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Vigorous Generation of Electric Power by Implementing Lunar Power System

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Abstract
This Paper gives an approach to the implementation of Lunar Solar Power (LSP) generation. The LSP System is a reasonable alternative to supply earth's needs for commercial energy without the undesirable characteristics of current options. The long term exploration and colonization of the solar system for scientific research and commercial interest depends critically on the availability of electrical energy. In this paper first we discuss about the present power scenario and to improve the power necessity for the future decades, the construction of LSP station, transmits electricity produced in moon to the earth, preferring microwave for transmitting the electricity, At last we discuss about the cost of installing the project and how to minimize the installation cost.
Index Terms—About Lunar Solar Power, Rectennas, Microwave, Solar cells, Relay satellites, Solar Power satellites.

I. INTRODUCTION

But of all the renewable and non-polluting sources solar power become the most the primary source of commercial power for everyone in the world to achieve the same high standard of living. Over the past 200 years the developed nations have vastly increased their creation of per capita income compared to the other nations. In parallel, the developed nations increased the use of commercial thermal power to ~6.9Kwt/person. In fact, most people in the developing nations use much less commercial thermal power and most have little (or) no access to electric power.

By the year 2050, people will require at least 20,000 GWe of power. This requires approximately 60,000 GWt of conventional thermal power generation. Such enormous thermal energy consumption will exhaust economical recoverable deposits of coal, shale, oil, natural gas, uranium and thorium. As a result, of conventional systems become useless. Terrestrial renewable systems are always captive to global climate change induced by volcanoes, natural variation in regional climate, industrial haze and possibly even microclimates induced by large area collectors. Over the 2 1st century, a global stand –alone system for renewable power would cost thousands of trillions of dollars to build and maintain. Energy costs could consume most of the world's wealth. We need a power system that is independent of earth's biosphere and provides an abundant energy at low cost. To do this man –kind must collect dependable solar Power in space and reliably send it to receivers on earth. The MOON is the KEY.

II. PRESENT AND FUTURE POWER SCENARIO

In 1975 Goeller and Weinberg published a fundamental paper on the relation of commercial power to economic prosperity. They estimated that an advanced economy could provide the full range of Goods and services to its population with 6kWt/person. As technology advances, the goods and services could be provided by ~2 kWe/person of electric power. There will be approximately 10 billion people in 2050.They must be supplied with ~6 kWt/person or ~2 kWe/person in order to achieve energy and economic prosperity. Present world capacity for commercial power must increase by a factor of ~5 by 2050 to 60 kWt or ~20 TWe ($T=10^{12}$). Output must be maintained indefinitely. Conventional power systems are too expensive for the Developing Nations. Six kilowatts of thermal power now costs ~1,400 $/Y-person. This is ~50% of the average per capita income within the Developing Nations. Other major factors include the limited availability of fossil and nuclear fuels (4,000,000 GWt-Y) and the relatively low economic output from thermal energy (~ 0.25 $/kWt-h). Humans must transition to solar energy during first part of the 21st Century to extend the newly emerging world prosperity. However, solar and wind are intermittent and diffuse. Their energy output is too expensive to collect, store, and dependably distribute.

