Estimating Potential Solar Energy With Three Different Architecture Designs Using Crystalline Silicon Modules

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***Abstract*— These days, the main issues are fossil fuels and air pollution, which has led several nations to expand their investments in the development of renewable energy. Nowadays, the use of solar energy is growing steadily in popularity across all applications, from residential to commercial. The tilt angle of the solar system is the most important part of the design which is related to the rooftop architecture. The performance of three different architecture rooftop designs is examined in this research, including Flat roof, Gable roof, and Shed roof with the same total area. According to the modeling results, the shed roof design is the best design with the highest extracted energy and a large amount of air pollutions will be removed from the air.**

Keywords—component; Architecture design, solar energy, pollution free

I. INTRODUCTION

The earth temperature is rising as a result of the steadily growing depletion of non-renewable energy sources used to generate electricity, which causes massive emissions of greenhouse gases [1]. Solar energy is the only dependable alternative to conventional energy sources due to the growing global population and the quick depletion of non-renewable energy sources [2]. One of the most promising answers to the global energy crisis is converting solar energy by power converters such as dc-dc boost converters and inverters to feed the power grid [3-5]. Since it is not cost-effective to transmit electricity to isolated and rural areas, solar photovoltaic systems have shown to be dependable for generating electricity worldwide [6]. In order to reduce greenhouse gas emissions, solar energy is becoming more and more popular in metropolitan areas [7]. Due to the limited supply of land in highly populated areas, the cost of land or the rent on a roof is also high at the same time. Under these conditions, solar photovoltaic system installation must provide for the maximum capacity of solar panels in the roof-top installations [8]. There is no doubt that the tilt angle is a very important factor to harvest solar energy. Also, the tilt angle is related to the architecture of the house [9]. In a number of circumstances, solar panels can be installed on the roof. The most common method is to tilt the panels during installation so that they match the latitude angle of the site [10]. To gather more energy, the modules should be positioned with a latitude angle of 15 degrees less [11]. Due to the lack of requirement for shade, some persons with limited rooftop space may choose to install their modules with a zero-tilt angle, which stimulates the deployment of further modules [12]. Therefore, the shape of the rooftop has a big impact on how much solar energy can be gathered. In this paper, three different rooftop designs will be presented [13].

II. STRUCTURE DESIGNS

It follows that the quantity of solar energy that can be captured is significantly influenced by the rooftop's design. The three main types are flat, gable, and shed roof constructions [14]. In this study, solar modules are placed without the use of a base or other holding mechanism [15]. The first instance is seen in Fig. 1 with 24 solar panels installed on a level rooftop with a zero-degree inclination.

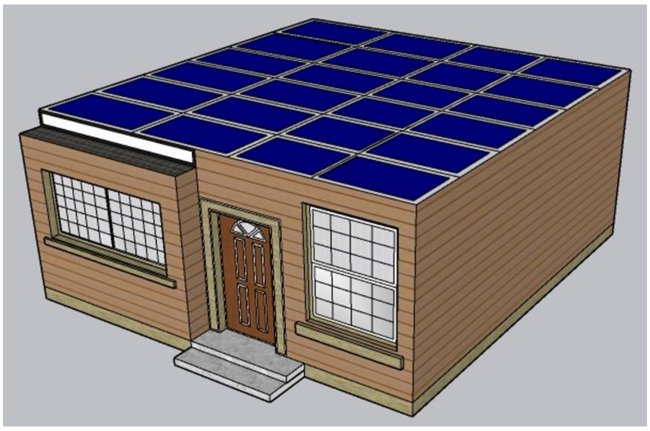

Fig. 1. Flat rooftop structure

As shown in Fig. 1, 24 modules may be fitted on a 48 square meter flat rooftop with a zero-degree inclination [16]. The open gable construction in Fig. 2

enables the owner to install just 12 modules on the rooftop.

Fig. 2. Gable rooftop structure

A total of 12 modules can be fitted, as shown in Fig. 2, with a tilt angle equal to the location's latitude angle. Lubbock's latitude angle is 33.5 degrees. To obtain the most solar electricity in this situation, the roof should be inclined at a 33.5-degree angle [17]. Additionally, Fig. 3 shows the third building structure, which is a shed roofing.

