*i*Journals: International Journal of Software & Hardware Research in Engineering (IJSHRE)
ISSN-2347-4890
Volume 10 Issue 9 September 2022

Calculating Maximum Power Generation Capacity of The Roof Space Through Solar Panels Using Image Processing and Satellite Images

Yashita Saxena
Jumeirah English Speaking School
Al Reem 3, Arabian Ranches, Dubai
Email : saxenayashita@gmail.com

Reetu Jain
Supervisor, On My Own Technology Pvt. Ltd., 2A, Pace House, 7 Swastik Society, Gulmohar Road, Vile Parle West, Mumbai - 400049, Maharashtra, India.
Email-id: reetu.jain@onmyowntechnology.com

Abstract:

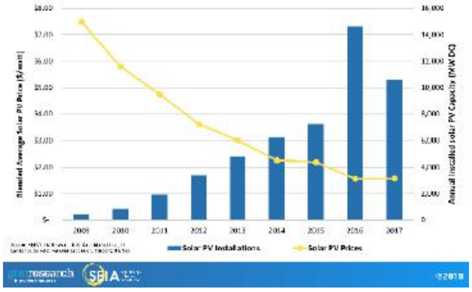
Currently, solar power is one of the most popular forms of non-renewable energy that most nations are adopting to reach their sustainability goals. However, there are problems that hinder many individuals from opting to install solar power. One such problem is the amount of space it requires. To solve this issue, I decided to design a code that focuses on optimizing rooftop areas to allow the greatest number of solar panels to be installed. This will allow efficient production of energy that can be used by both households and firms. Furthermore, placing these solar panels on rooftops will expose these panels to undisturbed sunlight throughout the day without any shadows, or objects getting in their way. This way, we won't have to dedicate land space to creating large solar panel farms, especially because most urban cities are highly populated with very little space to spare for solar panels. My program uses satellite images and uses image processing using python libraries to calculate the area on rooftops. It then suggests how many, south-facing, solar panels can be safely installed on rooftops, and the average amount of energy they are likely to produce. I have collected satellite images from google maps with their scales reflecting the actual size of the roof compared to the image. Then the code processes the image and scales it using the distance scale in the image with the help of OpenCV and Numpy Libraries. After scaling, it automatically crops the roof area and detects the usable area on the roof, giving the maximum number of panels that can be installed on the roof along with the blueprint of their location and orientation. My solution can be used as a reliable tool to analyze the maximum amount of energy that can be generated from a specific roof area.

Keywords: ***solar panels, rooftops, optimization, image processing, mapping, space utilization, environment, renewable energy, sustainability***

I. INTRODUCTION:

A. Need for solar panels

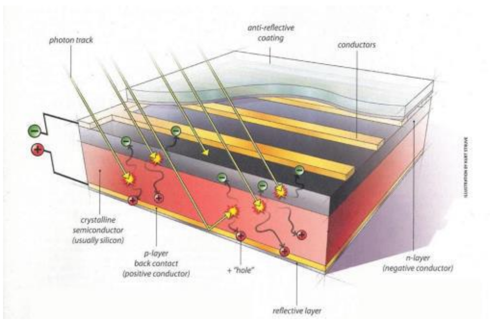
Solar rays are incident on the Earth's surface in almost all regions of the planet for a reasonable amount of time. A total of 173,000 terawatts of solar energy strikes the earth continuously. This is more than 10,000 times the energy we use worldwide. Using this energy to produce energy for firms and homes is an effective method of sustainable energy production. This is because, using solar panels to create electricity doesn't release harmful greenhouse gases such as carbon-dioxide into the atmosphere. It is also easy to install and maintain and in the long run, costs less than using fossil fuels, which release



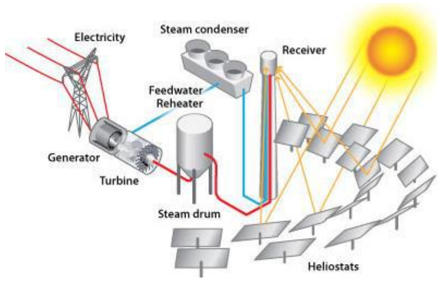
harmful gasses into the atmosphere, contributing to global warming. Another advantage of the us of solar panels is that they require less space compared to other renewable energy production methods such as windmills and dams. It is essential that we begin shifting to greener forms of energy production to preserve our planets resources and the environment.

