Chapter 9

INSTITUTIONAL ISSUES

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FINANCING, OWNERSHIP, AND CONTROL

The questions of who would finance, own, and control a solar power satellite (SPS), and to what extent, are interrelated. As a project that would involve the Nation's space and energy sectors, as well as several Government agencies, there are numerous issues to be considered regarding the proper allocation of risks and responsibilities. The following discussion will examine: 1) current policy and structure of the space and energy sectors; 2) the relation between Government and private-sector activities; 3) the importance of distinguishing between the different phases of SPS development and operation; and 4) possible historical and hypothetical models for an SPS project.

Space and Energy Sectors

Space

In the United States, space capabilities have been primarily instigated and funded by the Federal Government (with much of the actual development and construction done by private firms under contract to the National Aeronautics and Space Administration (NASA)). Launchers, launch facilities, and tracking networks are currently Government monopolies that may be leased to private companies, Government agencies, or foreign countries for specified purposes. Only certain payloads are built and owned by nongovernmental bodies. Within the Government, NASA is responsible for R&D of civilian space-systems that, when development is completed and the operational stage begins, are turned over to another part of Government or to the private sector. Scientific missions, such as deep-space probes, are run by NASA, as are launch facilities such as Cape Canaveral. Military and intelligence operations are largely separate even in the R&D phases, with control exercised by the Department of Defense (DOD) or specific intelligence agencies.

Energy

Electricity is provided by public and private utilities, which are regional monopolies regulated by State authorities. R&D and construction of generating equipment—turbines, nuclear reactors, switching gear— is done by private firms, who sell to utilities. The utilities operate and maintain equipment, build transmission lines, and market electricity to end-users Due to severe capital constraints and a lack of expertise in space operations, utilities are unlikely to own and operate SPS in the way they currently do with other types of powerplants, though they may well be responsible for the ground-receivers. In the case of SPS, there is a question as to who would carry out these various activities,

Although energy production in the United States has traditionally been handled in a decentralized manner by private industry, increased sensitivity to the importance of energy issues since the 1973 oil embargo has led to various attempts at formulating a national energy policy, centered in the newly created Department of Energy (DOE). DOE's scope and responsibilities in areas such as basic research and engineering have yet to be determined; funding is being provided for projects in photovoltaics, conservation, nuclear power, synfuels, and other areas. DOE can be expected to have a prime role in any SPS project.

Government-Private Sector Relations

What would be the degree of Federal involvement with the SPS at different stages, such as R&D, construction, and operation; and in different areas, especially financing, transportation and transmission, and marketing?

The arguments for Federal involvement center around fears that the private sector will not be able to undertake an SPS project, because of the very high costs and risks, and the long and uncertain payback period. There is also concern that private-sector development, even if economically feasible, might be detrimental because of monopoly by a single firm or consortium, and environmental and international policy considerations requiring public control.

Cost estimates for different SPS scenarios are very imprecise; the most comprehensive estimates have been done by NASA for the reference design and call for a total investment of $102 billion (1977 dollars) over 22 years for construction of the first 5-GW SPS, i.e., before any return on investment (see ch. 5). The key questions are whether the private sector can or would raise these amounts of capital, and how investment costs and management responsibilities might be shared between Government and industry.

Though the reference figures are highly tentative, the general magnitude of the project and its division into discrete stages are likely to be similar regardless of what design is used. None of the alternatives has been examined in nearly the detail of the reference design, largely because the technologies are less well-developed. The following discussion will focus on reference figures but should be applicable to any SPS system of similar magnitude.

Difficulties With Private Involvement

A total investment of $40 billion to $100 billion over 22 years–with additional much larger investments to build a complete system —would be unprecedented for private-sector financing of a single project.

Private capital can be raised by borrowing, issuing bonds or stocks for sale to the public, or from profits. Especially in the first years, borrowed funds would be available, if at all, only at prohibitively high interest rates. Stocks and bonds would be unlikely to attract large investors when profitability lies some 30 years in the future. Both institutional investors and large corporations allocate only a small proportion of their funds for high-risk long-term projects; in some cases, such as pension funds, there are legal limitations on high-risk investments. Uncertainty, whether technical, political, or economic will deter potential investors.

The incentives required to spur any private interest would in themselves involve drawbacks. A company taking a major risk on SPS would expect to be compensated by exclusive patents and other guarantees, in effect with a monopoly. Government regulation would have to take risks into account by allowing a very high rate of return, i.e., allowing the owners to charge high rates for SPS electricity. A private monopoly charging above-average prices could prove to be politically embarrassing.

An SPS system will require a great deal of political support both locally, nationally, and internationally: land-use conflicts, monopoly considerations, environmental standards, tax incentives, and radio frequency allocations are a few of the political issues that SPS will need to confront. Private development and ownership may be seen as leading to an excessive concentration of power outside effective public control

Difficulties With Federal Involvement

Any large long-term project, public or private, dealing with advanced technology may suffer from financial and management problems: lack of coordination between parts of the program; inadequate supervision of contractors; financial and production bottlenecks in specific areas that delay other parts of the program; inaccurate initial estimates of costs and completion times, and so on. However, Government programs often have special constraints that need to be taken into account. Without a profit motive and the discipline of responsibility to owners and stockholders, there is less incentive to reduce costs. Civil service regulations can interfere with hiring and firing and limit salary ranges, decreasing flexibility and making it difficult to retain personnel Annual Government funding produces uncertainties and leaves programs vulnerable to political pressures and pork-barrel compromises. Government-funded R&D in the public domain requires special supervision, since without the incentive of exclusive rights to patents and processes, firms doing research may tend to inflate costs and draw out delivery schedules.[1] Any extensive Government funding could divert funds from other space, energy, and R&D programs, whose backers might ask for compensation.

Explicit Federal involvement may increase the probability of military participation in some or all SPS activities, complicating most forms of international cooperation and possibly leading to detrimental changes in the SPS design or operating characteristics.

Finally, a federally financed or owned SPS would increase centralized control over an important sector of the economy and would lead to greater politicization of America's energy industry.

Phases of SPS Development

Federal v. private investment is not an either/or proposition. In general, Federal involvement would be necessary in the early stages, and become increasingly less so, assuming the system remains technically and financially feasible, as the project becomes operational. The basic problem is how to differentiate between the various and overlapping stages and ensure adequate management and continuity throughout.

SPS development can be divided into successive stages (as described in ch. 5): research, engineering, demonstration, and so on. Federal financing and management of the research and engineering phases might turn into a combined Federal-private program as more directly commercial phases were undertaken. The question is at what point and to what degree private investors will be willing to enter the project. On the one hand, investors would prefer to see as much as possible paid for by the Government; but early investors would have an advantage in setting program priorities and establishing a dominant position. Involvement of owners and operators at the earliest possible stages would help to ensure that the completed system is suited for commercial operation, that internal procedures and structure are appropriate to private ownership, and that the transition from development to operation proceeds smoothly.

The SPS would consist of a number of distinct systems, each of which must be developed separately and simultaneously: e.g., transportation, energy conversion and transmission, orbital construction, and ground stations launchers and solar cells, for instance, may be useful and profitable regardless of whether SPS is built or not. Should their development be charged to SPS? If so, their use and sale might help to offset the risks of the program as a whole; on the other hand, their development adds considerably to the SPS cost. It can be argued that public funding should be reserved for those parts of the project that private investors will not handle and that segments with near-term commercial applications should be left to the private sector. As in any complex program, there is the question of internal apportionment of risks and benefits. Successful items can help to subsidize less profitable projects, provided funds are transferable from one division to another, allowing for risky high-return investments, but also for Edsels.

In the case of SPS it is essential that each component be developed on time and to the proper specifications for the system as a whole to function. Management must be given sufficient authority to produce appropriate products., even if particular divisions suffer; say, if SPS solar cell designs are not optimal for ground-based users. Major investors in a privately funded SPS will have their own particular interest–aerospace companies in launchers, electronics firms in microwave hardware, utilities in delivered power — that could compromise the project's overall goals. Government supervision, whether by partial ownership, regulatory oversight, or appointment of directors, may mitigate certain conflicts but is no guarantee of smooth sailing. Federal concern for a broadly conceived public interest may be affected by a desire for continued control and supervision, or by the interests of particular agencies. For instance, DOD may place

[1] Mark Gersovitz, "Report on Certain Economic Aspects of the SPS Energy Program," OTA contract No 03 3-26700, 1980, pp 1719

emphasis on booster and LEO to CEO transport development for its use (see ch. 7), perhaps affecting launcher design or the allocation of program funds. NASA may wish to emphasize and prolong the R&D phase. Annual budget review may increase costs by creating uncertainty and requiring project managers to spend large amounts of time drawing up and justifying annual budgets.

Possible Models

Perhaps the best way to further examine possible financing and management scenarios is through historical and hypothetical models that might be applicable to SPS. In each instance there are several questions to be asked: 1) Is it complete: can this model support an SPS program from start to finish, or is it applicable only to certain phases or components? 2) How are risks apportioned: who pays, and who reaps the benefits of a successful project? 3] How efficient and flexible is it: can it adapt to changing economic and technical circumstances, and can it attract support from a variety of sources, particularly foreign investors?

Historical Models

NASA

NASA is an independent Government agency with a general mandate to engage in R&D and testing and to conduct launches for civilian space activities. Although NASA has in the past centered its efforts on high-visibility manned projects, such as Apollo and the Space Shuttle, it has also conducted major programs in telecommunications, remote-sensing, and the sciences, such as the Viking and Voyager interplanetary probes.

NASA is funded by general tax revenues appropriated annually by Congress. NASA funds are overwhelmingly—90 to 95 percent— spent on outside contracts with private firms, research centers, and other Government agencies, foreign as well as domestic. NASA itself helps to set priorities and policies, oversees and coordinates contractor performance, and operates specific facilities (on a cost-reimbursable basis) for research and launches.

- *Advantages.* – NASA is already in place, with 22 years of experience. It has well-established relationships with private contractors, other parts of the Government, and foreign. companies and Government agencies. It has the technical and administrative expertise to evaluate most of the major components of the SPS, many of which— interorbit transfer vehicles, assembly and construction facilities — are part of current NASA plans.
- *Disadvantages.* –Annual funding for NASA projects creates difficulties in implementing long-term plans that are likely to go in and out of political favor. It also hampers agreements with foreign firms and agencies, that have had problems in the past when NASA budget cuts have forced cancellation of joint programs. Legislative changes to permit ongoing funding would greatly improve NASA's position.

  NASA's emphasis on R&D and prototype development (NASA's ability to participate in commercial ventures is unclear and subject to restrictions) could create problems in developing a commercial product such as SPS; NASA might have to relinquish control after the demonstration phase. There is often reluctance to complete R&D phases, since completion means loss of the project. Coordination with eventual users and owners may be underemphasized. Amending NASA's charter to allow for beginning-to-end development and operation would alleviate this problem, but might be harmful to the agency's R&D mission.

  The broad scope of NASA activities has meant that, within and without the agency, there have been conflicts over the relative priority of scientific v. applications, or manned v. unmanned missions. The SPS could be criticized for diverting funds and attention from competing programs; intra-agency squabbling might interfere with the project. Excessive concentration on SPS could prevent NASA from accomplishing other tasks, although many aspects of SPS development would be applicable to other space activities.

Funding all, or even a large part, of the SPS through general tax revenues would produce strong pressure for continued Government control. Since the risks are borne, involuntarily, by the general public, justification in the form of visible public benefits may have to be provided. These benefits could take the form of electricity-rate reductions, tax-reductions, or other types of returns. Turning SPS or SPS technology over to private profitmaking firms may be unacceptable. Such a prospect could discourage private interest; this difficulty is common to all publicly financed ventures.

TENNESSEE VALLEY AUTHORITY (TVA)

TVA, the Nation's largest utility, was established in 1933 to provide power for a region that commercial utilities were not willing to develop. Until 1959, TVA received annual Federal appropriations; since then it has raised capital by issuing bonds, the amount of which is subject to congressional approval, as well as by charging customers for its services. At that time, TVA was forbidden from expanding its service area, in order to avoid competition with private utilities. In 1978 TVA's borrowing authority was raised to $30 billion.[2] A TVA-type independent authority, initially financed by tax revenues and authorized at some point to issue self-backed bonds, could be a possible model for SPS development and operation.

- *Advantages.* — Initial Federal financing would allow for pursuit of R&D and prototype development. Adoption of TVA practices, such as the absence of civil service requirements, would free the authority from certain Government inefficiencies. Issuing bonds would subject the issuer to the financial judgments of investors and make the risks of the project more palatable, since much of the investment would be voluntary rather than by congressional or executive decision. The concentration of a newly established authority on a single-project would avoid the internal conflicts inherent in having it undertaken by an established agency.
- *Disadvantages.* — It is not clear at what point private financing would become available on a large scale, and hence how much must be spent out of general taxes. The larger the public part of the investment, the more likely are the public-interest problems outlined previously.

Financing through bonds does not provide for the type of accountability available through congressional appropriation, or through public ownership via the stock market Specific arrangements for public oversight, given the monopoly position of such an entity, would have to be made. Ownership of patents and products generated by public investment would have to be clarified, given the possibility of competition between private firms and the authority in the latter stages of development and operation.

HIGHWAY TRUST FUND

Since 1956 the Federal Government has spent over $7.5 bill ion (in current dollars) to finance the Interstate Highway System and a number of other road and highway programs. The money for these investments has been channeled through the Highway Trust Fund, which receives revenue from taxes on gasoline and diesel fuels, on heavy trucks, and other sources. These funds are not spent by the Federal Government, but apportioned to the States to pay for their share of highway systems.

