ARCHITECTURE CIVIL ENGINEERING ENVIRONMENT
The Silesian University of Technology No. 1/2023

doi: 10.2478/ACEE-2023-0010

ASSESSMENT OF THE CURRENT STATE OF PHOTOVOLTAIC PANEL MOUNTING SYSTEMS AND RELATED CONCERNS IN NORTHERN CYPRUS

Shaghayegh Ostovar RAVARI [a*], Ayten Özsavaş AKÇAY [b], Rifat RESATOGLU [c]

[a] MSc; Near East University, Faculty of Civil and Environmental Engineering, Near East Boulevard, ZIP: 99138, Nicosia, North Cyprus
*Corresponding author. E-mail address: *sh.ostovar987@gmail.com*

[b] Assistant Prof.; Near East University, Faculty of Architecture, Near East Boulevard, ZIP: 99138, Nicosia, North Cyprus

[c] Associate Prof.; Near East University, Faculty of Civil and Environmental Engineering, Near East Boulevard, ZIP: 99138, Nicosia, North Cyprus

Received: 28.08.2022; Revised: 23.01.2023; Accepted: 24.02.2023

Abstract
The efficiency of energy resources and the research and development of electricity generation technologies from renewable energy sources are becoming increasingly important as the use of renewable energy has increased. Northern Cyprus has undertaken attempts to boost the use of renewable energy sources and reduce its reliance on petroleum-based products, similar to many other countries, and as a result, Solar energy utilization has recently grown in this country. This article assesses the current state of PV panel mounting systems and related concerns in Northern Cyprus. In this regard, extensive and reliable data were collected from five distinct sources including authorities, ministries, stakeholders, and inspections. The current state of PV panel mounting systems was evaluated based on data analysis, and the main weaknesses, major concerns, and critical problems were identified. Ultimately, two fundamental recommendations were made to overcome the identified problems. First, developing stringent guidelines to properly use renewable energy sources while minimizing side effects and unwanted losses, second, considering quality control and strict supervision to inspect the implementation of standards.

Keywords: **Northern Cyprus; Photovoltaic panels; Power generation; Renewable energy; Resource efficiency; Solar energy.**

1. INTRODUCTION

Energy supply is one of the most pressing concerns for the future of any country and is directly related to the economic growth of different nations [1]. For centuries, electricity has been produced from various non-renewable energy sources, which have had negative consequences on all living organisms, endangering the quality of life on Earth, causing air pollution, rising sea levels, increasing CO_2 emissions, and increasing global warming rate [2-4]. Furthermore, the rapid depletion of fossil fuel resources around the world and the increase in their costs are other problems of using these energy sources and indicate the urgent need to find effective solutions for the future [5, 6]. As a result, considerable efforts are currently being made to identify effective solutions, with more emphasis on alternative energy sources, one of which is the use of renewable energy sources [7]. The use of renewable energy sources reduces dependence on non-renewable sources of energy, decreases CO_2 emissions, protects the environment, alleviates the energy crisis, and reduces utility costs [4, 6].

The Earth is 150 million kilometres from the Sun, and the total energy reaching the Earth's surface is esti-

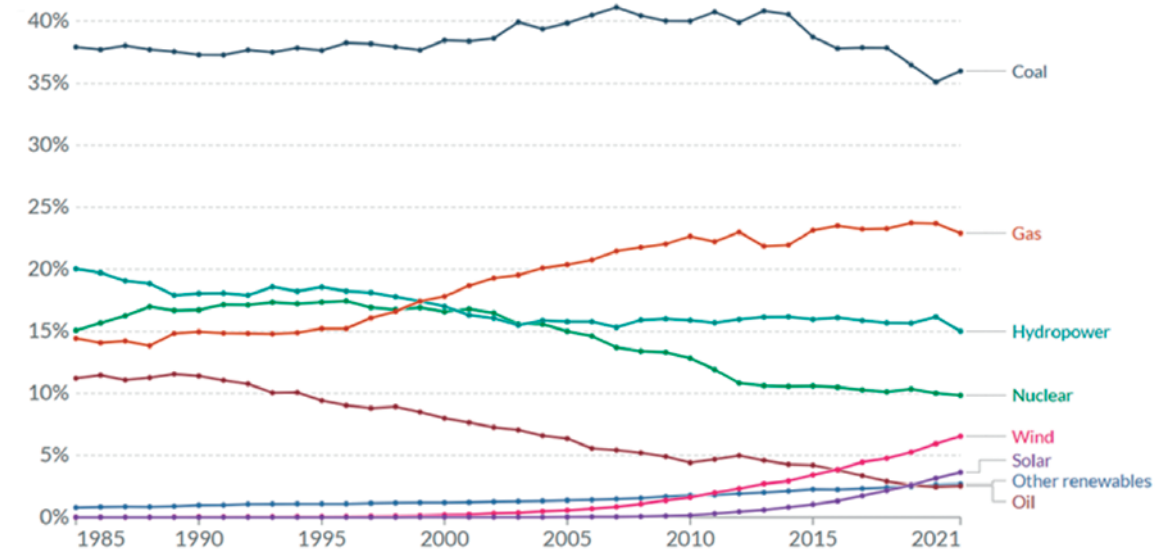


Figure 1.
Share of electricity production by different sources in the world from 1985 to 2021 [10]

mated to be about 1.08×10^{14} kW. The total annual solar radiation reaching the Earth's surface is about 3.4×10^{6} EJ, more than 7,500 times the total annual energy consumption worldwide. [8, 9]. Meanwhile, human life is still incredibly dependent on non-renewable energy sources. In 2021, 36.49% of the global electricity was produced from coal, 3.1% from oil, 22.16% from gas, 9.94% from nuclear, 15.28% from hydropower, 6.59% from wind power, 3.72% from solar energy, 2.73% from other renewable energy sources. As shown in Figure 1, the share of renewable sources of energy has been growing slightly over the last decade in the world [10].