B. Different methods of producing solar energy

Photovoltaic (PV) cells: PV cells are the most common and widely known form of producing solar energy. They directly convert solar rays into electricity using semiconductor material. When photons strike the cell, the electrons excite and break free from their atomic bonds. They are forced into one direction, creating a flow of current. There are a few different types of PV cells such as monocrystalline, thin film and polycrystalline. These are easy to use because of the flexible methods of installation, however, they are not very efficient. However, over the years, they have been getting cheaper.



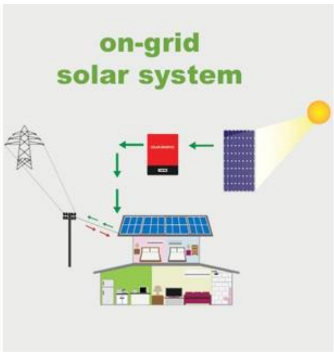
Concentrating solar-thermal power (CSP): CSP systems use mirrors to reflect the rays of the sun onto receivers that collect solar energy and convert them into thermal energy. This thermal energy can then be used to produce electricity or can be stored for future use. This type of energy however is mostly used by large power plants. It is more efficient than photovoltaic cells because the solar energy is directly incident to the receivers, but it requires a lot of space and is usually only used for large scale energy production rather than for domestic purposes.



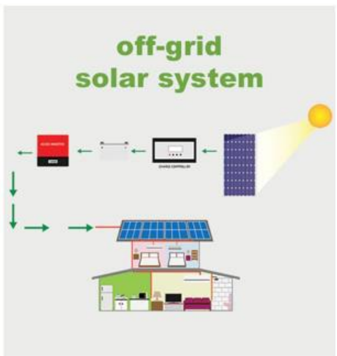
Hybrid Solar Panels: this is a combination of thermal and photovoltaic solar surfaces. These panels are capable of simultaneously generating both heat and electricity owing to their capabilities of capturing the entire spectrum of light. They can convert both infrared (heat) rays and ultraviolet into heat ant electricity which make them a very useful and reliable option to those looking to switch to solar power. These are especially useful on roofs where there is limited area because the space required to generate as much electricity as photovoltaic and thermal panels can be achieved in a 40% reduced area.

C. Methods of implementation of solar panels:

On grid: This refers to the solar panels being tied to your nation's/electricity provider's utility grid. Such as the DEWA in Dubai. This would mean that any extra power that you produced using your solar panels would be sent off to the grid. This can be beneficial because the extra power you send can later be cashed out in situations where your solar panels failed to generate enough power. This also means that all the solar energy produced will be effectively utilised without the need to purchase extra battery back- up systems to store the excess energy.



Off grid: This refers to solar panels that are not connected to your nation's/electricity provider's utility grid. This means that they solely provide power to the place where they are installed and the households/firms rely on them solely. However, this may not be as cost effective because external battery



back-up systems would need to be purchased to store energy in case the solar panels failed to generate power.

Hybrid solar systems: These systems generate power in a similar fashion to normal on-grid solar power plants, however they use special inverters and betters that allow energy to be contained for later use. Thus system used a combination of solar and batteries that can interact with the electricity grid and provide energy to households. These systems are very effective because of the built in batteries however it is more expensive to install.

D. Problems with their implementation on a domestic level

Price: Installing solar panels at homes have a high initial cost. Roof panels cost an average of $16,000. This is can be a large proportion of income for a lot of households making them hesitant from switching to renewable energy. However, in the long run, they are an effective alternative to producing energy.

Installation: It can be challenging to set up solar panels at homes because it requires professional attention. If it is not rightly done, it may add to costs in the long run as the panels may get damaged or be inefficient.