The rationale for Federal financing was that an improved road-system would aid the Nation's defenses, as well as improve commerce by decreasing transportation costs. The system was planned on a national scale, but takes advantage of existing State highway departments to implement the proposed network. No central construction or maintenance firm was needed [3]

The distinctive feature of the system is its use of specific taxes on a commodity directly related to the project. Through the tax on gaso-

[2] "Increasing the TVA Bond Celling, " hearings before Senate Environment and Public Works Committee, Feb 23, 1979

[3] Porter (' wheeler, *Highway Assistance Programs A Historical Perspective*, Congressional Budget Of flee, February 1978

line and diesel fuel, transport users have contributed in proportion to their total transportation expenditure. An additional tax on heavy commercial trucks has ensured that large users, who were responsible for a high proportion of maintenance costs, would contribute appropriately. Unlike tolls or direct fees for highway usage, revenue could be collected before the roads themselves were completed. An analogous tax to finance a fund for SPS might be levied on current domestic and commercial electricity consumption (though from a strictly financial point of view the tax need not be directly related to energy congumption.)

- *Advantages.* —The use of a designated tax provides more assured and predictable funding than general revenue taxes that need to be reallocated on a yearly basis. By taxing electricity consumption the costs would be borne by the future beneficiaries of SPS. If desired, taxes on other forms of energy could also be imposed; all energy taxes would have the added benefit of encouraging conservation. As private investment was found, the tax could be reduced, or revenues could be spent elsewhere.

  The size of the tax, if levied on electricity alone, would not have to be large to generate significant revenue. A tax of 2 mills/kWh would produce over $4 billion per year (at current consumption rates) while raising consumer costs by less than 5 percent.[4]

- Disadvantages. — A tax on electricity may cause consumers to switch to other forms of energy, harmin_g utilities Higher electricity costs will inflate prices of electricity-intensive products, such as alum inure.

  The organizational framework to manage the SPS will have the same difficulties as other Government agencies, especially in handling the transition to private ownership.

U.S. SYNTHETIC FUELS CORP.

The Synfuels Corp. was established in June 1980 with a specific mandate to produce the equivalent of 2 million barrels per day of crude oil by 1992. The corporation is instructed to do so by, in decreasing order of preference: 1) price guarantees, purchase agreements, or loan guarantees; 2) loans; 3) joint ventures. The corporation's goal is to facilitate private-sector synfuel production, and to produce synfuels itselt only as a last resort. Initial funding was set at $20 billion, with total funding of up to $88 billion envisioned. Funds are to be provided from the windfall-profits tax on domestically produced oil. [5]

A possible SPS corporation would resemble the Synfuels Corp. in being a high-cost energy production plan with a specific goal and timetable It would differ in that it would involve creating a single firm rather than funding numerous private enterprises.

- Advantages. — The Synfuels Corp. has the advantage of a discrete goal and timetable, with maximum flexibility as to achievement. The etmphasis on price and loan guarantees to encourage rather than replace conventional financing arrangements should reduce the cost, assureing projects are successful. Direct Government control will be avolded, unless no private ventures whatever are forthcoming.

- Disadvantages. – It is far too early to tell whether the Synfuels Corp. will accomplish Its goal, or will do so without exorbitant costs Critics fear that an indiscriminatory 'shotgun" approach may result in funding numerous uncompetitive ventures, in the hope of finding one that works; while the revenue taken from the oil companies in taxes may prevent the development of additional fuel sources. The promise of "easy" Government money and soft loans may discourage efficient financial and managerial practices.

  While the Synfuels Corp. can pick and choose from a number of relatively well-developed and predictable projects, the SPS Corp would have to generate its own organization. The SPS Corp. could not, especially at first, simply be a channel for funding to private firms, or for loan guarantees.

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[4] Peter Vajk, *SPS Financial Management Scenarios*, DOE contract No EG77-C-01 -4024, October 1978, p 36

[5] *nergy Security A et,* Publ ic Law 96-924, 96th Cong , June 30, 19H() pt B

COMSAT

Comsat was founded in 1962 as a federally chartered corporation to establish and run satellite communications (see ch. 7). Comsat did not receive direct Federal funding, but was given the fruits of extensive and continuing NASA research on telecommunications satellites,[6] as well as the right to use NASA launch services on a reimbursable basis (which does not reflect R&D costs). The Government retained a measure of control through Comsat's operating charter and by appointing board members, who were initially divided between Government, communications common carriers, and private investors. Capital was raised by issuing stock, which from the outset was well-received by investors. As of 1979, Comsat stock was held overwhelmingly by noncommon carriers; 3 of 15 Board members were Presidential appointees, the rest being elected by stockholders.

- *Advantages.* — A Comsat-styled SPS corporation would be independent of direct Government control and free to operate as a private, profitmaking corporation. Government supervision would be provided without the need for onerous restrictions. Comsat has been highly successful internationally via its participation in Intelsat, and a "Solarsat" corporation might find it easier to engage in international activities than would a Government agency. Such an organization could inherit the results of Government-financed R&D and engineering with less of a political outcry than if control were to be turned over to established private firms such as aerospace or oil companies; Comsat was established in large part to prevent AT&T from gaining a satellite communications monopoly.
- *Disadvantages.* — Issuing common stock would not suffice to raise capital for the early development stages. The transition from Government to private funding would have many of the difficulties already mentioned.

PRIVATE JOINT-VENTURES

A private SPS project could be undertaken either by an established firm, a new company, or a joint-venture of existing companies and financial institutions. For the reasons mentioned (high cost, uncertainty, long period before payback, and too many eggs in one basket) no single firm, whether new or established, is likely to undertake SPS development unaided

A joint-venture or consortium is formed when a single project or enterprise is of interest to several parties, no one of which is willing to finance or manage it on its own, as with the Alaskan pipeline. Or, companies may be legally prevented from exercising sole ownership for antitrust reasons, while a single system may be technically desirable. For instance, the Federal Communications Commission (FCC) required Comsat and IBM to add a third partner (Aetna Insurance) when forming Satellite Business Systems (SBS). In any consortium, partners are likely to have a particular interest in the consortium's success above and beyond immediate profitability. In SBS's case, IBM Corp. and Aetna intend to be major customers of the system, and IBM Corp. will supply operating equipment.[7]

- *Advantages.* — Potential major partners in an SPS consortium would be: aerospace companies, oil/energy firms (including possible emergent industries in photovoltaics, synfuels, or other energy sources); and electric utilities. A consortium that could draw on the resources of firms in these major industries would find it easier to borrow money, sell stocks and bonds, and use profits for SPS investment. According to most estimates, the utility industry alone will be spending hundreds of billions of dollars over the next 30 years to replace old generators and build new capacity; an SPS project would not constitute an unmanageable proportion of total industry investment,

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[6] NASA communications research was phased out under the Nixon administration, which looked to Comsat and the private sector to maintain U S preeminence in communication satellite technology However, in 1978 the Carter administration reinstated NASA's leading role in communications R&D, largely to offset foreign government R&D efforts

[7] "Court Upholds SPS," *Aviation Week and Space Technology,* Mar 10 1980, p 22

- *Disadvantages.* – However, there would still be difficulties in funding the initial phases. While aerospace and electronics firms would begin to benefit relatively early in the project, oil/energy companies and utilities (that have the bulk of the resources) will see returns only towards the end. utilities in particular, as part of a publically regulated industry, will find it difficult to set rates so as to raise funds for R&D or speculative purposes, as opposed to purchase of more established technologies. For instance, the $2 billion Great Plains coal gasification project was to be financed by a surcharge on gas rates charged by consortium members. Although DOE approved the rate hikes, customers — such as General Motors — and State officials protested against being asked to subsidize synfuels investments.[8] The Federal district court then disallowed DOE's action, effectively blocking the project.

  Consortia are more likely to arise in the investment and operation phases, when individual members' interests are more clearly defined, and risks have been reduced. The very high costs and large size of a full-scale SPS system, as well as the monopoly dangers of a system under the control of single company, may make inter- or intra-industry consortia attractive.

Hypothetical Models

In discussing possible SPS financing scenarios, some writers have proposed completely novel methods with no historical precedent. Foremost among them are the Taxpayer Stock Corp., a new form of Government financing; and a private approach, the staging company.[9]

TAXPAYER STOCK CORP.

Under this method, taxpayers would receive shares in a public corporation, financed by general tax revenues, in proportion to the percent of taxes used to finance SPS. Shareholders could then trade their shares on the market, as with any other corporation. Those who did not wish to support SPS could sell their stock for immediate returns.

Although such a scenario has the advantage of diffusing SPS ownership, it is difficult to see how SPS shares would retain their full value on the market; if they did, funding via taxes would not have been necessary in the first place. Shareholders would instead be left with devalued pieces of paper, unless they are purchased by the Government — with tax dollars — to maintain a reasonable price. This would amount to a straightforward Government subsidy.

STAGING COMPANY

The staging company is essentially a bootstrap operation whereby sufficient revenues are generated during the R&D phase to attract further capital. The firm would invest its initial funds in existing aerospace and high technology companies, gaining patent rights and new technology — via joint ventures — as well as conventional investment returns. The success of the company's first investments, and its increasing expertise, would attract further speculative investors; the staging company is in effect a mutual fund. Eventually, the company would begin to finance SPS R&D directly, concentrating on those aspects with near-term returns. At some point conventional financing would become available for the investment and operation phases.

Such an approach is unlikely, unless its first investments turn out to be in budding Xeroxes or IBMs, to raise the $33 billion estimated to be necessary for the reference design R&D and prototype phases. In 1978 Christian Basler established International Satellite Industries, Inc., to test his concept; it failed when neither New York nor California would allow ISI stock to be sold.[10]

Conclusions

It is clear from the review of possible models that there are many ways to finance the latter stages of a successful SPS program, but that

'Robert D Hershey, "Gasification Plant Rising Amid Many Snags," New *York Times, Nov 17, 1980,* p 1

'For further discussion see Vajk, op cit , pp 32-40

"('onversation with Stephen Cheston, President, Institute for the Social Science Study of Space, December 1980 the initial phases would in all likelihood have to depend on some sort of Federal funding. Some combination of the suggested methods may prove attractive.

In establishing an SPS organization, attention should be paid to several factors. First, there should be provisions for stopping the project if it becomes unfeasible. Large initial investments will create considerable momentum, which may cause wasteful development to continue unless authority is given to terminate. This is especially true for Government enterprises.

Second, at all phases careful attention must be given to public policy concerns: environmental protection, regional interests, and military involvement. Private companies must not think SPS can be developed in secrecy or without reference to a wide public environment (see ch 8, Issues Arising in the Public Arena).

Third, early and continuous efforts should be made to involve and inform potential international partners to attract investment aid, forestall competition, and ensure that the global market for SPS is kept in mind when technical and managerial decisions are made. A narrow focus on domestic concerns, by Government or industry, may jeopardize SPS unnecessarily. (see ch. 7, International Implications).

[11]Gersovitz, p 36

THE IMPLICATIONS FOR THE UTILITY INDUSTRY

Introduction

The interest of the utilities in the SPS would depend on technology related factors such as stability and reliability, as well as those more directly related to the economics of electricity generation and distribution (i. e., siting, capital investment and Government regulation). Each of these factors would require more study as more is learned about the various SPS alternatives. From what is now known, it appears that the technical barriers to integrating SPS into the utility grid are solveable, particularly if the units of SPS generated power are of the order of 1,000 MW or less. It is also apparent that for the utilities to develop sufficient confidence in SPS, one or more units would have to be tested over time.

More troublesome are the economic risks of SPS. When considering adding a new plant, utilities must plan far ahead of actual system integration for the associated transmission lines and other generating capacity (i.e., intermediate or peaking plants to supplement the baseload powerplants). Failure of the SPS to meet expected implementation deadlines would result in severe economic loss for the utility. The need for extensive trials and testing of a new plant render it highly unlikely that the SPS could become part of utility grids until several years after a commercial prototype were built. Although SPS could force some regulatory changes, there seem to be no strong regulatory barriers to implementing SPS.

Table 50 summarizes the projected characteristics of the SPS that would be of interest to the electrical utilities.

The Utilities' Planning Process

The Current Situation

Because of the recent rapid rise of all energy costs and subsequent efforts to conserve, the utilities find themselves in an uncertain position for the future. In the past, the utilities experienced fairly steady, high peakload growth rates, resulting in a correspondingly high rate of growth (7 percent) of generating capacity, a rate that leads to a doubling of capacity every 10 years. Recently, however, average peakload growth has fallen sharply. Lower economic growth rates and price-induced conservation efforts have had a strong effect on consumption I n response, the average growth of installed generating capacity has also fallen. The

Table 50.—Characteristics of the SPS Systems

System characteristics	The reference system"	Solid-state sandwich design"	Laser system"	Mirror system (baseline SOLARES)[15]
Delivered power from each satellite (at the busbar)	5,000 MW	1,500 MW	500 MW	135 GW (10 GW possible)
Total system of.	300 GW	Not projected	Not projected	810 GW over 6
Implementation rate	2 per year for 30 years	—	—	7
Start of deployment.	A.D. 2000	2010-2020 (estimate)	2010-2020 (estimate)	2010-2020 (estimate)
Lifetime of each satellite	30 years	30 years	30 years	?
Transmission frequency . . . ,	2.45 gigahertz (i.e , microwave)	2.45 gigahertz	10 microns (infrared)	Reflected sunlight — I.e., continuous spectrum
Designed capacity factor .,	90 percent	90 percent	70-80 percent	?
Rectenna size.	10 km x 13 km at 35° lat. plus 1 km buffer	6.5 x 5.5kw at 35° lat. plus 1 km buffer	36 meter diameter	39-km diameter
Terrestrial conversion mode.	Microwave dipole antenna-rectifier and inverters	Microwave dipole antenna-rectifier and inverters	Thermal conversion	Thermal, photovoltaic conversion
Major potential causes of interruption.	Maintenance, satellite eclipses (max. 21/2 hr near equinoxes)	Maintenance, ecilpses Of Satellite? (max 2 ½ h r near equinoxes)	During any thick cloud cover, maintenance	During any thick cloud maintenance

[12]"'Sa,ellite Power System Concept Development and Evaluation Program Reference System Report DOE report No DOE/E R-0023, October, 1978

[13]G. M. Hanley, et al , "Satellite Power Systems (SPS) Concept Definition Study, " First Performance Review, Rockwell International Report No SSD79-0163, NASA MSFC contract No NAS8-32475, Oct. 10, 1979

[14]W. S. Jones, L L Morgan, J. B. Forsyth, and J P Skratt, "Laser Power Conversion System Analysis: Final Report, Vol. I I," (Lockheed Missiles and Space Co , report No LMSC-D673466, NASA report No CR-159523, contract No NASA ;-211 37, Mar 15, 1979

[15]K W Bil l man, W P G i l breath, and S W Bowen, 'Orbiting Mirrors for Terrestrial Energy Supply, " in 'Radiation Energy Conversion in Space, Progress in Astronautics & Aeronautics Series, K W Billman (ed), VOl 61 (New York AI AA, July 1978), pp 61 80

SOURCE: Off Ice of Technology Assessment

U.S. total of installed electrical generating capacity in 1978 and 1979 rose by an average rate of 3.1 and 3.2 percent respectively, rates that cause a doubling of capacity every 22 years. Growth rates in some sections of the country have been zero or negative in the same time span.

