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THE EFFECT OF PHOTOVOLTAIC (PV) PANEL TILT ANGLE FOR BEST ENERGY GENERATION IN HOT CLIMATE

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Abstract: **In this paper, Photovoltaic (PV) panel usages would be analyzed at its best performance in hot climate with different tilt angles. In the case of my research case studies will be selected from hot climates, different tilt angle will be researched on and calculated in order to find the best design principles for PV panel designs. According to the findings, before designing the PV panel to the roof or facade or to the site, it is the most important to know the latitude of the place. The reason is to find the correct optimum tilt angle. According to the investigations, tilt angle that is known as inclined angle of the photovoltaic (PV) panel, is changeable due to the location of place, climatic conditions and the solar radiation. In Cyprus for instant, tilt angle is 20° in summer and 50° in winter. On the other hand, if the panels designed fixed in North Cyprus, optimum tilt angle is taken between 28° and 30°. Secondly, optimum tilt angle of England is 65° in winter and 35° in summer periods. By the way, due to variable tilt angles during a year, sun trackers should be given as a suggestion. On the other hand, orientation of the PV panel is the second important aspect to consider. This is because; PV panels should be oriented to south direction in Northern Hemisphere and to the north direction if the location is in Southern Hemisphere. Solar radiation should be considered to know the countries solar radiation amount to select the correct PV panel type and size. At the same time, electricity usage of the building should be calculated in order to find panel numbers to install.**

Keywords: **PV Panels, Climates, Tilt Angle, Orientation.**

1. INTRODUCTION

Photovoltaic (PV) panel usage in the world is evolving day by day. Therefore, photovoltaic (PV) installations were started to be use especially in recent years in Northern Cyprus like other developed countries such as England, Germany and America. However, during the installation of the photovoltaic (PV) panels, companies do significant errors. These errors are wrong PV cell selection, not appropriate tilt angle, wrong installation spaces and orientation of the PV panels.

The aim of this paper is to find the optimum tilt angle of solar PV panel at which the yearly interest would be met most extreme. Solar PV is one of the most widely used renewable energy resources. The yield of the panel is most elevated when the occurrence beam is opposite to the panel plane. Because of variations in the locus of the sun throughout the year, the arrangement of the panels ought to be change due to the sun position for greatest and maximum generation; distinctive tilt angle will give diverse generation throughout the year. The generation at optimum tilt angle will not maximize the generation of energy over the year rather it will augment the interest met by moving the vitality to deficiency season from surplus season. Another idea to amplify the vitality of solar PV is by changing the tilt angle and thus limit the deficiency to take care of the demand of a detached power framework this system is introduce in the paper.

By using photovoltaic panels in different climates, it is important to choose the right direction, organize them, choose the most efficient type of cell and calculate the correct angle of inclination according to the latitude of the place. According to former researchers, the plates should be oriented to the south in the northern hemisphere. This research suggests that future researchers can study in depth the advantages and disadvantages of southward stabilization. Secondly, the panels are heated because there is no gap between the roof surface and the panels. For this reason, it is necessary to look for the exact distance between the roof surface and the panels. Hybrid solar panels (HIT solar cells) would be the most efficient cell types. The efficiency and cost of the panels should be examined. Finally, the differences in efficiency between the installation of the roof and the installation of the facade can be studied.

What is the best photovoltaic (PV) tilt angle in hot climate

- Does excessive heat affect the performance of photovoltaic (PV) panels
- How does photovoltaic (PV) tilt angle affect its energy generation
- What is the best photovoltaic (pv) orientation in northern hemisphere or hot climates

At the point, in the past, photovoltaic impact was found by Alexander Becquerel in 1839. Subsequently, this pattern started to build up each passing day. First solar collectors installed on rooftops in the mid-1970s. (Zauscher, 2006). Photovoltaic (PV) are sun oriented cell frameworks that convert daylight straightforwardly into electricity. Photovoltaic frameworks are for the most part partitioned into two. Daylight is changed over to electricity by PV cells (Aysan, 2011). The word Photovoltaic originates from the Greek dialect. Photo signifies "light" and voltaic signifies "creating electricity". (Hegger et al, 2009). Furthermore, protons of daylight are exchanged to the electrons of the photovoltaic module components by photovoltaic. The littlest piece of the photovoltaic is named as cell. A solitary PV cell has an ability to create vitality somewhere in the range of 1 and 2 Watts. At the point when 36 quantities of cells are consolidated together, a module/panel is made. A cluster can be made with the blend of a few modules and boards. PV cell shape can be seen rectangular, roundabout and square. Every cell's measurement can be 10x10 cm (Sev, 2009). According to Kazek (2012), photovoltaic (PV) module can be framed with aluminum and without any frame. At the same time, base of PV module can be plastic, metal or double surface.

There are three principle kinds of photovoltaic cell types. These are mono-gem (mono-crystalline) that have 16-19% cell effectiveness limit; second sort is poly-gem (multi-crystalline or poly-crystalline) that has 14-15% cell productivity limit and finally, thin-film undefined silicon (A-si) panel type that has 5-7% proficiency. Zone prerequisites of different cell type boards can be variable. Roughly, 8m2 is required for poly-crystalline, 7m2 is required for mono-crystalline and 15m2 is required for thin-film shapeless silicon per kilowatt (kW). These rates are taken under 25°C and 1000W/m2 sun powered illumination standard testing conditions (Welch, 2010). Then again, a board with another cell type has as of late been utilized which is named as HIT photovoltaic module. Agreeing Mishima et al (2010), HIT was guaranteed as most noteworthy transformation productivity of 23% for down to earth measure crystalline silicon sun powered cell.

