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Optimum Tilt Angle for Photovoltaic Panels in Famagusta, Cyprus

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Abstract: **This examination gives assessments of photovoltaic (PV) Panels ideal tilt angles for Famagusta Cyprus. As indicated by the discoveries, previously structuring the PV Panels to the rooftop or Facade or to the site, it is most essential to know the scope of the place. The reason is to locate the right ideal tilt angle. As per the examinations, tilt angle that is known as slanted edge of the photovoltaic (PV) Panel, is variable because of the location, climatic conditions and the sun radiation. In Cyprus, tilt point is 20° in summer and 50° in winter. Then again, if the panels are fixed in North Cyprus, ideal tilt point will be taken somewhere in the range of 28° and 30°. Another critical angle to be considered in the installation of PV panel is the orientation of the PV panels. This is on the grounds that; PV panels ought to be situated to south direction in Northern Hemisphere and toward the north direction if the area is in Southern Hemisphere. Sun radiation ought to be considered to know the sun-powered radiation adds up to choose the right PV panel type and size. In the meantime, power use of the building ought to be ascertained with the end goal to discover board numbers to install.**

Keywords: **Tilt angle, PV system, Solar Photovoltaic, Solar radiation.**

1. INTRODUCTION

Environmental problems and increasing energy consumption costs escalation create a number of fundamental problems in electric power production. Thus, renewable energy plays an important part in the future, surpassing all or part of conventional energy sources. Solar energy deserves much more attention because of its clean, non-polluting, and sustainable use, and other advantages. It is a unique energy that fundamentally solves the energy crisis as well as the environmental problems. Solar radiation differs with geographic latitude, time of a day and seasons due to the various sun positions. To maximize the collection and use of solar radiation, a PV panel should be installed at the appropriate tilt angle and orientation under various circumstances.

Photovoltaic (PV) panel usage in the world is keeps increasing daily. Therefore, photovoltaic (PV) installations were started especially in recent years in Northern Cyprus. Like other developed countries such as Germany, England and America. However there are still lots of errors during the installation of the photovoltaic (PV) panels, significant errors done by companies and personnel. These errors are wrong PV cell selection, wrong installation spaces and orientation of the PV panels and also wrong tilt angle.

Recently, many researchers have searched for the optimum tilt angle of photovoltaic (PV) panel. Dixit used the artificial neural network (ANN) estimator taking the H_g, φ and E_L of the site as inputs, to estimate the optimum tilt angle almost instantaneously while testing.

A lot of studies have given equations that allow for the theoretical calculation of the optimal tilt angle over time of a solar collector based on Earth-sun geometry (e.g., Kern and Harris, 1975; Koronakis, 1986; Lewis, 1987; Gunerhan and Hepbash, 2009; Chang, 2009; Talebizadeh et al., 2011; Yadav and Chandel, 2013). Many of this these studies have derived simple linear expressions of optimal tilt angle versus latitude. However, optimal tilt depends not only on latitude but also on weather conditions, including cloud cover and the altitude above sea level. Because of the difficulty in

determining optimal tilt angle as a function of cloud cover and weather conditions, calculators such as PVWatts (NREL, 2017), are often used to estimate optimal tilt angles at specific locations. Here, we first use PVWatts to estimate 1–4 optimal tilt angles for each country of the world.

Because of the lot of errors that are done during the installation, case studies are selected from different cities around the world and the different ways they used to determine the optimal tilt angle will be used to solve this problem for Famagusta. Aim of the research paper is to provide designers here in Famagusta with the accurate and correct information about the optimal tilt angle for all the seasons experienced in Famagusta.

2. LITERATURE REVIEW

As per Beyit and Dervişoğulları (2009) with the end goal to deliver 1kWp, 7-9m2 panels of modules are required at mono-crystalline silicon to give 11-16% vitality effectiveness. Furthermore, 8-9m2 panels modules required at poly-crystalline silicon (EFG) to be 10-14% vitality effective. Thirdly, 11-13m2 panels modules required at thin-film copper-indium-dieseline to be 6-8% vitality effectiveness. Thin film is less efficient than mono-crystalline and poly-crystalline. In any case, thin film is both reasonable for high temperature situations (hot climatic areas) and shade shadow conditions. Appropriately; vitality creation is increased when sun based radiation is high. Incidentally, if the sun based radiation is higher, most extreme vitality creation is created. Along these lines, top power is the most extreme created control vitality by a solitary module. Previously, introducing the photovoltaic modules; the area of the house and the accessibility of sun based vitality ought to be explored (crest control). Pinnacle intensity of Cyprus can be considered as a normal of 5 hours. Also, edge of the photovoltaic (PV) modules must be found. These edges can be found by utilizing designs that is indicating sun based board plots for different northern scopes. For example Karpaz is situated in 35°N scope of North Cyprus. So boards should confront south. For better productivity; between months April and October, slanted edge must be somewhere in the range of 10° and 25°. Then again, between months November and March, slanted edge ought to be somewhere in the range of 25° and 55°. For Cyprus, introduction of the slanted point can be 45°. As an answer, edges can be planned moveable as per the bearing of the sun (Angle can be 35° and 45°).

