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Passivated Emitter and Rear Cell (PERC) Assessment and Potential in Palestine

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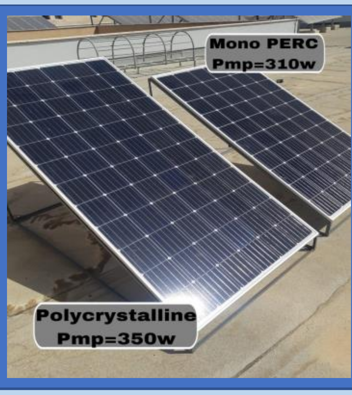
Abstract: Palestine has limited energy sources and must import different fuels from neighboring countries, hence renewable energy sources like solar energy are necessary. One of the most important and promising clean renewable energy sources available today that also helps cut expenses and effort is solar energy. Solar energy is captured and stored by solar panels. Solar panels come in a wide variety now, and new kinds are always being developed to maximize solar energy absorption, require the least amount of maintenance, and endure a longer time. This study will compare the performance of the polycrystalline solar cell unit and the PERC unit, both of which will be impacted by Palestine's environment, by conducting an experimental investigation into the behavior of the unit. The PERC panel's temperature was lower than the polycrystalline panel's because of the addition of a heat-reflecting layer, which increased the PERC panel's efficiency. The efficiencies of the two panels were compared at the same level of solar radiation. It has been demonstrated that PERC efficiency is higher when solar radiation is the same. The solar energy absorbed in the PERC panel actually increases because of the reflective coating that helps the PERC cell to optimize its benefit from the sun's radiation. When polycrystalline and PERC panels were compared, the former produced more electricity per unit of area.



Keywords: PERC, Polycrystalline, PV, Palestine, Solar energy.

Introduction

The world has witnessed a significant increase in energy consumption over the past fifty years. The energy sources have evolved and diversified over time, especially with the trend towards using renewable energy to preserve the environment and reduce climate change (1-3). While some countries are still highly dependent on fossil fuels, such as oil, coal, and natural gas, other countries are beginning to integrate alternative energy with other energy sources. The importance of energy in national development is nearly universally acknowledged (4). In general, there is a strong link between the level of development, economic growth, and energy use (4, 5).

Fossil fuels are critical for our global energy demands, accounting for more than 80% of primary energy usage (6). Because of their low mining and extraction costs and wide availability, the world has relied heavily on fossil fuels for energy. The consequences for the climate and natural systems were disastrous. The use of fossil fuels emits massive amounts of hazardous gases (e.g. CO_2, SO_2, HC, CO, NOx). The majority of fossil fuels have been demonstrated to impair the ecosystem, climate, and human health (6-8). The use of renewable energy has been increasingly popular around the world in recent years. In 2018, renewable energy's share of global power capacity increased to over 33%, and renewable energy technologies were demonstrated to be reliable, giving the most cost-effective power generation options in many instances (9). Solar photovoltaic (PV) modules are in high demand around the world. In 2016, a new record of 75 gigawatts (GWa) was added to the global installed capacity. This brought the total installed capacity to over 300 gigawatts (10). The astounding annual growth rate may continue in the foreseeable future, with projections ranging from 74 to 85 Gwa (11). Despite the tremendous growth in demand, PV producers are experiencing overcapacity once again, and the sector remains cost-sensitive. Most scientific and technological advancements will now be driven by lowering cost in terms of $/Wp (cost per unit peak output power) (12). In the year 2019, the global quantity of electrical energy produced by solar cells was 120 GW, while the amount of energy produced by solar water heaters for water heating was 1646 GW, with 56 percent of families utilizing solar heaters (7, 13). Since its inception, scientists have tried to improve solar photovoltaic technology in order to produce cells with improved efficiency and yield. As a result, the efficiency of these cells increased by around one degree every year until it achieved efficiencies of more than 20% for commercial solar cells and more than 40% for special-purpose solar cells (12, 14).

In Palestine, solar PV is being deployed for a wide range of applications, including residential and commercial rooftop installations, standalone off-grid systems for remote communities, and grid-connected systems for utility-scale power generation. Solar PV in Palestine is not only helping to address

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the energy challenges of the region, but also contributing to economic development, job creation, and environmental sustainability. The adoption of solar PV in Palestine is expected to continue growing as the technology becomes more affordable, accessible, and integrated into the energy mix of the region (9, 14).

There are several modules of solar panels are currently in use. These types have differed in their layer arrangement and their composition materials. One of these modules is the PERC cell which will be assessed in this study.

