

# Comparative Study of the Performance Improvement of Four PV Technologies Controlled by a Solar Tracker - Case of Agadir city in Morocco

Bouachrine Brahim<sup>1</sup>, Bouhouch Lahoussine<sup>2</sup>, Ihlal Ahmed<sup>3</sup>

<sup>1,2,3</sup>Faculty of Science, IbnZohr University, Agadir-Morocco

---

## ABSTRACT

This work is devoted to the synthesis results of the Ppv power measurement obtained by four photovoltaic panels (PV) technologies with and without a solar tracker. Following this comparative study, under different weather conditions of Agadir city, we came to the performances evaluation of PV technologies under study, namely; monocrystalline Silicon, polycrystalline Silicon, amorphous Silicon and CIS (Copper-Indium-Selenium).

**Keywords:** Solar cells; Solar irradiation; Tracker; mono-Si, poly-Si and amorphous; CIS.

---

## INTRODUCTION

Renewable energies are the energy sources graciously offered by nature and available in abundance. They are associated with the forces of nature, and therefore considered as inexhaustible as the energy from the sun. These energies occupy an increasingly important role in the global energy mix. It is important to remember that energy demand increases with a rate proportional to the population and economic growth of a country. According to statistics, the total energy consumption in the world is projected to increase by 44% during the period from 2006 to 2030 [1]. Solar energy is not exploited only by its rays as a heat source to produce electricity, but also by using electromagnetic radiation to generate electricity through photovoltaics (PV). In this sense, the PV solar module industry has grown rapidly in recent decades. Currently, several technologies are developed for the realization of PV cells, generally classified into two groups: those using silicon crystalline form (Si-Si Mono and Poly) and those based on thin layers such as amorphous silicon (Si amorphous) and Copper Indium di Selenium (CIS) [2]. The performance and life duration are very different from one technology to another as well as the conversion efficiency, while being dependent from one region to another [3, 4, 5].

As regards, Dependence on performance of weather according to scientific literature, the results show the significant effect of temperature on the efficiency of the photovoltaic cell. Indeed, as the temperature decreases augment the performance of a percentage 0.5% [6, 7]. However the most important performance is that of the Si-Mono technology with a value of 18%, in favorable weather conditions radiation and temperature [8]. In addition, the study of the effect of the accumulation of dust on the surface of PV modules, has been made by some authors [9, 10]. It follows, according to this comparative study on the performance of several types of PV technologies, thin films that require frequent cleaning in an independent season.

In this context, the work we have carried out has allowed us to present a comparative study of four different technologies and to be able to choose the most appropriate technology for the Agadir region. In fact the city of Agadir, is located in southwest of Morocco, lies under a sunny climate almost all year. To carry out this study, series of estimated measurement were made in order to have a distribution of solar radiation on the city. Our paper is organized as it follows: after an introduction, Section 2 provides a description of the environment and the test of used bench. In Section 3 we present the various results while analyzing the performance of different PV technologies used; namely the Si-Mono, Poly-Si, Si-Amorphous and CIS. In fact, in this section we present the comparative study of reduced electric power produced by the PV panels with or without solar tracker. Finally, a conclusion concluded the work presented in this paper.

## DESCRIPTION OF THE ENVIRONMENT AND TEST BENCH

The evaluation of the potential solar of the Agadir city is performed using a meteorological station composed of different sensors for evaluating the following variables: the global radiation  $G_g$  and diffuse  $G_d$ , ambient temperature  $T_a$  and temperature of the PV panels, relative humidity  $H_r$  and speed of the wind  $V$ , and its direction  $D_v$ .

The temperature values ( $T_{avr}$ ) indicated in the graphs of the results below, we have obtained it by averaging the measurement taken above ( $T_u$ ) and that, taken in the middle ( $T_m$ ) of PV panel, trying eliminating drafts in temperature sensors entourage. The system set up to conduct the surveys of the characteristics of PV panels, as shown in Figure 1, it consists of: a variable resistive load, multimeter Agilent type high of precision, temperature sensors and solar radiation and a computer for control and archiving measurements. With this system a series of steps is performed for PV panels of different technologies, with or without two-axis tracker driven program. Performance evaluation of the PV panels in four different technologies that are available in the market, have the parameters summarized in Table 1 below.

