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ANALYZING AND OPTIMIZING THE ORIENTATION OF SOLAR CELLS USING HELIOSCOPE TECHNOLOGY

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ABSTRACT
Renewable energy is an alternative pathway to reduce greenhouse gas emissions and it also can help to meet the continuous increased electricity demand. According to the perspective of Bangladesh, solar energy is one of the most viable option for distant areas like rural areas, the Hill-districts and Haor regions, which will play a significant role to upgrade the living standards of the mass population of rural people. But installation place requirement remains an issue for small country like Bangladesh. Thus a optimal number of solar panels and their orientation has become a important factor. HelioScope is such technology to answer that question to certain extend. This software helps to find the maximum usage the available space. Southeast University's academic building has been considered to perform the simulation test. Total 180 solar panels has been found as the optimized number in 700 m^2 area considering shadow effect, tilt angel, solar irradiation, height of installation, solar reflection, temperature. Orientating the solar panels within the given area to achieve the maximum production of solar energy is the goal of this report.

Keyword: Renewable Energy, PV Solar, Electricity, HelioScope.

INTRODUCTION
Renewable energy is an alternative pathway to reduce greenhouse gas emissions and it also can help to meet the continuous increased electricity demand. The impacts of a global temperature boost on our condition have moved toward becoming clearer and progressively perceptible in late decades, with a great part of the issue brought about by human action. These impacts, together with the weight on accessible common assets on the planet, have clarified that we have to diminish our effect on our condition (Kanters, J., 2015). According to the perspective of Bangladesh, there are different types of sources for renewable energy. Solar energy is economically viable option for distant areas like rural areas, the Hill-districts and Haor regions, which will play a significant role to upgrade the living standards of the mass population of rural people. A large portion of the remote areas people are not likely to be covered by the national electricity grid network due to the inaccessibility and low consumer density. Solar energy technologies can be considered as viable technical options for remote off-grid areas. Deploying renewable energy technologies will not only provide electricity, but also it is likewise capable of bringing about change in the life of the mass people.

Bangladesh is a semi-tropical region country lying in the northeastern part of South Asia which gets an abundant amount of sunlight year-round. The average bright sunshine duration in Bangladesh in the dry season is about 7.6 hours a day, and in the monsoon season is about 4.7 hours. About 20%-23% people of the total population are still out of the coverage of the national grid electricity (Deb et al., 2013). Bangladesh is geographically located in degrees 20°34' and 26°39' North and longitudes 80°00' and 90°41' East. Thus, it is an ideal territory to use the sunlight to produce substantial amount of solar generated electricity. Furthermore, as it is a subtropical country, throughout the year abundant light is accessible for solar electricity production. In Bangladesh, the accessible sun based radiation is 4-6.5 kWh/m² which is most outrageous radiation. The significant amount of sun light is generated during March-April and least is in December-January (Anam, 2011).

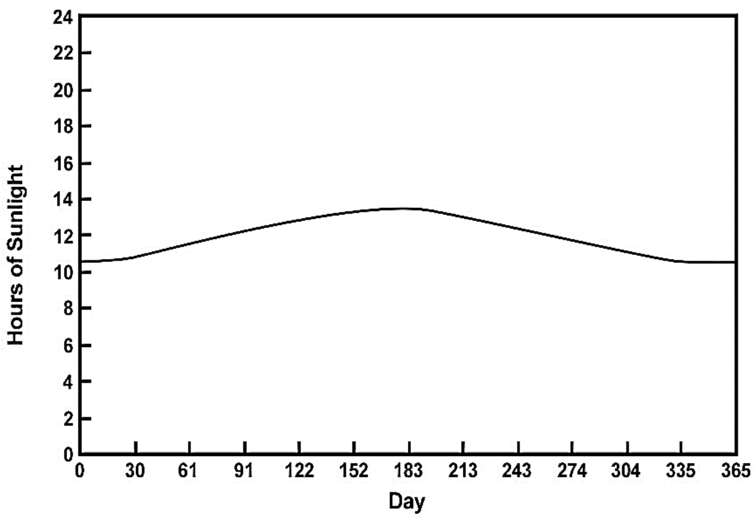


Figure-1: The amount of hours of sunlight in Bangladesh.

