

SPACE SOLAR POWER FOR EARTH FROM EARTH ORBITS AND THE MOON

Peter E. Glaser

Lexington, MA, USA

(pgeg@aol.com)

INTRODUCTION

The "perpetual struggle for room and food" foreseen by Malthus nearly 200 years ago is now joined by the growing concerns of global energy shortages before the majority of the people on Earth will have benefited from existing terrestrial energy sources to increase their living standards.

There is a growing consensus that future generations will live in a world where gas, oil and coal will be increasingly scarce resources, and valued as chemical feed stocks rather than fuel. The reality of the finite nature of carbon based energy production is grudgingly being acknowledged.

Energy economists are debating whether the peak availability of energy resources will be reached before 2010, and whether by mid-century, deposits of gas and oil will have been exhausted. Even coal deposits may not meet global energy needs especially if the effects of global warming are shown to be responsible for climate changes resulting in melting of the polar ice fields, and other deleterious effects on the ecology.

Nuclear energy although promising has widely known drawbacks including eternal vigilance over all process steps including nuclear waste disposal, and the potential for diversion of nuclear materials for atomic weapons. None of these drawbacks have so far been completely eliminated. Fusion generated power on Earth, if major obstacles can be removed, may at an undefined future time become possible.

Life on Earth, could not have evolved without the ceaseless radiation from the sun into space of which only a minute fraction is intercepted by the Earth. Already there are significant efforts underway to benefit from the sun's energy on Earth. However, the demands for energy on Earth, as useful and worthwhile the present efforts to convert solar energy for a wide range of applications may be, they are limited by the diffuse nature of solar radiation, the diurnal cycle, weather conditions, and the requirements for energy storage for about 12 hours a day. Because of these drawbacks the energy demands in this century will exceed by far the contributions of terrestrial solar energy conversion systems.

Space-based solar energy systems have been developed since the beginning of the space-era, and are installed in a large variety of satellite systems ranging from communication satellites to the International Space Station. Solar energy converted in space for use on Earth, "Space Solar Power" (SSP) relies on the continuous and inexhaustible energy of the sun converted directly into electricity with solar cells in space. The electricity is fed to microwave generators incorporated into transmitting antennas. SSP could meet foreseeable global energy

requirements, and ensure that the Earth will remain a hospitable planet for humans and all other forms of life in the future. Centers of sustainable development based on energy from space can provide the focus and financial infrastructure needed to stimulate sustainable regional development for the global populations.

THE RATIONALE FOR SOLAR SPACE POWER (SSP) FOR USE ON EARTH

The implicit convictions of well-meaning individuals in the 20th century were that regional developments, complex river management schemes, exploitation of solid, gaseous and liquid fuels, control of nuclear power, and at an undefined future time fusion would meet foreseeable energy needs. It is increasingly recognized that these well-intended human activities can result not only in exhausting carbon-based global energy sources, but in unforeseen direct or indirect impacts on the Earth climate and ecology ranging from the disquieting to the catastrophic. Underlying these impacts is the exponential population growth resulting from improvements in sanitation and health care, with a projected global population of 10 billion by mid-century demanding higher living standards.

The technology exists to create a global energy supply system that is compatible with the Earth's ecology, relies on an inexhaustible energy source for as long as the sun shines, especially when compared to existing and planned methods of generating electricity. SSP lends itself to complete integration with the existing investments in the electric power supply infrastructure.