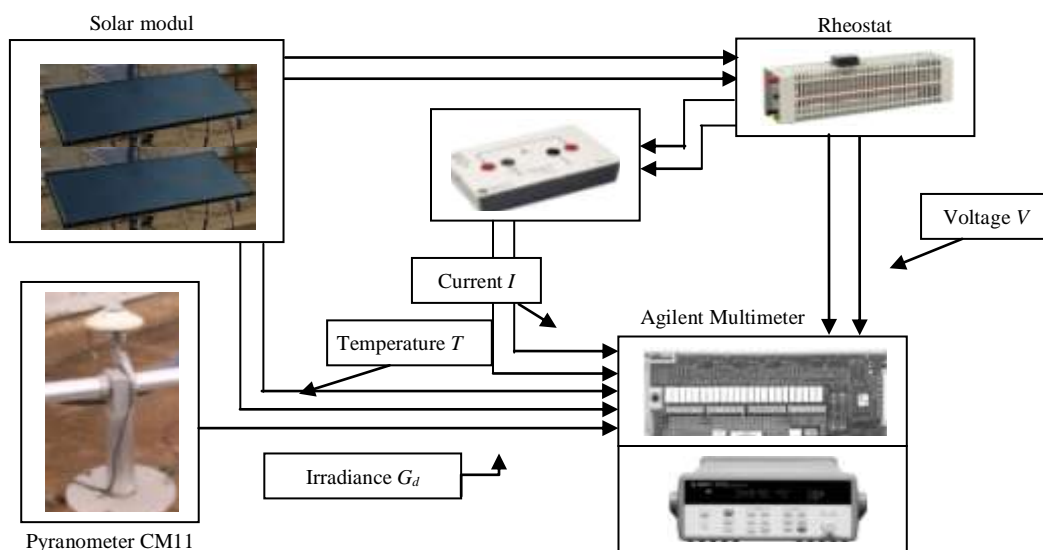


Figure 1: Setup measurement

Table 1: Various PV technologies under testing laboratory

Technology	Reference PV module	Number of solar cells	$P_{max}$ at STC (W)	Dimensions (mm)		
				Length (mm)	Width (mm)	thickness (mm)
Mono-Si [11]	ET-M53630	36	30	633	427	34
Poly-Si [12]	MSX64	36	64	1108	502	50
Poly-Si [13]	KC-40	12	40	652	526	54
Amorphous-Si [14]	FEE-14-12	Film	14	930	317	12.5
CIS [15, 16]	WSG0036E070	Film	70	1205	605	35

The first readings of measures we have performed covers direct connection "Charge-panel PV" for each technology. These measures concern the  $I_{pv}$  current from the PV panel and the  $V_{pv}$  voltage presented between its terminals. These records were then allowed us to characterize each technology in a  $G_d$  irradiation and for a specific  $T_{moy}$  temperature. The different measurement points obtained via an acquisition card are stored for possible post-treatment, but also they are used for  $I_{pv}$ - $V_{pv}$  graph plotting as a basis to evaluate the performance of the four technologies under test. We deduce from these measures, the reduced power  $P_r$  on the various technologies of the PV modules. This reduced power  $P_r$  is calculated in accordance with irradiation and the average temperature of the module according to equation (1):

$$P_r = \frac{P_{mes}}{P_{max}} \quad (1)$$

With  $P_{mes}$  representing the measured power and  $P_{max}$  is the peak power delivered by a PV panel. The latter is provided by the manufacturer of PV module in standard conditions (STC).

