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Article

A Method of Assessing the Selection of Carport Power for an Electric Vehicle Using the Metalog Probability Distribution Family

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Abstract: This article presents a method for assessing the selection of carport power for an electric vehicle using the Metalog probability distribution family. Carports are used to generate electricity and provide shade for vehicles parked underneath them. On the roof of the carport, there is a photovoltaic system consisting of photovoltaic panels and an inverter. An inverter with Internet of Things functions generates data packets which describe the operation of the entire system at certain intervals and sends them via wireless transmission to a cloud server. The transmitted data can be processed offline and used to determine the charging capacity of individual electric vehicles. This article presents 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. Based on the calculations, an electric vehicle was selected that can be charged from the carport.

Keywords: photovoltaic plants; electricity production; charging electric vehicles; carport; energy management; distributed generation; zero-emission transport

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1. Introduction

The ever-increasing number of vehicles in the world significantly contributes to air pollution. Transport is the second largest emitter of air pollution after the generation of energy from conventional sources [1]. That is why it is so important to generate energy from renewable energy sources and use it to power ecological vehicles with electric drive; they do not emit any pollutants while driving, whether in the city or on the highway. Engineers and scientists are looking for effective methods to assess the energy consumption of different types of vehicles. The aim is to minimize fuel and energy consumption in various ways. Electricity generation and consumption systems also require monitoring and optimization.

In the third decade of the 21st century, many of the newly produced devices have functions of the Internet of Things. This means that these items may directly or indirectly collect, process and/or exchange data via a computer network and the Internet. Concurrently, other growing trends on a global scale are the advances in electromobility [2–9], obtaining energy from renewable sources and alternative fuels [10–16] and reducing exhaust emissions from means of transport [17–24]. The analysis of the literature and the state of knowledge confirmed that there are many technologies on the market for obtaining data from photovoltaic systems, electric car chargers and electricity meters taken from the power grid [2,25,26]. It appears that many of these devices have one-way communication and apply different data-exchange formats. The lack of uniform data-exchange formats significantly hinders the integration of these devices and their use in managing the electricity produced and consumed [27].

The market for electric and plug-in hybrid vehicles is growing at a rapid pace. These vehicles have an increasing range on a single charge and greater performance [28]. The common feature that connects them is the ability to charge traction batteries from external energy sources. The energy to charge them can come from renewable energy sources.

The authors propose to analyze the entire ecosystem of electricity generation for the charging of electric vehicles. As an example of such an ecosystem, the infrastructure located in Lublin Science and Technology Park (LSTP) in Poland was selected. Selected elements of energy generation for the needs of powering buildings and charging electric vehicles are presented in the infographic in Figure 1.

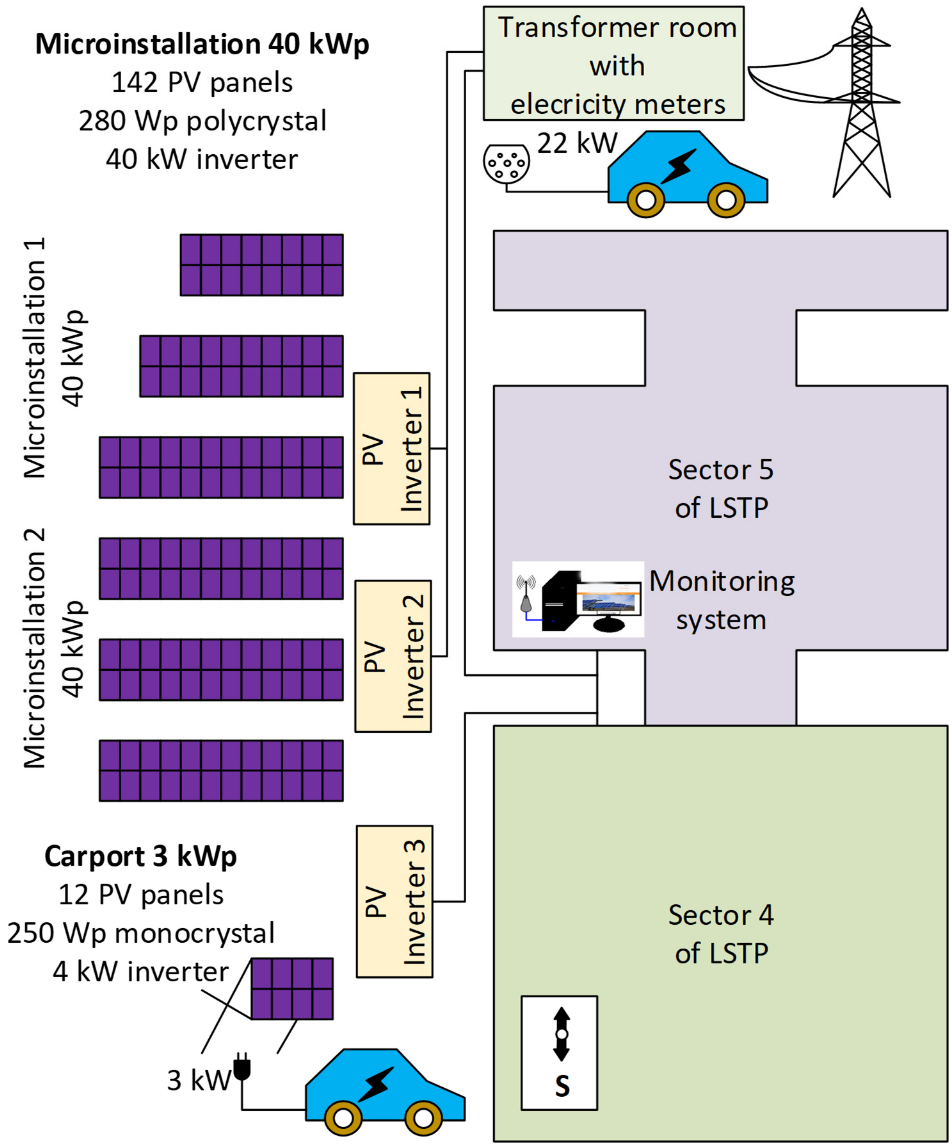


Figure 1. Selected elements of energy generation for the needs of powering buildings and charging electric vehicles in LSTP.

The electric-vehicle-charging ecosystem consists of the following components (Figure 2):

- Photovoltaic field [29];
- Charger for electric vehicles;
- Bidirectional energy meter;
- Photovoltaic carport [30];
- Electric vehicles.

Figure 2. Selected elements of the power generation ecosystem for electric vehicle charging at LSTP.

The first of the Internet of Things devices is a mounted- on-the-ground photovoltaic system with a peak power of 40 kWp. The photovoltaic inverter in such an installation sends a data package to the cloud every few minutes, primarily including the generated instantaneous power and the amount of energy produced on its basis [31]. In our research, we have already encountered several different formats of data generated by photovoltaic systems. The latest online platforms [32] allow the measurement and visualization of the power produced by photovoltaic systems and the power consumed by the receivers, and based on this, the calculation of the self-consumption power (this is presented in Figure 3). Data obtained and stored in the cloud can be processed and used to generate reports on the daily, monthly and annual performance of the photovoltaic system [33]. The user and administrator interface of the photovoltaic system is the appropriate software for desktop and portable computers as well as applications for mobile devices such as smartphones and tablets. Using the software and the applications, it is also possible to remotely diagnose the system as a result of reading the error codes stored in the system's memory [34]. A 22 kW electric-vehicle-charging pole has been connected to the ground-based photovoltaic farm in LSTP.