Kumar, Thakur, Makade and Shivhare (2011) contend that photovoltaic exhibits should have been tilted at the right edge to boost the execution of the framework. This can be known as the slanted point of the photovoltaic modules. With the end goal to locate the tilted edge a few figurings required. Month to month normal every day sun based light parts ought to be noted. Khatkar Kalan (Punjab) that is an area in Indian State of Punjab. It is discovered that the ideal tilt edge changes between 60.5◦ (January) and 62.5◦ (December) consistently. In winter (December, January, and February) the tilt ought to be 57.48◦, in spring (March, April, and May) 18.16◦, in summer (June, July, and August) 2.83◦, and in harvest time (September, October, and November) 43.67◦. The yearly normal of this esteem was observed to be 30.61◦ which is almost equivalent to the edge chose at Khatkar Kalan. Scope and Longitude of Punjab is noted as 30°4'N, 75°5'E.

Mousazadeh, Keyhani, Javadi, Mobli and Abrinia (2009) contemplated on the sun trackers gadgets. In like manner sun trackers are such gadgets for expanding the vitality effectiveness and productivity enhancement. Regular developments of earth and day time influence the vitality proficiency. (Sun based radiation expands the vitality creation). Know that sun trackers keeping the best introduction with respect to the sun. Moreover, sunlight based trackers not prescribed utilizing for little sun oriented boards in light of high vitality misfortunes. The most effective and well known sun following gadget was established to be as polar hub and azimuth/rise types.

As indicated by Rakovec, Zaksek, Brecl, Kastelec and Topic (2011), climatic, geological and topographical assortments can cause changes in the photovoltaic (PV) potential. Slovenia is chosen as a contextual investigation with the end goal to comprehend the changes. At the introduction of the board, in winter, vast tilt and south-bound introduction is required then again, in mid years, level establishment of board is favored. Slovenia has 45.5°N and 47°N scope. Normal scope is noted as 46°N. Coincidentally, on 21th March and 21th September tilt point of PV board will be 44°. On 21th of June (summer) tilt edge will be 20.5° and on the 21th of December, tilt edge determined as 67.5° (winter). Diverse atmosphere qualities impact the ideal tilt. (Grade edge) "It is imperative to stretch those ideal introductions and tilts are emphatically influenced by neighborhood climate and climatic conditions."

Makrides, Georghiou, Zinsser and Werner (2007) contemplated that temperature is an extraordinary factor that influences day by day and occasional execution of PV boards. For example, module temperature of PV boards reach to 70°C in Cyprus particularly at noontime hours in late springtimes. Two urban communities are contrasted all together with comprehend which boards are more proficient. Cyprus and Germany is chosen as a contextual analysis. Distinctive sorts of mono-crystalline, poly-crystalline and thin-film introduced at both Nicosia and Stuttgart. Therefore, Mono c-Si and thin-film advances have best execution for the two nations.