Low efficiency: Solar panels are known to have a low efficiency because a lot of factors can affect their production of energy. These factors include the production of dust on the surface on solar panels that prevent it from effectively converting energy from the sun rays into electricity. Furthermore, the weather conditions and angle of orientation also play a role in determining the efficiency of the panels. For example, in the winter, the sun is further away in the sky, therefore, steeper angles produce more energy because the sun rays fall perpendicular to the solar surfaces. However, in the summer, the panels should have a low inclination because the sun is higher up in the sky. The temperature also affects the efficiency of these panels because when it gets too hot, resistance builds up within the circuit and may cause damage to the solar panels.

E. Space in urban/populous cities

Solar panels require a lot of space to set up and urban cities like Mumbai lack enough space to occupy these. Therefore the best option that remains for the installation of these panels is on rooftops. My program allows the optimization of the area on rooftops to install the maximum number of solar panels on rooftops to produce the greatest amount of power.

II. Literature Reviews

Can solar power deliver? (Nelson & Emmott, 2013)

Solar power represents a vast resource which could, in principle, meet the world's needs for clean power generation. Recent growth in the use of photovoltaic (PV) technology has demonstrated the potential of solar power to deliver on a large scale. Whilst the dominant PV technology is based on crystalline silicon, a wide variety of alternative PV materials and device concepts have been explored in an attempt to decrease the cost of the photovoltaic electricity. This article explores the potential for such emerging technologies to deliver cost reductions, scalability of manufacture, rapid carbon mitigation and new science in order to accelerate the uptake of solar power technologies.

From this paper I understood that there are multiple ways that help make the production of solar panels cheaper, hence making them more cost effective. The paper talks about using techniques such as "printing or coating" to reduce module costs. It discusses the use on new inorganic materials that can be processed directly from solutions, as well as further investigations which reveal the potential which can be gained by PV devices that combine the he properties of organic semiconductors with the optoelectronic properties of inorganics. These new methods of effectively producing solar modules also reduces carbon emission during their production because the process is more efficient compared to the previous, more energy consuming, process. It also promotes the scalability of such technology by making it significantly cheaper. It promotes the research of using more abundant materials to build PV cells which will allow manufacturers to easily mass-produce and meet the required demand easily. Most cells are made of Silicon because of its semi conductivity, however its scarcity has made solar power more expensive and less accessible. Furthermore the report mentions that integrating solar surfaces into "building components" and other "flexible structures and textiles" will promote the easy use of this technology while keeping costs low.

Solar PV Planning Toward Sustainable Development in Chile: Challenges and Recommendations (Silva, Agostini, & Nasirov, 2016)

Over the past decade, the promotion of renewable energy projects in Chile, especially solar energy projects, has become increasingly important, as energy dependence from foreign fossil fuels has increased and concerns regarding climate change continue to grow, posing a significant challenge to the local economy. Even though recent developments toward a more sustainable energy matrix in Chile have significantly increased the investment in the solar energy sector, social and environmental fragilities, combined with the lack of well-functioning institutions and the historical marginalization of indigenous communities who have been affected by several energy projects, result in gradually increasing conflictive situations. Unless proper mechanisms are designed and implemented to rapidly and correctly address these challenges, Chile could miss the opportunities that solar energy projects can provide to the development of its communities and to the economic growth of its regions. This article studies solar photovoltaics planning in Chile, focusing on the recent developments and the main challenges ahead, and proposes policy recommendations for effectively addressing these challenges.