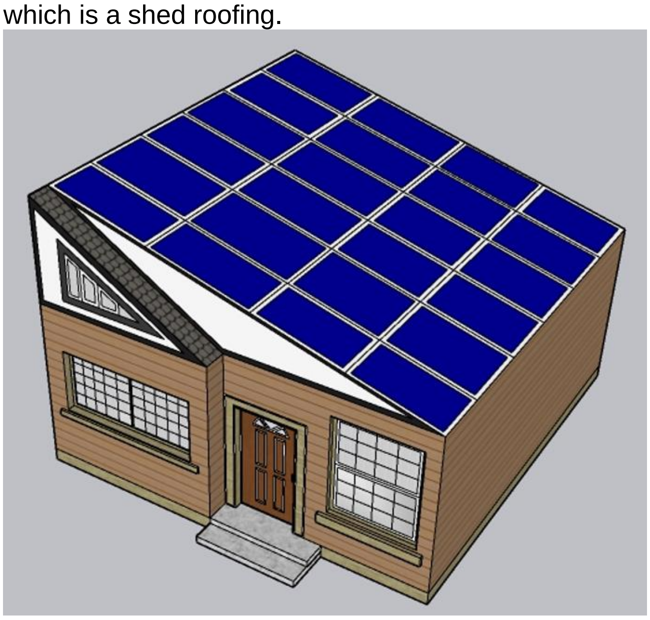

Fig. 3. Shed rooftop structure

According to Fig. 3, the shed construction should be inclined at a similar angle to the location's latitude. This capability enables the installation of up to 24 modules [18]. The three constructions mentioned above will be compared in this essay based on the local weather and solar radiation in Lubbock.

III. CRYSTALLINE SILICON CELLS

In this paper, crystalline silicon solar cells are utilized. Due to the material's affordability and continuous dominance over other PV technologies, crystalline silicon solar cell technology continues to be a leading and cutting-edge technology in the photovoltaic revolution [19]. Despite the fact that it is a sophisticated technology, researchers are still working on silicon-based technology in a few specific technical and practical ways [20]. In order to lower the overall cost of the PV modules, PV manufacturers now produce solar cells using silicon that has been upgraded for use in solar energy [21]. When opposed to silicon used for electronics, silicon for solar applications has a shorter minority carrier life [22]. However, these materials have a larger concentration of chemical and mechanical flaws, such as grain boundaries, transition metals, and dislocations, which reduce the minority carrier lifetime in solar grade silicon [23]. Minority carrier lifetime is a crucial Silicon feature that has a big impact on how well solar cells work electrically [24].

IV. PV SYSTEM DESIGN

Photons are converted to energy by solar cells. Fig. 4 illustrates the analogous circuit for each cell.

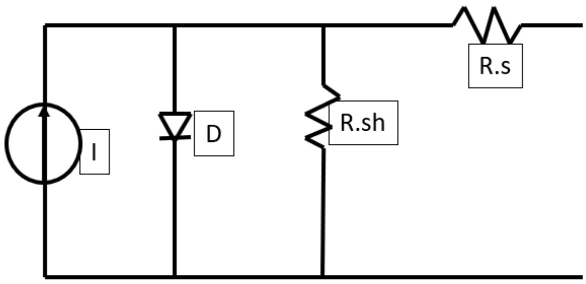

Fig. 4. One diode solar cell circuit

Based on Fig. 4, the photons will be converted by using a diode, two resistors, and a semiconductor. Each module has 72 cells in series with the size of 2 square meters. The solar modules in use have an efficiency of 21% and a life expectancy of around 30 years [25].

Table 1. Panel features

Cells per module	72	Size	2*1 m
maximum power	360.65 W	Latitude of the location	33.5°
modules	24	Type of module	Crystalline Silicon
Efficiency	21 %	Mounting system	Fixed
Operate temp	-30 to 60 °C	Weight	19.1 kg

According to table 1, the maximum power production per each module is 360.65 watts.

V. Methodology and Results

The system is simulated in each of the three possible architectures using the system advisor model. Because only half of the roof area can be used when employing a gable construction, the system can generate lower electricity. The monthly production utilizing the Gable structure is shown in Fig. 5.

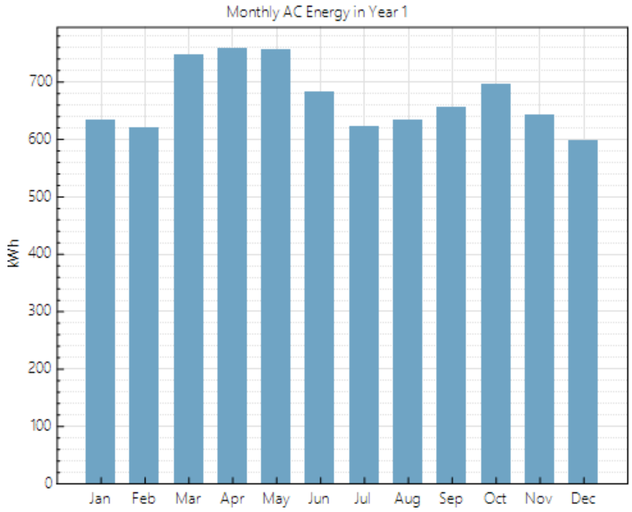

Fig. 5. Monthly production using Gable structure

As it can be seen from above figure, the highest extracted power is for March, April, and July. Also, Fig. 6 shows the yearly energy production for Gable structure.

