



## Overview of Space Based Solar Power

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### Abstract

The rapid increase in the world population is leading to the environmental pollution, global warming and other global crisis. Supply of electric power has become a huge concern due to this population burst and global industrialization. To overcome this issue, solar power has become one of the pivotal energy sources. In current scenario, numbers of photovoltaic and other solar powered installations are increasing around the world and in space to achieve energy independence. In space, electricity produced by photovoltaic conversion of solar energy and it is environment friendly energy source. Terrestrial solar power installations do not produce much electric power, because the sunshine in earth is unpredictable whereas celestial power generation is unlimited as in space, the sun will always be shining.



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### Introduction

The space-based solar power (SBSP)<sup>1</sup> means to gather solar energy in space and distribute it to Earth. Because there is no darkness in space, we can create more electric power. However, on Earth, 50 to 60% of solar energy is wasted as it travels through the atmosphere. Due to the high cost of transporting material into orbit, space-based solar power devices convert sunlight into microwaves. SBSP is classified as a renewable energy source and in India by 2022 it is expected to produce around 175 GW of renewable energy.<sup>2</sup> In order to achieve this, the development and installation of efficient but cost-effective photovoltaic cells<sup>3-6</sup> on terrestrial land and in space has become

a primary importance. But, due to the expense of the launch vehicle, installing a solar power system in orbit is too expensive. In this review article, some of the measures to reduce the cost of space based solar power has been discussed.

### Design and Discussion

#### Three Elements of Space-Based Solar Power

Solar energy is collected in space using reflectors or inflatable mirrors, which is then transferred to solar cells or heaters for thermal systems. Because there is no night in space, sunlight is absorbed by the solar panels 24 hours a day, providing a continual supply of base-load electricity.

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The collected solar energy is sent to a photovoltaic antenna, where it is converted to electricity and subsequently to a high-intensity microwave beam, which is then delivered to the ground through a microwave transmitter dish. Rectenna, a ground-based receiver, absorbs all of the energy and turns it to electricity, which is then sent to the end-user via various transmitting antennas.

**Microwave or Laser Beams are used to Transmit Power to Earth Wirelessly**

Even accounting for the transmission losses, each satellite is able to deliver a large quantity of power. This energy can be safely transmitted in the microwave region using laser beam by employing following methods.

**Laser Beam Wireless Power Transmission**

A laser beam transfers a high-intensity light through space and environment to a photovoltaic cell receiver in the laser beam wireless power transmission technology. The following processes are taken by the receiver to transform the energy back into electricity.

- A system of optics moulds the laser light according to the needed beam size.
- The DC power captured in space is employed to form a monochromatic light beam.
- The laser is targeted towards the designated Earth receiving location via a control system.

The photovoltaic receiver works in a similar way as solar power harvesting, in which sunlight falling on solar cells generates energy. This technology, on the other hand, employs high-intensity laser beams on customized photovoltaic cells, allowing for better efficiency than solar cells now enable. The laser beam may be aimed to any receiver right below the satellite with an unobstructed line-of-sight transmission path using mirrors and telescopes.

**Laser Power Beaming**

NASA envisioned laser power beaming as a stepping stone toward deeper space industrialization. NASA researchers focused on the possible use of lasers for space-to-space power beaming in the 1980s, with a particular emphasis on the creation of a solar-powered laser. In 1989, it was proposed that power may be sent to space using laser, but the expense of bringing the concept to operational state was too exorbitant. Grant Logan proposed in 1988 that an Earth-based laser be used to power an electric thruster for space propulsion, with technical specifications worked out in 1989. To convert ultraviolet laser light, he proposed diamond solar cells operating at 600°C.

Laser power beaming will have some advantages and disadvantages as listed in Table 1.

