Comparative Studies on Integration of Photovoltaic in Hot and Cold Climate

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Abstract- **Photovoltaic modules (panels) have potentiality of generating clean, silent, electricity without burning of fuel fossil which may cause tremendous damage to our natural environment. When photovoltaic is integrated in building envelope, it would serve a dual purposes, first generate electricity secondly serves as a building element. For the photovoltaic integration to fulfill its optimum goal it should uplift building appearance, and enhance aesthetic quality and flexibility of the building. The objective of this research is to investigate the efficiency of photovoltaic integration in building in hot and cold climates, and how could it be optimized for sustainable development. The methodology adapted was based on comparative case studies of office buildings from hot climate, where Sudan was chosen as case study area, and for cold climates NCC Office building in Finland. It was discovered that thin film PV panel is more appropriate for hot climates and polycrystalline for cold climates.**

***Index Terms*— Mono-crystalline, Poly-crystalline, Thin film, PV Integration, Efficiency**

I. INTRODUCTION

Photovoltaic is beautiful, tidy, immaculate, safe and effective tool that has been used in building for long time. Technological development that occurs in building material and construction technology made photovoltaic cells appropriate to be integrated in building envelope.(1) Until recently researchers concern on energy efficiency and utilization of renewable resources in building concentrates mostly on residential buildings. Notable advancement was made in the issue of subsidizing energy use in small scale residential building. Now days , researchers interest shifted from a small housing to larger public building types, this is more obvious and appropriate due to a tremendous increase in the population growth rate of people living in large cities across the world. (2) Generally, photovoltaic operates by converting energy from solar radiation in to electricity. PV panels have no mobile parts it operates silently without any noise emanating from them, and required less maintenance cost, without giving off greenhouse gasses or any pollutants as in fossil fuel generators. (3) The International Energy Agency (IEA) proposed that, if solar energy is amicably utili it could supply up to 11% of the world electricity production in the year 2050.This could only be achieved in situation where by many countries, encourages investments in renewable energy sector (PV panels) in the next 5-10 years, and reducing investment expenses. (4) & (URL.1) In building integrated photovoltaic(BIPV) system, PV panels are installed to substitute building fabric, therefore it serves as a climatic barrier for the building occupant, hence,and generates electricity, therefore, contribute as a cost effective element in built environment. (5) & (6)

1.1 STATEMENT OF THE PROBLEM

Photovoltaic modules (panels) have potential of generating clean electricity without burning of fuel fossil which may cause tremendous damage to our natural environment. When photovoltaic is integrated in building envelope, it would serve a dual purposes, first generate electricity secondly serves as a building element. For the photovoltaic integration to fulfil its optimum goal it should affect building appearance, enhance its aesthetic quality and flexibility. This research aimed at comparing photovoltaic integration in hot and cold climate to find out the most suitable type of photovoltaic is most efficient to be used in each of the two climates. The research would put more emphasis on building façade integration.

1.2 RESEARCH OBJECTIVE

The objective of this research is to investigate the efficiency of photovoltaic integration in building in hot and cold climate, and how could they be optimized for sustainable development.

1.3 RESEARCH QUESTIONS

1- Is it possible to generate same quantity of energy from photovoltaic in both cold and hot climate?

2- How could we improve photovoltaic integration to achieve sustainable development?

3- What type of photovoltaic is efficient in each of cold and hot climate?

1.4 RESEARCH METHODOLOGY

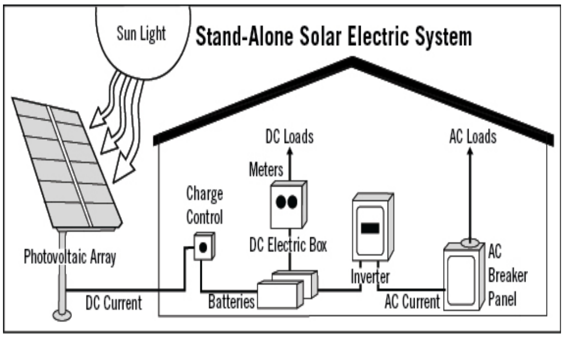
The research methodology adapted in this research work is based on intensive literature review, comparative studies of various cases studies of photovoltaic integration of photovoltaic in cold and hot climatic regions, to arrive at final outcome.

II. LITRITURE REVIEW

2.1 PHOTOVOLTAIC TECHNOLOGY

Photovoltaic generates electricity through changing solar energy in to direct electric current by utilizing semi-conductors that exhibit the Photovoltaic properties. Photovoltaic power production uses solar panel made up of solar molecules comprising photovoltaic materials. Materials employed in photovoltaic cells production includes Môn crystalline silicon, polycrystalline silicon, etc.(7) Even though most photovoltaic cells utilized nowadays are from similar base material (silicon) but various technologies give cells their peculiar notables qualities. The most popular cells type used to days are; monocrystline cells these are of the size of 10 cm x 10 cm, their efficiency is between 14 % to 17% this is under European weather condition, can generate energy of 900- 1000 kwh for each installed cell. Polycrystalline cells of same size have efficiency of 12% and able to generate 750 to 800 Kwh, finally thin film silicon is normally fixed on above glass characterized by transparent metal coat, these cell efficiency is between 5%-8% and can generate 600 to 800kwh. (8)

Photovoltaic application can be categories as off grid and grid system. Off grid system is applied in residential setting or small scale building located far away from any national grid connection. This system normally supply energy for house hold use only, as shows in figure 1, In grid system photovoltaic provide energy to structures that are already connected to national grid .Moreover this system provide energy for residential, industrial and commercial buildings. The energy generated here normally more than the required quantity, therefore the surplus quantity is sent back to the national grid.(9) See figure2.