Solar energy refers to source of energy which can be directly attributed to the light of the sun or the heat that sunlight generates (Smith, 1995). Solar cell is an electrical device which converts the energy from the solar lights directly into electricity by the photovoltaic effect via physical and chemical phenomenon. The installation of solar energy technology has grown exponentially at the worldwide level in the course of the most recent decade (Timilsina et al., 2012).

In the twenty first century, we are going to encounter so many climate change issues as well ecological issues that we already started to face today. To protect ourselves, we will need a long haul potential activities and massive plan for our sustainability. We need to explore and utilize renewable energy sources in such a way where renewable energy source assets is seemed to be a standout amongst the most productive and viable arrangements. The current installed solar energy capacities for India and China are estimated to be 6 and 65 GW, respectively (Bergin et al., 2017).

Researchers had an experiment using the HelioScope software in India, it produced 15.33 MWh energy from 40 solar panel with 21^0 tilt. They used PVSyst and HelioScope to get the results (Goel and Sharma, 2020). On the other hand in Indonesia, Damiri and his team designed a solar system for Industrial Rooftop Building using HelioScope. The expected production was found to be around 56 MWh energy using 150 solar panels (Damiri et al., 2019). The ability to generate own demand electricity and it not be dependent on anyone. Renewable energy is an alternative pathway to reduce greenhouse gas emissions and it also can help to meet the continuously increased electricity demand. According to the perspective of Bangladesh, solar energy is one of the most viable. But the installation place requirement remains an issue for small countries like Bangladesh. Thus an optimal number of solar panels and their orientation has become an important factor. HelioScope is such technology to answer that question to a certain extent. This software helps to find the maximum usage of the available space. Southeast University's academic building has been considered to perform the simulation test. 700 m^2 areas are found for installation considering shadow effect, tilt angel, solar irradiation, the height of installation, solar reflection and temperature. Orienting the solar panels within the given area to achieve the maximum production of solar energy is the goal of this report.

MATERIALS AND METHODS

Tilt point of the photovoltaic (PV) array is the way to yield an ideal energy output. Sun panels or PV exhibits are most productive, when they are opposite to the sun's ray. The sun oriented azimuth edge is the azimuth edge of the sun, showing the heading of the sun, the most normally acknowledged show for sun powered radiation investigation is the north to clockwise, so the east is kept 90 °, the south 180 ° and the west 270 °.

HelioScope is a novel program developed by Folsom Lab USA for planning and evaluating the photovoltaic framework. It has a few highlights of PVsyst including the structure usefulness of AutoCAD, which enabled originators to do a total structure with one bundle. The area's location, exhibit arrangement, PV module and inverter particular are the principal sources of info required by HelioScope. This product enables the clients to gauge vitality creation that records for misfortunes because of climate and atmosphere. Concealing, wiring, segment efficiencies, board crisscrosses, and maturing can (likewise) be broken down to give proposals to gear and cluster format. These components show yearly generation, climate informational collection, execution proportion and other framework parameters to regenerate the results. HelioScope emulates as an electronic instrument, so there's no physical product is needed to download or install and we can utilize it from any associated PC rather than purchasing the program, you can pay a month to month or yearly expense. We have to enlist with a HelioScope to represent a 30-day preliminary variant which is very helpful for students to execute the experiments. HelioScope is a web-based tool. It uses weather files, shading analysis, physics of solar modules, wire resistance, and other factors to perform its simulation. HelioScope uses actual wire models and lengths based on the layout to calculate wire resistance, and hourly sunlight-electrical production values to determine current levels.

In this report, we analyzed different-different azimuth and tilt to get maximum power generation. The methodology system has been divided into three cases. It is found that azimuth 10 degree is better from other azimuth value. So, azimuth 10 degrees have been used in all three cases.

In this research project, our experiment is simulated on our Southeast University's academic building rooftop. Solar modules were simulated at three different tilt angles with same azimuth 10 to compare the energy production outcomes.

Case 1: Energy Production of PV cell installed at azimuth 10^0 and Tilt 2^0
Case 2: Energy Production of PV cell installed at azimuth 10^0 and Tilt 6^0
Case 3: Energy Production of PV cell installed at azimuth 10^0 and Tilt 10^0

The size of the roof is taken as 146`x52`. Row-to-row spacing is 4 feet, frame size 3 feet *6 feet wide and 3 feet above the ceiling with the position of the solar panel. No shading/ trees are found near the building roof.

