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INCREASING THE EFFICIENCY OF BIFACIAL HALF CELL SOLAR PANELS WITH REFLECTIVE BACKSIDE MATERIALS

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Abstract – It has been observed that the monocrystalline bifacial solar cell, which is now widely used, increases the power and efficiency of the designed module. Contrary to other known cell types, additional power can be obtained from the reflections obtained on the back surface and offers potentially better power outputs than standard modules. Bifacial cells are a more advanced cell type that uses absorption from albedo to increase solar gain. Bifacial cells can potentially absorb solar radiation on both surfaces of the cell to increase the amount of power and provide a higher power output than single-surface cells. In such cells, reflections from both the front and rear surfaces are captured by adding a rear electrode plate to the body. In order to use this feature of the cell efficiently, a correctly placed reflective surface design is required. In this work some different back plates are used to see the effect of reflections on the gain of bifacial solar panels.

Keywords – Albedo Reflection, Reflective Surface, Bifacial Solar Cell, Power Gain

I. INTRODUCTION

Bifacial solar cells have been a hot topic in the solar industry in recent years. With the development of technology, the need for energy is increasing day by day. Although there are ways to obtain energy, one of the most popular and clean energy sources is the sun. One of the various ways of obtaining energy from the sun is to absorb the light radiation from the sun by using various solar cells and convert them into electrical energy. Mono crystalline and polycrystalline cells are the most common of many solar cells that are widely used with today's cell technology 691]. There are various studies to increase the efficiency of these cells and to obtain more power [2]. Solar modules need more research and development due to the increase in retail sales and demand to solar panels. With the developing technological developments, bifacial cells have been manufactured and used with higher efficiency [3]. Bifacial cells are achieved by using a transparent conductive oxide (TCO) layer on the backside of the solar cell, which allows light to pass through and be absorbed by the cell. These bifacial cells gain more efficiency and power by absorbing the solar radiation falling on their surface [4]. One of the main benefits of bifacial solar cells is that they can generate more energy per unit area compared to monofacial cells. It is known that solar modules produced with monofacial cells do not gain any gain from the reflections (back plate) on the back cover of the module [5]. The improvement results obtained in these modules are known to gain between 1% and 3% [6]. Monofacial cells absorb only the reflections from the front, but bifacial cells provide efficiency from both sides. This is especially true in areas with high albedo, such as snow-covered ground, reflective rooftops, and water surfaces. Bifacial solar cells can also produce more energy in the early morning and late afternoon when the angle of the sun is low, which is when monofacial solar cells are less efficient [7]. Bifacial cell has an electrically active surface in both directions and therefore its gain in reflections is much higher [8]. However, there are some challenges associated with the use of bifacial solar cells. For example, shading can reduce their efficiency, and they require a special mounting system to ensure that both sides of the cell receive sunlight. In addition, bifacial solar cells can be more expensive than monofacial cells due to their additional layer and mounting system. Despite these challenges, the use of bifacial solar cells is on the rise. According to a report by the International Renewable Energy Agency (IRENA), bifacial solar panels are expected to account for up to 35% of the global solar market by 2030. As the cost of production decreases and technology continues to improve, bifacial solar cells are likely to become even more widespread in the future, contributing to the transition to clean and renewable energy sources.

II. Materials and Method

A. Monofacial vs. Bifacial Solar Module

Although there is not much difference visually in mono crystalline single-surface and double-surface systems, there is a great difference in efficiency. In single-surface systems, solar radiation is absorbed from a single surface, while in double-surface systems it is absorbed from both surfaces. It is possible to get much higher yields from bifacial cells with various improvements among them. Certainly, here are some key differences between monofacial and bifacial solar cells:

- Absorption of light: Monofacial solar cells absorb light from one side only, while bifacial solar cells absorb light from both the front and backsides. This makes bifacial cells more efficient in areas with high albedo [17], such as snow-covered ground, reflective rooftops, and water surfaces.
- Energy output: Bifacial solar cells can produce more energy per unit area compared to monofacial cells, especially in areas with high albedo. This is because they can absorb light from both sides, increasing their energy output.
- Efficiency: Bifacial solar cells can be more efficient than monofacial cells, especially in low light conditions. They can produce more energy in the early morning and late afternoon when the angle of the sun is low, which is when monofacial cells are less efficient.
- Cost: Bifacial solar cells can be more expensive than monofacial cells due to their additional layer and mounting system. However, as the cost of production decreases and technology continues to improve, this difference in cost is expected to become smaller.
- Shading: Bifacial solar cells are more sensitive to shading compared to monofacial cells. This is because they require both sides of the cell to receive sunlight in order to produce energy.

Overall, bifacial solar cells have the potential to be more efficient and generate more energy compared to monofacial cells. However, their higher cost and sensitivity to shading may limit their use in some applications.