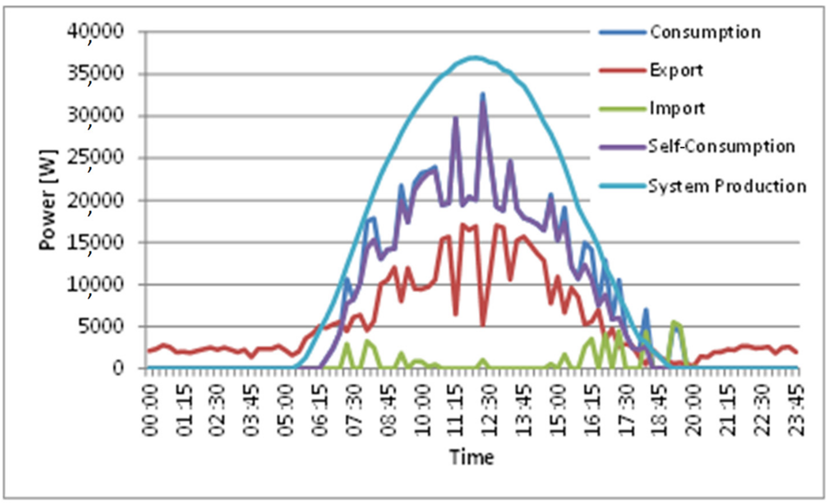


Figure 3. Power-over-time graphs.

The second of the Internet of Things devices are the chargers for electric vehicles. This term is used to describe various types of infrastructure aimed at supplying electricity for charging the onboard traction batteries of vehicles [35]. There is a two-way communication between the charging pole and the vehicle battery management system (BMS) to ensure safety throughout the charging process [36]. Almost every electric-vehicle-charging point has a built-in electricity meter. Its measurement is needed to determine the electricity consumption of each user and billing. Individual users are usually identified by magnetic cards. Charger operators have a continuous view of the charger's operating parameters via LAN, Wi-Fi or SIM card. LSTP has a 22 kW charging pole with a Type 2 (3-phase AC) and Schuko (1-phase AC) socket for charging electric vehicles [37]. The process of charging an electric vehicle from a charging pole connected to a ground-based photovoltaic installation is shown in Figure 4.

Figure 4. Charging an electric vehicle from a charging pole connected to a ground-based photovoltaic farm in LSTP.

The receivers of electricity produced by the photovoltaic system and distributed by the charging pole are the electric vehicles of LSTP employees and tenants. However, what if you want to charge an electric vehicle at night or on a less sunny day? The charging pole for electric vehicles is also connected to the power grid and can draw electricity from it. The amount of energy consumed from the electricity grid is measured using an electricity meter. Modern meters are already devices of the Internet of Things, and they also enable us to measure electricity returned to the power grid. Older ones do not offer such a function, but they can be equipped with an appropriate communication beacon.

Another important element of the LSTP energy ecosystem is the carport [38,39]. Carports are used to generate electricity and provide shade for vehicles parked underneath them. Carports are an excellent solution for customers who do not have space on the roof of their house to install a photovoltaic system and, at the same time, do not want to waste a large area of land for the installation of a ground photovoltaic system. Photovoltaic panels located on the roof of the carport generate direct current (DC) electricity, which is then converted into alternating current (AC) energy by an inverter. The carport located in LSTP is also an Internet of Things device and will be described in more detail later in the article.

Photovoltaic systems are typically used to generate electricity to power appliances located in homes or institutional buildings. However, electric vehicles are the largest consumers of electricity generated from photovoltaic systems [40]. Electric vehicles are quiet, ecological and provide good driving performance. The range of electric vehicles is increasing, and they can effectively be used for not only driving around a city but also for further intercity travel and even international trips. Moreover, electric vehicles can be and are rapidly becoming devices of the Internet of Things. Communication devices located inside them are able to send data about the current location of the vehicle and its driving parameters [41]. Operators of electric-vehicle-charging points are offering more and more online platforms for planning routes [42]. In the area of electric vehicle charging infrastructure in Europe, a continuous increase in the number of electric-vehicle-charging points and an increase in charging power is observed [43].

In this article, the authors will present the real data obtained from the Internet of Things devices installed and tested in LSTP in Poland. The authors will present the possibilities of obtaining and processing measurement data from the Internet of Things devices in order to manage electricity produced by a photovoltaic system and consumed by electric vehicles [44]. In the next part of the article, the use of the Metalog family of distributions to predict the production of electricity by the carport with the accuracy of the probability distribution will be presented [45].

2. Objects and Research Methodology

The first research object is the carport. It consists of 15 photovoltaic panels, but only 12 of them are active and generate electricity. The carport has been presented at fairs and exhibitions many times; 3 solar panels out of 15 were damaged during transport and do not generate electricity. The constructors used monocrystalline photovoltaic panels produced by glass–glass technology. Each panel has a peak power of 250 Wp. The peak power of the carport is 3 kWp. Choosing the right type of photovoltaic panel depends on their specific application in specific geographical conditions [46]. At the time of the installation of the carport (2016), monocrystalline panels were a very advanced and innovative technology in relation to the commonly used polycrystalline panels. An additional innovation in favor of their use was the method of the construction of the panel itself. The photovoltaic elements were placed between two panes of glass, hence the name 'glass–glass'. Such panels are characterized by a better heat dissipation than traditional panels mounted on a plastic base. The designers of the carport expected more energy to be produced as a result of better cooling. This hypothesis was later confirmed in practice.

The angle of inclination of the panels on the carport is 30 degrees, and the entire carport is directed exactly to the south.

Each panel has a built-in individual optimizer that allows you to track the performance of each panel separately, which is shown in Figure 5. The structure of the carport was designed and made by one of the authors together with a group of students in the field of Transport. The carport generated over 20 MWh of electricity during the period from May 2016 to April 2023. The Internet platform enables the export of the photovoltaic system operating parameters in *.csv format to a file. It is important that it is possible to export the instantaneous generated power in 15 min intervals as well as the amount of energy produced each day.

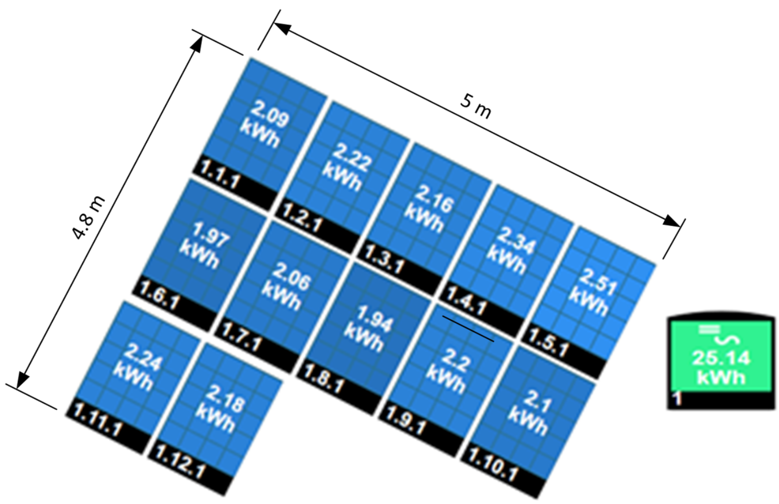


Figure 5. The amount of energy produced by individual panels in the carport.

The second research object is the Nissan Leaf, the electric vehicle. It was manufactured in 2015 and has a traction battery with an energy capacity of 24 kWh. Based on conversations with the owner, the authors determined that the range of the vehicle is around 150 km [47]. Therefore, such a vehicle can be characterized as an urban vehicle with the ability to cover short intercity routes. The vehicle has two charging sockets. The first one is the Chademo socket for fast charging with a direct current. Through the Chademo connector, the vehicle battery is charged with a direct current generated by an external DC charger. The maximum battery charging power is 40–50 kW. However, the charging power depends on the state of charge of the battery (SoC). The Chademo fast-battery-charging process takes less than 1 h. The other socket is called Type 1 and is a single-phase socket that supplies single-phase AC power to the onboard charger. The vehicle has a 3.6 kW onboard charger. This power is drawn from the charging pole shown in Figure 4 using an electrical cable connected to the Type 2 socket in the post. The Type 1 and Type 2 connectors only supply AC power to the vehicle's onboard charger. The maximum power of the charger is 3.6 kW. Thus, charging the battery with an energy capacity of 24 kWh takes less than 7 h. Type 2 connectors can deliver 22 or even 50 kW. However, it is the power of the charger installed in the vehicle that determines the power consumption and charging time of the battery. If you use a Schuko socket, you need a different cable, as shown in Figure 6 on the right. With it, the vehicle can be charged from any Schuko socket located in the house, garage or garden. In the case of charging a vehicle from the Schuko socket, the charging power was additionally limited to 2.2 kW. This is due to the fact that this connector is commonly found in private homes. In this way, vehicle manufacturers want to protect the electrical installation in homes against excessive overload caused by charging electric vehicles [48]. It takes 11 h to fully charge (SoC = 100%) a battery that has been completely discharged (SoC = 0%). Such a full charge can be achieved in a private house overnight. When charging the battery at night, the energy must be taken from the power grid or from an energy storage. However, lithium-ion batteries can be freely recharged regardless of the charge level; the charging process can also be interrupted at any time without negative consequences. Many electric vehicle users charge their vehicles at work, while staying at a hotel or while shopping. People are looking for ways to charge electric vehicles for free. Some institutions, such as the aforementioned stores, encourage customers to shop with them in this way.

