

# Design and Development of Solar tree

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**Abstract** -The design and development of solar trees represent an innovative approach to harnessing solar energy in urban environments. Solar trees are aesthetically appealing structures that mimic the shape and function of real trees, while integrating solar panels into their branches or canopy. This abstract presents an overview of the design and development of solar trees, highlighting their potential benefits, challenges, and future prospects.

Solar trees offer several advantages over traditional solar installations. By utilizing vertical space and integrating into urban landscapes, they address the challenge of limited land availability for solar power generation. The branching structure of solar trees provides shade, making them suitable for public spaces, parks, parking lots, and sidewalks. They can also serve as charging stations for electric vehicles, enhancing sustainability in transportation.

The design of solar trees involves careful consideration of various factors, including solar panel efficiency, material selection, structural stability, and aesthetic integration. Advances in photovoltaic technology have led to the development of flexible and lightweight solar panels that can be seamlessly integrated into the tree-like structures. These panels can efficiently capture sunlight from different angles, maximizing energy production throughout the day.

Challenges in solar tree development include optimizing energy output, ensuring structural integrity in various weather conditions, and

balancing cost-effectiveness with environmental impact. Additionally, the integration of smart technologies, such as sensors and energy management systems, can enhance the efficiency and functionality of solar trees.

The future prospects of solar tree technology are promising. As renewable energy becomes increasingly important for sustainable development, solar trees can play a significant role in meeting urban energy demands. Ongoing research and development efforts aim to improve the efficiency and cost-effectiveness of solar tree designs, as well as explore new applications and configurations.

In conclusion, the design and development of solar trees offer a unique and visually appealing solution for urban solar power generation. By utilizing vertical space and integrating renewable energy into urban landscapes, solar trees have the potential to enhance sustainability, reduce carbon emissions, and contribute to the transition towards a clean energy future.

## 1. Introduction

The energy demands throughout the globe has been increasing exponentially with the coming of the age of technology. As of today, energy derived from fossil fuels form the backbone of the energy supplied to human civilization. The use of fossil fuels to power the human civilization results in humongous amounts of greenhouse gases being released in the atmosphere. Hence, we are in dire need of alternate sources of energy that are clean and inexhaustible. Even after the advent of several

clean and renewable sources of energy such as solar and wind energy; fossil fuels like coal, oil and natural gas etc. fulfill majority of energy requirements of the world. Limitations of the energy utilization technology keep the renewable sources for being utilized at their full potential.

Solar energy is one such clean, inexhaustible, and renewable type energy which is abundantly available on the Indian territory. In India, with about 300 clear and sunny days the solar energy incidence is approximately 5 quadrillion kilowatt-hours(kWh) per year, which exceeds far beyond the demand and energy produced by any fossil fuel

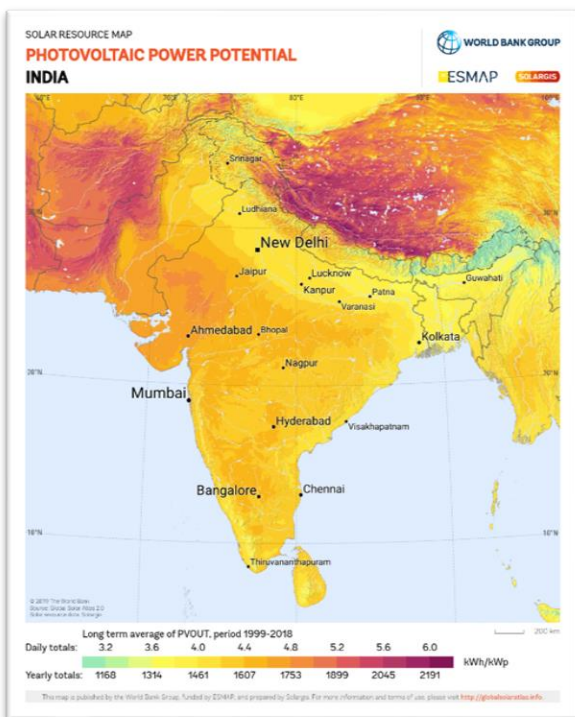


Figure 1 P.V. solar potential map of India

energy resource. Solar energy has received attention and investment as the Indian government realizes it's potential. But still it's productivity depends on the area covered by the solar panels hence, my research problem is how to achieve high efficiency in a very limited space? The proposed solution is the development of a solar tree which employs biomimicry and thus takes little ground space, generates energy and adds on the aesthetic of the environment in which it is placed.

