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Article

Selection of a Photovoltaic Carport Power for an Electric Vehicle

Edgar Sokolovskij [1,*], Arkadiusz Małek [2], Jacek Caban [3], Agnieszka Dudziak [4,*], Jonas Matijošius [1] and Andrzej Marciniak [2]

[1] Department of Automobile Engineering, Faculty of Transport Engineering, Vilnius Gediminas Technical University, Plytinės g. 25, LT-10105 Vilnius, Lithuania; jonas.matijosius@vilniustech.lt
[2] Department of Transportation and Informatics, WSEI University, Projektowa 4, 20-209 Lublin, Poland; arkadiusz.malek@wsei.lublin.pl (A.M.); andrzej.marciniak@wsei.lublin.pl (A.M.)
[3] Department of Automation, Faculty of Mechanical Engineering, Lublin University of Technology, Nadbystrzycka 36, 20-618 Lublin, Poland; j.caban@pollub.pl
[4] Department of Power Engineering and Transportation, Faculty of Production Engineering, University of Life Sciences in Lublin, Głęboka 28, 20-612 Lublin, Poland
* Correspondence: edgar.sokolovskij@vilniustech.lt (E.S.); agnieszka.dudziak@up.lublin.pl (A.D.)

Abstract: The increasing number of electric vehicles is forcing new solutions in the field of charging infrastructure. One such solution is photovoltaic carports, which have a double task. Firstly, they enable the generation of electricity to charge vehicles, and secondly, they protect the vehicle against the excessive heating of its interior. This article presents the functioning of a small carport for charging an electric vehicle. Attention is drawn to the problems of selecting the peak power of the photovoltaic system for charging an electric vehicle. An economic and energy analysis is carried out for the effective use of photovoltaic carports. In this article, we present the use of the Metalog family of distributions to predict the production of electricity by a photovoltaic carport with the accuracy of probability distribution.

Keywords: photovoltaic carport; electric vehicle; power; green energy; environmental indicators; Metalog

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1. Introduction

Ensuring the energy security of electric vehicles (EVs) primarily concerns the availability of charging points capable of covering the demand for the electric power of vehicles. Currently, almost all areas of our lives have been mechatronized. The first step was the electrification of existing mechanical solutions at the beginning of the 20th century, in order to achieve greater reliability and improve safety. Over the years, it was proven that the electric drives were much more reliable, more efficient and definitely more ecological than the then-steam drives [1]. In addition, the electrification of cities and villages has cleared human settlements of CO_2 emissions and other flue gas components produced during coal combustion in boilers [2]. Due to the fact that alternating current enables the transmission of electricity over long distances with low transmission losses, it is possible to supply many consumers. In addition, humanity simultaneously began to use alternative [3] and renewable energy sources (RES) [4] to meet its energy needs. At the beginning, electric drives were used in stationary mode, but with their development they began to be used in mobile mode [5]. The biggest problem that emerged was energy storage. However, with the evolution of technology, traction batteries appeared on the market, the electric capacity of which ensures that the vehicle can travel several hundred kilometers [6]. Currently, batteries of this type are becoming cheaper and more reliable [7]. In the work of [8], the impact of driving cycles on the range of the vehicle was examined, which showed that in the urban environment electrically powered vehicles travelling at low speeds are highly efficient. Another factor of the increase in the popularity of the electric drive of vehicles is the fast charging of the battery with high current [9]. Therefore, there is an increasing interest in battery electric vehicles (BEVs) [10–12] and other means of transport using electric drive [13,14], which contributes to the reduction of CO_2 emissions from transport. In turn, hybrid electric vehicles (HEVs) proved to be a good solution, filling the gap between the desirable features of electric drive systems, including long range and more affordable costs, unlike conventional vehicles [10,12,15,16]. In some countries, as early as in 2022, it was declared that the production of diesel engines would cease, as well as the production of gasoline engines by 2028. Of course, humanity faces many challenges, e.g., research on the risk or reliability of drive. A very important trend observed in science is research into the impact of innovative technologies on the natural environment and human life [17].

Many global trends can be observed in the area of electricity production and distribution. Due to the shrinking resources of crude oil and coal, as well as their high emissivity in the form of carbon dioxide, energy based on RES has been introduced in many countries. Huge dams on water reservoirs, windmill farms or hectares of land covered with photovoltaic panels are already a daily sight [18]. Nuclear energy has returned to favor and many more countries are planning to base their energy independence on this source. Apart from large traditional and alternative power plants, elements of distributed energy often emerge with acceleration [19]. For instance, it can be in the form of solar panels for heating hot water in individual households or in the form of photovoltaic systems (PV systems) supplying prosumers with electricity. Our vehicles can also run on many types of fuel; we can easily and safely buy diesel, petrol and liquefied petroleum gas (LPG) at every petrol station [20]. At selected stations in Europe and Poland, it is possible to refill your car with ethanol (E85) [21], compressed natural gas (CNG) [22,23] and even hydrogen [24,25]. Many vehicles can be powered by two or three types of fuel (dual or tri fuel) [21,25–31].

At no time in history has such a diversification of energy generation sources, available fuels, and devices and vehicles been performed on such a scale [32]. The recovering economy after the SARS-CoV-2 pandemic in 2020–2021 requires even more energy in various forms. As shown by Setter et al. in their paper [33], during the pandemic in some cities, the volume of transport and distribution of individual shipments (e.g., groceries, delivery of ready meals, etc.) increased by more than 100%. It should be noted that these deliveries were mostly made by vehicles with internal combustion engines. This paper includes a recommendation for the location of urban logistics centers, which would allow the use of EVs, including autonomous vehicles.