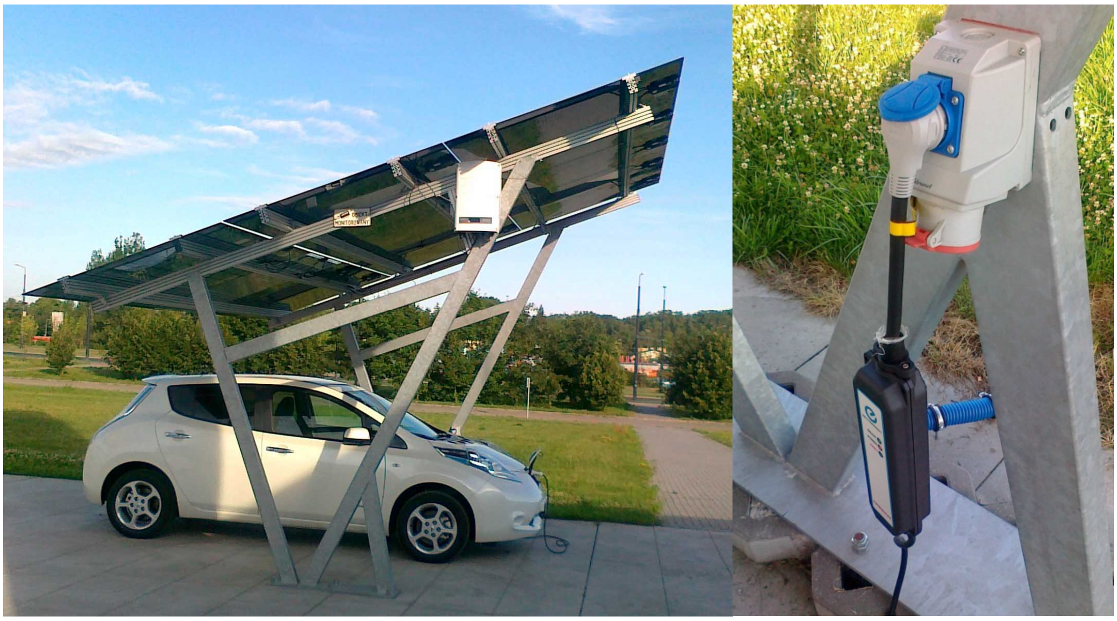


Figure 6. Carport test objects and an electric vehicle during the battery-charging process.

The main limitation related to the use of energy from photovoltaic systems to charge electric vehicles is the lack of energy generation at night and the very small amounts of energy generated in the winter months in Poland [30]. The latter limitation depends on the geographic location of the country and seasonally occurring insolation. Other renewable energy sources do not have these limitations. Hydropower plants generate electricity all the time. Wind farms generate electricity day and night when the wind blows. The best solution is to have an energy mix in which energy comes from various renewable sources [49].

Both test objects in the form of the carport and an electric vehicle during the battery-charging process are shown in Figure 6. The latest carports use additional energy storage to collect the energy produced and use it later to charge electric vehicles [50].

In previous articles, the authors used traditional statistical methods to describe the amount of energy generated by photovoltaic systems [29]. However, they were assessed as not being very useful for analyzing data provided by IoT devices in real time.

Metalog modeling is performed in real time. New data are automatically taken into account by the algorithms updating the previous distribution according to the Bayes rule. The new data update the a priori distribution to a posteriori. This is fundamentally different from the traditional approach to statistics [51]. Process planning in controlled conditions deviating from the natural, expensive data collection and statistical analysis are carried out offline, and the results obtained are no longer real-time results. If the amount of data increases, you can raise the order of the matched Metalog [52].

The authors applied a data-speaking approach to processes taking place in real conditions. More and more objects and devices are devices of the Internet of Things with sensors monitoring the operation of the entire device along with its close and distant surroundings (which is its context). We built a model based on machine learning algorithms, and then we asked questions to the model to find out the effects of the changes. Inference algorithms allow for the fact that the answers to the questions asked are not searched for in the database of historical process data but are generated by predictive and diagnostic reasoning algorithms.

This article presents 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 [51]. The amount of electricity produced on particular days of the month by the carport located in LSTP is used to determine the cumulative distribution function (CDF). It is a continuous function. Then, the probability distribution function is determined. The Metalog layout family allows you to make calculations for a specific carport located in a specific location (the city of Lublin in Poland) and in a specific context (location on the ground, location on the roof, inclination of panels, shadowing). The Metalog family of distributions allows you to determine the percentiles in the production of electricity by the carport and answer the question of what its value will be with the accuracy of the probability distribution. Using the Metalog family of distributions, we obtain information from a knowledge base, not from a database [52]. The difference is essential: in a database, the answer to the question asked is obtained as a result of searching the database; in the case of a knowledge base, the answer to the question is obtained as a result of running an inference algorithm. Based on the calculations, the correctness of the selection of an electric vehicle that can be charged from the carport is assessed.

The mathematical description of the Metalog family of probability distributions is presented in the work of its creators. Keelin and Howard provide a detailed description in their article [52] (Appendix A on page 17). They also run a website on which the principles of the operation of the software that is created on the basis of this method are described in detail [53]. In addition, other scientists who have used the Metalog distribution families present in their articles a mathematical description of the algorithms used [54].

3. Results

3.1. Analysis of the Instantaneous Power Generated by the Carport

The first purpose of the analysis is to calculate the probability of generating more than 2.2 kW of power by the tested carport. This corresponds to the power drawn by the Nissan Leaf's onboard charger. The course of the power generated by the carport over time for three days in September 2022 is shown in Figure 7. Lubelskie Voivodship is characterized by the highest insolation in Poland. Polish conditions regarding the aspect of generating energy from renewable sources were described in detail in [55]. The average area air temperature in September 2022 in Poland was 12.3 °C.

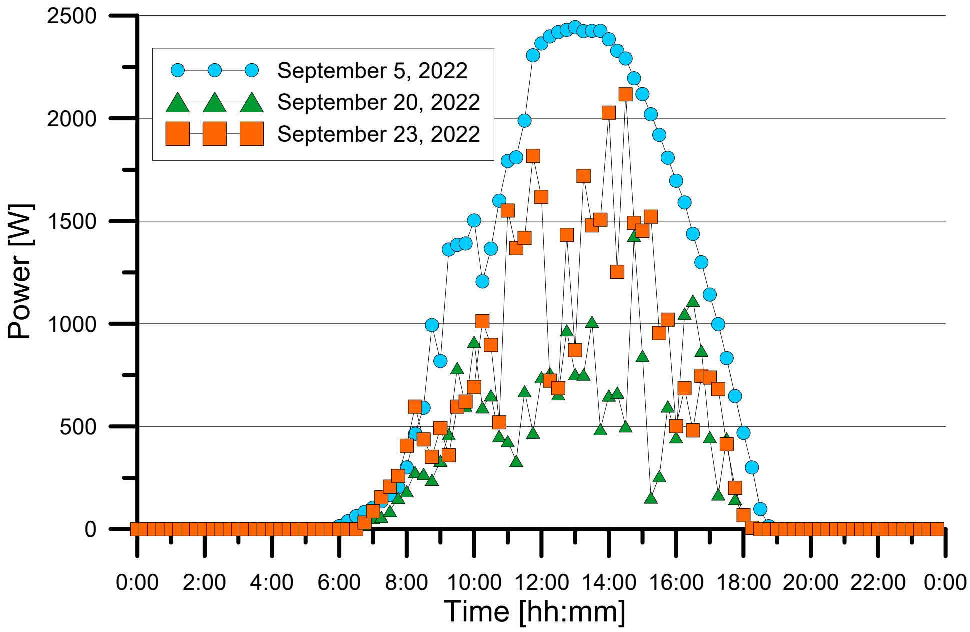


Figure 7. Course as a function of time of the power generated by the LSTP carport on 5, 20 and 23 September 2022.

