Prepared Statement
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An Economics View of Satellite Solar Power

Mr. Chairman and distinguished members of the subcommittee, thank you for inviting me to meet with you today. My name is Molly K. Macauley and I am a Senior Fellow at Resources for the Future, an independent, nonpartisan research organization established in 1952 to conduct independent analyses of issues concerned with natural resources and the environment. The views I present today are mine alone. Resources for the Future takes no institutional position on legislative, regulatory, judicial, or other public policy matters.

BACKGROUND

I am an economist and have been a member of the Resources for the Future staff since 1983. During that time, I have specialized in the analysis of space policy issues with a focus on economics. I have conducted research on space transportation and space transportation vouchers; economic incentive-based approaches, including auctions, for the allocation of the geostationary orbit and the electromagnetic spectrum; the management of space debris; the allocation of resources on space stations; the public and private value of remote sensing information; the roles of government and the private sector in commercial remote sensing; and the economic viability of satellite solar power for terrestrial power generation and as a power plug in space for space-based activities. This research has taken the form of books, lectures, and published articles. My research is funded by grants from the National Aeronautics and Space Administration (NASA) and by Resources for the Future (RFF).

INTRODUCTION

I have been asked to speak today about the economics of space solar-power generation (SSP). My comments are based on recently completed research sponsored by NASA and conducted with experts from the energy industry. NASA asked us to look at SSP economics around 2020, when many space experts expect SSP to be technically achievable. ***It is important to note that our purpose was neither to advocate nor to discourage further investment in SSP but to provide a framework by which to gauge its economic feasibility if such investment occurs.***

Our daunting task was to characterize the market for electricity during that future period. We were to identify key challenges for SSP in competing with conventional electricity generation in developed and developing countries, discuss the role of market and economic analysis as technical development of SSP continues in the coming years, and suggest future research directions to improve the understanding of the potential economic viability of SSP.

I've listed my coauthors at the end of my remarks, as well as other experts with whom we met to discuss specific aspects of the SSP market. These included experts in epidemiology and public health; the economics of the environmental and climate change-related effects of energy use; energy and national

security; nuclear power (for lessons learned in introducing new energy technologies); and energy investment in developing countries.

I'd also like to add that our study was funded by NASA but the Agency gave us full liberty to carry out an independent course of study and publish our results. We have presented our findings to NASA managers and technologists working on SSP and many of our recommendations have been acted upon.

SUMMARY OF OUR STUDY

Satellite solar power (SSP) has been suggested as an alternative to using terrestrial energy resources for electricity generation. In our study we considered the market for electricity from the present to 2020, roughly when many experts expect SSP to be technically achievable. We found that a variety of trends from the present to 2020 should influence decisions about the design, development, financing, and operation of SSP. An important caveat associated with our observations concerns the challenge of looking ahead two decades. We based our observations on what we believe to be plausible estimates of a number of key indicators derived from the work of respected national and international research groups, the information and perspectives shared by the experts whom we consulted for the study, and our own judgment. While we believe this information is a valid basis for considering the competitive environment for SSP, we urge our audience to appreciate the pragmatic process and somewhat intuitive elements involved in their estimation. In what follows, I summarize our study. The full study is available at http://www.rff.org.

Our first set of observations concerns the market for electricity, in particular the key attributes of this market that are most relevant to investment in SSP:

The Market for Electricity

- Current trends indicate increasing global demand for energy in general, and electricity in particular, during this period. Electricity demand growth rates will vary significantly by region of the world and by stage of economic development. The highest growth will be in developing economies.

- Deregulation of electricity internationally will strengthen the trend towards decentralized, private ownership and management of utilities in most countries (developed and developing)—a major departure from the tradition of nationalized utilities in many countries.

- Nevertheless, investment in and operation of conventional electricity markets in developing economies likely will continue to be, or will be perceived as risky due to capital constraints, infrastructure limitations, and institutional and environmental factors.

- Constant-dollar electricity generation costs in 2020 likely will be no higher than prevailing recent levels and very likely will be significantly lower.

- The monetary value of environmental externalities in electricity generation appears to be significantly less than some studies have indicated.

- Global climate change is not presently a major factor in power investment decisions in developing countries. Willingness to pay for “clean” technologies tends to rise with increasing incomes, but in developing countries, clean energy may not be highest ranking among health and environmental concerns.

- Resource constraints on fossil fuels are unlikely to be a factor in this timeframe, other than possible short-term supply disruptions caused by political and economic factors.

Taken together, these observations suggest that conventional electricity generation in both developed and developing countries may be more than adequate in terms of (1) cost, (2) supply, and (3) environmental factors.

