GRAND-BASSIN : A STEP ON THE LADDER TO ENERGY FROM SPACE

Guy Pignolet*, Didier Vassaux*, Alain Celeste**
* CNES Centre National d'Etudes Spatiales, ** Université de La Réunion
* Paris, France, ** Saint Denis de La Réunion, France

Abstract

Solar energy seems to be the best environmental solution to the global energy problem and **S**pace **S**olar **P**ower may play a major role in our sustainable future. However, SSP systems are still way beyond the current horizons of our Economies and Politics. Intermediate steps have to be found to build a strategic ladder that will eventually take us to SSP implementation. **W**ireless **P**ower **T**ransportation by microwave is a key SSP technology, and the next step seems to be the realization of point to point WPT on the ground. Such a project is underway in the village of Grand-Bassin, in France, under the leadership of the University of La Réunion. Environment integration comes first along the priorities of the project and public acceptance is also considered to be a basic issue. In December 1998, a small permanent display was open to the public of tourists and visitors with presentations of WPT technology, study for Grand-Bassin and future SSP projects. A functional demonstrator implemented on the display actually beams a minute flow of energy between a microwave source and a set of collectors

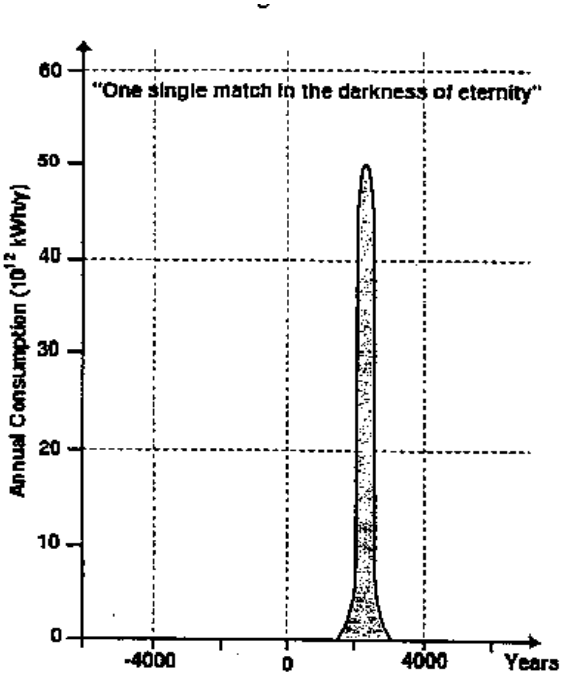
The environment

The global energy problem is upon us and it is the duty and the glory of our generation to solve it for the benefit of our grand-children. In many respects, solar energy seems to be the best environmental solution for the future and **S**pace **S**olar **P**ower systems appears to be an ecological, clean and sustainable solution to serve the energy needs of our planet, especially in the case of the larger megacities.

Limited resources …

Fossil energy resources, oil, gas and coal, contribute for the major part of the production of electrical energy, but the reserves are limited and they do not extend beyond half a century for oil and gas, one or two centuries for coal. The situation looks hardly better for nuclear energy where the resources of economically accessible fuel do not appear to be much larger. Furthermore there are some specific problems to the use nuclear energy.

Only one match !



Peter Créola, of the European Space Agency ESA, has illustrated this in a dramatic way by telling that Mankind may use one match and only one to light up its own future..[1]

Not only do we face resource shortage, but we should be also careful to avoid the ill-effects connected with the use of energy :

Preventing the greenhouse effect.. !