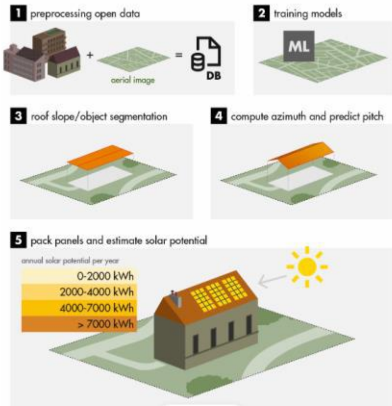
This article explains the challenges that arise in Chili due to an increase in the demand of electricity. The nation looks to switch to more sustainable forms of energy to meet this sudden rise in demand to reduce carbon emissions, hence they resort to solar power. To encourage households to install solar modules in their homes, the government launched a scheme which would allow households and business to sell any excess energy they produced into the national grid at a fixed tariff. This would encourage consumers to adopt solar power and help meet the nation's energy needs. This article reveals that the greatest hindrance to the employment of solar energy is the bureaucratic process that it involved. It states that in order to overcome such problems, the amount of excessive paperwork should be reduced and consumers should be incentivized and/or penalized in order to encourage them to switch to sustainable methods of energy production.

Two-sided solar panels that track the sun produce a third more energy (Lu, 2020)

This article discusses the use of two sided solar panels that track the sun to increase their level of output. According to the article, these panels can produce a third more energy than normal PV modules. This is because, not only are they able to track the sun and tilt accordingly, but they are also able to absorb the energy that is reflected from the ground. This means that they are able to absorb greater amounts of energy and as a result produce a greater output. However, their only trade-off is their cost. These panels are incredibly expensive to install and produce, as a result, the article states that while conventional solar panels produce less energy, they are currently better for households and firms because the investment is not worth it. However, in the long run, more research in this area can lead to the production of such panels for cheaper costs by using cheaper material that is more abundantly available and modifying the current supply chains. This way we would be able to produce more sustainable energy and meet the growing demand of energy without using non-renewable sources that release harmful gases into the atmosphere.

Predicting the Solar Potential of Rooftops using Image Segmentation and Structured Data (Andrieux, 2020)

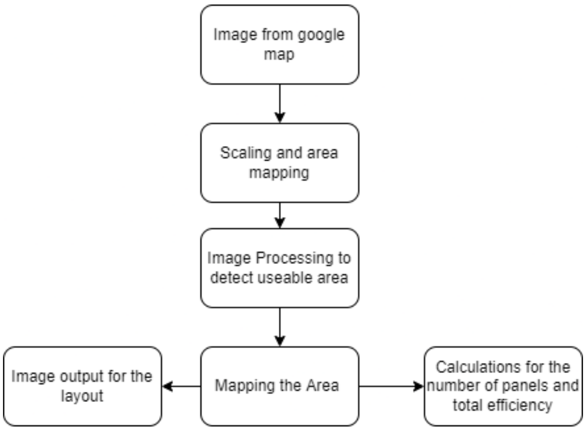
This report discusses a machine learning model designed by the author which aims to maximise the usage of solar panels. It uses similar technology to what I have used in my research project, however it does so on a larger scale. It uses solar images to train the model to estimate the optimal inclination of the panels and estimate the maximum number of solar modules that can be installed on the rooftop and the amount of energy they would produce. This solution aims to solve the key problems of space in urban cities and allows users to maximise the space they have to generate the maximum amount of power possible. Here is a breakdown of how it works:



By using such technologies and maximising power output, we will finally be able to tackle the energy crisis and the growing demand for energy as the world continues to consume non-renewable sources to produce energy.