Our second set of observations pertains specifically to challenges facing SSP:

Challenges for SSP in Competing with Terrestrial Electricity Generation

- The relative immaturity of the technologies required for SSP makes it difficult to assess the validity of estimated costs and likely competitiveness of SSP. For this reason, as in many space development initiatives, orders-of-magnitude reduction in the costs of space launch and deployment and other key technologies is critical. If these reductions occur, the economic viability of SSP would become more promising. Until then, it is premature for the U.S. government to make commitments such as loan guarantees or tax incentives specifically for SSP.

- State-of-the-art conventional power generation technologies increasingly incorporate numerous environmental controls, eroding somewhat the environmental advantage of non-fossil-fuel technologies such as SSP.

- Actual and/or perceived health risks associated with exposure to electric and magnetic fields generated by SSP are likely to be of significant public concern.

- National security and national economic considerations may discourage some countries from participating in an SSP system operated by another country or group of countries. Countries with these concerns may require equity participation in SSP, limit their reliance on SSP only to a small share of their energy portfolio, or decline use of the technology altogether.

These findings argue for the merits of furthering technical advance in technologies required not only for SSP but also for other space activities, and for special consideration of issues that transcend the technical design of SSP, such as health and national security concerns.

We also urged that economic study continue hand-in-hand with SSP technical design. During the course of our study, we shared our interim findings with the engineering teams working on SSP. All parties agreed that this interchange of ideas was mutually beneficial and contributed markedly to deepening our collective understanding of next steps for both the technical team's engineering studies and our economic analysis. The two must proceed in tandem, we all agreed, and specific recommendations as to further economic and market studies follow:

The Role of Economic and Market Analysis as Technical Considerations of SSP Progress

- The energy industry should be invited to be "at the table" in technical and economic analyses of SSP -- that is, to both participate in conducting the analysis and learn about the results. The electric utility industry may be particularly interested in helping to guide the development of SSP technical components that are also capable of application in other terrestrial commercial power markets (for example, development of solar cells).

- Modeling of the economics of SSP should explicitly incorporate analyses of risk and uncertainty; include marketplace data about competition from terrestrial energy markets; and provide a means for structuring an efficient long-term technology development program that includes industry participation.

- Continued public funding of SSP for terrestrial power markets must consider the relative return on taxpayer investment in SSP compared to other technologies, in general, and energy technologies, in particular (for instance, photovoltaics). It should be noted that some past projections of large market

penetration of new power generation technologies have not been borne out by actual experience (for example, nuclear, solar).

Finally, we identified specific topics for future research:

Additional Issues for Further Study

- Our focus in this report is on the use of SSP in terrestrial markets. SSP capabilities may have applicability to non-terrestrial systems such as the International Space Station, other large orbiting platforms, lunar bases, and other activities to explore and develop space. The benefits and costs of these opportunities should be investigated in the course of future SSP analyses.

- Real as well as perceived, safety, health, and environmental risks associated with SSP in both its terrestrial power and nonterrestrial power markets should be assessed and discussed in public forums, engaging both scientists and the public.

ADDITIONAL OBSERVATIONS

I'd like to conclude my comments by elaborating on several of our study's conclusions and making some additional observations relevant to our discussion today.

Our study did not consider the idea of satellites designed to relay power from earth-based generation facilities, but some of the findings in our study might be useful in discussion of that application of SSP.

The cost of power in 2020

Our study predicted the cost of U.S. electricity generation costs around the year 2020 -- a challenging task, but one to which we brought the best information and analysis that we could find. This estimate can be used as a benchmark for the relay concept: if it were to come on line in 2020 or so, can it provide electricity at less than this cost? If so, it could be economically competitive. The estimate is around 3 cents per kilowatt hour in developed countries, and around 5.5 cents per kilowatt hour in developing countries.

The environment

We found that the environmental costs of electricity generation tend to be smaller than popular discussion suggests. Issues of pollution, deforestation, and global warming are receiving growing attention by the world community. However, cleaner forms of energy have been introduced into both the developed and developing world in numerous initiatives to ameliorate these problems, and some governments in developing countries have already have begun to use renewable energy technologies as a tool of economic development. Recent studies suggest that the damage, or social cost, of electricity generated by conventional means may be relatively small, particularly for the noncoal resources likely to figure increasingly in future capacity additions to electricity supply. The estimate of the social cost is about 2 cents per kilowatt hour.

Gas prices, brown outs, running out of oil

The question, "are we running out of oil?," has been a concern for at least the last 100 years. During the first half of the twentieth century, analysts and officials of the U.S. Geological Survey predicted an exhaustion of U.S. oil reserves within 10 to 20 years. Since then, there have been other alarming studies about depletion, but time and again these have proven wrong. They fail to distinguish between proved, recoverable reserves and discoverable resources. Technological change, including three-dimensional seismic exploration, horizontal drilling, and deeper drilling in the oceans has led to production prospects that were not predicted twenty-five years ago.

