Chapter 6
What Is the Economic Basis for Solar Power Satellites?

Abstract This chapter addresses the financial attractiveness of clean and abundant energy delivered continuously to Earth 24-hours-a-day when compared with the rising energy costs and environmental damage caused by carbon-based energy sources. Steps forward are considered.

The Case for Sunsats

In 1995 Ralph Nansen wrote, "The future of mankind is dependent on abundant, low-cost energy that will not destroy the world." In his book *Sun Power: The Global Solution for the Coming Energy Crisis*, he asserts there is only one known source for that energy, and it is "giant [solar power] satellites [that will sit] in the silence of space, covered in a mantle of silky black solar cells, intercepting the life-giving rays and sending the energy to the Earth" (Nansen 1995, p. 6).

Nansen should know; he spent 31 years with the Boeing Company, primarily working in space engineering. As Boeing solar power satellite program manager, Nansen gathered the team of engineers, scientists and associated contractors that developed the overall SPS concept under the auspices of the Department of Energy and NASA.

In *Sun Power*, he identified five criteria by which any new energy source should be judged. It should be (1) non-depletable, sustainable; (2) non-polluting, environmentally clean; (3) low-cost, over a long period of time; (4) in usable form; and (5) be available to all (Nansen 1995, pp. 6–7).

Nansen also developed a series of interrelated rationales as to why the United States should commit to solar power satellite development, believing such an effort would:

- Give us a national purpose.
- Help us maintain our competitive edge in the world economy.
- Utilize the talents of our scientists, engineers and companies.

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- Free us from dependence on foreign oil.
- Enable us to better protect our environment.
- Open the space frontier for commercial development (Nansen 1995, p. 140).

Nansen had a unique opportunity to make his case before the U.S. House of Representatives Subcommittee on Space and Aeronautics in September 2000 when he testified on "the feasibility of space solar power." He had addressed the subcommittee in 1978 when he accompanied the president of Boeing Aerospace to testify on the same topic. This time he was speaking as the president of Solar Space Industries, a company he formed in 1993 to promote solar power satellite development.

"Much has changed in the last 22 years since I was here," he told the subcommittee, "but one thing that hasn't changed is the fact that solar power satellites are still not under development. However the time is now right for their development to begin" (Nansen 2009, p. 106).

Nansen went on to explain, "The studies conducted in the late 1970s determined the technical feasibility and the potential promise of solar power satellites for delivering abundant, low-cost, non-polluting electric energy to all the nations of the world. Studies since that time have reaffirmed this conclusion. In addition, much of the infrastructure that did not exist in the 1970s has been developed for other programs, dramatically reducing the development costs" (Nansen 2009, p. 106).

Nansen pointed out the plausibility of transmitting energy from one region on Earth that has excess energy capabilities to other world locations by reflecting wireless power transmission beams via relay satellites in space orbit. Because the relay satellites would be lightweight, they could more efficiently and economically be launched into space.

One of the key issues is what the government should be doing, Nansen told the subcommittee in 2000. His personal view was that development of solar power satellites should be primarily a commercial enterprise, but because of the size of such a program and its international implications, it should start as a government/industry partnership. "The primary role of the government would be to provide leadership and seed money to initiate the program, coordinate international agreements, support the development of high technology multi-use infrastructure, establish tax and funding incentives, and assume the risk of buying the first operational satellite" (Nansen 2009, p. 107).

Nansen was confident the energy produced by solar power satellites would create a large enough market if the perceived risk of their commercial viability were reduced to an acceptable level for the investment community.

Bilateral Project Development

In 2010, this author, as editor of the *Online Journal of Space Communication*, wrote an editorial in *Space News* lauding President Barak Obama's new National Space Policy, which supported "a robust and competitive space sector" (Flournoy et al. 2010a, b). This editorial was endorsed by the leadership of the Society of Satellite

Professionals International, the National Space Society and the for-profit Space Energy AG.