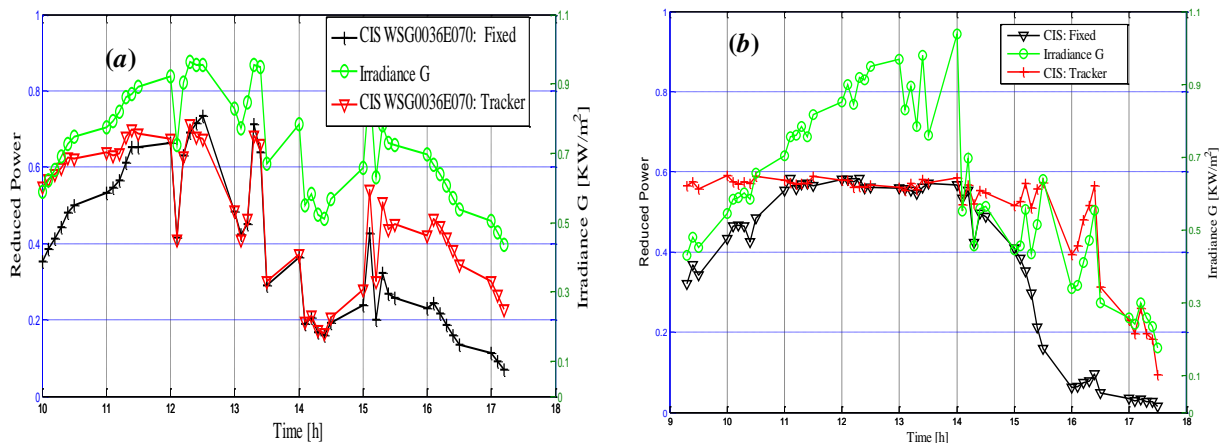
## PERFORMANCE OF THE TRACKER SOLAR AND PV TECHNOLOGIES

### A. Comparison of reduced output power from PV modules with and without tracker

#### 1) The case of PV modules types CIS

The 2-a and b are two different days (23-8-2014 and 01-4-2014), the daily comparison of the reduced powers  $P_{Fixed}$  and  $P_{Mobile}$  issued by two PV panels CIS same type of technology; one fixed and inclined at an angle of  $45^\circ$  toward the south

to the same height as other placed on a mobile support. Both PV panels are installed one next to the other so that their active surface receives nearly the same amount of light, while lying in an almost identical thermal environment. On these figures, we also defer changes in illumination  $G_d$  during the aforementioned two measuring days. From these graphs, we see that reduced powers and  $P_{Mobile}$  prefix issued by the two PV panels at the beginning and end of the day is quite large, with extra power up to about 50% to 10 h, in the case Mobile PV panel. By cons, these reduced powers, and  $P_{Fixed}$   $P_{Mobile}$  are almost equivalent, from noon until about 14h30, where the sun is perpendicular to the active surfaces of both PV panels.



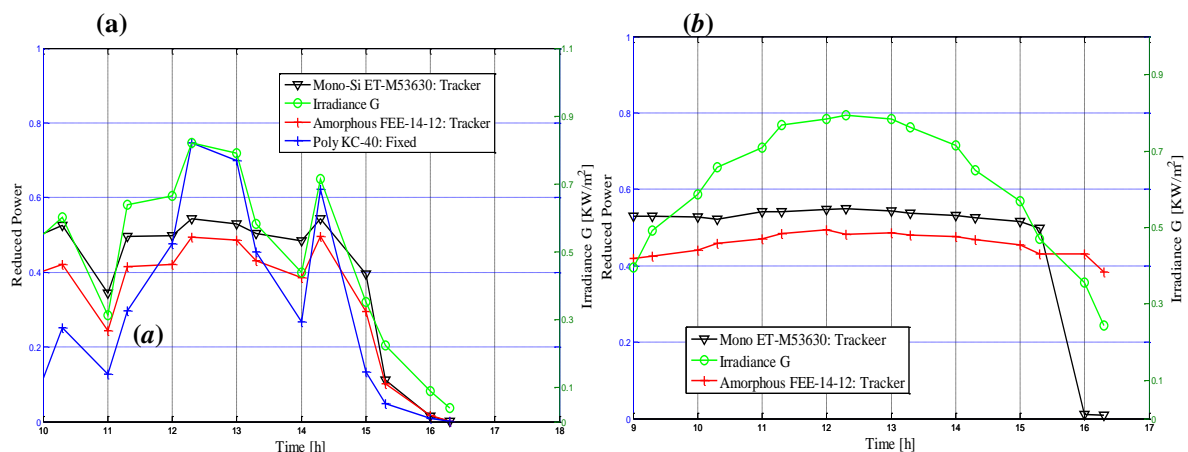
**Figure 2. Comparison of reduced powers issued by 2 PV module CIS, one fixed and the other mobile 1 axis,  $G_d$  by illumination during a sunny day:**  
a) 23-8-2014 with  $T_{moy} = 41$  °C, b) 01-4-2014 with  $T_{moy} = 43$  °C