Metric	Value
Annual AC energy in Year 1	8,044 kWh
DC capacity factor in Year 1	21.0%
Energy yield in Year 1	1,836 kWh/kW
LCOE Levelized cost of energy nominal	7.14 ¢/kWh
LCOE Levelized cost of energy real	5.70 ¢/kWh
Electricity bill without system (year 1)	$1,514
Electricity bill with system (year 1)	$662
Net savings with system (year 1)	$852
Net present value	$4,387
Simple payback period	11.1 years
Discounted payback period	NaN
Net capital cost	$11,920
Equity	$0
Debt	$11,920

Fig. 6. Yearly production using Gable structure

According to Fig. 6, the yearly energy production is near to 8000 kWh. The hourly power production is simulated in SAM and can be seen in Fig. 7.

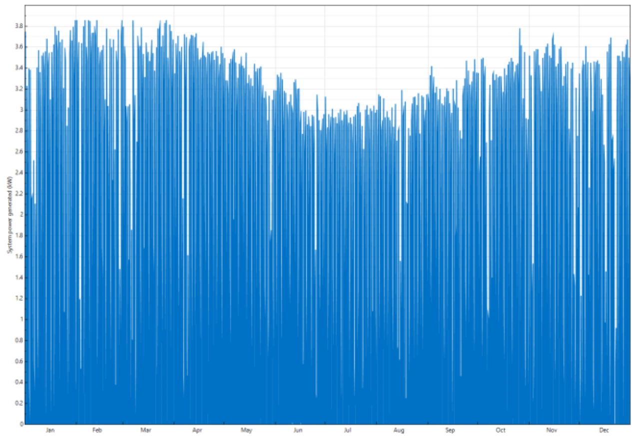

Fig. 7. Hourly production using Gable structure

Based on above figure, the hourly energy production is the highest during spring season in Lubbock. By utilizing Flat structure, the production will be increased owing to the fact that all roof area can be used. Fig. 8 depicts the monthly production using Flat structure.

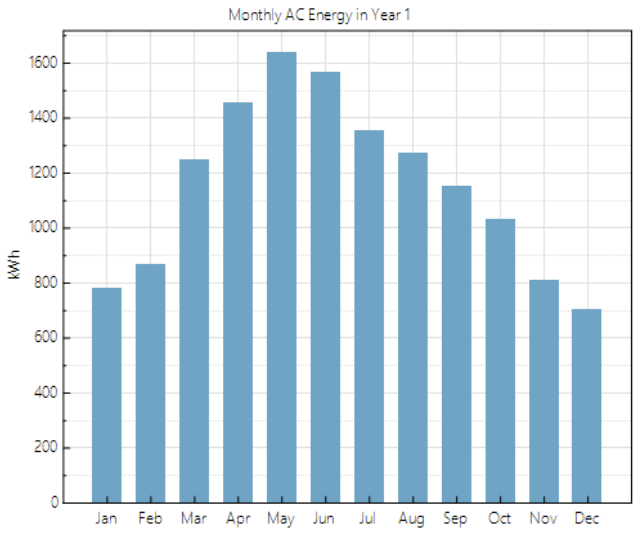

Fig. 8. Monthly production using Flat structure

The modules' tilt angle is zero in the flat construction. As it can be seen from above, summer will thus be the season with the largest harvests. The annual energy output for the Flat structure is shown in Fig. 9.

Metric	Value
Annual AC energy in Year 1	13,865 kWh
DC capacity factor in Year 1	18.3%
Energy yield in Year 1	1,603 kWh/kW
LCOE Levelized cost of energy nominal	8.18 ¢/kWh
LCOE Levelized cost of energy real	6.53 ¢/kWh
Electricity bill without system (year 1)	$1,514
Electricity bill with system (year 1)	$358
Net savings with system (year 1)	$1,155
Net present value	$2,970
Simple payback period	16.2 years
Discounted payback period	NaN
Net capital cost	$23,541
Equity	$0
Debt	$23,541

Fig. 9. Yearly production using Flat structure

According to Fig. 9, the yearly energy production is 13865 kWh. The hourly power production is simulated in SAM and can be seen in Fig. 10.