Historically, wealth has been created when the power of the human intellect combined abundant energy with rich materials resources. There is a growing conviction that it is possible to convert solar energy in space with materials launched from Earth, and eventually to use construction materials available on the moon to provide inexhaustible energy from the moon to meet the needs of the Earth's population in future millennia.

basic concept of SSP relies on the use of photovoltaics for the direct conversion of solar energy into electricity with solar cell arrays. The solar cell arrays of the SSP installation deployed in orbit or on the lunar surface are designed to generate electricity. The microwave transmission system had its origin in the demonstration of microwaves by Hertz in 1886. Tesla already in 1908 attempted beaming power from Long Island, New York to Europe. Microwave generators, in wide use today in industry and homes, are incorporated in a planar phased-array transmitting antenna. The transmitting antenna directs a microwave beam of low power density precisely to one or more receiving antennas at desired locations on land or offshore. At the receiving antenna the microwaves are safely and very efficiently converted into electricity and transmitted with electrical transmission lines to users. The receiving antennas can be located offshore especially if the concept of "ocean cities" is found viable in the future.

The concept of "Power from Space" was first publicly presented by the author in 1968, and a US patent was issued to him in 1971. The first successful demonstration of wireless power transmission for use in SSP was performed at the NASA Space Antenna facility at Goldstone, California in 1975. During this demonstration 30 kW were beamed over a distance

of one mile to the receiving antenna where the microwave beam was converted directly to electricity with an efficiency of 82%.

Since then space technologies for SSP have been studied and demonstrated on Earth and in space to meet performance and safety requirements by growing numbers of academic institutions, industry groups, and government agencies in China, France, India, Japan, Russia, Ukraine, and USA. The results of these ongoing global development efforts are that the concept of SSP is considered a realistic global power supply option which can be developed in the foreseeable future. There is a growing consensus not only within the space technical community but also in the electrical power supply industry that there is a compelling rationale for developing SSP.

The development of power from space for use on Earth is an achievable application of known space technologies that can be demonstrated on an increasing scale during the next decades. It will require both capital and participation on a global scale.

The undertaking of this global development must be on a profitable basis for all nations for otherwise SSP will not be available when today's energy sources are either exhausted in this millennium or alternative energy sources are found to be wanting for either technical, economic ecological or societal reasons..

The SSP represents an evolutionary direction of expanding successful applications of the relevant technologies developed on Earth together with the major accomplishments of space missions performed in the last century. President's Kennedy's historic challenge to the space community to land a man on the moon in the next decade was at that time a greater challenge than obtaining power from space for use on Earth.

With the demonstrated feasibility of the applicable technologies there is increasing confidence that economic, societal , environmental and ecological criteria can be met, ensuring that SSP will be in compliance with United Nations policy and legal requirements, and capable of satisfying global energy demands in this century.

The possibility that global society will accept a declining living standard and a degrading global environment appears to be highly unlikely. There is no viable alternative but to plan to develop all possible benign forms of energy production which include the conversion of solar energy in space for use on Earth.

The successful implementation of SSP could usher in not only a new era of energy resource development of global benefit, and provide the impetus to extend human activities beyond the confines of the Earth, but also divert near-Earth objects from catastrophic impacts with Earth.

This may be possible with launching powerful laser beams powered by lunar SSP installations to intercept such objects on a collision trajectory with Earth.

CONCLUSION

While there appear to exist several options to meet future global energy needs, most currently known energy sources have inherent documented limitations which call into question their availability on a scale essential to ensure future equitable global access to energy sources compatible with the Earth's ecology. There is still time to develop and select the most desirable power generation options before commitments are made that would result in unsustainable global development.

There still are many opportunities to increase reliance on the benefits of solar energy on Earth and in space for use on Earth to ensure that this will remain a planet hospitable for all forms of life.

LITERATURE SOURCES

Brown, W.C., *Experimental Airborne Microwave - Supported Platform*, Technical Report, Rome Air Development Center, Rome, NY, TADC - TR : 188, 1965

Glaser, P.E., *The Future of Power From the Sun*, Intersociety Energy Conversion Engineering Conference, Boulder, CO, pp. 90–103.