To generate electricity from solar energy, photovoltaic (PV) panels are used to convert solar radiation into electricity [7]. However, some considerations should be made to improve the efficiency of PV panels for electricity generation, including shading conditions, installation tilt angle, access, land use plan, land cost, and weather conditions such as sunlight duration, ambient temperature, relative humidity, wind speed, and transparency index [11–14]. Some of the mentioned factors have significant effects on the performance of PV panels, for example, shading on a quarter, half, and three-quarters of a PV panel can reduce its efficiency by 33.7%, 45.1%, and 92.6%, respectively. Consequently, there should be minimal shading on the panels at the installation site [1]. On the other hand, the installation site should be easily accessible, with a low risk of vandalism and theft at the same time [12]

The aesthetics of the building is critical after the installation of PV panels, which has been investigated by collecting data through surveys in different countries, including the investigation of detailed consumer preferences for the aesthetics of solar panels, such as colour, surface pattern, frame, visibility, and assessment of the relationship between PV panel appearance, functional performance, and cost of the PV panels among U.S. residents [6], the determination of the relative value of aesthetics compared to other features such as investment costs, payback period, reliability, and services required by homeowners in the Netherlands [15], and the assessment of the aesthetics of PV panels and the aesthetics of the building after the installation of PV panels, as well as the budget status of PV panels among Swiss homeowners [16]. But according to the literature reviews, Northern Cyprus has not been the subject of any studies on these concerns.

Other methods were also used to evaluate the effects of PV panels on a landscape, such as using the visual Q methodology to identify the effects of PV panels on the landscape and harmony with the environment [17] and using a combined method of simulation and surveys to investigate the relationship between the energy production potential of rooftop PV panels and building aesthetics [18].

Furthermore, the effects of dust, various tilt angles, and different orientations on the efficiency of PV panels in Northern Cyprus were studied by comparing one-year measured data, simulations, and analyt-

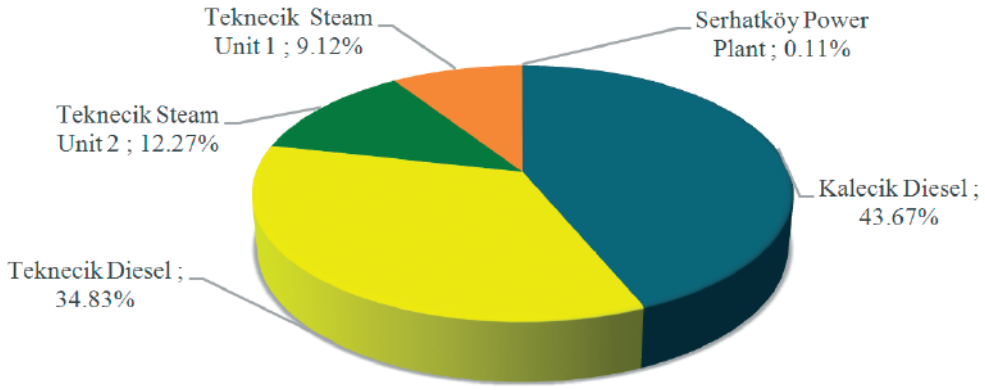


Figure 2.
The share of each North Cyprus power plant in electricity production [27]

ical calculations [19]. Suitability, cost, economic aspects, and the overall efficiency and sustainability of PV panels due to their correlation with structures were investigated using qualitative research methods at both international and Northern Cyprus levels [20]. The sustainability of the installation of solar power plants in Northern Cyprus, as well as their potential environmental and economic benefits, were investigated according to the Metenorm V6 (MN6) measurement program [21]. The effects of wind loads on rooftop PV panels were examined based on ASCE 7-16 and TS498 in Northern Cyprus. The effects of beam span length, load-bearing systems, column arrangement, available roof area, and required distance between arrays were taken into account while evaluating the cost and weight of mounting systems [22].

This study evaluates the current state of PV panel mounting systems in Northern Cyprus and assesses the related concerns based on the perspective of users, companies, relevant authorities, and mounting system design conditions, and figures out the strength of the related standards. The findings of this study have beneficial effects on improving PV panel performance, reducing the negative effects of mounting systems on buildings and urban landscapes, and increasing the willingness of residents to use PV panels.