1. Mono-crystalline (single-crystalline) silicon
2. Poly-crystalline (multi-crystalline) silicon
3. Thin-film amorphous silicon
4. HIT (Hetero Junctin with Intrinsic Thin Layer) (Mixture of Ultra-thin

Amorphous silicon and Mono-crystalline silicon)

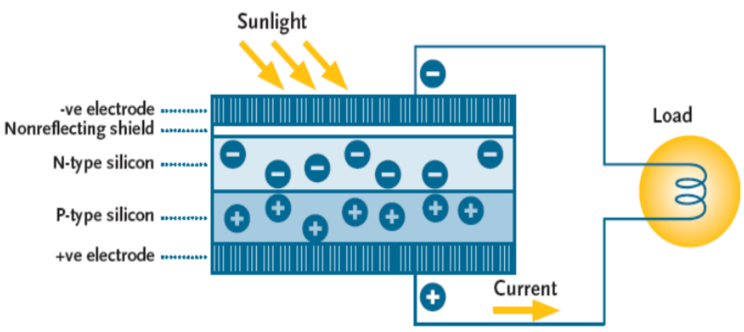


Figure 1: Principles of Operation for PV Cell (Welch, 2010)

PV panels consist of little solar cells, which are connected as one. Semiconducting material are used in the manufacturing of PV cells, however silicone is the commonly used material. Even though the solar cells are small in nature when put together as solar cells or array, they work efficiently; electric field is created when sun shines over the little cells. When there is a high sunray, the production of electricity becomes higher and vice versa. Nevertheless, the cells can work even without a direct sunlight; electricity is still produced in a cloudy day. PV panels are flexible, available and in can be found in different sizes and shapes which are easily mounted on newly built structure or existing building. Solar tiles can be used as an alternative of PV panels in terms of spacing issues but is however more expensive then PV panels

Excessive heat can significantly reduce the output of a PV system. It may seem counter-intuitive, but the efficiency of solar panel is negatively affected due to high temperature. Photovoltaic modules are tested at a temperature of 25 degrees C (STC) – about 77 degrees F., which depends on the installed location, excess heat can reduce PV output efficiency by 10-25%. If temperature increases, the output of the solar panels increases exponentially, while voltage output is reduced. The voltage reduction is so predictable, that it could be used to accurately measure temperature. As a result, the production of electricity by solar panel is severely affected by heat. Nevertheless, there are couple of ways to prevent such from happening

2. LITERATURE REVIEW

PV panels, also known as photovoltaic, are generally confused with solar thermal systems, but they work in another way. Unlike solar thermal systems, which are used to produce hot water, PV panels capture the sun's energy and convert it into electricity.

The electricity generated by domestic PV panels is mostly used for powering household appliances and equipment. According to According to Barkaszi and Dunlop (2001), the most typical PV system is the grid-connected system, which as its name indicates, is connected to the national grid. This means that at night, when the solar panels do not work, you can use electricity from the grid. Moreover, if your solar system produces more electricity than what you need, you can sell the surplus back to the grid. Welch (2013) argues that photovoltaic panels should be placed before taking environment in consider. Because, if they were located where photosynthesising plants would normally grow, they simply substitute one potentially renewable resource (biomass) for another. It should be noted, however, that the biomass cycle converts solar radiation energy to chemical energy (with significantly less efficiency than photovoltaic cells alone). According to Beyit and Dervişoğulları (2009) in order to produce 1kWp, 7-9m2 panel modules needed at mono-crystalline silicon to provide 11-16% energy efficiency. Secondly, 8-9m2 panel modules needed at poly-crystalline silicon (EFG) to be 10-14% energy efficient. Thirdly, 11-13m2 panel modules needed at thin-film copper- indium-dieseline to be 6-8% energy efficient.

Before, installing the 4 photovoltaic modules; the location of the house and the availability of solar energy should be investigated (peak power). Peak power of Cyprus can be considered as an average of 5 hours. Additionally, angle of the photovoltaic (PV) modules must be found. These angles could be found by using graphics that is showing solar panel angles for various northern latitudes. For instance, Karpaz is located in 35°N latitude of North Cyprus. So panels should face south. For better efficiency; between months April and October, inclined angle must be between 10° and 25°. On the other hand, between months November and March, inclined angle should be between 25° and 55°. For Cyprus, orientation of the inclined angle can be 45°. As a solution, angles can be designed moveable according to the direction of the sun (Angle can be 35° and 45°). Kumar, Thakur, Makade and Shivhare (2011) argue that photovoltaic arrays needed to be tilted at the correct angle to maximize the performance of the system. This is known as the inclined angle of the photovoltaic modules. In order to find the tilted angle several calculations needed. Monthly average daily solar irradiation components should be noted. Khatkar Kalan (Punjab) that is a location in Indian State of Punjab. It is found that the optimum tilt angle changes between 60.5◦ (January) and 62.5◦ (December) throughout the year. In winter (December, January, and February) the tilt should be 57.48◦, in spring (March, April, and May) 18.16◦, in summer (June, July, and August) 2.83◦, and in autumn (September, October, and November) 43.67◦. The yearly average of this value was found to be 30.61◦ which is nearly equal to the angle selected at Khatkar Kalan. Latitude and Longitude of Punjab is noted as 30°4'N, 75°5'E.