As the high growth rate of electricity demand and subsequent expansion of the utility industry has subsided, the industry has had to rethink its posture with respect to adding new capacity, I n addition to the uncertainties of future demand, increasing costs for fuel, more stringent environmental standards, public opposition to nuclear powerplants and technological changes are also affecting the planning process. What is perhaps of most concern, however, is the increasing difficulty private utilities face in raising the large amounts of capital needed for building new capacity or replacing old, inefficient plants

In response, the utilities are placing more emphasis on understanding the interaction between reserve margins, types of capacity, and reliability requirements. They are also sharply reducing the amount of new capacity, delaying Installation of some plants, canceling others, Although on average the difference between total capacity and average annual load is greater than ever before, some industry executives have expressed concern that these planned reductions in generating capacity wi II leave the United States seriously deficient if the current trend towards lower growth of peak demand reverses itself. others, generally outside the industry, have suggested that increased conservation measures can bring the need for new generating capacity to zero or less, leaving the industry, on the average, in the posit ion of simply replacing or refurbishing outmoded plants

Planning Process

U S generating capacity in 1980 was about 600 gigawatts. * The peak load that this capaci-

*A gigawatt (GW) of power is equal to 1,000 megawatts ty is expected to serve is about 410 GW. To meet this load, the generating capability is composed of about 10 to 15 percent of peaking units, 20 to 25 percent of intermediate and 60 to 65 percent of baseload generating units. A planning reserve margin of 20 to 25 percent above peak demand is required to allow the utility to continue to serve the customer when any of the operating units fails and when unusual load peaks occur.

For a given utility system, the reserve is related directly to the expected reliability of the total system. Although the exact amount of reserve needed is currently debated within the industry,[16] the rule of thumb that most utility systems use to calculate their necessary reserve is that they must have no more than one generating outage or failure to meet expected demand in 10 years, a failure that may be as short as a minute or as long as several hours. In practice, this criterion results in some days of line voltage reductions and a few days of appeals to customers for conservation, but a very low probability of outage in any one year.

A utility is not simply a set of generating plants, transmission lines, and transformers. It is a complicated interactive network in which individual components affect each other through an intricate set of feedback loops. A failure in one part of the system may set off a failure in another part. Adequate reliability is ensured by building enough redundancy into the system to meet most contingencies, whether from system failure or from unexpected surges in demand.

The amount of redundancy required for a given system depends heavily on the reliability of the equipment in the system and the utilities' experience with them. To calculate the necessary reserve, the utilities generally use several methods, the simplest of which, called the contingency outage reserve criteria, will serve to illustrate the most important features of reserve planning.

[16] A Kaufman, L T Crane, Jr, B M Daly, R J Profozich, and S J Bodily, "Are the Electric Utilities Gold Plated?" committee print, 96-IFC 12 Committee on Interstate and Foreign Commerce, United States House of Representatives, 1979

After projecting the peak load requirements of the system, utility planners add an amount of generating capacity equal to that which might be unavailable because of scheduled maintenance. System reliability will then be achieved if sufficient excess capacity over and above this amount is available to cover one or more of the sorts of contingencies listed in table 51.[17] This method tends to treat the system in gross terms and does not generally allow for important details of a given system such as the variations of peak load throughout the year or the percentage of time it will be capable of generating given levels of power at different seasons. For this, a more sophisticated analysis would be needed.

Planning for New Technologies

The SPS is one among many new technologies that the utilities are considering in planning for the future. These include *regional* technologies such as ocean thermal energy conversion and geothermal; *intermediate or peaking* technologies such as wind, solar thermal and solar photovoltaic without storage; and *baseload* possibilities such as advanced coal, breeder reactors and fusion. In addition, some utilities are considering grid connected dispersed technologies such as solar thermal, solar photovoltaics, wind, and fuel cells. Planning for such a mixed bag of technologies is a complicated and time-consuming process. As figure 44 illustrates, the time from the initial conception of a new technology to actual integration into the utilities' grid can be extremely long– up to 40 years or more. Not only must utility suppliers develop the components of the individual technology, they must make it technologically and economically attractive to

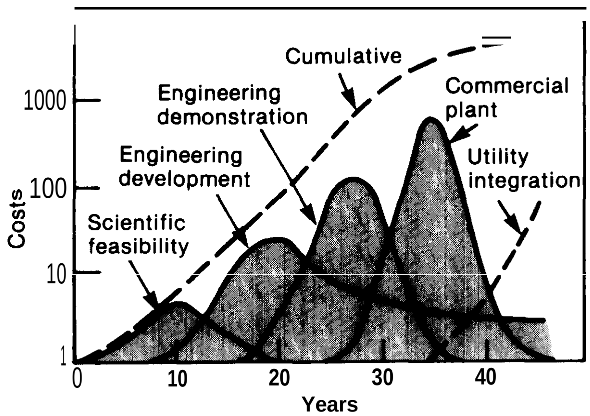
[17] Ibid

Table 51.—Major Grid Contingencies

1. Loss of the largest generating unit in the system
2. Loss of the two largest generating units in the system
3. A failure in the largest transmission facility in the system
4. A combination of the above
5. An error of a specific magnitude in load projection

SOURCE A Kaufman, L T Crane, Jr., B. M. Daly, R J. Profozich, and S. J. Bodily, "Are the Electric Utilities Gold Plated?" committee print, 96-IFC 12. Committee on Interstate and Foreign Commerce, United States House of Representatives, 1979.

Figure 44.—Phases of R&D



SOURCE: R L Rudman and C. Starr, 1978 "R&D Planning for the Electric Utility Industry," in *Energy Technology V* Government Institutes, Inc , Washington

the utilities and, in addition, develop a large supportive infrastructure. Thus, the vast bulk of the time spent in the long chain of technology development is in the phases following scientific feasibility— newly conceived technologies are not likely to fill near-term supply deficiencies.

Assuming that an engineering demonstration of a new technology is successful, its ultimate fate would depend on several factors whose influence can only be seen dimly at the time when scientific feasibility is proved. Comparative costs are a prime consideration, but public acceptance, the complexities of the technology, and the ease with which it can be integrated into the existing utility infrastructure are also important (see ch. 6). The utilities use some or all of the following criteria to judge a new technology:[18]

ECONOMIC CRITERIA

- **Cost** *to the User.* — Bus bar costs are important but an expensive long-distance transmission and distribution system may price a technology that is otherwise competitive at the busbar out of the market. This problem could apply to any very large, highly centralized facility.
- *Reliability.* – Plants that are highly capital intensive must operate at high capacity factors in order to minimize electricity costs. Thus, numerous forced or unplanned shutdowns for a given plant would make its technology less desirable. In general, a new technology can be expected to sustain a higher rate of forced or unplanned shutdown than a more mature one. Current mature nuclear plants and coal plants with scrubbers sustain forced outage rates as low as 15 and 19 percent of their total availability respectively. As the industry gains even more experience, it will probably be able to reduce this rate even more.
- *Ease of Maintenance.* — It is extremely important to be able to maintain and repair components of the generating system quickly and easily. Nuclear and fossil fuel plants currently experience planned outage rates of 15 and 10 percent, but utility experts believe that these rates can be reduced by several percent. Here again, mature technologies fare better than newer ones. However, the percentage of maintenance doesn't tell the whole story. The timing of the maintenance is also important. If it is possible to plan maintenance during periods when electricity peak loads are lower, the adverse effect on the utility is thereby reduced.

RESOURCE AVAILABILITY

Here, fossil or other depletable energy sources will suffer in competition with renewable sources such as wind-, solar-, fusion-, or breeder-generated fissile material. Further, because the Sun or wind are more available in some regions of the country than in others, terrestrial renewable technologies will vary in their attractiveness.

SYSTEM CAPABILITY AND FLEXIBILITY

- *Control and Operating Characteristics.* — The more stable a power system, the better. Short-term transient outages must occur under conditions that allow the utility grid to accommodate them as a matter of course.

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[18] R L Rudman and C Starr, "R&D Planning for the Electric Utility Industry," in *Energy Technology V* (Washington, D C Government Institutes, Inc , 1978)

[19] Ibid

- *Ability to Tolerate Abnormal Events.* –A system that is otherwise acceptable to the utilities may fail to be adopted because it is easily disturbed, i.e., small perturbations in operating mode lead to wide swings of electrical output.
- *Unit Rating.* –Although economies of scale are very real in generating equipment, smal ler capacity units may often be desirable, because they are easier to repair and replace than the large ones.
- *Environment/ Issues.* — Environmental impacts produce an economic cost that, while often impossible to specify, have a strong effect on the acceptability of a given technology. In addition, some technologies may have environmental side effects that are unacceptable no matter what price the uti l ity is willing to pay (e. g., the potential effects of the addition of large amounts of carbon dioxide to the atmosphere).

LICENSING

"Licensing . . . is currently the largest single issue facing al l new technologies. "[20] The issues that will affect the licensing procedure such as siting, health and safety, and environmental concerns must be identified and reckoned with early in the development of the technology. They also have a direct effect on the cost of a technology.

Once a generating technology has proven its commercial feasibility, it generally takes another 20 years or so for it to be used significantly. The complexity of the technology, institutional barriers, market growth (housing, industry, etc.) market initiative (dispersed v. central use), and system size will all have their effects on the rate at which a given technology will penetrate the total utility market.

Engineering Implications of the SPS for the Utilities Grid

The SPS would make numerous special demands on the utility grids. Some are related to the fact that the primary generator or collector would be based in space. Others are characteristic of all large-scale baseload technologies. In this section, we will proceed through each technology, citing the most important effects each alternative will have on the utilities.

The Reference System

- 5,000-M *W Capacity.* – Because of the grid reliability requirements, the large size of the reference system plant would limit the number of individual utilities or utilities' systems that could accommodate it. As a rule of thumb, a utility generally will not purchase a single unit that wou ld constitute more than *10* to 15 percent of the utility's total generating capacity. " In other words, a single plant must be no more than one-half of the system's total reserve capacity of 20 to 25 percent.

  If a utility could accommodate a first SPS of 5,000 MW, it could accept another provided it met a less stringent application of the penetration rule. In other words, the system would benefit somewhat by redundancy of generating units *provided* there was a low probability of both failing at once.

  As an example, for a utility to accept a 50,000-MW satellite, it must have a system capacity of 5,000/0.13 = 38,000 MW. This exceeds the capacity of any single current utility. Assuming current average rates of growth of 3.2 percent for the industry, it would exceed the capacity of all utilities save TVA in the year 2000. It might, of course, be possible for a group of several utilities with the appropriate total capacity and adequate grid interconnections to take on 5,000 MW of power. According to the rule for reserve capacity, for the group to then assume another 5,000 MW, its total capacity would have to be large enough for the two satellites together to constitute 20 percent or less of a system capacity of 50,000 MW. The exact percentage any given consortium of utilities would be willing to

[20] I bid

[2] P J Donalek and J L Whysong, "Utility Interface Requirements for a Solar Power System, " Harza Engineering Co , DOE contract No 31-109-38-4142, report No DO E/E R-0032, September 1978

accept would depend on its view of the probability of two SPS units and another unit or transmission line failing at the same time (see table 52).

As an additional consideration, it should also be noted that supplying 5 GW of reserve power from elsewhere in the system would put a great strain on the dispatching capability of the utility.

- *Lack of Inertia in SPS Power Generation.* — The frequency stability of a utility system is directly related to the rotating mass or mechanical inertia of its collection of generators. It is, in effect, analogous to a giant flywheel kept in motion by numerous small driving elements on its rim. Just as a flywheel adjusts only slowly to a sudden removal or addition of individual driving elements, the utility network takes several seconds to adjust to the loss or gain of megawatts of power. A generator added to the system adds additional mechanical inertia as well as power. Because the SPS reference design would add power but no additional inertia, i.e., it might come on or go off line virtually instantaneously, it would create surges that would be difficult for the system to accommodate. In order to use SPS-generated power, the utilities would have to develop new modes of ensuring frequency stability and control since the present operating mode depends implicitly on the mechanical inertia of the system. One possibility is to add short-term (15 minutes to 1 hour) battery storage capacity to the rectenna. Such an adjustment would add a small amount to the cost of SPS power.

- *Variations in SPS.* – Rectenna power output would vary seasonally because of the eccentricity of the Earth's orbit. As currently designed, the SPS would deliver 5,000 MW when the Earth is at maximum distance from the Sun. At its closest approach during the northern winter, each rectenna will deliver about 10 percent more power, or 5,500 MW. However, because the variation has a year-long period, it would be relatively easy to adjust for it continually.