Moreover, according to these figures 2-a and b, solar radiation can reach important values during a great period of the day, especially between 9 h and 16h30, with maxima around noon. Outside of these hours, the radiation is too low for mass use. We also note that during all measurement days, the shape of reduced powers  $P_{Fixed}$  follows almost the same pace as that of the illumination  $G_d$ .

## 2) The case of "Mono-Si"PV modules and Amorphous-Si

On the same figures 3-a and b we represent the reduced power output from the PV panels and solar illumination  $G_d$  during the days of 4 and 5-11-2014. According to these figures, we note that for almost seven hours of the day, a large solar power reaches the floor of Agadir, up to a maximum of  $800 \text{ W/m}^2$ , especially during this month of November, with minimums of  $400 \text{ W/m}^2$ .

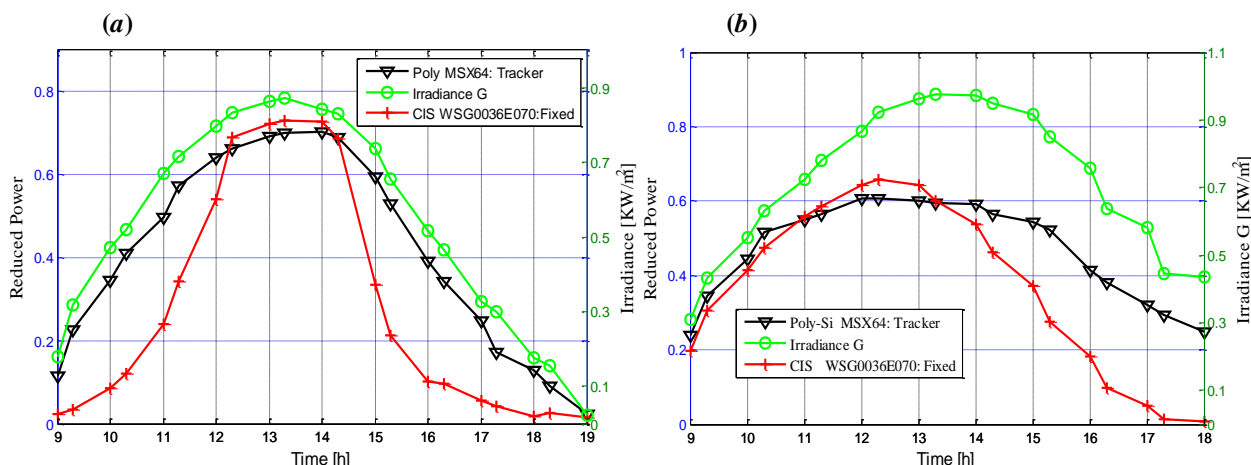
As above, as shown in figure 3-a, we compare the reduced powers  $P_{Mono-Si}$  and  $P_{Amorphous-Si}$  delivered by two mobile PV panels with tracker with two axis, Mono-Si and Amorphous-Si, with reduced powers  $P_{Si-Poly-f}$  produced by a fixed PV panel technology Poly-Si. Since the comparison in Figure 3-a, we can see that for the type of PV module Si-Poly fixed, when the sun's rays are perpendicular to its surface area, the reduced power  $P_{Si-Poly-f}$  produced is greater than that of other technologies but limited to a few hours of the day (noon to 14h). However, these two PV panels, Mono-Si and Amorphous-Si equipped by tracker, delivered almost uniformly reduced power for most of the sunny day from 9 h to 15h30.



**Figure 3. Comparison of reduced powers issued by 3 PV module (Si-Mon, Si-Amorphous, Poly-Si The fixed (Poly-Si) and other mobile, by illumination  $G_d$  during sunny day:**  
a) 04-11-2014, with  $T_{moy} = 36.6$  °C, b) 05-11-2014, with  $T_{moy} = 33.2$  °C

### 3) The case of "Poly-Si" PV modules mobile and CIS fixed

The technology panel PV Si-Poly has a two-axis tracker, for against the CIS panel is fixed and faces south with a  $45^\circ$  tilt. In the case of these two PV panels, Figure 4 gives the comparison of the reduced power they produce.