RESULTS

Result analysis is essential because analytics assist humans in making decisions. Therefore, analyzing to produce the best results for the decisions to be made is an important part of the process, as is appropriately presenting the results. The result analysis is a part of a larger process of deriving any research.

Case 1

By Using HelioScope technology we are analyzing Southeast University campus roof's free space. Performance ratio was found 81.1% at the available space by utilizing 57.6 kW photovoltaic modules at a 10^0 azimuth. Below figure shows the solar panel orientation along with heat map.

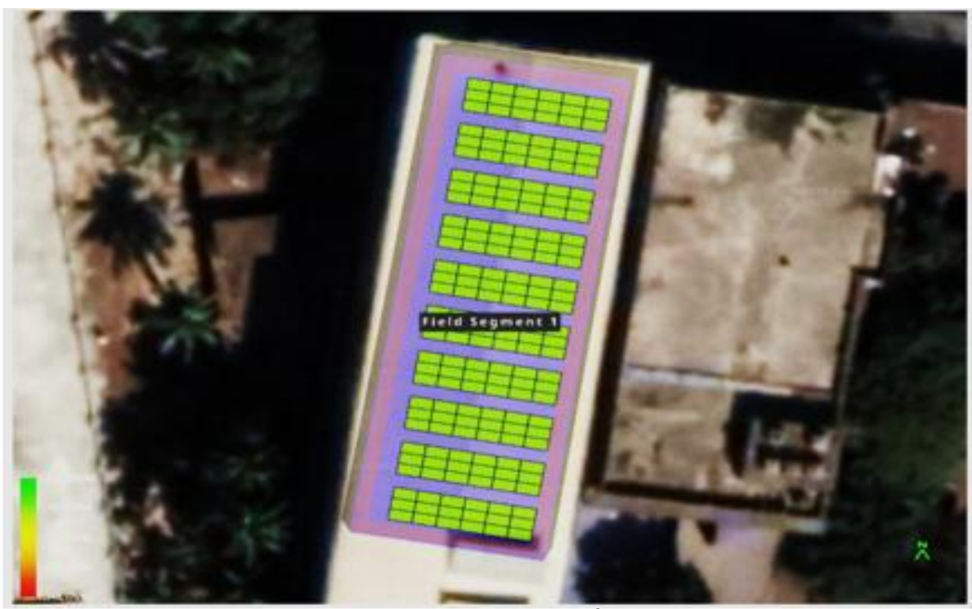
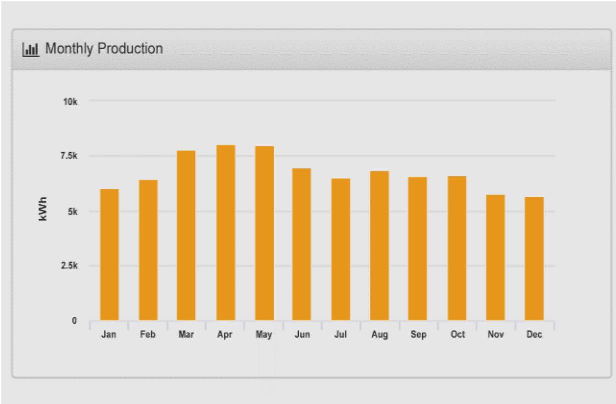


Figure-2: Heat Shading Map at Tilt Angle 2^0 (Case 1)

This simulation case 1 highest generation was found during the summer season (March-May) as expected and the lowest production from November- January.