III. LUNAR SOLAR POWER GENERATION

Two general concepts have been proposed for delivering solar power to Earth from space. In one, Peter Glaser of Arthur D.Little, Inc. (Cambridge, MA), proposed in 1968 that a huge satellite in geosynchronous orbit around Earth could dependably gather solar power in space. In the second concept fig: 1, discussed here, solar power would be collected on the moon. In both ideas, many different beams of 12cm wavelength microwaves would deliver power to receivers at sites located worldwide. Each receiver would supply commercial power to a given region. Such a receiver, called a rectenna, would consist of a large field of small rectifying antennas. A beam with a maximum intensity of less than 20% of noontime sunlight would deliver about 200 W to its local electric grid for every square meter of rectenna area. Unlike sunlight, microwaves pass through rain, clouds, dust, and smoke. In both scenarios, power can be supplied to the rectenna at night Several thousand individual rectennas strategically located around the globe, with a total area of 100,000 km^2, could continuously provide the 20 TW of electric power, or 2 kW per person, required for a prosperous world of 10 billion people in 2050. This surface area is 5% of the surface area that would be needed on Earth to generate 20 TW using the most advanced terrestrial solar-array technology of similar average capacity now envisioned. Rectennas are projected to cost approximately $0.004/kWe•h, which is less than one-tenth of the current cost of most commercial electric energy. This new electric power would be provided without any significant use of Earth's resources several types of solar power satellites have been proposed. They are projected, over 30 years, to deliver approximately 10,000 kWh of electric energy to Earth for each kilogram of mass in orbit around the planet. To sell electric energy at $0.01/ kWh, less than $60 could be expended per kilogram to buy the components of the power satellites, ship them into space, assemble and maintain them, decommission the satellites, and finance all aspects of the space operations. To achieve this margin, launch and fabrication costs would have to be lowered by a factor of 10,000. Power prosperity would require a fleet of approximately 6,000 huge, solar-power satellites. The fleet would have more than 330,000 km^2 of solar arrays on-orbit and a mass exceeding 300 million tones. By comparison, the satellite payloads and rocket bodies now in Earth geosynchronous orbit have a collective surface area of about 0.1 km^2. The mass launch rate for a fleet of power satellites would have to be 40,000 times that achieved during the Apollo era by both the United States and the Soviet Union. A many decade development program would be required before commercial development could be considered.

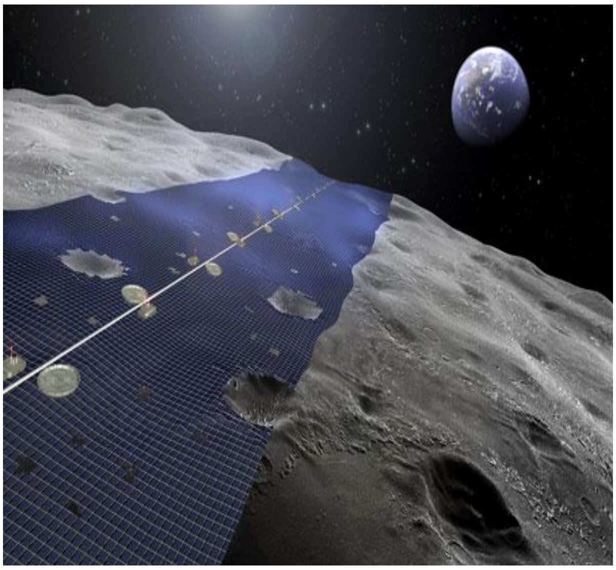

Figure: 1

IV. LUNAR SOLAR COLLECTORS

Fortunately, in the Lunar Solar Power (LSP) System, an appropriate, natural satellite is available for commercial development. The surface of Earth's moon receives 13,000 TW of absolutely predictable solar power. The LSP System uses 10 to 20 pairs of bases—one of each pair on the eastern edge and the other on the western edge of the moon, as seen from Earth—to collect on the order of 1% of the solar power reaching the lunar surface. The collected sunlight is converted to many low intensity beams of microwaves and directed to rectennas on Earth. Each rectenna converts the microwave power to electricity that is fed into the local electric grid. The system could easily deliver the 20 TW or more of electric power required by 10 billion people. Adequate knowledge of the moon and practical technologies has been available since the late 1970s to collect this power and beam it to Earth. Successful Earth–moon power beams are already in use by the Arecibo planetary radar, operating from Puerto Rico. This radio telescope periodically images the moon for mapping and other scientific studies with a radar beam whose intensity in Earth's atmosphere is 10% of the maximum proposed for the LSP System. Each lunar power base would be augmented by fields of solar converters located on the back side of the moon, 500 to 1,000 km beyond each visible edge and connected to the earthward power bases by electric transmission lines. The moon receives sunlight continuously except during a full lunar eclipse, which occurs approximately once a year and lasts for less than three hours. Energy stored on Earth as hydrogen, synthetic gas, dammed water, and other forms could be released during a short eclipse. Each lunar power base consists of tens of thousands of power plots fig:

5 distributed in an elliptical area to form fully segmented, phased-array radar that is solar-powered. Each demonstration power plot consists of four major subsystems.