Mousazadeh, Keyhani, Javadi, Mobli and Abrinia (2009) studied on the sun trackers devices. Accordingly, sun trackers are such devices for increasing the energy efficiency and efficiency improvement. Seasonal movements of earth and daytime affect the energy efficiency. (Solar radiation increases the energy production). It is important to know that sun trackers keeping the best orientation relative to the sun. Additionally, solar trackers not recommended using for small solar panels because of high energy losses. The most efficient and popular sun-tracing device was founded to be in the form of polar axis and azimuth/elevation types.

Makrides, Georghiou, Zinsser and Werner (2007) studied that temperature is a great factor that affects daily and seasonal performance of PV panels. For instance, module temperature of PV panels reach to 70°C in Cyprus especially at midday hours in summer times. Two cities are compared in order to understand which panels are more efficient. Cyprus and Germany is selected as a case study. Different types of mono-crystalline, poly-crystalline and thin-film installed at both Nicosia and Stuttgart. As a result, Mono c-Si and thin-film technologies have best performance for both countries.

According to Rakovec, Zaksek, Brecl, Kastelec and Topic (2011), climatic, topographical and geographical varieties can cause changes in the photovoltaic (PV) potential. Slovenia is selected as a case study in order to understand the changes.

At the orientation of the panel, in winter, large tilt and south facing orientation is needed on the other hand, in summer times, flat installation of panel is preferred. Slovenia has 45.5°N and 47°N latitude. Average latitude is noted as 46°N. By the way, on 21 March and 21th September tilt angle of PV panel will be 44°. On 21th of June (summer) tilt angle will be 20.5° and on the 21th of December, tilt angle calculated as 67.5° (winter). Different climate characteristics have a huge influence on the optimal tilt. (Incline angle) "It is important to stress those optimal orientations and tilts are strongly affected by local weather and climatic conditions."

According to Mieke (1998), tropical climate (like Malaysia) has high ambient temperature and humidity during wet seasons. So, during wet seasons A-si (Amorphous) array produces up to 20% more energy than P-si (Poly-crystalline) array.

At the same time according to Akhmad et al. (1997), A-si (Amorphous) modules may be more suited to tropical climates. Amin et al (2009) argues that amorphous silicon, Copper Indium Diselenide (CIS) have better performance ratio than mono and multi-crystalline silicon solar cells in Malaysia climate conditions.

The second type of PV panel system is the stand-alone system, which is not connected to the grid. In this case, you can add batteries to the system to have electricity when it gets dark. This system can be convenient in remote areas where there is no alternative for other source of electricity. Nowadays, thousands of people power up their homes and business with the help of PV panels.

In order to do a precise research, significant rules are needed. First, it is important that side of the equator of the area ought to be known for situating photovoltaic (PV) panels bearing effectively. Secondly, type of climate and panel type is imperative to choose the most effective cell type as indicated by the climatic states of the area. Thirdly, latitude and longitude is critical for finding the ideal tilt angle of the area. In this manner, area of the panel must be mounted right to get the most sun powered radiation and maintain a strategic distance from shading. Finally, panels ought to be bolstered right to maintain a strategic distance from outside components and to be ventilated well.

The world is partitioned into two by equator. The part that stays at the northern planet is also known as northern hemisphere of the globe and south part of the world is known as southern side of the equator. Northern Side of the equator is the half of the planet that is north of the equator. Directions of Northern half of the globe is appeared with 45° 0′ 0″ N, 0° 0′ 0″ E. Furthermore, southern side of the equator is the other portion of the world that lies south of the equator. Directions of Southern side of the equator is appeared with 45° 0′ 0″ S, 0° 0′ 0″ E. (Wikipedia, 2013) Duffie and Beckman (1991) said that, "For sun powered vitality applications in the northern half of the globe, ideal introduction is viewed as that of due south. As a rule, PV boards are set by this general principle".

The establishment of a PV module decided area concerning the equator. On the off chance that the area is at the north of the equator, (northern side of the equator) PV panels ought to be arranged toward the south bearing. In the event that the area is at the south of the equator (southern half of the globe) PV panels ought to be situated toward the north course. Then again, ideal tilt angle is the required point of panels for accepting the best sun powered energy.

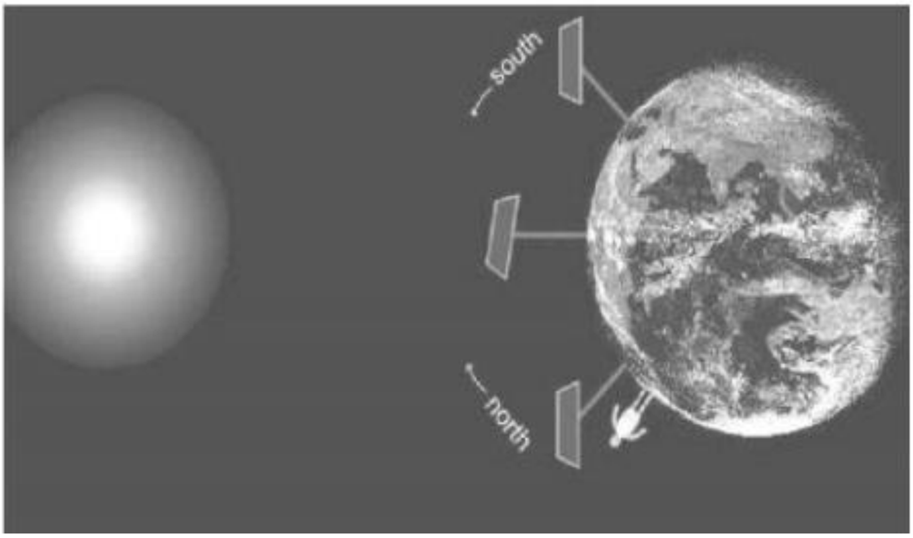


Figure 2: Orientation in Northern and Southern Hemisphere (Sundaya, 2013)