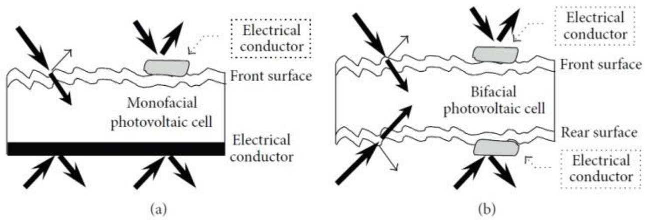

Fig. 1 Cross-section configurations of (a) monofacial and (b) bifacial solar cells [9]

Fig. 1 shows cross-section of monofacial and bifacial solar cells [9]. In Fig. 1(a), it can be seen that the radiation from the sun is reflected or absorbed by only one surface, while the other side is not used. For this reason single-face form can only be able to convert the radiation coming from the front surface into electrical energy. In Fig. 1(b), it can be seen that the radiation from the sun is reflected or absorbed by both surface so that backside is also can take sun radiations which will result converting the radiation coming from both surfaces into electrical energy. Bifacial gain can be calculated with equation (1).

$$Bifacility = \frac{Front\ Surface\ Effiency}{back\ Surface\ Effiency} \quad (1)$$

Equation (1) based on the assumption that the solar radiation is of the same density at both the posterior and anterior surfaces.

The efficiency of bifacial solar cells depends on several factors, including the quality of the cell's materials and the amount of sunlight it receives.

Bifacial solar cells can have an efficiency ranging from around 15% to over 25%, depending on the specific design and manufacturing process.

The yield of a bifacial solar cell depends on several factors, including the amount of sunlight it receives, the angle at which the sunlight strikes the cell, and the cell's operating temperature. In general, bifacial solar cells can generate more energy than monofacial cells, especially in areas with high albedo or in low light conditions. However, shading can significantly reduce the energy output of a bifacial cell, so careful design and installation is important to ensure maximum efficiency. Bifacial solar cells also require a special mounting system to ensure that both sides of the cell receive sunlight. This can increase the cost of installation, but it can also increase the yield of the cell by allowing it to capture more sunlight.

Overall, the efficiency and yield of a bifacial solar cell depend on a variety of factors, and careful design and installation is important to ensure that the cell is able to generate maximum energy output. As technology continues to improve and costs decrease, bifacial solar cells are likely to become an increasingly important part of the renewable energy landscape. In this experiment Tongwei solar cell used with 23.2% efficiency (Table 1). This bifacial solar cell called name 182-100BB where productivity change according to setup and test environments [15].

B. Tongwei 23,2% Solar Cell Features

Tongwei Solar is a Chinese solar cell manufacturer that produces both monofacial and bifacial solar cells. Their bifacial solar cells, known as "Tongwei bifacial solar cells," are designed to absorb sunlight from both the front and backsides, which allows for higher energy output compared to traditional monofacial cells. Tongwei bifacial solar cells use a special structure that incorporates a transparent conductive oxide layer on the backside of the cell, which allows for the absorption of additional sunlight. This design has been shown to increase the energy output of the cell by up to 30%, depending on the specific conditions and installation method. In addition to their high energy output, Tongwei bifacial solar cells are known for their durability and resistance to environmental factors such as high temperatures and humidity. They are also compatible with a variety of mounting systems, including both fixed and tracking systems, which allows for greater flexibility in installation. The characteristics of the Tongwei bifacial cell used in this study are given in (Table 1).

Table 1. Technical Data and Design

Technical data and design		
Dimensions	182mm * 182mm ± 0.5mm	TkVoltage : -0.36%/K
Thickness	175±17.5μm	TkCurrent : +0.07%/K
Front (-)	10*0.06 ±0.03mm bar (silver), 150 ±15 fingers Blue (dark blue) anti-reflective film (silicon nitride)	TkPower : -0.38%/K
Rear (+)	Rear electrode width (silver) 1.2 ±0.3 mm, 170 ±17 fingers	Rsh≥50Ω , Irev2≤1.0A

The Voc (Isc) values and test performances of the cell measured in Tongwei laboratories and test conditions at 1000W/m^2 are given in (Table 2). Solar cells are typically tested under standard test conditions (STC) in order to provide a common basis for comparing their performance. STC are defined as follows:

- Irradiance: The solar cell is tested under a constant light source with an intensity of 1000 W/m^2, which simulates the intensity of the sun at noon on a clear day.
- Temperature: The solar cell is tested at a temperature of 25°C (77°F).
- Air Mass: The solar cell is tested under standard air mass conditions of 1.5, which represents the average path length of sunlight through the Earth's atmosphere.

Under these conditions, the solar cell's performance is measured in terms of its maximum power output, voltage, and current. However, it is important to note that the actual performance of a solar cell can vary depending on the operating conditions, such as the amount of sunlight it receives, the temperature, and the load connected to the cell.

Table 2. Light Intensity Reliability

Light intensity reliability					
Density (W/m²)	1000	900	800	600	400
Voc	1,000	0.996	0.991	0.998	0.962
Isc	1,000	0.903	0.803	0.602	0.403

The use of a transparent back surface in a bifacial solar cell is an important feature that allows for increased absorption of sunlight and improved energy output. The back surface of a solar cell typically consists of a metal electrode layer, which reflects some of the sunlight and reduces the efficiency of the cell. In a bifacial solar cell with a transparent back surface, the metal electrode layer is replaced with a transparent conductive oxide (TCO) layer, which allows sunlight to pass through and be absorbed by the cell from both the front and backsides. This design increases the effective area of the cell that can absorb sunlight and generates more electricity.