Among the goals of the President's National Space Policy was increased international cooperation on mutually beneficial space activities to "broaden and extend the benefits of space" and "further the peaceful use of space" (Obama 2010, p. 4) The editorial noted that these words represented "good news for those of us working to design and launch the new types of satellites that will collect solar energy in space and deliver it to Earth as a nonpolluting source of electrical power…. We believe space, as a shared resource, can best be explored and developed by a partnership of nations and businesses working together."

"Since acquiring clean and abundant energy is a common requirement for economic growth and an eventual necessity for the health of all societies, harvesting space solar power is a logical human endeavor when the high frontier is precisely where energy is most plentiful. But achieving success with large-scale commercial innovation in outer space requires long-range planning, pooling of financial resources, sharing of knowledge and expertise, and the careful framing of a way forward that will earn and sustain the public trust" (Flournoy et al. 2010a, b).

In naming the CEOs who would serve on his new advisory board on trade issues, President Obama noted in July 2010 that the United States is on track to double exports in the next 5 years, and he pointed to some of the ways the American economy is being repositioned to better compete abroad. When adding that announcement to the outcomes of the June 2010 Canada summit of the Group of 20 major industrial countries and recent federal policy statements intimating that certain export controls will be relaxed and cooperation in space will be encouraged, the signers of the *Space News* piece were hopeful that the United States would be entering a new era of openness for international business.

To this end, those who signed the editorial agreed, "We would like to see some greater leadership and support given to space solar power development by NASA and the U.S. Departments of Energy and Commerce. A helpful first step would be a U.S.-led space solar power feasibility study to which all interested nations are invited to contribute" (Flournoy et al. 2010a, b).

In the context of the new U.S. National Space Policy, the authors believed that a feasibility study could lead the way in assessing and promoting "appropriate cost and risk sharing among participating nations in international partnerships." Such a study would demonstrate the U.S.'s "tangible leadership in space," leveraging the capabilities of allies while assuring continuing adherence to the U.N. Treaty on Exploration and Use of Outer Space—now signed by 125 countries, including China and India—that dictates "nuclear weapons and other weapons of mass destruction" shall not be placed in outer space (Flournoy et al. 2010a, b).

The editorial noted that, at the International Space Development Conference held in Chicago in May 2010, multiple nations participated in a National Space Society-initiated Solar Power Symposium to examine in-depth the opportunities and challenges for energy generation in near space. Former Indian President A. P. J. Abdul Kalam, scientist, aeronautical engineer and proponent of space solar power, addressing the symposium via videoconference, spoke to the need for international

cooperation in space, proposing a multilateral global initiative that could map out what needs to be done to bring space solar power into being.

"From our perspective," the editorial stated, "space solar power is a meaningful science, engineering and commercial challenge that deserves our attention and investment. In the wake of the Gulf of Mexico oil disaster, we think it is time for the U.S. to put space solar power on our national energy agenda. At the same time, we must seek opportunities to learn from and participate with Canada, China, India, Japan, the European Union and others taking their first tentative steps to bring space solar energy to Earth" (Flournoy et al. 2010a, b).

The editorial noted that in a June 2010 *Times of India* commentary on strategic international diplomacy, U.S. Senator John Kerry expressed support for a partnership with India that would include "the quest for new technologies and fresh ideas for economically viable ways to speed the shift to renewable energy sources."

The authors stated, "We believe that within the mainstream of global science, engineering and environmental management there are game-changing ideas and technologies that await testing. It is time to see some space solar power demonstration projects. Of all the possible alternative energy sources on the near horizon, we believe space solar power is our best chance for addressing the worldwide challenges of climate change, renewable energy and continued economic growth" (Flournoy et al. 2010a, b).

Indo-U.S. Collaboration

In April 2011, Rajeswari Pillai Rajagopalan, an analyst with India's Institute of Security Studies, wrote an article urging the United States and India to jointly develop an alternative energy source that would help the world free itself of nuclear technology, stating, "With the earthquake and the subsequent tsunami that hit Japan on March 11, isn't it time for India and the United States to make serious commitments to space-based solar power?" (Rajagopalan 2011).