Figure, 1- off- grid system
Source: (Enlighten power solution)

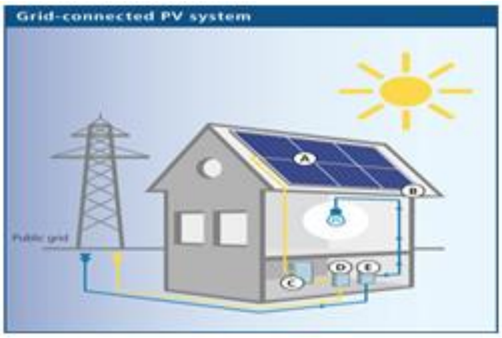


Figure2.Grid connection photovoltaic systems
source: (2015 Sharp Electronics.)

2.2 TYPES OF PHOTOVOLTAIC CELL

Photovoltaic cells can be grouped into crystalline silicon, thin-film technology and nano solar cell.

Crystalline solar cell is produced from chemical compounds, because silicon cannot be found in its pure form in nature. However its production involved a series of refining production processes which made it to be relatively expansive.(10)

2.2.1. MONOCRYSTALLINE SOLAR CELLS

Was first produced in 1955, it resample's polycrystalline in its performance, efficiency and reliability, it is produced in circular form and then cut to the required sizes and form to avoid loss; it is available in dark blue colour. (URL.2) Môn crystalline molecule installation is expansive but has high efficiency in generating energy.(11) Môno crystalline cell of 10 cm X10 cm, with thickness of 360 micron, having efficiency of 14%-17% can produce 900-1000 kw/h when working under European climate (12) it is less tolerant to high temperature, because at high temperature it produces less energy, however this type of solar cell is more efficient in use under cold and clear sky days.

2.2.2. POLYCRYSTALLINE SOLAR CELLS

Polycrystalline, cells are connected in series, they are relatively cheap if produced in mass, but in situation where individual produced the cost will be higher. The demerits of polycrystalline cell is that their efficiency is 12- 14% less than that of Môn crystalline. (URL.3) Polycrystalline cells of 10cm x 10cm with efficiency of 12% can produce an energy of 750-850 kw/h when operates under European weather condition. (13) It is more widely used in cold climates due to its less production cost compared to Môn crystalline, and relatively efficient and it could be used in hot climate too if it is well ventilated.

2.2.3. **THIN FILM TECHNOLOGY**

It is produced through fixing thin layers of semiconductors materials in strong material base. Its thickness is approximately on micron. Even though it is less efficient than polycrystalline and Môn crystalline, but it has better brighter future prospective, because it can be used in large energy power stations. Moreover, thin film can be produced in mass due to its raw material cheapness and availability. (14) This cells have merits of dependency on incidence radiations and temperature however can efficiently operate in over shading. Variability in its shape made it more flexible in use. (15) Presently the modern thin film is produced from amorphous silicon and its alloys. However, thin film have attained efficiency of 13% in lab scale.(16)This type of cells are widely used in hot climates for its tolerance to high temperature , efficiency under low solar energy radiation intensity and its more economically wise. See figure 3

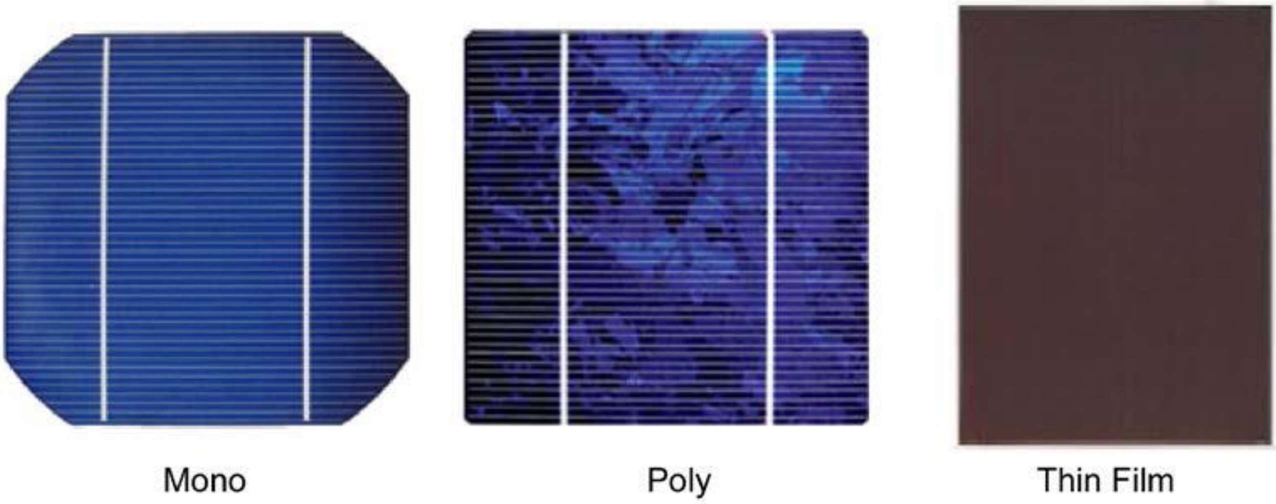


Figure 3 : Types of photovoltaic cells
Source: http://www.pvsolarchina.com.