The authors decided to study three typical cases of generating energy on a sunny day (5 September), partial cloud cover (23 September) and heavy cloud cover (20 September). Graphs were made for the data coming from the data cloud and made available for viewing and saving on a computer hard drive in *.csv format. The data presented in the charts show that not on all days was the power of the carport higher than 2.2 kW. As the graphs present, for only a few hours on 5 August, the power generated by the carport was higher than 2.2 kW.

GeNIe 4.0 Academic software was used for a detailed analysis of the power generated by the carport [56]. The cumulative distribution function (CDF) and the probability density function (PDF) are shown in Figure 8. These studies were unsuccessful due to the distortion of the calculation of the probability distribution of the power produced by the carport by measurements being taken at night, when the carport does not generate energy.

It was decided to limit the next tests to measurements of the carport's power during the day only, and only the measurement data from 5 September 2022 between 8.00 a.m. and 6.00 p.m. were taken into account. This time, the correct cumulative distribution function (CDF) and probability density function (PDF) graphs for the power generated by the carport were obtained, as shown in Figure 9.

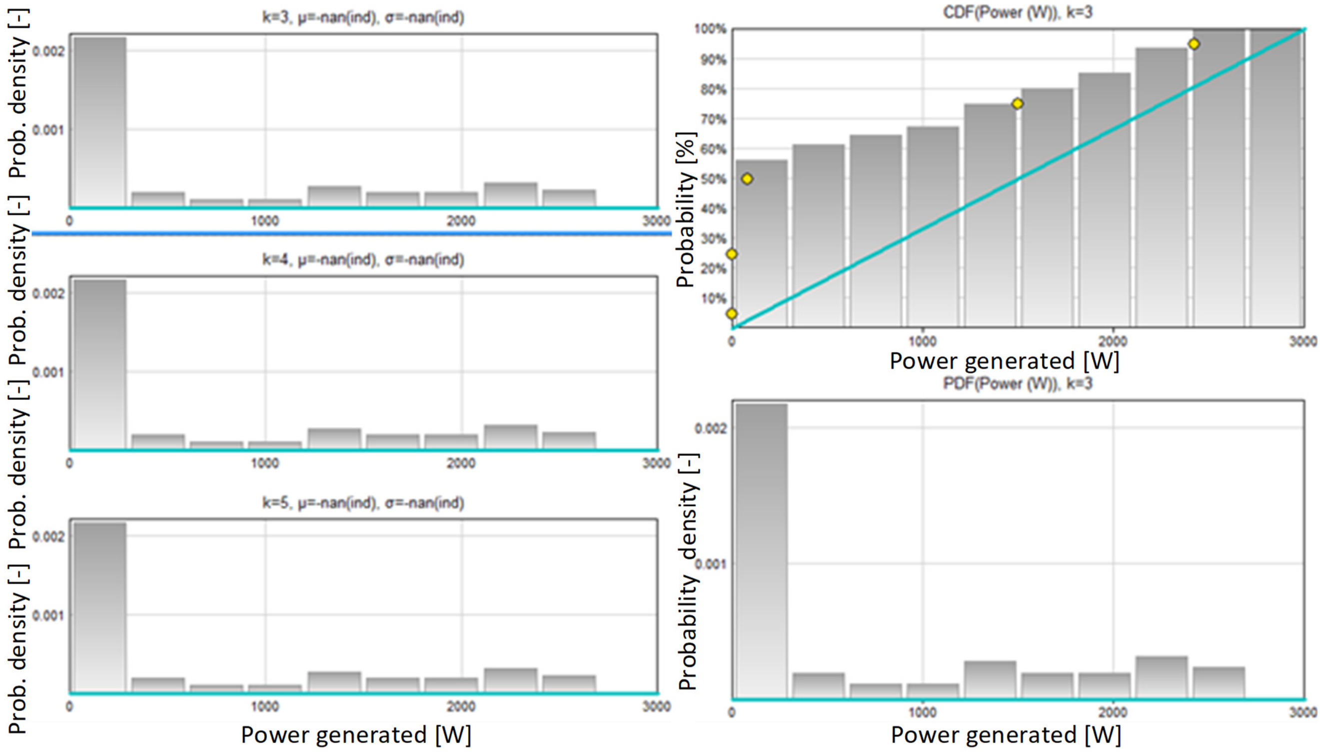


Figure 8. Cumulative distribution function (CDF) and probability density function (PDF) graphs.

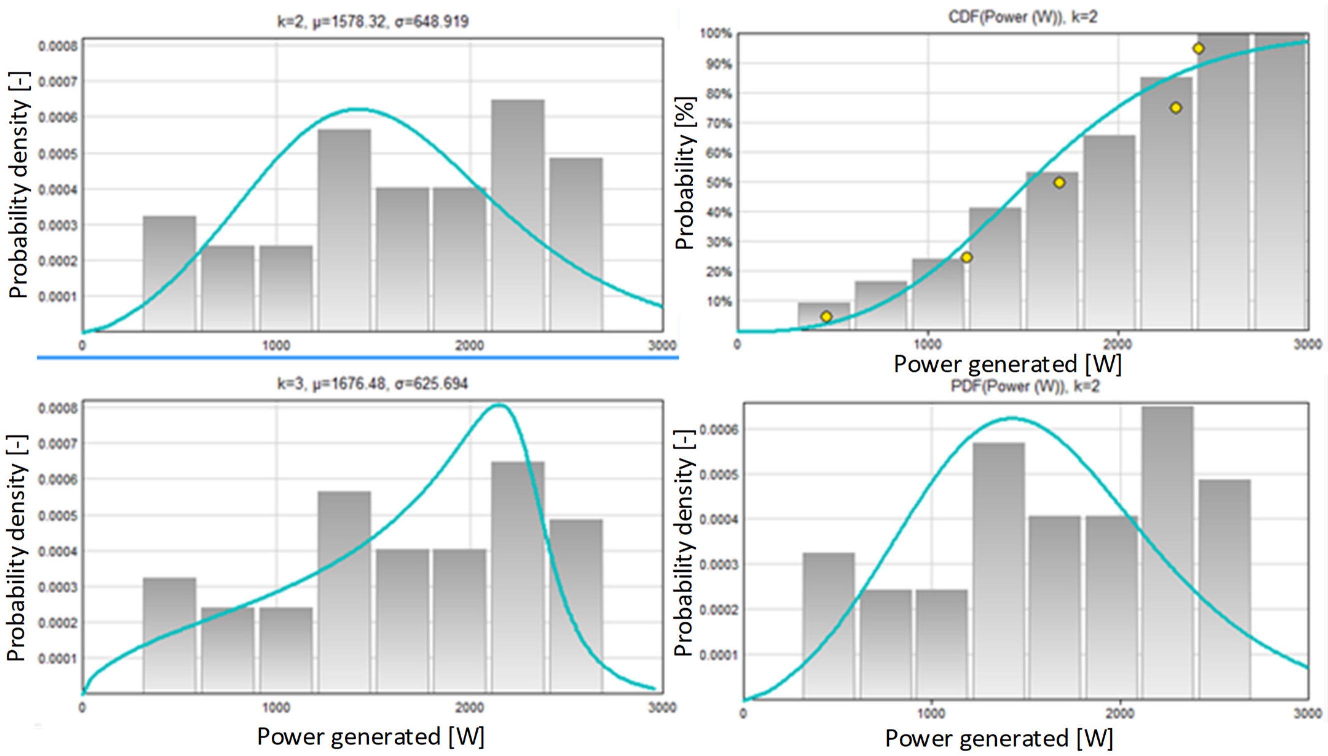
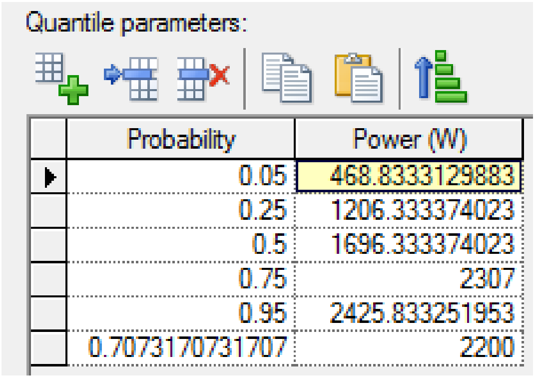


Figure 9. Cumulative distribution function (CDF) and probability density function (PDF) graphs for power generated by the solar carport.