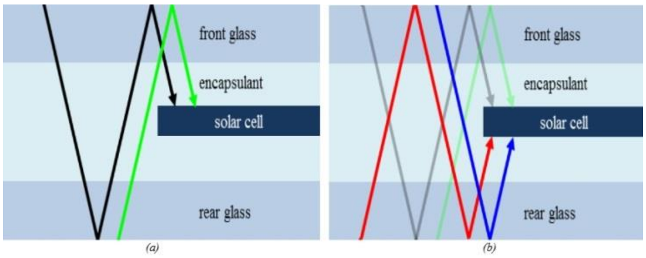

Fig. 2 (a) Reflection your earnings schematic drawing only faced cellular and transparent back with lid modules, (b) Reflection gains schematic drawing two surfaces cellular and transparent back with lid modules [10].

Fig. 2 (a and b) shows the direction of light reflection from the front surface and back surface of the designed module to the cell surface and the directions it takes in single-surface and double-surface modules. The solar radiation reflection in bifacial cells appears to be absorbed by both sides of the cells [11].

As mentioned before test light source has an intensity of 1000 W/m^2 which is often referred to as standard test conditions (STC) and provides a basis for comparing the performance of different solar cells. The intensity of the light source is an important parameter that affects the efficiency and output of a solar cell. As the intensity of the light increases, so does the amount of electrical power that can be generated by the cell. However, if the intensity of the light is too high, the cell may become overheated, which can reduce its efficiency and lifespan. In addition to the intensity of the light source, the spectral distribution of the light can also affect the performance of a solar cell. Different types of solar cells are optimized to absorb different parts of the solar spectrum, so the spectral distribution of the light source can affect the cell's efficiency and output [7].

Module yield earnings to those depends on:

The yield and earnings of a solar module depend on several factors, including:

- The efficiency of the solar cells: This refers to the amount of sunlight that is converted into electricity by the solar cells. The higher the efficiency, the more electricity the module can produce.
- The area of the solar module: The larger the area of the module, the more sunlight it can capture and convert into electricity.
- The temperature of the solar cells: Solar cells are less efficient at high temperatures, so the yield of a solar module will be lower in hot climates.
- The angle and orientation of the solar module: The angle and orientation of the solar module can affect the amount of sunlight it receives, which in turn affects its yield.
- The spectral distribution of the sunlight: Different types of solar cells are optimized to absorb different parts of the solar spectrum. The spectral distribution of the sunlight can affect the efficiency of the solar cells and therefore the yield of the module.
- The quality of the materials and manufacturing: The quality of the materials and manufacturing process used to make the solar module can affect its efficiency and lifespan, which in turn affects its yield.
- The shading and soiling of the solar module: Shading and soiling can reduce the amount of sunlight that reaches the solar cells, which reduces the yield of the module.

$$\text{ISCgain} = \text{a}.\exp\frac{d}{b} + c = \frac{Isc(0mm) - Isc(d)}{Isc(0mm)} \quad (2)$$

The solar ISC is the short-circuit current of a solar cell or solar module, which is the current that flows through the cell when the circuit is shorted or connected with no external load. In other words, it is the maximum current that a solar cell or module can produce when exposed to sunlight at a specific temperature and intensity. The short-circuit current is an important parameter that is used to calculate the maximum power output of a solar cell or module. The maximum power output occurs at a specific voltage known as the maximum power point, which is the voltage at which the product of the voltage and current is at its highest value. In Equation (2) is also valid for bifacial solar cells. short-circuit current for bifacial cells is higher at 0mm and other cell distances, as they experience transmission gains which alter their ISC gain. If transmission gains are estimated, it may be possible to correct the ISC (0mm). [12].

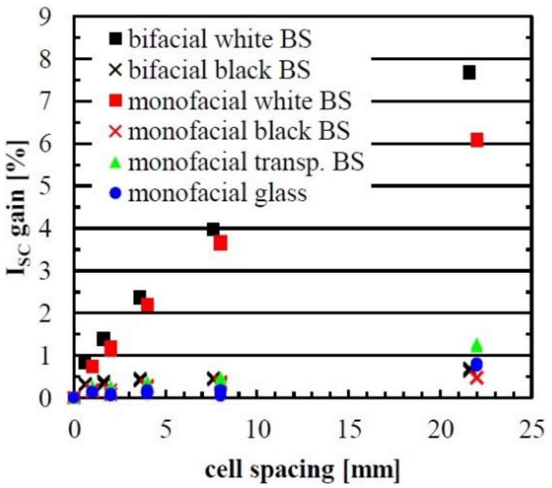

Fig. 3 Efficiency difference of single and double skin modules compared with different cell spacings and different back surface coatings [10]

The backsheet of a solar module is the outermost layer that serves as protection against environmental factors such as moisture, dust, and UV radiation. The backsheet can be made of different materials, including white or black polymer. The main difference between black and white backsheet solar modules is the color of the backsheet itself. Black backsheets are generally made of a black polymer material that absorbs more sunlight and heats up more quickly, which can increase the temperature of the solar panel and reduce its efficiency slightly. On the other hand, white backsheets are made of a reflective material that reflects more sunlight and stays cooler, which can help maintain the efficiency of the solar panel. Another point in module efficiency is the importance of the back surface material used and the distance between the cells. In similar studies [10], the distances between different materials and cells were changed and gain of black or clear backing materials is small compared to reflective coatings such as white backing. We can clearly see the difference in single and double surfaces back material here (Fig. 3). Both show the gains for increased coupling of reflective back caps for single bifacial cells. Measurements are made with only obverse radiation. We can clearly see the differences between bifacial cell gain is higher than monofacial cell gain. It has been concluded that the forces of the two surfaces of the modules can be increased by considering that they are reflected back by the covers [16].

