LUNAR SOLAR POWER, UTILIZATION OF LUNAR MATERIALS AND ECONOMIC DEVELOPMENT OF THE MOON

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Over the past 200 years the *Developed Nations* have vastly increased their creation of per capita income compared to the other nations (Figure 1) (1, 2, 3, 4). In parallel, the Developed Nations increased the use of commercial thermal power to ~6.9 kWt/person. The Developing Nations increased to an average of only 1.6 kWt/person. "t" refers to thermal power. In fact, most people in the Developing Nations use much less commercial thermal power and most have little or no access to electric power.

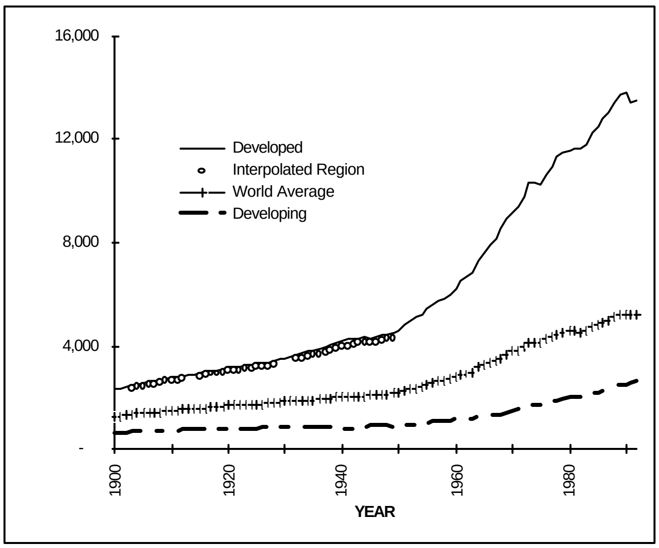

Figure 1. Gross World Product ($/Y) per Person

In 1975 Goeller and Weinberg published a fundamental paper on the relation of commercial power to economic prosperity (5). They estimated that an advanced economy could provide the full range of goods and services to its population with 6 kWt/person. As technology advances, the goods and services can could be provided by ~2 kWe/person of electric power (6). "e" refers to 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 (tera = 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. Others such as hydroelectric, wave, geothermal, and ocean thermal are too limited in total power.

Figure 2 shows a lunar/space solar power system that has been studied in detail (6, 7). The sun in the upper left. It illuminates power bases constructed on the east and western sides of the Moon as seen from Earth. Each base, when illuminated, converts sunlight into electric power and then into low intensity beams of microwaves. The beams are directed to receivers on Earth. The receivers, termed rectennas, convert the microwaves into electricity that is output to the local electric grid. One rectenna is depicted in the lower right side of Figure 2. The beams can operate at ~200 w/m^2 or approximately 20% of the intensity of sunlight at noon. Supplying 20 TWe requires fields of rectennas, distributed about Earth, that have a total area of ~100,000 km^2. This is a small fraction of the surface of Earth now devoted to the production and distribution of commercial power. Everyone on Earth can be supplied with 2 kWe/person.

Figure 2. Sun - Moon - Microwave Beam- Rectenna

The lunar portion of an LSP System prototype Power Base is depicted in Fig. 3. A Power Base is a fully segmented, multi-beam, phased array radar powered by solar energy. This Power Base consists of tens to hundreds of thousands of independent power plots such as depicted in the middle to lower right portion of Fig. 3. Each power plot emits multiple sub-beams. Sets of correlated sub-beams from all the plots are phased electronically to produce one power beam. A given base can project tens to hundreds of independent power beams. A power plot consists of four elements. There are arrays of solar converters, shown here as north-south aligned rows of photovoltaics. Solar electric power is collected by a buried network of wires and delivered to the microwave transmitters. Power plots can utilize many different types of solar converters and many different types of electric-to-microwave converters. In this example the microwave transmitters are buried under the mound of lunar soil at the Earthward end of the power plot. Each transmitter illuminates the microwave reflector located at the anti-Earthward end of its power plot. The reflectors overlap, when viewed from Earth, to form a filled lens that can direct very narrow and well defined power beams toward Earth. The Earth is fixed in the sky above the Power Base.