III. Our Solution

A. Concept



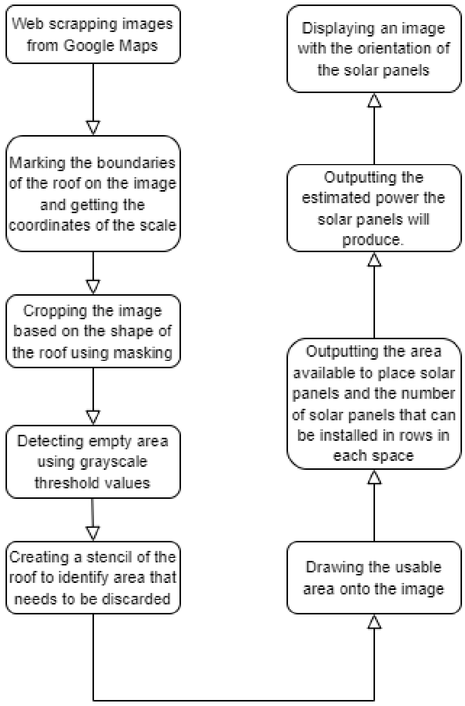
Our concept is to use satellite images to calculate the area on rooftops and depict the number of solar panels can be fitted onto the rooftop and how they could be oriented for optimization. My program also provides an estimated value for the total amount of energy that the panels can generate. It discards areas that are too small to position any solar panels, and ignores any objects that are present on the roof. This program can be very useful because currently most solar panel providers install panels solely based on the consumer's needs, ignoring the maximum power that can be generating by optimizing the area. If we used this program and optimized the area on rooftops, any extra energy that households produced could be sent to the national grid which would increase the amount of power generated from sustainable energy sources and decrease the need for using non-renewable energy sources such as the combustion of coal. This would allow nations to meet their growing energy demands while also optimizing space, which is especially necessary for populous urban cities.

B. Methodology:

To build this program, my methodology had multiple steps. These included:

1. Collecting satellite images from google maps.
2. Marking the area of the roof.
3. Cropping the image to focus on the usable area.
4. Empty area detection using the greyscale threshold and generating a mask.
5. Creating a stencil of the rooftop to detect area that needed to be discarded.
6. Drawing the usable area onto the image.
7. Outputting the area available for installing solar panels
8. Outputting the maximum number of solar panels that could be placed on the roof.
9. Outputting the estimated power they should produce.
10. Displaying an image with the right orientation of the solar panels to optimize the area.

1.Collecting satellite images from google maps:



This is a sample satellite image retrieved from google maps which has a scale on the bottom right which we will be using to calculate the total area available on the roof of this building.

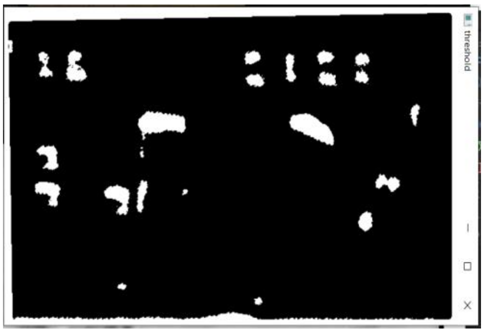
2.Marking the area of the roof:

Next we marked the boundaries of the area that we would use to place solar panels and the scale of the picture. The marked areas are evident by the red dots on the picture that were made by mouse clicks, this allows us to customize the program for different types and shapes of roofs.

3.Cropping the image to focus on the usable area:

This step allows us to crop the image and discard any unnecessary areas other than the roof that were captured. This makes it easier to carry out the next steps which will detect objects on the rooftop.

4.Empty area detection using threshold and Masking:

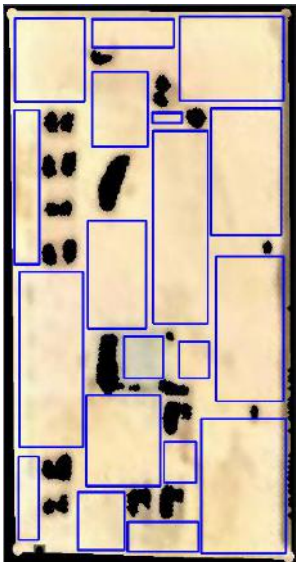


This step allows us to use grayscale threshold values and detect any objects on the rooftop that may interrupt the placement of the solar panels. By doing this, we can discard the area that cannot be used on rooftops.

5.Creating a stencil of the rooftop to detect area that needed to be discarded:

Finally, we create a stencil of the rooftop with the usable areas clearly identified, this will allow us to optimize the space on the rooftop by discarding any area that is already used up and placing the maximum amount of solar panels on the available area.

6.Drawing the usable area onto the image:



This step allows the user to map out all the usable area on the roof of a building. For each shape that is mapped out, the program identifies the number of panels that can be fitted into the specific area and the number of rows that would be utilized.

