Harnessing Solar Power—Transforming Fiction into Reality

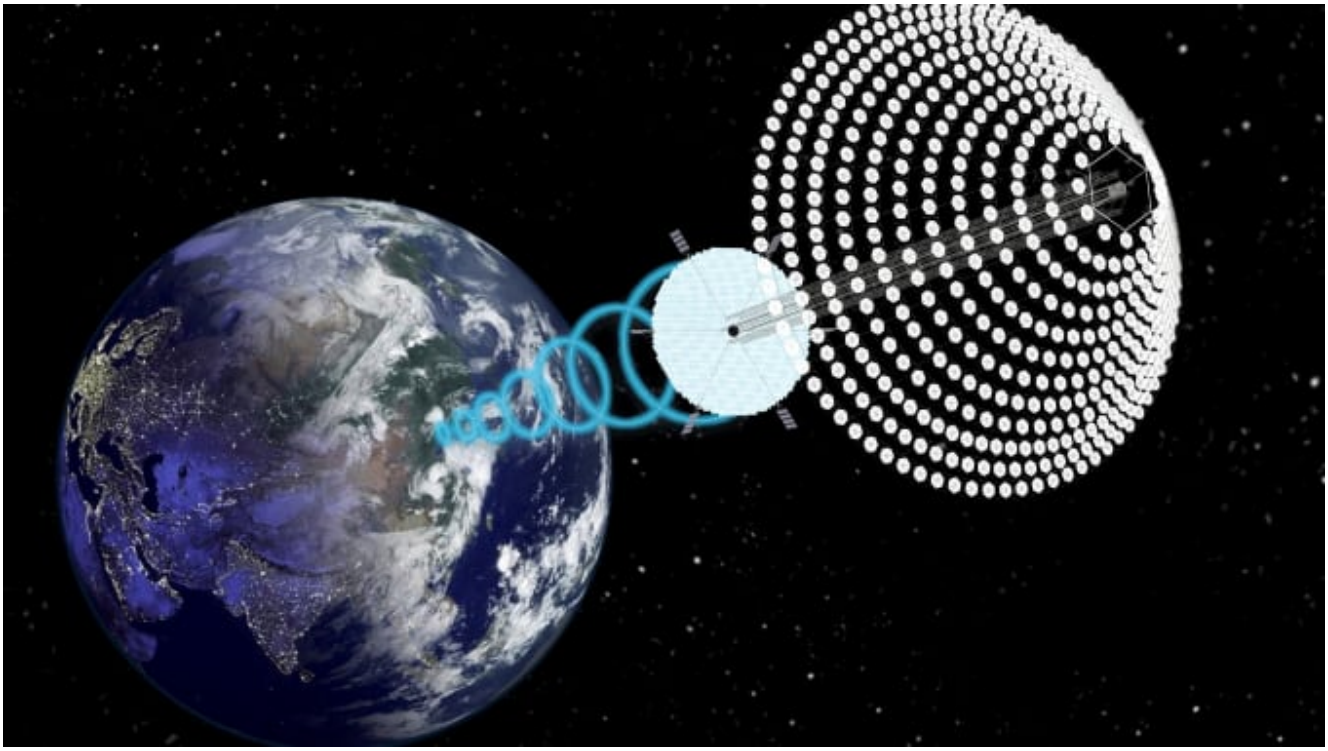
The earth is powered solely by the sun. The giant ignited mass of hydrogen and helium is a source of unlimited energy and has provided for every living creature on earth since time immemorial. We have efficiently harnessed the suns energy through indirect methods. Fossil fuel and coal, that come from the buried remains of living things which lived aeon's ago, is the major source of energy for human beings around the world. Humans have consumed around 160,000 TWh of energy in the year 2019, which is a whopping 320 times more than what we used to consume in the 1800s. Due to the exponential increase in both, the need for energy and pollution caused by conventional sources, science has been forced to look beyond them.

Solar power is the result of directly harvesting the sun's immeasurable potency. It is touted to be the largest resource of energy in the world by 2050. It is renewable, never runs out, and will help in the sustainable growth of human power needs. This is made possible by a tiny piece of layered semiconductor, termed a solar cell. While there are solar power stations in multiple countries around the world, the future of amassing solar energy is heading towards a theory straight out of science fiction—Humongous panels of solar cells being launched into space to orbit around the earth, in order to collect solar energy, is a concept that is being discussed at length in the sustainable energy and green power fields. A concept that started out in a fictional book, might prove to be the answer to the ever-present question of how our need for energy can be fulfilled without polluting the planet.

The Efficiency of Harnessing Solar Power in Space

When a solar power station is built on the earth's surface, it

has quite a few problems associated with it. Internal corrosion of the panels due to moisture and rain, micro-cracks in solar cells due to constant expansion and contraction, and ecological changes due to the immediate environment are a few of the challenges. Solar Plants also consume water for cooling and panel washing, making it harder for water-scarce areas to implement solar plants, as they will directly compete with farms and municipalities for water supply.



