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The Vital Need for America to Develop Space Solar Power

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An interesting and timely debate has begun within the American pro-space community about the need to support the start of the commercial development of space solar power (SSP). Given strongly held personal and organizational preferences for space science, suborbital commercial human spaceflight, the human exploration of Mars, etc., it's not surprising that achieving a consensus to support and strongly advocate for starting the commercial development of SSP has not yet been reached. In this article, I argue that the time for such support has arrived. Such support will not only help America and many other nations avoid energy scarcity later this century, but it will also help advance America into a new era of the space age focused on space industrialization that will broadly benefit all pro-space agendas.

SSP provides America and the world with a new and substantial sustainable energy alternative

For those not familiar with the SSP concept, it involves building extremely large space platforms, usually located in geostationary orbit (GEO), to convert sunlight into electrical energy and then transmit this energy to very large ground receivers where the energy is fed into electric utility grids. Invented in 1968 by Dr. Peter Glaser, the concept was promoted by Professor Gerald K. O'Neill of Princeton University in the 1970's and studied extensively by NASA and industry in the late 1970's and early 1980's and, again, in the late 1990's. (For additional information, see the SSP library on the National Space Society's web site.)

Interest in SSP has reemerged in response to the public's growing appreciation of the need to develop new sustainable energy sources. Compared to other terrestrial renewable alternatives, GEO SSP has four important advantages:

- Its scale of potential generation capacity is very large, an important consideration in formulating policies and plans to avoid future energy scarcity.
- It should have the ability to provide high quality electrical power—nearly 365 days of the year, 24 hours a day—for baseload electrical power supply comparable to nuclear energy.

- It should have nearly world-wide access/usability enabling countries to achieve a degree of energy independence even when traditional renewable energy sources are not practical.
- It should have important terrestrial environmental benefits, including avoiding thermal waste heat ejection and minimizing the land area otherwise needed for terrestrial renewable energy generation.

The threat of energy scarcity is quite real and should not be ignored by the pro-space community

When Professor O'Neill wrote The High Frontier: Human Colonies in Space in the 1970's, he addressed the need for humanity to develop new renewable energy sources to replace non-sustainable carbon fuels. He made use of Dr. Glaser's SSP concept as the economic purpose for building off-world habitats and initiating space industrialization.

In my recent white paper, "The End of Easy Energy and What to Do About It," I focused on the issue of energy security and what needs to be done as we move toward 2100. To accept the paper's conclusion that starting the development of SSP is now vital, an appreciation of the future energy needs and supply situation is needed. Thus, a few energy statistics are helpful to better understand the challenges that we all will face in the coming decades—within the lifetimes of our children and grandchildren—to successfully provide what is correctly described as the "lifeblood" of modern civilization.

By 2100 and due entirely to population growth, the United States will require about 1.6X more energy than we are using today. With a population of about 307 million, the United States today uses about 17 billion barrels of oil equivalent (BOE) of energy annually from all sources—with roughly 85 percent coming from non-sustainable easy energy (oil, coal, and natural gas). By 2100, with a projected population of 560 million, the United States will require about 28 billion BOE annually even with a modest decrease in per capita energy use through "energy conservation". From 2010 to 2100, the United States will need in total about 2,000 billion BOE of energy. At $100 per BOE, Americans would spend about $200 trillion on energy over the next nine decades.

The world's energy needs during the remainder of this century are likely to climb even more rapidly than those of the United States as the world's developing nations seek economic prosperity and political stability. Today, with only about 5 billion modern energy consumers, the world uses about 81 billion BOE per year—at roughly the same average per capita energy use as in the United States in 1900. As in the United States, about 85 percent of the world's energy comes from non-sustainable easy energy sources. To project the world's energy needs in 2100, 90 percent of today's average per capita energy use in Japan, Western Europe, and South Korea was used as the basis for the projection. Per capita energy use in these industrial nations—about one-half of that in the United States—represents an energy-frugal standard of living that still enables widespread prosperity and political stability. In 2100, with about 10 billion energy consumers in economically-prosperous and politically-stable countries, the world will need about 280 billion

BOE annually. This constitutes an increase from today's energy consumption by a factor of about 3.4X. With these assumptions, between 2010 and 2100, the world will need about 17,000 billion BOE of energy and, at $100 per BOE, would spend roughly $1,700 trillion on energy.