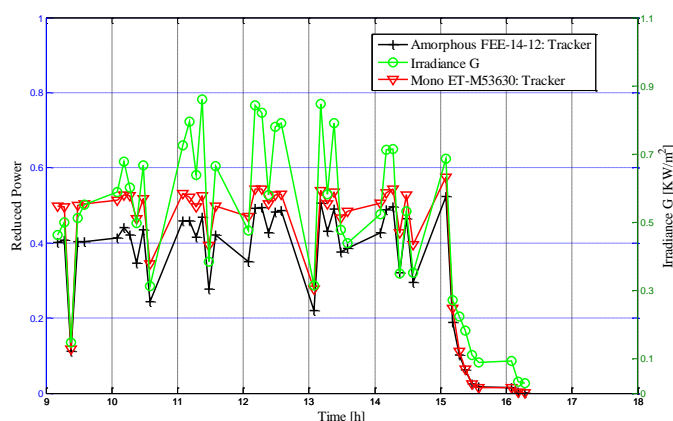


**Figure 4. Comparison of reduced powers issued by 2 PV module Poly-Si-Mobile and fixed CIS, by illumination  $G_d$  during a sunny day:**  
a) 19-6-2014 with  $T_{moy} = 37^\circ\text{C}$ , b) 04-4-2014 with  $T_{moy} = 42.6^\circ\text{C}$

### B. Comparison of reduced powers of different technologies with tracker

#### 1) The case of "Mono-Si" and "Amorphous-Si" mobiles PV modules

In this case, the technology of PV panels, Mono-Si and Amorphous-Si are installed on mobile devices with dual-axis tracker, controlled by a program. The results collected are summarized in figure 5 which provides the changing illumination  $G_d$ , during the day on 8-11-2014 and comparing reduced power of Mono-Si ( $P_{\text{mon-Si}}$ ) and Amorphous-Si ( $P_{\text{amour-Si}}$ ). First, the comparison shows the effectiveness of the tracking system, for both PV panels, as they deliver an almost uniform electric power throughout the sunny day. On the other hand, the difference between the reduced powers produced by these technologies is relatively large, which is probably due to the fact that the two panels do not have the same electrical characteristics. We also note that the graphs reduced powers  $P_{\text{Mono-Si}}$  and  $P_{\text{Amorphous-Si}}$  almost follow the irregularities of the changing illumination  $G_d$  with time, which proves once more the effectiveness of trackers.



**Figure 5. Comparison of reduced powers issued by 2 PV module Mono-Si and Amorphous both mobile by illumination  $G_d$  during the day 08-11-2014 with  $T_{moy} = 18^\circ\text{C}$**

#### 2) The case of "Poly-Si" and CIS mobiles PV modules

In this experiment, two mobile PV panels are used; one is technology Si-Poly and the other of the CIS. In this case, Figure 6 shows the effect of the use of solar trackers on supplied power from the PV panel. In the same figure we also represent the variations of the luminous flux during the day 31-3-2014. According to these results, we find that on the one hand, for most of the day with a  $G$  irradiance exceeds  $500 \text{ W/m}^2$ , the CIS PV module, provided more power than the Si-Poly, which makes sense because the CIS is more powerful. Moreover, we note that towards the end of the day, when  $G_d$  is quite low, the CIS technology produces slightly more power than the Poly-Si. This latter finding is probably due to

the fact that the high level of performance CIS modules products by Würth Solar used, and it's approved by certification according to EN-61646 [17].