A concept of a space-based solar project dubbed SPS-ALPHA as visualised by aerospace engineer John Mankins, a former employee at NASA. [Image Credits: CNBC]

Solar plants have incredible energy output potential, but their actual output is leagues below the expected figures. This is due to the solar cells not being able to produce energy throughout the day. Sunlight does not reach these solar plants with the same intensity for 24 hours, and over 30% of the sunlight that reaches the surface is terrestrially reflected back into space. 12 hours of nightfall and cloudy conditions results in a dip of energy output by them. Seasonal changes on the earth are also a severe hindrance for the

regular supply of solar energy. With the disadvantages they pose by being on the ground, scientists have been working towards finding a solution for the efficient harvesting of solar power—launching the solar panels into space.

Solar plants based in space can solve most of the issues related to the inefficiency and unreliability of solar power. The sunlight is of much higher intensity and reaches the panels 24×7. Irregular production due to weather patterns and seasonal changes are nullified. The panels can be made to face the incoming rays, allowing them to produce a lot more energy per unit area than it usually does on the surface. This also means that the area of solar panels that we will need in outer space will be a lot lesser. While the implementation of Space Solar Power Stations seems like a no-brainer, there are multiple problems that pose a huge challenge for the implementation of these plants.

Progression in SPSS research

Space Solar Power Station (SSPS) is a power generating station based on solar energy set up in the Earth's orbit. The idea of this entire process has been in talks for nearly a century. A Russian scientist, Konstantin Tsiolkovsky formulated the idea in the 1920s, which later served as an inspiration for writers and movie directors. 'Reason', a short story by the renown science fiction writer Isaac Asimov is also based on this revolutionary concept. In 1968, an American scientist named Peter Glaser, the then vice president of Arthur D Little [ADL] was granted a patent for long-range power transmitting techniques with microwaves using very large antennas. This led NASA and ADL to sign a contract to rope in four more companies to research power generation in space.

It took ten long years for the U.S. Congress to grant permission to the Department of Energy [DOE] and NASA to further investigate this concept. With a funding of $50 million—it remains one of the most expensive research

operations to be undertaken. In the 1990s, NASA discontinued this project due to financial constraints and a lack of political backing due to the change of administration caused by the U.S. federal elections. In 1997, NASA conducted its 'Fresh Look' study to examine the feasibility of SSPSs. NASA claimed that SSPS technology could be very expensive, with the primary cost being the transportation of materials into the Earth's orbit and hence would not be feasible—at least for the next few decades.

On 2 November 2012, China proposed a collaboration with India that mentioned a few clauses related to the SSPS initiative which stated, "The possibility of establishing a Space-Based Solar Power initiative so that both of them can work together." Since then, multiple space research organisations such as the United Kingdom Space Agency, the Japanese Aerospace Exploration Agency, and the European Space Agency have been working on this project. They have been developing multiple technologies to transform this science fiction-based idea into reality.

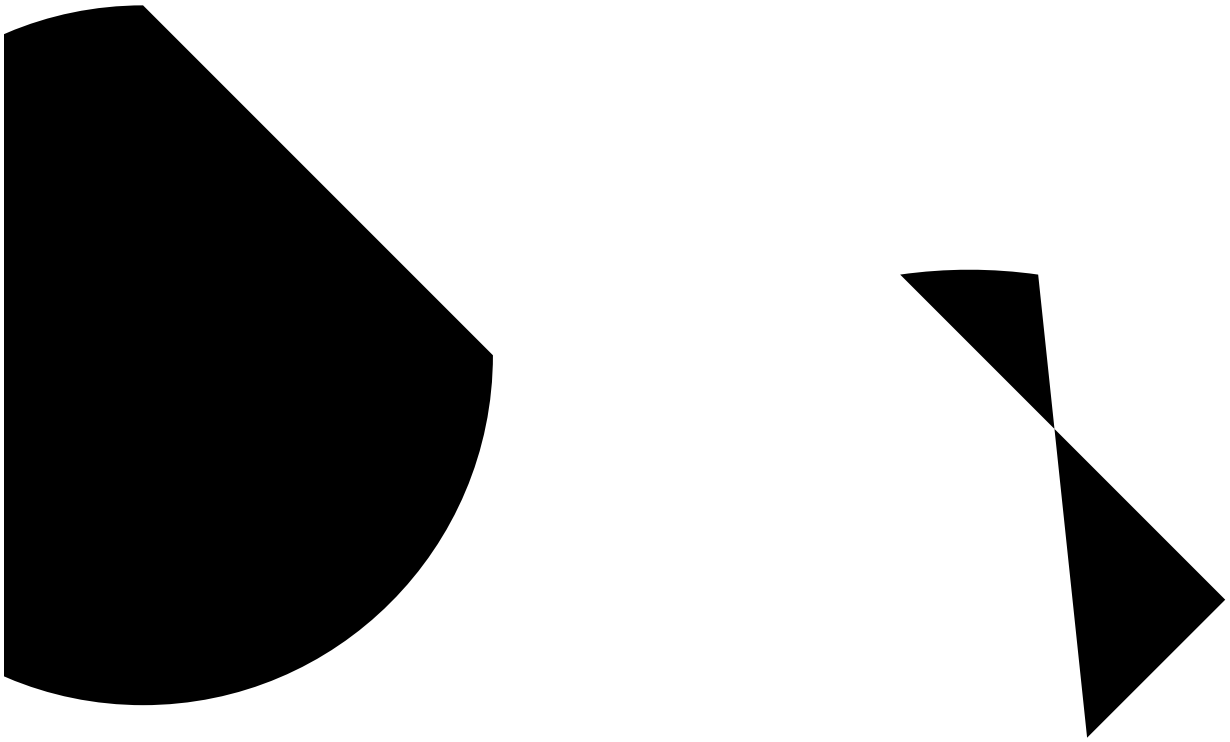
Is the Idea Feasible Enough?