With such a dramatic increase in world energy demand, a reasonable question is how much easy energy resources are left to use? Using the World Energy Council's 2007 estimates, current world proved reserves of all oil, coal, and natural gas total about 6,000 billion BOE. Based on the optimistic estimates of some experts, a further 6,000 billion BOE of easy energy might be obtained through additional exploration and recovery improvements. For example, if nearly all shale oil in the United States were to be recovered, this could add upwards of 2,000 billion BOE. At best, one may conclude that there might be about 12,000 billion BOE of easy energy left to recover. A less optimistic planning value, due to growing legal and treaty constraints on exploration and recovery, would be 9,000 billion BOE.

To highlight the difficulty in finding significant additional resources of this magnitude, the much debated Arctic National Wildlife Reserve (ANWR) has an optimistic total of only about 12 billion BOE of recoverable oil. To add 3,000 billion BOE of additional proved reserves this century, a new "ANWR" must be discovered about every four months! Recent oil exploration history shows that such new major "finds" are now rare. Most additional proved reserves will likely come from improved extraction methods that increase recovery from known deposits and from opening known deposits to production that have been previously set aside, such as shale oil.

How long will easy energy supplies last? A prosperous world will require on the order of 17,000 billion BOE of energy through 2100. Against this demand, easy energy may be expected to supply 9,000-12,000 billion BOE. Without an aggressive increase in new sustainable energy sources—nuclear and renewables—world easy energy supplies will be exhausted before the end of the century unless a large portion of the world's population remains in a state of energy deprivation. Even with an aggressive increase in building new sustainable energy sources, it is likely that all of the known 6,000 BOE of oil, coal, and natural gas proved reserves will be used as the world builds the sustainable energy infrastructure needed to supply 280 billion BOE of energy annually by 2100.

Today, Americans live at the peak of the era of easy energy. By the end of the century and perhaps decades earlier, this will change as most of the world, including the United States, will be running on sustainable energy sources. The greater extent to which additional easy energy resources are excluded from exploration and production, the sooner we will by necessity transition to a general reliance on sustainable energy sources and the sooner we may experience energy scarcity by having insufficient sustainable energy supplies. Time is not on our side in addressing this challenge! The threat of energy scarcity, even in the United States, is very real. It will likely become a primary public policy driver as public awareness of the challenges inherent in transitioning to sustainable energy, as discussed in the following, are better understood.

Today's terrestrial sustainable energy sources can only provide a modest part of the solution

Both the United States and the entire world get about 15 percent of their energy from sustainable sources. To meet the 2100 need for 1.6X more energy for the United States, our current sustainable energy production must expand by a factor of about 11. To meet the world's needs for about 3.4X more energy by 2100, current world sustainable energy production must expand by a factor of about 24. *In the United States, this means that today's total energy production capacity of nuclear, hydroelectric, geothermal, wind, ground solar electric, and land biomass must be added every decade through the end of the century. For the world, the current sustainable energy production capacity must be added every four years.*

To help put the needed growth into perspective, assume that hydroelectricity will be used to provide the world's additional sustainable energy production. China's Three Gorges Dam will have about 23 GW of generation capacity when completed. America's Hoover Dam has 2 GW of generation capacity. If the world's additional sustainable energy needs were to be met solely with hydroelectricity, 12 Three Gorges Dams (equal to 138 Hoover Dams) must be brought online every year through the end of the century. This raises the important planning questions: Can this be accomplished with only current terrestrial solutions? Can it be accomplished in the United States?