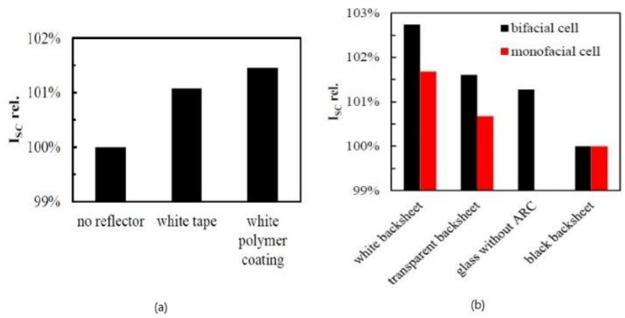

Fig. 4 (a) short-circuit current graph of bifacial solar cells in modules with 4mm pitches with different reflective surfaces, the reflective surface formed by the non-reflective surface, the reflection surface formed by the white band and the reflection surface formed by the white glossy back surface (b) short-circuit current gain of single surface and double surface solar cells with different back coatings ; Efficiency differences obtained with only front surface reflection using 2mm cell spacing distance[10]

Single surface back surface materials are not preferred due to power losses in the modules produced today. Transparent back surface materials are more suitable for the appropriate use of radiation and reflective elements coming from the cell spaces[13]. White bifacial modules – improved STC performance combined with bifacial energy yield research show us bifaciality is preserved and cover coupling gains can be observed. We can explain in Fig. 4 that the back surface materials used in bifacial equipment have more power with reflective surfaces. Modules produced with bifacial cells are partially transparent when exposed to wavelengths of 1000nm. Beam transmission creates a secondary light absorption due to the module back surface material and reflective panel. It leads to additional gains in the range of 0.5 – 0.8% for bifacial cells in modules with reflective back covers materials (Fig. 4b).

III. Results

In order to determine the effect of the reflection surface on the efficiency of solar panel, firstly, measurements were made using a black colored light absorbing reflection surface that would prevent light reflection. Then concrete, mat white paint surface, white glossy plastic plate, and aluminum foil plate were applied as backside reflective material. Experimental setup physical structure, mathematical background and test results are given below.

A. Mathematical Background

By reflecting light that would otherwise be lost back onto the rear cells, the reflective plate can increase the amount of electricity generated by the module. Rear reflective plates are used in some solar modules to enhance their bifaciality, or the ability to generate electricity from both sides of the panel. The rear reflective plate is made of a highly reflective material, such as in this experiment aluminum or white backsheet, and it is placed behind the rear cells of the module to reflect light back onto them in (Fig. 5a&b)

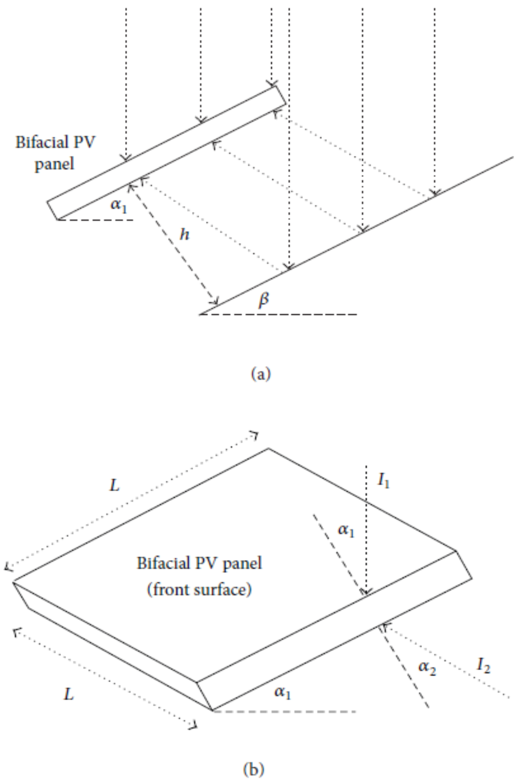

Fig. 5 (a) Double-surface panel integrated with exterior mirror reflector. (b) Schematic diagram of the solar radiation incident to the front and the surfaces of the *L* bifacial solar panel

The efficiency of solar panels depends on the amount of light received by the front and back surfaces and the efficiency of the surfaces, as stated in the formula (1).

$$\text{Bifacility} = \frac{Back\ Surface\ Efficiency}{Front\ Surface\ Efficiency} = \frac{E_{back}}{E_{front}} \quad (3)$$

The reflection of the light on the front surface can be formulated with equation (4) which is depicted in Fig. 5a.