## 2. Motivation

The motivation to choose this topic as my major project came from the realization that plants absorb sunlight to create energy in an extremely efficient way; through the process of evolution over millions of years' plants and trees have fine-tuned their energy utilization methods and techniques.

Not only that but the way they grow and their architecture provides key information as to how to utilize solar energy. Hence, the solar trees designed under this project follows the principle of biomimicry and are designed under the influence of the design of Sunflower.



Figure 2 Sunflower

## 3. Literature

### 3.1 Concentrating Solar Collectors

A concentrating collector comprises two main components: a receiver and a concentrator. The receiver is responsible for absorbing radiation and converting it into another form of energy, while the concentrator, an optical system, directs the beam radiation onto the receiver.

Concentrating collectors offer the advantage of providing energy at significantly higher temperatures compared to flat plate collectors (FPCs) or evacuated tube collectors (ETCs). They achieve this by redirecting solar energy passing through an aperture onto a receiver, often necessitating sun tracking. Through

optical means such as mirrors or lenses, these collectors concentrate solar energy before converting it into heat. The concentration process involves reflecting or refracting solar radiation.

Furthermore, concentrating solar collectors can be further classified as imaging and non-imaging type;

Non-imaging type:

- Compound parabolic collector (CPC)

Imaging type:

- Parabolic trough collector (PTC)
- Linear Fresnel reflector (LFR)
- Parabolic dish reflector (PDR)

Concentrated solar collectors offer the ability to concentrate solar radiation using mirrors or lenses, enabling reflection and refraction. However, they come with both advantages and disadvantages when compared to flat plate collectors.

S.no.	Advantages	Disadvantages
1	<i>The utilization of a concentrator system allows the working fluid to attain elevated temperatures, surpassing those achievable by a flat-plate system with an equivalent solar energy collecting surface. Consequently, this disparity enables the realization of a heightened thermodynamic efficiency.</i>	<i>The amount of diffuse radiation gathered by concentrator systems is contingent upon the concentration ratio, resulting in a relatively low collection of diffuse radiation.</i>
2	<i>By employing a concentrator system, it becomes feasible to establish a thermodynamic equilibrium between the</i>	<i>For the collector to effectively track the movement of the Sun, the implementation of a tracking system of some</i>

	<i>temperature level required for a specific task and the capabilities of the system. This enables the operation of various higher temperature devices such as thermionic or thermodynamic devices, aligning the system's capabilities with the intended task.</i>	<i>sort is imperative.</i>
3	<i>The thermal efficiency is enhanced due to the relatively smaller heat-loss area compared to the receiver area.</i>	<i>Over time, solar reflecting surfaces can experience a decline in their ability to reflect sunlight and may necessitate periodic cleaning and refurbishment to maintain optimal reflectance.</i>
4	<i>Reflecting surfaces are characterized by their lower material requirements and simpler structural design compared to flat-plate collectors (FPC). Consequently, the cost per unit area of the solar collecting surface is lower for a concentrating collector, making it more cost-effective than an FPC.</i>	
5	<i>Reflecting surfaces are characterized by their lower material requirements and simpler structural design compared to flat-plate collectors (FPC).</i>	