Some argue that terrestrial sustainable energy sources can meet this challenge. In my white paper, this possibility was explored through a simple 2100 sustainable energy scenario focusing on meeting the United States' 2100 needs. (Note that in 2100, the United States will need about 10 percent of the world's total energy supplies.) In this scenario, these optimistic assumptions were made regarding nuclear and renewable energy expansion in the United States:

- Nuclear enriched uranium fission electrical power generation would be expanded from 101 GW today to 175 GW in 2100 (representing 10 percent of the world's total 2100 nuclear capacity and consistent with a 120-year world supply of uranium from land resources without reprocessing or breeding).
- Hydroelectric generation capacity would be expanded from 78 GW to 108 GW (the estimated practical maximum in the U.S.).
- Geothermal energy would be expanded from 3 GW to 150 GW (reflecting the Department of Energy's goal for the western United States by 2050).
- 1.1 million 265-ton land and off-shore wind turbines would be built covering 150,000 sq. mi. and stretching in a 5-mile wide band along 4,500 miles of coastline.
- 59,000 sq. mi. of ground solar photovoltaic systems would be built in the southwestern desert states (with 100 percent land use).
- 1.3 billion dry tons of land biomass (based on 2005 Departments of Energy and Agriculture projections) would be collected annually from all cropland and accessible forestland and converted to biofuels and oil substitutes.

Nuclear, hydroelectric, geothermal, and a modest percentage of wind-generated electrical power are assumed to provide dispatchable electrical power generation to replace coal- and natural gas-fired generators. (Dispatchable generation capacity is what utilities require to prevent brownouts and blackouts while ensuring that customer needs can be met anytime.) Because of the variability of the wind and ground insolation, most wind-generated electricity and all ground solar electricity is assumed to be used to produce hydrogen and hydrogen-based synfuels. All biomass is assumed to be converted to fuels and other oil substitutes.

Even with these optimistic assumptions, these expanded sustainable energy sources would provide only about 30 percent of the United States' needed 1,750 GW of 2100 dispatchable electrical power generation capacity and about 39 percent of the needed 17 billion BOE of 2100 annual fuels production. In the post-easy energy era, the United States would have a shortfall of about 1,200 GW of dispatchable generation capacity and 11 billion BOE of annual fuels production despite over 210,000 sq. mi. of the continental United States being used for wind and solar farms. In 2100, with a population that will have nearly doubled, these optimistic projections of U.S. sustainable energy sources would only provide about the same per capita energy supply as the United States had in 1900—about one-third of what is currently being provided.

As discussed in my white paper, the 2100 sustainable energy supply situation for the entire world will be comparable to the United States. With 10X more energy needs and 20X more population than the United States, comparable projections for the sustainable energy production potential for the world finds that only about 47 percent of the needed 17,500 GW of 2100 dispatchable electrical power generation capacity and 37 percent of the needed 172 billion BOE of 2100 annual fuels production could be optimistically provided. The world would have a shortfall of about 9,300 GW of dispatchable generation capacity and 108 billion BOE of annual fuels production despite having over 2 million sq. mi. of land being used for wind and solar farms, collecting and converting 12 billion dry tons of biomass from all cropland and accessible forestland, and building the equivalent of 3,000 Hoover Dams of hydroelectric, geothermal, and nuclear generation capacity.

Absent a clear public consensus to dramatically reduce U.S. per capita energy use to near 1900 levels and a willingness to let many billions of people worldwide continue to live in a state of energy deprivation—currently 1.6 billion people do not have access to electricity and 2.4 billion people do not have access to modern fuels per the U.N.—additional sustainable energy sources will need to be developed. A rational U.S. energy policy and implementation plan must address this issue. This is why starting the commercial development of SSP gains importance.