Kelly and Gibson (2011) contemplated on four indistinguishable photovoltaic exhibits with the end goal to expand the sun based photovoltaic vitality catch at various seasons including shady, sans cloud and bright climates. A few estimations were done inside a characterized course of events with the end goal to discover which sort of tilt edge is appropriate for radiant and shady days. Incidentally, it is more productive to plan DTS setup (level plate sun based gadget pointed specifically towards the sun) amid the bright days since daylight is caught twice contrasted with the H arrangement (Solar cluster with an even tilt, 0° pointed towards the apex). Also, H setup (Solar exhibit with a flat tilt, 0° pointed towards the peak) builds the sun based vitality catch by about 40% at overcast days. Amid the longitudinal examination strategy period, 4 kind of indistinguishable PV exhibits structured looking to south. Multi-crystalline (mono-crystalline) cells that are known as the most productive cell type were utilized. Clusters made by 10 modules. As indicated by Kelly and Gibson (2011); tilt point is set equivalent to the site scope. Study is done at Milford which has 42°N scope. Amid the study 57° tilt point given to initially exhibit, 42° tilt edge to second cluster, 27° to third cluster and in conclusion 0° given to the fourth exhibit. Toward the finish of the study, it is comprehended that tilt point would be 18.9° in the season June (summer) and 64.2° in December (winter). Coincidentally, tilt edge 27° that is given to number 3 exhibit is the nearest cluster to DTS condition (level plate sun based gadget pointed straightforwardly towards the sun) close sun powered twelve on 21th June. The cluster with a tilt edge of 57° that is given to number 1 exhibit is nearest to the DTS condition close sun powered twelve on December 1. At the end, sun based following frameworks with current innovation can build the sun powered vitality catch by 30% versus a settled south-bound scope tilt establishment in the US. Also, sunlight based following frameworks increment vitality catch on overcast days.

Chang (2010) examined on various seven destinations of Taiwan with the end goal to discover appropriate the yearly ideal points. Mono-crystalline silicon type PV boards utilized and also, PC subprogram is utilized to account climatic conditions and scope of each site. Chang (2010) contends that the ideal yearly tilt point is roughly equivalent to the scope of the area. Toward the finish of the review, yearly ideal tilt plot for Taipei is 18.16°, Taichung is 17.3°, Tainan is 16.15°, Koosiung is 15.79°, Hengchung is 15.17°, Hualian is 17.16° and Taitung is 15.94°. The most minimal ideal tilt edge is noted as 15.17° for Hengchung yet the most astounding electrical vitality (kWh/m2) is 233.81.

As indicated by Mieke (1998), tropical atmosphere (like Malaysia) has high surrounding temperature and moistness amid wet seasons. Along these lines, amid wet seasons A-si (Amorphous) cluster delivers up to 20% more vitality than P-si (Poly-crystalline) exhibit.

In the meantime as indicated by Akhmad et al. (1997), A-si (Amorphous) modules might be more suited to tropical atmospheres.

Amin et al (2009) contends that indistinct silicon, Copper Indium Diselenide (CIS) have preferable execution proportion over mono and multi-crystalline silicon sun oriented cells in Malaysia atmosphere conditions.

As indicated by Azhar et al (2012), poly-crystalline (P-si) cell type has higher power yield proficiency contrast with mono-crystalline (M-si) and nebulous (A-si) in abnormal state of normal sun oriented radiation. (Hot atmospheres) On the other hand, poly-crystalline has low power yield contrasted with M-si and A-si photovoltaic modules. Furthermore, mono-crystalline power yield is better in high normal sunlight based radiation. Anyway control yield of cells drop as the module temperature achieves high qualities. As it tends to be contrasted and P-si and A-si, Mono-crystalline creates more warmth than alternate modules. Thirdly, shapeless power yield is better in low force of sun powered radiation than poly-crystalline and mono-crystalline. Be that as it may, in high normal sun based radiation, vitality yield of undefined is bring down contrasted with P-si and M-si. Indistinct has a cooler module temperature than pol-crystalline and mono-crystalline.

Toward the finish of the writing audit; nobody looked at the use of PV boards in hot and cool atmospheres. Coincidentally; "Correlation of Photovoltaic (PV) Panel Usage in Different Climates" is chosen as theory subject.

3. METHODOLOGY

Solar energy incident on solar PV surface is sum of beam and diffuse radiation. For maximized output from a PV system, it is important to understand the degree of dependence of solar radiation and inclination angle of PV system. In past few years, many simulation, modeling and experiment have been carried out to determine or estimate the solar radiation on inclined surface. All these research and experiment have specific technique and measurement. Some of these are not sufficient in their scope for determining the optimal tilt angle. In this work, PV simulation software will be used to determine average solar radiation on different tilt. And from this the maximum annual average solar radiation on different tilted surfaces will be obtained to determine/estimate optimum tilt angle.