In the 21st century, the power grid in many countries must be adapted to transmit more and more energy and the higher power consumed by individual users [34]. It should also be able to absorb even more energy produced from RES by smaller micro-installations [35]. Here, there is a challenge related to energy balancing in the distribution grid. This is where stationary and mobile electricity storage can be of aid [36]. Some EVs have the V2G (Vehicle to Grid) function, which enables the home to be powered from the energy stored in the vehicle’s traction battery. The infrastructure for charging electric vehicle batteries is growing exponentially [37]. It has the form of both low-power electricity poles and fast DC chargers with power up to 350 kW [38,39].

2. Materials and Methods

The electric drives of vehicles are characterized by quiet operation [40] and high efficiency [41]. Due to this, they are often used to drive small city vehicles [42] and city buses [43]. Currently, entire fleets of electric vehicles are frequently being introduced [44,45]. Scientists are involved in the optimization of electric drive systems [46,47] and traction batteries [48]. Each year, better-performing vehicles are introduced to the markets [49]. Many electric vehicle on-board systems are more efficient than traditional solutions [50].

In order for the safe and reliable functioning of energy-generating devices and energy receivers, it is necessary to monitor and supervise these facilities properly [51–53]. This is possible as a result of the introduction of the global Internet network in the world over the last three decades. Currently, most sources and receivers of electricity are Internet of Things (IoT) devices and fulfil the functions of Industry 4.0 [54]. Device monitoring, diagnostics and their maintenance is possible by sending chosen parameters to the data cloud, where they are analyzed on-line or off-line [55]. Therefore, thanks to advanced on-line platforms, electricity management is not a problem, even in large areas. Types and connections of electricity generation infrastructure and its receivers are shown schematically in Figure 1 [56,57].

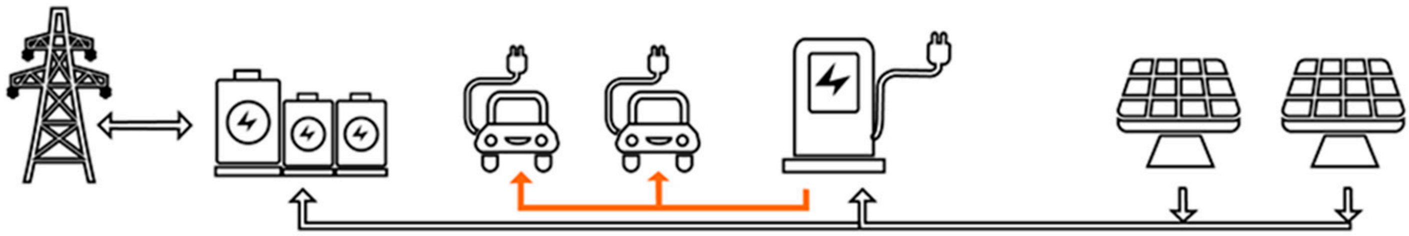

Figure 1. Electricity supply and reception infrastructure.

The next infographic, shown in Figure 2, presents the possibility of charging electric cars with RES in the form of a ground-based photovoltaic system.

Figure 2. Charging electric vehicles with renewable energy.

Carports are an effective source of solar energy that can be used to charge electric vehicles [58]. Carports not only generate the necessary electricity, but also provide shade for the vehicle parked under it. For these reasons, carports are an ideal solution for charging EVs [59]. Carports are, therefore, an ideal solution for installation in large parking lots in front of office buildings and shopping centers. The EVs of customers or employees will be protected against excessive sunlight and can additionally be charged.

The analysis of the literature shows that scientists are increasingly using the Metalog family of distributions to describe various processes. Using the Metalog family of distributions, we obtain information from a knowledge base, not from a database. The difference is that in the database, the answer to the questions asked is obtained as a result of searching the database, while the knowledge base answers the question by running an inference algorithm. This approach is similar to asking the question: What if? Based on Metalog, determining the probability for a given daily amount of energy produced requires a simulation process that uses the inverse function of the Empirical Distribution. The GeNIe 4.0 Academic software has built-in Metalog distribution families and allows us to quickly determine the Empirical Distribution, the Probability Density Function and an easy way to extract information from the knowledge base.

GeNIe 4.0 Academic software was used for off-line calculations. The presented calculations support the decision-making process of the constructor of photovoltaic carports. The authors did not install their own additional power measurement system and the amount of energy produced by the carport. The data sent by the photovoltaic inverter to the MQTT broker were used. One of the authors was the operator of the MQTT server, as a result of which he had access to the transferred data. The amount of energy produced was measured with an accuracy of 0.1 kWh.

Metalog distributions are a new system of continuous one-dimensional probability distributions designed for flexibility, simplicity and ease/speed of use in engineering practice and science. The Metalog system consists of unbounded, partially bounded and bounded distributions, each of which offers almost unlimited shape flexibility compared to Pearson, Johnson and other traditional probability distributions. Unlike other distributions that require non-linear optimization for parameter estimation, Metalog quantile functions and PDF Probability Density Functions have simple closed-form expressions. Metalog distributions are linearly quantile-parameterized using cumulative CDF data. In 2016, Keelin was the first to show how Metalog distributions can support data and distribution research in fish biology and hydrology [60].

Keelin and Howard [61] offer a family of continuous probability distributions, matching methods and tools that provide enough flexibility in shape and constraints to closely match virtually any probability distribution or data set. The authors have shown that Metalog applications improve decision-making and can be widely used in virtually any application of continuous probability in any field of human endeavor.

Metalog is a flexible probability distribution that can be used to model a wide range of density functions using only a small number of parameters obtained from experts. Scientists prefer using the Metalog family of distributions to describe processes in various fields of science, such as theology [62], mathematics [63] and cybernetics [64].