Glaser, P.E., *Power from the Sun: Its Future*, Science, Vol. 162, 1968, pp. 857-866

Glaser, P.E. et al. *Feasibility Study of a Satellite Solar Power Station*, NASA Lewis Research Center, Cleveland, OH, CR-2357, NTIS , N74-17784, 1974

US Department of Energy, *Satellite Power System (SPS) Concept Development and Evaluation Program (CDEP) Plan: July 1977 - August 1980*, DOE/ET - 0034, US. Government Printing Office, No. 061-000-00031-3, , DC, 1978

Dickinson, R.M. and Brown, W.C., *Radiated Microwave - Supported Platform Power Transmission System Efficiency Measurements*, Technical Memorandum 33-727, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 1979

US Department of Energy, *An Assessment of the SPS and Six Alternative Technologies*, DOE - ER - 0099, April 1981

Sarkisjan, et al., *Socio-Economic Benefits connected with the Use of Space Power and Energy Systems*, IAF - 85 -188, 36th Congress of the International Astronautical Federation, 1985

Deschamps, L., Electricite de France, and Demerliac, Y., Eurospace, *Industrial Development of Energy Production in Space*, IAF-88-215, 39th Congress of the International Astronautical Federation, 1988

Cheney, M. Tesla, Barnes & Noble, New York, NY, 1993, p.158

Akiba, R. et al, *International Space Year - Microwave Energy Transmission in Space*

Experiment, Report No. 652, The Institute of Space and Astronautical Science,
Kanagawa, Japan, September 1993

Aviation Week & Space Technology, *Mir fires beams at Swedish Satellite*, vol. 140,
no. 14, April 4, 1994, pp. 71-72

Nansen, R., *Sun Power, The Global Solution for the Coming Energy Crises*,
Ocean Press, Ocean Shores, WA, ISBN 0-9647021-1-1-8, 1995

(4)

Glaser, P.E. and Trotti, G.L., *Wireless Power Transmission from Space to Offshore Receiving
Antennas to meet Ocean Cities Energy Needs*, Proceedings of Ocean Cities '95 Conference,
Monaco, Societe des Electriciens et des Electroniciens, Paris, 1995, pp. 211 - 215

Erb, R.B., *Power from Space – The Tough Questions*, 45th Congress of the International
Astronautical Federation, Paper IAF-95.R2.01, Oslo Norway, October 2-6, 1995

Criswell, D.R. and Thompson, R.G., *Data Envelopmenmt Analysis of Space and Terrestrially-
based , Large-Scale, Commercial Power System for Earth*, Solar Energy Journal,
vol. 56, no.1, January 1996, pp. 119-131

Osepchuk, J.M., *Health and Safety Issues for Microwave Power Transmission*, Solar Energy
Journal, vol. 56, no.1, January 1996, pp. 53-60

Nagatomo, N., *An Approach to Develop Space Solar Power as a New Energy System for
Developing Countries*, Solar Energy Journal, vol. 56, no.1, January 1996

Glaser, P.E., Davidson, F.P. and Csigi, K.I., eds. *Solar Power Satellites, A Space Energy
System for Earth*, John Wiley & Sons, New York, NY, 1997, ISBN 0-471 96817X

Mankins, J.C., *Space Applications of Affordable Large Power Systems*, IAF-99-R.3.0,
presented at 50th International Astronautical Congress, Amsterdam, Netherlands, October 48,
1999

Moore, T., *Electricity From Space*, EPRI Journal, Electric Power Research Institute,
P.O. Box 1042, Palo Alto, CA 94303, Spring 2000

Glaser, P.E., Guest Editor, *Space Policy*, Volume 16, No. 2, May 2000, Elsevier Ltd.
www.elsevier.com/locate/spacepol

Garshnek, V., Morrison D., Burkle Jr. F.M., *The mitigation, management, and survivability of
asteroid/comet impact with Earth*, *Space Policy*, Volume 16, No.3. August 2000, Elsevier Ltd.

Glaser, P.E., *Space Solar Power for Earth*, **Eco Earth**, Volume 1, No.1, October 2000, p. 7,
International Institute for Sustainable Future, Mumbai – 21, India, iisfb@giasbm01.vsnl.net.in