

SPACE WATER

The Vision for Producing Fresh Water Using Space Power

Space Water Consensus Group

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1 Executive Summary

There is an escalating climate crisis that is stressing the Earth's environment. It is partially a result of the increasing accumulation of carbon dioxide and methane greenhouse gases in the lower atmosphere. One area that is significantly affected is the water infrastructure around the planet including hydropower, flood defense, drainage, and irrigation systems. The effect of adverse climate change on freshwater systems aggravates population growth, weakening economic conditions, land-use changes, and urbanization. In the western U.S., for example, reduced water supplies plus increased demand are likely to provoke more interstate and urban-rural competition for over-allocated water resources.

Seawater desalination has existed for decades and is a proven technology for supplying water in coastal areas. Continued population growth in coastal areas makes it economically feasible to begin considering seawater desalination as a larger source for metropolitan water supplies. Fresh water reclaimed from seawater is 15-50% efficient depending upon the production process, which can be osmosis, distillation, or a hybrid of both.

Offshore oil and gas platforms already use seawater desalination to produce fresh water for platform personnel and equipment. We propose, as California coastal oil and gas platforms come to the end of their productive lives, that they be re-commissioned for use as large-scale fresh water production facilities. Solar arrays, mounted on the platforms, are able to provide the power needed for seawater desalination during the daytime.

However, for efficient fresh water production, including on oil platforms, a facility must be operated 24 hours a day. We propose the use of solar power transmitted from orbiting satellites (Solar Power Satellites – SPS) to substantially augment the solar array power generated from natural sunlight. The advantage of a SPS in geosynchronous orbit (GEO) is that it is able to produce power at nighttime, thus enabling 24 hours a day operations. A SPS would be conceptually similar to existing commercial communication satellites but with a much larger solar array. A single satellite could power at least one seawater distillation plant on a converted offshore oil platform during the night and supplement the power during the day to provide clean energy and water for urban or agricultural on-shore areas. The center beam power from a SPS received at Earth's surface is about $\frac{1}{2}$ Sun.

Production of industrial quantities of fresh water on re-commissioned oil and gas platforms, using energy transmitted from solar power satellites, is *a breakthrough concept for addressing the pressing climate, water, and economic issues of the 21st Century*. It is a novel combination of mature technologies that provides new solutions. As such, we recommend sponsored, expert team feasibility studies to evaluate this vision for producing fresh water using space power.



2 Climate Change and Water Shortage

2.1 Climate Change Stresses Social Infrastructure

Climate change is stressing the Earth's environment. It is occurring because of increasing accumulation of two trace-species "greenhouse" gases in the lower atmosphere, i.e., carbon dioxide (CO₂) and methane (CH₄). These gases, which are long-lived in the stratosphere, are very effective at trapping the re-radiated infrared radiation from the surface. Carbon dioxide and methane are not equal in their heat-retention capacity; methane is 20 times more effective at trapping heat than is carbon dioxide. By the 1980's the sources of increasing carbon dioxide were identified as fossil fuel burning and forest fires, particularly as part of rainforest clearing. The sources of increasing methane were identified as cattle production (flatulence), rainforest deforestation (termite activity), and rice cultivation (organic compound decay).

The Intergovernmental Panel on Climate Change (IPCC) reports¹ that the trend in the global surface-to-stratosphere temperature is a warming of 0.74°C per century (1906–2005). There has been an escalation in the warming rate over the past 50 years. In that period, the sea level has risen about 150 millimeters (6 inches) and it is continuing to rise at about 3 millimeters (an eighth of an inch) per year². One reason for the acceleration of global warming may be the increase in methane. As the arctic permafrost thaws, more of this gas is released and this amplifies the warming trend. Some of the measureable effects of this temperature rise are melting polar cap ices, rising sea levels, and more severe storms.

By 2050, climate change is projected to decrease the annual average river runoff and water availability in the mid-latitude drier regions and the dry tropics while increasing runoff at high latitudes and in some wet tropical areas. What this means for the average person is that many semi-arid and arid areas such as the Mediterranean Basin, western USA, southern Africa, Australia, and northeastern Brazil will likely see a decrease in their water supply. This trend will be contrasted with increased flooding, including during the winter, for northern Europe, central and northern USA, northern China, and the wet tropical regions in Southeast Asia, Africa, and South America.