The major challenge of SSPS lies in the transportation of solar panels to space in order to allow it to orbit the earth and collect solar energy. Scientists and researchers across the globe have been working relentlessly to overcome any obstacles that might impede the progress of the SSPS project.

Researchers have proposed a way to enable solar power generation by using a **swarm of mini-satellites**, which can be launched into space and then re-joined to form bigger panels. However, in late 2016 a group of researchers from Caltech demonstrated a modular power station prototype that consists of small solar tiles that can be configured to form into a gigantic solar panel once it reaches outer space.

Scientists at the University of Liverpool have demonstrated a method of creating ultra-light solar cells, **using 3D printing**

techniques, that can be placed on solar sails. Solar sails are a spacecraft propulsion technique that depends on photons which impart momentum to any object when exposed to sunlight. These sails, being foldable and compact, can open up once they reach outer space and help propel the spaceship using solar energy.



Solar sails depend on the momentum imparted by photons to keep spacecraft and objects in space moving [Image Credits: NASA]

The Chinese national space agency has developed **OMEGA,** a technology that they believe can be operational within a

decade. OMEGA, which primarily depends on hyperboloid photovoltaic cell arrays, has everything from power management to the power transmitting machinery inbuilt. The Chinese researchers claim that this will be fully set up in the earth's orbit by 2050 and can produce up to 2GW of energy—equivalent to 6 million solar panels on the earth's surface—and transmit it back to the earth through the help of an antenna.

Power can be transmitted back to the Earth in two different ways. The **rectenna**, which stands for rectifying antenna, converts electromagnetic waves into direct current. This process was recently demonstrated in Hawaii, and researchers claim that this method of transmission is the most plausible one to be used. **Laser power beaming**, another popular method, was considered as the stepping stone for further industrialisation of space. In the 1980s, researchers at NASA worked on the potential use of lasers for space-to-space power beaming, focusing primarily on the development of a solar-powered laser. In 1989, it was suggested that power can be beamed using lasers from Earth to space. In 1991, the SELENE project (SpacE Laser ENErgy) facilitated the study of beaming laser power for supplying power to a lunar base. The SELENE program was a two-year research effort and was closed even before it was demonstrated, citing high operational costs.

What the future holds for SSPS technology

Transmitting the electricity back to the earth's surface will prove to be a challenge that needs immediate attention. Even though the Japanese Aerospace Exploration Agency (JAXA) has demonstrated a plan to transmit the energy with the help of electromagnetic fields and antennas, the idea is not foolproof. Scientists and researchers are still figuring out the most viable ways of transmitting energy. In addition to research and development expenses, setting up a power station in outer space can cost millions of dollars and has no guarantee of success. Hence, many space agencies are in a

state of perplexity and remain modest when asked about this idea.

The Three Gorges dam, one of the largest in the world, is also the largest power station on the planet, capable of producing 22.5 GW of power. [Image Credits: Britannica]

The Three Gorges Dam in China is the largest power station on the planet with a capacity of 22.5 Gigawatts. If we plan to set up a power station of this calibre in space, it can cost more than Germany's GDP. A one-gigawatt power station on Earth could weigh around 20,000 metric tonnes. By this measure, it is nearly impossible to set up a power plant with the capacity of Three Gorges in space. In addition to these constraints, a one-gigawatt plant can cost up to $20 million if it is 100% efficient, but sending this through a Falcon Heavy Rocket can cost up to $2000/kg, which is around $40 billion for a one-gigawatt station. These numbers increase exponentially if the Ariane of the ESA or Long March of the CNSA is used as the launch vehicle.

Scientists across the globe are pondering over the possibilities and are exploring newer horizons in this domain. Setting the project up can be vital in fighting against climate change by minimising the impact on the Earth’s environment. If solar power stations in space are actually made possible, provided each kilowatt costs less than or equal to the current power charges on Earth, the entire process of energy generation, transmission, and utilisation around the world will be revolutionised.

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