Short-term variations would be much more serious. Around the equinoxes, the satellite would lie in the Earth's shadow for a short period each night around midnight. These "eclipses" of the satellite would vary trom a few seconds duration at the start of the 31-day eclipse period to a full 72 minutes at the equinox and then decrease again to zero. Because the antenna array would require a warmup period of 15 to 60 minutes, outages at the rectenna would vary from 30 to 140 minutes. Because the eclipses would be highly predictable and would occur at midnight in late March and September when loads are often low (typically 40 to 60 percent of the peak for summer peaking systems), they would be unlikely to constitute a problem for the system's reserve capacity.* However, following the load swing during the shortest eclipses would place a strain on the ability of the utility to respond because of the need to replace 5,000 MW very rapidly unless storage were in place.

Without short-term storage, the rate at which SPS power would decrease during an eclipse would undoubtedly pose control problems for the grid. As the satellite entered the Earth's shadow, it would lose power at the rate of 20 percent per minute, too fast for the grid to respond. In general, the maximum power fluctuation a grid can accommodate is about 5 percent per minute. However, it would be possible to shut down the satellite at an acceptable rate somewhat ahead of the eclipse.

The satellites and rectennas would require replacement or maintenance of numerous components (klystron amplifiers, solid-state amplifiers, laser components, photocells, dipole antennas, etc.) several times a year. Normally the outages associated with routine maintenance could be scheduled during periods of low electricity demand and are estimated[22] to constitute a loss of

*The demands on different utility systems vary regionally Thus, the truth of this statement must be examined on a region-by-region basis

[22] I Grey "Satellite Power System Technical Options and Economics," OTA working paper, Solar Power Satellite Assessment, 197'4

120 hr/yr of SPS power. Assuming maintenance could be scheduled during eclipse periods, the total time the satellite would be unavailable due to maintenance could be considerably less than this.

Boeing[23] has summarized the various losses of power to which the referenced SPS might be subject (table 52). Conspicuously missing, however, is the possibility of satellite equipment failure. It will be of considerable interest to everyone concerned to identify as many potential sources of *unplanned* SPS shutdown as possible.

Other possible variations in the amount of transmitted power have to do with the mechanism for controlling the position of the beam on the rectenna, which would be accomplished by a pilot beam directed from the rectenna to the satellite in space. Because of the finite time of travel in space for an electromagnetic signal, the time between sensing a position error at the rectenna and correction of it at the rectenna would be about 0.2 see, causing an oscillation in power output at a frequency of 5 Hz. Again, the 5,000 MW nominal output would strain the capabilities of the utility grid to follow the resultant load variations if short-term storage capacity were not made a part of the SPS system.

- *Power Reception, Transmission, and Distribution.* –At the rectenna, the power collec-

[23] "SPS/Utility Grid Operations, " sec 14 of DI 80-25461-3, Boeing Corp

Table 52.—Potential for Power Variations From the Reference System SPS

Source of power variation	Range percent	Frequency of occurrence per year	Average duration of outage per occurrence min/yr	Total outage hr/yr	Maximum power reduction GW	Average yearly energy loss GW hr	Time to maximum power loss	Scheduled Yes	Scheduled No
Spacecraft maintenance	0-100	2	2 x 3,600	120	5	600	6 min	X	
Eclipse	0-1oo	62	3,376 total 71 maximum per/occurrence	56.26	5	281.3	1 min	X	
Eclipse with shutdown and startup			5,270	87.8		439	1 min	X	
Wind storm	75-1oo	0.01	5,260	87.6	1.25	109.5	5 min		X
Earthquake	90-100	0.01	1,800	30	0.5	15	10 sec		X
Fire in rectenna system	80-100	0.01	840	14	1	14	30 min		X
Meteorite hit of spacecraft equipment	90-100	0.01	1,200	20	0.5	10	100 ms		X
Rectenna equipment failure	91.5-100	1	50	0.833	0.425	0.35	100 ms		X
Precipitation	93.3-1oo	50	1	0.833	0.335	0.28	1 m		X
Pointing error	94.8-100	5,000	0.6	0.833	0.29	0.24	1s		
Ionosphere	98.5-100	20	10	3.32	0.15	0.24	I s	X	
Ground control equipment failure	95-1oo	5	3	0.25	0.25	0.06	0.3 s		X
Aircraft shadow	99.99-1oo	20	20 m 1 m maxi occurrence	0.3	0.0005	0.0015	1s		X

Total without shutdown/startup: 331 hour (3. 77%) 1,030.8(2.350/~)
without shutdown/startup: 362 hour (4.1 20/.) 1,188.5(2.71 %)

SOURCE: "SPS/Utility Grid Operations", sec 14, D180-25461-3, Boeing Corp.

tion system would be divided up into units of 320 MW or less. The loss of any one or even a combination of several power blocks would present few problems for the grid because they would be relatively small compared to 5,000 MW. Transmission would be over four to five 500 KV lines or eight 345 KV lines. The loss of one of the transmission lines should not affect the stability of the system or the operation of the SPS. In the event of decreased load requirements, some excess power could be absorbed by the rectenna as heat. Sharp drops in power demand (e. g., an open circuit due, say, to a loss of several transmission lines) might cause overheating of the rectenna diodes if the system were unable to dissipate the excess power quickly enough. Hence, protective measures would be required.

Maintenance of the dipole antennas and rectifiers in the rectenna might present a major expense for the utility. Although the mean time to failure is projected to be 30 years,[24] this would mean that on the average, 7 to 8 diodes (in the rectifier circuit) could be expected to fail every second,[25] leading to an overall failure rate of 3 percent per year. Increased quality control of the manufactured components might mitigate some of the replacement needs by decreasing the failure rate. This procedure, though more expensive per unit, might be less expensive than replacing failed components.

Operating Capacity Factor. – In order to maximize capital investment, the SPS, if developed, should be operated as close to its "nameplate rating" as possible, i.e., 5,ooO MW. However, during periods of very light load (e.g., at night during the spring and fall) even current baseload nuclear and coal units must sometimes be run at less than fu II capacity in order to follow the load swing. Such factors would make the real operating capacity of the reference SPS less than its maximum capacity, thereby causing it to be more expensive.

- *Rectenna Siting.* — The land requirements for the SPS reference system are "large (see ch. 8). At 350 latitude the rectenna plus its exclusion area would cover an elliptical area some 174 km^2 in extent. By comparison, the city of Chicago is 57o km^2, and Washington, D. C., 156 km^2. Finding available land far enough from population centers and military installations (to make potential electromagnetic interference slight) and near enough to the load centers to make transmission costs acceptable would not be a trivial exercise. Rectenna siting would involve the various regulatory agencies and wou ld have to be addressed by uti l ities very early in the overal l planning process.

Utilities in far northern latitudes would generally find siting more difficult because the necessary rectenna area and rectenna exclusion area increases with increasing latitude. Some of the most acceptable locations are in the Southern and Southwestern United States where terrestrial photovoltaics and solar thermal devices will also be most economic to operate. Offshore siting wou ld also be possible, though this option wou ld require extensive study.

The Solid-State Variation

The sol id-state sandwich appears to be more economical to build and place in orbit in smaller units (about 1.5 GW),[26] mitigating-automatical [y problems arising from the control of 5 GW of power from the reference system ı n addition, a smaller rectenna would make it possible to place the rectenna closer to load centers or in offshore locations.

Because it is a microwave system, it would share the same stability problems that the reference system wou ld experience.

Laser System

The laser system would present a different set of challenges and opportunities for the

[24] R Andryczyk, P Foldes, J Chestek, and B Kaupang "Solar Power Satellite Ground Stations, " *IEEE Spectrum,* July 1979, "Satellite Power Systems Utility Impact Study," EPRI AP-I 548 TPS 79-752, September 1980 J G Bohn, J W Patmore, H W Faininger

[25] A D Kotin, "Satellite Power System (SPS) State and Local Regulations as Applied to Satellite Power System Microwave Receiving Antenna Facilities, " DO E-H CP/R-4024-05, 1978

[26] Hanley, op cit

utilities. Because it can generate electricity by employing infrared radiation to heat a boiler, it could perhaps be used to repower existing coal, oil, or nuclear facilities. A ground-based thermal collector would generate steam that could be used directly to drive a turbine. In addition, the scale of the proposed satellite/ground system (100 to 500 MW) would fit existing utility capacity quite wel 1. For cases where the laser were used for repowering an existing facility, no new transmission lines would be needed.

On the other hand, several intrinsic limitaions of the proposed laser system would make it difficult for the utilities to integrate it into their grid:

- *Weather Limitations.* — Although lasers of the overall power and power density of the proposed laser system could burn through light cloud cover, heavy clouds would make it unusable. Thus, it would be unsuitable in areas where clouds cover the region for more than a few percent of the year. It might be possible to use it in regions where there are more receiving stations than lasers to support them. Then, if station A were covered by clouds, for example, the laser feeding that station could be redirected to station B that was under no cloud cover. The resulting extra laser radiation at station B could then be used to generate more electrical power at that station to compensate for the loss of power at station A, assuming that B had the necessary extra capacity. This arrangement could work wel I for selected parts of the country, i.e., where the likelihood of cloud cover forming simultaneously over several stations was smal 1. However, since cloudy conditions tend to occur over large sections of the Nation at one time, the practicality of this notion would be limited.

Mirror System

A mirror system would be the most highly centralized technology of the four alternatives. Its proposers envision a few energy parks in which the increased daylight would be used to generate electrical energy — or perhaps, hydrogen. How it might be integrated into existing uti I ities is unclear. As an electrical system, it would require long transmission lines leading from the energy parks to the point of end use. However, hydrogen generated at the site could be transported by vehicles to other destinations.

This concept appears to require a national grid in order to make effective use of the large generating capacity of the site (from 10 to 135 GW). Stability would be much less of a problem for SOLARE S than for the microwave system because of the large number of satellites that would reflect sunlight, the inclusion of storage in the system, and because of the independent blocks of ground-based photovoltalcs or solar thermal plants at the site.

The SO LARES proposal would be subject to similar problems with clouds as the laser concept. However, the additional radiant energy *might* be great enough to dissipate clouds that would form in the region. For this reason, large mirrors have also been proposed for weather modification.[27]

Regulatory Implications of SPS[28]

Although this area has received only a cursory investigation at this time, it is clear that the potential for new forms of financial support and management structures for the SPS might engender new regulatory modes. In general, the SPS is likely to lead to greater centralization of the Nation's utility structure, leading in turn to a strong need for coordination between neighboring Public Utility Commissions or perhaps to completely new structures for regulating utilities.

Local v. Regional Control

Utilities have generally entered into a greater degree of cooperation with utilities in other States than have their associated regulatory agencies. This state of affairs will

[27] Vajk, op cit
[28] M Gersovitz, "Report on Certain Economic Aspects of the SPS Energy Program," OTA Working Paper, SPS Assessment, 1980

have to change with increasing use of high-capacity generating units and greater grid interconnections. A move toward regional planning and control will likely also come about because of the current disparity between States in siting and other regulations, making it more attractive for utilities to build in States where regulations are not as stringent or to purchase power from utilities that have a surplus of generating capacity.

In order to regulate their processes, new regional regulatory agencies are likely to be set up long before SPS could be part of the utility grid, leading to greater grid interties. The introduction of an SPS would undoubtedly hasten the process because the larger the grid, the more easily outages from a single rectenna or a laser receiver could be handled. The intermediate-scale solid-state system would fit into this kind of structure easily, but a larger scale SPS such as the reference system or SOLARES would necessitate an even more widespread system than is now envisioned. Although the laser system might be used to repower intermediate-sized generating facilities, the ever present possibility of massive cloud cover would require system interties in order to make the most efficient use of the available laser satellites.

Site Decisions*

Siting would be a major issue for each one of the alternative technologies and would also require the development of regional cooperation. A major question in SPS siting decisions is who would have the control; local, State, regional, or national entities? Currently, State or local regulatory boards make the ultimate decisions concerning plant siting. The Nuclear Regulatory Commission and the Environmental Protection Agency review these decisions. Except for Federal or State land, the planning for a 174 km' rectenna would likely involve several local jurisdictions, one more of whose land use regulations may not be compatible with an SPS rectenna. However, if the need for SPS power were great, there might be adequate reason to supercede local regulations in siting a rectenna. A single 5,000-MW rectenna could serve a large population, one which is very likely to be distributed across State lines. Coordination of regulatory authority could come from voluntary interstate agreements or from federally mandated regional planning.

*See also chs 8 and 9, pt C

The current debate about energy parks would be instructive in identifying and resolving some of these issues. Along with this, the trends toward regionalizing economic control on energy facilities and instituting a national power grid could provide the institutional framework for addressing siting issues for a rectenna or SOLARE S energy park.

Rate Structure

The magnitude of the capital investment that SPS and other future technologies would require would certainly cause some alteration of the utility rate structure. Just what form these alterations might take is currently unclear because they depend heavily on the form that the SPS companies would take and how they might be financed.

For example, if the utilities were to own individual SPS plants, they would wish to include their capital costs during construction (current work in progress) in the current rate base. Most States are presently unwilling to allow this. However, the extraordinarily high capital costs of other sorts of new generating capacity may make this scheme a necessity. On the other hand, if SPS power were to be bought directly from an SPS corporation and sold to the customer, the concern about adding capital costs during construction to the rate structure would be eliminated for the utility regulatory agency and shifted to another sector of the economy (though they would still be reflected in busbar costs).

SPS Corporations and the Utilities.

Currently, the utilities purchase equipment and knowhow from competing corporations who build and service generating equipment. Because of the scale of investment necessary to supply the supportive infrastructure for building an SPS, the SPS corporation might well evolve as a monopoly, requiring monopoly-type regulation on the Federal level. Whether generating plants or power are sold, it is likely that the Federal Government would be heavily involved in the regulation of SPS rates and in siting, reliability, and other aspects of integrating the SPS into the utilities' structure. Such a state of affairs would be likely to lead to a greater degree of centralization of the electrical industry whether a national power grid were instituted or not.