Martin Green, an Australian scientist, and his colleagues at the University of New South Wales introduced new innovative PERC (passivated emitter and rear cell) technology in the 1980s. This method uses a standard solar cell and adds an additional layer to the backside (15). The passivation layer is the additional layer. The passivation layer functions as a mirror, reflecting light that has already passed through the panel. This allows lighting a second chance to be absorbed by the solar cell, resulting in increased solar radiation absorption. The front side of the solar cell has been the sole focus of solar cell manufacturers for many years. Because of PERC technology, the backside of the solar cell may now actively participate (15, 16). Over 90% of solar cells produced worldwide are made from silicon wafers with a screen-printed full-area aluminum (Al) coating that contacts the whole back wafer surface and has been in use for more than two decades. Hence, the so-called aluminum back-surface field (Al-BSF), the aluminum back-surface area, which relates to the selective aluminum doping on the back surface of the wafer, considerably hinders the recombination of photo-generated charge carriers. Additionally, the full-area aluminum coating prevents some infrared radiation from passing through, which reduces the solar cell's efficiency in capturing light. Because of these two loss modes, the efficiency of current industrial silicon solar cells with full-area Al-BSF is capped at around 20%. In 1989, a cell concept known as the "passivated emitter and rear cell," which circumvents these limitations, was created on a small scale in the lab. (PERC). In order to decrease charge carrier recombination and increase internal rear reflectivity and infrared light absorption, the first lab-type PERC solar cell used a silicon dioxide layer on the rear silicon wafer surface (15-18).

Power conversion efficiency is essential for growing the photovoltaic (PV) sector (PCE). By the 2030s, improvements in PERC solar cell structural techniques could even elevate the technology to the top of the field. For the passivation layer in PERC solar cells, many passivating materials are used, including SiO2, Al2O3, and SiNx. These passivating materials enhance the PCE of PERC solar cells, reduce rear-side recombination losses, and reduce light reflectance while enhancing light trapping (18).

Table 1. summarizes the results of the scientific research that are related to PERC and AL-BSF (Polycrystalline) panels. In conclusion, PERC panels offer higher efficiency and better performance in low-light conditions, making them suitable for installations with limited space or shaded areas.

Particularly in the setting of Palestine, where solar energy has become widely used and research has advanced, applied research concentrating on solar energy panels and their related technologies is essential. Given Palestine's particular environment, it is imperative that these new technologies be investigated and assessed. This is significant because it is the first time that Passivated Emitter and Rear Cell (PERC) technology is being tested and evaluated in a real-world setting in Palestine. Relevant insights will be extracted from the results of an experimental test carried out on the top of the engineering building at An-Najah National University in Nablus. This research endeavor aims to contribute to the understanding of the performance and viability of PERC technology in the specific context of Palestine, providing valuable knowledge for further advancements in the field of solar energy research in the region.

Table (1): The scientific research findings on the comparison of PERC and AL-BSF (Polycrystalline) solar panels in the context of solar energy.

Aims and Conditions	Findings
The total inversion of hierarchical Al BSF and PERC cells with and without encapsulation was simulated	In comparison to the Al-BSF cell, PERC cells have a higher infrared reflectivity. 2018 (19).
An index termed 'module preferable rank (MPR)' is introduced to compare six different types of PV modules. Solar irradiation at a site located at Latitude 13.6214^{O}N and Longitude 79.2903^{O}E is measured physically by using a solar radiation sensor on the day just next to the vernal equinox.	Module preferable rank has been found to be relatively high for monocrystalline PV modules, followed by poly PV modules, and relatively low for amorphous silicon PV modules, in terms of efficiency, the area required per kWp capacity, a maximum possible capacity that can be erected within concerning site location, and possible electricity generation. 2021 (20).
In this work, the characteristics of the current-voltage curve) I-V) are linked to the fraction scales in cells in a group of 38 cells of the four-cell (AL-BSF) and (PERC) units that display a range of fractions and electrical properties.	The statistical relationship between the characteristics of cell cracking from the electroluminescence (EL) images and the parameters of the (I-V) curve was shown on 38 a sample from PERC and AL-BSF with a moderate to severe fraction. According to the investigation, both at the module and individual cell levels, the Al-BSF modules underperformed the PERC modules. PERC cell breaches have more dendritic tendencies than Al-BSF modules, but they still have poorer electrical isolation. Also, the EL characteristics show that Al-BSF module cracks were more likely to shunt than PERC module cracks. 2020 (21).
A series of tiny units were subjected to wet heat (85°C, 85 percent RH) for a total of 2,500 hours.	The PERC mini-modules lost 10.0 percent of their energy throughout the exposure, whereas the Al-BSF mini-modules lost 12.7 percent of their initial strength. 2019 (22).
The unit's heat sources are all recognized, and we combine one-dimensional research with 3D ray tracing analysis in the spectral region from 300 to 2500 nm. As well as a 4°C lower working temperature for the PERC unit at 1.4 suns, which is helpful under actual operating conditions but has an unnoticed impact under normal test settings.	Modules with PERC cells exhibit lower operating temperatures at MPP in a non-temperature-regulated environment, according to both experimental and simulation studies. The analysis showed that Burke's cells have a low ability to absorb parasites in infrared rays, and thus a decrease in cell temperature. 2017 (23).