$$\eta_{\text{PV}_{\text{on}}} = \frac{E_{front}}{L_1(Cos\alpha_1)} \quad (4)$$

The reflection of the light on the front surface can be formulated with equation (5) which is depicted in (Fig. 5b)

$$\eta_{\text{PV}_{\text{back}}} = \frac{E_{back}}{L_1(Cos\alpha_2)} \quad (5)$$

In Equation (2) on its two surfaces.

$$\text{K}_{\text{bif}} = \frac{\eta_{\text{PV}_{\text{back}}}}{\eta_{\text{PV}_{\text{front}}}} \quad (6)$$

Table 3. Bifacial factor measurements as a function of slope angle

Panel slope (degree)	0	10	20	30
K_{bif}	1.00	1.00	0.98	0.96

The reflective performance of the reflector is dimensionless. The parameter is the ratio of the intensity of the reflected radiation and reaching the reflector surface of radiation density on:

$$\eta_{\text{reflector}} = \frac{I_2}{I_1} \quad (7)$$

By eveluating the equations (4), (5), (6) in (7), the panel bifacial can be:

$$\text{panel\_bifaciality} = \text{K}_{\text{bif}}\, \eta_{\text{reflector}} \frac{Cos\alpha_2}{Cos\alpha_1} \quad (8)$$

Bifacial factor measurements as a function of slope angle K_{bif} changing with different angle value also defined in Table 3.

Fig. 6 shows a simple schematic of a bifacial PV panel integrated with a different external reflector. Fig. 6a shows a single point radiation with only surface reflection. Fig. 6c shows a diffuse type reflection of the diffuse beam radiation reflected from the reflector surface on the back surface of the cell in a bifacial panel (Fig. 6c). The semi-mirror type reflector shown in Fig. 6b reflects some of the solar radiation to the back surface, like a mirror-type reflector, while some of the solar radiation is scattered [14]. As seen in the figures, we can see more clearly that it is reflected at different angles on different surfaces and what kind of path this reflection follows.

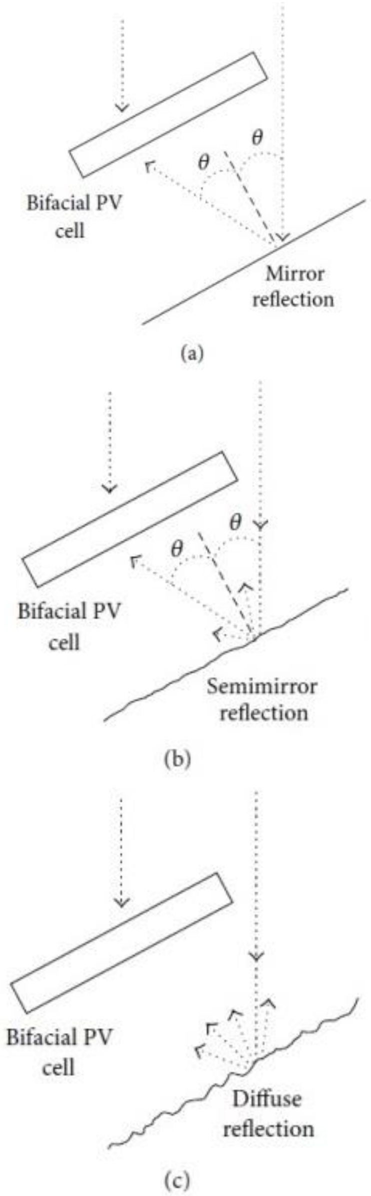

Fig. 6(a) Double-surface panel integrated with exterior mirror reflector, (b) Schematic diagram of the solar radiation incident to the front and the surfaces of the *L* bifacial solar panel [9].

B. Experimental Setup

Bifacial modules are designed for optimum performance with minimum space and are available in modules produced in different powers. These may vary depending on the application and the cell efficiency used. An HT 550W bifacial module dimentions 2285mm×1133mm×35mm. For bifacial module, module using reflective surface on bottom surfaces efficiency can be increased. More power can be obtained in less surface area than monofacial modules.

The following measurements were used during this study, along with the analysis of each trial:

- Direct radiation
- Diffuse radiation
- Aperture plane total radiation
- IV test power outputs during trial times recorded every minute

The used products:

- 3 x HT72-18X Transparent 550 W bifacial solar modules
- Huawei 3 kW Inverter Sun2000L 3KTL – Single Phase
- MC4 Solar Connector IP67
- Dw Angle Protractor Miter Angle Meter Ruler 120X150 mm
- GSOLAR IV TEST MACHINE
- REFLECTIVE MATERIALS
- In six trials, purposefully varying reflective materials and geometries were used under four different arrays.

Physical construction of the backside materials are depicted in Fig. 7 and backside materials Albedo coefficients are given in Table 4.