General Implications for the SPS

Centralization v. Decentralization

Two opposing forces currently affect the utilities industries—a move towards greater centralization and an opposite trend towards greater decentralization. On the one hand, economies of scale, shared facilities, and the benefits of regional planning make greater centralization attractive. On the other, the desire of individuals, communities, and many companies for a greater degree of energy self-reliance for economic or social reasons suggests that the utilities will have to adjust to an increased demand for grid-integrated dispersed systems.[29] The utilities are just beginning to address these issues squarely. Market pressures may make dispersed units increasingly more attractive (see ch. 5, *Energy in Context)* at the same time that the Federal Government supports the development of new central technologies. The main issue for the utilities to address is how to accommodate both ends of the scale in their planning.

Market Penetration

From the point of view of the utilities that would either purchase SPS generated power for distribution in a grid or purchase receiver installations to incorporate directly into their own systems, the ultimate total volume of SPS generated power would depend on a number of factors in addition to cost. Even if the busbar cost of SPS electricity was highly competitive with other future options, SPS market penetration could be limited by reliability requirements and by the technical difficulties of grid-dispatch that we have already discussed.

- *Reserve Requirements.* –The criterion that any two units (e. g., transmission line, generating plant, etc.) in a utility system must constitute less than 20 percent of the total system capacity leads to a minimum size for any single utility system for a given SPS capacity (see *Planning* Process). Thus, two 5,000-MW plants could be accommodated by a utility system with total capacity of 33,000 to 50,000 MW or greater. Smaller utilities' systems could accommodate appropriately smaller SPS plants. But in making decisions about whether to proceed with SPS or not, it is important to estimate how much total SPS capacity the U.S. utilities grid overall could accommodate. The projected total capacity of the reference system is 300 GW. Could the utilities grid in 2030 or 2040 accommodate that capacity?

Simply scaling up from the individual utility or utility grid, using the 20 percent criterion, 300 GW total SPS capacity implies 1,500 GW total electrical capacity in 2030 or 2040, about 2‘A times current capacity.

It is clear that under these stringent conditions, a low electricity demand would preclude development of SPS from the utilities point of view. The 20-percent requirement is certainly overly stringent, since in effect, it implicitly assumes that the entire SPS fleet would fail at one time (i. e., no reserve power would be available from other utilities). On the other hand, satellites that would be subject to eclipse (i. e., all those in geostationary orbits) would be eclipsed in groups, not singly. For a few days around the equinoxes, approximately 18 satellites would be eclipsed at once. * Roughly speaking this means that a band of Earth some 1,250-miles wide in longitude would suffer SPS power outage at one time. Thus, there is a distinct limit to the amount of lost generating capacity that nearby utilities could supply during the eclipse period. Utilities and their regulatory commissions would only be likely to in-

[29] D Morris and J Furber, "Decentralized Photovoltaics" OTA Working Paper, SPS Assessment, 1980

*A satellite placed at each degree of longitude corresponds to 15 satellites per hour of time crease their proportion of SPS beyond the 20 percent or so of reserve capacity if they were consistently able to draw power from beyond the "shadowed" region, or if the March/September night peaks are low enough to offset this difficulty. In other words, the larger the grid served by SPS the smaller the reserve capacity that would be required in any one region.

For the country as a whole then, a 20-percent penetration for the reference SPS or any geostationary SPS must be seen as an average limit. Utilities with appropriate backup could accept more. Others, because of their size, location, or special needs would only accept less than 20 percent.

A 20-percent penetration of SPS would constitute 120 GW in the low scenario and about 490 GW in the high one. At a 90-percent capacity factor, the contribution of electrical energy from SPS would be 3.2 Quads in the low scenario and 13 Quads in the high scenario (44 percent of the total electrical energy consumed in both cases).

- *Vulnerability.* –Another aspect of SPS that the utilities would certainly investigate in comparison with other generating options is its vulnerability to hostile actions[30] (see ch. 7), and to unforeseen technical failure.

Of perhaps far more concern to the utilities would be any vulnerability to technical failure (especially common mode failure) or to human error. As noted earlier, the utility grid would experience some difficulties in adjusting to planned outages from the reference SPS. Unplanned ones would be far more difficult to adjust for, though they are a common feature of utility operation. The potential for unplanned failure of any of the alternative SPS options would only be fully known if a decision is made to proceed with one option and a full-scale demonstration were built and tested extensively.

Perhaps the most technically sensitive component of the satellite system is the beam-focusing apparatus. In the microwave design, a pilot beam sent from the rectenna to the satellite antenna would control the phasing of the beam transmitters. With the loss of the pilot beam, the SPS power beam would quickly defocus, a safety feature that would prevent accidental or intentional wandering of the beam. The laser beam would be controlled in a similar manner. It would be important to design this apparatus to be insensitive to minor perturbations in operating mode, yet sensitive enough to maintain its safety qualities. Orientation of the reflecting mirrors of the SOLARES system would be entirely mechanical and would be controlled by built-in thrusters. Because the mirror system would be highly redundant, the loss of one mirror would not be catastrophic. It would also be essential to design the SPS to be as free as possible from human error. As the nuclear industry realizes, designing a technologically complex system in which the potential for human error is small is a difficult and complex task. Here again, experience with operating systems would be essential to utility acceptance.

System Comparison

The most acceptable SPS option for the current utilities to pursue may be the solid-state or a similarly sized microwave. It would provide baseload power with minor weather interference at a scale more in keeping with current utility practice (i e., 1.5 GW). If future utility systems develop the capability and the experience to handle larger increments of generating capacity, an SPS similar to the reference system would be more acceptable, though siting problems might be very great.

The laser and mirror concepts, though offering some interesting potential, suffer from severe weather constraints. The possibility that laser SPS could be used to repower fossil fuel plants would make it of particular interest in regions of relatively low cloud cover. One of the significant drawbacks of the mirror concept is that it would require the utility and overall energy industry to make a radical

[30] P Vajk, "The Military Implications of Satellite Power Systems" NASA/DOE SPS Program Review Meeting, April 1980, Lincoln, Nebr

change from its current structure because of its very high degree of centralization (10 to 135 GW per site). This would be particularly true for an SPS system operating in other countries where the grid system is either nonexistent or very small (see ch. 7, International Issues).

Timing of Grid Integration.

If SPS followed the pattern of other new energy technologies it would take a long time to be integrated into the utilities structure. The reference system scenario[31] suggests that the first SPS could be deliverig power to the grid in about 20 years time. But nuclear power, which has been used for generating steam for 30 years, and became an active option for the utilities in 1960 still constitutes only 9 percent of the country's total capacity (54,000 MW). *

In the face of this past experience, it seems more likely that the demonstration and testing phases of the SPS would be longer and therefore involve higher costs than can presently be envisioned. The utilities are faced with providing reliable power to their customers. Looking at SPS from a utilities standpoint, it seems highly unlikely that the first SPS would be part of the utility grid before 2010.

This estimate is based on technology similar to the reference system technology. Developing a laser SPS might take considerably longer because we simply have less experience with high-powered lasers. The SOLARES system would be technically easier to build, but the institutional and political barriers to creating the associated large energy parks could well slow its development to beyond 2020.

Rate of Implemental ion

The reference system assumes additions of 10,000 MW per year to the grid. Assuming electricity demand makes feasible 10,000 MW additions to U.S. generating capacity, it is unlikely that the rate would begin at that high level. Again, the utilities would want to have considerable experience with the first SPS before they would be willing to invest in additional units. Thus, it is more likely that the annual rate of implementation would begin at less than 5,000 MW on the average and build to higher levels as utilities gain experience and (onfidence in SPS.

Planning for SPS

Acceptance of SPS by the utilities would depend on a number of factors, not the least of which would be utility involvement in planning for SPS. But for the utilities to invest their time and money in such an effort, they would have to be convinced that it is worth their while. Thus, SPS must be considered to be economically, environmentally, and socially acceptable compared with the other future energy options. Much depends on a comparative analysis of the available options. And because comparative assessment is necessarily a process carried out over many years, the utilities must Involve themselves in all phases of that process. A comparative assessment done today, though instructive, is as a snapshot compared to a motion picture. As we know more about each technology in the comparative group, the particular parameters will change, leading to a reassessment of the desirability of each technology.

""Satellite Power System Concept Development and Evaluation Program Reference System Report, " op cit

* Nuclear power actual ly produces 13 percent of the electricity sold

ISSUES ARISING IN THE PUBLIC ARENA

SPS Debate

Public involvement in the development of technologies has grown significantly in the last two decades. Debate has focused on the environmental. health and safety. economic and military issues surrounding new technologies, The supersonic transport, nuclear powerplants, PAVE PAWS radar facilities and high-voltage transmission lines are examples of technologies that have been subject to recent public controlversy. Since SPS would probably be a federally funded technology (at least in the research, development, and demonstration — RD&D phases) with long-term and widespread ramifications, public input in the development process is crucial, especially in the early stages. Moreover, the potential effectiveness of public resistance to technological systems, and the public's interest in direct participation makes public understanding and approval imperative for the development of SPS.

The assessment of likely public attitudes towards SPS is difficult, however, because SPS is a future technology. At present, public awareness of SPS, while growing, is minimal. Even if opinions about SPS were well-formed today, it is likely that these attitudes would change with time. Public thinking could be influenced by the other energy and space technologies, perceived future energy demand and general economic and political conditions.[32] The state of SPS technology and estimated SPS costs could also be important determinants. In addition, the degree of public participation in the SPS decisionmaking process could play a part in future opinions about the satellite.

Most public discussion on SPS has been confined to a small number of public interest and professional organizations. OTA has drawn heavily on the views of these groups because they represent selected constituencies that could play a key role in influencing future public thinking and motivating public action. While OTA cannot determine whether or not the public would ultimately accept SPS, these interest groups can help identify the issues and philosophical debates that may arise in the future.

Interest Groups

A small number of public interest and professional organizations have expressed their views on SPS. In general, many of the individuals and groups that support the development of SPS also advocate a vigorous space program. SPS proponents, represented by organizations like the OMNI Foundation, view the exploitation of space in general, and SPS in particular, as important means in overcoming terrestrial energy and resource limits.[33] To the L-5 Society, which has been the most vocal SPS lobbyist, the satellite system is "a stepping stone to the stars,"[34] an important milestone towards the society's goal, the colonization of space Groups like the Aerospace Industries Association of America[35] and the SUN SAT Energy Council, a nonprofit corporation established to explore the SPS concept,[36 37] believe that SPS is one of the most promising options available for meeting future global energy needs in an environmentally and socially acceptable manner. Professional organizations such as the American Institute of Aeronautics and Astronautics[38] and the institute of Electrical and Electronics Engineers[39] support continued evaluation of the concept.

Opponents of SPS characteristically support terrestrial solar and "appropriate" technologies and are often concerned about environmental issues. The Solar Lobby[40 41] and the Environmental Policy Center,[42] for example, fear that an SPS program would drain resources and momentum from small-scale,

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"*Solar Power Satellite Public Opinion Issues Workshop, A Summary,* Feb 21-22, 1980, Office of Technology Assessment

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"C Henson, A Harlan, and T Bennett, "Concerns of the L-5 Society About SPS," *The Final Proceedings of the Solar Power Satellite Program Review,* Apr ,22-25, 1980, DOE, Cent-800491, July 1980 p 542

'5 Aerospace Industries Association, Statement submitted for the record in *Solar Power Satellite,* hearings before the Subcommittee on Space Science and Applications, U S House of Representatives, Mar 28-30, 1979, pp 241-242

'6 P G laser, "Solar Power Satellite Development – The Next Steps, Apr 14, 1978, in *Solar Power Satellite,* hearings before the Subcommittee on Space Science and Applications, U S House ot Representatives, Apr 12-14, 1978, No 68, pp 165-178

'7 J Freeman (ed) *Space Solar Power Bulletin, VOI 1, No 1* and 2, SUNSAT Energy Council, 1980

"' *Solar Power Satellites,* AIAA Position Paper, Nov 29, 1978, prepared by the AIAA Technical Committee on Aerospace Power Systems, and the AIAA Technical Committee on Space Systems

'<'H Brown, "Statement on 'Solar Power Satellite Research, Development, and Evaluation Program Act of 1979,'" in *Solar Power Satellites,* hearings before the Subcommittee on Space Science dnd Applications, U S House of Representatives, Mar 28- 30, 1979, No 15, pp 4-8

"'('I itizens Energy Project, Solar Power Satellites News Update, Solar Power Satellite Fact Sheet, Coal ition Against Satellite Power Systems Statement (newsletters), 1980

41 G DeLoss, ' Solar Power Satellite, " *Sun Times,* July 1979, p p 4-5

42 G De Loss, testimony in *Solar Power Satellite,* hearings before the Subcommittee on Space Science and Applications, U S House of Representatives, Mar 28-30, 1979, No 15, pp 109-114

ground-based, renewable technologies. They argue that compared to the terrestrial solar options, SPS is inordinately large, expensive, centralized, and complex and that it poses greater environmental and military risks. The Citizen's Energy Project has been the most active lobbyist against funding SPS and has coordinated the Coalition Against Satellite Power Systems, a network of solar and environmental organizations.[43] Objections to SPS also have been raised by individuals in the professional astronomy and space science communities that see SPS as a threat to the funding and practice of their respective disciplines.[44] [45] While there is a wide spectrum of support for SPS in the advocates' community, ranging from cautious support of continued research to great optimism about the concept viability and deployment, almost all opponents object to Government funding of SPS research, development, and deployment.