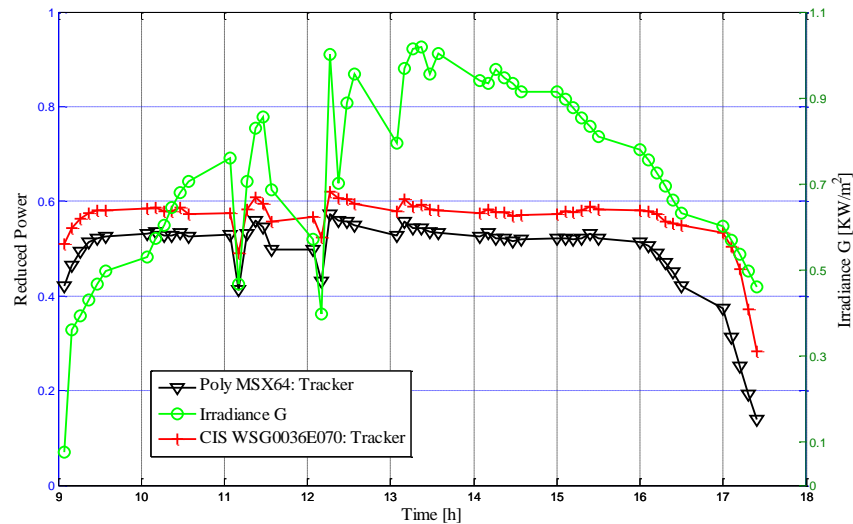


Figure 6. Comparison of reduced power produced by 2 PV module Poly-Si and CIS both mobile, by illumination  $G_d$  during the day 31-03-2014 with  $T_{moy} = 43^\circ C$

Finally, to evaluate the performance of different technologies under test, we represent in Figure 7 Reconcile regarding changes in power reduced depending on the sunlight. From this comparison, we can make the following deductions: When the solar irradiance is quite low, Amorphous type of technology produces more energy than others. On the other side, when solar radiation is important, we find that energy production is quite significant in the case of Si-Poly technologies and CIS.

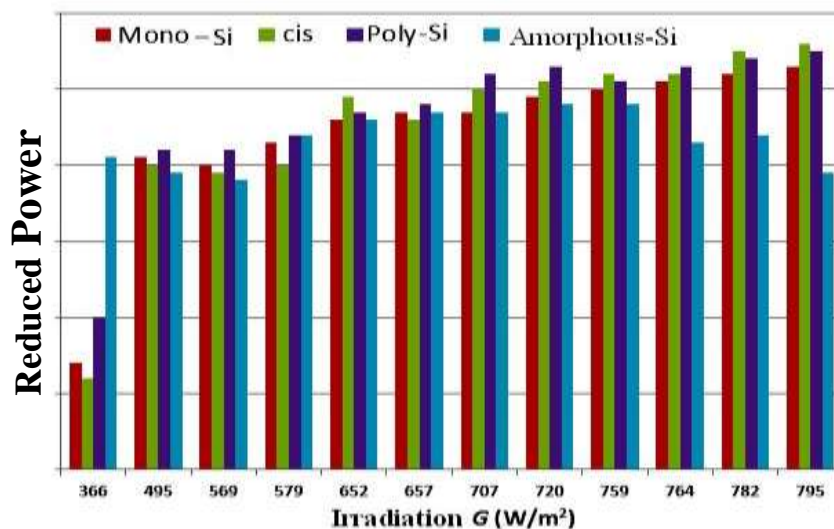


Figure 7. Comparison of powers in reduced  $G_d$  function for other technologies at  $T_{moy} = 31^\circ C$  under  $366 W/m^2$  and  $T_{moy} = 43^\circ C$  under  $795 W/m^2$

## CONCLUSION

A comparative study is performed to conclude on the energy performance of four photovoltaic panels of different technologies, when exposed to sunlight even in weather conditions in Agadir city. It follows then, according to our study, the modules Poly-crystalline silicon and CIS perform better aware of sunny days with higher daily returns, especially when the temperature increases, in the case of Poly-Cristallin compared to CIS. While the amorphous silicon technology, it is more efficient in conditions where direct solar radiation is low, while the diffuse is more important.

In the case of Agadir city, it is located in a remarkable geographical location seen that throughout the year, it is characterized by several months of sunshine and average temperatures enough. This character is positive thinking leading to the production of photovoltaic electricity, medium or large scale, through technology facilities in polycrystalline silicon, well positioned and equipped with solar trackers.