She continues, "The Japanese crisis has triggered worldwide re-thinking on the feasibility of pursuing nuclear energy to meet growing global energy demands. This has kick-started a debate also in India not only on the safety of nuclear plants but also on other energy options. It is time that India and the United States and the countries around the world looked at an often-overlooked option: SBSP [space-based solar power]."

Dr. Rajagopalan pointed out that former Indian President Abdul Kalam had been a promoter of space solar power at the Aeronautical Society of India and more recently participated in a 2010 press conference on this topic hosted by the National Space Society in Washington, DC. The initiative to restart serious discussion of SBSP in conjunction with the U.S.-based National Space Society is now called the Kalam-NSS Energy Initiative.

She quoted from a speech Dr. Kalam gave in New Delhi in November 2010, writing that "by 2050, even if we use every available energy resource we have, clean and

dirty, conventional and alternative, solar, wind, geothermal, nuclear, coal, oil, and gas, the world will fall short of the energy we need by 66%. There is an answer, an answer for both the developed and developing countries. This is a solar energy source that is close to infinite, an energy source that produces no carbon emissions, an energy source that can reach the most distant villages of the world, and an energy source that can turn countries into net energy exporters" (Rajagopalan 2011).

Dr. Rajagopalan further noted that the International Energy Agency predicts the worldwide demand for primary energy will increase by 55% between 2005 and 2030—a 1.8% hike per year on average. For India, the demand is expected to be more than double by 2030, growing at 3.6% per year, and in light of those figures, Rajagopalan questioned why SBSP is not being pursued:

> With energy demand growing rapidly, the SBSP option offers huge opportunities. Such an option will also be reportedly a cleaner energy option. This option would also significantly augment India's capabilities in the space domain, which will have far-reaching positive spin-offs in the ever-changing security environment in Asia. This will bring the much-desired focus on the question of technology transfer between India and the United States, Japan and Israel.
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> What has prevented the SBSP from becoming a real option? Is it the enormous cost involved in developing the option or is it an option that never got the popular attention due to the multiplicity of departments involved? Proponents argue that the cost of SBSP should not be compared to the direct costs involved. The cost-benefit analysis needs to be done on a different scale, including the direct and indirect cost of global warming and climate change. Otherwise, the costs of developing this technology may seem exorbitant (Rajagopalan 2011).

Her article cited a 2009 U.S.-India agreement to establish a science and technology board and an endowment to carry out S & T research. She said this could be an enabling vehicle "because this fund seeks to finance projects on a broad spectrum of issues of mutual benefit such as biotechnology, health and infectious diseases, advanced materials and nanotechnology science, clean energy technologies, climate science, basic space and atmospheric and Earth science among others." The S & T "Rupee funds" were established in the 1980s to encourage and fund bilateral projects.

"While this can potentially be an excellent case for public–private partnership, the initiative has to come from the government. India's foray into space and its space policies have had strong civilian and developmental roots and accordingly the government needs to place the SBSP within its overall national space policy. India's decision to pursue SBSP will have multiple impacts—clean energy, clean environment, advancement in the space arena with technology transfer as a given between India, the United States and Japan" (Rajagopalan 2011).

The Commercial Sector

The commercial Space Energy Group AG has focused its business plans on both space-based and terrestrial solar power production.

Its website states that the company is "committed to becoming a world leading social enterprise—an organization driven by an ambitious vision to use commerce

and innovation to change the world for the better." The company maintains that affordable, reliable, safe, clean energy is the catalyst for change in commercial and social dynamics that no other product or industry can match. Under the "About/Why Space Energy?" section, the company reports:

> It is an indisputable fact that global energy usage is at a record high and continuing to rise fast. Demand in several areas of the global economy is already outpacing supply. Traditional hydrocarbon energy reserves are depleting at an ever-increasing rate, and most experts agree that there is only enough proven uranium reserves to last one more generation. In addition, the use of hydrocarbon and nuclear fuels are widely acknowledged to be leading contributors to significant environmental and health problems (Space Energy 2011).