7.Outputting the area available for installing solar panels:

The total usable area is displayed by the program, the area is displayed in metres squared. This gives us a rough idea of the area available after all the objects on the roof have been discarded. This area also neglects small spaces that can’t be utilized to place solar panels.

8.Outputting the maximum number of solar panels that could be placed on the roof

```
150 78
no of lines 2.0
panels per line 3.0
total panels 6.0
50 156
no of lines 4.0
panels per line 1.0
total panels 10.0
100 234
no of lines 6.0
panels per line 2.0
total panels 22.0
50 156
no of lines 4.0
panels per line 1.0
total panels 26.0
100 117
no of lines 3.0
panels per line 2.0
total panels 32.0
50 78
no of lines 2.0
panels per line 1.0
total panels 34.0
100 0
no of lines 0.0
panels per line 2.0
total panels 34.0
50 78
no of lines 2.0
panels per line 1.0
total panels 36.0
```

```
50 117
no of lines 3.0
panels per line 1.0
total panels 39.0
0 195
no of lines 5.0
panels per line 0.0
total panels 39.0
50 156
no of lines 4.0
panels per line 1.0
total panels 43.0
100 78
no of lines 2.0
panels per line 2.0
total panels 47.0
100 39
no of lines 1.0
panels per line 2.0
total panels 49.0
50 39
no of lines 1.0
panels per line 1.0
total panels 50.0
50 0
no of lines 0.0
panels per line 1.0
total panels 50.0
0 39
no of lines 1.0
panels per line 0.0
total panels 50.0
0 78
no of lines 2.0
panels per line 0.0
total panels 50.0
```

This step displays the number of panels in each row and the number of rows that can be installed in a specific shape that has been drawn onto the roof. This gives accurate estimations because it disregards areas that are too small to fit any panels and includes space that panels would need when they are placed next to one-another.

9.Outputting the estimated power they should produce and displaying an image with the right orientation of the solar panels to optimize the area:

Finally, the program outputs the estimated amount of energy that the solar panels will produce. This is done using a simple calculation. Each panel produces approximately 240 Watts per hour which can then be multiplied by the number of panels.

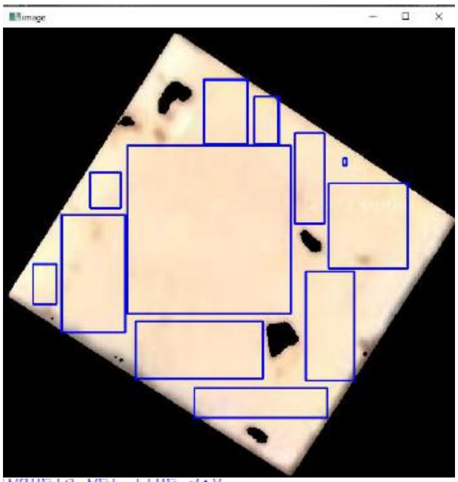
C. Testing and results

I tested this program on images of various rooftops. This allowed me to test the reliability of this code in different circumstances. Through the testing, I found some errors which I was able to fix such as being able to draw the empty area on the roof from either side. In the end, the program now has a high accuracy and minimal errors and should be able to perform on most rooftops. A few examples are added below.

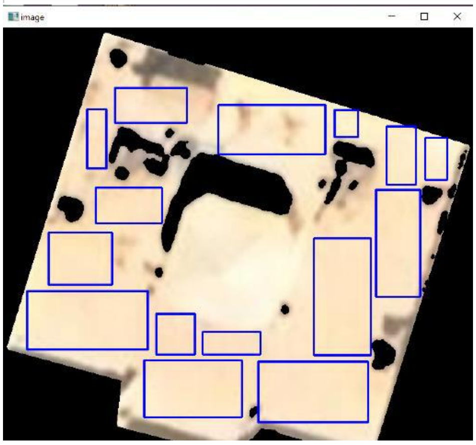
IV. Conclusion and Future Scope

In conclusion, this program produced promising results in terms of providing us with an accurate estimate of the number of solar panels that can be placed on rooftops when the area is optimized. This way, when companies decide to install solar panels

```
total panels 31.0
45.26
estimated power generated in one hour: 7440.0 Watts
```