	<p><i>Consequently, the cost per unit area of the solar collecting surface is lower for a concentrating collector, making it more cost-effective than an FPC.</i></p>	
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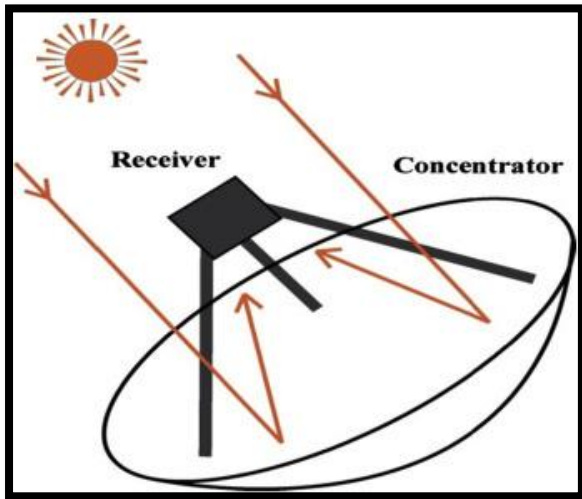


Figure 3 Parabolic dish reflector

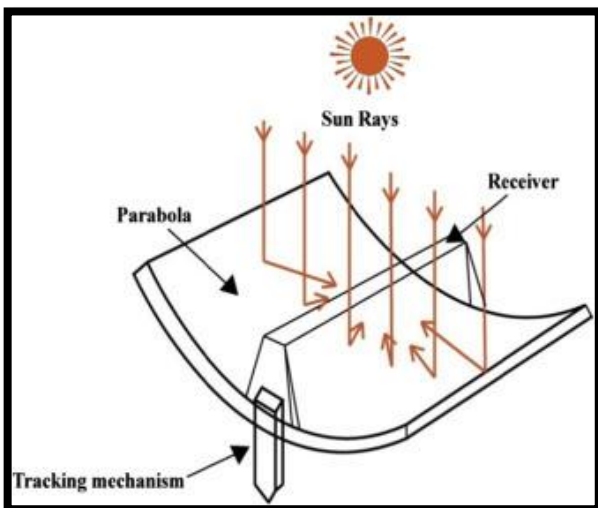


Figure 4 Parabolic trough collector

### 3.2 Non-concentrating solar collectors

Sunlight is absorbed by a non-concentrating solar collector in the same way that it is by the sun. Non-concentrating sun collectors use both direct beam radiation and diffuse radiation, in

contrast to concentrating solar collectors. Non-concentrating collectors have essentially equal aperture and absorption areas.

The most popular type of solar collectors are flat plate collectors, which are frequently used for applications like space and water heating. These collectors have channels for fluid circulation and an absorber plate, which is typically black in color. To maximize solar energy transmission while minimizing re-radiation losses, a transparent cover is used. Dark coatings are frequently added on the absorber plate to improve absorption.



Figure 5 Flat plate solar collector

A popular type of non-concentrating solar collector is the evacuated tube collector. They use a glass tube to create a tight vacuum around the absorber, efficiently withstanding atmospheric pressure. This absorber's surrounding vacuum environment dramatically reduces heat loss through convection and conduction, improving the efficiency of energy conversion.

### 3.3 Solar Panels

Photovoltaic (PV) panels, often known as solar panels, are gadgets made to transform sunlight into electrical energy. They are made up of several linked solar cells that collect sunlight and convert it into useful electricity.

The solar cell, which is commonly made of silicon, is at the heart of a solar panel. Direct current (DC) is produced using the photoelectric effect (PEE), a phenomenon. The solar cell's surface is hit by photons from sunshine, which then transfer energy to the silicon atoms' electrons, releasing them from

their atomic bonds. An electric current is created as a result of the liberation of the trapped electrons.

On the solar panel, solar cells are placed in a grid-like arrangement and frequently covered with materials like glass or plastic. Through the use of metal conductive strips, they are joined to create a circuit that enables the capture and use of the flow of electrons.



Figure 5 PV panel

### 3.4 Photovoltaic solar cells

PV (photovoltaic) solar cells directly convert sunlight into electricity through the photovoltaic effect. Here is a simplified explanation of how PV solar cells function:

**Semiconductor Material:** PV solar cells are typically composed of a semiconductor material, commonly silicon, chosen for its semiconducting properties.