For filling the coming electrical power shortfall, SSP is today's engineering development-ready answer

A key element of a well-reasoned U.S. energy policy is to maintain an adequate surplus of dispatchable electrical power generation capacity. Intelligent control of consumer electrical power use to moderate peak demand and improved transmission and distribution systems to more broadly share sustainable generation capacity will certainly help, but 250 million additional Americans and 5 billion additional electrical power consumers worldwide by 2100 will need substantially more assured generation capacity. Three possible energy sources that could achieve sufficient generation capacity to close the 2100 shortfall are methane hydrates, advanced nuclear energy, and SSP. The key planning consideration is: Which of these are now able to enter engineering development and be integrated into an actionable sustainable energy transition plan?

Methane hydrate is a combination of methane and water ice where a methane molecule is trapped within water ice crystals. The unique conditions necessary for forming these hydrates exist at the low temperatures and elevated pressures under water, under permafrost, and under cold rock formations. Some experts estimate that the undersea methane hydrate resources are immense and may be able to meet world energy needs for a century or more. Why not plan to use methane hydrates? The issues are the technical feasibility of recovering methane at industrial-scale levels (tens to hundreds of billions BOE per year) and doing so with acceptable environmental impact. While research into practical industrial-scale levels of recovery with acceptable environmental impact is underway, acceptable production solutions have not yet emerged. As a result, a rational U.S. energy plan cannot yet include methane hydrates as a solution ready to be implemented to avoid future energy scarcity.

Most people would agree that an advanced nuclear generator scalable from tens of Megawatts to a few GW, with acceptable environmental impact and adequate security, is a desirable long-term sustainable energy solution. Whether this will be an improved form of enriched uranium nuclear fission; a different fission fuel cycle, such as thorium; or, the more advanced fusion energy is not yet known. Research into all of these options is proceeding with significant research advancements being achieved. However, until commercialized reactor designs are demonstrated and any environmental and security issues associated with their fueling, operation, and waste disposal are technically and politically resolved, a rational U.S. energy plan cannot yet include advanced nuclear energy as a solution ready to be implemented to avoid future energy scarcity.

We are left with SSP. Unless the U.S. Federal Government is willing to forego addressing the very real possibility of energy scarcity in dispatchable electrical power generation, SSP is the one renewable energy solution capable of beginning engineering development and, as such, being incorporated into such a rational sustainable energy transition plan. Hence, beginning the engineering development of SSP now becomes a necessity.

Of course, rapid advancements in advanced nuclear energy or methane hydrate recovery or the emergence of a new industrial-scale sustainable energy source may change the current circumstances favoring the start of the development of SSP. But not knowing how long affordable easy energy supplies will remain available and not knowing to what extent terrestrial nuclear fission and renewable energy production can be practically and politically expanded, reasonableness dictates that the serious engineering development of SSP be started now.

SSP will jump-start the next era of the space age

Successfully developing SSP and building the integrated spacefaring logistics infrastructure necessary to demonstrate SSP and prepare for serial production of the geostationary platforms can only be successfully undertaken by a true spacefaring nation. The United States is not there yet because, as the U.S. National Space Policy emphasizes, we have not yet developed the "robust, effective, and efficient space capabilities" needed for America to effectively utilize space this century.

Planning and executing a rational U.S. energy policy that undertakes the development of SSP will jump-start America on the path to acquiring the mastery of industrial space operations we need to become a true spacefaring nation. This path will follow our nation's hard-earned success, as seafarers and aviators, of building a world-leading maritime industry in the 18th and 19th centuries and an aviation industry in the 20th century. With this new spacefaring mastery, today's dreams of expanded human and robotic exploration of space, of humans on Mars, of space colonies, of lunar settlements, etc., will all move from the realm of wishful daydreams into an exciting future of actionable possibilities. The goal of nearly all American pro-space organizations is to make such a future a reality. Energetically supporting the incorporation of SSP into U.S. energy planning and strongly advocating for the start of the development of SSP is how pro-space organizations can NOW take action to make their vision part of America's broad-based spacefaring future. This is, indeed, a WIN-WIN opportunity that we cannot afford to miss.

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