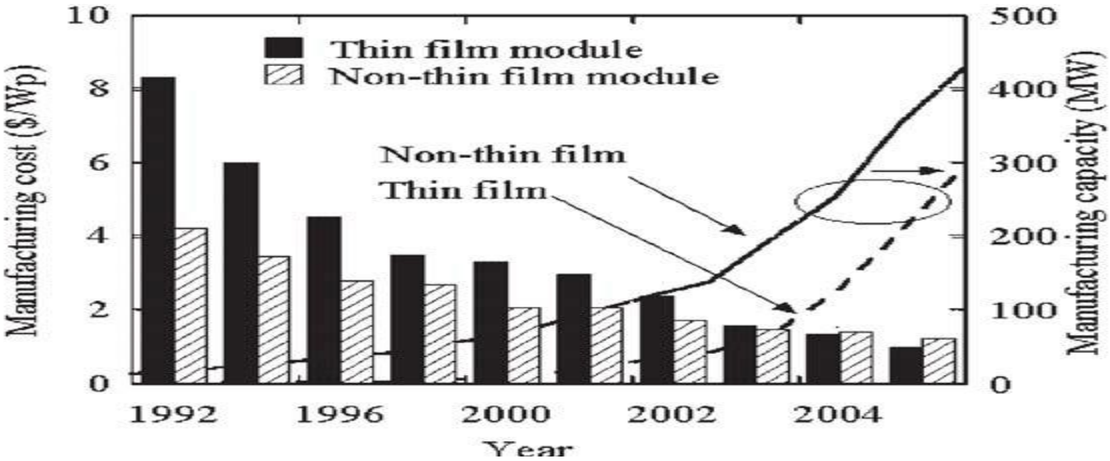


Figure 4 : Comparing manufacturing costs for thin film and non-thin film
(Source: Chopra, Paulson and Dutta 2004, 71)

Table:I PV, Solar cells efficiency

	Type	Appx. Cell Efficiency	Appx.modular Efficiency	Area Requirement
1	High performance hybrid silicon		17-18%	6-7m^2/kW_p
2	Mono-crystalline silicon	13-17%	12-15%	7-9m^2/kW_p
3	Polycrystalline silicon	12-15%	11-14%	7-10m^2/kW_p
4	Thin-film CIS		9-99%	9-11m^2/kW_p
5	Thin-film CdTe		6-8%	12-17m^2/kW_p
6	Thin-film amorphous silicon		5-7%	14-20m^2/kW_p

Source:(Roberts and Guariento; Thomas et al., 2001)

Source: Roberts and Guariento, Thomas et al, 2001

2.3 **BUILDING INTEGRATED PHOTOVOLTAIC (BIPV)**

In this system, photovoltaic serves both as generating electricity means and building structure element, good examples of PV integration are, roofing, atrium, façade and shading devices. Photovoltaic in addition to its power supply, it however, contributes to the aesthetics and prestige values of the building .(17)In (BIPV) system PV serve as climatic barrier, therefore it is necessary that the rain tightness and durability should be adequately considered, air gap should be left under the solar cell or panel to allow air circulated to be cold down as high temperature reduces the efficiency of mono- crystalline and polycrystalline cells, high temperature have less effect on thin film cells.(18) The challenges faces PV is shading from neighbouring buildings most especially in highly dense urban areas, other problems are orientations, tilt angle, therefore it is important for system designer to generate checklists to reduce these challenges for the entire PV system to work efficiently. (19)

2.3.1 PHOTOVOLTAIC PRODUCTION OPTIMIZATION

For BIPV to be optimized, the designer must compromise between quantity of energy generated out of PV and the architectural environment where it is going to be installed in, however the choice of the best technology of BIPV depends on the following variables:-

1- **Orientation**: - the quantity of solar radiation falling in the module surface depends on its orientation and its angle of inclination, however as the integration environment distance from equator increased the more steeper their angle of inclination increase.

2- **Shading** :- shading have negative impact on the yield of PV, panel or molecule, therefore it should be avoided by good planning, shading may be caused by vegetation's, neighbouring buildings, new building, dirt or dust accumulations can reduces PV efficiency..(URL.4)

4- **Temperature: -** the cell temperature in most instances higher than lab temperature which is 25 C degrees, this lead to reduction in cells efficiency. This reduction in turn increased the payback period, therefore make the system inefficient for users.(20)

5- The incident solar radiations on PV panels fixed in the building façade in most instance is not perpendicular to the façade surfaces, therefore this decreased the intensity of solar radiation to the cell .(20,21)

2.4 TYPES OF INTEGRATION

2.4.1 FAÇADE INTEGRATION

Façade integration system can be done in various techniques, these includes integral vertical and sloppy glazing modules. PV can be integrated in our contemporary modern façade system as curtains wall. When PV panels substitutes conventional building material, labour, and installation cost will be reduced. Also tremendous development have been achieved in BIPV to serve as multi-functional element to generate energy, serve as thermal insulation material, protect building interior from weather elements and noise control.(URL.5) See figure 5

Figure, 5: Façade integration
Source: (Green ability commercial ecosense)

2.4.1.1 **VERTICALL WALL**

In this system PV panels served as curtain walls, PV is either semi- transparent or opaque PV modules could be utilized as cladding finishes to wall surfaces as well and generate energy. However with applying standards PV modules sizes, a façade would be transformed to a very beautifully appealing, highly technical and smart. (22, 23)See figure 6&7

Figure6 : PV integrated into the opaque parts of the façade
Credit: http://csc.esbensen.dk/.