## REFERENCES

- [1]. J. Khan, Mudassar H. Arsalan, "Solar power technologies for sustainable electricity generation - A review", *Renewable and Sustainable Energy Reviews*, Vol 55, pp. 414-425, 2016.
- [2]. C. Cañete, J. Carretero, and M. Sidrach-de-Cardona, "Energy performance of different photovoltaic module technologies under outdoor conditions", *Energy*, Vol 65, 2014, pp. 295-302.
- [3]. S. Edalati, M. Ameri, and M. Iranmanesh, "Comparative performance investigation of mono- and poly-crystalline silicon photovoltaic modules for use in grid-connected photovoltaic systems in dry climates", *Applied Energy*, Vol 160, 2015, pp. 255-265.
- [4]. M. E. Başoğlu, Abdul. Kazdaloğlu, T. Erfidan, M. Z. Bilgin, and B. Çakır, "Performance analyzes of different photovoltaic module technologies under İzmit, Kocaeli climatic conditions", *Renewable and Sustainable Energy Reviews*, Vol 52, 2015, pp. 357-365.
- [5]. C. E. C. Nogueira, J. Bedin, and R. K. Niedzialkoski, "Performance of monocrystalline and polycrystalline solar panels in a water pumping system in Brazil", *Renewable and Sustainable Energy Reviews*, Vol 51, 2015, pp. 1610-1616.
- [6]. M. Benghanem, A.A. Al-Mashraqi, and K.O. Daffallah, "Performance of solar cells using thermoelectric module in hot sites", *Renewable Energy*, Vol 89, 2016, pp. 51-59.
- [7]. S. Chander, A. Purohit, and A. Sharma, "A study on photovoltaic parameters of mono-crystalline silicon solar cell with cell temperature", *Energy Reports*, Vol 1, 2015, pp. 104-109.
- [8]. M. Fisac, F. X. Villasevil, and A. M. López, "High-efficiency photovoltaic technology including thermoelectric generation", *Journal of Power Sources*, Vol 252, 2014, pp. 264-269.
- [9]. P. Ferrada, F. Araya, A. Marzo, and E. Fuentealba, "Performance analysis of photovoltaic systems of two different technologies in a coastal desert climate zone of Chile", *Solar Energy*, Vol 114, 2015, pp. 356-363.
- [10]. M. Saidan, A. G. Albaali, E. Alasis, and J. K. Kaldellis, "Experimental study on the effect of dust deposition on solar photovoltaic panels in desert environment", *Renewable Energy*, Vol 92, 2016, pp. 499-505.
- [11]. Solar module monocrystal ET-M53630, Site web : <http://www.erm-energies.com/p885-module-monocrystallin-et-solar-30wc-12v.html?catId=176>.
- [12]. MSX-64 PDF Spec sheet, MSX-60 and MSX-64 Photovoltaic Modules, 1997 Solarex, 630 Solarex Court, Frederick, MD 21703 USA. Site web: [http://www.solarelectricsupply.com/fileuploader/download/download/?d=0&file=custom%2Fupload%2FSolarex-MSX64\\_1.pdf](http://www.solarelectricsupply.com/fileuploader/download/download/?d=0&file=custom%2Fupload%2FSolarex-MSX64_1.pdf).
- [13]. KYOCERA Corporation, KC40, High Efficiency Multi-Crystal Photovoltaic Module, Web site: <http://www.kyocerasolar.com/assets/001/5158.pdf>
- [14]. Free energy europe, Amorph FEE-14-12, Web site: <http://www.apexpowerconcepts.com/fee-14-12.pdf>.
- [15]. B. P. Jelle, C. Breivik, and H. D. Røkenes, "Building integrated photovoltaic products: A state-of-the-art review and future research opportunities", *Solar Energy Materials & Solar Cells*, Vol. 100, 2012, pp. 69-96.
- [16]. GeneCIS solar module 70W, WSG0036E070, Würth-Solar GmbH & Co. KG, site web: <http://www.iltayenerji.com.tr/dosyalar/wurthsolarCIS2.pdf>.
- [17]. B. Dimmler, and R. Wächter, "Manufacturing and application of CIS solar modules", *Thin Solid Films*, Vol 515, 2007, pp. 5973-5978.