Solar cells collect sunlight, and buried electrical wires carry the solar energy as electric power to microwave generators. These devices convert the solar electricity to microwaves of the correct phase and amplitude and then send the microwaves to screens that reflect microwave beams toward Earth. Rectennas located on Earth between 60º N and 60º S can receive power directly from the moon approximately 8 hours a day. Power could be received anywhere on Earth via a fleet of relay satellites in high inclination, eccentric orbits around Earth as shown in fig: 3. A given relay satellite receives a power beam from the moon and retransmits multiple beams to several rectennas on Earth required by an alternative operation. This enables the region around each rectenna to receive power 24 hours a day. The relay satellites would require less than 1% of the surface area needed by a fleet of solar-power satellites in orbit around Earth. Synthetic-aperture radars, such as those flown on the Space Shuttle, have demonstrated the feasibility of multi-beam transmission of pulsed power directed to Earth from orbit. Relay satellites may reflect the beam or may receive the beam, convert it in frequency and phasing and then, transmit a new beam to the rectenna. A retransmitter satellite may generate several beam and simultaneously service several rectennas. The orbital reflector and retransmitter satellites minimize the need on earth for long distance power lines. Relay satellites also minimize the area and mass of power handling equipments in orbit around earth. There by reducing the hazards of orbital debris to space vehicles and satellites.

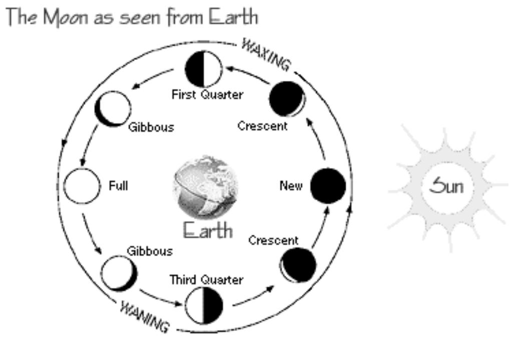

Figure: 2

V. FABRICATION OF THIN FILM CRYSTALLINE

A. Silicon Solar Cells

The silicon film is a proprietary process, and only a very general process is designed as shown in fig: 1. The generic process consists of ceramic formation, metallurgical barrier formation, polycrystalline layer deposition, emitter diffusion and contact fabrication. The conductive ceramic substrate is fabricated from selected low-cost materials. The metallurgical barrier prevents the substrate impurities from entering and contaminating the active thin silicon layer. The randomly textured and highly reflecting metallurgical barrier improves light trapping. A suitable p- type doped 30 – 100 micro-cm active layer is deposited from a liquid solution. Phosphorus and aluminum impurity gathering are used for bulk quality improvement. Cells with large areas of 240, 300 and 700 cm^2 are developed. A cell with an area of 675 cm^2 has demonstrated the record efficiency of 11.6 – 17.7%. The waste products present in the lunar surface are silicon, iron, TiO_2, etc. These products can be used as raw materials for solar cell fabrication. A special compound called anorthite is used for extracting the above said components. Carbothermal reduction of anorthite,

$$4CH_4 \xrightarrow{1400^{o}C} 4C + 8H_2$$

$$CaAl_2Si_2O_8 + 4C \xrightarrow{1860^{0}c} CaO + Al_2O_3 + 2Si + 4CO$$

(Anorthite)

$$4CO + 12H_2 \xrightarrow[\text{NI Catalyst}]{250^{o}C} 4CH_4 + 4H_2O$$

$$4H_2O + \text{electrolysis} \xrightarrow{75^{o}C} 4H_2 + 2O_2$$

Closed cyclic process yielding both OXYGEN and SILICON:

$$CaAl_2Si_2O_8 + 4C \longrightarrow CaO + Al_2O_3 + 2Si + 4CO$$

Carbon compounds can also be used to extract Oxygen, Fe, and TiO_2 from Lunar Illmenite. The iron is used for interconnect and TiO_2 for antireflect.