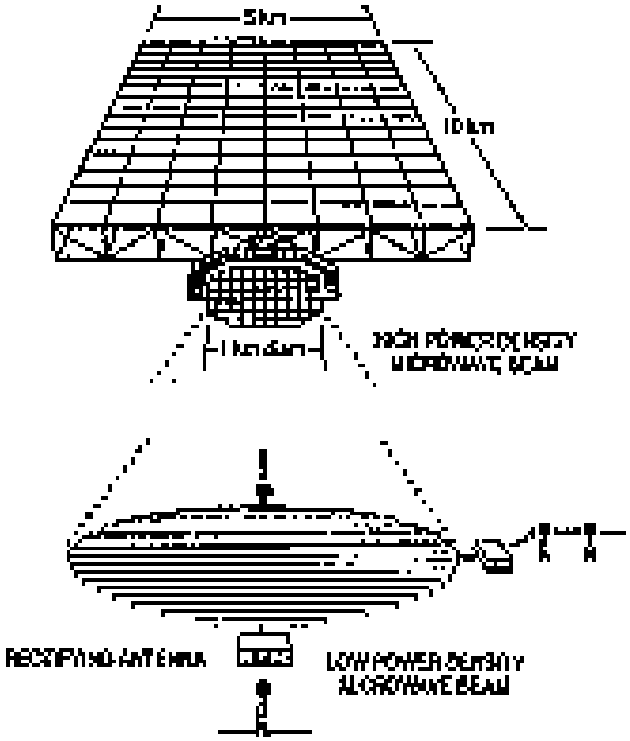
The Kyoto Conference has requested world governments to reduce the CO^2 emission in the production of energy. Neither nuclear powerplants nor Space Solar Power are expected to produce any at time of operation, but they induce CO^2 emission while they are being constructed. Of all the energy systems we may consider

over their total life cycle, SSP are the cleanest in terms of emission of CO^2.

Space Solar Power

Peter Glaser invented the SSP concept of Space Solar Power in 1968. Many WPT experiments were made in the seventies and later, and in the U.S., the DOE proved the feasibility of the SSP concept. New studies were initiated in Japan at the beginning of the nineties, and NASA completed a "Fresh Look Study" a few years later.

The "reference" system

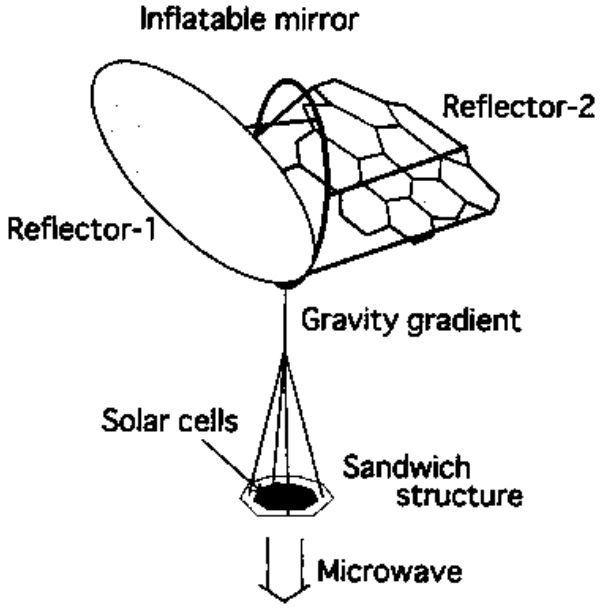


It was conceived in 1979 by the U.S. Department of Energy, following the ideas of Peter Glaser, inventor of the concept of Space Solar Power. The estimated costs were prohibitive, but it was alter shown by the Space Studies Institute that they could be greatly reduced if Moon materials were used for the construction of the SPS.

The Sandwich structure

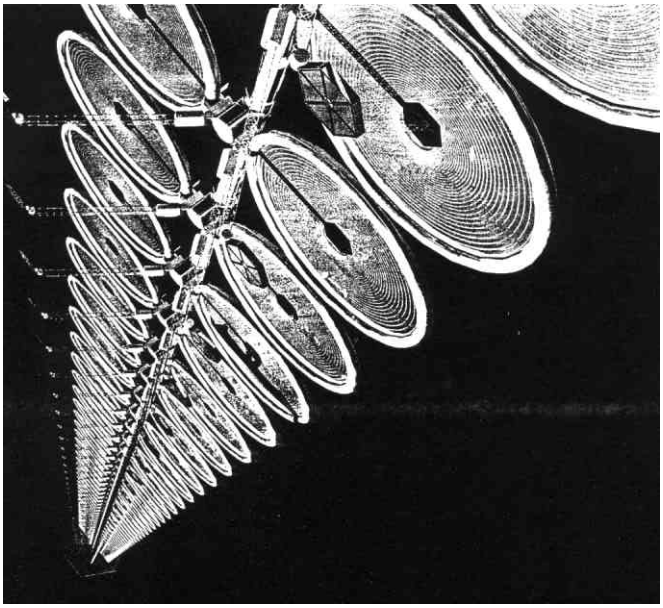
To decrease the overall mass, Nobuyuki Kaya, from Japan, has envisioned to locate the electronics between the high energy photovoltaic cells and the microwave projection elements. This would simplify greatly the construction of the system. Selective coating of the reflectors would improve the conversion efficiency of the cells.