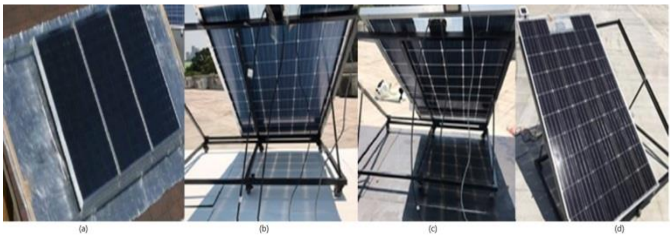

Fig. 7(a) Aluminum foil back plate reflection surface (b) White glossy plastic back plate (c) Mat white painted back plate (d) Concrete back plate

Table 4. Reflection Material Test Albedo Coefficient

Test No.	Reflective Surface	Albedo Coefficient
TEST1	Aluminum foil back plate reflection surface Fig. a	0.85
TEST2	White glossy plastic back plate Fig. 7b	0.80
TEST3	Mat White painted back plate Fig. 7c	0.3-0.6
TEST4	Concrete back plate Fig.7d	0.2-0.3
TEST5	Any without a material(Black Colored Light Absorbing)	0.1

On test 1-4, in situ minimum errors between output power and predicted power output is 1.44%, 1.42%, 0.65% and 0.27% respectively. Maximum errors 2.76%, 2.25%, 2.15%, and 2.8% in the modeling proposed in this study, the TEST BED experimental mistake rate, about 5% determined. Standard measured IV module is depicted in Fig. 8.

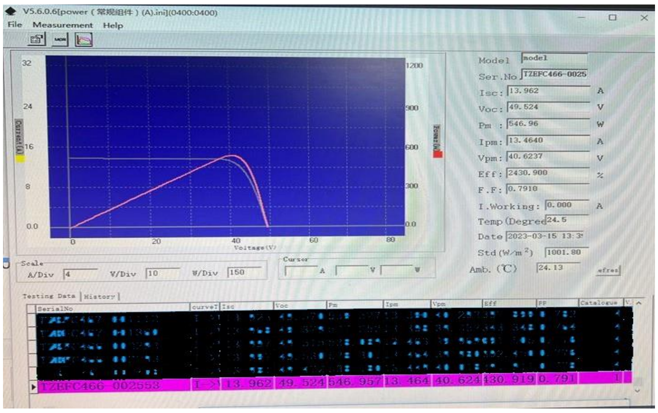

Fig. 8. IV Test Measurement

C. Experiment Result

This section describes the average power differences between the different types of reflector in each of the five trials. We can formulate that power difference as:

$$Avarage\ Power\ Difference = \left(\frac{\left(\sum_{i-1}^{n}\frac{Y_i - X_i}{X_i}\right)}{n}\right).100 \quad (8)$$

In Equation 8, X is power output of normal module in Watt/minute, and Y is power output of double layer in Watt/ minute. Measurement result for reflective surfaces are given in below tables.

Any without a material (Black Colored Light Absorbing)

To determine the reflective material effect firstly, as a reference point, a black colored light absorbing surface is used. The results are given in Table . There was no change in the measurements of the module with black light absorbing material on the bottom without any material, and the measurement reliability was in line with the theoretical data, and no increase or potential difference was observed in the 0.021% gain measurements.

Concrete back plate

Generally in sun farms the solar panels are constructed on concrete. Concrete reflective surface results are given in (

Table). We can observe a slight increase in strength on the concrete surface. We see that the reflections here create a slight but noticeable change in power values by the bifacial cells. We can understand that this value is higher because it has an effect of 0.2, which is the albedo coefficient. As it is understood from the measurements and analyzes that there is a power difference of 1.57% With this difference was measured module power as 562.548Wp.

Table 5. Any without a material (Black Colored Light Absorbing)

Any without a material(Black Colored Light Absorbing)										
Solar No: TZE FB	**Cell Eta**	**Cell Power**	**Theory Power**	**Voc (V)**	**ISc (A)**	**Vm (V)**	**Im (A)**	**FF**	**PMax**	**% Gain**
458-006233	23,2	7,69	553,680	49,697	13,921	39,942	13,865	0,800	553,798	0,021
458-005183	23,2	7,69	553,680	49,448	13,960	39,871	13,889	0,802	553,781	0,018
458-006305	23,2	7,69	553,680	49,658	13,998	39,706	13,947	0,797	553,779	0,018
458-008662	23,2	7,69	553,680	49,716	13,666	40,310	13,738	0,815	553,779	0,018
458-008452	23,2	7,69	553,680	49,848	13,959	40,124	13,801	0,796	553,757	0,014
458-008333	23,2	7,69	553,680	50,023	13,961	40,084	13,815	0,793	553,752	0,013
458-005158	23,2	7,69	553,680	49,706	13,972	39,933	13,867	0,797	553,742	0,011
458-007474	23,2	7,69	553,680	49,702	13,974	39,945	13,863	0,797	553,741	0,011
458-007630	23,2	7,69	553,680	49,799	14,001	39,850	13,895	0,794	553,717	0,007
458-008667	23,2	7,69	553,680	49,797	13,693	40,412	13,701	0,812	553,683	0,001