Then, the information on the power generated by the carport was obtained from the knowledge base. The program's answer to the question asked is as follows: the probability of generating power equal to or less than 2.2 kW by the carport on 5 September 2022 is

0.7073 (last row in Figure 10). Thus, the probability of the carport generating more than 2.2 kW is 1-0.7073.



Quantile parameters:

Probability	Power (W)
0.05	468.8333129883
0.25	1206.333374023
0.5	1696.333374023
0.75	2307
0.95	2425.833251953
0.7073170731707	2200

Figure 10. A method of obtaining information from the knowledge base.

The probability of the carport generating more than 2.2 kW of power on 20 and 23 September 2022 is 0. The analyses show that the photovoltaic carport is not able to generate more than 2.2 kW to power the vehicle's onboard charger from the energy it produces. This means that in the case of the carport and electric-vehicle configuration in question, it is not possible to operate the system in an off-grid configuration. Without a connection to the power grid of the LSTP sectors, the carport is not able to generate enough power to generate more than 2.2 kW in the required time of 11 h. The conclusion is that the carport must work in conjunction with the energy network (on-grid). Shortages of power needed to charge an electric vehicle can be supplemented from the power grid. The surplus of energy produced will also go there and power the receivers located in the LSTP buildings.

3.2. Analysis of the Daily Amount of Energy Produced by the Carport

The report presented by ACEA (January 2022) shows that the average annual mileage of vehicles in Poland in 2020 was 8607 km. This means that an average Pole drives less than 24 km a day. Using very simplified calculations, the Nissan Leaf vehicle can therefore be charged once every 6 days because its range on a single charge is estimated by the owner at 150 km. However, many people drive their electric vehicle more than the statistical 24 km per day. For further calculations, the authors assumed an average daily mileage of 50 km. To cover such a route, the tested Nissan Leaf vehicle needs approx. 8 kWh of electricity. Figure 11 depicts the amount of daily energy produced by the examined carport in September 2022. The presented data were downloaded from the platform monitoring the work of the carport and displayed in the program for graphic presentation in the form of charts. Such simple data show that during 16 working days that month, the energy generated by the carport was higher than 8 kWh.

Such analysis can also be performed for other months and years of the operation of the photovoltaic system on the carport. A daily production of electricity of more than 8 kWh per day is possible in Poland during the summer months. Figure 12 shows the daily energy production by the carport in July 2020. The presented data were taken from the platform monitoring the work of the carport. The data-collection system on cloud servers is able to collect and securely store data from the operation of the carport throughout the life of the device.

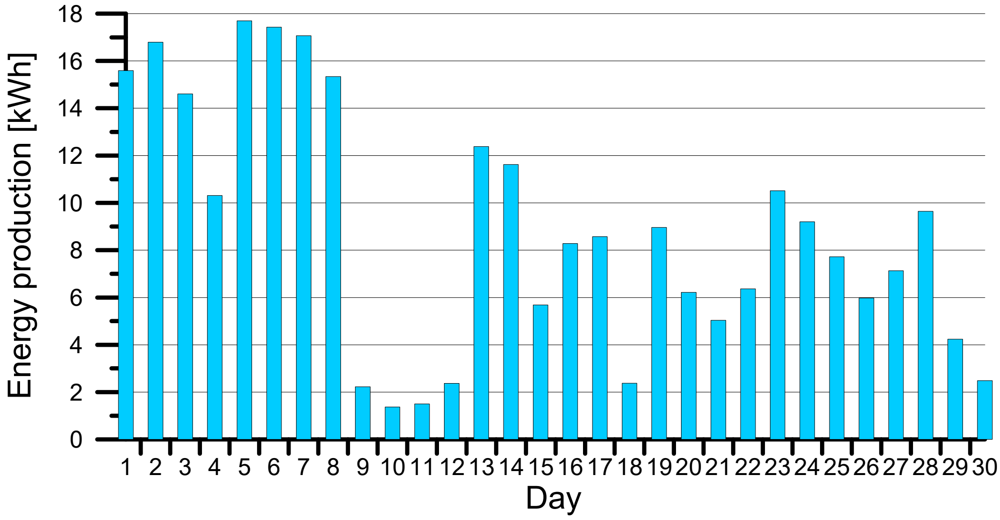


Figure 11. Daily electricity production by the LSTP carport in September 2022.

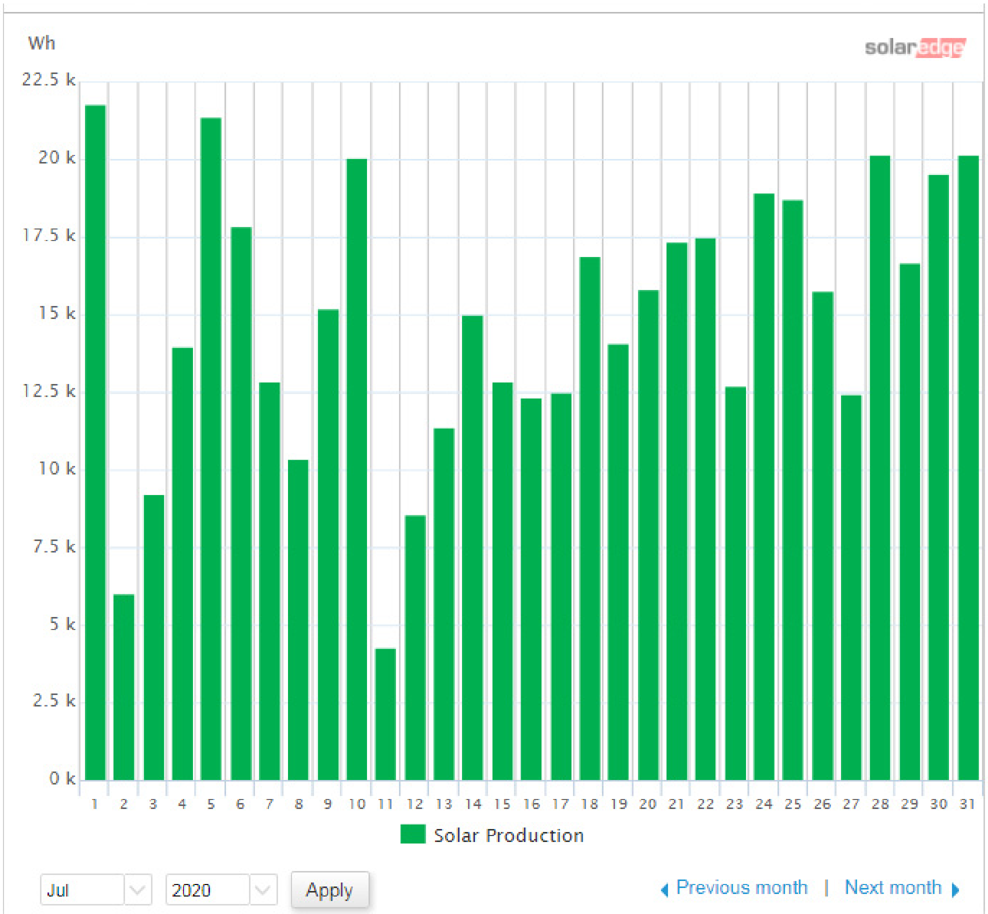


Figure 12. Daily electricity production by the LSTP carport in July 2020.