Figure 7: Tobias Grau Production Building in Germany has PV integrated into it south glazed facade Credit: http://csc.esbensen.

2.4.1.2 .**PV INTEGRATION IN INCLINED WALLS**

When photovoltaic is integrated in inclined building facades it adds to its aesthetic qualities, in addition to its functionality which entailed the optimum orientation of PV molecules or panels to attract maximum intensive solar radiations from incident ray.(URL.6) One of the interesting examples of inclined wall integration is Solar- Fabrik Building Freiburg, Germany, PV panels of an area of 575 meter squares are integrated to cover the whole façade of the building. PV panels produces one- fifth of the building consumption of electricity. PV panels are however, also mounted in front of the wall facing south direction at an angle in a manner to shield glazed building in summer from solar radiation incident at higher angle. During winter, the sun incident is at lower angle, therefore sun penetrates deep in to the building interior, to heat the building passively.(URL.7) See figure 8.

Figure 8 : Inclined PV integrated façade of Solar-Fabrik building, Freiburg, Germany Credit: http://www.solar-fabrik.de/.

Another example is Daxford Solar Office Building, here PV is installed in the façade is inclined at an angle of 60 degrees, to fulfil the following, first to ensure that PV obtain maximum solar radiations, secondly to address the problem of any visual discomfort that might be caused in form of glare. However so far daylight penetrates south façade through PV panels bands, in normal days, therefore there will be no need for artificial elimination.(24)See figure 9

See figure 9: PV integrated inclined wall of Daxford Solar Office Credit: superstock.com/

2.4.1.3 **PHOTOVOLAIC AS SHADING DEVICES**

PV cells can be integrated in building to serve as shading element as well and to generate electricity. The integration can be in different shapes, sizes, colours and patterns. PV panels can be semi-transparent, or opaque, however they can be installed to shad south, west and east façade and produce large quantity of electricity too. (25) PV cell when integrated in window could create a semi- transparent facade. However these types of applications serve as shading element. PV cell laminated with Glass could substitute cladding element, they could be used as sky light or clerestories so far they are not design as see through (26) see figure 10.

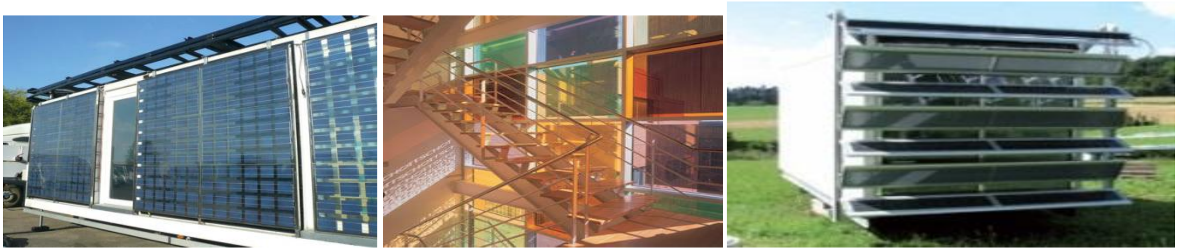


Figure 10 PV integration as a shading device and in windows

Source: (Handbook for Solar Photovoltaic (PV) Systems)

2.6.1. PHOTOVOLTAIC EFFICIENCY

For PV system to be highly efficient in hot climate, there is a need for molecules or arrays back to be ventilated when temperatures are high, ventilation can be done either bay passive means, that is raising the PV molecules to allow air circulation to pass through the molecules back, hence reduced its temperature or by active means, through permitting fan to blow air to the back, or passing pump water to the back of the panel. (URL 8). See figure 11 below

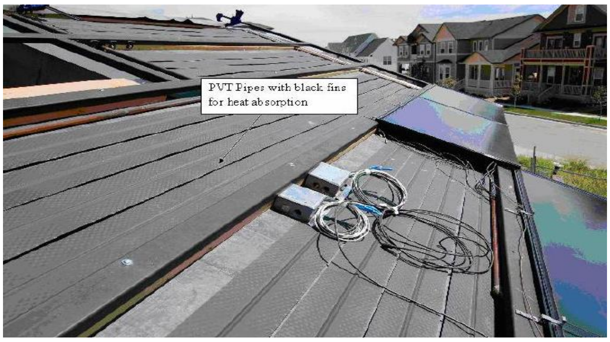


Figure 11: PVT system with pipes and fins on the University of Colorado 2007 Solar Decathlon house

Source: (Horizon Renewals, 2013)

Polycrystalline operates in an average sun radiation exhibits higher energy outcome than Môn crystalline and thin film technology, however, in situation where by solar radiation is low, its outcome generation the less than the other two PV panels. It is molecular temperature is lower than Môn crystalline but a little bit higher than thin film technology. Therefore this is an indication that its efficiency in hot climate is better than Môn crystalline but less than thin film.