The performance limitations at each contact are explored, as well as the challenges and prospects for passive photothermal control of PV modules based on sub-bandgap light rejection using idealized reflectors and scatterers placed at distinct interfaces within crystalline Si modules.	With a 100 percent subband gap reflection, it was discovered that sub-bandgap reflectance from the unit glass lowers the yearly weighted average operating temperature by 3.3 K for Al-BSF units and 2.9 K for PERC units. For Al-BSF modules, the sub-bandgap inversion at the cell interface can reduce the temperature by up to 2.2 K (1.8 K), and the increased back reflection of the cell can reduce the temperature by up to 1.2 K, the directional dispersion can reduce the temperature by up to 1.5 K. 2021(24).
A scientific experiment to regenerate solar cells due to the age-related deterioration of boron-oxygen	According to the study, PERC-type cells regenerate more quickly than full-area Al-BSF-type cells. It is discussed why PERC-type cells benefit from injection-level effects. It is shown that the presence of a second hydrogen-containing layer on the back has a positive impact as well, most likely as a result of increased hydrogenation of the silicon bulk. 2015 (25).
By using Suns-V OC's UV + heat exposure, external quantum efficiency, and microwave photolysis, the mechanical performance and characteristics of bare PERC and Al-BSF cells are gradually measured. Structure for Analysis	In this work, PERC cells demonstrated two primary routes of energy loss: one through a decline in minority carrier lifetime and posterior lateral diffusion/recombination, and one through bulk/emitter recombination and voltage loss. Nevertheless, PERC cells were superior to AL-BSF cells. 2018 (26).

Methodology

To investigate the uses of PERC cells in the Palestinian climates, a PERC cell, and a Polycrystalline (POLY) cell were installed on the roof of the engineering building at An-Najah National University in Nablus. The panels were installed at an angle of 29 degrees to obtain the maximum amount of solar energy radiation. Table 2 shows the technical specifications of the PERC and Polycrystalline (POLY) panels, and the two panels are shown in Figure 1.

A portable thermometer (42510A) is used to measure the temperature of panels. I-V400 curve tracer equipped with HT304N and SOLAR02 is used to measure the solar radiation and power output. Temperature, solar radiation, and power output were collected for both panels during September and October of 2022 between the hours of (9 AM - 2 PM). Table 3 lists the measurement tools used in this study and their specifications.

Table (2): Technical specifications of PERC and POLY panels

Panel	Model	V_{OC} (V)	I_{SC} (A)	P_{mp} (W)	η (%)
PERC	TP660M-310	40.10	9.69	310	18..9
POLY	SR 350-72M	47.24	9.56	350	18.03

The amount of light that solar panels convert into power is referred to as solar panel efficiency. With the same amount of light, the higher the efficiency, the more electrical power is produced from the panel. The efficiency for each panel was calculated using the following formula:

$$\eta = =\frac{Pout}{Pin} * 100\% \qquad (1)$$

Table (3): The measurement tools used in this study.

measurement tools	The specifications
Infrared thermometer (42510A: Wide Range Mini IR)	The temperature range of the (42510A) Portable thermometer is (-50 to 650°C) with an accuracy of (0.1 - 999.9) degrees. Infrared thermometers are temperature-sensing devices that use electromagnetic radiation to determine the temperature from a safe distance.
I-V400w Curve Tracer	The I-V400w is a multi-field detection instrument that detects the I-V curve and its key characteristic properties on a single module as well as strings of modules for PV systems up to 1000V and 15A. The device contains several accessories that aid in defining the various variables, including HT304N and SOLAR02.
HT304N	a reference cell for measuring solar irradiation
SOLAR02	A remote unit for measuring irradiation, temperature, and tilt angle

Figure (1): PERC and POLY solar panels.