Month	GHI (kWh/m²)	POA (kWh/m²)	Shaded (kWh/m²)	Nameplate (kWh)	Grid (kWh)
January	130.0	126.1	126.1	6,793.3	6,034.0
February	138.7	135.9	135.9	7,372.7	6,442.6
March	170.0	167.9	167.9	9,145.8	7,794.8
April	174.8	174.1	174.1	9,499.6	8,068.0
May	171.8	172.0	172.0	9,354.5	7,999.7
June	148.6	148.9	148.9	8,090.1	6,929.8
July	138.8	139.1	139.1	7,545.7	6,484.2
August	146.6	146.4	146.4	7,961.3	6,803.7
September	141.5	140.5	140.5	7,640.1	6,533.7
October	144.4	141.8	141.8	7,695.2	6,580.9
November	125.5	122.0	122.0	6,577.2	5,716.6
December	123.3	119.2	119.1	6,397.6	5,659.0

Figure-3: Monthly production for case 1

Our project considered the ambient temperature module to increase generation which can be calculated as follow:

$$T_m = E(e^{a+bWS}) + T_a \quad \ldots\ldots\ldots \quad (1)$$

Where, T_m is the module temperature (^{0}C), T_a is the ambient temperature (^{0}C), E is the solar irradiance on the module (W/m^2), W_S is the wind speed, a is the coefficient for which module temperature, and b is the coefficient for which module temperature drops with wind speed. By using equation (1) for module temperature, 8.1% loss was countered by an increased temperature caused by the reduced efficiency. Total loss is found 20.4%.

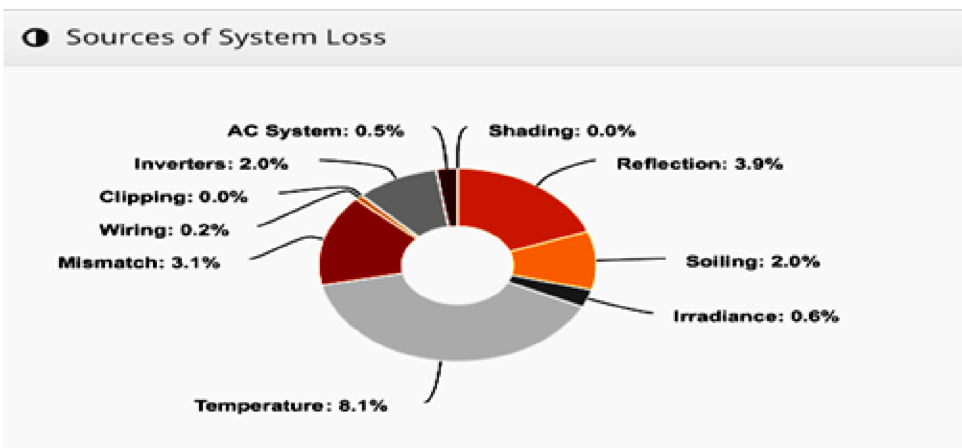


Figure-4: Overall system losses for case 1.

This Simulation output result total collector irradiance 1,632.2 kWh/m^2. Energy deliverable to grid is 81,047.1 kWh. Average Operating ambient temperature is 27.7^{0}C and average operating cell temperature is 37.7^{0}C.

Annual Production			
	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	1,754.1	
	POA Irradiance	1,734.1	-1.1%
	Shaded Irradiance	1,734.0	0.0%
	Irradiance after Reflection	1,665.5	-3.9%
	Irradiance after Soiling	1,632.2	-2.0%
	Total Collector Irradiance	**1,632.2**	**0.0%**
Energy (kWh)	Nameplate	94,073.0	
	Output at Irradiance Levels	93,497.1	-0.6%
	Output at Cell Temperature Derate	85,929.6	-8.1%
	Output After Mismatch	83,257.7	-3.1%
	Optimal DC Output	83,102.9	-0.2%
	Constrained DC Output	83,102.9	0.0%
	Inverter Output	81,454.3	-2.0%
	Energy to Grid	**81,047.1**	**-0.5%**
Temperature Metrics			
	Avg. Operating Ambient Temp		27.7 °C
	Avg. Operating Cell Temp		37.7 °C
Simulation Metrics			
	Operating Hours		4709
	Solved Hours		4709

Figure-5: Annual production (Case 1)

Case 2

In case 2 we have selected tilt angle 6^0 and analyze these objects to know the diffused solar radiation on PV modules and the impact on annual solar PV generation. Below Figure illustrate the shading heat map of the modules on the rooftop.