The Sandwich structure (basic concept)



The Sun Tower

The project studied by John Mankins and his team at NASA is realistic, if the costs of transportation could be reduced by a factor of twenty through the development of space tourism.

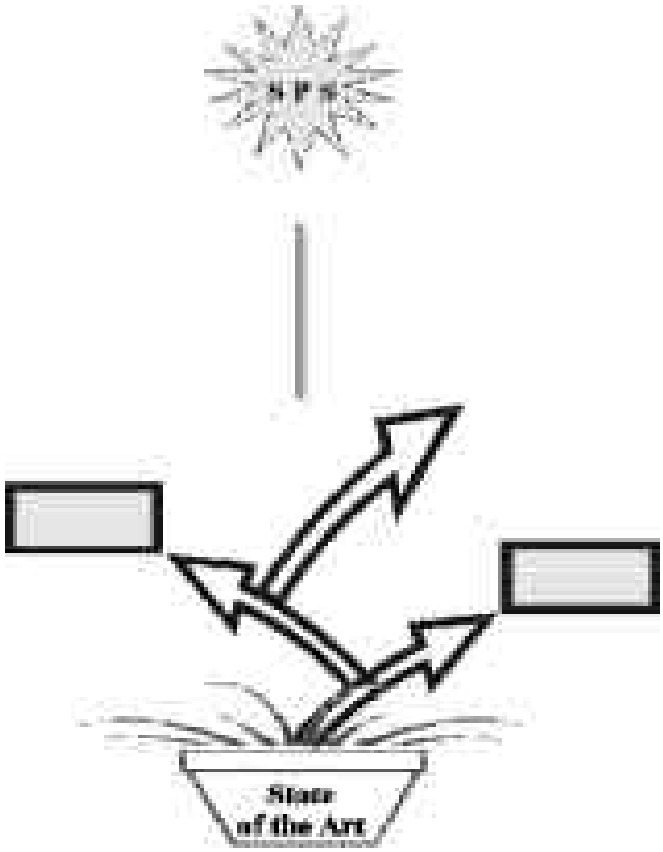


The strategic ladder

The construction of SSP systems is far beyond the current horizons of economy and politics. It is therefore not possible to engage now into such programs, whatever important they appear for the very survival of the future generations. What is possible today is the engagement of projects that lead to the same direction while having their own merits in the short and medium term, such as point to

point links on the ground, free-flier modules in orbit, or power systems for high altitude long endurance platforms that could be used for local applications in Earth observation and telecommunications.

Climbing towards the future …



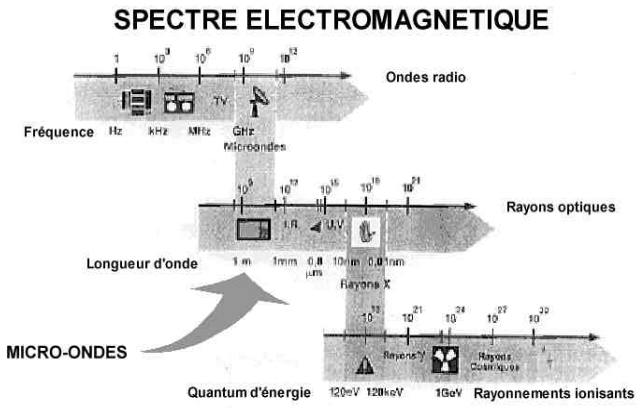
Intermediate steps have to be found with their own merits, to build over the forthcoming decades a strategic ladder that will eventually take us to the decision of SSP implementation. After the many ground and air experiments that have demonstrated **W**ireless **P**ower **T**ransportation by microwave, a key technology on the way to SSP, the next step seems to be the realization of a point-to-point WPT on the ground.