Results and Discussion

A sample of collected data for temperature, solar radiation, and power output on the 2nd of October 2022 is shown in Table 4. Figure 2 shows the average daily temperature for both PERC and POLY panels on selected days. It can be noticed that the average temperature of the POLY panel is approximately three or more degrees higher than that of the PERC panel, except in the early morning they are approximately equal. Figure 3 shows the average monthly temperature for PERC and POLY solar panels. According to the data in Figure 3, the POLY panel's average monthly temperature is roughly three degrees higher than the PERC panel, and a rise in solar cell temperature results in a reduction in the amount of energy produced.

Table (4): Collected data for both PERC and POLY panels on the 2nd of October 2022.

HOUR	T_{PLOY} (C°)	T_{PERC} (C°)	I_{POLY} (W/M^2)	I_{PERC} (W/M^2)	P_{POLY} (W/M^2)	P_{PERC} (W/M^2)
9	34.1	33.1	390	360	68.5	72.7
10	41.1	39.9	587	605	106.7	114.2
11	57.7	56.6	751	792	130.4	141.1
12	51.1	50.2	826	882	140.7	154.0

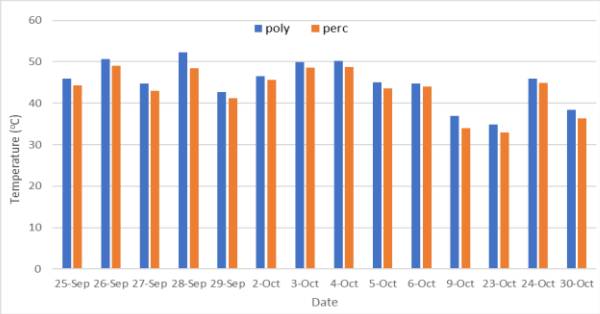

Figure (2): The average temperature of selected days for PERC and POLY solar panels.

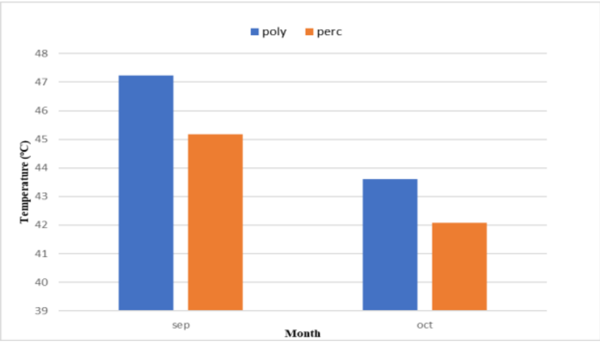

Figure (3): Average monthly temperature for PERC and POLY solar panels.

The ability of the solar cell to produce electrical power depends on the amount of solar radiation absorbed by the solar cell. The layers added in the PERC technology help the solar cell absorb the largest possible amount of incoming rays and reflect them internally. The solar radiation data were measured using the IV-400 solar panel device and the curve shows that the two values are close. It was however observed that the radiation in the PERC plate was higher, which can be attributed to the accuracy of measurement.

With the same parameters and the availability of panels with the same size and power, the power data were gathered using an IV-400 solar panel instrument. Figure 4 shows the computed power per unit area for both panels on the chosen day.

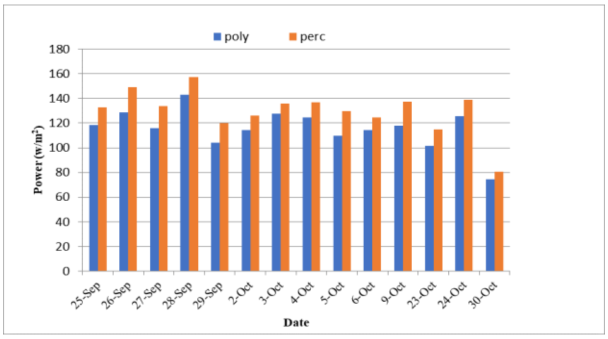

Figure (4): Average daily power for PERC and POLY solar panels on selected days.

Figure 4 shows that the daily average power per unit area of the PERC panel is higher than that of the POLY panel. The highest power value recorded was for the PERC panel with a value of 177 W/m^2, and the lowest energy value was for the PERC panel with a value of 51.93 W/m^2.

According to the data in Figure 5, the average power generated by the PERC panel is higher than the average power generated by the POLY panel.