The IPCC notes that there may be longer-term consequences of climate change than were previously thought. Their report identifies that carbon dioxide is increasingly absorbed into the world's oceans, which raises their heat content and changes their circulation patterns. The latency, or ocean's ability to transfer heat out, occurs on time-scales of several hundreds of years and this suggests that climate change will continue on the order of many centuries rather than decades. Since the ocean heat is exchanged with the atmosphere through thermal coupling, there are probable consequences such as an additional rise in sea surface height due to thermal



expansion and an intensification of regional climate variability with hot–cold as well as dry–wet extremes due to ocean circulation changes.

2.2 Fresh Water Shortages are Projected to Increase

The IPCC reports that climate change is affecting the water infrastructure around the planet. This infrastructure includes hydropower, flood defense, drainage, and irrigation systems as well as water management practices. The adverse effects of climate change on freshwater systems aggravate the impacts of other stresses such as those from population growth, changing economic activity, land-use changes, and urbanization. Globally, water demand is projected to grow in the coming decades primarily due to population growth and increasing affluence. Regionally, more demand for irrigation water is expected.

Because changes in moisture precipitation patterns affect agricultural and urban water use, malnutrition and water scarcity on a global scale may become the most important health consequences of climate change.

For the western U.S., the projected warming by 2050 is very likely to cause large decreases in snowpack, earlier snowmelt, more winter rain events, increased peak winter flows and flooding, and reduced summer flows with secondary consequences of increased drought conditions, lower crop yields, and forest fires. Overall, the reduced water supplies, coupled with increases in demand, are likely to exacerbate state-to-state and urban–rural competition for over-allocated water resources.

3 Seawater Desalination as a Coastal Solution

3.1 Coastal Populations are Large and Growing

It is no coincidence that the world’s population centers, along with those in the U.S., are heavily concentrated along coastal areas. Moderate climates and access to global seaports as well as commerce have accelerated this historical population growth trend. Approximately 153 million people (53 percent of the U.S. population) live in coastal counties as of 2003³ and 3 billion people worldwide live within 200 kilometers of a coastline⁴. This large growth of coastal populations makes it economically feasible to consider using seawater desalination as a source for metropolitan water supplies. This trend has accelerated in California coastal communities, for example. For comparative purposes later in this paper, we note that Santa Barbara, California (a small city) had a 2004 population of 90,305.

3.2 Seawater Desalination as a Mature Technology

Seawater desalination has existed for decades and is a mature technology. Fresh water is reclaimed from seawater with an efficiency of 15-50%, depending upon the production process. The California Coastal Commission (CCC) compares the two main technologies, i.e., distillation and reverse osmosis (RO).

An advantage of distillation plants is their economy of scale. Distillation plants



do not shut down their operations for cleaning or replacement of equipment as often as RO plants, although tube bundles do need occasional replacement and cleaning. Pretreatment requirements for distillation plants are less because coagulants are not needed to settle out particles before water passes through the membranes as in RO plants. Additionally, distillation plants do not generate waste from backwash of pretreatment filters.

An advantage of RO plants is that feedwater generally does not require heating, which means that the thermal impacts of discharges are lower. RO plants have fewer problems with corrosion, they usually have lower energy requirements, and they tend to have higher recovery rates for seawater, e.g., around 45%. The RO process can remove unwanted contaminants, such as trihalomethane-precursors, pesticides, and bacteria and they take up less surface area than distillation plants for the same amount of water production.

The CCC lists 12 existing facilities along the California coast (tables 1 and 2) with another 19 proposed (table 3). The sizes of the facilities vary according to design. Proposed or existing California desalination plants range from 80 square feet to 7.5 acres. Heights are from 15–20 feet for typical reverse osmosis equipment and 30–45 feet for typical distillation equipment.

3.3 Achievable Fresh Water Production Rates

Fresh water production can range from 20 - 112,000 acre-feet/yr. An example of fresh water production is the Santa Barbara Charles Meyer desalination facility (A), which can create 30,000 m³ (cubic meters) of fresh water per day. The facility construction cost was \$34M over 5 years from vote to dedication (1991-1995). The desalination facility is able to serve about 45,000 people at this capacity, or about ½ the population of Santa Barbara. As a comparison to other water sources, the Santa Barbara fresh water production per day is estimated to be about 3% of the Colorado River water flow (1×10⁶ m³ per day at the Yuma Arizona 4th St. Bridge) (B), <1% of the Owens Valley water flow into Southern California (5×10⁶ m³ per day), and 0.003% of the California aqueduct water flow into Southern California (1×10⁹ m³ per day) (C).





4 Fresh Water Production Locations

4.1 Challenges Inherent in Coastal Locations

Coastal locations (tables 1–3) can have a variety of environmental and society impacts and these are summarized in table 4. Each of these impacts, however, can be mitigated with proper planning and design.