3. Results and Analysis

The object of the research is a photovoltaic carport installed at WSEI University car park in Lublin (Poland). The carport consists of four polycrystalline panels with a total power of 1 kWp. The carport is made of welded steel profiles with anti-corrosion coating (galvanized) placed on a supporting structure in the form of two crossed vertical profiles (see Figure 3). The roof structure of the carport on which the panels are mounted is made of aluminium profiles. The inclination angle of the photovoltaic panels mounted on the carport is 30°. The carport is positioned exactly to the south. It was designed by one of the authors, together with a group of students from the University. It is used to charge a small electric car: a Renault Twizy. When an electric vehicle is not connected to the carport, all the energy produced supplies the nearby laboratory. The carport has a compact design and can be quickly disassembled and reassembled. Three electric receivers can be supplied simultaneously from the carport, with an alternating voltage of 230 V. The test objects in the form of a carport and a small electric car, a Renault Twizy, are shown in Figure 3. Renault Twizy is the smallest vehicle produced by Renault and is used to transport two adults around the city. It has traction batteries with a capacity of 6.1 kWh, which provide it with an autonomy of 60 to 100 km.

Figure 3. Carport at the WSEI during the charging of the Renault Twizy EV.

To be precise, the inverter in the photovoltaic carport has the functions of the Internet of Things. Due to the additional communication module, it is possible to wirelessly transfer measurement data (via Wi-Fi) to the data cloud. The authors use measurement data on the daily and monthly amount of energy produced by the carport for the analysis presented in the article. The amount of energy produced by a photovoltaic system is crucial in optimal energy management. The amount of energy produced by the photovoltaic system, the amount of energy consumed by the electric vehicle when charging the battery and the energy consumption of the building are the components of the energy balance. An MQTT broker is an intermediary entity that enables MQTT clients to communicate. Specifically, an MQTT broker receives messages published by clients, filters those messages by topic, and distributes them to subscribers. Currently, each manufacturer of inverters used in photovoltaic systems has an MQTT broker. This is a standard that is required by individual customers and large producers of energy from renewable energy sources. In addition to the data on the instantaneous power generated by the system and the amount of energy produced, the MQTT broker receives large amounts of measurement data that are later applied for diagnostic purposes.

Typically, it takes about 4 h to recharge fully discharged Renault Twizy batteries. Figure 4 shows graphs of electric vehicle charging power (Pev) and carport power (Ppv) vs. time. According to the presented data on the graph, the charging process took 210 min. The charging power of the electric vehicle was not constant throughout the charging process. The on-board charger of the vehicle initially consumed 1200 W. Then, charging took place for almost 3 h with a power of 1800 to almost 2000 W. Around 15.00, there was a decrease in the charging power of the electric vehicle battery. The Battery Management System (BMS) reduced the charging power from approx. 2000 W to approx. 400 W. Charging with lower power usually lasts approx. 15–30 min, until the traction battery is fully charged (SoC = 100%). Then, the BMS completes the charging process and the power drawn drops to 0 W. The power generated by the carport (Ppv) ranged from 800 to 600 W. This means that the electric vehicle was charged on a sunny and cloudless day. The carport was connected to the power grid (on-grid connection). This connection makes it possible to draw additional energy from the power grid when the energy generated by the carport is not sufficient to charge the vehicle [65]. The opposite of this solution is an off-grid installation, where the PV installation is not connected to the power grid [60].

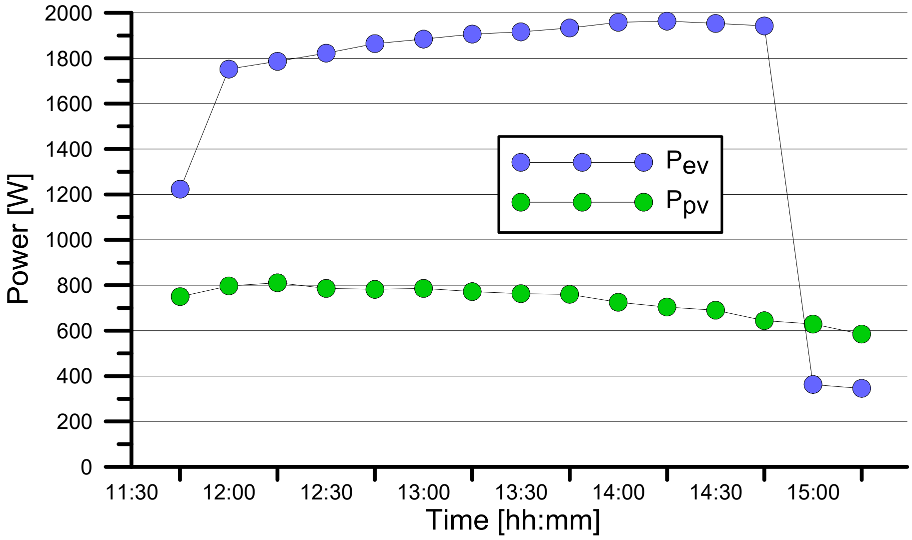

Figure 4. Graphs of the power generated by the mini carport (P_{pv}) and the power consumed during vehicle charging (P_{ev}).

In this case, the vehicle consumed almost 6 kWh of electricity to be fully charged. At that time, the carport generated 2.75 kWh of electricity, which is 46% of the demand. Analyzing the graph presented in Figure 4, it can be concluded that the WSEI carport cannot cover the instantaneous power needed to charge this EV. The missing power is taken from the power grid by the charger. The situation presented in Figure 4 is rare because the charging process took place in very good sunlight conditions, which are not usually present during the year. Thus, the energy generated by the system is much less than that shown in this example. It should be remembered that each PV installation is characterized by the high uniqueness of the generated power, which is closely related to the prevailing weather conditions and is characterized by seasonality (seasons). Therefore, the peak power of the PV installation cannot be the only parameter on the basis of which one determines the power demand and selects the size for a specific EV.