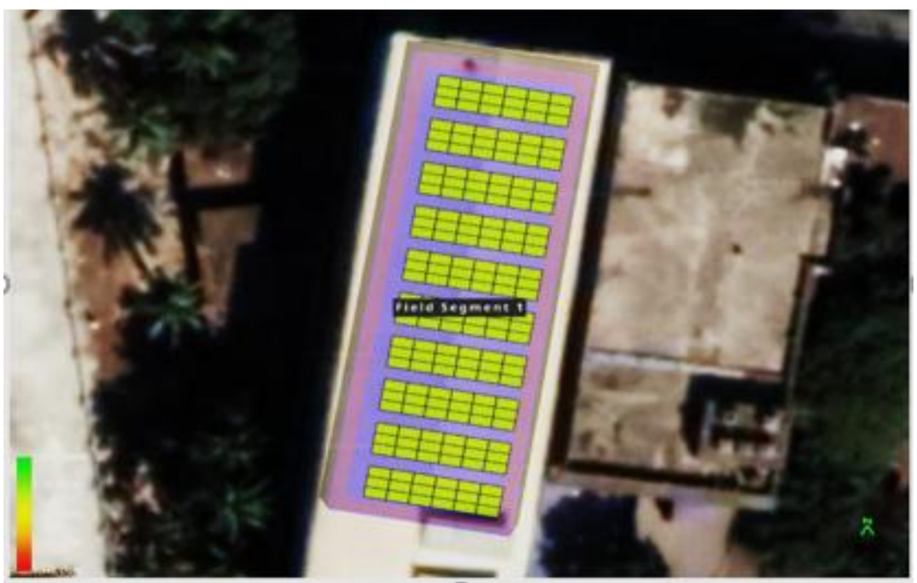
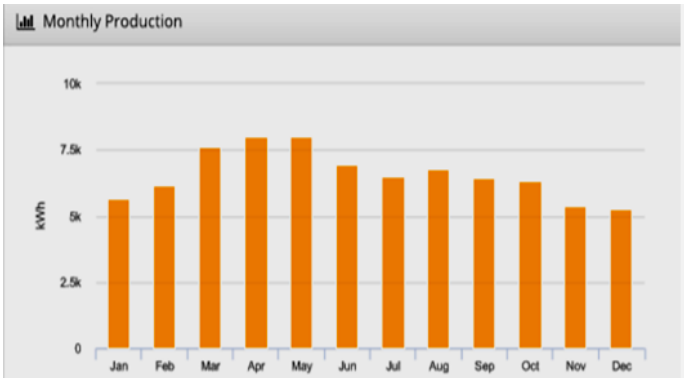


Figure-6: Heat Shading Map at Tilt Angle 6^0

In this arrangement the highest generation was found during the summer season (March-May) and the lowest production from November- January. Outcomes can be seen in the result



Month	GHI (kWh/m²)	POA (kWh/m²)	Shaded (kWh/m²)	Nameplate (kWh)	Grid (kWh)
January	130.0	118.2	117.9	6,327.3	5,636.4
February	138.7	129.9	129.6	7,025.0	6,160.7
March	170.0	163.4	163.0	8,881.3	7,593.3
April	174.8	172.2	171.8	9,386.5	7,989.3
May	171.8	172.0	171.4	9,348.5	8,005.4
June	148.6	149.4	148.9	8,112.2	6,955.3
July	138.8	139.3	138.8	7,555.4	6,501.3
August	146.6	145.6	145.2	7,913.9	6,773.9
September	141.5	138.2	137.8	7,502.5	6,432.9
October	144.4	136.3	136.0	7,370.3	6,321.8
November	125.5	115.0	114.7	6,162.9	5,373.8
December	123.3	110.6	110.4	5,897.8	5,233.0

Figure-7: Monthly generation production (Case 2)

This Simulation output result total collector irradiance 1,5873.3 kwh/m^2 and energy deliverable to grid 78,977.3 kWh. Average operating ambient is temperature 27.7^{0}C and average operating cell temperature37.4^{0}C.

