



Application of Graphical User Interface in Photovoltaic Technology

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Abstract: *Photovoltaic (PV) system is one of the most widely used renewable energy technology other than hydropower and wind. Unlike the conventional way of generating electricity that uses fossil fuels and gas which releases CO₂, PV has the ability to generate electricity without releases CO₂. Graphical user interface on the other hand gives users access to all the tool's features in a single, easy-to-use interface. The main objective of this paper is to present a review of the GUI techniques for the photovoltaic technology system. The review in this paper shows the potential of GUI as a design tool for a photovoltaic technology. In addition, GUI is very useful to improve the photovoltaic technology process in order to make sure the system can provide sufficient electricity to meet the load requirement.*

Keywords: *GUI, PV Technology, Review, Solar Electricity*

1. INTRODUCTION

The radiation from the Sun that can produce heat, cause chemical processes, or generate electricity is known as solar energy. The overall amount of solar energy received on Earth exceeds the world's present and projected energy needs by a large margin. Solar energy has the ability to meet all future energy needs if employed correctly. Solar panels are extremely tough and can endure even the most extreme weather conditions, including hail up to one inch in diameter. Everyone can benefit from solar energy. It is being welcomed by people from all socioeconomic backgrounds. Solar energy systems are still being installed by homeowners of all ages. Solar power has indisputable environmental benefits, but it's also popular as it benefits solar owners' money. Solar energy is generally consumed in real time, with any excess sent back to the utility grid or stored in a battery. In the evenings and other times when sunlight is scarce, solar homes must rely on utility grids or battery storage for



power. PV energy are a produced product, and they have an environmental impact, just like any other building process, from the substances needed to make the panels to transit or even beyond. Next, a Graphical User Interface (GUI) is a visual representation of communication that allows the user to engage with the machine more easily. It is a typical user interface that contains graphical representations such as buttons and icons, and communication can be accomplished by interacting with these icons rather than the more traditional text-based or command-based methods. The main objective of this paper is to present a review of the GUI techniques for the photovoltaic technology system.

PV Technology

The researchers in [1] have stated that solar energy is a pollution-free energy source that outperforms non-renewable sources fossil fuels like coal and oil in terms of global preservation. They have found out that PV agriculture in China is a viable option for addressing agricultural power requirements while also achieving environmentally friendly agriculture productivity. They have concluded that the municipal authorities should promote farmers' ability to acquire PV agricultural production technology knowledge, improve farmers' efficiency in obtaining new technical information, and encourage farmers, friends, and acquaintances to express ideas and communicate.

Next, the researchers in [2] found out that some components for installing the open-source weather station, such as cement, ties, and attaching bolts, were left out because they are dependent on the installation method and have a wide range of applications depending on the installation location. The researchers have implemented that a photovoltaic module can serve as a reference cell for solar energy generating capability and agrivoltaic potential in the installation region in addition to delivering power. They have concluded that agrivoltaics, or the founder of harvests and solar panels, is gaining popularity. And has been shown to improve water efficiency and land productivity for a variety of organic crops such as lettuce, spinach, and strawberries, as well as wheat, rice, grapes, potato, celeriac, clover grass, and winter wheat.

Then, the researchers in [3] stated that the shift to renewable energy and low carbon emissions has been a worldwide concern due to the increasing scarcity of fossil fuels and the deterioration of the atmosphere. They found out that the amount of PV power generated has increased by 3.11 percent. They have concluded the primary components for generating electricity are photovoltaic panels and wind turbines.

Besides that, the researchers in [4] found out that as per the research on electric mobility, their findings show the understanding and prior experience with electric vehicles have a positive impact on tendency toward electric tractors, and that the utility of electric tractors lessens with respect to family farms and environmental propensity as monthly costs involved between tractors increase. They propose that technical innovation be focused on lowering production costs, increasing work capacity, and increasing engine power of electric tractors to make them more suited for a wider range of farming systems, with the goal of improving the agricultural sector's resource efficiency.

The researchers in [5] have concluded that renewable energy sources that are green and non-polluting, such as hydroelectricity, are becoming more popular. They found out that except for the solar panels, the balance of system contains all photovoltaic system components. The subsystem's primary energy consumption concern is charging, which is accomplished using photovoltaic electricity. A third subsystem is necessary in addition to these two to ensure that the electricity generated by the photovoltaic modules is properly applied to the load.