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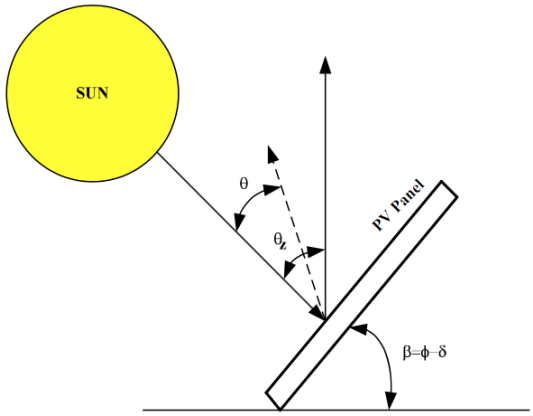

Fig 1: Incidence and tilt angels

Incidence angle is used in the design of solar energy systems

With the use of simulation software data was collected about the

Gazimağusa, Cyprus - Sunrise, sunset, dawn and dusk times, table

Future | Past

Date	Sunrise	Sunset	Length	Change	Dawn	Dusk	Length	Change
Today	06:36	16:32	9:56		06:08	17:00	10:52	
+1 day	06:37	16:32	9:55	00:01 shorter	06:09	17:00	10:51	00:01 shorter
+1 week	06:41	16:32	9:51	00:05 shorter	06:13	17:01	10:48	00:04 shorter
+2 weeks	06:46	16:34	9:48	00:08 shorter	06:18	17:03	10:45	00:07 shorter
+1 month	06:53	16:44	9:51	00:05 shorter	06:25	17:12	10:47	00:05 shorter
+2 months	06:44	17:12	10:28	00:32 longer	06:17	17:39	11:22	00:30 longer
+3 months	06:12	17:41	11:29	01:33 longer	05:46	18:07	12:21	01:29 longer
+6 months	*05:31*	*19:54*	14:23	04:27 longer	*05:01*	*20:24*	15:23	04:31 longer

Notes: *Daylight saving time*, * = Next day.

Fig 2: Gazimagusa, Cyprus sunrise, sunset, dawn and dusk times, table. (GAISMA2018)

Gazimağusa, Cyprus - Sunrise, sunset, dawn and dusk times, graph

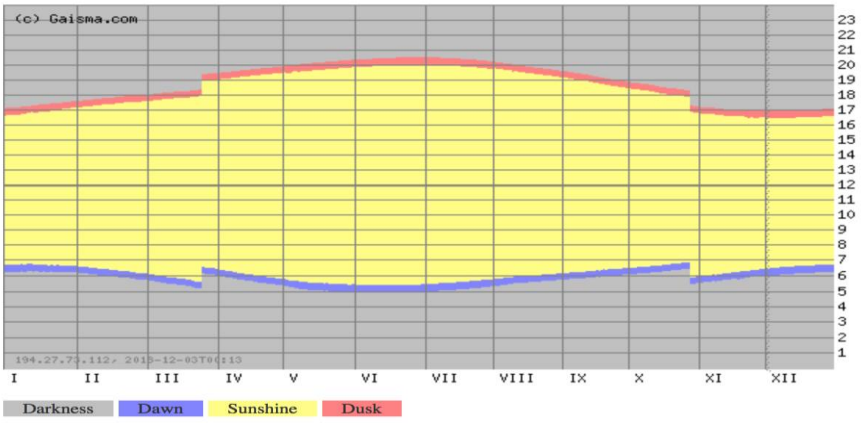

Fig 3: Gazimagusa, Cyprus sunrise, sunset, dawn and dusk times, graph(GAISMA2018)

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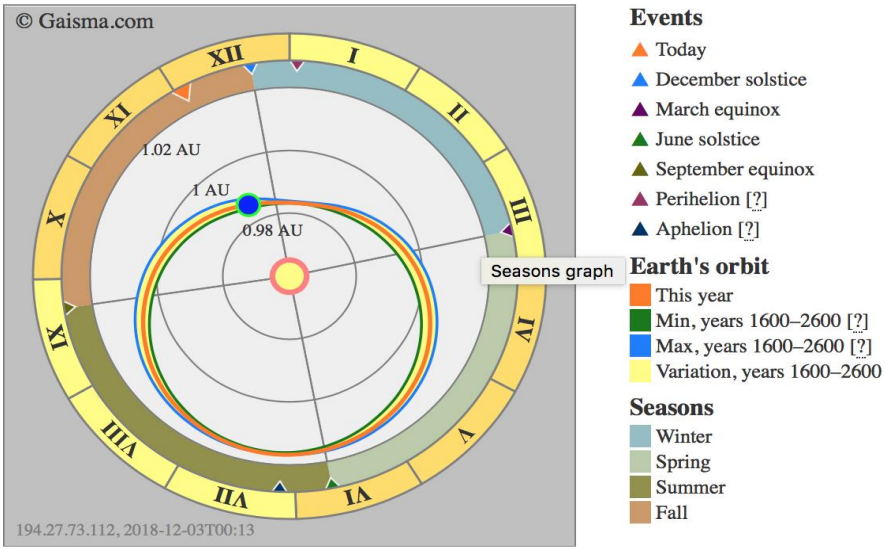
Gazimağusa, Cyprus - Seasons graph and Earth's orbit



Notes: Earth's orbit is highly exaggerated for illustrative purposes.