1.1. Study area

This study is focused on Northern Cyprus. Cyprus is the third largest island in the Mediterranean region, located 33 degrees east of Greenwich and 35 degrees north of the Equator. Cyprus has a Mediterranean climate with typical seasonal changes: summers are hot and dry, lasting from May to September, while winters are usually rainy from November to mid-March. Autumn and spring are short seasons that separate summer and winter [23]. Climate change has affected the island over the last decades and has had extensive consequences such as changes in rainfall levels, changes in temperature, droughts, and extreme weather events such as hurricanes and tornados, which have affected the average wind speed on the island. Besides, tornadoes were rare in the Mediterranean region, however, their number and strength have increased in recent years due to climate change and global warming [24, 25]. These changes have directly caused widespread damage to infrastructure and equipment, especially mounting systems of PV panels including partial or total loss of PV panel arrays, damage to adjacent facilities, human and financial losses, electricity shortages, power outages, and damage to other buildings [26].

1.1.1. Energy production in Northern Cyprus

In the northern part of the island, the Northern Cyprus Electricity Authority (KIB-TEK) is responsible for supplying electricity. Although Northern Cyprus has attempted to reduce its reliance on oil products for generating electricity in recent years, electricity generation still relies mostly on non-renewable energy sources. Northern Cyprus imports oil products, which has led to dependence, energy crises, a volatile energy market, and rising electricity prices [5, 7]. KIB-TEK generates the required electricity using five power plants, the contribution of each power plant is shown in Figure 2 [27].

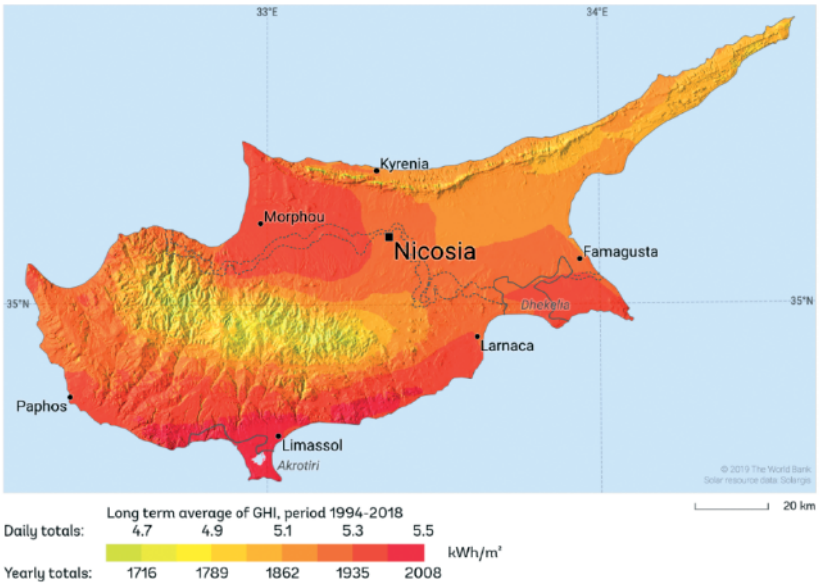


Figure 3.
Global horizontal irradiations (GHI) in Cyprus [29]

1.1.2. The potential of using solar energy in the study area

Cyprus has approximately 300 sunny days and receives between 2600–3500 hours of sunshine annually [7, 28]. Its average daily global horizontal irradiation varies from 4.80 kWh/m2 to 5.44 kWh/m^2 [29]. Therefore, Cyprus has exceptional conditions and substantial potential for the use of solar energy due to its unique geographical location [29, 30].

1.2. Problem statement

PV panels are known as an external element for building structures and are installed on both new and existing buildings. In addition to their advantages, PV panels can cause problems for the roof of the building, including structural problems, interrupting roof water flow, and damaging the waterproof layer of the roof. On the other hand, the mounting system of PV panels might have a variety of problems, such as aesthetic problems, adverse effects on the overall landscape of cities, glare problems, structural issues of the mounting system, and connection failures [6, 31, 32].

In the addition, the tilt angle of PV panels is an important criterion. PV panel performance is enhanced and maximized by capturing solar energy that is installed at appropriate tilt angles in each area [19, 33]. Furthermore, shading on a quarter, half, and three-quarters of a solar panel reduces its efficiency by 33.7%, 45.1%, and 92.6%, respectively [11]. According to the analysis, the tilt angle of photovoltaic panels varies depending on the location, weather conditions, and solar radiation [34]. Based on the studies and YEK reports, the optimum tilt angle for PV panel installation in Northern Cyprus is 25 to 35 degrees [34–37].

Although electricity generation using PV panels is expanding in Northern Cyprus, there is no official regulation or standard for the installation of PV panels in the country, except for a few general rules set by some municipalities and the Ministry of Electricity. Therefore, PV panels are mounted by solar panel installation companies in various shapes and systems, without any structural and architectural supervision, and recently they have faced extensive problems. As a result, many architects, structural engineers, residents, some members of the parliament, the Minister of Economy, and the Minister of Energy have complained about the installation of PV panels, especially on roofs, and these issues have even been raised in various communities and platforms (scientific meetings, parliament, etc.). The main problems of PV panels are divided into four groups, which are listed below:

- Safety and serviceability problems
- Installation problems
- Financial losses
- Visual problems

This article aims to collect extensive and accurate data, assess the current state of PV panel mounting systems, identify major weaknesses, key problems,

and concerns related to PV panel mounting systems in Northern Cyprus, investigate the root causes of the problems, and finally make suggestions for mitigation of issues and increasing the efficiency of installed PV panels.