B. Carbon Monoxide Cycle

$$FeTiO_3 + CO \longleftrightarrow Fe + TiO_2 + CO_2$$
$$2CO_2 \longleftrightarrow 2CO + O_2$$

C. Methane Cycle

$$FeTiO_3 + CH_4 \longleftrightarrow Fe + TiO_2 + CO + 2H_2$$
$$2CO + 6H_2 \longleftrightarrow 2CH_4 + 2H_2O$$
$$2H_2O \longleftrightarrow 2H_2 + O_2$$

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VI. MICROWAVE

For direct microwave wireless power transmission to the surface of the earth, a limited range of transmission frequencies is suitable.

Frequencies above 6 GHz are subject to atmospheric attenuation and absorption, while frequencies below 2 GHz require excessively large apertures for transmission and reception. Efficient transmission requires the beam have a Gaussian power density. Transmission efficiency η_b for Gaussian beams is related to the aperture sizes of the transmitting and receiving antennas:

$$\eta_b \sim 1 - \exp(-\tau^2) \text{ and}$$
$$\tau = \pi D_t D_r / (4\lambda R)$$

Where D_t is the transmitting array diameter,
D_r is the receiving array diameter,
η_b .is the wavelength of transmission and
R is the range of transmission.

Frequencies other than 2.45 GHz, particularly 5.8 GHz and 35 GHz are being given greater attention as candidates for microwave wireless power transmission in studies and experiments. The mass and size of components and systems for the higher frequencies are attractive. However, the component efficiencies are less than for 2.45 GHz, and atmospheric attenuation, particularly with rain, is greater. A typical Microwave transmitter is shown in fig: 3.

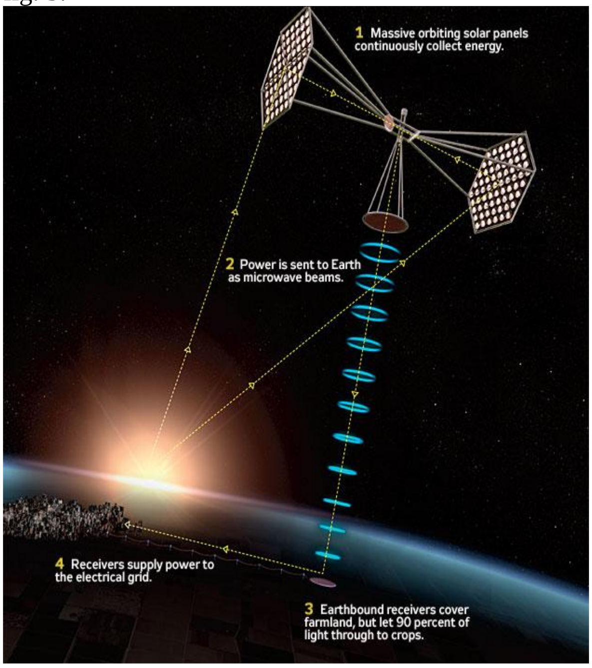

Figure: 3

VII. COST FORECASTING

To achieve low unit cost of energy, the lunar portions of the LSP System are made primarily of lunar derived components. Factories, fixed and mobile, are transported from the Earth to the Moon. High output greatly reduces the impact of high transportation costs from the Earth to the Moon. On the Moon the factories produce 100s to 1,000s of times their own mass in LSP components. Construction and operation of the rectennas on Earth constitutes greater than 90% of the engineering costs.

Any handful of lunar dust and rocks contains at least 20% silicon, 40% oxygen, and 10% metals (iron, aluminum, etc.). Lunar dust can be used directly as thermal, electrical, and radiation shields, converted into glass, fiberglass, and ceramics, and processed chemically into its elements. Solar cells, electric wiring, some micro-circuitry components, and the reflector screens can be made out of lunar materials. Soil handling and glass production are the primary industrial operations. Selected micro circuitry can be supplied from Earth. Use of the Moon as a source of construction materials and as the platform on which to gather solar energy eliminates the need to build extremely large platforms in space. LSP components can be manufactured directly from the lunar materials and then immediately placed on site. This eliminates most of the packaging, transport, and reassembly of components delivered from Earth or the Moon to deep space. There is no need for a large manufacturing facility in deep space. The LSP System is the only likely means to provide 20 TWe of affordable electric power to Earth by 2050. According to criswell in the year 1996 Lunar solar power reference design for 20,000GWe is shown in table. It's also noted that the total mass investment for electricity from lunar solar energy is less than for Terrestrial solar energy systems.