Another important parameter of vehicle traction batteries, apart from the charging power, is their energy capacity, i.e., the amount of electricity stored in the battery expressed in kWh. The range of each EV depends on the amount of energy stored in the battery and the actual energy consumption. The test vehicle (Renault Twizy) has a nominal battery capacity of 6.1 kWh. which is approximately the amount corresponding to the daily electricity demand of an average-sized single-family house. The vehicle can cover a distance of 60 to 100 km on a fully charged battery, depending on speed and vehicle characteristics. Based on previous long-term research conducted by the author [43], it appears that the average range of the vehicle on one full charge is 65 km.

The analysis of the daily amount of energy produced by the WSEI carport on individual days in June 2022 is shown in Figure 5. As one may notice, the amount of electricity produced is in a wide range, from 1.5 to over 6 kWh. In addition, the maximum amount of energy produced in June 2022 is close to the energy capacity of the battery of the tested EV.

Photovoltaic electricity generation systems, including photovoltaic carports, are devices of the Internet of Things, which means that they generate data on instantaneous power and calculate the amount of energy generated in a given period of time. Data packets are sent every few minutes to the data cloud, where they are archived and can be viewed using user-friendly software. The administrator of such a portal can also download and process these data. Therefore, IoT devices “speak to us” using measurement data, which are usually used to monitor correct operations and for diagnostic purposes. By using more advanced methods of data processing, they can also be used for optimization and planning purposes.

In this section of the article, we will present the use of the Metalog family of distributions to predict the production of electricity by a photovoltaic carport with the accuracy of the probability distribution. The amount of electricity produced by the carport on particular days of the month is used to determine the Cumulative Distribution Function (CDF), which is a continuous function. Then, the Probability Distribution Function is determined. The Metalog family of distributions allows one to make calculations for a specific photovoltaic carport located in a specific location (Lublin in Poland) and in a specific context (location on the ground, azimuth, shading).

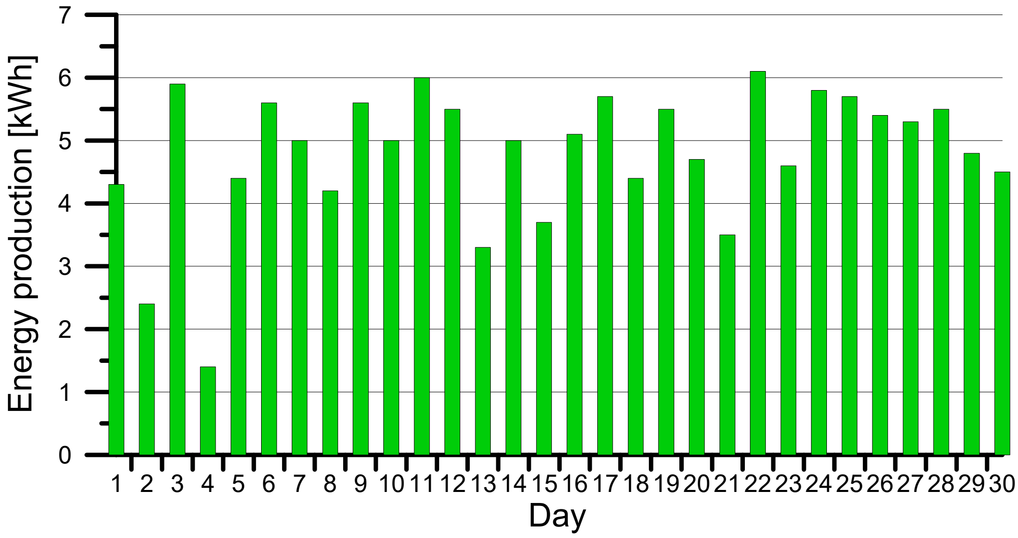

Figure 5. Daily electricity production by the WSEI mini carport in June 2022.

The Metalog family of distributions, parametrized with quantiles, allows us to determine the percentiles in the production of electricity by a photovoltaic carport and to determine what its value will be with the accuracy of the probability distribution (Table 1). The Metalog approach discusses the composition of generative probabilistic models. It is a complex decomposition. From the shape of the density function, it can be concluded that there are several different contexts for the functioning of the carport.

Table 1. Quantile parameters.

Probability	Energy Production (kWh)
0.05	2.400000095367
0.25	4.400000095367
0.5	5
0.75	5.599999904633
0.95	6

Basic statistical calculations show that in June 2022 the minimum value of the energy produced was 1.4 kWh, the maximum value was 6.1 kWh, and the average value of the energy produced was 4.79667 with a standard deviation of 1.08389. The Metalog family of distributions allows for a more flexible fitting of CDF and PDF to the real data.

Then, we determined the Empirical Distribution of the Distribution (Figure 6) and the Probability Density Function (Figure 7).