Ideal tilt angle varies according to the latitude of the region. Mikell (2008) argued that in order to determine greatest measure of electricity from a photovoltaic panel, it is important to ensure that the panel is optimally arranged. There are numerous thoughts regarding by what means ought to be the ideal tilt angel of the panels. So, Hottel (1954) argued that optimum tilt angle ought to be in addition to 20 degree (+20°). Kern and Harris (1975) recommended that optimum tilt angle be in addition to 10 degree (+10°). Hyewood (1971) said that tilt angle must be short 10 degree (- 10°). Yellot (1973) argued that optimum tilt angle could be two angles. One point is for summer (-) and one for winter times (+). Incidentally, optimum tilt angle ought to be in addition to and short 20 degree (±20°). Lewis (1987) recommended that ideal tilt angle could be fewer than 8 degrees in summer periods and in addition to 8 degrees in winter periods. So ideal tilt angle is noted ±8°. "As a standard guideline, photovoltaic are typically situated at a tilt angle around equivalent to the scope of the site and confronting south." (Mehleri, Zervas, Sarimveis, Palyvos, Markatos, 2010).

As seen from Figure 2.4, sun is lower in winter according to summer times. By the way, tilt angle for winter should be +15 degrees and -15 degrees in summer times. According to Mehleri et al (2010), optimal tilt angle for cold period should be larger compared to the hot periods. This change in tilt angle would improve the quantity and uniformity of the produced power.

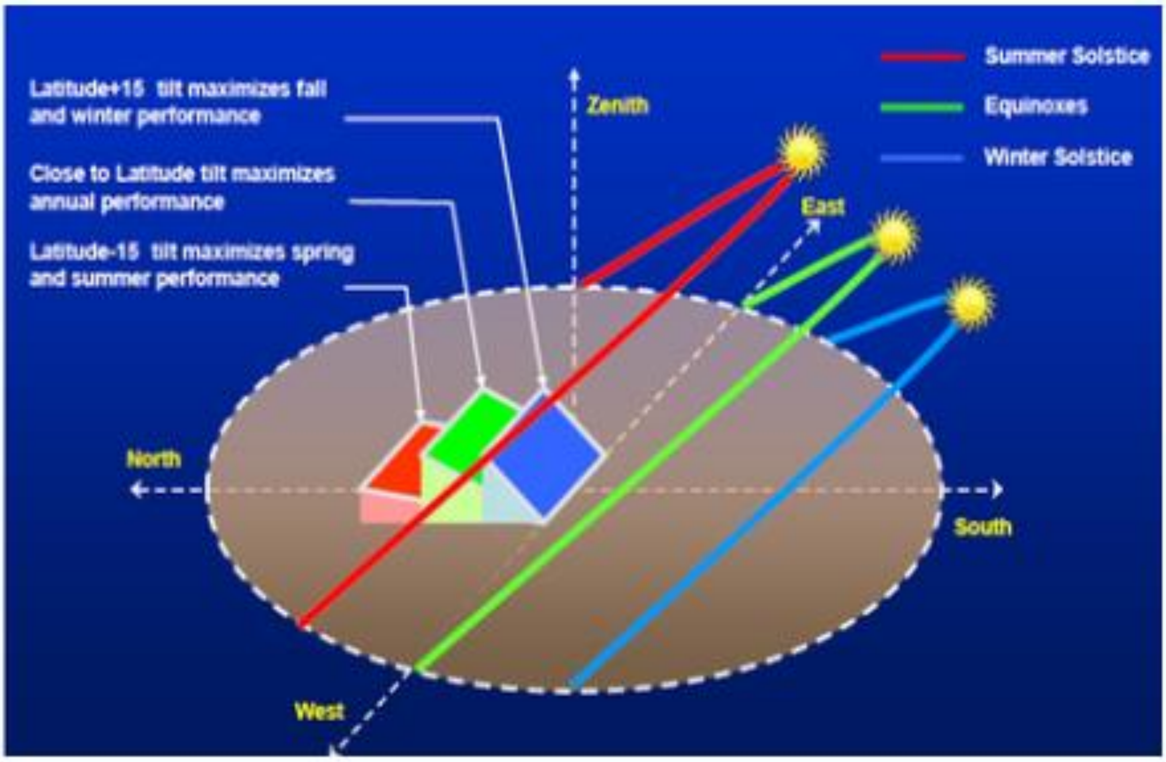


Figure 3: Array Tilt Angle Affects Seasonal Performance (Brooks, Dunlop, 2012)

In order to find the tilt angle of the current installations that was done on the roof surface, right triangle trigonometric calculation can be used.

In order for PV panels to operate efficiently, it is important to know *latitude and optimum tilt angle of the area or region*. It is important to know that solar radiations intensity is higher near equator and it decreases as we distance away. To obtain optimum tilt angle in hot and cold climate, in summer the optimum angle must be reduced by -15 degrees, in winter by +15 degrees. However, in summer PV panels received solar radiation at higher angle and at lower angle in winter.