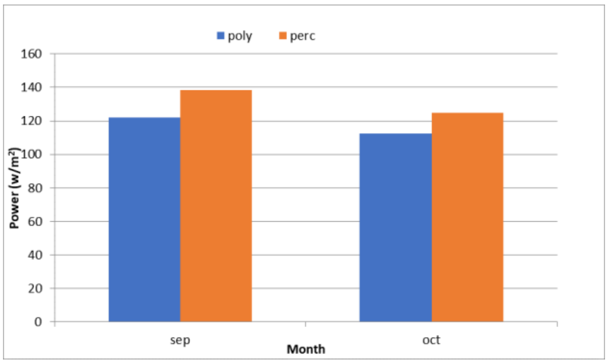

Figure (5): Average monthly Power for PERC and POLY solar panels.

Figure 6 displays the average efficiency for each panel for the months of September and October. It is evident that there is a 7% difference in the efficiency of the PERC and POLY panels. As a result, for every unit of area, the PERC panel may produce more electricity than the POLY panel. Given that a PERC panel generates more energy than a POLY panel under the experiment's conditions, this supports the recommendation to employ one instead of the other. The PERC panel's highest efficiency of 18.7% is lower than the efficiency stated in the literature (16–22). The precision of the experimental instruments and measurements might be the cause of the variation in the efficiency rating.

In general, the results show a slight increase in the efficiency of the PERC panel compared to the POLY panel. Whereas, it is expected to have a higher increase in efficiency, as stated in the literature (16, 17), which can be attributed to the effect of the clouds in the autumn period.

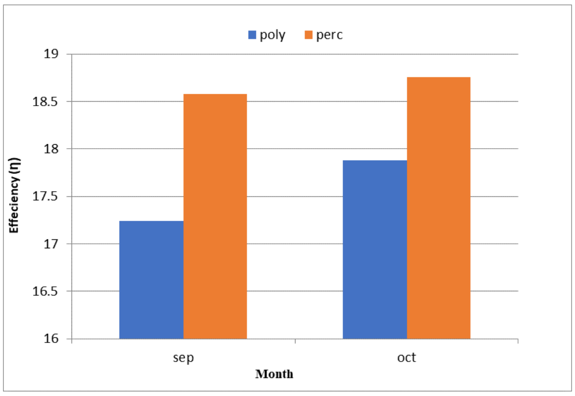

Figure (6): Average monthly efficiency for PERC panel and POLY panel

Conclusion

PERC (Passive Emitter and Rear Cell) is a new technology where additional layers are added to the back of the solar cell and these layers reflect the solar radiation passing through the cell to be used again. PERC technology has dominated the photovoltaic market during the past four years. The new technology has proven its high efficiency and reliability. It has also reached its theoretical limit of 24.5% cell efficiency due to its high ability to overcome challenges related to the high-temperature cell and surface electrons recombination.

This effort involved a comparative study between the POLY panel and the PERC panel for panels. Only in the early morning were the two plates' temperatures almost identical. The PERC surface was somewhat cooler than the other panel, demonstrating the superiority of PERC technology. The temperature difference between the two panels was three degrees or more.

Higher power was generated since the PERC technology outperformed POLLY at the same solar radiation levels. Because the PERC board has a layer that reflects solar radiation so that it may be used for other purposes, it actually absorbs more solar radiation than POLLY. It is thus advised to employ PERC panels in Palestine in order to boost electricity production and shorten the payback period.

It is expected that the results of this pilot study in Palestine (The Hot MENA Region) to encourage the use of this technology in the local market. However, one of the main limitations of this study is that it was conducted in the autumn period and the results are expected to change in the summer period.

This technology has dominated the photovoltaic market during the past four years.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The raw data required to reproduce these findings are available in the body and illustrations of this manuscript.

Author's contribution

The authors confirm their contribution to the paper as follows: study conception and design: Ramez Abdallah, theoretical calculations and modeling: Ramez Abdallah, Salameh Abdel-Fattah; data analysis and validation, Salameh Abdel-Fattah, Mahmoud Assad. draft manuscript preparation: Belal Bazari, and Abdallah Shawhnee. All authors reviewed the results and approved the final version of the manuscript.

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Conflicts of interest

The authors declare no conflict of interest.

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List of Abbreviations

PV: Photovoltaic

PERC: Passivated Emitter and Rear Cell

POLY: Polycrystalline

CO_2: Carbon dioxide

SO_2: Sulfur dioxide

HC: Hydrocarbons

CO: Carbon monoxide

NO_x: Nitrogen oxides

AL-BSF: Polycrystalline panels

EL: Electroluminescence

I_{SC}: Short circuit current

V_{OC}: Open circuit voltage

η: Photovoltaic efficiency

P_{out}: Output power

P_{in}: Input power

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