The researchers in [6] implemented various sorts of Semi-transparent PV (STPV) modules based on crystalline silicon (c-Si), thin-film (a-Si, Copper Indium Gallium Selenide (CIGS), and Cadmium Telluride (CdTe), dye synthesised solar cells (DSSCs), organic PVs (OPVs), and crystalline phases, as well as novel technologies of concentrating PVs (CPVs), and luminescent solar concentrators (LSCs). They have found out due to their absorption characteristics, semitransparent OPV (STOPV) cells have piqued attention as a way to supplement the spectrum light requirements for plant development. They have concluded that the PV systems are more cost-effective in dispersed energy generating settings than grid electricity or diesel generators, and they have the greatest operational practicality in rural locations and isolated agriculture contexts such as ranches, orchards, and greenhouses.

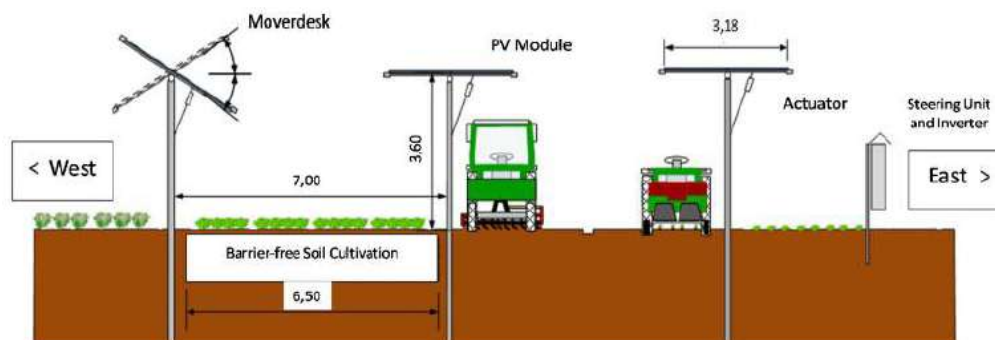


Fig. 1 shows the typical agrivoltaic system developed by the researchers in [6].

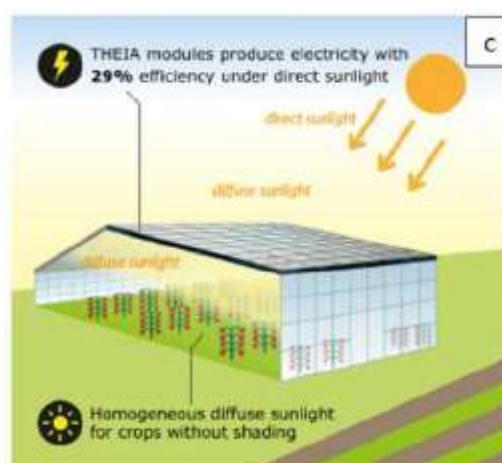


Fig. 2 shows the integrated modules in a greenhouse implemented by the researchers in [6].



Furthermore, the researchers in [7] stated that for nearly a decade, micro renewable energy systems such as photovoltaic (PV) systems have been the focus of considerable research, but throughout that time, the focus has rarely switched to adoption issues and consumption. Their research backs up the VBN model, claiming that customers' attitudes, subjective norms, perceived behaviour control, and personal factors moderate the link, leading to their environmental concern over PV implementation. They found out that if the indicated substantial impediments are appropriately addressed in the adoption decision, the diffusion of solar photovoltaic systems at the home level may be boosted.

The researchers in [8] found out that smart grids/smart systems are promising, presenting numerous benefits and problems, such as in the construction industry, which offers an increasing market and is transforming communities. They have concluded that the photovoltaic systems show studies of smart grids with PV systems identified several key points, including the adoption of specific tariffs, reduction in peak energy demand, development of two-way communication, real-time control, cyber security, standardisation, PVs with water heaters, encouragement of BIPV/smart-grid configurations, and estimation of the systems in various regions.