Thin film solar panel could be used both in hot and cold climates , it is however relatively very cheap compared to the other two, but its disadvantage is that it is less efficient than the other two types, therefore to compensate this set back, the installed area should be increased. For hot climate, Thin film is the most appropriate type because it is more tolerant to heat, it is cheap and can operates even when the climate is cloudy and dusty. Therefore, in Sudan Telecommunication tower it is been used, because the weather is semi desert, very hot, dusty in summer, therefore, thin film is highly recommended in hot climates Mieke (1998). However poly-crystalline too can be used, because is less affected by high temperature, if we provide (15- 20) gap or good ventilation or cooling using water for back of the cell it will operates efficiently, however it is more economically wise than mono-crystalline.

Cyprus' latitude is noted as 35°N. According to the Ibrahim (1995) optimum tilt angle should be +15° of latitude in winter and -15° of latitude in summer times. So, tilt angle of Cyprus should be 50° for winter and 20° for summer. By the way, the average of two angles is found 35°. Therefore, the solution is equal to the local latitude.

Garp and Gupta (1978) argued that; in order to find the yearly average tilt angle, modules tilt angle should be equal to the local latitude. On the other hand, 9 months pass like summer and 3 months are pass winter. Therefore, formula for finding fixed tilt angle for Turkish Republic of North Cyprus (TRNC)

(Number of Summer Months x Summer Tilt Angle) + (Number of Winter Months x Winter Tilt Angle) / Total Months

$$(SM \times STA) + (WM \times WTA) / 12$$

$$((9 \times 20) + (3 \times 50)) / 12 = 27,5° \approx 28°$$

3. METHODOLOGY

Methodology of this research due to the hot climate of Cyprus, case study will be analyzed by using System Advisor Model (SAM) software and calculations. Panel dimensions, supporting elements, distance between the panels will be measured by meter. SAM is the ideal free online tool used to estimate the solar electricity production of a photovoltaic (PV) system. It gives the annual output power of solar photovoltaic panels.

As a photovoltaic Geographical Information System, it proposes a google map application that makes it easy to use. This application calculates the monthly and yearly potential electricity generation E [kWh] of a Photovoltaic system with defined modules tilt and orientation.

In conclusion, suggestions is be given to the selected cases to understand how to design PV panels correctly. Design suggestions should be made to achieve these problems while designing PV panels and increasing energy efficiency for optimal performance. In order to get the best efficiency in cases such as panels designed in place buildings, solar tracking devices prefer to change the direction of the plate according to the direction of the sun. Furthermore, the photovoltaic panels should be embedded in the facade or the roof, for the photovoltaic panels on the roof of the buildings; new design solutions and suggestions should be presented. Because of this research, it would be useful to design, guide and assemble panels in the most accurate manner in accordance with climatic conditions.

The tilt angle of the photovoltaic (PV) array is the key to an optimum energy yield. Solar panels or PV arrays are most efficient, when they are perpendicular to the sun's rays. The performance of photovoltaic (PV) solar module is affected by its tilt angle and its orientation with horizontal plane. PV systems are one of the most important renewable energy sources for our world energy demand. The study showed the importance of investigating the effect of tilt angle on the performance of photovoltaic. The study includes one set PV module tilted at 00, 150, 300, 450, and 60o (in both X, and Y direction). In these positions the values of current, voltage, power and solar radiation intensity were measured. The optimum positions were determined as the positions in which maximum values of solar intensity and maximum power can be obtained. The simulation results are extracted using the **System Advisor Model (SAM)**, which gives a constant irradiance (1000w/m2), and this leads to real results instead of using the sun radiation, which is fluctuated during the testing time.

Solar power, in particular photovoltaics (PV), has been noted to be one of the fastest growing sources of electricity globally. This is mostly because solar energy is abundant, inexhaustible, clean, free and low maintenance, unlike its non-renewable counterparts such as fossil fuels. As the adoption of PV continues to increase, PV systems need to improve in terms of technological maturity and affordability in order to maintain the balance between electricity supply and demand

One way to achieve this improvement is through forecasting. Forecasting is the use of performance models to estimate the expected energy output of a given PV system. The use of simulation software packages is a popular technique for forecasting as it not only allows users to model, but also to analyze PV systems and their yields. During simulations, performance models use the *PV system's design, orientation, weather data and location* to predict the energy yield for a given period.

Currently, there are quite a number of solar PV simulation software packages to choose. Different software packages have different features that make them more suitable tasks than others do. I will focus on System Advisor Model (SAM), SAM is a software package developed by the National Renewable Energy Laboratory (NREL) in the United

States of America. SAM was originally called the Solar Advisor Model, but has since expanded its focus to also cover non-solar technologies such as geothermal power, wind power and biomass power, hence the name change. It's categorized as a financial and performance modelling software because it helps assess the operation of a proposed or actual renewable energy system and ties that in with an evaluation of the costs thereof. A typical SAM simulation consists of the following basic steps:

1. Selecting, from the interface, the required renewable energy technology and financing option.

2. Selecting the appropriate set of simulation and financing models. SAM does this, based on the options selected in Step 1.

3. Specifying the necessary input variables such as the weather data file, site location and equipment. The supported weather files are typical meteorological year files (TMY2 or TMY3) and energy plus weather files (EPW)

4. Running the simulation. For advanced analyses, the user can configure simulations for sensitivity or optimization before running the simulations. The user can then view the simulation results on a variety of graphs and reports generated automatically by SAM in the user interface's results section. There is also an option to export the results to a third-party software package for presentation or further analysis. SAM's features allows it to cater to the needs of a variety of users including project developers, engineers, manufacturers, academic researchers, technology developers and policy makers and analysts

This solar angle calculator tells you the optimum angle to get the best out of your system. To get the best out of your photovoltaic panels, you need to angle them towards the sun. The optimum angle varies throughout the year, depending on the seasons and your location and this calculator shows the difference in sun height on a month-by-month basis

Although, the sun is frequently moving all through the day to get the best from your photovoltaic system (PV), panels most also be place correctly to be able to tract the sun as it moves. Unfortunately, trackers are much more expensive then even buying additional panels. The amount of electricity solar tracker uses to be able to track the sun also disclaim much of its benefits.