Fig 4: Famagusta seasons graph and earth's orbit (GAISMA2018)

Gazimağusa, Cyprus - Solar energy and surface meteorology

Variable	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Insolation, kWh/m²/day	2.50	3.45	4.76	6.06	7.21	8.00	7.99	7.33	6.10	4.49	2.98	2.26
Clearness, 0 - 1	0.50	0.54	0.58	0.61	0.65	0.70	0.71	0.71	0.69	0.64	0.55	0.49
Temperature, °C	12.94	12.63	14.14	17.25	20.94	25.15	28.48	28.84	26.48	22.87	18.41	14.66
Wind speed, m/s	6.31	6.69	5.85	5.14	4.82	5.06	5.55	5.44	5.03	4.73	5.31	5.99
Precipitation, mm	87	66	49	24	13	3	0	2	4	29	54	101
Wet days, d	11.1	10.0	8.0	4.7	2.6	1.1	1.1	1.6	1.3	3.8	6.0	10.9

These data were obtained from the NASA Langley Research Center Atmospheric Science Data Center; New et al. 2002

Fig 5: Gazimagusa, Cyprus solar energy and surface meteorology (GAISMA2018)

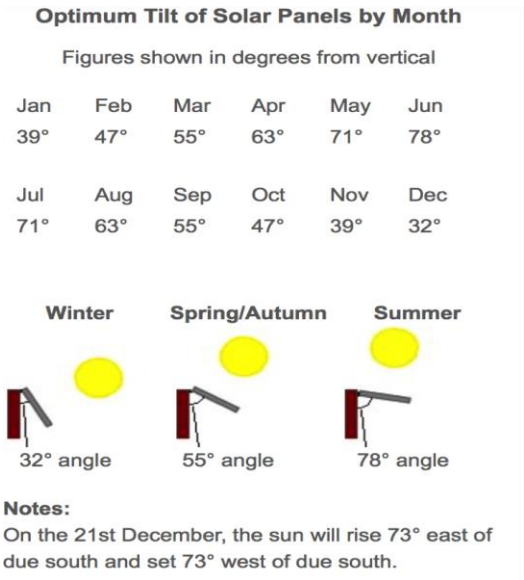


Fig 6

4. RESULTS AND CONCLUSION

There are various ways to determine the optimum tilt anle for photovoltaic panels. A lot of investigators have investigated this there some equations that have been generated for this particular purpose. The created equation can compute not just the optimum tilt angle when the sun oriented board is expected south in the Northern Hemisphere and due north in the Southern Hemisphere, yet in addition it could ascertain the optimum tilt when the board pushes toward the west or toward the east. This equation finds the optimum tilt angle with any introduction for the sunlight based board while the standard guideline is only for due south or north. The outcomes demonstrate that the deviation increments as the surface azimuth angle moves from due south in the Northern Hemisphere or moves from due north in the Southern Hemisphere. The outcomes demonstrate likewise that estimations of the optimum tilt angle for various azimuth angles join to a similar point at the north and south poles where there is no impact for the azimuth angle. With the use of the data collected optimum tilt was found for every month of the year and different seasons of the year

And based on this simulated data the average angle for the 3 seasons is calculated and it therefore the optimum best for fixed photovoltaic modules, this angle is 55 degrees. This is the angle that the photovoltaic module will harness or be used most efficiently all year round.

Energy generation utilizing solar PV technologies can be improved by setting the PV system inclination to the optimum tilt angle for the whole year. In this examination, we have favored the PV recreation programming to compute optimal tilt angle. This simulation result can be taken as reference for researchers, PV installer and designers keen on introducing photovoltaic exhibits to introduce it at an ideal tilt to get the boosted solar energy which brought about greatest PV power yield. The utilization of solar energy as an elective energy source in Famagusta could help the development of occupation populaces lives inside these territories.

REFERENCES

[1] C. Y. Lin and D. Syrgabayeva, “Mechanism of environmental concern on intention to pay more for renewable energy: Application to a developing country,” *Asia Pacific Manag. Rev.*, vol. 21, no. 3, pp. 125–134, 2016.