Wireless Power Transportation

In the early sixties, Bill Brown, in the USA, pioneered the field of WPT by flying a small helicopter powered by a microwave beam :

Energy and waves

Ours is a world of energy, which appears basically under two aspects, matter and waves. Waves spread over the electromagnetic spectrum, from the lower frequencies to cosmic rays. All waves carry energy as they radiate : the higher the frequency, the higher the energy of the individual photon. When the energy of wave radiation is absorbed by matter, it is transformed into heat, this is the thermal effect. The most energetic radiation may rip electrons away from atoms and modify the structure of molecules, this is the ionizing effect. Microwaves frequencies are far too low to have ionizing effects.



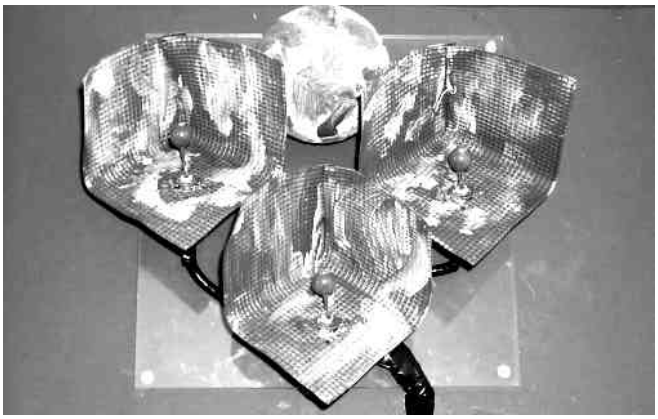
However the total continuity of the spectrum, three types of radiation are often considered : the radio waves, the optical rays, that travel in a straight line, and the high energy radiation, which have ionizing effects. Hyperfrequencies, also called microwaves, are on the overlap between radio and optics. Just as light, they can be projected.

2.45 billion Hertz !

This is the frequency of electrical and magnetic vibrations of the micro-waves used in ISM (industrial, scientific and medical) applications. This is the frequency used in domestic ovens, where the energy is transformed into heat. In WPT applications, the microwaves are transformed back to DC electrical power. The 2.45 GHz allows the projection of relatively well focused beams which can travel through the atmosphere without much losses whatever the actual meteorological conditions and which can be effectively directed to the reception sites where the energy is collected.

Projectors …

Magnetrons, which are used in domestic ovens and for industrial heating, are inexpensive, have an efficiency of about 90%, but they are difficult synchronize together as an array. Klystrons are efficient but expensive. Solid state FET's are very simple but their efficiency is poor.



Projectors of the Grand-Bassin functional model

Collectors

In the rectennas, the waves collected by the antennas are rectified by diodes which deliver low voltage direct current. In the cyclotron wave converters (CWC) systems, the energy of microwaves is transfered to an electron beam which generates high voltage direct current.

Collectors of the Grand-Bassin functional model

The Grand-Bassin Project

A point-to-point WPT project is undertaken Grand-Bassin, in France, by the University of La Réunion, with a power of **10 kW** to be transported over a distance of **700 meters** to a small mountain village.

In 1991, following the SPS'91 international symposium organized by Lucien Deschamps, of the French SEE, the Laboratory of Industrial Engineering (in French "LGI") of the University of La Réunion, initiated studies with the prime objective of implementing a first fully operational point to point WPT link to provide power to this remote isolated location in the midst of the island.

With a view that above all SPS and WPT will in the long term be global and local solutions to environment problems the priorities for the project have been set with environment integration coming first along the line, next being keeping the cost as low as possible, and eventually achieving a reasonable technical efficiency.

The village of Grand-Bassin, 700 m down away.

Point to point transportation

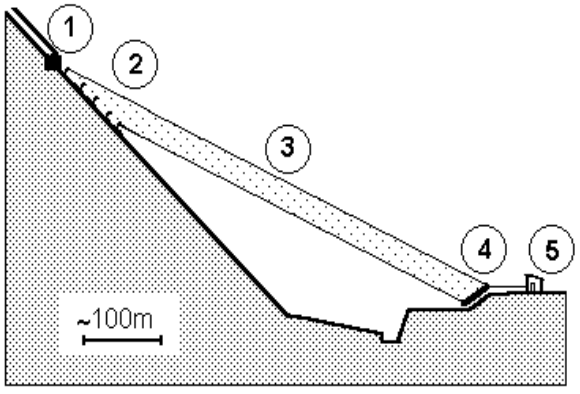
1. Water pumps / Grid power

2. Beam Projector Array

3. Microwave Beam

4. Receiving CWC/Rectenna Array

5. End Users



An international study

Experts from the United States, Japan, Russia and Europe have joined forces with the researchers of the University of La Réunion to elaborate a realistic project.[2]