2. METHODS

2.1. Data collection procedure

In order to conduct a thorough investigation and evaluation of the problems, extensive and detailed data were collected from five separate sources through documents, interviews with stakeholders and relevant authorities, and site inspections of some mounting systems of PV panels, which are:

1. YEK (Renewable energy resources board)

The YEK representative was questioned regarding the installation of PV panels in Northern Cyprus in the following areas:

- Rules and standards for installing PV panels
- Relevant guidelines
- Terms and conditions of authorized places for PV panel installation
- Desire to install PV panels
- Related inspections and monitoring procedures for installing PV panels

2. KIB-TEK (Northern Cyprus Electricity Authority)

Some data were collected on the number of Low Voltage (LV) PV panel projects, most of which are installed on rooftops, the number of Medium Voltage (MV) PV panel projects, and the total electricity generated by PV panels in Northern Cyprus. These data are annual and cover the years 2014 to 2020.

3. PV panel installation companies

Some questions were asked of seven PV panel installation companies. The questions were divided into five categories, which are listed below:

- The background of the company
- Roof considerations (Available roof area, locations of the project, PV arrays and other equipment, size of electrical services, roof condition, roof orientation, roof age, proximity to other equipment, risk assessment, accessibility, and working spaces)
- Installation considerations (Shading issues, aesthetics and beauty, codes, and local standards)
- Mounting system (Materials of the mounting system, the tilt angle of PV panels, height of the mounting system)
- Mounting system calculations and analysis methods (Consideration of related design loads, suitable loads calculation methods, appropriate load-resisting system, structural analysis for each case)

4. Users of PV panels

Thirty-two users of PV panels were asked questions in three different areas, which are listed below:

- Mounting system problems
- Side effects of mounting systems
- User concerns

5. Site inspection and taking photos

Field observations of 50 projects and a detailed inspection of 10 projects were carried out, and several photos were taken of different parts of PV panel mounting systems.

2.2. Data Analysis Procedure

After collecting the desired data from relevant sources, the growth rate of PV panel installation and the rise in electricity generated by PV panels between 2014 and 2020 were investigated. Next, the findings of interviews with the representative of YEK, PV panel installation companies, and PV panel users were analyzed and categorized.

Since Northern Cyprus does not have a regulation or standard for rooftop PV panels, thirteen regulations and guidelines from other nations were reviewed and the primary requirements and parameters for the installation of rooftop PV panels were gathered. In the next stage, field observations and detailed inspections were carried out, and the mounting systems were controlled based on the parameters determined by those regulations and guidelines.

Then, the main weaknesses and major problems in the procedure of designing and installing mounting systems of PV panels, mounting system calculations, analysis methods, and architectural and aesthetic considerations were investigated based on the findings of interviews with PV panel installation companies, reviewing the standards, and site inspections. Finally, recommendations were given to enhance the condition of rooftop PV panels in terms of safety, serviceability, efficiency, and aesthetics.

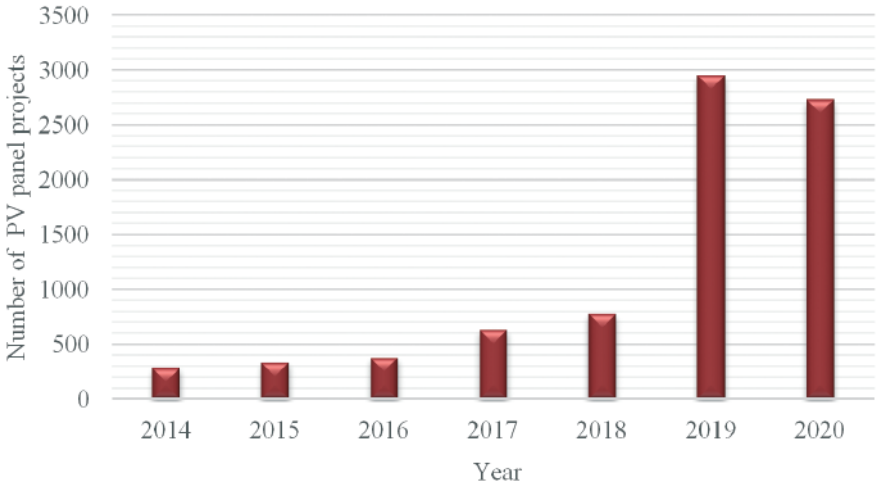


Figure 4.
Number of completed PV panel projects in Northern Cyprus from 2014 to 2020 (Author prepared by using data from YEK)

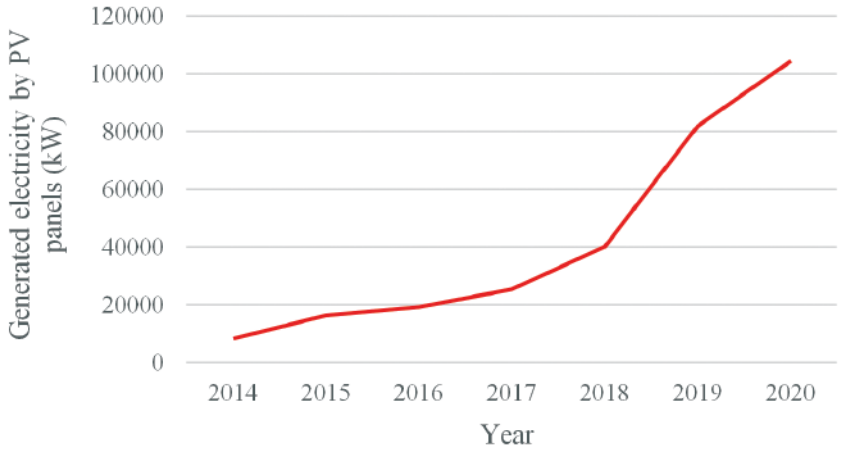


Figure 5.
Total electricity generated by PV panels from 2014 to 2020 in Northern Cyprus (Author prepared by using data from YEK)