Môn crystalline generates more energy under high solar radiation, it produces less than polycrystalline at higher temperature, and it creates more heat than the two former ones as it operates.

Thin film technology panels have the ability of producing more energy in cloudy days and under high temperatures in hot regions, but at high solar radiation it produces less than the other two.(27)

2.6.2 PHOTOVOLTAIC PANELS COST

There are wide range of PV available in market today, Môn crystalline PV though very efficient but relatively more expansive than the others, due to its complex and expansive production process. However, despite its high cost still remain the most favourable one due to tremendous improvement it attaints, in reduction of wafer thickness and increase in surface area from 100 cm square to 240 cm square (28) Môn crystalline characterized by its high efficiency, uniform shapes, and highly durable; for polycrystalline has a low maintenance cost, and long life span functionality. Thin film costly effective, light in weight highly flexible in use. The table II shows the most familiar PV technology used today.(URL.9) S

Table.II

PV CELL	Môn crystalline	Polycrystalline	Thin Film
Typical module efficiency	15-20%	13-16%	6-8%
Best research cell efficiency	25.0%	20.4%	13.4%
Area required for 1 kWp	6-9 m2	8-9 m2	13-20 m2
Typical length of warranty	25 years	25 years	10-25 years
Lowest price	0.75 $/W	0.62 $/W	0.69 $/W
Temperature resistance	Performance drops 10-15% at high temperatures	Less temperature resistant than Môn crystalline	Tolerates extreme heat

Source: http://energyinformative.org/solar-cell-comparison-chart-mono-polycrystalline-thin-film/.
Information date is for 2013.

2.6.3 PV PANELS OPTMUM TILT ANGLE & ORIENTATION

Equator passes through the earth planet dividing it in to two equal parts, named northern hemisphere located north to equator and south hemisphere located south to equator. The optimum orientation in situation where the panel is in northern hemisphere is that the panel should face true south direction, if the panel is in southern hemisphere, it should however, face true north direction. Books and articles advised that tilt should be plus +15 in winter and minus -15 in summer. (URL.10) Duffie and Beckman (1991) advocated that optimum orientation for PV panel in northern hemisphere is towards south direction. However panels are installed in reference to this mentioned law. Fixing of PV panels is normally attributes to their positions due to equator. Moreover, optimum tilt angle is defined as the angle by which panels receive maximum solar radiation.(29) See figure 12

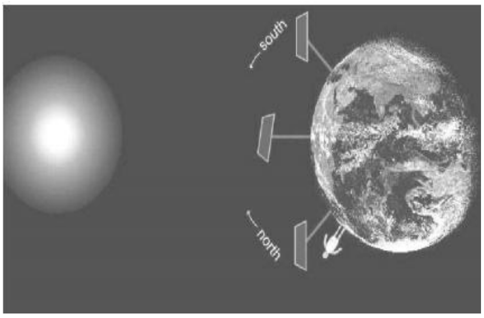


Figure 12: Figure Orientation in Northern and Southern Hemisphere (Sundays, 2013)

Tilt angle seem to be subject of argument among many researchers, Lewis (1987) recommended that tilt angle is minus -8 in summer and plus +8 in winter. Yellot (1973) advocated that tilt angle could be plus and minus (±20°). (30) In line with the thumb rule PV panels are installed at tilted angle nearly equal to the latitude of the PV location area and facing south. (31) See figure 13

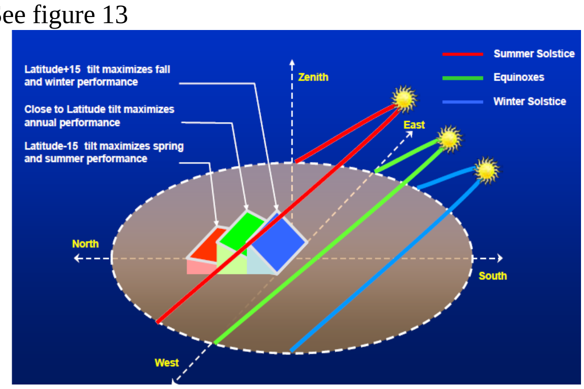


Figure 13; Array Tilt Angle Affects Seasonal Performance (Brooks, Dunlop, 2012)

The quantity of solar radiations received by PV panel depends to great extent on the following factors:-

1- Position or orientation of the PV panel.
2- Angle tilt of the panel.
3- Geographical location.(32)

In order to obtain maximum solar radiation optimum tilt angle should be used. The two case study areas are Sudan for hot climate and Finland for cold climate. The table below used here is from statistical data base of NASA. (33) As shown in the Table 3 below.

Table 1 Solar radiation received, based on annual fixed tilt and monthly optimum angles in Finland and Sudan (kWh/m²/day) [57].

