X	
Age 41–50										X
Age 51–65			X							
Place of residence—village	X	X	X	X		X	X	X	X	X
Place of residence—City up to 50,000					X					
Place of use of the photovoltaic installation—Household	X	X	X		X	X	X	X	X	X
Place of use of the photovoltaic installation—Economic activity				X						
Source of financing for the photovoltaic installation—Purchase with cash		X		X	X	X	X	X	X	
Source of financing for the photovoltaic installation—Bank loan	X		X							X
Electricity supply—PGE Dystrybucja S.A.		X			X	X				
Electricity supply—Tauron Dystrybucja S.A.	X		X	X			X	X	X	X

The decision table for 10 rules is presented above. During the tests, conditions and activities that did not affect the decision-making process were removed. A set of conditions was selected from the resulting decision table, which is presented in Table 2.

Table 2. Set of conditions.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
1	-	1	-	-	-	-	1	-	-	-
2	1	-	-	-	1	-	-	1	-	-
3	-	-	1	1	0	1	0	0	1	1
4	-	-	1	-	-	-	-	-	-	-
5	-	-	-	-	-	-	1	-	-	-
6	-	1	-	-	-	-	-	1	-	-
7	-	-	-	-	-	-	-	-	1	1
8	-	-	-	-	-	-	-	-	-	-
9	-	-	-	1	1	-	-	-	-	-
10	1	-	-	-	-	-	-	-	-	-
11	-	1	1	1	1	1	1	-		1
12	1	-	-	-	-	-	-	1	1	-
13	1	-	-	-	-	-	-	-	-	-
14	1	1	1	1	1	1	1	1	1	1
15	0	1	1	-	-	-	-	-	-	-

Table 2. *Cont.*

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
16	1	1	1	1	1	1	-	-	1	1
17	-	-	-	-	-	-	-	1	-	-
18	-	-	-	-	-	-	1	-	-	-
19	0	1	0	0	0	0	0	0	1	0
20	1	-	-	1	-	-	-	-	-	-
21	-	-	-	-	1	1	1	1	-	-
22	-	-	-	-	-	-	-	-	-	1
23	-	-	1	-	-	-	-	-	-	-
24	-	1	-	1	-	1	-	-	-	1
25	1	-	1	-	1	-	-	1	-	-
26	-	-	-	-	-	-	-	-	1	-
27	-	-	-	-	-	-	1	-	-	-
28	1	1	1	1	0	1	0	0	1	0
29	1	0	0	1	0	1	1	1	0	0
30	0	0	0	0	1	0	0	0	0	1
31	0	1	0	0	0	1	0	0	0	1
32	0	0	1	0	1	1	0	1	1	1
33	0	0	0	1	1	0	1	0	0	1
34	-	1	-	-	-	-	-	-	-	-
35	-	-	1	-	-	1	-	-	-	-
36	1	-	-	1	1	-	1	1	1	1
37	-	1	-	-	-	-	-	-	-	-
38	-	-	1	-	-	1	1	-	-	-
39	-	-	-	-	1	-	-	1	1	1
40	1	-	-	-	-	-	-	-	-	-
41	-	-	-	1	-	-	-	-	-	-
42	1	1	1	1	1	-	1	-	-	1
43	-	-	-	-	-	1	-	-	-	-
44	-	-	-	-	-	-	-	1	1	-
45	1	1	0	0	1	1	1	0	0	1
46	0	1	0	0	0	0	0	0	0	0
47	1	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	1	0	0	0	1
49	1	0	1	0	0	0	1	1	0	0
50	0	0	1	1	0	1	0	0	0	0
51	0	0	0	1	0	1	0	1	0	0
52	0	0	0	1	0	0	1	0	0	0
53	0	0	0	0	0	0	1	0	0	0
54	0	0	0	1	0	0	0	0	0	0
55	0	0	0	0	1	0	0	0	0	0
56	1	0	1	0	1	0	0	0	0	0
57	1	0	1	0	1	0	1	0	1	0
58	1	1	-	-	-	-	-	-	-	-
59	-	-	-	-	-	-	-	1	-	-
60	-	-	-	-	-	1	1	-	-	1
61	-	-	1	1	1	-	-	-	1	-
62	-	-	1	1	-	1	-	-	1	-
63	1	-	-	-	-	-	1	-	-	-
64	-	-	-	-	1	-	-	-	-	-

1, 63 | A2, A5, A7
2, 62 | A1, A5, A7, A8
3, 61 | A3, A4, A5, A6, A9, A10
4, 60 | A3, A4, A5, A9
5, 59 | A6, A7, A10
6, 58 | A2, A8
7, 57 | A1, A2, A3, A9, A10