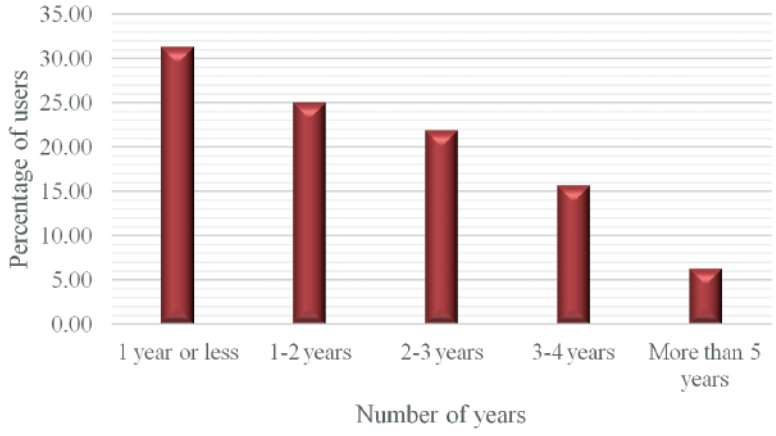


Figure 6.
The years of using PV panels (Author)

Table 1.
Results of interviews with PV panel installation companies

Category	Criteria	Number of companies out of 7
Roof considerations	Available roof area	7
	Locations of the project	5
	PV arrays and other equipment	7
	Size of electrical services	4
	Roof condition	7
	Roof orientation	7
	Roof age	7
	Proximity to other equipment	7
	Risk assessment	6
	Accessibility	5
	Working spaces	6
Installation considerations	Shading issues	5
	Architectural and aesthetic	3
	Codes and local standards	0*
Mounting system	Materials of the mounting system	4
	The tilt angle of PV panels	3
	Height of the mounting system	3
Mounting system calculations and analysis methods	Consideration of related design loads	3
	Suitable loads calculation methods	2
	Appropriate load-resisting system	3
	Structural analysis for each case	2

* There is no local code or standard for installing PV panels.

Table 2.
Responses of PV panel users to the conducted survey

Criteria	Description	Results	Percentage
Mounting system problems	Mounting system problems	The mounting systems of PV panels have problems during or after installation.	53 %
Side effects of mounting systems	Roof problems	The roof has some problems such as water leakage due to the installation of solar panels.	31 %
	Impact on aesthetics	The solar panel system affected the beauty and aesthetics of the building.	72 %
User concerns	Concerns about maintenance	Users are concerned about maintaining solar panels.	34 %
	Concerns about PV panels on very windy days	Users have ever been worried about solar panels on very windy days.	63 %
	Occasional inspection of PV panels	Users have been on the rooftops regularly to inspect the panels and are worried about everything going well.	66 %

3. RESULTS

According to data collected from KIB-TEK, 285 PV panel projects were completed in 2014 in Northern Cyprus, while this number has increased to 2,724 in 2020. The total number of PV panel projects in Northern Cyprus was 8,539 cases as of April 11, 2021. Figure 4. depicts the number of PV panel projects that have been completed each year in Northern Cyprus from 2014 to 2020 based on KIB-TEK data.

The total electricity generated by PV panels in Northern Cyprus from 2014 to 2020 is shown in Figure 5 based on KIB-TEK data.

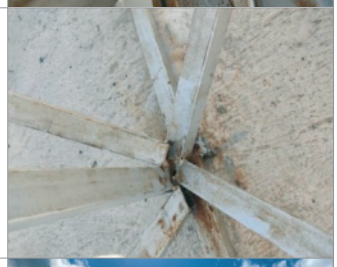
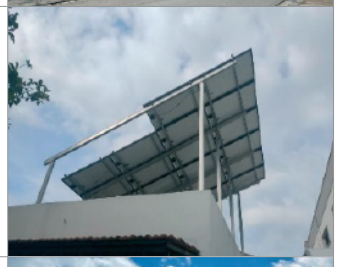
Seven PV panel installation companies were interviewed. The results of interviews with PV panel installation companies are shown in Table 1. This table shows the number of companies that consider each of the mentioned criteria.

Thirty-two users of rooftop PV panels were interviewed in this study. Figure 6 represents the years of using PV panels.

Table 2. reports the questions asked to the users in this survey and the percentage of positive responses to each question.