Apart from that, researchers in [9] implemented the modules made of crystalline silicon (c-Si) waste management C-Si technology dominates the PV market, and c-Si PV trash has traditionally been deposited unprocessed into landfills throughout the world and during the decomposition process in landfills, dangerous chemicals can leach into the ground, contaminating groundwater and the ecosystem. They have found out that without a quick policy shift from the promotion of new PV installations to life cycle management of photovoltaic assets, the world would soon be in a situation similar to the current single-use plastic catastrophe. They have concluded that because it is simpler to maintain purity and homogeneity in cells of smaller sizes, the efficiency of PV modules differs significantly from that of a cell of the same technology manufactured at the research scale.

The researchers in [10] found out that during its five decades of existence, solar photovoltaic thermal (PVT) technology has gone through numerous phases, and several review articles on the subject have been produced. They have concluded that conventional energy is a non-renewable source of energy derived from unstable and diminishing natural reserves containing natural gas, fossil fuels, petroleum oil, coal, or nuclear energy. Wind and solar energy will dominate among the many renewable energy choices, contributing 24 percent and 19 percent to the power industry, respectively, by 2050.

Next, the researchers in [11] have implemented preservation of electrical energy from a PVT panel and an electric heater driven by a PVT panel in a solar basin that still allows for standalone desalination during times when the sun is not shining. Each step of multiple effect distillation (MED) consists of a low compression vessel/chamber where salt water is dispersed over the heating tube bundles. They have concluded that for standalone desalination in remote regions, a photovoltaic thermal – humidification dehumidification system would be a superior solution.



The researchers in [12] have found out that countries are putting increased emphasis on decreasing greenhouse gas (GHG) emissions by shifting away from fossil-fuel-based electricity generation and toward renewable energy generation, thereby leading to the generation of sustainable energy. They have concluded that the wide variety of water flow rates and low solar radiation intensity limit the use of photovoltaic thermal collectors.

The researchers in [13] stated that in recent years, a significant electrification process of the most remote rural villages with decentralised clean energy has been growing in the Latin American and Caribbean (LAC) region, where PV energy stood out for its features of autonomy and continuous cost savings. They found out that the Rural Electrification Project with Photovoltaic Solar Technology (Phase II) in 216 residences in nine rural villages in the Republic of Cuba's Guantánamo province demonstrates very good developments in terms of increasing the residents' standard of living, particularly their health and wellbeing. They have concluded that given that the food preparation process consumes the most energy at certain times of the day and that the PV system has a limited delivery capacity, it is suggested that solar thermal energy, in the presence of solar stoves and ovens, be considered as an approach to enhance the electricity supply to other domestic duties.

The researchers in [14] found out that household variables such as entrepreneurial acumen in family members, ethnic profile, social, and economic concerns all increase the possibility of choosing Solar photovoltaic (SPV) technology over other accessible microtechnology, according to the research. They have concluded despite the availability of various microtechnology, different driving forces and impediments are responsible for the adoption of SPV technology in Indian households.

The researchers in [15] implemented an analytical technique in their studies and five analytical techniques were chosen in the investigation based on the following two conditions which are the PV electrical inputs should be straightforward to get from the manufacturer datasheet or from an outside calibration using IV curve data and the methodologies should have been widely established for predicting the maximum power of PV modules. They proved that losses due to soiling in PV modules may be calculated without the use of a special monitoring device. They have concluded that in comparison to previous models that extract soiling losses from historical PV performance time series, the examined approaches can estimate losses in real time with only a few inputs.



Fig. 3 shows the setup done on University of Jaen's rooftop for researchers in [15].

The researchers in [16] have found out that with the rising usage of fossil fuels in the twenty-first century, the frequency and intensity of production and everyday activities have reached unparalleled levels in history. They have implemented a technique for assessing photovoltaic (PV) technology based on cumulative prospect theory (CPT) and hybrid information in order to provide an accurate appraisal of PV technologies. They have concluded that single-crystalline silicon (Sc-Si) and Cadmium telluride (CdTe) always rank first and second in sensitivity analysis findings of expected tendencies, and Sc-Si retains an edge over CdTe in terms of technicality and conventional market characteristic. Multi-crystalline silicon (Mc-Si) and copper indium gallium selenium (CIGS) are consistently ranked third and fourth, respectively, with CIGS holding a social benefit and sustainable development edge over Mc-Si. Amorphous silicon (A-Si) is always ranked sixth.