Annual Production

	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	1,754.1	
	POA Irradiance	1,690.1	-3.6%
	Shaded Irradiance	1,685.7	-0.3%
	Irradiance after Reflection	1,619.7	-3.9%
	Irradiance after Soiling	1,587.4	-2.0%
	Total Collector Irradiance	**1,587.3**	**0.0%**
Energy (kWh)	Nameplate	91,483.6	
	Output at Irradiance Levels	90,876.7	-0.7%
	Output at Cell Temperature Derate	83,662.9	-7.9%
	Output After Mismatch	81,120.8	-3.0%
	Optimal DC Output	80,975.0	-0.2%
	Constrained DC Output	80,975.0	0.0%
	Inverter Output	79,374.1	-2.0%
	Energy to Grid	**78,977.3**	**-0.5%**
Temperature Metrics			
	Avg. Operating Ambient Temp		27.7 °C
	Avg. Operating Cell Temp		37.4 °C
Simulation Metrics			
	Operating Hours		4709
	Solved Hours		4709

Figure-8: Annual production (Case 2)

As the operating temperature drops off a bit from 37.7^{0}C to 37.4^{0}C but system loss almost remains same. The average operating ambient temperature is 27.70C. The direct irradiance on a panel or Plane of Array (POA) is the irradiation coming directly from the sun multiplied by the cosine of the angle of incidence which has increased by 3.6% at 6^0 tilt angle (Singh and Banerjee, 2016).

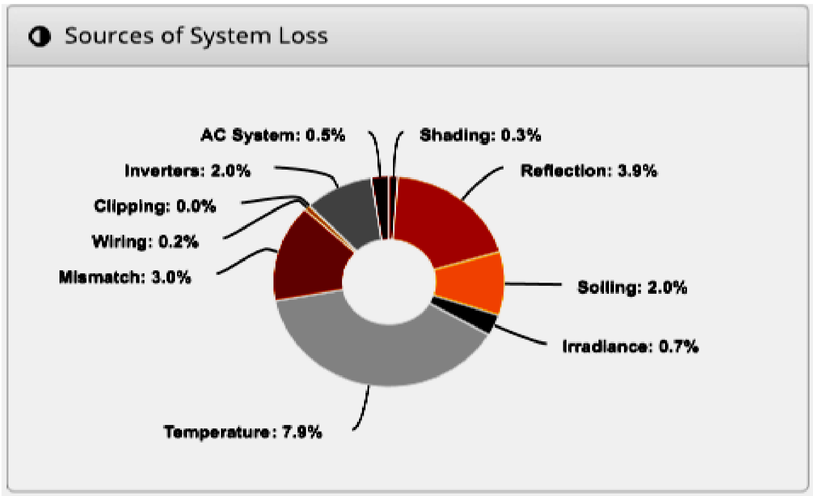


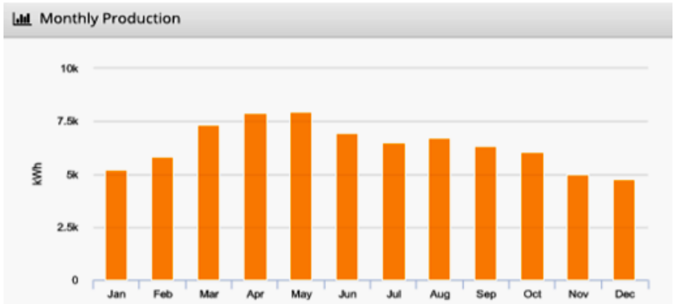
Figure-9: Shading Report Tilt Angle 6^0

Case 3

In case 3 we have taken the tilt angle at 10^0 with azimuth remains same as above case and analyzed results to know the diffused solar radiation on PV modules and its effect on annual solar PV generation.

Figure-10: Heat Shading Map at Tilt 10^0.

The monthly production trends remain same as above cases which can be seen in the figure. During summer period, the generation is on the higher side.



Month	GHI (kWh/m²)	POA (kWh/m²)	Shaded (kWh/m²)	Nameplate (kWh)	Grid (kWh)
January	130.0	109.8	109.1	5,816.0	5,203.3
February	138.7	123.5	122.6	6,626.3	5,841.5
March	170.0	158.3	157.2	8,550.3	7,345.6
April	174.8	169.7	168.4	9,200.7	7,862.1
May	171.8	171.3	169.8	9,266.0	7,965.5
June	148.6	149.3	147.9	8,067.0	6,941.4
July	138.8	139.1	137.7	7,501.6	6,478.2
August	146.6	144.4	143.1	7,802.0	6,703.9
September	141.5	135.4	134.2	7,305.8	6,291.8
October	144.4	130.3	129.4	6,992.3	6,024.3
November	125.5	107.5	106.8	5,707.4	4,998.4
December	123.3	101.7	101.1	5,360.5	4,775.6

Figure-11: Monthly production

This simulation output results collector irradiance 1,530.2 kWh/m^2 and energy deliverable to grid is 76,431.6.1 kWh. Average Operating ambient temperature is 27.7^{0}C and average operating cell temperature 37.0^{0}C.