The result of the review of guidelines and standards

Table 3.
Problems of mounting systems of PV panels based on inspections

Problem	Explanation	Photo
Rust problems	Rust problems are due to weather conditions and the lack of galvanized elements. While based on the Northern Cyprus Solar Power Generation Plant Technical Specification, which in Turkish is called "Kuzey Kıbrıs Güneş Enerjisi Üretim Santrali Teknik Şartnamesi", the service life of mounting systems of PV panels is at least 25 years and all elements of the mounting system must be made of galvanized steel.	
Connection problems	The design and implementation of connections between system members and connections between the system and the roof are crucial. But the following problems were observed in some installation systems: 1. A large number of members are connected at one point. 2. The implementation of joints, especially in welded joints, is extremely inappropriate.	
Height of the mounting system	The height of mounting systems affects the aesthetics of the building and its surrounding area. In addition, as the height of the mounting system increases, the effect of wind load increases. Several high-rise mounting systems are seen in Northern Cyprus, while the effect of the height of the mounting system was not been considered during the design phase.	
Distance to the edge	The distance between the rooftop PV panels and the roof edge is significant for several reasons, including: 1. It affects the aesthetics of buildings and urban areas. 2. Provides convenient access for maintenance and cleaning PV panels. 3. Provides access to all parts of the roof in case of danger.	
Aesthetics	It is crucial to preserve the aesthetics of buildings and the surrounding area after installing rooftop PV panels, however mounting structures sometimes cause visual pollution due to the disorganized state of the panels or high-rise and bulky mounting systems.	
The tilt angle of PV panels	The recommended tilt angle range for Northern Cyprus, according to YEK data, is 25 to 35 degrees. However, panels are installed in this region at a variety of tilt angles, and installation companies do not take the recommended tilt angles into account.	

of different countries regarding rooftop PV panels shows that some criteria related to rooftop PV panels are essential to improve the safety, aesthetics, serviceability, and efficiency of PV panels, which are listed below:

- Height of mounting system
- Distance to the edge of the roof
- The tilt angle of PV panels
- Materials of the mounting system
- Connections of the mounting systems
- Aesthetics of the building after installing PV panels

Field observations and detailed inspections were carried out considering these criteria.

Based on the site investigations, the problems of installed PV panels in Northern Cyprus can be divided into six categories, which include rust problems, connection problems, the height of the mounting system, the distance between the mounting system and the edge of the roof, aesthetics problems, and tilt angle of PV panels. These problems are further discussed in Table 3.

4. DISCUSSION

As previously mentioned, electricity generation in Northern Cyprus is currently largely dependent on non-renewable sources. But despite the problems mentioned by users, the desire to install rooftop PV panels in North Cyprus is increasing dramatically. Based on interviews with the YEK representative, users, and companies, public attention to the harms of using fossil fuels, public awareness of electricity generation by PV panels, rapid growth in global electricity consumption per capita, advertising, rising electricity prices, and expansion of PV panel installation companies and related services in this country are the main reasons for the increased desire to install them. According to data gathered from YEK, there were 82 PV panel installation companies in Northern Cyprus as of April 2021, and as shown in Figure 4, the number of PV panel installation projects in 2020 was 855% higher than the number of projects in 2014. On the other hand, the total electricity produced by PV panels in Northern Cyprus increased by approximately 1163% between 2014 and 2020. While based on interviews by the representative of YEK, there is no national standard regulation that covers the entire country and takes into account all aspects of the installation of PV panels, only some municipalities have set some standards.

However, interviews with PV panel installation companies reveal that the majority of them are unaware of the technicalities, the details of installation, and the significance of PV panel mounting systems, and do not consider effective factors such as the proper tilt angle for panel installation. In addition, they ignore the side effects and negative consequences of PV panels, such as their detrimental effects on the aesthetics of structures, landscapes, and cities. On the other hand, based on interviews with users, some mounting systems encountered problems during or after installation, and many users stated that they were concerned about the PV panels and regularly checked PV panels to make sure that everything was working properly. The majority of users are still worried about PV panels in certain weather conditions, such as windy days.

The installation and design of PV panel mounting systems in Northern Cyprus have significant flaws, as determined by an assessment of the current state of the PV panel mounting systems and associated issues using the gathered data, reviewing various standards from other nations, and inspections. Many important factors that might damage panels, mounting systems, and adjacent facilities, cause partial or complete loss of PV panel arrays, reduce power generation, result in financial and human losses, and more are ignored by PV panel installation companies.

Therefore, given the current situation, various principles must be taken into account, including the material used for mounting systems, the maximum allowable height of the mounting system, the distance between the mounting structure of PV panels and the edge of the roof, the appropriate tilt angle range, proper mounting systems design for each case, and consideration of buildings and the aesthetics of the surroundings after installing PV panels to ensure system longevity and optimal performance, protect the safety of systems and residents, prevent financial losses, maintain the aesthetics of the building, and coordinate PV panels with urban architecture.

The standard for installing rooftop PV panels in Nicosia, Northern Cyprus has been set on July 1, 2021, but it has various flaws, many items have not been considered, and in addition, some parts of the standard are incomprehensible and confusing. On the other side, this standard does not take any improvement for PV panels that had been installed before providing this standard, while many rooftop mounting systems were built with a low level of serviceability, high risks of failure in many cases, and significant effect on the aesthetics of the building before developing this standard.