If the SPS debate continues in the future, it is likely that several other kinds of groups would take a stand on SPS.[46] For example, antinuclear groups could oppose SPS on many of the same grounds that they object to nuclear power: centralization, lack of public input, and fear of radiation, regardless of kind. Antimilitary organizations might also object to SPS if they foresaw military involvement. It is likely that community groups would form to oppose the siting of SPS receivers in their locality if the environmental and military uncertainties were not adequately resolved or if public participation in the siting process was not solicited. Rural communities and farmers in particular could also strongly oppose SPS on the grounds that, like highways and high-voltage powerlines, it would intrude on rural life.

Issues

The issues that repeatedly surface in the SPS debate are shown in table 53. It should be noted that in most of the discussion, it is assumed that SPS would be a U.S. project (at least in the near term). If the question of SPS were posed in an international context, it is possible that the flavor of the following arguments would be altered considerably. Currently, public discussion is focused on the question of R&D funding. It is anticipated that as public awareness grows, the environmental, health, safety, and cost issues will receive more public attention. Questions of centralization, military implications and the exploitation of space could also be important.

R&D PROGRAMS

The primary purpose of an SPS R&D program in the near term would be to keep the SPS option open. However, opponents argue that it makes little sense to investigate this complex, high risk technology when other more viable alternatives exist to meet our future energy needs.[47] In particular, they fear that SPS would divert funds and valuable human resources from the terrestrial solar technologies, which they perceive as more environmentally benign, versatile, less expensive to develop, and commercially available sooner than SPS.[48] Opponents also argue that a Government R&D program for SPS would fall easy prey to bureaucratic inertia, and that no matter what the results of R&D, the program would continue because the investment and attendant bureaucracy would be too great to stop.[49] Moreover, opponents believe that political inertia will be generated from the relatively large amount of money that is presently allocated to organizations with a vested interest in SPS as compared to those groups opposed to SPS. In addition, they are concerned that studies evaluating SPS for the purpose of making decisions about R&D funding do not compare SPS with decentralized solar technologies; they argue that without this kind of analysis, the public would be unwilling to make a commitment to SPS funding.

[43] Citizen's Energy Project, op. cit.

[44] "Solar Threat to Radioastronomy," New Scientist, Nov. 23, 1978, p. 590.

[45] Peter Boyce, Executive Officer of the American Astronomical Society, prwate communication

[46] *Solar Power Satellite: Public Opinion Issues Workshop, A Summary,* Feb. 21-22,1980, Office of Technology Assessment

[47] K Bossong and S. Denman, "A Critique of Solar Power Satellite Technology," *INSIGHT,* March 1980

[48] Citizen's Energy Project, op. cit

[49] *Solar Power Satellite: Public Opinion Issues Workshop, A Summary,* Feb 21-22, 1980, Office of Technology Assessment

Table 53.—Major Issues Arising in SPS Debate*

Pro	Con
R&D funding	
• SPS is a promising energy option	• SPS is a very high-risk, unattractive technology
• The Nation should keep as many energy options open as possible	• Other more viable and preferable energy options exist to meet our future energy demand
• An SPS R&D program is the only means of evaluating the merit of SPS relative to other energy technologies	• SPS would drain resources from other programs, especially terrestrial solar technologies and the space sciences
• SPS R&D will yield spinoffs to ether programs	• No matter what the result of R&D, bureaucratic inertia will carry Government programs too far
cost	
• SPS is likely to be cost competitive in the energy market	• SPS is unlikely to be cost competitive without Government subsidy
• Cost to taxpayer is for R&D only and accounts for small portion of total cost; private sector and/or other nations will invest in production and maintenance	• Like the nuclear industry, SPS would probably require ongoing Government commitment
• SPS will produce economic spinoffs	• Projected cost are probably underestimated considerably
	• The amount of energy supplied by SPS does not justify the cost.
Environment, heath, and safety	
• SPS is potentially less harsh on the environment than other energy technologies, especially coal	• SPS risks to humans and the environment are potentially greater than those associated with terrestrial solar technologies
	• Major concerns include: health hazards of power transmission and high-voltage transmission lines, land-use, electromagnetic interference, upper atmosphere effects, and "sky lab syndrome"
Space	
• Space is the optimum place to harvest sunlight and other resources	• SPS is an aerospace boondoggie; There are better routes to space industrialization and exploration than SPS
• SPS could be an important component or focus for a space program	• SPS is an energy system and should not be justified on the basis of its applicability to space projects
• SPS could lay the ground work for space industrialization and/or colonization	
• SPS would produce spinoffs from R&D and hardware to other space and terrestrial programs	
International considerations	
• One of the most attractive characteristics of SPS is its potential for international cooperation and ownership	• SPS could represent a form of U.S. and industrial nations' "energy imperialism," it is not suitable for LDCs
• SPS can contribute significantly to the global energy supply	• Ownership of SPS by multinational corporations would centralize power
• SPS is one of few options for Europe and Japan and is well suited to meet the energy and resource needs of developing nations	
• An international SPS would reduce concerns about adverse military implications	
Military Implications	
• The vulnerability of SPS is comparable to other energy systems	• Spinoffs to the military from R&D and hardware would be significant and undesirable
• SPS has poor weapons potential	• Vulnerability and weapons potential are of concern
• As a civilian program, SPS would create few military spinoffs	

Table 53.—Major Issues Arising in SPS Debate* —Continued

Pro	Con
Centralization and scale	
• Future energy needs include large as well as small-scale supply technologies; urban centers and industry especially cannot be powered by small-scale systems alone	• SPS would augment and necessitate a centralized infrastructure and reduce local control, ownership, and participation in decisionmaking
• SPS would fit easily into an already centralized grid	• The incremental risk of investing in **SPS** development is unacceptably high
Future energy demand	
. Future electricity demand will be much higher than today	. Future electricity demand could be comparable or only slightly higher than today with conservation
. High energy consumption is required for economic growth	• The standard of living can be maintained with a lower rate of energy consumption
• SPS as one of a number of future electricity sources can contribute significant y to energy needs	• There is little need for SPS; future demand can be met easily by existing technologies and conservation
• Even if domestic demand for SPS is low, there is a global need for SPS	• By investing in SPS development, we are guaranteeing high energy consumption, because the costs of development would be so great

[a]Arguments mainly **focus** on the SPS reference system.

SOURCE: Office of Technology Assessment.

Advocates, on the other hand, view SPS as a potentially viable and preferable technology.[50] **They argue that an R&D program is the only means of evaluating SPS vis-a-vis other energy technologies. Moreover, if the Nation can afford to spend up to $1 billion per year on a high-risk technology like fusion, it could certainly afford SPS research that would be much less expensive.**[51] **proponents maintain that SPS research will yield many spinoffs to other technologies and research programs whether or not SPS is ever deployed.**[52 53] **They also respond to claims of bureaucratic inertia by citing several cases in which large projects, such as the SST and the Safeguard ABM system, were halted in spite of the large investment. 54 They argue that at the funding levels currently discussed for R&D, the risk of program runaway is very low.**

COST

Economic issues have played center stage in the SPS debate. Almost every journal account of SPS (particularly those critical of the satellite) has highlighted its cost.[55 56 57] **The**

"'P. Glaser, **"Solar Power From Satellites, "** *Physics Today, February* **1977,**

"Solar Power Satellite: *Public Opinion Issues Workshop, A Summary,* **Feb. 21-22, 1980, Office of Technology Assessment**

[52]**P** Glaser, **"Development of the Satellite Solar Power Station,"** **in** *Solar Power* **from** *Satellites,* **hearings before the Subcommittee on Aerospace Technology and National Needs,** U S **Senate, Jan 19,21,1976, pp 8-35**

[53]T A. Heppenheimer, *Colonies in Space* (City, State: Stack**pole Books, 1977)**

"Solar Power *Satellite: Public Opinion Issues Workshop, A Summary,* **Feb. 21-22, 1980, Office of Technology Assessment.**

"J Marinelli, **"The** Edsel **of** The Solar Age," *Environmental Action,* **July/August 1979,**

"R Brownstein, "A $1,000,000,000 Energy Boondoggle; Science Fiction Buffs Will Love It, " *Critical* **Mass** *Journal,* **June 1980.**

"L Torrey, **"A Trap to Harness the Sun," New** *Scientist,* July **10, 1980**

predominant questions revolve around R&D priorities and capital and opportunity costs. In addition, the calculation of costs themselves and cost comparisons between technologies could be subject to extensive scrutiny and debate.

Proponents argue that the only cost open for public discussion is the cost of RD&D to the taxpayer.[58,59] The bulk of the SPS investment would be carried on by the private sector in competition with other inexhaustible energy alternatives. Furthermore, much of the RD&D cost could be returned from other space programs such as nonterrestrial mining and industrialization that build upon the SPS technological base.[60] Advocates also contend that an SPS program would produce economic spinoffs by providing domestic employment and by stimulating technological innovation for terrestrial industry.[61] Some proponents also argue that as an international system, SPS could lead to the expansion of world energy and space markets.[62,63] In addition, in a global scenario, the United States would bear a smaller portion of the development costs. Finally, advocates believe that in spite of the large investment costs, SPS would be economically competitive with other energy technologies.[64,65]

Opponents argue that the present cost estimates are unrealistically low.[66] They expect that like other aerospace projects and the Alaskan pipeline, the cost of SPS would significantly increase as SPS is developed. Furthermore, the U.S. taxpayers would be required to support this increase and to maintain an ongoing commitment to SPS above and beyond the RD&D costs, just as they have for the nuclear industry.[67] The National Taxpayers Union, in particular, sees SPS as a "giant boondoggle that will allow the aerospace industry to feed its voracious appetite from the federal trough."[68] Opponents argue that SPS would not alleviate unemployment substantially because it provides unsustainable jobs to the aerospace sector alone.[69] Most opponents also do not believe that SPS will be cost competitive and argue that the amount of energy produced by SPS would not justify its large investment cost.[70]

The most critical issue for opponents is the question of opportunity cost, i.e., the cost of not allocating resources for other uses.[71] They argue that a commitment to SPS R&D would jeopardize rather than stimulate the development of other energy technologies. Opponents also argue that SPS might foreclose opportunities for alternate land use, Federal nonenergy R&D funding, allocation of radio frequencies and orbital slots, resource uses and jobs.

ENVIRONMENT, HEALTH, AND SAFETY

Opponents contend that the environmental risks and uncertainties of SPS far exceed those of the terrestrial solar options.[72] They are most concerned about the effects of microwaves on human health, airborne biota and communications systems. Critics of SPS also argue that it would severely strain U.S. supplies of certain materials, thereby increasing our reliance on foreign sources.[73] In addition, opponents ques-

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[58] *Solar Power Satellite: Public Opinion Issues Workshop, A Summary,* Feb. 21-22, 1980, Office of Technology Assessment.

[59] K Heiss, testimony in *Solar Power Satellite,* hearings before the Subcommittee on Space Science and Applications, U S House of Representatives, Mar 28-30, 1979, pp 132-158

[60] G. Driggers, letter and statement submitted for the record in *Solar Power Satellite,* hearings before the Subcommittee on Space Science and Applications, U S House of Representatives, pp 407-416

[61] Glaser, "Solar Power Satellite Development–The Next Steps," op cit

[62] *Solar Power Satellite: Public Opinion Issues Workshop, A Summary,* Feb. 21-22, 1980, Office of Technology Assessment

[63] Heppenheimer, op. cit

[64] P. Glaser, "The Earth Benefits of Solar Power Satellites," *Space Solar Power Review,* vol 1, No 1 &2, 1980

[65] R. W Taylor, testimony in *Solar Power From Satellites,* pp 48-51.

[66] K. Bossong, S. Denman, *Solar Power Satellites or How to Make Solar Energy Centralized, Expensive and Environmentally Unsound,* report No. 40, Citizens Energy Project, June 1979

[67] *Solar Power Satellite: Public Opinion Issues Workshop, A Summary,* Feb 21-22, 1980, Office of Technology Assessment

[68] J Greenbaum, National Taxpayers Union, letter to the Senate Energy and Natural Resources Committee, expressing views on H R 12505, July 7, 1978

[69] Richard Grossman, Environmentalists for Full Employment, private communication, July 25, 1979

[70] Bossong and Denman, op cit

[71] *Solar Power Satellite: Public Opinion Issues Workshop, A Summary,* Feb 21-22, 1980, Office of Technology Assessment

[72] Citizen's Energy Project, op cit

[73] J Hooper, Star Gazer's *Alert,* update to "Pie in the Sky" (newsletter), The Wilderness Society

tion putting Earth resources in space where they cannot be recycled or retrieved. " Opponents also cite the large amount of land needed for receiver siting, high-voltage transmission lines, the effects of launches on air and noise quality, the potential for unplanned reentry of LEO satellites ("Skylab Syndrome"), reflected sunlight from the satellites and potential adverse effects on climate and ozone as serious problems. [75]

Advocates, on the other hand, maintain that compared to other baseload or large-scale energy technologies, SPS would incur less environmental risk. [76] [77] [78] In particular, its climatic effects would be far less severe than those of fossil fuels and its bioeffects would probably be much less hazardous than those of coal and nuclear. Proponents claim that the principal advantage of SPS as opposed to terrestrial solar and hydroelectric is that it would ueless land per unit energy.[79] Most advocates are confident that while electromagnetic interference and some atmospheric effects could be a problem, acceptable methods can be found to mitigate most of the environmental impacts of SPS. Some proponents also argue that one of the major benefits of SPS is that it transports to space many of the environmental impacts typically associated with the generation of power on Earth.[80] Moreover, air and water pollution and resource strains could be alleviated if the Nation mined the Moon or asteroids. Some advocates have also stressed the importance of weighing environmental concerns against the needs for inexpensive energy.[81] A few contend that while environmental issues have ranked high in the public mind, convenience and the cost of energy are becoming more important. Opponents, on the other hand, contend that environmental concerns will remain predominant and that the public perception of environmental risks will ultimately dictate costs.