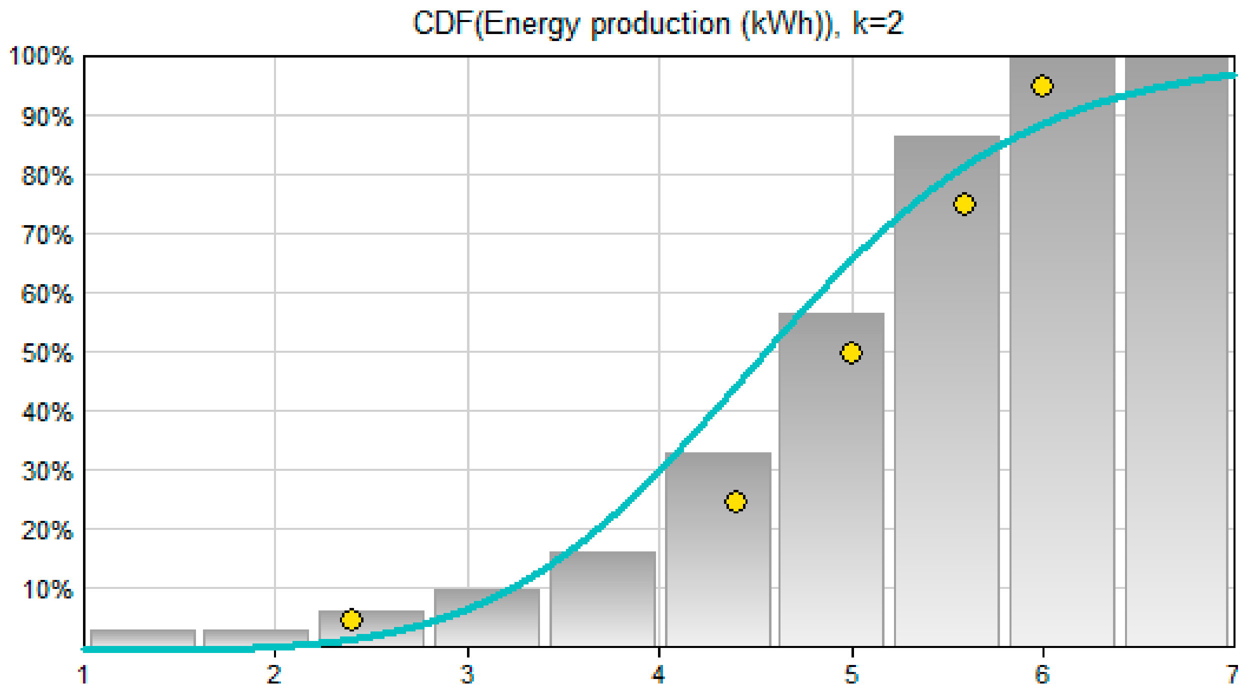

Figure 6. Empirical Distribution Function (sea color line) for daily energy produced by the WSEI carport in the month of June 2022 and quantile parameters (yellow symbols).

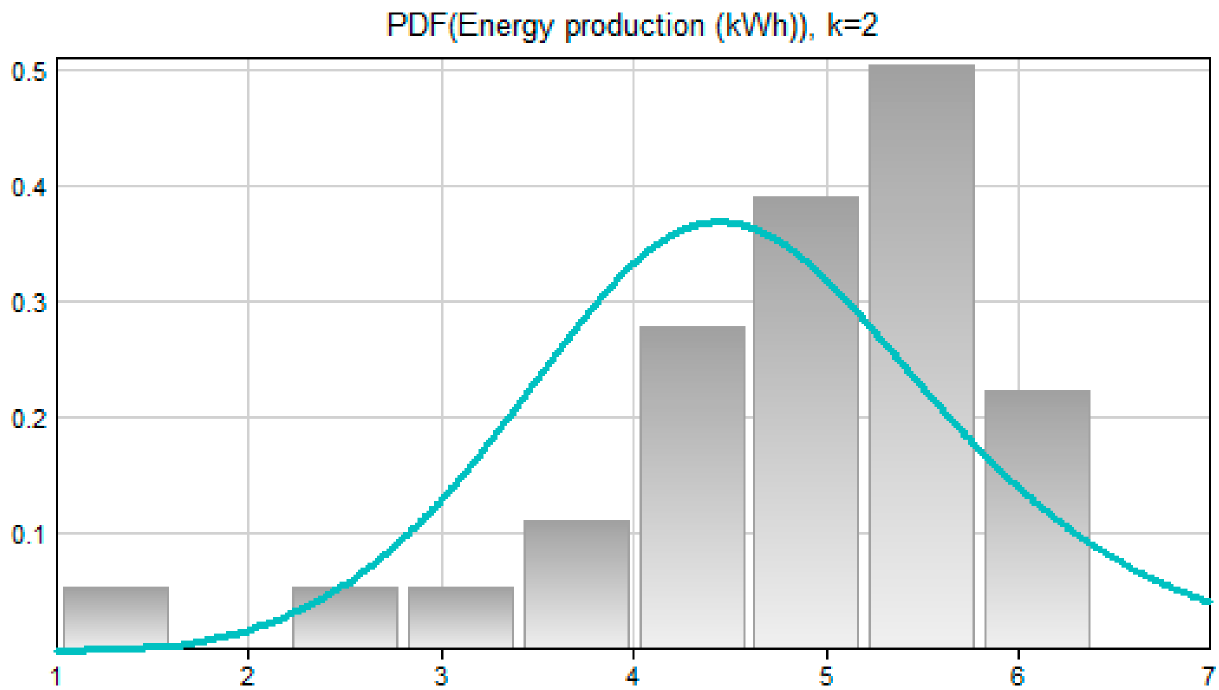

Figure 7. Probability Density Function (sea color line) for the daily energy produced by the WSEI carport in June 2022.

The GeNIe 4.0 Academic software makes it possible to determine the Empirical Distribution and the Probability Density Function for various k factors (Figure 8).