Table 6. Concrete Back Plate

Concrete Back Plate										
Solar No: TZEFB	**Cell Eta**	**Cell Power**	**Theory Power**	**Voc(V)**	**ISc(A)**	**Vm(V)**	**Im(A)**	**FF**	**PMax**	**% Gain**
458-006309	23,2	7,69	553,680	49,581	13,977	39,923	14,091	0,812	562,548	1,576
458-004107	23,1	6,25	553,680	49,672	14,002	40,193	13,996	0,809	562,541	1,575
458-005118	23,2	7,69	553,680	49,609	13,953	40,332	13,948	0,813	562,538	1,575
458-006281	23,2	7,69	553,680	49,813	13,965	40,151	14,010	0,809	562,536	1,574
458-008372	23,2	7,69	553,680	49,449	13,977	40,208	13,991	0,814	562,533	1,574
458-006530	23,2	7,69	553,680	49,862	13,975	40,220	13,986	0,807	562,532	1,574
458-006694	23,2	7,69	553,680	49,709	13,978	40,287	13,963	0,810	562,526	1,573
458-008942	23,2	7,69	553,680	49,889	13,688	40,944	13,739	0,824	562,526	1,573
458-007005	23,2	7,69	553,680	49,629	13,973	40,156	14,009	0,811	562,522	1,572

Mat White painted Surface

The first reflective surface is white painted surface. It is known that white color reflects the sun lights. Results of mat white reflective surface are given in (

Table). It can be seen that on the white painted surface, a reflection surface given by the paint is obtained according to the previous experiments and this is a visible increase in the power values. It is seen that this power increase comes from a higher albedo reflection coefficient value. Despite the reflection surface given by the white painted reflection surface module white paint, a power increase of up to 3.0% was observed with the reflection coefficient reflected by the albedo light radiation that it absorbs. This power increase is clearly seen in the voltage and current measurement graphs. As it is understood from the measurements and analyzes made with different modules and non-variable materials, with this difference was measured module power as 570.75 Wp.

Table 7. Mat white Painted Back Plate

Mat White Painted Back Plate										
Solar No: TZEFB	**Cell Eta**	**Cell Power**	**Theory Power**	**Voc(V)**	**ISc(A)**	**Vm(V)**	**Im(A)**	**FF**	**PMax**	**% Gain**
458-008381	23,2	7,69	553,68	50,276	13,959	41,112	13,883	0,813	570,756	2,990
458-006703	23,2	7,69	553,68	49,782	13,990	40,642	14,044	0,820	570,751	2,990
458-006175	23,2	7,69	553,68	49,668	13,983	40,617	14,051	0,822	570,729	2,990
458-006963	23,2	7,69	553,68	49,785	14,009	40,416	14,121	0,818	570,716	2,990
458-008061	23,2	7,69	553,68	49,875	13,999	41,021	13,913	0,817	570,714	2,980
458-008244	23,2	7,69	553,68	50,001	13,987	41,117	13,880	0,816	570,703	2,980
458-008075	23,2	7,69	553,68	49,965	13,977	40,855	13,969	0,817	570,701	2,980
458-005587	23,2	7,69	553,68	49,669	13,930	40,860	13,967	0,825	570,696	2,980
458-008465	23,2	7,69	553,68	50,029	13,962	41,010	13,916	0,817	570,685	2,980

White Glossy Plastic Plate

Table 84) as can be seen from the measurement tables, the back plate that we use as glossy plastic has sent more photons to the back surface of the nodule, thanks to both its brightness and the reflection surface of the plastic. Here, we see how important the degree of reflection is and the more

The second reflective surface is white glossy plastic plate. Results are given in (
the reflection is reflected from a bright surface, the better efficiency it gets. Thanks to the reflection of the glossy surface, 3.98% a power increase of up to. As can be understood from the measurements and analyzes with this difference was measured module power as 576.65 Wp.

Table 84. White Glossy Plastic Back Plate

White Glossy Plastic Back Plate										
Solar No: TZEFB	**Cell Eta**	**Cell Power**	**Theory Power**	**Voc(V)**	**ISc(A)**	**Vm(V)**	**Im(A)**	**FF**	**PMax**	**% Gain**
458-008381	23,2	7,69	553,680	50,023	13,991	40,698	14,169	0,824	576,653	3,984
458-006703	23,2	7,69	553,680	49,948	13,985	40,975	14,072	0,825	576,605	3,976
458-006175	23,2	7,69	553,680	50,090	13,985	40,966	14,075	0,823	576,594	3,974
458-006963	23,2	7,69	553,680	49,823	13,997	40,691	14,166	0,827	576,416	3,944
458-008061	23,2	7,69	553,680	50,044	13,960	41,062	14,036	0,825	576,335	3,931
458-008244	23,2	7,69	553,680	49,835	13,999	40,643	14,178	0,826	576,229	3,913
458-008075	23,2	7,69	553,680	49,935	13,976	40,877	14,093	0,825	576,080	3,888
458-005587	23,2	7,69	553,680	49,790	13,987	40,922	14,077	0,827	576,076	3,888
458-008465	23,2	7,69	553,680	49,898	14,009	40,851	14,099	0,824	575,973	3,870
458-005869	23,2	7,69	553,680	49,917	13,969	41,045	14,032	0,826	575,951	3,867

Aluminum Foil

Table). In the measurements made, it is seen that the best result is obtained from the back surface covered with aluminum foil. Although the material used has a high albedo number, it is seen that it scatters the light radiation in the best way and diffusely and suffers very small losses. Although there are measurement differences exceeding 5% in

The third reflective surface is aluminum foil. Results are given in (
the measurements made, serious increases were observed in voltage and amperage values. In formulas and experiments, we see that the diffuse reflection is better absorbed by the bifacial cells and is beneficial in increasing power. As it is understood from the measurements and analyzes made with this difference was measured module power as 582.87.