Figure 13 shows the charts of the cumulative distribution function (CDF) and the probability density function (PDF) for the daily energy generated by the carport in September 2022.

The authors decided to make accurate calculations related to the amount of energy produced daily by the carport. For this purpose, the information on the energy generated by the carport was obtained from the knowledge base. The program's answer to the question inquired is as follows: the probability of the daily production of electricity equal to or less than 8 kWh by the carport in the month of September 2022 is 0.4666. So, the probability of producing more than 8 kWh is 1-0.4666.

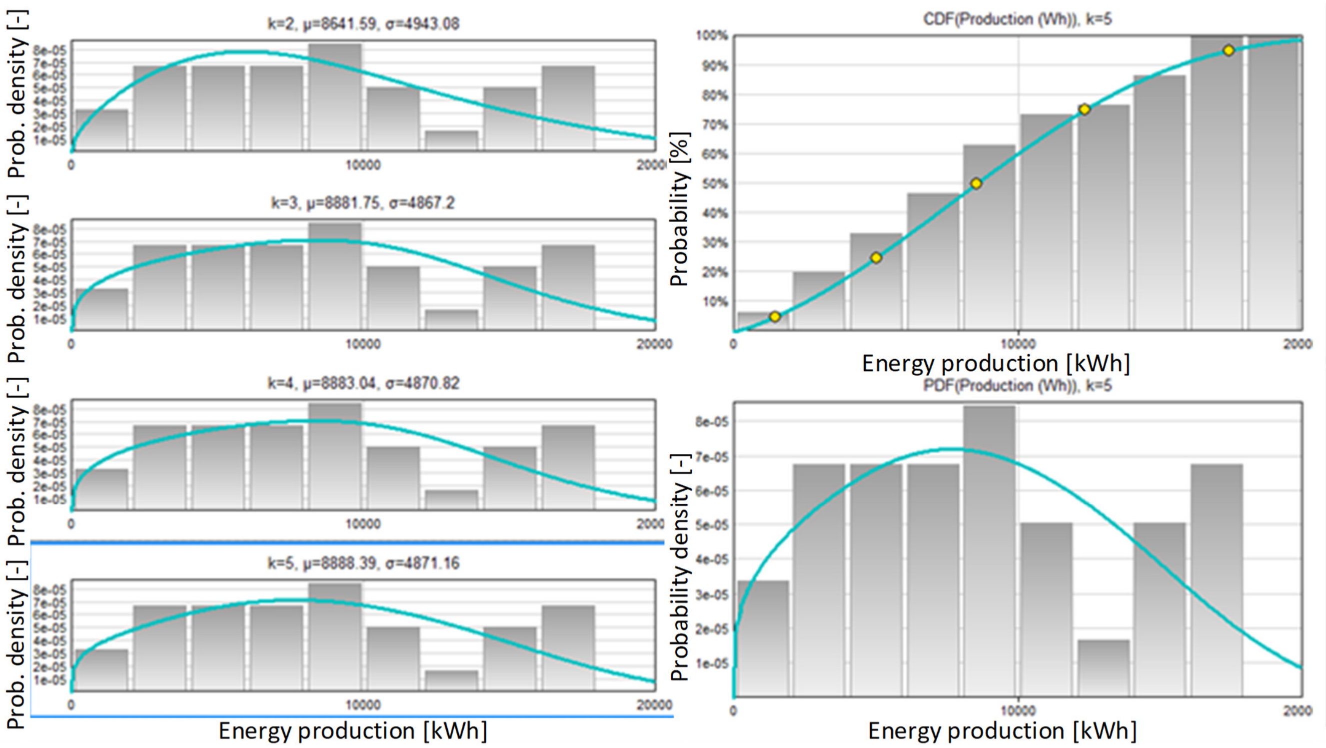


Figure 13. Cumulative distribution function (CDF) and probability density function (PDF) graphs for the daily energy generated by the carport.

3.3. Analysis of the Monthly Amount of Energy Produced by the Carport

Data from the photovoltaic-system-monitoring platform are convenient when planning the charging of electric vehicles from carports and ground and rooftop photovoltaic systems. As we wrote earlier, the Nissan Leaf electric vehicle needs 8 kWh of electricity to travel 50 km. Within a month, this translates into 240 kWh of electricity, on which the vehicle can cover 1500 km. Figure 14 shows a comparison of the monthly energy production by the carport in particular years of operation. The presented data show that in the months from March to September, the carport is able to provide the required amounts of energy. In the autumn and winter months from October to February, the carport is unable to produce the expected amount of energy. The monthly energy production of the carport can also be calculated using the Metalog family of distributions.

Not only the owners of carports and other photovoltaic installations can access large amounts of real data from various photovoltaic systems installed around the world, but some manufacturers of photovoltaic inverters also have large cloud resources and make them publicly available. An example is the SolarEdge platform [54], which allows access to the monitoring systems of many installations that use the company's inverter. Figure 15 shows the monthly generated graphs of the 3 kWp system installed in Randburg, South Africa. The performance of Polish and South African photovoltaic installations can be quickly compared with each other. South Africa's insolation is not as seasonally volatile, and the amount of energy produced is more similar in the different months of the year.

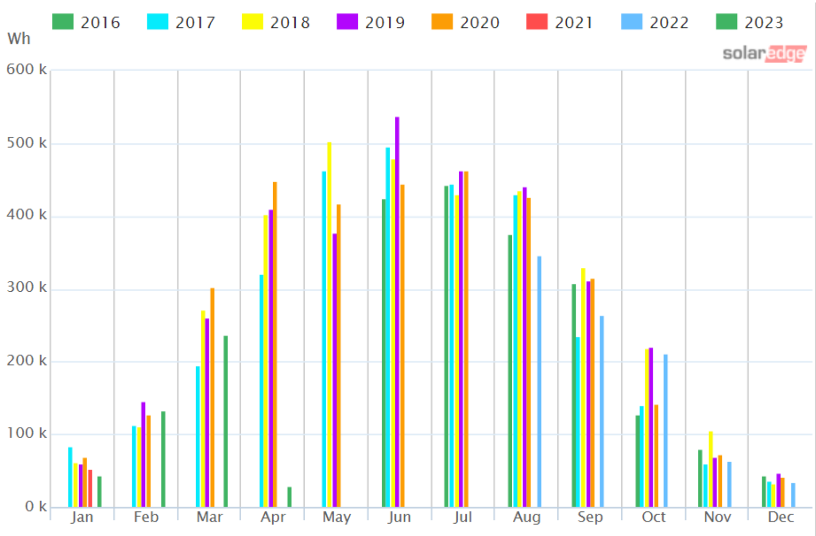


Figure 14. Comparison of the monthly energy production by the carport in individual years of operation.

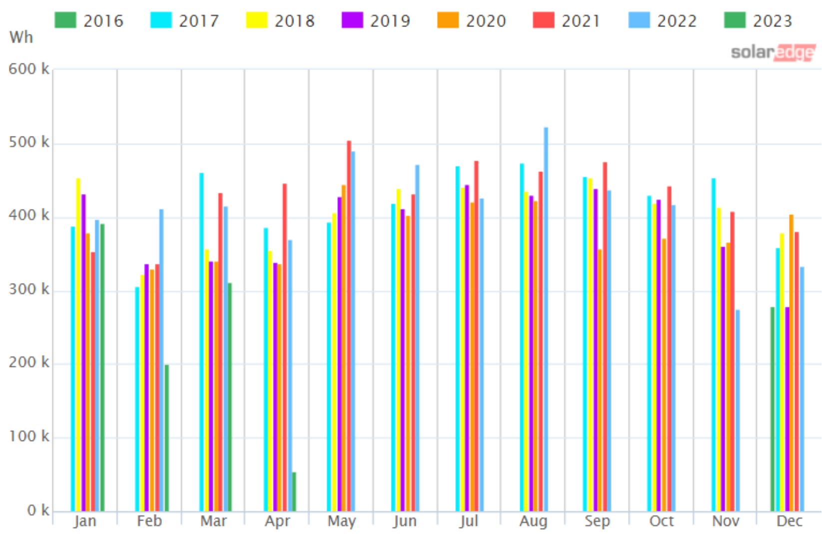


Figure 15. Comparison of the monthly energy production of a 3 kWp-peak photovoltaic system installed in Randburg, South Africa, by year of operation [57].