Historically, public involvement in technological controversies has often been spurred by concerns about the environmental risks. Environmental issues could be very important in future public thinking about SPS as well.[82] It is also likely that SPS would serve to bring controversies over the impacts of other technologies to the forefront, most notably the bioeffects of microwaves and high voltage transmission lines (60 cycle). While the public might be concerned about all environmental impacts (see table 28), those that most immediately affect people's health and well-being would dominate discussion. Moreover, environmental issues would be most focused and amplified at the siting stages of SPS development (see Siting section). Public acceptance of SPS will depend strongly on the state of knowledge and general understanding of environmental hazards. It will also depend on the institutional management of the knowledge; who determines the extent and acceptability of the public risk may be just as important as the data itself.

The most critical environmental issue for the reference system at present is the biological effect of microwaves, not only because the uncertainties are so great, but also because of the existing controversy over microwave bioeffects in general. As the proliferation of microwave and radio frequency devices has increased dramatically, this issue has received considerable attention in the public arena. A great many newspaper and journal articles,[83] as well as television segments on 60 minutes and 20/20,[84] and Paul Brodeur's book, *The Zapping of America: Microwaves, Their Deadly Risk and the Cover-Up*[85] signal growing public

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"DeLoss, "Solar Power Satellite, " op cit

[75] *Solar Power* Satellite: *Public Opinion Issues Workshop, A Summary,* Feb 21-22, 1980, Office of Technology Assessment

"C laser, "Solar Power Satellite Development–The Next Steps," op cit

[77] Heppenheimer, op. cit

"G. O'Neill, *The High Frontier: Human Colonies in Space* (New York William Morrow & Co , Inc , 1977)

[79] Glaser, "The Earth Benefits of Solar Power Satellites, " op cit.

[80] G W Driggers, "SPS Significant Promise Seen, " *The Energy Consumer,* September 1980, pp 39-40

[81] *Solar Power Satellite: Public Opinion Issues Workshop, A Summary,* Feb. 21-22, 1980, Office of Technology Assessment

[82] Ibid

[83] S Schiefelbein, "The Invisible Threat, " *Saturday Review,* Sept 15, *1979,* pp 16-20

[84] A Bachrach, *Satellite Power System (SPS) Public Acceptance,* October 1978

[85] Paul Brodeur, *The Zapping of America* (New York W W Norton & Co Inc , 1977)

concern over the increase of "electronic smog."

The press has been particularly suspicious of the motives and conclusions of the apparently small, closed community of microwave researchers and decisionmakers in the 1950's and 1960's. Suggestions of vested interests, conspiracy, and coverups stem from the confidential classification of microwave research by radio frequency users such as the military and the microwave device industry and the lack of attempts to solicit public input.[86] Whether or not such motives in fact existed, the public and press, fearful of the word "radiation," have expressed little confidence in "official" claims that microwaves are as safe as they are purported to be.

The political edge of the scientific controversy has also been sharpened by several incidents over a 10-year period of microwave irradiation of the U.S. embassy in Moscow. The peak power of the modulated field was 18 microwatt, far below the U.S. guideline.[87] Although neither electronic jamming or surveillance seemed to be the purpose of the waves, there was concern about attempted behavior control and health hazards that led to Project Pandora and other studies. These investigations tended to conclude that the embassy workers did not encounter health hazards traceable to their exposures.[88] Few follow-up studies have been conducted however, and suspicions still exist. Public opinion seems to have been influenced by the extensive publicity these episodes have received. Articles questioning the ethics and motives of the State Department leave the reader feeling that the issues were never adequately resolved.

Most recently the proposed American National Standards Institute and National Institute of Occupational Safety and Health (NIOSH) microwave standards have been criticized. The Natural Resources Defense Council (NRDC) claims that the NIOSH criteria document that will form the basis of the NIOSH standard, fails to provide a scientifically and medically sound standard; while it admits the existence of many low-level effects, it proposes a thermal standard and fails to adequately address low-level non-thermal effects.[89] NRDC argues that the proposed standard was arbitrarily chosen, just like its predecessor. NRDC recommends that the criteria document be recommissioned, that a balanced team of experts work with NIOSH and another review the document and that a temporary emergency standard of 1 mW/cm^2 for 10 MHz to 300 GHz, be promulgated.

In spite of the proliferation of microwave ovens, public resistance to the siting of technologies that use the radio frequency portion of the electromagnetic spectrum has been strong and often effective. Local residents have opposed the construction of broadcasting towers and radar installations, as well as high voltage transmission lines (ELF radiation). (See Siting section.)

SPACE

SPS would represent a giant leap in our present commitment to space. To some, this space component and its supporting infrastructure would be an unnecessary and expensive commitment,[90] while others enthusiastically embrace SPS as the first step towards an extraterrestrial future for human kind.[91] Others argue that a commitment to space is desirable, but that SPS would be the wrong route to get there. It is likely that the discussion of the SPS concept would precipitate extensive debate over national priorities, domestic space policy and the international and military implications of space.

Proponents of SPS argue that space is the optimum place to harvest sunlight[92] and other resources that are needed for an Earth plagued by overpopulation, resource limitations, and a threatened environment. Many envision a

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[86] Ibid.
[87] Schiefelbein, op. cit.
[88] A. Lilienfeld, et al, Foreign Service *Health* Status *of Foreign Service* and Other Employees From *Selected* Eastern European *Posts Final Report,* Department of Epidemiology, the John Hopkins University, July 31,1978

[89] Louis Slesin, letter to Dr Anthony Robbins, NIOSH, from NRDC, July 11, 1979
[90] Citizen's Energy Project, op cit
[91] Henson, Harlan, Bennett, op cit
[92] Brownsteln, op clt

future in which the U.S. mines, industrializes and colonizes space as a hedge against these limits to growth.[93 94 95] SPS is one step in this vision, for it not only would deliver energy to Earth but would also spur the development of hardware, management, expertise and energy for use by other space activities. In fact, some proponents have suggested that without SPS, the space program will atrophy;[96] that SPS would give NASA a clear context in which to plan other space projects. Some advocates see SPS, like Apollo, as a way to restore the frontier spirit by dispelling the gloom associated with limits to growth.[97 98]

Many opponents, on the other hand, call SPS an aerospace boondoggle. " They argue that SPS, as an energy system, should not be justified on the basis of its applicability to other space pro jets. Moreover, it is argued that it is not necessary to go to space in order to generate technological spinoffs; the Nation can encourage technological competence and innovation in more direct and less expensive ways. [100] Some critics of SPS also argue that SPS would serve to escalate and accelerate confrontations in space.

In the future, public opinion about space and SPS in particular will be influenced by the relative status of space programs in this and other countries.[101] For example, the pursuit of SPS programs in other nations might act as an impetus for the United States to participate in or develop its own SPS. In light of the experience with Skylab, it is clear that the success or failure of U.S. space projects such as the space shuttle will have a marked effect on public thinking. Grassroots organizations supportive of space, and the popularity of science fiction and space-oriented entertainment, could also play a role in determining attitudes toward the exploitation and exploration of space. A growing public interest in space utilization or exploration and increased appreciation of the pragmatic benefits of space could put SPS in a favorable light.[102] Equitable international agreements about the use of space could also spur support for SPS. On the other hand, ambiguous space agreements, international conflicts, or the escalation of space weaponry could turn public opinion away from SPS. Negative public thinking about space activities and SPS could also stem from the technical failure of a major space vehicle or satellite.

INTERNATIONAL CONSIDERATIONS

Beyond its immediate implications as a space system, there are other international issues associated with SPS. The satellite system is seen as a possible focus for either global cooperation or global conflict by advocates and opponents alike. '03 However, opponents are especially skeptical of the feasibility of a multinational system; they doubt that international cooperation would occur until most of the existing conflicts on Earth are resolved. SPS opponents are most concerned that SPS would represent U.S. "energy imperialism" by dominating the cultural and technical development of lesser developed countries (LDCs).[104] Reliance on the industrial nations would impinge on third world attempts at energy independence. Furthermore they argue that SPS would do little to alleviate the near term energy needs of LDCs, whereas most terrestrial solar technologies could. Opponents also fear that control of SPS by multinational corporations would accelerate the movement of economic and political power away from individuals and communities.[105]

The characteristic of SPS that is most attractive to some proponents, on the other hand, is the potential for multinational cooperation. [106 107] In fact, a few contend that

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[93]Glaser, "Development of the Satellite Solar Power Station, " op. cit

[94]Heppenheimer, op c i t

[95]0' Neill, op. cit

[96]Peter Glaser, private communication

[97]Glaser, "Solar Power Satellite Development–The Next Steps, " op. cit

98 Heppenheimer, op cit

[99]Greenbaum, op cit

[100]Office of Technology Assessment, op cit

101 Ibid

[102]Ibid

[103]Ibid

[104]Ibid

[105]Bossong and Denman, "A Critique of Solar Power Satellite Technology, " op cit

[106]G laser, "The Earth Benefits of Solar Power Satellites, " op cit

[107]P G laser, "The Solar Power Satellite Research, Development and Evaluation Program Act of 1979, " testimony in *Solar Power Satellite, 1979,* pp 215-224

this is the only feasible arrangement for SPS;[108] a multinational SPS would alleviate many of the problems associated with a unilateral SPS, e.g., military implications and high costs. Proponents also argue that SPS would enhance the economies and industrial development of LDCs by meeting their primary energy needs.[109] They maintain that electricity from SPS could be used to produce methanol, transported to rural areas in labor intensive pipelines for heating, cooking, and small industries.[110] SPS might also be used for mariculture to provide food. SPS advocates maintain that for oil- and sun-poor Japan and Europe, SPS is one of the very few energy options available. Some also argue that the deployment of SPS would slow the proliferation of nuclear technology in the third world. [2]

MILITARY IMPLICATIONS

Military issues are intimately related to space and international considerations. Proponents stress that SPS microwave and mirror systems would be ineffective weapons and no more vulnerable than a terrestrial powerplant. ' While some believe that a military presence in space is unavoidable, it is clear that there are better ways to achieve military competence than with SPS. A primary concern for opponents is that SPS would provide a technological base that would further military capabilities and serve to escalate military conflicts.[114] Many opponents feel that, like the shuttle, military involvement with SPS is inevitable and that because of its vulnerability, SPS would accelerate the need for a military presence in space. Opponents are also concerned that because of their highly centralized nature, SPS satellites and receiving stations would be targets for attack from terrorists and hostile nations.

[t is likely that the military issue will be of great concern to the public, although it is not apparent how the military implications of SPS would be viewed. For example, a perceived military potential of SPS and its supporting infrastructure might be seen as a real benefit to a public concerned about both national security and energy needs. [5] Many might even expect a military presence in space. The laser system would probably engender more concern over military applications than the microwave or mirror designs. Clearly, future opinion will be influenced by the state of space weaponry in this and other nations, future agreements about the use of space, and the state of terrestrial weapons as well as arms limitations and the perceived military stature of the United States relative to the rest of the world.

CENTRALIZATION AND SCALE

Debate over future energy strategies often involves questions of general social values rather than a narrow choice of specific technologies. One of the issues fundamental to this debate is that of centralization of energy production. The degree of centralization underlies many of the other issues discussed here including siting, ownership, public participation, military implications, and the choice between terrestrial solar and SPS.

Opponents of large-scale technologies object to society's increasing reliance on complex technologies and centralized infrastructures that, they argue, tend to erode the viability of democratic government by concentrating economic and political power in the hands of a few, and reducing individual and community control over local decisions.[116] Critics of SPS argue that it would augment and necessitate centralization by requiring a massive financial-management pyramid.[117] Utility, energy, and space companies and Federal agencies would combine into a simple conglomerate, in which small business would play little or no part. They reason that decisions about local energy development, receiver and transmission line siting and economic and environmental planning would necessarily be made by Federal

[108] Glaser, private communication, op cit
[109] Heppenheimer, op cit
[110] D Criswell, P. Glaser, R Mayur, B O'Leary, G O'Neill, and J Vajk, "The Role of Space Technology in the Developing Countries," *Space Solar* Power Review, VOl 1, No 1 & 2, 1980
[111] Bachrach, op cit
[112] Driggers, op cit
[113] Office of Technology Assessment, op cit
[114] Ibid
[115] Ibid
[116] Bossong and Denman, "A Critique of Solar Power Satellite Technology, " op cit
[117] Citizen's Energy Project, op cit

and industrial decision makers at a national or perhaps multinational level.[118] Many opponents argue that decentralized solar technologies are preferable to SPS because they employ a wider range of skills, encourage participation of small firms, are more directly accessible to the individual consumer and equitably allocate their negative environmental impacts to the same people who receive the benefits. In addition, unlike SPS that must be built in large units to be economic, terrestrial solar technologies can flexibly accommodate large or small variations in energy demand. ' Moreover, unlike SPS, they do not require large contiguous land areas, a large initial investment, large energy backup units or a national utility grid to ensure adequate reliability. Dispersed energy technologies are also considered more appropriate for lesser developed nations because they are better matched to end-use needs, produce relatively small impacts on local culture and environment and don't require foreign financing, materials, complex infrastructures or hardware.[120] Opponents of SPS also view its scale as a severe detriment from an energy planning perspective because the incremental risk of investing in an SPS development program would be unacceptably high; a case of "too many eggs in one basket.[121]

Most proponents of SPS argue that the Nation's energy future will be characterized by a mix of centralized and dispersed energy generating systems, but that only centralized technologies like SPS will be able to meet the needs of industry, large cities, transportation and fuel production.[122] In addition, the centralized nature of SPS facilitates its adoption into the existing electricity infrastructure.[123] Some organizational centralization may result, but this will occur in the utility and aerospace sectors, already strongly centralized, and so it will not cause a significant new concentration of power.