Annual Production

	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	1,754.1	
	POA Irradiance	1,640.2	-6.5%
	Shaded Irradiance	1,627.1	-0.8%
	Irradiance after Reflection	1,561.8	-4.0%
	Irradiance after Soiling	1,530.6	-2.0%
	Total Collector Irradiance	**1,530.2**	**0.0%**
Energy (kWh)	Nameplate	88,195.7	
	Output at Irradiance Levels	87,547.6	-0.7%
	Output at Cell Temperature Derate	80,764.9	-7.7%
	Output After Mismatch	78,497.9	-2.8%
	Optimal DC Output	78,361.4	-0.2%
	Constrained DC Output	78,361.4	0.0%
	Inverter Output	76,815.7	-2.0%
	Energy to Grid	**76,431.6**	**-0.5%**
Temperature Metrics			
	Avg. Operating Ambient Temp		27.7 °C
	Avg. Operating Cell Temp		37.0 °C
Simulation Metrics			
		Operating Hours	4709
		Solved Hours	4709

Figure-12: Annual production case 3

Even though the temperature loss is kept decreasing but the generation of energy is also falling significantly as seen in the result. Total loss is now 20.7%.

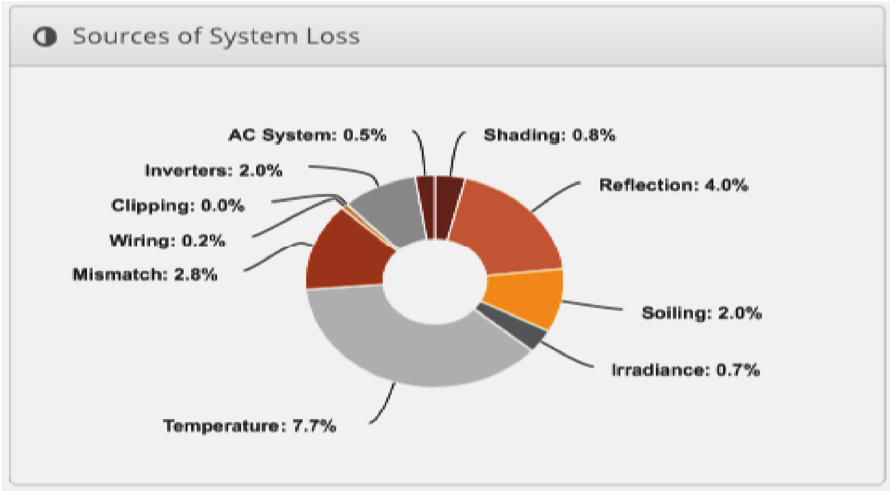


Figure-13: System Loss case 3

The analysis is performed at tilt angles 2°, 6° and 10° at Southeast University rooftop and their monthly and annual generation is shown in figure 14.