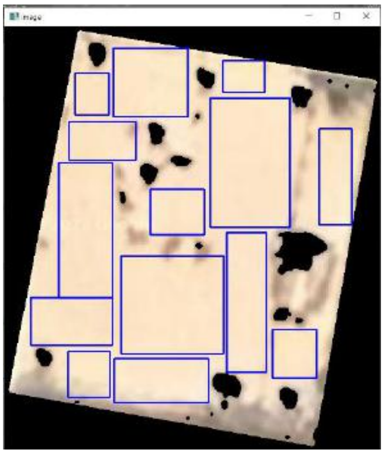
```
total panels 182.0
265.71999999999997
estimated power generated in one hour: 43680.0 Watts
```



```
total panels 52.0
75.92
estimated power generated in one hour: 12480.0 Watts
```

on rooftops, they can consider how to maximise energy output which will benefit urban cities with high energy demands. Consumers of these solar panels can not only use the energy they produce for themselves but also sell the energy to the national grid which can then be utilized by other citizens. The program also considers the orientation of the solar panels as it always draws the areas onto the map in a south facing orientation. This way, the panels can receive maximum sun rays, which they can then convert into energy. The main aim of the program was to improve the implementation of solar panels and ensure that areas were optimized to produce the maximum amount of energy possible and the aforementioned has been demonstrated by the results.

To improve this code, we can add elements of machine learning which will make the program



more accurate and it will be able to analyse multiple types of roofs such as angular roofs. To further maximise the energy that the solar panels can produce, the program can take into account the weather conditions and precise location of instalment in order to identify the latitude and suggest an optimal angle at which the solar panels should be installed.

This program can also be made more accurate by carrying out field testing, this will identify any problems in the program that were not previously detected.

References

1. Andrieux, F. (2020, April 14). *Predicting the Solar Potential of Rooftops using Image Segmentation and Structured Data*. Retrieved June 24, 2022, from Medium: https://medium.com/nam-r/predicting-the-solar-potential-of-rooftops-using-image-segmentation-and-structured-data-61198c39d57c
2. Chandler, D. l. (2011, October 26). *Shining brightly: Vast amounts of solar energy radiate to the Earth constantly, but tapping that energy cost-effectively remains a challenge.* Retrieved June 10, 2022, from MIT News: https://news.mit.edu/2011/energy-scale-part3-1026
3. *Hybrid Solar Panels – Solar Energy for beginners*. (n.d.). Retrieved July 2, 2022, from Endef solar solutions: https://endef.com/en/hybrid-solar-panels-solar-energy-for-beginners/
4. Lu, D. (2020, June 3). Two-sided solar panels that track the sun produce a third more energy. *NewScientist*. Retrieved June 23, 2022
5. *Microsoft Word - Solar roof top*. (2017, July 11). Retrieved from https://apserc.nic.in/pdf/Solar_roof_top.pdf
6. Nelson, J., & Emmott, C. J. (2013). Can solar power deliver? . *Philosophical Transactions: Mathematical, Physical and Engineering Sciences*.
7. Newkirk, M. (2015, May 16). *What Is A Hybrid Solar System?* Retrieved June 27, 2022, from Clean Energy Reviews: https://www.cleanenergyreviews.info/blog/2014/8/14/what-is-hybrid-solar
8. Silva, C., Agostini, C. A., & Nasirov, S. (2016). Solar PV Planning Toward Sustainable Development in Chile: Challenges and Recommendations. *The Journal of Environment & Development*.
9. Solar Energy Industries Association. (n.d.). *Photovoltaics*. Retrieved June 10, 2022, from SEIA: https://www.seia.org/initiatives/photovoltaics
10. U.S Department of Energy. (n.d.). *How Does Solar Work?* Retrieved July 10, 2022, from https://www.energy.gov/eere/solar/how-does-solar-work