[2] R. G. Vieira, F. K. O. M. V. Guerra, M. R. B. G. Vale, and M. M. Araújo, “Comparative performance analysis between static solar panels and single-axis tracking system on a hot climate region near to the equator,” *Renew. Sustain. Energy Rev.*, vol. 64, pp. 672–681, 2016.

[3] R. Karkee, S. Khadka, G. Luitel, M. Devkota, and B. Khadka, “Comparing and Optimizing of Solar Insolation on Yearly , Monthly and Seasonally Basis for Solar Devices Performance in Nepal,” no. 1, pp. 26–33, 2017.

[4] C. B. Christensen and G. M. Barker, “Effects of tilt and azimuth on annual incident solar radiation for United States locations,” *Proc. Sol. Forum 2001*, pp. 225–232, 2001.

[5] H. P. Garg, “Treatise on Solar Energy: Fundamentals of Solar Energy,” vol. 1, pp. 375– 381, 1982.

[6] S. A. Kalogirou, *Solar Energy Engineering: Processes and Systems*, Second. Oxford, UK, 2014.

[7] M. Suri, T. Huld, T. Cebecauer and E. Dunlop, “Geographic Aspects of Photovoltaics in Europe: Contribution of the PVGIS Website”, IEEE J. Sel. Topics Appl. Earth Observations and Remote Sensing, Vol.1, No.1, pp.34-41, March 2008.

[8] G. Notton, C. Cristofari, M. Muselli, P. Poggi and N. Heraud, “Hourly Solar Irradiation Estimation: From Horizontal Measurements to Inclined Data”, in IEEE-ISEIM, Corte- Ajaccio, France, 2006, pp.234-239.

[9] Dinesh Kumar Sharma, et al., Review and Analysis of Solar Photovoltaic Softwares, International Journal of Current Engineering and Technology, Vol.4, No.2 (April 2014), E-ISSN 2277 – 4106, P-ISSN 2347 – 5161.

[10] Qais Azzam Khasawneh, et al., Determining the Optimum Tilt Angle for Solar Applications in Northern Jordan, JJMIE, Vol. 9, No. 3, June.2015, ISSN 1995- 6665,Pages 187 – 193.

[11] Vijaya Lalita. P et al. Energy and Comfort Management in Energy Efficient Buildings Using RETSCREEN Software-A Case Study Analysis, Int. Journal of Engineering Research and Applications, ISSN : 2248- 9622, Vol. 3, Issue 6, Nov-Dec 2013, pp.378-381.

[12] Creating Low-Cost Energy-Management Systems for Homes Using Non-Intrusive Energy Monitoring Devices, Rebecca L. Sawyer, Jason M. Anderson, Edward Lane Foulks, John O. Troxler, and Robert W. Cox 978-1-4244-2893-9/09/ 2009 IEEE.

[13] Mahendra Lalwani, et al., Investigation of Solar Photovoltaic Simulation Softwares, IJAER Volume 1, No 3, 2010, ISSN - 0976-4259.

[14] Nwokocha CO, et al., Estimation of solar radiation in South eastern Nigeria. International Journal of Natural and Applied Sciences 2009; 5 (3):223-8.

[15] Hamid Moghadam, et al., Optimization of solar flat collector inclination, Desalination 265 (2011) 107–111. [11]. Hamdy K. Elminir, et al., Optimum solar flat-plate collector slope: Case study for Helwan, Egypt, Energy Conversion and Management 47 (2006) 624–637.

[16] Adnan Shariah, et al., Optimizing the tilt angle of solar collectors, Renewable Energy 26 (2002) 587–598.

[17] Lave M, Kleissl J., Optimum fixed orientations and benefits of tracking for capturing solar radiation in the continental United States. Renew Energy 2011; 36:1145– 52.

[18] Ekadewi A. Handoyo, et al., The optimal tilt angle of a solar collector, Energy Procedia 32 (2013) 166 – 175. [15]. Murat Kacira, et al., Determining optimum tilt angles and orientations of photovoltaic panels in Sanliurfa, Turkey, Renewable Energy 29 (2004) 1265–1275.

[19] Jasmina Radosavljević, Amelija Đorđević, Defining of the intensity of solar radiation on horizontal and oblique surfaces on Earth, Working and Living Environmental Protection Vol. 2, No 1, 2001, pp. 77 – 86.

[20] Abdul Qayoom Jakhrani, et al., Estimations of incident solar radiation on tilted surface by different empirical models, International Journal of Scientific and Research