Therefore, to get the best out of PV panels, they must be placed facing the south with the best optimum tilt angle to receive the best sunlight as much as possible. The correct angle for your project will depend very much, as to when you want to get the best out of your photovoltaic system. To get the best performance in summer, photovoltaic panels should be angled according to the height of the sun in the sky during these months. Improving your winter performance simply means your photovoltaic panels should be angled towards the winter months in order to get the best performance at that time of year.

If you are opportune to adjust your pv panels all through the year, you will benefit more compared to a fixed position, the optimum performance from your solar system will be more effect all of the time

Notes:

On 21 December, the sun will rise 73° east of due south and set 73° west of due south.

On 21 March/21 September, the sun will rise 91° east of due south and set 91° west of due south.

On 21 June, the sun will rise 109° east of due south and set 109° west of due south.

4. RESULTS AND DISCUSSIONS

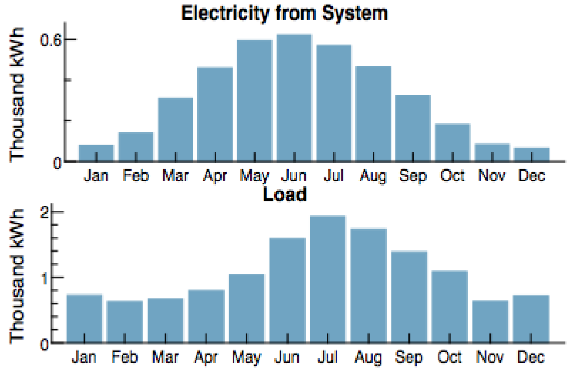
System Advisor Model (SAM) was used to generate result of the best tilt angle in Cyprus. Knowing that Cyprus is located in the Northern hemisphere, South is said to be the best direction for maximum sun ray in terms of photovoltaic energy consumption, Using a simulation software (SAM) System Advisor Model i was able to run some test, which generated different results for different tilt angles inputed in the software.

System Advisor Model Report for 30 Degree Tilt Angle

Performance Model

PV System Specifications	
System nameplate size	4 kW
Module type	0
DC to AC ratio	1.2
Rated inverter size	3.33 kW
Inverter efficiency	96 %
Array type	fixed roof mount
Array tilt	30 degrees
Array azimuth	0 degrees
Ground coverage ratio	N/A
Total system losses	14.08 %
Shading	no

Results	Solar Radiation	AC Energy
	(kWh/m2/day)	(kWh)
Jan	0.69	68
Feb	0.86	74
Mar	2.03	168
Apr	3.97	329
May	5.67	488
Jun	6.39	531
Jul	5.57	478
Aug	4.22	355
Sep	2.58	190
Oct	1.02	83
Nov	0.67	62
Dec	0.63	63
Year	2.86	2,894



Year 1 Monthly Electric Bill and Savings ($)

Month	Without System	With System	Savings
Jan	121	113	7
Feb	106	93	12
Mar	113	86	27
Apr	137	91	45
May	197	77	119
Jun	289	189	100
Jul	339	247	92
Aug	309	235	74
Sep	254	204	49
Oct	203	176	26
Nov	109	102	7
Dec	121	115	5
Annual	2,302	1,734	568

NPV Approximation using Annuities

Annuities, Capital Recovery Factor (CRF) = 0.1023		
Investment	$0	Sum:
Expenses	$-1,100	$0
Savings	$400	NPV = Sum / CRF:
Energy value	$600	$0

Investment = Installed Cost - Debt Principal - IBI - CBI
Expenses = Operating Costs + Debt Payments
Savings = Tax Deductions + PBI
Energy value = Tax Adjusted Net Savings
Nominal discount rate = 9.06%

Payback Cash Flow (Payback Period = 20.4 years)

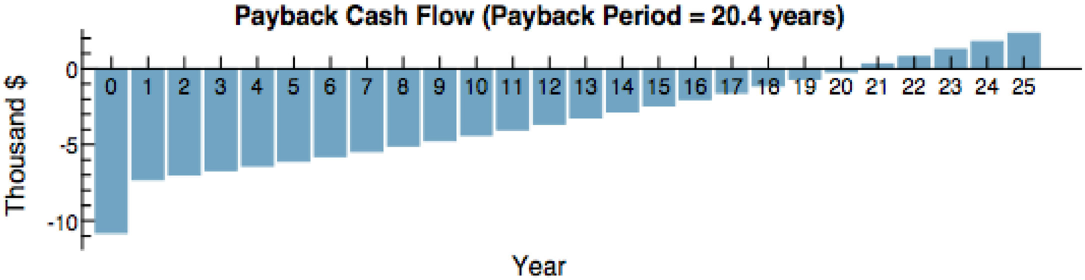


Table 1: simulation 30°

The software was tested with three different tilt angle to help simulate the best tilt angle in Cyprus. As discussed earlier in my introduction, in Cyprus, for ultimate, tilt angle is 20° in summer and 50° in winter, but if the panels designed are fixed in North Cyprus, optimum tilt angle will be taken between 28° and 30° this means the average tilt angle should be 35°. Therefore the best tilt angle in Cyprus should be in the range of 30° to 35°. Knowing the average degree that will yield the best electric generation i run a test for 30°, 45° and 60° to prove my findings of the best ultimate tilt angle in North