[1] "Office of Technology Assessment, op cit

'"DeLoss, testimony in *Solar Power Satellite*, op cit

""Off ice of Technology Assessment, op cit

"'DeLoss, "Solar Power Satellite, " op cit

"'Office of Technology Assessment, op cit

[123]R Stobaugh and D Yergin, *Energy Future (New* York Ran dom House, 1979)

In general, advocates of large-scale technologies like SPS maintain that centralized systems are more reliable and easier to implement than dispersed technologies. Centralized powerplants also produce environmental impacts that are localized and hence directly affect fewer people. It is argued that dispersed power generation does not reduce centralized decisionmaking; in order to be economic these systems will require mass production, standardization, and regulation and an extensive distribution and service network.[124] Centralized technologies, at least, are more convenient from the user's perspective. Advocates also contend that centralized technologies and infrastructures are a better means of ensuring equity among the Nation's citizens.[125] For example, many people, predominantly in the inner cities, will continue to rely on centralized delivery systems because they cannot afford the capital costs to do otherwise.

While the public might not couch the problem in terms of "centralization, " it is clear that people will be concerned about technologies and systems that appear to prevent them from directly influencing the conditions of their own lives.[126] Public thinking about SPS will then be determined by the extent of public participation in the planning and decisionmaking process, experience with centralized and dispersed technologies, attitudes towards energy, space, and utility conglomerates as well as the perceived influence and benefits (e g., convenience) of centralized technologies.

FUTURE ELECTRICITY DEMAND

Those in favor of SPS tend to foresee an energy future characterized by high electricity consumption and an expanded power grid.[127] Many equate economic well-being to high energy growth rates.[128] Even if the United States is not able to absorb all of an SPS

[24]H Brooks, "Critique of the Concept of Appropriate Technology", In *Appropriate Technology and Social Values — A Critical Appraisal,* F Long and A Oleson (eds) (Cambridge, Mass Ballinger Publishing Co , 1980)

[25]Office of Technology Assessment, op cit

[26]Ibid

[27]Offic e of Technology Assessment, *The Energy Context of SPS Work shop, A Summary,* September 1980

"Off Ice of Technology Assessment, *Solar Power Satellite Public Opinion Issues Workshop, A Summary,* Feb 21-22, 1980 system, they argue that on a global scale there will always be high demand.[129] [130] Proponents also argue that if SPS is able to provide relatively cheap, environmentally benign and plentiful energy, then it will be consumed and demand will be high. '3' Some argue that no matter which demand scenario is finally realized, we need to investigate every possible electricity option today, so that we have adequate choices in the future.

Most opponents, on the other hand, envision an energy future dominated by conservation and solar technologies.[123] Some believe that electricity should play a minor role in our energy supply mix because of its thermodynamic inefficiency.[133] Furthermore, most opponents contend that even if electricity demand were to increase somewhat, it could be satisfied with existing technologies.[134] They argue that by developing large-scale energy systems such as SPS, we are guaranteeing high energy use because the investment in their development is so great.

Public attitudes about SPS will depend on the relative cost and availability of energy, the advancement and proliferation of electrical end-use technologies, attitudes towards energy companies and forecasters of electricity demand, and the sense of energy security as determined by domestic supply v. reliance on foreign sources. 35

SPS Technical Options

How might future public reaction to alternative SPS systems differ?[136] Table 54 identifies some of the relative benefits and drawbacks of the proposed SPS systems as they might be perceived by the public.

[129]O'Neill, op cit.
[130]Glaser, private communication, op cit
[131]Office of Technology Assessment, *The* Energy Context of *SPS Workshop, Op.* cit
[132]Ibid
[133]A B Lovins, "Energy Strategy The Road Not Taken?" - Foreign *Affairs,* October 1976
' "Office of Technology Assessment, The Energy Context *of SPS Workshop,* op. cit
"sOffIce of Technology Assessment, *Solar Power Satellite: Public Opinion Issues Workshop,* op cit
[136]Ibid

Siting

Historically, public debate over the introduction of a technology has been most pronounced at the siting stage. It is during the siting phase that public opposition to a technology has been most vocal, organized, and effective. Citizens have taken direct action against the siting of powerplants, airports, prisons, high-voltage transmission lines and military facilities by forming local and national groups, publicizing their cause through the media, taking legal action, demonstrating, and occasionally resorting to civil disobedience and violence.[137] In general, siting controversies revolve around issues of environmental effects, health and safety risks, reduced land values and fair compensation, private property rights, opportunity costs, vulnerability to attack, and public participation in land-use decisions.[138] It is clear that in the absence of national land-use policies, conflicts over land-use priorities will escalate as the population grows, and friction between rural and urban America and local communities and regional or national decision makers will increase "9

For SPS, siting is a major issue. * SPS would be particularly prone to siting difficulties because of its large contiguous land requirements, its potential military implications, and its use of nonionizing electromagnetic radiation (e. g., microwaves or lasers) in power transmission and distribution. This last factor is most important because of considerable uncertainties associated with the environmental and health risks of electromagnetic radiation as well as possible interference with electromagnetic systems. These uncertainties and

[137]L Caldwell, L Hayes, and I MacWhirtey, *Citizens and the Environment Case Studies in Popular Action* (Bloomington, Ind Indiana University Press, 1975)
[138]Office of Technology Assessment, op cit
[139]Ibid
*It is assumed that SPS receivers would be sited on land Offshore locations are also possible and might alleviate many of the SPS land-use problems, but are not specifically addressed here Also not considered here are possible multiple land uses If it can he shown that land can safely and economically be used for siting SPS receivers and other uses (e g , agriculture, pasture land) simultaneously, then siting on private land might not be a problem However, in the absence of detailed assessments on the costs and environmental impacts of multiple uses, it is assumed in this section that land is dedicated to SPS receivers alone

Table 54.—Potential Benefits and Drawbacks of SPS Technical Options

Advantages	Disadvantages
Laser system . Does not use microwaves . Of SPS systems, requires less land area per site and can deliver smaller units of energy	• Possible weapon • Health and safety impact of beam wanders • Weather modification
Mirror system • Most environmentally benign of SPS systems • Least weapons potential of all SPS systems • Least complex to demonstrate, most immediately reliable system • Possibly least expensive system	• Largest land requirements per site • Illumination of night sky • Weather modification . May fall out of low-Earth orbit
Solid state . Can deliver smaller units of power than mirror or reference system • Land per site is smaller than mirror or reference system . Satellites in GEO (in vulnerable to unplanned reentry) and can be placed over the ocean • Less weapons potential than lasers . Fairly well-developed technology	• Microwave bioeffects • Electromagnetic interference
Reference system • Satellites in GEO (invulnerable to unplanned reentry) and can be placed over the ocean • Less weapons potential than lasers • Fairly well-developed technology	. Microwave bioeffects • Electromagnetic interference

SOURCE: Office of Technology Assessment

their institutional management have been responsible in part for controversies over the siting of a great many other technologies that utilize the radiowave spectrum. Community resistance to the siting of radar installations, broadcasting towers, and high-voltage transmission lines, for example, has been particularly strong and unexpectedly effective.

Citizens groups have actively opposed transmission lines in a number of States including Oregon, New Hampshire, lowa, and Montana.[140] As a result of public action in New York, the State Public Service Commission has expanded the minimum right-of-way for new lines and established an Administrative Research Council to study and assess health risks."' The legislatures of a few New York counties have adopted resolutions opposing the construction of 765 KV lines. '42 In Minnesota, farmers battled with the public utilities over the construction of a powerline through 8,000 acres of prime farm land. '43 After attending public hearings and installing solar and wind devices in their homes to reduce their dependence on the utilities, some became frustrated with what they perceived as the unresponsiveness and dishonesty of the utilities and finally resorted to demonstrations, destroying utility towers and equipment.

The siting controversies most relevant to the SPS microwave systems are the disputes over the Navy's Project SEAFARER (Surface ELF* Antenna for Addressing Remotely-Deployed Receivers), a 25,600-mi^2 underground radio antenna for communication with nuclear submarines; and the Air Force's PAVE PAWS (Precision Acquisition of Vehicle Entry Phased Array Warning System), a radar system.'" When the Navy attempted to locate SEAFARER at different times in Wisconsin, Texas, New Mexico, Nevada, and Michigan, it encountered vehe-

[140]" The New Opposition to High-Voltage Lines, " *Business Week,* November 1977

'41A. Marino and R Becker, "H igh Voltage Lines. Hazard at a Distance," *Environment,* vol 20, No 9, p 6-15

[142]K Davis, "Health and High Voltage, " *Sierra Club Bulletin,* July 1, August 1978

[143]H Nuwer, "Minnesota Peasant's Revolt, " *Nation,* vol 227, Dec 9, 1978

* E 1 F (extremely low frequency) radio waves

[144]P Brodeur, *The Zapping of America, Their Deadly Risk and Cover-up (New* York W W Norton & Co , 1977)

ment local opposition. Residents in these communities were concerned about the health hazards of ELF radiation. Ranchers in Texas were also worried about the effects on livestock. Opponents raised other issues including vulnerability to nuclear attack, private property rights, and decreased land values. 45 Referenda defeated SEAFARER's construction in several counties in Michigan, and in an unprecedented action, the Governor of Michigan rejected the military program.[146] The Governor of Wisconsin also accused the Navy of suppressing environmental impact studies that reported possible environmental and health hazards.[147] Although the ELF program is still being funded, it has yet to find a new site.

Legal action has also been taken against the Air Force's plans to build PAVE PAWS in Cape Code, Mass., and Yuba City, Calif.[148] Fear of adverse microwave bioeffects, especially long-term, low-level effects, sit at the heart of the controversy. While the Air Force stressed that health risks were negligible and emphasized the need for national security, local groups argued that the data did not support the claim that PAVE PAWS will not jeopardize their health.[149]

Several key observations can be made from these disputes. First, farmers, ranchers, and rural Americans are becoming an increasingly active social force working against the intrusion of urban America on their rural quality of life. As one OTA workshop participant familiar with powerline siting controversies remarked, "Developers say that high voltage transmission lines wouldn't make any more noise than a highway would and the reaction of people is 'What do you mean? –That's why we're out here. We don't want to be near the highways' . . , . (Rural Americans) are sacrificing the kind of life they are out therefor, for the energy excesses of urban America.[150] In many cases, communities would prefer to leave a site overgrown than consent to any kind of development. For SPS as well as other powerplants, dumps, mines, and military installations, siting in remote areas could be a difficult task, especially in parts of the country where residents have already mobilized against other large-scale projects.[151] According to another workshop participant, one farmer, when asked about the SPS proposal, responded, "I've had enough. I'm ready to get my gun out."[152]

Another factor that emerges from siting controversies is that while concerns over the environmental and health risks of a technology are very important to nearby residents, this issue may mask related concerns such as unsightliness and devaluation of local property values[153] that may be more important to the local community. For example, in the Minnesota powerline dispute, the fundamental issue for many of the farmers was the question of land-use, i.e., farmland v. right-of -way. '54 However, this issue was channeled into environmental and health concerns that had greater political leverage in the courts and to which the utilities and the general public were more responsive. While the health effects of ELF radiation were the most frequently articulated concern of communities opposing SEAFARER, it is clear that to some residents, economics really lay at the heart of the controversy [155] These people were primarily concerned that land values might decrease if potential buyers worried about the health effects, and might not have opposed the siting if they had been justly compensated. Other residents were most concerned that the presence of SEAFARER would make their land more vulnerable to military attack; this would threaten their safety and could also reduce the value of their land.[156]

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[145]G Ellis, "Sanguine/SEAFARE R," *Sierra Club Bulletin*, vol 61, No 4, April 1976

[146]Brodeur, op cit

[147]S Schiefelbein, "The Invisible Threat, " *Saturday Review*, Sept *5,1979*, pp 16-20

[148]Brodeur, op cit

'4'S. Kaufer, "The Air Pollution You Can't See, " New *Times*, Mar 6,1978

[150]Office of Technology Assessment, op cit

"I bid

[52]Ibid

[53]1 bid

"'1 bid

[155]Joseph Thiel, Texas State Department of Health, private communication, Nov 28, 1979

[156]P Boffey, "Project SEAFARER Critics Attack National Academy s Review Group," *Science*, vol 192, June 18, 1976, pp 1213-1215

This second observation also points to the complex interrelationship between environmental and health risks, costs, land and air use, private property rights, esthetics, and public control over local decisions. For SPS, it is clear that the choice of transmission frequency and power distribution as well as public radiation standards could have a great bearing on the area of land that would be required as a buffer zone, the number of people potentially affected, compensated, and/or relocated, and hence the cost of developing SPS. In addition, the size of each SPS unit and its location could determine the extent, number and therefore cost of transmission lines that would have to be sited. The cost of a proposed energy facility such as SPS can also be increased if developers do not solicit public participation and disputes and court battles delay construction. Siting should therefore be considered as early as possible in the development process; public input is an essential element in the development and design strategy.

Finally, it is clear that many of the siting disputes might have been resolved earlier and more easily if the channels of communication between developers and the local community had been more open. Public participation should be solicited whenever and wherever possible, ideally even before the siting stage. Too often, residents become frustrated and resentful towards developers and officials who make inadequate and occasionally dishonest' attempts to involve the public in meaningful decisionmaking. This practice has led the public to seek other forums to voice complaints, thereby delaying decisions and driving up costs. SPS developers must be well-informed about the environmental, economic, and military implications of SPS and should arrange for open dissemination and discussion of that information. In addition, no matter what objective research findings are, public perceptions of potential hazards are largely influenced by public confidence (or lack thereof) in "official" interpretation of that data (see Environment, Health, and Safety). Whether justified or not, the public is considerably more cautious and fearful of the biological effects of microwaves and other electromagnetic radiation than are many representatives of Government and industry. But until the uncertainties are resolved to the public's satisfaction, the past cases strongly suggest that local resistance to SPS receivers could be substantial.