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 constitute greater than 90% of the engineering costs.

There are no “magic” resources or technologies in Fig. 2 or Fig. 3. 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 microcircuitry 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.

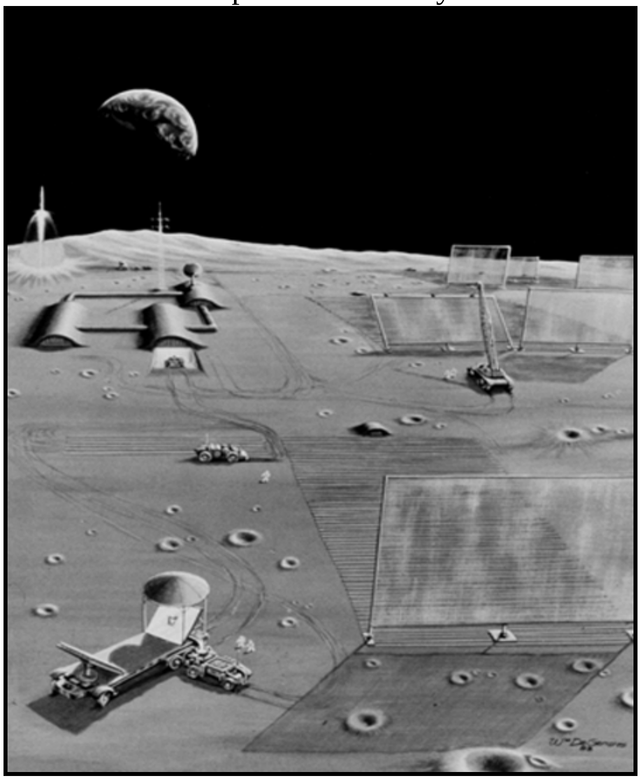

Fig. 3 LSP System Prototype Power Base

LSP installations create huge net new wealth on the Moon. Suppose, averaged over 100 years, that the LSP System sells 20,000 GWe at 1 ¢/kWe-h to rectennas in the rectennas on Earth. Gross sales are 1.7 T$/Y. Costs will be ~ 0.1 T$/Y. Net profit, before taxes, is ~ 1.6 T$/Y. The 100 year-long cash stream has a present value of 25 T$ at a 7%/Y discount rate.

Suppose 10% of the stock is held by LSP employees who organize, build, and operated the lunar power bases. At any one time approximately 25% would be on the Moon. Their present discounted value would be ~ 125 M$/person and their annual earning would be ~ 8 M$/Yr. The following table shows the per capita wealth on the Moon resulting from a distribution of wealth characteristic of a high technology economy this is limited in natural resources. The per capita "human resource" value is slightly higher than major sports figures in the United States and considerably lower than Mr. William Gates and other major early investors and employees of *Microsoft*. If 100 million Earthlings bought 30% of the stock at $20,000/person their ROI would be ~ 4,900$/Y or 24%/Y.

2050 Wealth per Person	Average Total $	human resources	produced assets	natural resources
LSP/Moon	$\$120 \bullet 10^6$	$\$100 \bullet 10^6$	$\$22 \bullet 10^6$	$\$12 \bullet 10^6$

The LSP Systems are based on well understood technologies in electronics, radar, conventional materials and manufacturing. Most of the key demonstrations can be done on Earth (6). Many key demonstrations have already been performed. The LSP System can enable humanity to begin producing net new wealth from clean, abundant, and affordable net new solar electric energy.

References

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2. "Developed Nations" refers to member nations of the Organization of Economic Cooperation and Development. They are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States. The calculations in this paper included Korea in the "Developing Nations." "Oceania" refers to the large Pacific Islands, not including New Zealand or Japan.

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