Space Energy points out, "As developing countries continue to grow and embark on major electrification efforts, energy shortages will become one of the most serious challenges facing governments this century. China and India alone will need to raise energy-generating capacity by a staggering 4–5 times over the next 20 years in order to meet demand—an equivalent of bringing on-line two large coal-fired power stations per week, every week."

> The risk of energy shortages could mean more than high prices. In the twentieth century, many wars were motivated in part by the need to secure future energy supplies—and, according to the U. S. Pentagon, the risk of such conflict remains high in the twenty-first century.
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> Aside from averting conflict associated with resource wars, abundant clean energy has the potential to truly improve life around the world in many ways. Rural electrification can offer one of the fastest ways out of poverty for developing areas. It can ensure that food and medicines are preserved and made available where they are needed the most. It can provide power for water purification and desalination and light so that children can study and develop their potential (Space Energy 2011).

In its May 2011 Space Energy Progress Report, the company notes, "Contrary to the recent global economic situation, the solar industry is thriving. Solar panel costs in the United States dropped by 12.5% just in the first quarter of 2011 and demand for solar power is rising, driven by measures such as the California law that requires the state to obtain a third of its energy from renewable sources by 2020" (Space Energy 2011).

"Individual, institutional and corporate investors are increasingly recognizing the potential of this industry. The first quarter of 2011 saw over $2.5bn USD invested by venture capitalists in the clean technology sector, with the majority of that money going to solar power. This is a 13% rise from the year before."

Intermediate Steps

Globus, Barau and Radu have proposed strategies leading to an "early profitable powersat." Since space solar power implementation suffers from extremely large dimensions driven by the size and weight of on-orbit microwave antennas—requiring large capital inputs and long development cycles—this team outlines the merits of

small, single-launch powersats that are designed to address niche markets. They say infrared power beaming based on fiber lasers and very lightweight collection structures using thin-film solar cells are potential solutions for bringing closer to financial feasibility single-launch-to-orbit in space solar power deployments. The approach they suggest is to keep launch and in-orbit collection costs down, but also to also deliver power (even though still expensive) to those clients, such as the U.S. military and other off-the-grid operations, currently paying a premium for energy (Globus et al. 2011).

These and other solutions are explored in an extensive "financial and organizational analysis" in connection with an aerospace management project conducted at the Toulouse Business School, Toulouse, France (Xin et al. 2009).

Concluding Thoughts

A prime goal of the Society of Satellite Professionals International, the professional development association of the satellite and space industry, is to help in expanding the satellite services market.

SSPI Director of Development Louis Zacharilla, paraphrasing business guru Peter Drucker, wrote in *SatMagazine*: "Without markets, or with markets that are in decline, competition becomes a desperate, zero-sum game. With expanding markets, opportunities emerge, innovation persists and capital flows. Expanding markets are virtuous, and in their wake the satellite community becomes more secure and attracts needed talent" (Zacharilla 2010).

The energy market is not on the horizon for the satellite services industry—not domestically, not internationally, not next year and possibly not in the next decade. Nevertheless, the signs point in that direction, which leads the author to predict that Sunsats, gathering the Sun's energy in space and delivering it to Earth as electrical power, will eventually dominate all other satellite businesses, including the currently very profitable comsat business.

Given the dire need for alternative sources of clean and abundant energy to avert global catastrophe, it is not hard to think of Sunsats as the latest new impact technology, the breakthrough development that expands the market, the business innovation that lifts the prospects of all related businesses. Satellite manufacturing and launch services, for example, will benefit in the near term, but also profiting will be all types of spinoffs to satisfy long-term needs here on Earth and in space.

Rather than sending comsats to the dustbin of history, competitive adaptation to the needs of the future energy market will be the basis for satellite services renewal. It can be imagined that healthy Sunsat systems successfully serving global energy markets will also be a big step forward in the further commercialization of space.

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