Terrestrial Thermal power system	- 310,000 tones / GWe.
Terrestrial Photovoltaic	- 430,000 tones / GWe.
Lunar solar power	- 52,000 tones / GWe.

VIII. MERITS OF LSP

In technical and other aspects there are two reasons for which we prefer LSP are:

Unlike earth, the, moon is the ideal environment for large area solar converters.

- The solar flux to the lunar surface is predictable and dependable.
- There is no air or water to degrade large area thin film devices.
- Solar collectors can be made that are unaffected by decades of exposure to solar cosmic rays and the solar wind.
- Sensitive circuitry and wiring can be buried under a few- tens of centimeters of lunar soil, and completely protected against solar radiations

temperature extremes. Secondly, virtually all the LSP components can be made from local lunar materials.

- The high cost of transportation to and from the moon is cancelled out by sending machines and small factors to the moon that produce hundreds to several thousand times their own mass in components and supplies power to different parts of the world as in fig : 4.
- Lunar materials will be used to reduce the cost of transportation between the earth and the moon and provide supplies.

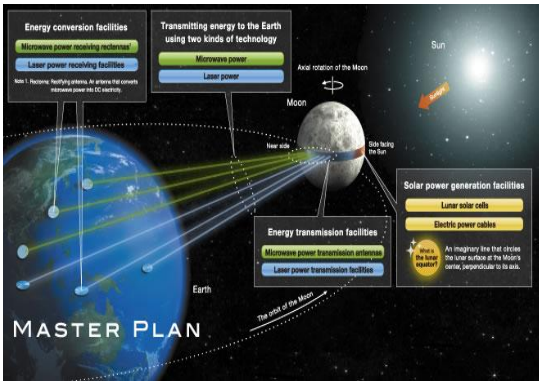

Figure: 4

A. *Additional Features of LSP*

The design and demonstration of robots to assemble the LSP components and construct the power plots can be done in parallel. The crystalline silicon solar cells can be used in the Lunar Solar Power Generation design of robots which will further decrease the installation cost and will be automated as in fig: 5.

B. *Economical Advantages of LSP and Crystalline Silicon Solar Cell*

- Crystalline silicon solar cells almost completely dominate world – wide solar cell production.
- Excellent stability and reliability plus continuous development in cell structure and processing make it very likely that crystalline silicon cells will remain in this position for the next ten years.
- Laboratory solar cells, processed by means of sophisticated micro – electronic techniques using high quality Fe-Si substrate have approached energy conversion efficiencies of 24%.

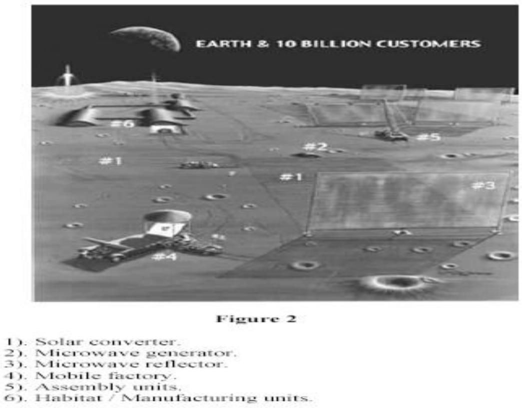

Figure: 5

IX. CONCLUSION

The LUNAR SOLAR POWER (LSP) system will establish a permanent two planet economy between the earth and the moon. The LSP System is a reasonable alternative to supply earth's needs for commercial energy without the undesirable characteristics of current options. The system can be built on the moon from lunar materials and operated on the moon and on Earth using existing technologies. More-advanced production and operating technologies will significantly reduce up-front and production costs. The energy beamed to Earth is clean, safe, and reliable, and its source—the sun—is virtually inexhaustible.

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