4. Conclusions

This article presents a method for assessing the selection of carport power for an electric vehicle using the Metalog probability distribution family. Carports are used to generate electricity and shade for vehicles parked underneath them. On the roof of the carport, there is a photovoltaic system consisting of photovoltaic panels and an inverter. An inverter with Internet of Things functions generates data packets describing the operation of the entire system at certain intervals and sends them via wireless transmission to a cloud server. This article proves that the transmitted data can be processed offline and later be used to determine the charging capacity of individual electric vehicles. The article presents 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 analyses presented in this article show that the photovoltaic carport is not able to generate more than 2.2 kW to power the vehicle's onboard charger from the energy it produces. This means that in the case of the carport and electric vehicle configuration in question, it is not possible to operate the system in an off-grid configuration. Without a connection to the power grid of the LSTP buildings, the carport is not able to generate enough power to generate more than 2.2 kW in the required time of 11 h. The conclusion is that the carport must work in conjunction with the energy network (on-grid).

In the next step of the research, the authors decided to make accurate calculations related to the amount of energy produced daily by the carport. For this purpose, the information on the energy generated by the carport was obtained from the knowledge base. The tested Nissan Leaf electric vehicle needs 8 kWh of electricity to travel 50 km. Within a month, this translates into 240 kWh of electricity, on which the vehicle can cover 1500 km. The presented data show that in the months from March to September, the carport is able to provide the required amounts of energy. In the autumn and winter months from October to February, the carport is unable to produce the expected amount of energy.

The presented method is universal and can be used both to calculate the probability of generating a specific amount of power in a given time and to calculate the amount of energy produced daily by carports and other photovoltaic installations.

The authors intend to continue their research. In the future, the carport will be expanded with a stationary energy storage. The calculation of its energy capacity will be the research goal of the next article.

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References

1. Nassar, Y.F.; Aissa, K.; Alsadi, S. Air Pollution Sources in Libya. *Res. Rev. J. Ecol. Environ. Sci.* **2018**, *6*, 63–79. Available online: https://scholar.ptuk.edu.ps/handle/123456789/213 (accessed on 26 April 2023).
2. Colmenar-Santos, A.; Muñoz-Gómez, A.-M.; Rosales-Asensio, E.; López-Rey, Á. Electric vehicle charging strategy to support renewable energy sources in Europe 2050 low-carbon scenario. *Energy* **2019**, *183*, 61–74. [CrossRef]
3. Čulík, K.; Štefancová, V.; Hrudkay, K.; Morgoš, J. Interior Heating and Its Influence on Electric Bus Consumption. *Energies* **2021**, *14*, 8346. [CrossRef]
4. Dizo, J.; Blatnický, M.; Semenov, S.; Mikhailov, E.; Kostrzewski, M.; Drozdziel, P.; Šťastniak, P. Electric and plug-in hybrid vehicles and their infrastructure in a particular European region. *Transp. Res. Procedia* **2021**, *55*, 629–636. [CrossRef]
5. Liberto, C.; Valenti, G.; Orchi, S.; Lelli, M.; Nigro, M.; Ferrara, M. The Impact of Electric Mobility Scenarios in Large Urban Areas: The Rome Case Study. *IEEE Trans. Intell. Transp. Syst.* **2018**, *19*, 3540–3549. [CrossRef]
6. Marczak, H.; Drozdziel, P. Analysis of Pollutants Emission into the Air at the Stage of an Electric Vehicle Operation. *J. Ecol. Eng.* **2021**, *22*, 182–188. [CrossRef]
7. Mruzek, M.; Gajdáč, I.; Kučera, L.; Gajdošík, T. The Possibilities of Increasing the Electric Vehicle Range. *Procedia Eng.* **2017**, *192*, 621–625. [CrossRef]
8. Tomaszewska, A.; Chu, Z.; Feng, X.; O'Kane, S. Lithium-ion battery fast charging: A review. *eTransportation* **2019**, *1*, 1–28. [CrossRef]
9. Wahid, M.R.; Budiman, B.A.; Joelianto, E.; Aziz, M. A Review on Drive Train Technologies for Passenger Electric Vehicles. *Energies* **2021**, *14*, 6742. [CrossRef]
10. Dittrich, A.; Beroun, S.; Zvolsky, T. Diesel gas dual engine with liquid LPG injection into intake manifold. *Eng. Rural. Develop.* **2018**, 1978–1983. [CrossRef]
11. Gnap, J.; Dočkalik, M. Impact of the operation of LNG trucks on the environment. *Open Eng.* **2021**, *11*, 937–947. [CrossRef]
12. Liu, Y.; Yang, X.; Zhu, Z. Economic evaluation and production process simulation of biodiesel production from waste cooking oil. *Curr. Res. Green Sustain. Chem.* **2021**, *4*, 100091. [CrossRef]