**Photon Absorption:** When sunlight, consisting of photons, strikes the solar cell, the semiconductor material absorbs the photons, transferring their energy to the atoms within the material.

**Electron-Hole Pair Generation:** The absorbed energy excites the electrons in the semiconductor material, leading to the creation of "electron-hole" pairs. The electrons are released from their atoms, becoming free to move.

**Electric Field:** The structure of the solar cell establishes an electric field within the material. Typically, a p-n junction is present, where one

side (p-type) exhibits an excess of positive charge (holes), while the other side (n-type) has an excess of negative charge (electrons).

**Charge Separation:** Due to the electric field, the free electrons are pushed toward the n-side of the solar cell, while the holes are pushed toward the p-side. This separation of charges results in a voltage difference between the two sides of the cell.

**Current Flow:** If an external circuit is connected to the solar cell, the separated electrons and holes can flow through the circuit, creating an electric current. This current can be utilized to power electrical devices or stored in batteries for future use.

**Sunlight to Electricity:** As long as sunlight is available, the process of photon absorption, electron-hole pair generation, charge separation, and current flow continues, generating electricity.

## 4. Methodology

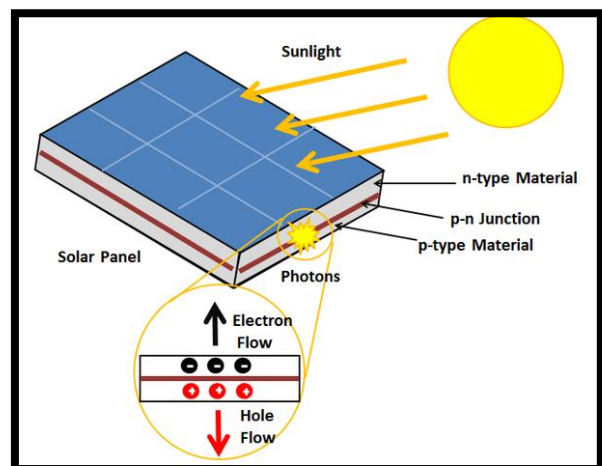


Figure 6 PV effect in solar panel

### 4.1 Apparatus Components

Following components were used in making the testing apparatus:

- Arduino UNO
- Jumper wires
- Solar panel
- Pan-tilt mechanism
- Light dependent resistors



- Other electrical equipment such as: servo motors, resistors etc.