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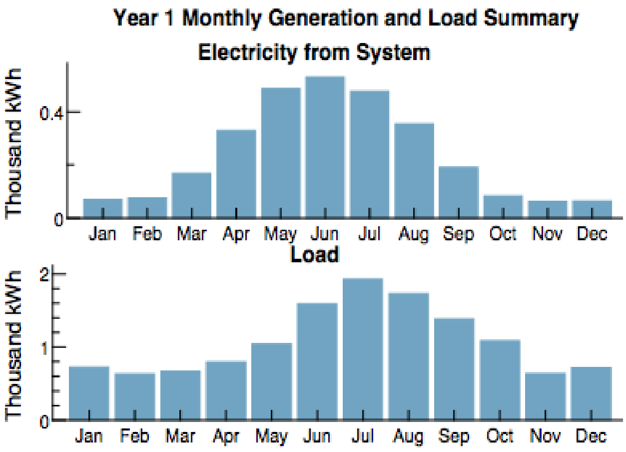
Cyprus. The first test was carried on with 30° tilt angle, the result shows that April to August has the best electricity generation due to summer heat again, 30° tends to be the best angle for photovoltaic (PV) in Cyprus, it has the highest generation of electric generation.

System Advisor Model Report for 45 Degree Tilt Angle

Performance Model

PV System Specifications	
System nameplate size	4 kW
Module type	0
DC to AC ratio	1.2
Rated inverter size	3.33 kW
Inverter efficiency	96 %
Array type	fixed roof mount
Array tilt	45 degrees
Array azimuth	0 degrees
Ground coverage ratio	N/A
Total system losses	14.08 %
Shading	no

Results	Solar Radiation (kWh/m2/day)	AC Energy (kWh)
Jan	0.96	79
Feb	1.85	139
Mar	3.44	308
Apr	5.32	459
May	6.87	594
Jun	7.48	619
Jul	6.6	568
Aug	5.4	464
Sep	3.99	321
Oct	2.32	182
Nov	1.12	84
Dec	0.75	65
Year	3.84	3,887



Year 1 Monthly Electric Bill and Savings ($)

Month	Without System	With System	Savings
Jan	121	114	6
Feb	106	99	7
Mar	113	95	17
Apr	137	100	36
May	197	115	81
Jun	289	202	86
Jul	339	262	77
Aug	309	252	57
Sep	254	224	29
Oct	203	190	12
Nov	109	103	5
Dec	121	115	5
Annual	2,302	1,877	425

NPV Approximation using Annuities

Annuities, Capital Recovery Factor (CRF) = 0.1023		
Investment	$0	Sum:
Expenses	$-1,100	$-100
Savings	$400	NPV = Sum / CRF:
Energy value	$400	$-1,000

Investment = Installed Cost - Debt Principal - IBI - CBI
Expenses = Operating Costs + Debt Payments
Savings = Tax Deductions + PBI
Energy value = Tax Adjusted Net Savings
Nominal discount rate = 9.06%

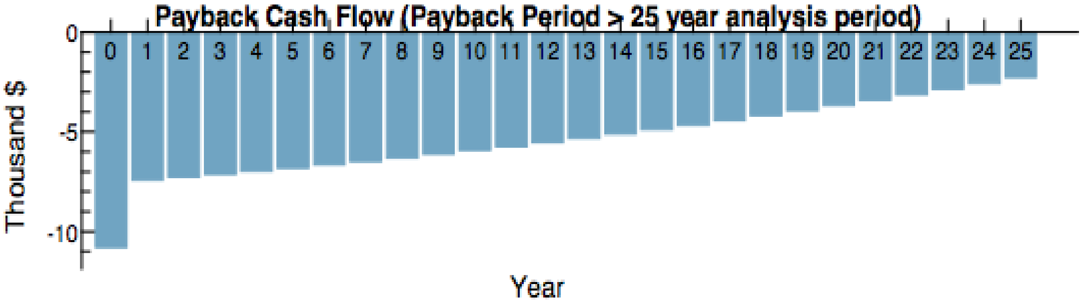


Table 2: simulation 45°

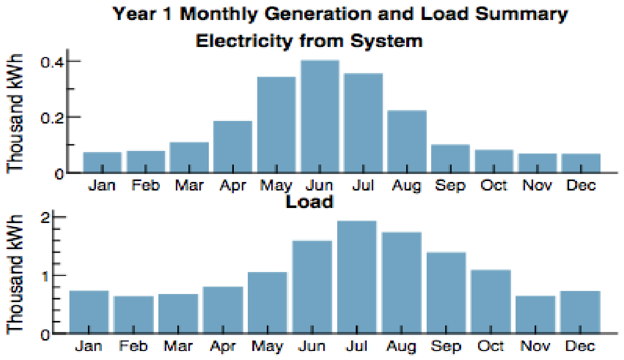
The second (45°) test was carried and the result shows slightly lower performance, which indicate May to October to be the best energy generation for photovoltaic (PV) panel while the Third result is not so high in performance in terms of capturing wide range of heat gain, 60 degree was used as the tilt angle. Below is the result of the simulation generated by system advisor model (SAM).