5. CONCLUSIONS

In light of the findings of this study and the existing state of affairs, there are serious flaws in mounting systems in Northern Cyprus and there are two key steps that Northern Cyprus needs to take to address these issues and challenges. Based on the findings of this study, the following recommendations are provided:

Firstly, clear, precise, and stringent guidelines in order to properly employ renewable energy sources to generate electricity while minimizing side effects and unwanted losses. Northern Cyprus must offer trustworthy, regulated, and appropriate standards or guidelines in this area. These standards will outline all useful and important characteristics and factors in the areas of PV panel mounting systems, PV panel installation techniques, and PV panel operation that should be taken into consideration during the design, installation, and operation of these systems. The following should be strictly taken into account in the standard, according to the findings of the study:

- Aesthetics of landscapes
- Design loads
- Materials of mounting systems
- Height of mounting systems
- Distance between the mounting system and the edge of the roof
- The tilt angle of PV panels

Secondly, Northern Cyprus lacks a regulatory authority to oversee the implementation of mounting system standards; as a result, even the general guidelines for PV panel mounting systems issued by some municipalities are not followed due to a lack of quality control and stringent supervision. Consideration of proper inspection by the competent body guarantees that the regulations and requirements are carefully adhered to. It would be beneficial for the Turkish Municipality of Nicosia to deal with this issue in detail and be a pioneer for other municipalities.

It should be noted that these two steps must be implemented simultaneously in order to solve issues associated with installing PV panels and mounting systems, increase electricity generation, improve the safety of PV panels and citizens, minimize concerns and losses, lessen reliance on oil-based products, maintain the aesthetics of cities, save financial resources, and increase residents' desire for the installation of PV panels.

ACKNOWLEDGMENT

The authors' special thanks go out to YEK board members, Ms. Merin Elgin for providing the data required for this study and KIB-TEK. Special appreciation to users and installation companies who made valuable and significant contributions.

REFERENCES

[1] Islam, M. R., NurAlam, M., & Karim, R. Solar PV System Design and Installation at Roof Top to Partial Fulfillment of Elevator and Common Load.

[2] Gergelova, M. B., Kuzevicova, Z., Labant, S., Kuzevic, S., Bobikova, D., & Mizak, J. (2020). Roof's potential and suitability for PV systems based on LiDAR: A case study of Komárno, Slovakia. *Sustainability, 12*(23), 10018. DOI:10.3390/su122310018

[3] Wujek, P., & Sprawka, P. (2019). New PV Micro-Modules on Standard Roof Tiles. Rigas Tehniskas Universitates *Zinatniskie Raksti, 23*(2), 338–346. DOI: 10.2478/rtuect-2019-0072

[4] Sudimac, B., Ugrinović, A., & Jurčević, M. (2020). The application of photovoltaic systems in sacred buildings for the purpose of electric power production: the case study of the cathedral of st. Michael the archangel in Belgrade. *Sustainability, 12*(4), 1408. DOI: 10.3390/su12041408

[5] Yenen, M., & Fahrioglu, M. (2013, May). Wind and solar energy assessment of Northern Cyprus. In 2013 12th international conference on environment and electrical engineering (pp. 376–381). IEEE. DOI: 10.1109/EEEIC.2013.6549545

[6] Bao, Q., Honda, T., El Ferik, S., Shaukat, M. M., & Yang, M. C. (2017). Understanding the role of visual appeal in consumer preference for residential solar panels. *Renewable Energy*, 113, 1569–1579. DOI: 10.1016/j.renene.2017.07.021

[7] Okoye, C. O., & Abbasoğlu, S. (2013). Empirical investigation of fixed and dual axis Sun tracking photovoltaic system installations in Turkish Republic of Northern Cyprus. *Journal of Asian Scientific Research, 3*(5), 440–453.

[8] Kassem, Y., Gökçekuş, H., & Güvensoy, A. (2019). Solar Potential assessment in Near East University, Northern Cyprus. *Int. J. Eng. Res. Technol*, 12, 3061–3069.

[9] JJ1264 WEC resources solar 111013 js - world energy council. (n.d.). Retrieved April 30, 2022, from https://www.worldenergy.org/assets/images/imported/2013/10/WER_2013_8_Solar_revised.pdf

[10] Ritchie, H., Roser, M., & Rosado, P. (2020, November 28). Electricity mix. Our World in Data. Retrieved April 30, 2022, from https://ourworldindata.org/electricity-mix

[11] Kumar, A., & Chandi, M. L. A. R. K. (2019). Modelling of PV Arrays-An effective approach. International *Journal of Applied Engineering Research, 14*(12), 2850–2854.

[12] Gonzalez Montoya, D., Bastidas-Rodriguez, J. D., Trejos-Grisales, L. A., Ramos-Paja, C. A., Petrone, G., & Spagnuolo, G. (2018). A procedure for modeling photovoltaic arrays under any configuration and shading conditions. *Energies, 11*(4), 767. DOI: 10.3390/en11040767

[13] Kuznetsov, P., Yuferev, L., Voronin, D., Panchenko, V. A., Jasiński, M., Najafi, A., ... & Martirano, L. (2021). Methods Improving Energy Efficiency of Photovoltaic Systems Operating under Partial Shading. *Applied Sciences, 11*(22), 10696. DOI: 10.3390/app112210696

[14] Nazar, R. (2015). Improvement of efficiency of solar panel using different methods. *Int. J. Electr. Electron. Eng, 7*(1), 12–17.

[15] Breukel, A., van Dijk, C., & Spee, K. (2016). The relative importance of aesthetics in the adoption process of solar panels in the Netherlands. *EESD*, 8, 73–80.

[16] Petrovich, B., Hille, S. L., & Wüstenhagen, R. (2019). Beauty and the budget: a segmentation of residential solar adopters. *Ecological Economics*, 164, 106353.