8, 56 | A1, A3, A4, A5, A7, A9
9, 55 | A1, A3, A5
10, 54 | A2, A3, A4, A5, A6, A7, A10
11, 53 | A1, A4, A8, A9
12, 52 | A1, A7
13, 51 | A1, A2, A3, A4, A5, A6, A7, A8, A9, A10
14, 50 | A2, A3, A4, A6, A8
15, 49 | A1, A2, A3, A4, A5, A6, A9, A10
16, 48 | A1, A3, A7, A8
17, 47 | A6, A7, A10
18, 46 | A1, A2, A9
19, 45 | A1, A2, A4
20, 44 | A1, A2, A5, A6, A7, A8, A10
21, 43 | A8, A9, A10
22, 42 | A3, A6
23, 41 | A1, A2, A3, A4, A5, A6, A7, A10
24, 40 | A1, A3, A4, A5, A8
25, 39 | A1, A9
26, 38 | A5, A7, A8, A9, A10
27, 37 | A1, A2, A3, A4, A6, A7, A9
28, 36 | A1, A2, A4, A5, A6, A7, A8, A9, A10
29, 35 | A5, A10
30, 34 | A2, A3, A6, A10
31, 33 | A3, A5, A6, A8, A9, A10
32, 32 | A4, A5, A7, A10

$$(a_1 + a_5)(a_1 + a_8)(a_1 + a_9)(a_1 + a_2)(a_1 + a_3)(a_1 + a_4)(a_1 + a_6)(a_1 + a_{10})(a_1 + a_7) \quad (1)$$

$$(a_2 + a_7)(a_2 + a_8)(a_2 + a_3)(a_2 + a_4)(a_2 + a_5)(a_2 + a_6)(a_2 + a_9)(a_2 + a_{10})(a_2 + a_7) \quad (2)$$

$$(a_3 + a_4)(a_3 + a_6)(a_3 + a_9)(a_3 + a_{10})(a_3 + a_2)(a_3 + a_5)(a_3 + a_1)(a_3 + a_8)(a_3 + a_7) \quad (3)$$

$$(a_4 + a_3)(a_4 + a_6)(a_4 + a_9)(a_4 + a_{10})(a_4 + a_5)(a_4 + a_2)(a_4 + a_7)(a_4 + a_{10})(a_4 + a_1) \quad (4)$$

$$(a_5 + a_1)(a_5 + a_8)(a_5 + a_4)(a_5 + a_2)(a_5 + a_6)(a_5 + a_7)(a_5 + a_{10})(a_5 + a_1)(a_5 + a_3) \quad (5)$$

$$(a_6 + a_3)(a_6 + a_4)(a_6 + a_9)(a_6 + a_{10})(a_6 + a_2)(a_6 + a_5)(a_6 + a_7)(a_6 + a_{10})(a_6 + a_8) \quad (6)$$

$$(a_7 + a_2)(a_7 + a_3)(a_7 + a_4)(a_7 + a_5)(a_7 + a_6)(a_7 + a_{10})(a_7 + a_8)(a_7 + a_{10})(a_7 + a_9) \quad (7)$$

$$(a_8 + a_1)(a_8 + a_5)(a_8 + a_2)(a_8 + a_9)(a_8 + a_6)(a_8 + a_7)(a_8 + a_3)(a_8 + a_9)(a_1 + a_{10}) \quad (8)$$

$$(a_9 + a_3)(a_9 + a_4)(a_9 + a_6)(a_9 + a_{10})(a_9 + a_{10})(a_9 + a_1)(a_9 + a_{10})(a_9 + a_5)(a_9 + a_7) \quad (9)$$

$$(a_{10} + a_3)(a_{10} + a_4)(a_{10} + a_6)(a_{10} + a_9)(a_{10} + a_2)(a_{10} + a_7)(a_{10} + a_5)(a_{10} + a_9)(a_{10} + a_7) \quad (10)$$

The data collected in the questionnaires made it possible to create a decision table based on the responses obtained. The decision table showed the best possible variant of the decision-making process for the purchase and installation of photovoltaic panels, starting from the selection of the month in which the first contact with the company took place for the installation power and warranty period. Due to the fact that, in the research, the decision-making process took place before its analysis, the data from the decision table can be treated as an instruction to make decisions in similar situations.

5. Conclusions

The increase in the share of renewable energy sources in the country's energy balance ensures an increase in energy security, reduces dependence on energy imports and results in savings in the use of fossil fuel resources [21]. Currently, in Poland, almost one million

prosumers have a photovoltaic installation. The main reasons for investments are economic issues as well as care for the natural environment [26–28].

Logistics processes play a significant role in the implementation of photovoltaic investments. The period from ordering to implementation of the installation is crucial in the economic calculation of the return on investment. Therefore, the time qualified in the procurement process is crucial for the final economic result to be at the level assumed at the outset. The entirety of the success of the investment depends to a large extent on the process of transporting the elements of the photovoltaic installation. Damages caused during the transport process may be of key importance for the implementation of the entire investment. Based on the research, it was noticed that the transport process does not have a negative effect on the transported elements. The storage of photovoltaic panels prior to their installation on the contracting authority's property is a high-risk activity, and the fault as to any damage may be difficult to prove. In this study, the elements of the photovoltaic installation were not damaged during their storage, which does not change the fact that this component of the storage process should be taken into account and possibly improved. The most complicated process in managing renewable energy sources is the distribution process. This is responsible not only for the delivery of installation elements to the indicated address, at the right time, in the right quantity and at the right price, but also the entire process related to energy distribution [1,20,21,29].

The conducted analysis shows the relationship between logistics and renewable energy sources. Effective management of logistics processes has a direct impact on the efficiency of the installed home solar power plant. Logistics processes are an extremely important link in the photovoltaic chain [14,15,26,30,31].

Author Contributions: Conceptualization: M.D.-G. and E.K.; methodology: M.D.-G. and E.K.; software: M.D.-G. and E.K.; formal analysis: M.D.-G. and E.K.; investigation: M.D.-G. and E.K.; data curation: M.D.-G. and E.K.; writing—original draft preparation: M.D.-G. and E.K.; writing—review and editing: M.D.-G. and E.K.; visualization: M.D.-G. and E.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

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