At the end of 1996, a demonstration of feasibility was made in Bois-Court. The studies for Grand-Bassin were validated in several international meetings, and LGI has undertaken to build a full prototype as a step towards the construction of the operational system.

The power grid …

In the project for Grand-Bassin, the primary source of energy will be the regional power grid, available night and day whatever the meteorological conditions. Next, an array of phase-locked microwave projectors will create the directed energy beam. This wireless and totally invisible virtual conductor will have a diameter of about fifteen meters and a basically cylindrical shape. The beam will carry the energy over a distance of some 700 m. The transported energy will be distributed over a section of 200 square meters. The density of energy will be well below the density transported by ordinary sunbeams.

End users

This distribution of the energy flow over a large section area will allow crossings of the microwave beam without any risk. At the other end of the beam, a field of energy converters will combine diode type rectennas and possibly cyclotron wave converters to feed a system that will change the direct currents to "wall-plug" 220 Volt AC power. Since the WPT works only on/off without much possibility for power modulation, a small pool of storage batteries will help as a "buffer" to regulate the beaming of energy according to demand. The already existing photovoltaic panels will be integrated into the system of energy distribution to the end users.

Economic Efficiency !

In the laboratories, efficiencies of about 85% can be achieved at each one of the three basic steps of the process : conversion of electricity to microwaves, collection of the beam, and re-conversion of microwaves to electrical power. Thus, the global technical efficiency of the system may approach 60%. In the case of Grand-Bassin, the studies aim in priority to a good integration in the environment, then to reasonable construction costs, and only in the third place to the technical efficiency, with a target efficiency of about 60% at every step, which can be achieved easily at a reasonable economic cost.

Even with 20% global efficiency of the WPT system, when power will be transported by a microwave beam, it will still remains 4 times less expensive than the electricity provided by the photovoltaic panels.

Source)	(Projector	Collector)	(User
	AC ⇩ MW	⇨ ⇨	MW ⇩ AC
	60%	60%	60%
50 kW	30 kW	18 kW	11 kW

Energy, from source to end user

The public demonstrator

Public acceptance is considered to be a basic issue in the process, education is thought to be essential. LGI, supported by CNES and by the city of Le Tampon, has developed a small permanent demonstrator for the information of the general public.[3]

The presentation at CNES …

Meeting in Paris, left to right : Dieter Kassing, of ESA Prospective Dept., * Didier Vassaux, of CNES Prospective Dept., Nobuyuki Kaya, of University of Kobe & IAF Power Committee, John Mankins, of NASA Prospective Dept., Pierre Marx, of CNES Prospective Dept., Guy Pignolet, of CNES Prospective Dept. and of University of La Réunion, Lucien Deschamps, of Fondation 2100, Marcel Toussaint, of Eurospace.

On the 7 December 1998, the Direction of Future Studies of CNES invited in Paris SSP and WPT specialists from Europe, USA and Japan, to join with Professor Kaya, Chairman of the Energy Committee of the IAF, the International Federation of Astronautics, as a sign of the renewed interest of space agencies for the study of space solar power. On this occasion the experts were able to observe and operate for the first time the demonstrator

made by LGI of the University of La Reunion, before its installation in the old school of Grand-Bassin.

On the 21st December 1998, the small permanent display was open to the public of tourists and visitors in Grand-Bassin, with presentations to explain WPT technology, the study for Grand-Bassin and future SSP projects. A functional demonstrator implemented on the display actually beams a minute flow of energy between a microwave source and a set of collectors which power small lights and a tiny motor in model houses. This shows by experience that we are no longer in the realm of science fiction and that our world is ready for WPT and SSP.