Table 9. Aluminum Foil Back Plate Reflection Surface

Aluminum Foil Back Plate Reflection Surface										
Solar No: TZEFB	**Cell Eta**	**Cell Power**	**Theory Power**	**Voc(V)**	**ISc(A)**	**Vm(V)**	**Im(A)**	**FF**	**PMax**	**%Gain**
458-006326	23,2	7,69	553,68	50,158	13,991	41,372	14,089	0,833	582,870	5,008
458-007206	23,2	7,69	553,68	49,919	14,019	41,064	14,171	0,832	581,912	4,852
458-007375	23,2	7,69	553,68	50,063	13,983	41,046	14,176	0,831	581,888	4,848
458-007439	23,2	7,69	553,68	50,291	13,998	41,133	14,126	0,825	581,029	4,707
458-007809	23,2	7,69	553,68	50,080	14,001	40,984	14,176	0,829	580,984	4,700
458-007515	23,2	7,69	553,68	49,832	13,985	40,900	14,197	0,833	580,641	4,643
458-007513	23,2	7,69	553,68	49,981	13,986	41,131	14,108	0,830	580,270	4,582
458-007652	23,2	7,69	553,68	50,089	14,012	41,106	14,114	0,827	580,180	4,568
458-007509	23,2	7,69	553,68	50,281	13,982	41,095	14,114	0,825	580,018	4,541
458-007641	23,2	7,69	553,68	50,121	14,007	41,208	14,073	0,826	579,926	4,526

IV. DISCUSSION

The experimental results can be summarized as the reflectiveness increase the efficiency increase. Detailed evaluations are given into the below sections.

A. Black Colored Light Absorbing Material

This is the reference data for reflective material effect when used at the backside of solar panel. The results are given in (Table). Here, we can see that there is no change in the module power, therefore, as indicated by the ratio of 0.1 in the albedo coefficient (Table 4), we can see that it only receives radiation with the light ratio made from the front surface, and no efficiency can be obtained from the bifacial surface. That there is no difference with the theoretical calculations in the measurements and the back surface efficiency is not reflected in the measurements.

B. Concrete

Have concrete slabs on the sub-surface or concrete level with the leveled floor. In the measurements, we observe that it has an albedo reflection in the concrete (

Table) and a remarkable increase in efficiency in the double-faced cells. 1.57% in modules with concrete back surface It was observed that there was a power difference based on the as it is understood from the measurements and analyzes, the standard measurement 553.68 incoming module was measured as 562,548Wp.

C. Mat White painted Surface

Despite the reflection surface given by the white painted reflection surface module white paint, (

Table) a power increase of up to 3.0% was observed with the reflection coefficient reflected by the albedo light radiation that it absorbs. This power increase is clearly seen in the voltage and current measurement graphs. As it is understood from the measurements and analyzes made with different modules and non-variable materials, the standard measurement was 553.68 incoming module 570.75 Wp.

D. White Glossy Plastic Plate

As can be seen from the measurement tables, the back plate that we use as glossy plastic (

Table 84)has sent more photons to the back surface of the module, thanks to both its brightness and the reflection surface of the plastic. Here, we see how important the degree of reflection is and the more the reflection is reflected from a bright surface, the better efficiency it gets. Thanks to the reflection of the glossy surface, 3.98% a power increase of up to. As can be understood from the measurements and analyzes, the standard measurement 553.68 incoming module was measured as 576.65 Wp.

E. Aluminum Foil

In the measurements made, it is seen that the best result is obtained from the back surface covered with aluminum foil. Although the material used has a high albedo number (Table 4), it is seen that it scatters light radiation in the best way and diffusely, and it suffers very small losses. Although there are measurement differences exceeding 5% in the measurements made, serious increases in voltage and amperage values have been observed. As understood from the measurements and analyzes, the standard measurement was 553, 68 and the incoming module was 582, 87.

V. CONCLUSION

Bifacial solar cells are designed to capture sunlight from both the front and back surfaces of the cell, which can significantly increase their energy output compared to traditional solar cells. Back surface reflection is a technique used to further improve the efficiency of bifacial cells by reflecting some of the light that passes through the cell back onto the back surface, where it can be captured and converted into electricity. Power efficiency of bifacial solar modules can be increased using reflective materials at the backside. In this study mat white paint surface, white glossy plastic plate, concrete and aluminum plate are tested for backside reflective material and a power efficiency increase of 3%, 3.98%, 1.57% and 5% were observed respectively. It is seen that increment of the reflectiveness property of backside material will increase the power efficiency and up to 5% efficiency can be achieved by aluminum material. As a result, we see that bifacial cells convert incoming photons into electrical energy by using different rear reflection plates and there is a visible increase in power values. As it can be understood from the test results, the reflection on the diffuse and shiny surfaces gave better results than the other experiments. According to the theoretical calculations, an increase of up to 6% has been achieved in the efficiency and power values, which will make a difference with additional reflection on the power values of the bifacial cells.

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