The brown-outs over the past year in the western U.S. have been attributed as much to inadequate management of fuel supplies and transmission capacity as to shortages of fuel. The brown-outs were regional, not nationwide, suggesting that there is no overall shortage but that transmission and distribution are part of the challenge. In addition, the electricity industry estimates that about 30,000 megawatts of additional power could be on line by 2010 if plant constructions that have been announced take place.

Gasoline and home heating oil prices have soared this year -- but this is only the fourth time in over thirty years. The price of oil now -- about $30 a barrel -- is nowhere near what it was in the early 1980s, say, when the inflation-adjusted price was about $70 in today's dollars. The high gas prices have hardly affected the sales of low-mileage auto models like sports utility vehicles and gas consumption is still rising. The high prices were an annoyance for many consumers and a hardship for some low-income families who depend on oil to heat their homes. But for the country as a whole, they have not constituted a real economic crisis and they are now declining. For the future, from time to time, unexpectedly, the world's oil market will swing price dramatically up, but also down.

Energy security

The perceived risks of dependence on imported energy could lead to support for policies of greater self-sufficiency, leading in turn to higher electricity costs or alternative sources of energy. This question may present a rather unique challenge in the context of an SSP regime. A country may not want to be reliant on another country's space-generated power for a significant portion of its baseload electricity. It therefore may look to equity participation in SSP, seek other means of protecting itself against the potential discontinuity of external supply, or possible reject SSP out of hand.

Investing in developing countries

Another issue that may arise in the application of SSP in developing countries is the perceived risk associated with investing in these countries. The risk relates to unstable governments, economies, and currencies.

Innovation in power supply

Just as SSP represents a potential innovation in electricity supply, so, too, are new technological approaches being developed with which SSP would have to compete. An example is micropower, small local power plants that do not suffer huge transmission losses. Micropower may be most useful in developing countries as an alternative to building large transmission grids.

I hope these observations are useful in our discussion today, and thank you for the opportunity to meet with you.

AUTHORS AND EXPERTS CONSULTED

The study team for our SSP report included RFF scholars and experts from the energy industry. Listed together with their affiliations at the time of the study, they are:

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During the study, the authors met several times with other experts to discuss specific aspects of the SSP market. We are grateful for the information and viewpoints shared with us in briefings by these individuals:

John F. Ahearne, Sigma Xi (formerly with the U.S. Nuclear Regulatory Commission)

Jan A. J. Stolwijk, Department of Epidemiology and Public Health, Yale University School of Medicine

Gary Payton, U.S. National Aeronautics and Space Administration

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Biography

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Dr. Molly K. Macauley is a Senior Fellow at Resources for the Future (RFF), a nonprofit, nonpartisan research institution in Washington, D.C. She is also an Adjunct Professor in the Department of Economics at Johns Hopkins University and at Hopkins' School of Advanced International Studies. At RFF she heads RFF's Space Economics Research Program. For the past 9 years she has led the development of economic analysis for NASA's Earth Observations Commercialization Applications Program, and she participates in economics research on several other NASA projects, including programs at the Stennis Space Center and the Jet Propulsion Laboratory. She has received grants from the National Aeronautics and Space Administration, the U.S. Environmental Protection Agency, the National Institute of Standards and Technology, the Department of Energy, and RFF for her work. She has authored or co-authored two books and over thirty articles. In 1994, she was honored by the National Space Society as one of the "Top 25 Rising Stars" of the nation's space program. She has lectured extensively throughout the country on space economics, and is frequently called upon to give Congressional testimony on the space program and commercial space activities. Her research focuses on economic and policy analysis of space technologies and programs, including studies of the appropriate role for government in its interaction with the private sector; performance measures for government and government/commercial joint activities; and the relationship between space technologies and other public regulation (for instance, the implications of remote sensing technologies for environmental regulation, monitoring, and compliance). In addition, Macauley is on the Board of Directors of Women in Aerospace; she is President of the Board of Directors of the College of William and Mary's Thomas Jefferson Program in Public Policy; and she is a corresponding member of the International Academy of Astronautics. She was recently appointed to the NASA's Space Science Advisory Board and to a special task force of the National Academy of Science's Space Studies Board focusing on remote sensing issues. She also serves as the Director of Academic Programs at RFF, involving the management of prizes awarded competitively under the Joseph Fisher Dissertation program; the administration of Gilbert White Fellowships for visiting scholars; and the management of RFF's public Wednesday Seminar Series. At Johns Hopkins, where she has taught for 9 years, she leads courses in microeconomics, public finance, and science and technology. Her classes include large undergraduate introductory courses, with over 250 students; upper class advanced courses; and graduate courses.