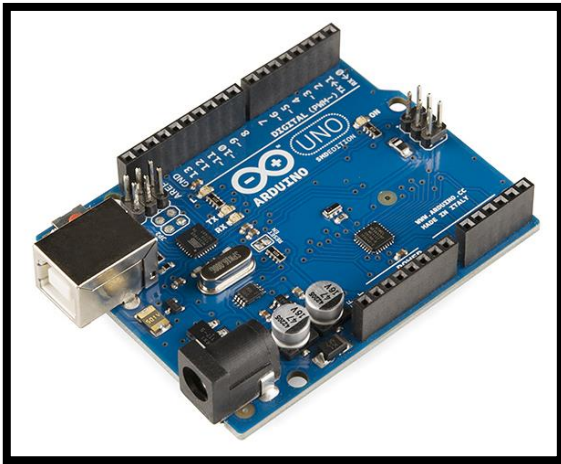


Figure 7 Arduino UNO

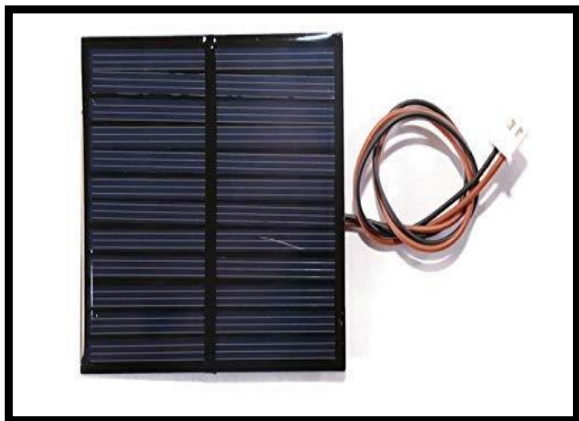


Figure 8 Solar Panel

#### 4.2 Working

### Solar data for Gwalior

05:01 — Dawn time in Gwalior

05:27 — Sunrise time in Gwalior

05:30—19:01 — Daylight time in Gwalior

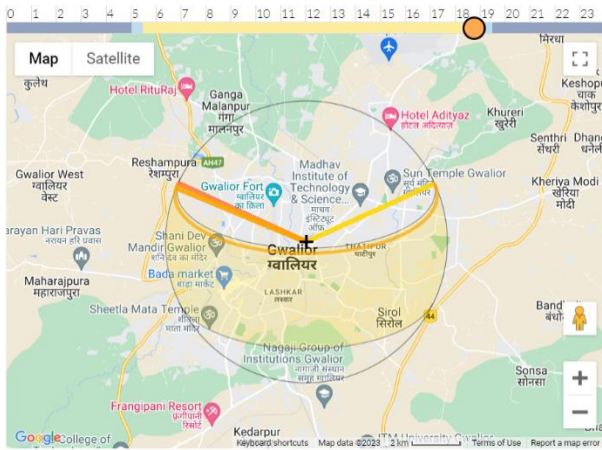
12:15 — Solar noon in Gwalior

19:04 — Sunset time in Gwalior

19:30 — Dusk time in Gwalior

**Position :**  
26.21828710,78.18283080  
**Timezone :**  
Asia/Kolkata  
**Daylight duration :**  
13h31mn  
**Shadow length (1m) :**  
20.71 m  
**Altitude :**  
2.76°  
**Azimuth :**  
112.56°

The prime objective of the usage of the apparatus was to determine the performance of solar panel under various daytime conditions. When placed upright the panel produced maximum amount of energy during the time of 12:00AM, the energy generated gradually increased with the sun position being directly above the panel from dawn and gradually decreased until dusk. While solar panels nowadays are placed at an optimized angle in order to produce maximum amount of electricity in a static position throughout the day or are rotated mono-axially in solar power-plants I chose to go with dual-axis solar tracking in order to keep the sun directly incident at the panel in order to produce maximum possible power from the panel. The trunk has a baseplate which can be used to mount the tree. The secondary panels can either be dual-axis solar tracking or can be static rotated at the optimal angle while their other function is to bio-mimic a tree and provide aesthetic quality to the solar tree.



Detailed sun information

- 00:00–03:58 – Night
- 03:58–04:31 – Astronomical twilight
- 04:31–05:01 – Nautical twilight
- 05:01–05:27 – Civil twilight
- 05:01 – Dawn
- 05:27 – Sunrise
- 12:15 – Solar noon
- 19:04 – Sunset
- 19:30 – Dusk
- 19:04–19:30 – Civil twilight
- 19:30–20:00 – Nautical twilight
- 20:00–20:32 – Astronomical twilight
- 20:32–00:00 – Night

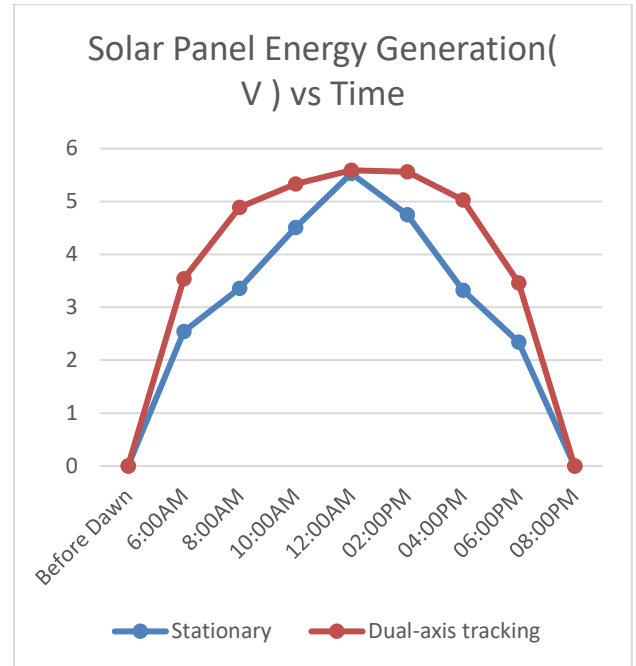


Figure 3 Solar Energy Generation (V) vs Time chart for static and dual axis solar tracking