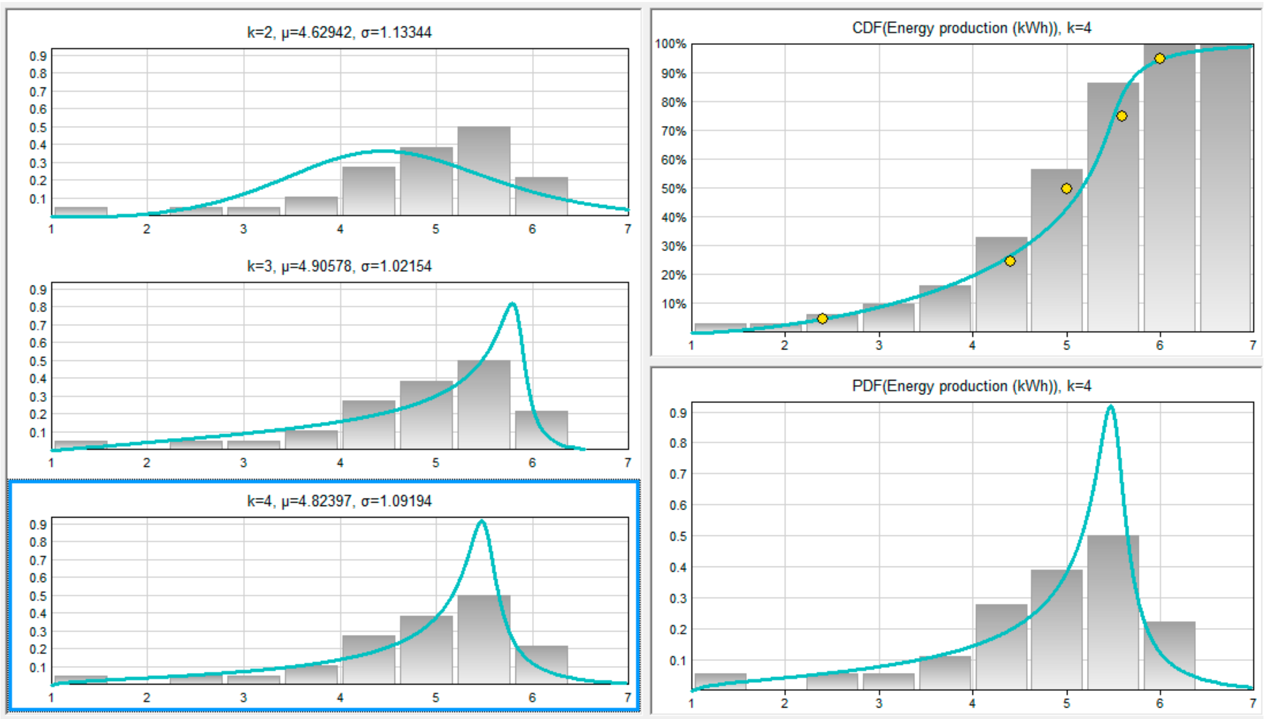

Figure 8. Empirical Distribution Function (sea color line) along with quantile parameters (yellow symbols) and Probability Density Function (sea color line) for the daily energy produced by the WSEI carport in the month of June 2022 for various k coefficients.

The next step is to obtain information from the knowledge base. The probability of energy production is calculated by the WSEI carport $\geq$ 6 kWh. This is the amount of energy needed to fully charge the Renault Twizy's traction battery. The program's answer to the question asked is as follows: The probability of daily production of electricity equal to or less than 6 kWh by the WSEI carport in the month of June 2022 is 0.9333. So, the probability of producing more than 6 kWh is 1–0.9333. A question can also be formulated regarding the probability of the energy produced by the WSEI carport of $\geq$3 kWh. The program's answer to the question asked is as follows: The probability of daily production of electricity equal to or less than 3 kWh by the WSEI carport in the month of June 2022 is 0.0667. So, the probability of producing more than 3 kWh is 1–0.0667, which is a sufficient result.

The physical interpretation of the obtained results is as follows: in June 2022, the WSEI carport, with a very low probability, produced energy higher than the energy capacity of the traction batteries of the Renault Twizy vehicle. However, the amount of energy produced greater than 3 kWh of energy was already with a very high probability. This means that it is possible that the Renault Twizy's batteries can be charged to half of their energy capacity.

Thus, the presented approach related to the use of the Metalog distribution family can be used to simulate various strategies for generating energy by photovoltaic carports, depending on the energy demand for charging the selected electric vehicle (characterized by the energy capacity of the battery). It is worth emphasizing once again that the presented calculations are made for a specific carport in a given location and in a specific context (e.g., time).

The production of electricity by photovoltaic systems varies seasonally [61]. In Polish climatic conditions, the amount of energy produced varies greatly in the summer and the winter [66]. During the winter period (November, December, January, February), the WSEI carport produces small amounts of electricity throughout the month. They correspond to several charges of the Renault Twizy's battery. In the summer time (May, June, July), the production of energy by the carport is definitely higher and allows for fully charging the vehicle's batteries about 20 times. On this amount of energy, a small electric vehicle has a range of over 1000 km. Long-term testing (7 years) of the Renault Twizy vehicle showed that this is the average monthly mileage of the tested vehicle. Moreover, as noted in [67–69], the monthly amount of energy produced is an important parameter characterizing PV systems. In Poland, as well as in many other countries around the world, invoices for electricity consumed are settled and paid on a monthly basis.

From the results presented above, it can be concluded that the daily amount of energy produced is critical in the selection of the carport power to charge the selected electric vehicle. Another important time period to be considered, subject to statistical analysis, is the monthly amount of energy produced. Individual users and people managing fleets of electric vehicles frequently summarize the amount of energy consumed and pay for it on a monthly basis. Thus, in addition to the daily energy production, the monthly electricity production is important. The amount of electricity produced by the WSEI carport in individual months of 2022 is presented in Figure 9.