**Table 1: Advantages and disadvantages of Laser Power Beaming.**

<b>Advantages</b>	<b>Disadvantages</b>
<ul style="list-style-type: none"> <li>• The interference with any of the communication signals will not be there</li> <li>• The quantity of instrumentation required will be very less when compared to microwave transmission</li> </ul>	<ul style="list-style-type: none"> <li>• will get affected by climatic conditions like rain and clouds, and hence unable to deliver continuous electricity</li> <li>• Has a limited conversion efficiency and require massive battery storage systems</li> <li>• If not properly treated, it poses a risk of skin and eye injury</li> </ul>

**A Rectenna, or Microwave Antenna, is used to Receive Power on Earth.**

**Microwave Wireless Power Transmission**

The source of RF energy, a transmit antenna, a transmission medium or channel, and a rectifying antenna, commonly referred to as the rectenna,

make up a microwave power transmission system, involving conversion of DC power from solar cells to radio frequency (RF) energy, generating and focusing a microwave beam that may be focused at specific places and at the receiver station, RF energy is collected and converted into electricity.

A typical satellite's solar arrays employs a transmitting antenna array with a diameter of about 1 km will generate 1.6 GW in space and an average of 1 GW on earth and guarantees that the transmitted beam has minimal divergence, which implies that when the RF energy reaches the Earth's surface, it will be more spatially focused. Schottky diodes, due to their low forward voltage drop and quick switching rates are used to rectify the alternating current received from antennas.

### **Laser–Microwave Hybrid Wireless Power Transmission System**

Both microwave and laser-based wireless power transfer techniques have advantages and downsides. Some researchers have investigated a hybrid strategy in order to come up with the best system possible. A laser would transport power from a solar array to an in-orbit base station in such a system (a photovoltaic array platform).

The base station would turn the laser's energy into electricity, which would subsequently be converted into microwave radiation and relayed to the Earth's receiver station. As a result, the laser beam is employed where there is no considerable attenuation from the environment, and then transmission switches to microwave radiation, which is significantly less attenuated by the atmosphere.

### **Energy Receiving and Distribution**

- Large amounts of energy are received on the ground via Rectenna, and then transferred to users.
- It's expected that over 90% of sunlight will travel through the rectenna.

### **Earth Based Receiver**

- It is made up of a lot of short dipoles.
- Microwave broadcasts from the satellite would be more efficiently received by the dipoles.
- They are most likely be span over many kilometers.

### **Technical Specifications**

The Sun Sats are must produce radio frequency power at a consistent pace with the fewest possible

disruptions.<sup>11</sup> The following are the three essential components.

- The solar cell arrays
- The battery backup system.
- The power conversion hardware

### **Solar Cell Arrays**

Each solar cell array will be made up of thin film photovoltaics with a power density of 16.8 kilowatts per kilogram. In a circular pattern, this material will be set out. The circle will have a diameter of three kilometers and a power output of five gigawatts. According to a simple power density estimate, roughly 595,238 kg of thin film photovoltaic will be required to create 10 gigawatts of total electricity. To help focus sun energy onto the photovoltaic cells, the solar arrays will be combined with a reflector array. The circular reflector array will be five kilometers in diameter and will likewise be put out in a round configuration. A support structure coated in the equivalent of highly reflective Aluminium foil will make up the reflector array. Each reflector array will have a mass of 1000 kg, not including support structure, assuming a thickness of about the same as a sheet of Aluminium foil (0.02 mm).

### **Battery Backup System**

Each Sun Sat will be supplied with a battery to ensure satellite connectivity during eclipses. NASA has previously conducted research on the many types of rechargeable batteries used in space applications. The study's figures were used. It is obvious to conclude from these numbers that Ag Zn batteries should be utilized because of their high power/weight and power/volume density. Because the battery would only be needed for 70 minutes during peak eclipse season and will only power the bare minimum of electronics to keep the satellite connected, it will not need to be very powerful. Heaters for the electronics, the communication TWTA (travelling wave tube amplifier) and antenna, as well as different onboard computers and diagnostics, will be included in the minimal hardware.