The demonstrator also greatly contributes to the necessary education of the public by explaining the advantages of WPT and the environmental benefits of SSP systems :

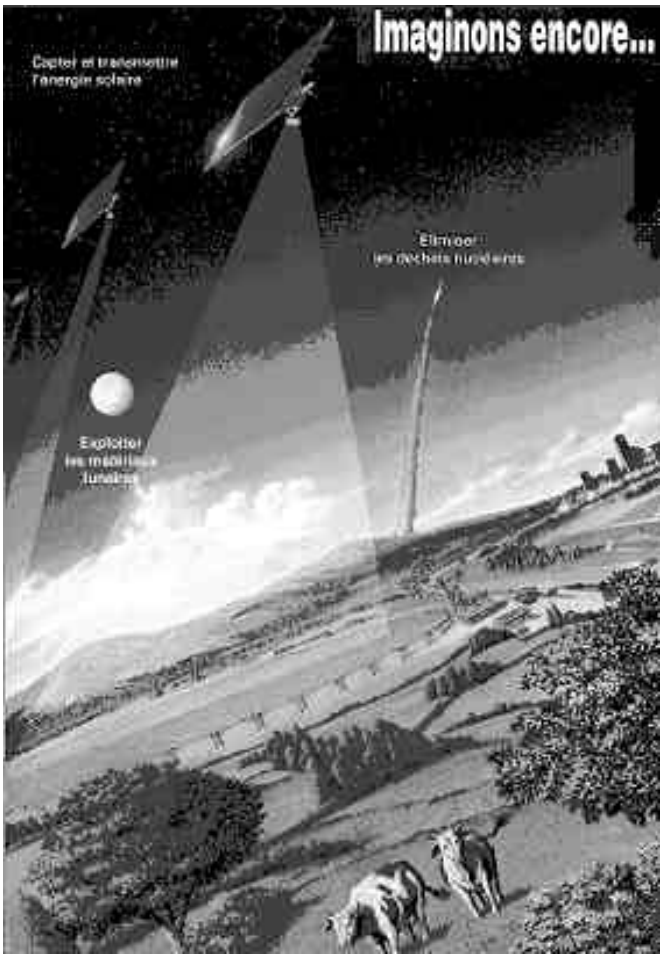
Definite benefits and little risk !

Microwaves at 2.45 Gigahertz have a wavelength of 12.2 cm. They do not conflict with the frequencies of visible light nor with the frequency spectrum of sunlight, where in both cases the wavelengths remain in the micrometer range. It is therefore easy to adapt WPT systems for a good integration into the landscape and the environment. It is also quite possible to let the needed sunlight through the WPT arrays and use it for the growth of plants underneath.

Also, in forty years of medical research, it was shown that the only danger from microwaves is the thermal risk. It can be easily prevented by spreading the energy of the beam over a large section area, with an energy density that will not exceed a level of 5 mW/cm². By comparison, the energy received from full sunlight is 100 mW/cm². The only danger zone in a WPT system is in the projector, between the primary source and the reflector. The dangerousness of a microwave generator is similar to the dangerousness of a halogen lamp of equivalent power, and a reasonable stand-off can ensure safety.

Double use for ground space !

In a SSP system, the orbital power station collects the solar energy and turns it into a microwave beam. On the ground, a field of rectennas turns back the energy to electricity. Rectennas can be transparent for the frequencies of the solar spectrum, and thus allow at the same time to use the land for the collection of energy and for agriculture as well.



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(2) Guy Pignolet, John Hawkins, Nobuyuki Kaya, Jean-Daniel Lan-Sun-Luk, Frédéric Lefèvre, Vladimir Loman, Yoshihiro Naruo, François Valette, Vladimir Vanke, "Results of the Grand Bassin Case Study in Reunion Island : Operational Design for a 10 kW Microwave Beam Energy Transportation", IAF-96-R.2.08, 7-11 October 1996, Beijing, China.

(3) Rolande Rivière, Michèle Bénard, Guy Pignolet, "Grand-Bassin Techno-Tourism for WPT and Space Power Education", IAF-97-P.4.01, 6-10 October 1997, Torino, Italy.

The demonstrator

and the permanent exhibition

in Grand-Bassin

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↖ The project for Grand-Bassin ↗

The basics of WPT ---------- SSP future projects

Projectors > > > Collectors

Contact : pignolet@grandbassin.net