System Advisor Model Report for 60 Degree Tilt Angle

Performance Model

PV System Specifications	
System nameplate size	4 kW
Module type	0
DC to AC ratio	1.2
Rated inverter size	3.33 kW
Inverter efficiency	96 %
Array type	fixed roof mount
Array tilt	60 degrees
Array azimuth	0 degrees
Ground coverage ratio	N/A
Total system losses	14.08 %
Shading	no

Results	Solar Radiation (kWh/m2/day)	AC Energy (kWh)
Jan	0.71	70
Feb	0.85	76
Mar	1.1	107
Apr	2.42	184
May	4.17	341
Jun	4.96	401
Jul	4.24	353
Aug	2.83	221
Sep	1.24	98
Oct	0.86	79
Nov	0.7	65
Dec	0.65	65
Year	2.06	2,065



Year 1 Monthly Electric Bill and Savings ($)

Month	Without System	With System	Savings
Jan	121	114	6
Feb	106	98	7
Mar	113	101	11
Apr	137	114	22
May	197	141	55
Jun	289	223	65
Jul	339	281	58
Aug	309	273	36
Sep	254	238	15
Oct	203	191	11
Nov	109	103	6
Dec	121	115	5
Annual	2,302	1,998	304

NPV Approximation using Annuities

Annuities, Capital Recovery Factor (CRF) = 0.1023			
Investment	$0	Sum:	
Expenses	$-1,100		$-300
Savings	$400	NPV = Sum / CRF:	
Energy value	$300		$-3,000

Investment = Installed Cost - Debt Principal - IBI - CBI
Expenses = Operating Costs + Debt Payments
Savings = Tax Deductions + PBI
Energy value = Tax Adjusted Net Savings
Nominal discount rate = 9.06%

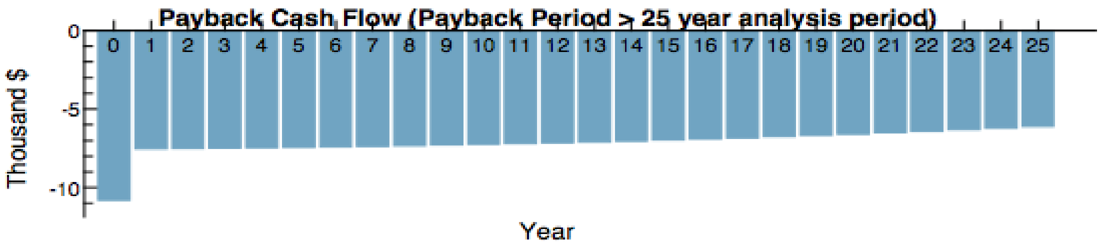


Table 3: simulation 60°

Furthermore, System Advisory Model helped in generating a monthly consumption of electricity for houses with PV panels and houses with out PV panels in respect to the given tilt angle, for instant for 30° tilt angle the highest electricity consumption is in July for houses with out PV is $339 while houses with PV panel is $247 in July while highest electricity consumption in July for 60° for houses with out PV is $339 and $281 for houses with PV panels. Taking the highest and the lowest tilt angle we will notice a difference in the consumption of electricity per month for houses with PV panel. Houses with PV and a tilt angle of 30° consume $247 while houses with 60° tilt angle consumes $281. There is a difference of $34 in the month of July, in other words 30° tilt angle is the best ultimate tilt angle in Cyprus.

5. CONCLUSION

It is mentioned at the previous chapters that, the most important is to know your region in order to decide on correct installation of the photovoltaic PV panels. Optimum tilt angle can be changeable according to the latitude of the place. When viewed from the world map, latitude of the places decreases from North Pole to the equator. At the same time, conversely solar irradiation increases. The increase in solar irradiation is showing a warming of the climates gradually in the regions from north to south. Optimum tilt angle of any region is calculated by knowing the latitude of the region. At the summer times, due to the angle of the sun is higher; the angle of the panel should be lower -15 degrees of latitude to be parallel to the sun. On the other hand, sun is lower compared to the summer times. For this reason, the angle of the panels should be +15 degrees of the latitude to be parallel. For example latitude of Cyprus is 35°N that is mentioned at the previous chapters. It is calculated that summer tilt angle should be 20° and winter tilt angle should be 50° for receiving the maximum sunshine. While latitude of England is 50°N. By the way, summer tilt angle should be 35° and winter tilt angle should be 65° for the England. In order to decide the number of panels, electric usage of the building should be known. At the end of finding the optimum tilt angle of the regions and the electric usage amount; location/position of the panels should be decided for the installation. If the number of panels are too much to install on the roof surface, and there is enough space at ground and facade; installation can be done as ground mount installation and facade installation.

The importance of architecture occurs in such a situation. If panel application is designed during the design of the buildings, sufficient need of angle and space area is provided by the architect. This kind of design can influence design positively in two ways. Both building perceived aesthetically and sufficient space is provided for panels. Eventually, PV panels can be concluded that some principles/rules are similar in both hot and cold climates. The important fact is knowing the region in which hemisphere. At hot climates, panels should be well ventilated in order to reduce the temperature of the cells. For instance in Cyprus, temperature of cell's increase to 65°C at the summer times. There should be appropriate gap between the panel and the roof surface. Otherwise, at cold climates, there is no need to leave gap between the panel and the roof surface. In contrast to hot climates, panels can provide extra insulation for the building if attached to the roof.

Because of the high latitude of colder countries, optimum tilt angle of panels are higher compared to the hot climates.

Lastly, the type of cell selection plays an important role during the installation. Amorphous thin-film is both efficient in hot and cold climates but at thin-film panels more installation area is needed. Therefore, cost of the panels will increase. Otherwise, mono-crystalline cell type's efficiency is decreases at too hot climates. Furthermore, mono-crystalline cell type is more appropriate for colder climates. On the other hand, poly-crystalline cell type is suitable both for cold and hot climates.

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