The researchers in [17] implemented the performance of cooling water and it is improved by using an advanced PV thermal (PV/T) system with phase change material (PCM). The temperature range of PCM may be used as thermal energy storage at night. They have found out that there are three generations of PV technology on the market; the differences between them are based on effectiveness, thermoelectrical ability, and affordability. After doing mathematical analysis, the exegerics efficiency rose by 7% for 2 percent volume concentration, 5 nm, and 0.015 m/s velocity flow. They have concluded since the power varies with changes in ambient temperature during the day, it is often not deemed cost-effective. Such PV/T systems can be improved by including a rough element within the cooling ducts, which is particularly appropriate for first-generation PVs in arid locations.

The researchers in [18] stated that in the present energy paradigm, the majority of power originates from fuel burning, rendering the economy largely reliant on non-renewable energy sources and causing irreparable ecological destruction. They have found out that the development of construction applications that can perform numerous tasks, such as pavement performance monitoring, freezing temperatures, reducing the urban heat island effect (UHI), and self-healing, is advantageous to the community. They have concluded that the dust adhesion is increased by around 80% when relative humidity is increased from 40% to 80%.

Because the residual value of the thermoelectric material is not used in the Levelized Cost of Energy (LCOE) calculation, the life cycle cost of the thermoelectric generation system will fall when the building scale climbs to an enormous scale.

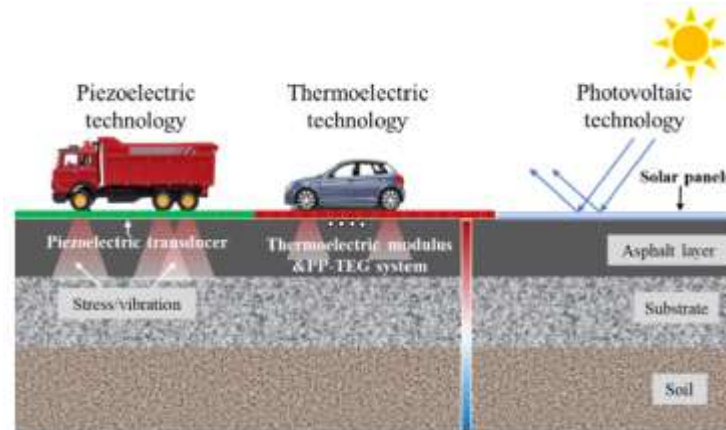


Fig. 4 shows the asphalt pavement technology for capturing electric energy done by the researchers in [18].

Application of GUI in PV Technology

The researchers in [19] stated that electrical power, which is now a basic requirement, plays a critical part in a country's economic development. The comparison of central inverter and microinverter systems integrated with PV generating systems was separated into three conditions: normal, partial shade, and dusting. They have implemented the fluctuation of irradiation versus time graph under normal conditions which is shown by a graphical user interface (GUI) pushbutton WPM2NC. Installing a 1kw PV system with micro-inverter and the same system with a central inverter resulted in a complete evaluation of the performance output. The MATLAB GUI is used to create graphs and perform different computations. They have concluded in the case of dusting and shading, the difference in output power between microinverter and central inverter topologies seems to be more than 10%.

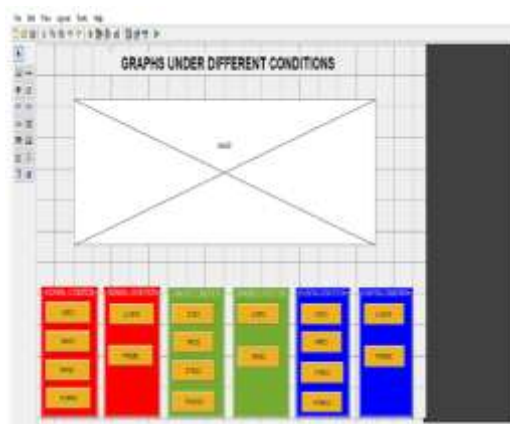


Fig. 5 shows the GUI installed by the researchers in [19] to do a comparison performance for their study purposes.



The researchers in [20] thought with rising worries about air pollution and global warming, clean renewable energy sources are projected to play a larger or more vital part in future global development. They have implemented the graph of power voltage characteristics at various isolations and temperatures aids in the analysis of a 200W solar panel. The LabVIEW Data Dashboard programme is used to access the server. They have concluded that the maximum power point tracking utilising measured parameters will increase the solar panel performance in GUI.