5. Results

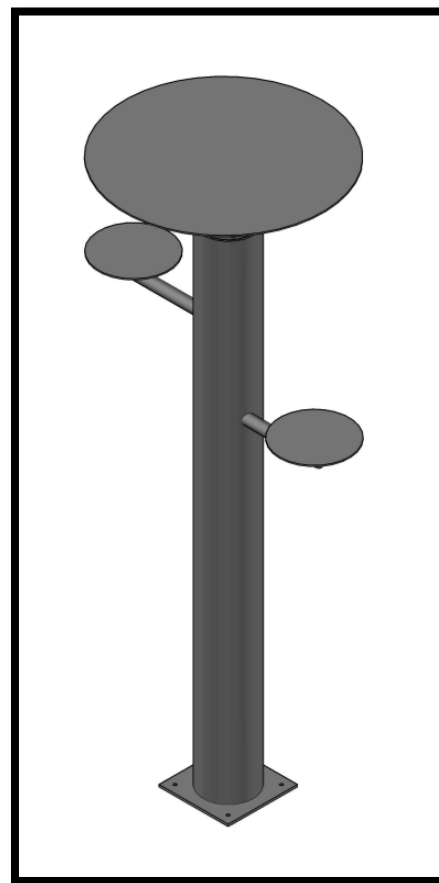


Figure 4 Isometric view

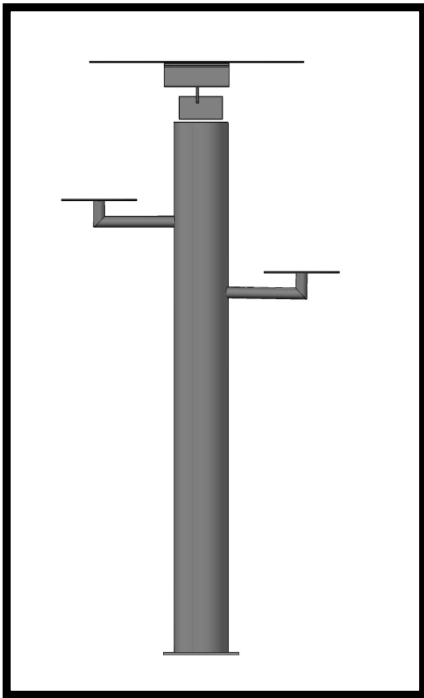


Figure 6 Left view

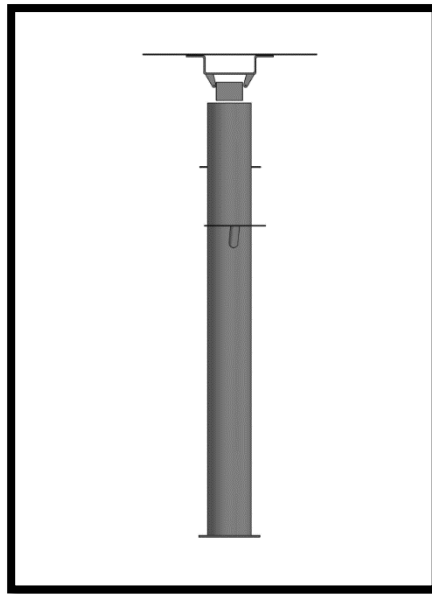


Figure 5 Front view

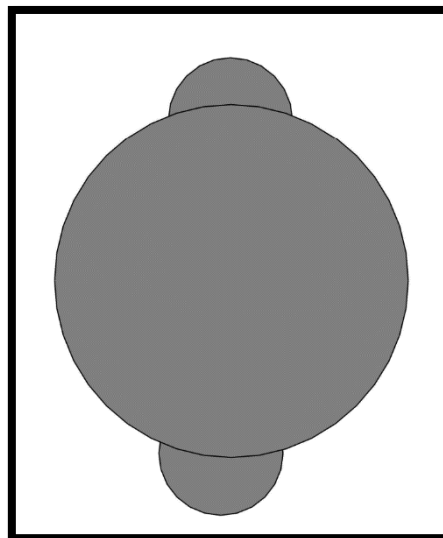


Figure 7 Top view

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S.no.	Part	Dimensions
1	Primary Solar Panel	Diameter: 1m Thickness: 5cm
2	Secondary Solar Panel	Diameter: 30cm Thickness: 5cm
3	Trunk	Diameter: 25cm Thickness: 1.5cm Height: 2.5m
4	Branches	Length: 37.5cm Thickness: 1cm Height: 10cm
5	Base Plate	Length: 35cm Width: 35cm Thickness: 1cm
6	Panel Attachment	Base Length: 30cm Base Width: 30cm



		Flange Length: 10cm Flange Width: 30cm Height: 10cm Thickness: 0.8cm
7	Fasteners	M10 x 1.5 (Base Plate) M5 x 0.8 (Panel)

Theoretically the tree will be able to produce approximately 1200kW of energy at peak sun. While realistically we can say that the levels may vary to around 1100kW of energy throughout the day. The energy generated will be approximately 140% of the energy produced by statically placed solar panels while only taking 10.2 % of the space on the ground.

### 6. CONCLUSION

The development of solar trees addresses several needs and challenges related to renewable energy generation and urban sustainability.

**Limited space utilization:** In densely populated urban areas, open spaces for large-scale solar installations are often limited. Solar trees provide an innovative solution by utilizing vertical space and transforming it into an energy-generating asset. They can be installed in parks, parking lots, sidewalks, and other public areas, making efficient use of available space.

**Aesthetic integration:** Solar trees are designed to blend harmoniously with urban landscapes. They feature an artistic and visually appealing structure that resembles a tree, with solar panels as leaves or branches. This aesthetic integration helps overcome the opposition to large solar installations due to their visual impact, making solar energy more acceptable in urban environments.