Month	Finland		Sudan	
	Tilt Ang 45	Opt Ang	Tilt Ang 15	Opt Ang
January	0.79	0.9	6.15	6.79
February	2.03	2.17	6.66	6.92
March	3.53	3.57	7.04	7.05
April	4.69	4.71	7.04	7.17
May	5.44	5.7	6.81	6.85
June	5.27	5.74	7.13	7.13
July	5.2	5.55	6.53	6.55
August	4.4	4.5	6.1	6.31
September	3.33	3.34	6.39	6.4
October	1.89	1.96	6.51	6.64
November	1.15	1.29	6.37	6.92
December	0.59	0.69	5.95	6.7
Annual	3.2	3.5	6.55	6.78

Table III : Optimum Tilt angle in Sudan and Finland
Source: Amogpai, A (2011)

III. CASE STUDY OF HOT CLIMATE

3.1 NATIONAL TELECOMMUNICATION HEADQUARTERS OF SUDAN

The construction of the 29 storey office building tower was to accommodate National Telecommunication Headquarter Sudan, the construction of elegant building started in May 2007.The aluminium system of (BIPV) was supplied by Sapa a Swedish based company. The photovoltaic panels are a total of 1400 panels,, it was rated in 2009 as world second largest thin film BIPV application, producing 104.67 KWP per year. A bout 2000 square meter Sapa system was utilized to create this interesting façade. (URL.11)

Because of the semi desert climatic condition of Khartoum city, which characterized by very high temperature, a amorphous silicon (thin film) cells were adapted in this building, instead of mono & poly crystalline which have higher efficiency than thin film, this due to the fact that mono & poly crystalline have greater tendency for exhibiting lower efficiency as the climate temperature escalates more than lab temperature of 25 degrees. However, it must be noted that thin film is more tolerant to high temperature, cloudy condition and even dusty environment than the other two types. Hence, all these factors made thin film inevitably the most suitable choice in the building. The table below show some fact about the project. See table IV

Systems provided:

aSi standard panels		
Opaque	600 panels	83.8 Wp
See-through	600 panels	81.0 Wp
aSi corner panels		
Opaque	100 panels	30.0 Wp
See-through	100 panels	27.9 Wp
Total installed capacity		104.67 kWp

Table IV: Technical information
Source: Sapa building system

A   B

Figure 14: A shows see through thin film type
Figure 13: B shows opaque thin film type

IV. CASE STUDY OF COLD CLIMATE

4.1 NCC HEAD OFFICE, HELISINKI, FINLAND

NCC Office building is site occupied 30000 square meter, located near the centre of the city of Helsinki, the building was commissioned in 2004, the aim of PV integration in building is meant as environmental responsive and for aesthetics aspiration. The planning of PV integration has been considered since the initial design stage of the building. The building accommodates 400 employees. However, the integration is adapted as racks on flat roof and smaller area of windows of the building, because building regulation of the town doesn't permit glass facade. The following table shows technical information about the PV integration.(34)

It must be noted that panels are installed high in the roof top, it cannot be seen by visitors' who are coming to the building, but it can be visually seen by people in neighbouring buildings and from a distance by people driving cars from metro, bicycle riders and so on. Polycrystalline photovoltaic is chosen here due to its relatively high efficiency in cold weather moreover it is more economically viable compare to mono-crystalline which is although highly efficient but very expansive. However, building regulation of the city have limited the PV panel integration if not the building would have produce more electricity. See table

PV location:	On racks on the flat roof and window integrated.
Cell type	Polycrystalline silicon
Orientation and tilt:	139 m^2 (165 modules) South facing with 45° tilt and 8 m^2 (7 modules) East facing with 90° tilt
Inverters:	6 inverters of type SWR 2500
Installed power:	16,5 kWp on the roof, 0,8 kWp on the windows.
Production:	1124 kWh (8.9.2004 - 11.10.2004)
Cost per m^2:	1020 €
Cost per kWp:	8.500 €

Table V: Technical information

Figure 14: NCC head office.(Amogpai, A ,2011)

Figure 15: Roof-line with PV installations.(Amogpai, A ,2011) ***Roof-line with PV installations.* (Amogpai, A ,2011)**

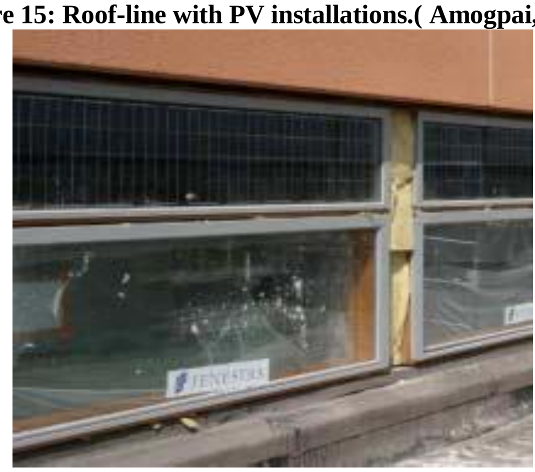


Figure 16: Window integrated PV installation. ***.PV installation on roof.* (Amogpai, A ,2011)**

(SOURCE: AMOGPAI, A 2011)

VDISCUSSION

All PV panels can generate energy both in hot and cold climates, but their efficiency differs, under optimum cell temperature of 25 degrees Môn crystalline is the most efficient, followed by polycrystalline then thin film. In hot climate thin film is the most efficient among the three types. For PV panels to receive optimum solar radiations the sun radiation incident angle must come perpendicular to the PV panel face. Cold clear day produce more energy output and hot overcast day produces less energy. For solar cell to optimally operate the cell temperature should not be more than the lab temperature which is 25 degree centigrade, increase above 60 degrees cause the cell to lose 0.5% efficiency decrease for any degree centigrade increase. PV cell installed in hot climate should be ventilated; however, the ventilation should be to the cell back by leaving gap of at least 15 cm.