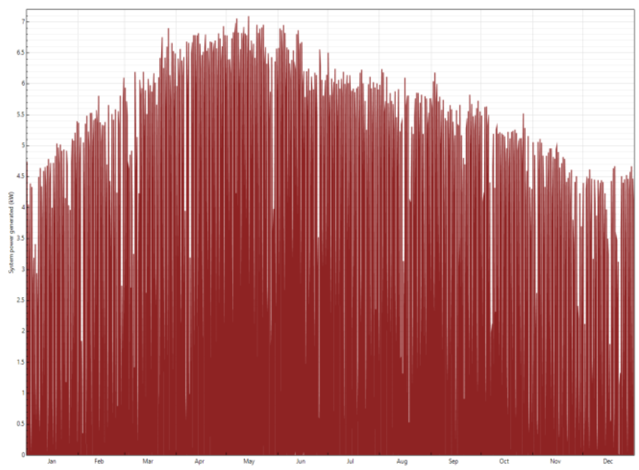

Fig. 10. Hourly production using Flat structure

According to the above graph, Lubbock's energy output per hour is at its maximum in the summer. The figures below show the simulation for the shed structure. The monthly energy produced by the Shed architecture is shown in Fig. 11.

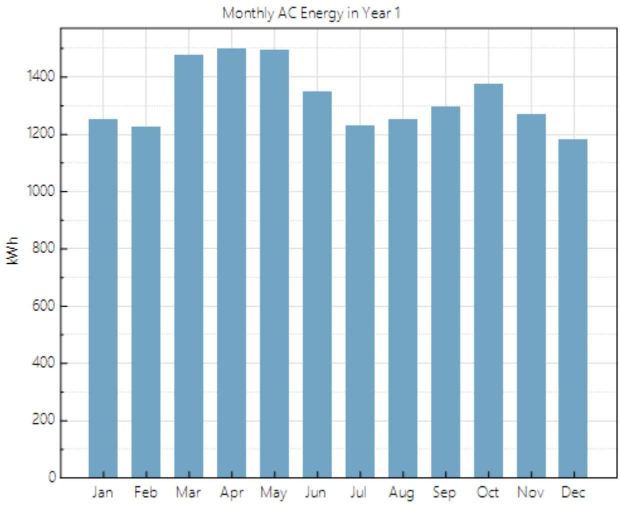

Fig. 11. Monthly production using Shed structure

The tilt angle of the roof of the Shed construction is 33.5 degrees, which is also the latitude angle of Lubbock. Fig. 12 displays the annual energy output for the Shed structure.

Metric	Value
Annual AC energy in Year 1	15,885 kWh
DC capacity factor in Year 1	21.0%
Energy yield in Year 1	1,836 kWh/kW
LCOE Levelized cost of energy nominal	7.14 ¢/kWh
LCOE Levelized cost of energy real	5.70 ¢/kWh
Electricity bill without system (year 1)	$1,514
Electricity bill with system (year 1)	$286
Net savings with system (year 1)	$1,228
Net present value	$3,816
Simple payback period	15.2 years
Discounted payback period	NaN
Net capital cost	$23,541
Equity	$0
Debt	$23,541

Fig. 12. Yearly production using Shed structure

The annual energy production, as shown in Fig. 12, is 15885 kWh. Additionally, SAM simulates the hourly power generation, which is seen in Fig. 13.

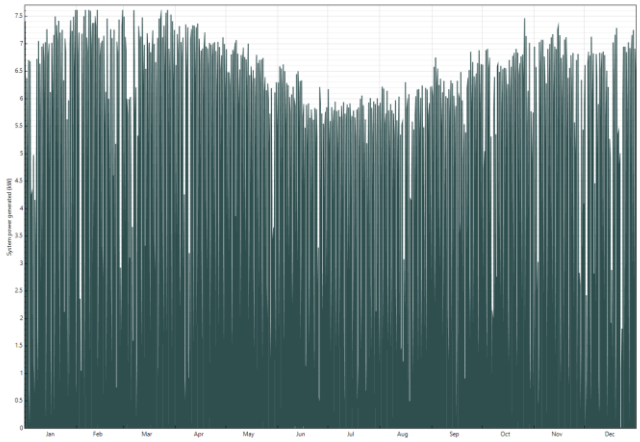

Fig. 13. Hourly production using Shed structure

As can be seen from Fig. 13, Lubbock's hourly energy output is highest in the spring and fall. It is unnecessary to emphasize that a shed with a tilt angle appropriate for the location's latitude is the finest design for collecting solar energy. The comparison of the three approaches is shown in Table 2.

Table 2. Comparison table

	Gable	Flat	Shed
Yearly production	8044 kWh	13865 kWh	15885 kWh
Net cost	11920 USD	23541 USD	23541 USD

According to the above statistics, Shed architecture produces the most energy, up to 15885 kWh. Additionally, the necessary cost of each construction is given, and the shed structure demonstrates that $23541 is required.

VI. Conclusion

The most crucial part of the design that is connected to the rooftop architecture is the tilt angle of the PV modules. In this study, the performance of three rooftop solar PV systems with varied architecture designs—flat roofs, gable roofs, and shed roofs—with the same total area is studied. According to the simulation results, the shed roof design is the best design with the most extracted energy, up to 15885 kWh, Additionally, by using the suggested technology, a large amount of air pollution will be removed from the environment.

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