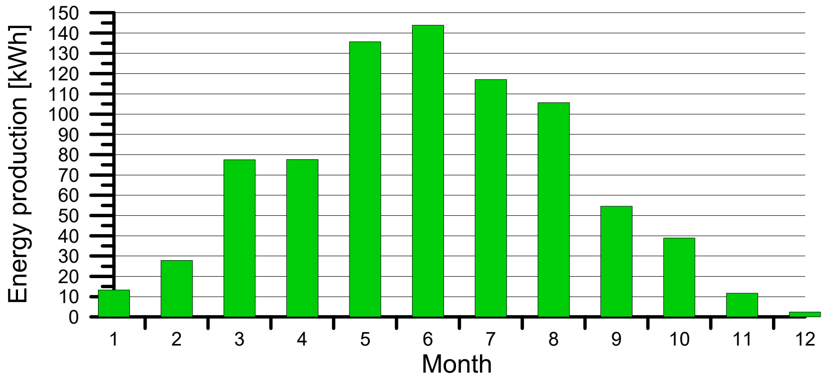

Figure 9. Monthly electricity production by the WSEI mini carport in 2022.

Basic statistical calculations show that in 2022 the minimum value of energy produced per month was 5.9 kWh, the maximum value was 143.9 kWh, and the average value of energy produced was 67.475 with a standard deviation of 49.558. The Metalog family of distributions also allows for more advanced statistical analysis in this case, including the determination of quantiles, as shown in Table 2.

Table 2. Quantile parameters.

Probability	Energy Production (kWh)
0.05	5.900000095367
0.25	27.79999923706
0.5	77.5
0.75	117.0999984741
0.95	143.8999938965

The next step is to determine the Empirical Distribution of the Distribution and the Probability Density Function for various k factors (Figure 10).

The following step is to obtain information from the knowledge base. The probability of energy production by the WSEI carport is calculated in a given month, amounting to 60 kWh. This is the amount of energy needed to fully charge the Renault Twizy's traction battery 10 times.

The program's answer to the question asked is as follows: The probability of monthly production of electricity equal to or less than 60 kWh by the WSEI carport in 2022 is 0.5. Thus, the probability of producing more than 60 kWh per month is 1–0.5. This means that in the middle months of the year, the WSEI carport is able to produce energy more than 10 times the demand required to fully charge a Renault Twizy.

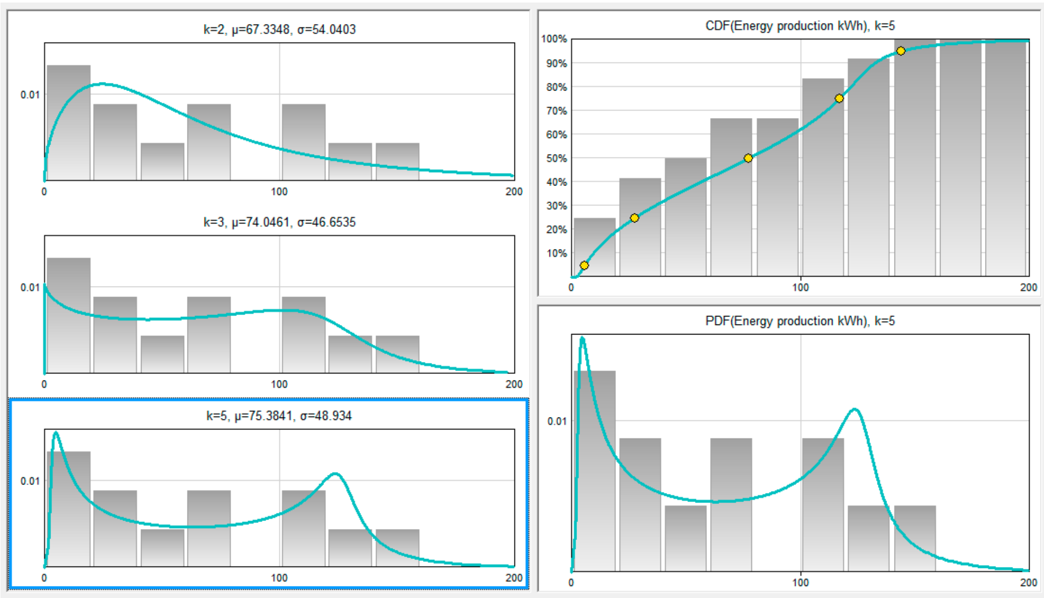

Figure 10. Empirical Distribution Function (sea color line) along with quantile parameters (yellow symbols) and Probability Density Function (sea color line) for the monthly energy produced by the WSEI carport in the year 2022 for various k coefficients.

4. Annual Energy Demand of an Electric Vehicle

According to the authors, the nominal size of the carport should be selected to cover the annual electricity demand of the car. This demand depends on the number of kilometers travelled per year (annual mileage) and the average energy consumption of the vehicle for 100 km. Figure 11 depicts the results of a simulation of energy consumption by vehicles with different energy consumption levels during particular years of operation, for an annual mileage of 10,000 km. Electric drives are currently installed in all types of vehicles [70,71]. An example of a small electric city vehicle with an energy consumption of 10 kWh/100 km is the Renault Twizy described in this article. In turn, the Nissan Leaf described above is a C-class electric car with an energy consumption of approx. 15 kWh/100 km. Larger limousines and sport utility vehicles (SUVs) consume up to 25 kWh of energy for 100 km.