The researchers in [21] stated that through the electrical panel with source inverter, the photovoltaic panel system provides electricity to the general distribution panel. The manual operation of such an electrical system necessitates a large number of people, which raises the total cost, and making a quick choice during a breakdown or an unstable scenario is difficult. It is confirmed that this technology is beneficial since it allows for remote monitoring of the process and the development of a new technical model that allows for decentralisation of the whole existing arrangement. They have concluded that this innovation is advantageous since it enables for wireless connectivity of the process as well as the development of a new technical model that allows for the decentralisation of the entire system.

Then. The researchers in [22] implemented a multi-objective optimized strategy based on the SPEA-II algorithm and an electro-thermal design procedure is used to build the created software. They have concluded that the tournament, cross-over, and genetic variation procedures are used in the optimization process to produce a collection of non-dominated performant solutions that meet all the design criteria.

The researchers in [23] stated that multiple sources of energy are being coupled to offer a continuous power supply to the demand. Hybrid power systems integrate the utilisation of several distinct power sources. The energy management system method is employed to optimise the PV system, fuel cell system, and battery bank in this study. In an actual experimental setting, it is confirmed. They've integrated ON/OFF loads based on the greatest amount of energy available from various forms of energy. They have concluded that under various working conditions, such as changing solar insolation or insufficient solar insolation, the energy management system (EMS) algorithm optimises fuel cell and battery bank power. In an actual test scenario, all of these case studies are authenticated.

A theoretical and experimental research was used by the researchers in [24] to assess the design and usability of the Building Operating System User Interface (BOS UI). It initially assesses the BOS UI's design by determining whether it satisfies the stated requirements for a generic user interface for creating network services. The test proves of the BOS UI is carried out in the form of trials, with people being asked to complete pre-determined activities and fill out surveys on the GUI. They have found out over 90 percent of the trial consumers acknowledged that the BOS UI provided them with adequate details and information that they would need in their everyday life, and it can enable them on saving budget. They've provided a design for a generic user interface that can work with a variety of architectural software packages.

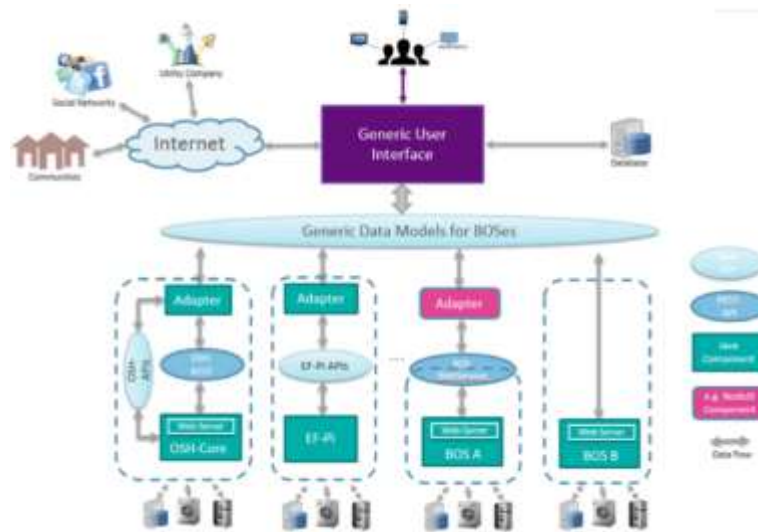


Fig. 6 shows the GUI in smart homes for the building operating systems in research [24].

The researchers in [25] thought that the global energy situation is influenced by a number of variables, including global climate change, worldwide geopolitical forces, and the rise in oil prices. They improved the prior off-line monitoring system and applied it to two distinct grid-connected PV stations using the URERMS ADRAR unit to fix current constraints and make the system more dependable. All of this includes new LabVIEW-based software that allows for real-time display of experimental measurements. They have concluded that the technology's real-time 2D and 3D relationships presenting of PV system data provides comprehension of the performance of PV network elements.

Moreover, to calculate the model coefficients for the Eastern Mediterranean Region of Turkey, polynomial and logarithmic models based on the AP approach were implemented by the researchers in [26]. The ANN model was used to estimate daily global solar radiation, and one of the study's key goals was to see if the ANN model could be used to build a non-linear relationship between solar radiation and other meteorological data.