13. Matijošius, J.; Orynycz, O.; Kovbasenko, S.; Simonenko, V.; Shuba, Y.; Moroz, V.; Gutarevych, S.; Wasiak, A.; Tucki, K. Testing the Indicators of Diesel Vehicles Operating on Diesel Oil and Diesel Biofuel. *Energies* **2022**, *15*, 9263. [CrossRef]
14. Pietra, A.; Gianni, M.; Zuliani, N.; Malabotti, S.; Taccani, R. Experimental Characterization of an Alkaline Electrolyser and a Compression System for Hydrogen Production and Storage. *Energies* **2021**, *14*, 5347. [CrossRef]
15. Piotrowska, K.; Piasecka, I.; Kłos, Z.; Marczuk, A.; Kasner, R. Assessment of the Life Cycle of a Wind and Photovoltaic Power Plant in the Context of Sustainable Development of Energy Systems. *Materials* **2022**, *15*, 7778. [CrossRef] [PubMed]
16. Połom, M.; Wiśniewski, P. Implementing Electromobility in Public Transport in Poland in 1990–2020. A Review of Experiences and Evaluation of the Current Development Directions. *Sustainability* **2021**, *13*, 4009. [CrossRef]
17. Wasiak, A.; Orynycz, O.; Tucki, K.; Świć, A. Hydrogen Enriched Hydrocarbons as New Energy Resources—As Studied by Means of Computer Simulations. *Adv. Sci. Technol. Res. J.* **2022**, *16*, 78–85. [CrossRef]
18. Conradie, P.; Asekun, O.O.; Skrúcaný, T.; Kendra, M.; Stopka, O. The effect of fuel on the energy consumption and production of greenhouse gases in transport. *Arch. Automot. Eng. Arch. Motoryz.* **2018**, *82*, 5–14. [CrossRef]
19. Dziewiątkowski, M.; Szpica, D. Evaluation of the conversion rate regarding hydrocarbons contained in the exhaust gases of an engine fuelled with compressed natural gas (CNG) using different catalysts operating at different temperatures. *Mechanika* **2021**, *27*, 492–497.
20. Górski, K.; Smigins, R.; Matijošius, J.; Rimkus, A.; Longwic, R. Physicochemical Properties of Diethyl Ether—Sunflower Oil Blends and Their Impact on Diesel Engine Emissions. *Energies* **2022**, *15*, 4133. [CrossRef]
21. Manko, I.; Shuba, Y.; Korpach, A.; Gutarevyc, S.; Ragulskiene, J.; Pauliukas, A. Measurement of fuel consumption and harmful emissions of cars when using different types of fuel. *J. Meas. Eng.* **2020**, *8*, 182–196. [CrossRef]
22. Mikulski, M.; Vasudev, A.; Hunicz, J.; Rybak, A.; Gęca, M. Combustion of hydrotreated vegetable oil in a diesel engine: Sensitivity to split injection strategy and exhaust gas recirculation. In Proceedings of the ASME 2020 Internal Combustion Engine Division Fall Technical Conference, ICEF 2020, Virtual, 4–6 November 2020.
23. Milojevic, S.; Savic, S.; Maric, D.; Stopka, O.; Krstic, B.; Stojanovic, B. Correlation between Emission and Combustion Characteristics with the Compression Ratio and Fuel Injection Timing in Tribologically Optimized Diesel Engine. *Teh. Vjesn.* **2022**, *29*, 1210–1219.
24. Šarkan, B.; Gnap, J.; Loman, M.; Harantová, V. Examining the Amount of Particulate Matter (PM) Emissions in Urban Areas. *Appl. Sci.* **2023**, *13*, 1845. [CrossRef]
25. Alwesabi, Y.; Liu, Z.; Kwon, S.; Wang, Y. A novel integration of scheduling and dynamic wireless charging planning models of battery electric buses. *Energy* **2021**, *230*, 120806. [CrossRef]
26. Du, J.; Liu, Y.; Mo, X.; Li, Y.; Li, J.; Wu, X.; Ouyang, M. Impact of high-power charging on the durability and safety of lithium batteries used in long-range battery electric vehicles. *Appl. Energy* **2019**, *255*, 113793. [CrossRef]
27. Available online: https://server.growatt.com/login (accessed on 5 April 2023).
28. Ehsani, M.; Singh, K.V.; Bansal, H.O.; Mehrjardi, R.T. *State of the Art and Trends in Electric and Hybrid Electric Vehicles*; IEEE: New York, NY, USA, 2021; Volume 109, pp. 967–984. [CrossRef]
29. Małek, A.; Dudziak, A.; Stopka, O.; Caban, J.; Marciniak, A.; Rybicka, I. Charging Electric Vehicles from Photovoltaic Systems—Statistical Analyses of the Small Photovoltaic Farm Operation. *Energies* **2022**, *15*, 2137. [CrossRef]
30. Sokolovskij, E.; Małek, A.; Caban, J.; Dudziak, A.; Matijošius, J.; Marciniak, A. Selection of a Photovoltaic Carport Power for an Electric Vehicle. *Energies* **2023**, *16*, 3126. [CrossRef]
31. Madeti, S.R.; Singh, S. Monitoring system for photovoltaic plants: A review. *Renew. Sustain. Energy Rev.* **2017**, *67*, 1180–1207. [CrossRef]
32. Available online: https://monitoringpublic.solaredge.com/solaredge-web/p/home/public?locale=en_GB (accessed on 5 April 2023).
33. Kostopoulos, E.M.; Spyropoulos, G.; Christopoulos, K.; Kaldellis, J.K. Solar energy contribution to an electric vehicle needs on the basis of long-term measurements. *Procedia Struct. Integr.* **2018**, *10*, 203–210. [CrossRef]
34. Gan, Y.; Chen, Z.; Wu, L.; Cheng, S.; Lin, P. Fault diagnosis of PV array using adaptive network based fuzzy inference system. *Proc. IOP Conf. Ser. Earth Environ. Sci.* **2020**, *467*, 012083. [CrossRef]
35. Globisch, J.; Plötz, P.; Dütschke, E.; Wietschel, M. Consumer preferences for public charging infrastructure for electric vehicles. *Transp. Policy* **2019**, *81*, 54–63. [CrossRef]
36. Erd, A.; Stokłosa, J. Main Design Guidelines for Battery Management Systems for Traction Purposes. In Proceedings of the XI International Scientific and Technical Conference Automotive Safety 2018, Casta, Slovakia, 18–20 April 2018. [CrossRef]
37. Gnann, T.; Funke, S.; Jakobsson, N.; Plötz, P.; Bennehag, A. Fast charging infrastructure for electric vehicles: Today's situation and future needs. *Transp. Res. D Transp. Environ.* **2018**, *62*, 314–329. [CrossRef]
38. Kulik, A.C.; Tonolo, É.A.; Scortegagna, A.K.; da Silva, J.E.; Urbanetz Junior, J. Analysis of Scenarios for the Insertion of Electric Vehicles in Conjunction with a Solar Carport in the City of Curitiba, Paraná—Brazil. *Energies* **2021**, *14*, 5027. [CrossRef]
39. Iringová, A.; Kovačic, M. Design and optimization of photovoltaic systems in a parking garage—A case study. *Transp. Res. Procedia.* **2021**, *55*, 1171–1179. [CrossRef]
40. Ibrahim, A.; Jiang, F. The electric vehicle energy management: An overview of the energy system and related modeling and simulation. *Renew. Sustain. Energy Rev.* **2021**, *144*, 111049. [CrossRef]
41. Fragiacomo, P.; Piraino, F.; Genovese, M. Insights for Industry 4.0 Applications into a Hydrogen Advanced Mobility. *Procedia Manuf.* **2020**, *42*, 239–245. [CrossRef]

42. Di Foggia, G. Drivers and challenges of electric vehicles integration in corporate fleet: An empirical survey. *Res. Transp. Bus. Manag.* **2021**, *41*, 100627. [CrossRef]
43. Schücking, M.; Jochem, P. Two-stage stochastic program optimizing the cost of electric vehicles in commercial fleets. *Appl. Energy* **2021**, *293*, 116649. [CrossRef]
44. Seddig, K.; Jochem, P.; Fichtner, W. Two-stage stochastic optimization for cost-minimal charging of electric vehicles at public charging stations with photovoltaics. *Appl. Energy* **2019**, *242*, 769–781. [CrossRef]
45. Nait-Sidi-Moh, A.; Ruzmetov, A.; Bakhouya, M.; Naitmalek, Y.; Gaber, J. A Prediction Model of Electric Vehicle Charging Requests. *Procedia Comput. Sci.* **2018**, *141*, 127–134. [CrossRef]
46. Nassar, Y.F.; Alsadi, S.Y.; Miskeen, G.M.; El-Khozondar, H.J.; Abuhamoud, N.M. Mapping of PV Solar Module Technologies Across Libyan Territory. In Proceedings of the 2022 Iraqi International Conference on Communication and Information Technologies (IICCIT), Basrah, Iraq, 7–8 September 2022; pp. 227–232. [CrossRef]
47. Stańczyk, T.L.; Hyb, L. Technological and organisational challenges for e-mobility. *Arch. Automot. Eng. Arch. Motoryz.* **2019**, *84*, 57–70. [CrossRef]
48. Habla, W.; Huwe, V.; Kesternich, M. Electric and conventional vehicle usage in private and car sharing fleets in Germany. *Transp. Res. D Transp. Environ.* **2021**, *93*, 102729. [CrossRef]
49. Nassar, Y.F.; Alsadi, S.Y.; El-Khozondar, H.J.; Ismail, M.S. Design of an isolated renewable hybrid energy system: A case study. *Mater. Renew. Sustain. Energy* **2022**, *11*, 225–240. [CrossRef]
50. Novoa, L.; Brouwer, J. Dynamics of an integrated solar photovoltaic and battery storage nanogrid for electric vehicle charging. *J. Power Sources* **2018**, *399*, 166–178. [CrossRef]
51. Keelin, T.W. The Metalog Distributions. *Decis. Anal.* **2016**, *13*, 243–277. [CrossRef]
52. Keelin, T.W.; Howard, R.A. *The Metalog Distributions: Virtually Unlimited Shape Flexibility, Combining Expert Opinion in Closed Form, and Bayesian Updating in Closed Form*; Stanford University: Stanford, CA, USA, 2021.
53. Available online: http://metalogdistributions.com/software.html (accessed on 22 May 2023).
54. Runolinna, M.; Turnquist, M.; Teittinen, J.; Ilmonen, P.; Koskinen, L. Extreme Path Delay Estimation of Critical Paths in Within-Die Process Fluctuations Using Multi-Parameter Distributions. *J. Low Power Electron. Appl.* **2023**, *13*, 22. [CrossRef]
55. Kleniewska, M.; Mitrowska, D.; Wasilewicz, M. Estimating Daily Global Solar Radiation with No Meteorological Data in Poland. *Appl. Sci.* **2020**, *10*, 778. [CrossRef]
56. Available online: https://www.bayesfusion.com/2022/06/27/genie-4-0/ (accessed on 26 April 2023).
57. Available online: https://monitoringpublic.solaredge.com/solaredge-web/p/site/public?name=Dryszczow&locale=en_GB#/dashboard (accessed on 26 April 2023).