**Distributed energy generation:** Solar trees enable decentralized energy generation, reducing reliance on centralized power plants and transmission infrastructure. By distributing solar panels across multiple locations, solar trees enhance energy resilience and minimize transmission losses associated with long-distance power delivery.

**Increased renewable energy adoption:** Solar trees promote the adoption of renewable energy by bringing it closer to urban communities. Their visibility and accessibility can raise awareness about solar power and encourage people to embrace clean energy solutions. Additionally, solar trees can be installed in areas where traditional rooftop solar installations are not feasible or accessible.

**Dual-use functionality:** Solar trees can offer additional functionalities beyond energy generation. They can incorporate features such as LED lighting, electric vehicle charging stations, Wi-Fi hotspots, seating areas, or even rainwater collection systems. By combining multiple functions, solar trees provide value-added benefits to the community and contribute to the overall urban sustainability.

**Educational and outreach opportunities:** Solar trees serve as educational tools by showcasing the benefits of renewable energy and the importance of sustainable practices. They can be accompanied by informative displays or integrated into educational programs to engage the public, particularly students, and increase awareness about solar power and environmental conservation.

**Carbon footprint reduction:** Solar trees contribute to reducing greenhouse gas emissions and mitigating climate change. By generating clean energy, they offset the use of fossil fuels for electricity production, which is a significant source of carbon dioxide emissions. Increased deployment of solar trees can help achieve renewable energy targets and transition to a low-carbon future.

Overall, the development of solar trees offers a unique and effective approach to expand renewable energy generation, enhance urban aesthetics, educate communities, and promote sustainable practices in densely populated areas.

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