5.1. COMPARISON OF PV INTEGRATION IN HOT AND COLD CLIMATE

S/ No	characteristics	Hot climate Project	Cold climate project
1	Lactation/Name	Sudan/ Telecommunication tower	Finland/ NCC Office Building
2	Climate type	Hot	Cold
3	Hemisphere	North	North
4	Integration type	Facade	Roof
5	Cell type	Thin film	Polycrystalline
6	Tilt angle	23.5	45
7	Shading	No shading	No shading
8	Ventilation	Need ventilation	No need for ventilation
9	PV orientation	To the south	To the south
10	Radiation angle	High	low

Table 6: Comparison between PV integration between Sudan and Finland

V. CONCLUSION

As it has been stated previously in literature review, 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, cheap and can operates even when the climate is cloudy and dusty, therefore in Sudan Telecommunication tower it is been used, due to the fact that the weather is semi desert, very hot, dusty in summer, therefore, thin film is highly recommended in hot climates. 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.

In cold climate the most recommended type of PV panel according to the literature is poly-crystalline, because it is efficiency is high in cold climate and more economically wise and it has longer life span. But it must be noted that all the three types can effectively operates in cold climate, but if we considered both efficiency, economical and payback time poly crystalline is the best. But all types can be jointly used in different ways in cold climate.

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REFERENCES

[1] Kiss, C & Kinkhead, J (1995) ''Optimal building-integrated photovoltaic applications'' .pp 1. Kiss Company Architects, New York.

[2] Henstnes , A . G. (1999) .'' Building Integration of Solar Energy Systems''. Journal of Solar Energy, 67(4-6), pp181, available at: www.elsevier.com/ locate / solener

[3] Li, D.H; Chow, S.K & Lee, E. W (2013) ''An analysis of a medium size grid- connected building integrated photovoltaic (BIPV) system using measured data''. Energy and Building journal vol.60 pp 383- 387 available at : www.elsevier.com/locate/enbuild

[4] Dincer, F (2011) ''The analysis on photovoltaic electricity generation status, potential and policies of the leading countries in solar energy''. Renewable and Sustainable Energy Review. Vol.15 pp 713-720 available at: www.elsevier.com/locate/rser

[5] Peng,C ; Huang,Y & Wu,Z (2011) ''Building-integrated photovoltaic (BIPV) in architectural design in China''. Energy and Building Vol 43 pp 3592–3598.

[6] Jelle, B.P & breivik, C (2012) ''State-of-art-the-art building integrated photovoltaic''. Science Direct. Energy Procedia Vol. 00 pp 3&4. Available at: www.sciencedirect.com

[7] Chu, Y (2011) ''Review and comparison of different solar energy technology.'' pp 18. Research Associate ,Global Energy Network Institute.

[8] Fuentes, M. (2007).'' Integration of PV into the built environment''. Available at : http://www.brita-in-pubs.eu/bit/uk/03viewer/retrofit_measures/pdf/FINAL_12_Integration_of_PV_red_kth_rev1.pdf. [Accessed 6 March, 2014].

[9] Zahedi, A, (2006) ''Solar Photovoltaic (PV) energy; latest developments in the building integrated and hybrid PV system''. Renewable Energy Journal 31(2006) pp 711-718 Available at: www.elsevier.com/locate/renene.

[10] Weller, et al (2010) ''Photovoltaic : Technology, Architecture, Installation. Typesetting & production Simone Soesters.

[11] Abdelkader, M. R; Al-Salaymeh, A; Al-Hamamre, Z ; & Sharaf, F (2010) A comparative Analysis of the Performance of Monocrystalline and Multiycrystalline PV Cells in Semi Arid Climate Conditions:the Case of Jordan. Jordan Journal of Mechanical and Industrial Engineering. Volume 4, Number 5, November 2010 ISSN 1995-6665 Pages 543- 552

[12] Dobrazanski, L, et al, (2012) Investigation of various properties of Môn crystalline silicon solar cell .Journal of Achievements in Materials and Manufacturing Engineering. Vol. 55 Issue, 2, p 1-9

[13] Thomas, R., Fordham, M. & Partners (eds.) (2001). Photovoltaic's and Architecture, London: Span Press.

[14] "Taking Off of New Photovoltaic Energy Revolution," Japan 21st, May 1996.

[15] Schristian, s (2003). Solar Architecture.(Strategies, Visions and Concepts). Publisher, Architecture Based. Boston, Berlin , Germany. PP 13 & 14.

[16] Dobrazanski, L, et al, (2012) Monocrystalline Silicon Solar Cells Applied in Photovoltaic System. Journal of Acheivements in Materials and Manufacturing Eng. Vol. 53 Issue, 1, pp1-7.

[17] Wolter, N (2003) Options for Integrating PV into Your Building. Available at:

[18] Jellea, B.P & Breivik, C (2012) State-of-the-art building integrated photovoltaic. Energy Procedia 20 (2012) pp 68 – 77

[19] Zomer,C.D et al (2013) Performance compromises of building-integrated and building-applied photovoltaic's (BIPV and BAPV) in Brazilian airports. Journal Energy and Buildings, Vol. 66 pp 607–615

[20] Kelly, N. J (1998)Towards A design Environment for Building Integrated Energy Systems : The Integration of Electrical Power Flow Modelling With Building Simulation. Unpublished PhD Thesis in Mechanical Engineering, University of Strathclyde, Glasgow, UK.