[17] Lu, M., Lin, A., & Sun, J. (2018). The impact of photovoltaic applications on urban landscapes based on visual Q methodology. *Sustainability, 10*(4), 1051.

[18] Idowu, O., Attah, A. U., & Marafa, U. (2019). Aesthetic Effects and Energy Generation Potentials of Roof Mounted Photovoltaic (PV) Panels on A Hostel Building: A Correlation Study. *Ethiopian Journal of Environmental Studies & Management*, *12*(3).

[19] Babatunde, A. A., Abbasoglu, S., & Senol, M. (2018). Analysis of the impact of dust, tilt angle and orientation on performance of PV Plants. *Renewable and Sustainable Energy Reviews*, 90, 1017–1026.

[20] Yarmohammadi, S. E. (2013). Evaluation of the appropriateness of photovoltaic (PV) panels for sustainable building in North Cyprus (Doctoral dissertation, Eastern Mediterranean University (EMU)-Doğu Akdeniz Üniversitesi (DAÜ)).

[21] Erciyas, O. (2014). Sustainability Assessment of Photovoltaic Power Plants in North Cyprus (Master dissertation, Eastern Mediterranean University (EMU)-Doğu Akdeniz Üniversitesi (DAÜ)).

[22] Resatoglu, R., Akçay, A. Ö., & Ravari, S. O. (2022). Structural analysis and comparative study of Photovoltaic Panel Mounting Systems in Northern Cyprus. *Revista Amazonia Investiga, 11*(56), 169–182. https://doi.org/10.34069/ai/2022.56.08.18

[23] Delipetrou, P., Makhzoumi, J., Dimopoulos, P., & Georghiou, K. (2008). Cyprus. In Mediterranean Island Landscapes (pp. 170–203). Springer, Dordrecht.

[24] Özerim, I., T-Vine, & T-Vine. (2020, November 20). Freak weather, including a tornado, inflicts widespread damage across North Cyprus. T. Retrieved May 10, 2022, from http://www.t-vine.com/freak-weather-including-a-tornado-inflicts-widespread-damage-across-north-cyprus/

[25] Agencies, D. S. W. (2020, November 21). Tornadoes hit northern parts of Turkish Cyprus, Damage Power Grid. Daily Sabah. Retrieved May 10, 2022, from https://www.dailysabah.com/turkey/tornadoes-hit-northern-parts-of-turkish-cyprus-damage-power-grid/news.

[26] Naeiji, A., Raji, F., & Zisis, I. (2017). Wind loads on residential scale rooftop photovoltaic panels. *Journal of Wind Engineering and Industrial Aerodynamics*, 168, 228–246. DOI: 10.1016/j.jweia.2017.06.006

[27] Kassem, Y., Çamur, H., & Alhuoti, S. M. A. (2020). Solar energy technology for Northern Cyprus: Assessment, statistical analysis, and feasibility study. *Energies, 13*(4), 940. DOI: 10.3390/en13040940

[28] Mustafa, R. J., Gomaa, M. R., Al-Dhaifallah, M., & Rezk, H. (2020). Environmental impacts on the performance of solar photovoltaic systems. *Sustainability, 12*(2), 608. DOI: 10.3390/su12020608

[29] Solargis. (n.d.). Global Solar Atlas. (n.d.). The World Bank Group. Retrieved October 22, 2022, from https://globalsolaratlas.info/download/cyprus

[30] Kassem, Y., Al Zoubi, R., & Gökçekuş, H. (2019). The possibility of generating electricity using small-scale wind turbines and solar photovoltaic systems for households in Northern Cyprus: a comparative study. *Environments, 6*(4), 47. DOI: 10.3390/environments6040047

[31] Kalogirou, S. A. (2015). Building integration of solar renewable energy systems towards zero or nearly zero energy buildings. *International Journal of Low-Carbon Technologies, 10*(4), 379-385. DOI: 10.1093/ijlct/ctt071

[32] Bosman, L. B., Leon-Salas, W. D., Hutzel, W., & Soto, E. A. (2020). PV system predictive maintenance: Challenges, current approaches, and opportunities. *Energies, 13*(6), 1398. DOI: 10.3390/en13061398

[33] Mamun, M. A. A., Islam, M. M., Hasanuzzaman, M., & Selvaraj, J. (2022). Effect of tilt angle on the performance and electrical parameters of a PV module: Comparative indoor and outdoor experimental investigation. *Energy and Built Environment, 3*(3), 278–290.

[34] Abdulsalam, H. S., & Alibaba, H. Z. (2019). Optimum Tilt Angle for Photovoltaic Panels in Famagusta, Cyprus. *IJSSHR*, 7, 29–35

[35] Darhmaoui, H., & Lahjouji, D. (2013). Latitude based model for tilt angle optimization for solar collectors in the Mediterranean region. *EnergyProcedia*, 42, 426–435

[36] Abdallah, R., Natsheh, E., Juaidi, A., Samara, S., & Manzano-Agugliaro, F. (2020). A Multi-Level World Comprehensive Neural Network Model for Maximum Annual Solar Irradiation on a Flat Surface. *Energies, 13*(23), 6422.

[37] Adedeji, M., Abbasoglu, S., & Senol, M. (2014). Determination of optimum tilt and azimuth angles for photovoltaic systems in Northern Cyprus.