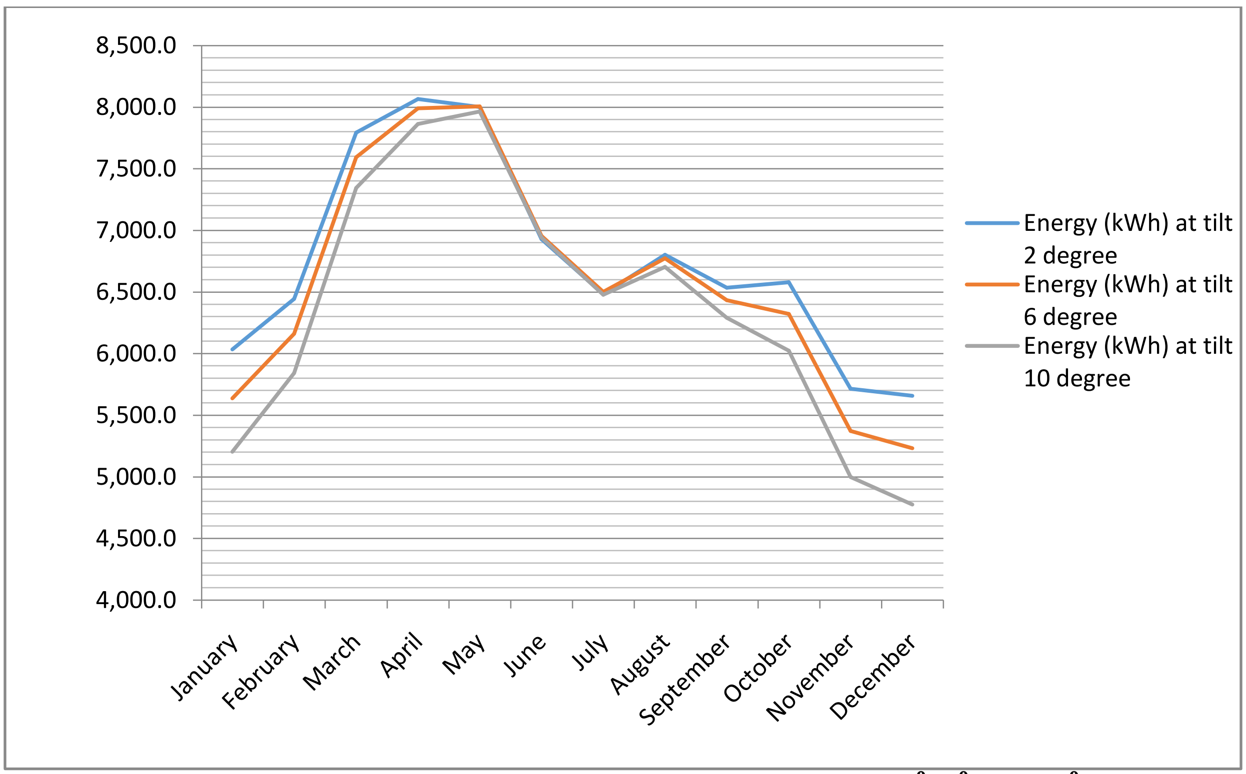


Figure- 14: Comparison of the PV generation (kWh) at tilt angles 2^0, 6^0 and 10^0.

Now finally if we analyze the outcome of the project, In Case 1 we use tilt $2^0$and found annual solar energy 81.04 MWh and perform a ratio of 81.1%. In Case 2 we use tilt 6^0 and annual energy yield is 78.97 MWh and perform ration also the same case1. In Case 3 we used tilt 10^0 and the outcome solar energy is 76.43 MWh with 80.9% of perform a ratio. Total 180 solar panels were installed to generate energy from solar ligh. In all cases tilt angle has an impact on the energy generation. If we analyze the Plane of Array (POA) irradiation for each case, it can be observed that the POA loss kept rising with the increase in tilt angle. POA does have an impact on the energy yield. Higher the POA loss means lower the production as it can be seen from the result. Figure 14 illustrating the energy generation trends throughout the year. From May to July, the energy generation almost remains identical. But the best possible outcome of this project can be found when the tilt is 2^0. As in the 1st case the POA loss is 1.1% only and the total energy production from solar cell is approximately 81 MWh within the given space.

CONCLUSION

The ever-rising population of the world and mass urbanization in developing and developed countries has been two of the major challenges to the power sectors. Bangladesh is the top 10 most populated country in the world, so it’s really major challenge for Bangladesh for develops in power sectors. Sustainable energy sources are getting used for sustainable power development, the solar system is an ideal path. Social, environmental, and economical benefits are associated with it. Analyze and Optimize the Orientation of Solar Cells using HelioScope Technology is an elective pathway to using proper space and generation maximum solar electricity. In different part of the country, HelioScope software can be used to with other software like HOMER Pro to get the right alignment of solar cells. Producing required energy is not only the challenge with solar system, but using as less area as possible is also very essential.

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Conflict of interest

None.

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