[21] Clarke J A, Hand J W, Johnstone C M, Kelly N J and Strachan P A,(1996)The Characterisation of photovoltaic-integrated building facades under realistic operating conditions, Proc. 4th European Conference on Solar Energy in Architecture and Urban Planning, Berlin, March.

[22] Fordham, M (1999) Photovoltaic's in Buildings A Design Guide. Publisher, Crown Copyright 1999

[23] Basnet, A (2012) Architectural Integration of Photovoltaic and Solar Thermal Collector Systems into buildings. Unpublished Msc Thesis, Norwegian University of Science and Technology.

[24] Phillips, D (2000) Lighting Modern Buildings. Architectural Press.

[25] Ghazali, A.M.& Abdul Rahman, A (2012) The Performance of Three Different Solar Panels for Solar Electricity Applying Solar Tracking Device under the Malaysian Climate Condition .Energy and Environment Research; Vol. 2, No. 1; 2012 .ISSN 1927-0569 E-ISSN 1927-0577.Published by Canadian Center of Science and Education.

[26] Cousins, P.J.; Smith, D.D.; Hsin-Chiao, L.; Manning, J.; Dennis, T.D.; Waldhauer, A.; Wilson, K.E.; Harley, G. & Mulligan, W.P. (2010). Generation 3: Improved Performance at Lower Cost, Proceedings of 35th IEEE Photovoltaics Specialists Conference, pp. 278-278, ISBN 978-1-4244-5890-5, Honolulu, Hawaii, USA.

[27] Duffie, J.A. & Beckman, W.A. (1991), Solar Engineering of Thermal Processes, 2nd ed., Wiley Inter science, ISBN 0471510564, New York (USA)

[28] Lewis G. (1987), "Optimum tilt of a solar collector. Solar and Wind Energy", Vol 4(No 3), pg. 407-410

[29] Yellott H. (1973), Utilization of sun and sky radiation for heating cooling of buildings. ASHRAE Journal 15 (1973) 31 .

[30] Mehleri E. D., Zervas P. L., Sarimveis H., Palyvos J. A., Markatos N. C. (2010), "Determination of the optimal tilt angle and orientation for solar photovoltaic arrays", Renewable Energy 35, p. 2468-2475

[31] Viitanen, J; Amogpai, A; Puolakka, M & Halonen, T (2010) Photovoltaic Production Possibilities and its Utlization in Office Buildings in Finland. International Review of Civilo Engineering. (I.R.C.E), Vol. 2, No. 1 pp 52-59.

[32] Zhao, O; Wang, P; & Goel, I (2010) Optimal PV panel tilt angle based on solar prediction. In IEEE 11th International Conference on Probabilistic Methods Applied to Power System (PMAB). IEEE. pp 425-430.

[33] Amogpai, A (2011)LED lighting combined with solar panels in developing countries. Unpublished PhD thesis, Aalto University

[34] Svensson, O and Wittchen, K. B (2004) Aesthetics of PV building integration. 5th FW Contract no. NNE5/2001/264 ,Fax Int. + 46 31 15 11 88 European Commission, DG Energy & Transport.

[35] URL.1http://www.euractiv.com/en/energy/solar-power/article-186329 (March 09,2010)

[36] URL.2- Solar, W. 2011. Three Photovoltaic Technologies: Monocrystalline, Polycrystalline and Thin Film [Online]. Available: http://www.wholesalesolar.com/Information-SolarFolder/celltypes.html [Accessed 21 December, 2014].

[37] URL.3- Solar Panels. Available at: http://www.innovativesolar.ca/documents/solarpanels.pdf.

[38] URL.4- Odersun. 2011. Manual for BIPV Projects.

Available at: http://www.odersun.com/uploads/pdf/Odersun-BiPV%20Manual-110902-EN-Download.pdf. [Accessed 10 December, 2014].

[39] URL.5. Krstic, A (n.d) Design and Construction Possibilities for Photovoltaic Integration in Envelopes of Existing and New buildings. Available at: http://www.doiserbia.nb.rs/img/doi/1450-569X/2007/1450-569X0716037K.pdf. (Accessed on 25-01-2015)

[40] URL.6.Solar fassade. 2011. Format and colour [Online]. Available: http://www.solarfassade.info/en/fundamentals/components/format_colors.php. [Accessed 27 December, 2014].

[41] URL.7- M9 Architects. 2009. State Vocational School [Online]. Available: http://www.m9-architekten.at/projekte/2001_imst-landesberufsschule/index.html. [Accessed 28 December, 2014].

[42] URL.8 Photovoltaic Efficiency: The Temperature Effect . Available at: http://yandex.ru/yandsearch?win=125&clid=1989274&text=Photovoltaic%20Efficiency%3A%20The%20Temperature%20Effect.

[43] URL9. Solar Cell Comparison Chart – Mono-, Polycrystalline and Thin Film. Available at: http://energyinformative.org/solar-cell-comparison-chart-mono-polycrystalline-thin-film/.

[44] URL.10 Optimum Tilt of Solar Panels, available at: http://www.solarpaneltilt.com/.

[45] URL.11. Sapa building system : Offices & Business Parks.

Available at: http://www.sapa-solar.com/pv-cells.html.