The researchers in [27] have created a GUI-based system that can determine if a train absorbs sunshine as it travels across a course in Korea. For the Gyeongbu line, solar irradiation on the train was estimated to be around 2 kWh/m². They have found out an hourly comparison analysis shows that amount of solar radiation is 0 Wh/m² when the sun is behind the horizon, while it peaks at 1,998 Wh/m² in early June, validating the accuracy of the UV automated system proposed in research work. They concluded that, under ideal conditions, the total CO₂ reduction would be around 56 tonnes per year.

The researchers in [28] implemented a power management algorithm that permits managing energy flows within system components which is created to ensure efficient utilisation of generated energy and to meet freshwater needs. They have found out a graphical interface developed in MATLAB GUI is used to simulate the controlled desalination system and present the various curves defining the behaviour of the hybrid power system. They have

concluded that the development of a hybrid system with a smart power algorithm is made easier using this GUI.

The researchers in [29] have made a design to bring together various strategies, which are usually discussed individually in the research, in order to avoid the fundamental stumbling block. It is accomplished in such a way that comprehending their theoretical underpinnings, strengths, and limits in comparison to other approaches of estimating solar radiations becomes evident rather than challenging. They have stated that lengthy observed datasets are uncommon, with varying lengths of record and varying levels of accessibility. To determine the appropriateness of usage, these sorts of data must be carefully evaluated and compared to other sources of data, such as estimated or modelled data. This is critical for correct PV panel size and system performance analysis, as well as the financial sustainability of a project for solar applications, making dependable solar radiation modelling programmes much more difficult. They have created a technology platform with a Graphic User Interface (GUI) platform that makes computation, saving, and visualisations of the multiple elements of cosmic rays on a particular surface and for a given site, along with mandatory processes that contribute to the classification of the solar radiation field via relevant data coding.

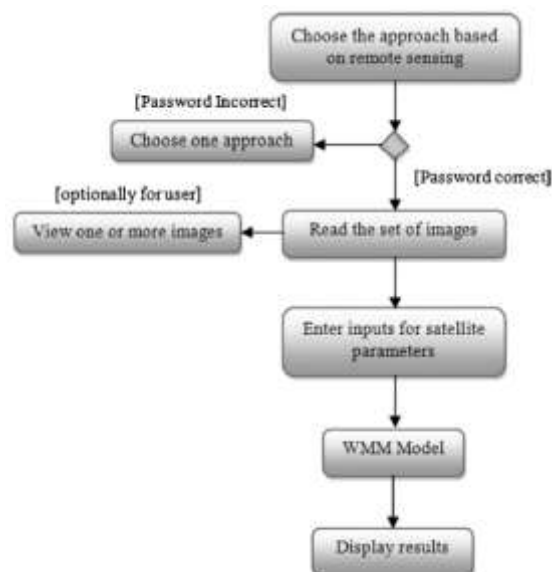


Fig. 7 shows the modelling approach for GUI prepared by the researchers in [29].

The researchers in [30] have stated that microgrids are a revolutionary idea in electricity distribution systems that are gradually becoming a realization all over the universe. They have found out that several concerns influence the fault current originally developed for the radial network as distributed generators (DGs) induce changes to fault current inside the microgrid. The power and fault current problems flow bi-directionally in both grid-connected and islanded mode of operation owing to selectivity problem/protection coordination the existence of DGs inside a microgrid. They have concluded that whereas if microgrid is built with inverter interfaced DGs, the damage may be worse since only a limited amount of fault current may be delivered during a breakdown. Analysis of the overcurrent protection



inadequacy during a disturbance would aid in the development of a novel design strategy for microgrid defence management.

2. CONCLUSIONS

Based on the review that has been made, the PV technology has already been used by recent researchers for energy consumption purposes. The large number of PV systems deployed each year demonstrates each country's sincerity and duty in the fight to rescue the planet by utilizing renewable energy. Same goes to GUI where it is used widely for its conveniences not only for experts but also for beginners in PV technology. For future research, the GUI could be collaborated with the PV technology such as sizing a stand-alone PV for PV fertigation. Because of the following electrical connection schema supplied in the GUI, the quality of a freestanding PV system will be improved, and the lifespan will be extended. Furthermore, by providing free electrical sizing software to PV system installers, the cost of installation will be reduced.

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