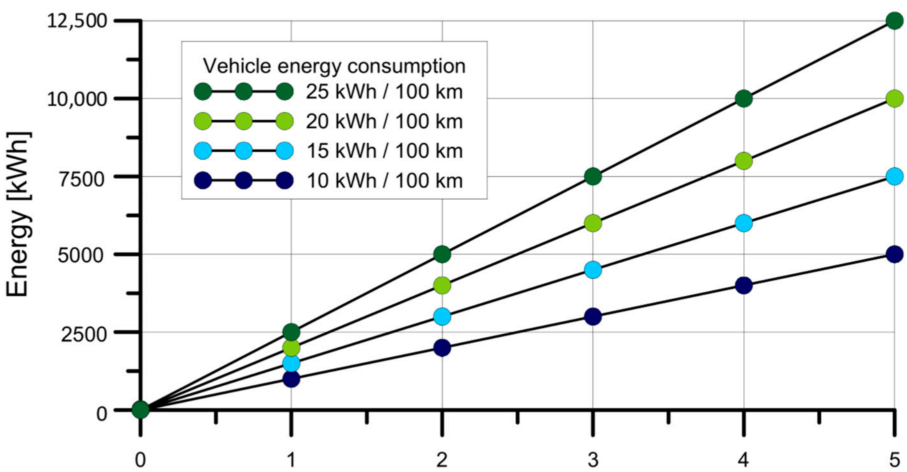

Figure 11. Demand for electricity in individual years of the vehicle at the mileage of 10,000 km/year.

In order to easily apply the graph in Figure 12 to select the size of the carport, one more principle should be borne in mind. The amount of electricity produced by a photovoltaic system with a peak power of 1 kWp in Polish climatic and weather conditions should be approx. 1 MWh (1000 kWh). PV systems mounted on carports often have better performance than those mounted on the ground or a roof. This is due to the better wind cooling of the panels on the carport. Air washing is easier and clearly affects the efficiency of the entire PV system.

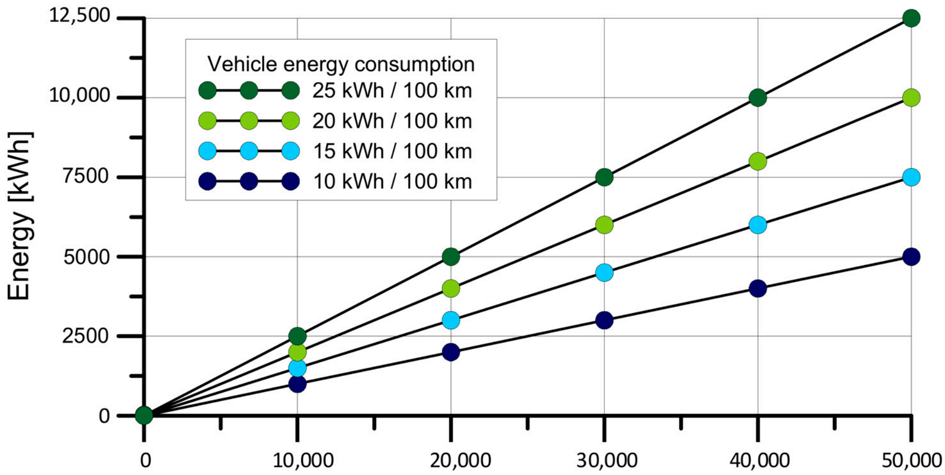

Figure 12. Annual demand for the electric energy of the vehicle with differences in mileage.

The results of the electricity demand for vehicles with different energy consumption levels appear similar if we make calculations depending on the annual mileage of an electric car instead of years (as in Figure 12). The results of such simulations are shown in Figure 12.

Both graphs shown in Figures 11 and 12 enable us to easily determine the peak power and thus the size of the photovoltaic carport, depending on the vehicle and annual mileage. The calculations are based on the assumption that all the energy produced by the carport will be used to charge the EV.

5. Conclusions

Due to the increasing number of electric vehicles in Poland, Europe and around the world, there is an increasing demand for charging them. The most ecological way to charge electric vehicles seems to be the use of renewable energy sources. Photovoltaic carports generate the electricity needed to charge electric cars and at the same time generate shade for vehicles parked under them. This article presents the use of the Metalog family of distributions to simulate the amount of electricity produced by a photovoltaic carport with the accuracy of the probability distribution. The Metalog family of distributions facilitates making calculations for a specific photovoltaic carport located in a specific location (Lublin in Poland) and in a specific context (location on the ground, azimuth, shading). From assuming the probability of the daily production of electricity by the carport and the daily demand of the electric vehicle for battery charging, one can infer the size of the constructed carport. In this way, it is possible to obtain specific assumptions about the newly designed carport based on data obtained from the operating carport. Hence, it is possible to calculate the probability of charging an electric vehicle with the energy obtained from the carport.

The authors also proposed to perform calculations on the probability of the amount of energy produced during individual months of the year. Considering the probability of the amount of energy produced in individual months and the energy consumption of an electric vehicle, this is of great importance due to the widespread use of monthly billing of electricity costs.

The conducted research shows that in an example of a summer month, the amount of energy produced daily by the WSEI carport is sufficient to charge half of the Renault Twizy's battery. Subsequent studies have shown that there is a high probability of generating the amount of energy needed to recharge the Renault Twizy's battery 10 times during the summer months. The obtained results are in very good agreement with the principles of using a small electric vehicle, i.e., a Renault Twizy, only in the warm months of the year.

This article presents calculations based on real data obtained from the operation of a photovoltaic carport. The authors of the article cooperate with companies involved in the production and assembly of photovoltaic carports. The presented method of using the Metalog family of distributions will be used in the future to accurately select the power of photovoltaic carports for specific models of EVs. The authors intend to continue carport research. In the future research, they intend to use bifacial photovoltaic panels, stationary energy storage and a hybrid inverter.

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Abbreviations

BEVs	battery electric vehicles
BMS	battery management system
EVs	electric vehicles
CDF	cumulative density functions
CNG	compressed natural gas
CO_2	carbon dioxide
DC	direct current
HEVs	hybrid electric vehicles
IoT	Internet of Things
LPG	liquefied petroleum gas
PDF	probability density functions
PV	photovoltaic
P_{pv}	power generated by the mini carport
P_{ev}	power consumed during vehicle charging
RES	renewable energy sources
SoC	state of charge
SUVs	sport utility vehicles
V2G	Vehicle to Grid

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