### **Power Conversion Hardware**

The Sun Sats' DC power will be sent back to Earth at a frequency of 5.8 GHz. This frequency was chosen not just for its low rain attenuation (a system restriction that cannot be controlled or avoided), but also because it is used by many

of the most innovative and efficient hardware designs. Furthermore, selecting a higher frequency enhances the gain of the antennas employed in the design, and hence the system's efficiency. There are several ways for converting DC to RF (Radio Frequency) energy, each with its own set of advantages and disadvantages. Only two devices remain after screening for goods that can operate in the gigawatt range and at the intended 5.8GHz frequency. klystrons and magnetrons.

Particle accelerators rely heavily on klystrons. A klystron accelerates a beam of electrons through a cavity in bunches. The electron bunches that flow across the cavity during an opposing magnetic field are accelerated by RF energy. The signal is subsequently amplified and sent to a second

cavity, from which it is routed out of the device. They have the ability to generate high power at efficiency of up to 65%. Because it uses both electric and magnetic fields, the magnetron is characterized as a "cross-field" device. In the presence of a steady magnetic field, heat is supplied to the inner, circular cathode. This results in the ejection of energetic electrons, which are driven circularly into the main cavity after colliding with the negatively charged cavities in the anode. This cycle is responsible for the amplification that happens at the main cavity's resonance frequency. According to research released in 2000 by NASA and JPL, they were able to produce an 85.5 percent efficient magnetron. Table 2 enlists the some of the advantages and disadvantages<sup>7-12</sup> of SSP.

**Table 2: Advantages and disadvantages of SSP.**

Advantages of SSP	Disadvantages of SSP
<ul style="list-style-type: none"> <li>• Unlike terrestrial solar or wind power plants, the solar collector in space is unaffected by the Day/Night cycle or weather, and is accessible at all times</li> <li>• In comparison to earth-based energy supplies or unfriendly foreign oil providers, SSP will give real energy independence</li> <li>• SSP can also generate a large enough market for the development of the low-cost space transportation system needed for its implementation. As a result, the solar system's resources will be more economically accessible</li> <li>• Unlike nuclear power facilities, there would be no demand for precious fresh water, and no hazardous waste will be produced</li> <li>• Unlike biofuels (bioethanol or biodiesel), this won't compete for increasingly important farmland that produces food and other essential resources</li> </ul>	<ul style="list-style-type: none"> <li>• The cost of launching satellites is high, but as the space sector becomes more commercialized, the cost of launching satellites will become less expensive</li> <li>• When using monocrystalline silicon solar cells, which have a 14 percent efficiency, the size of the rectenna construction is massive; however, when using triple junction gallium arsenide solar cells, which have a 28 percent efficiency, the collector area can be reduced by half, but they are still quite expensive</li> <li>• Structures of this size in space has never been attempted</li> </ul>

**Expected Outcomes for Reduce the Costs**

- From space, from lunar minerals launched into orbit
- As a result of a comet's impact
- Solar sails are being used.
- In addition, India is constructing a space station. Several rockets will launch to convey

cargo, we can also use these rockets to send space-based solar power equipment.

- Free or low-cost access to reusable space

**Conclusion**

Because many renewable energy sources are restricted, rising global energy demand is expected to continue for decades. Solar power is the

best alternative energy source since it has several substantial environmental benefits when compared to other ways to meeting the world's growing energy demands. Space solar power concepts may be ready for implementation, according to a recently completed "fresh look research." Solar power satellites, for example, should no longer be seen of as requiring unimaginable massive expenditures in power generation. From the perspectives of energy security, environmental security, national requirements, and economic competitiveness, space-based solar power is a strategic potential for America. There is a substantial development cost, but it is considerably lower than the costs of global warming, climate change, or carbon sequestration. The expense of producing space solar power must constantly be weighed against the cost of not

developing space solar power. The further reduction in the cost effectiveness of space based solar power stations is posing a new challenge to the researchers and has a big scope of improvements in the near future.

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#### Conflict of Interest

The authors declares that there is no conflict of interest.

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