Table 1. Projects Approved or Conditionally Approved by the CCC

1. Plains Explorations and Production (Gaviota) Oil and Gas Processing Plant
2. City of Morro Bay
3. City of Santa Barbara
4. Dept of Parks & Recreation, Hearst San Simeon State Historical Monument
5. Monterey Bay Aquarium
6. SCE, Santa Catalina Island
7. Offshore Oil and Gas Platforms

Table 2. Existing CA Coastal Desalination Projects Not Reviewed by the CCC

1. PG&E Diablo Canyon Power Plant
2. PG&E Morro Bay Power Plant
3. PG&E Moss Landing Power Plant
4. U.S. Navy, San Nicolas Island

Table 3. Other Proposed CA Coastal Desalination Plants

1. Alameda County Water District
2. Cambria Community Service District
3. Channel Islands Beach Community Services District
4. City of Buena Ventura
5. City of Fort Bragg
6. City of Goleta
7. City of Lompoc
8. City of San Luis Obispo
9. Los Angeles Department of Water and Power
10. Marin Municipal Water District
11. Marina Coast Water District
12. Mendocino County property owners
13. Metropolitan Water District of Southern California
14. Monterey Peninsula Water Management District
15. North Coast County Water District
16. Orange County Water District
17. Sands of Monterey development, Sand City
18. San Diego County Water Authority
19. U.S. Navy, North Island Naval Air Station & 32nd Street Naval Station, San Diego



Table 4. Identified Potential CA Coastal Zone Impacts

-
1. Air quality
 2. Commercial and recreational fishing
 3. Construction impacts on land and marine species and habitats
 4. Energy use
 5. Growth-inducing effects
 6. Marine resources impacts from feedwater intake and ocean discharge
 7. Navigation
 8. Noise
 9. Potential hazardous releases from accidents
 10. Public access
 11. Recreation
 12. Visual quality
 13. Water quality
 14. Water quantity (effects of drawdown or saltwater intrusion into groundwater)
 15. Cumulative impacts
-

4.2 Oil Platform Decommissioning and Their Re-use for Water Production

Table 1 lists that offshore oil and gas platforms have seawater desalination facilities already in operation. These are small facilities, which produce fresh water for platform personnel and equipment. The existence of these facilities demonstrates the maturity of small seawater desalination offshore facilities.

No new oil and gas platforms have been built in the California coastal waters since 1989. The California Artificial Reef Enhancement Program reports:

“To-date, seven California platforms have been decommissioned and the steel structures completely removed. The remaining 27 platforms continue to operate; however, most experts believe they are at, or near, the end of their economic lives. The U.S. Department of Interior, Minerals Management Service estimates that decommissioning the California Federal platforms will begin in 2010 and be complete by 2025.

“With a relatively small continental shelf, California has a high percentage of deep-water structures. One-third of the California platforms are in water depths of 300 to 1200 feet. This size will make their removal both technically challenging and costly to the industry. Rough estimates to completely remove all of the remaining platforms range from \$1.2 to \$2 billion⁵. With the fact that current technologies are inadequate to address many of the deepest platforms, the actual costs could be substantially higher. Complete removal is the only decommissioning option allowed under current regulations, once these platforms become obsolete.”

We propose, as the California coastal oil and gas platforms come to the end of their productive lives, that they be re-commissioned for use as fresh water produc-



tion facilities. While not all platforms may be suitable due to age, size, and scheduled decommission data, the platforms are, in general, large enough and strong enough to support industrial scale seawater desalination facilities, have successfully demonstrated small-scale desalination, and are ideally suited geographically for contributing to a California coastal fresh water supply need.

While the California coastal population and agricultural infrastructure has a growing need for fresh water and offshore platform facilities are suited to fill a role by location and industrial heritage, societal and environment concerns must be addressed. The CCC list of concerns (Table 4) needs adequate study in relation to using offshore platforms for fresh water production.



Assuming that environmental concerns are properly answered, the re-use of these platforms would certainly benefit: i) the coastal populations by providing an inexhaustible water supply; ii) the agricultural community by enabling the diversion of some existing urban water sources to agricultural use; iii) the oil and gas industry by enabling it to realize a tremendous cost savings by not removing the platforms and to create revenue by leasing them for water production use; and iv) the environment by preventing local sea floor damage that occurs during platform removal and by reducing the global carbon footprint if the energy concept we describe below is utilized.



5 Energy Efficiency Required for a Production Facility

5.1 Seawater Desalination Water Production can be Energy Intensive

Energy requirements for desalination plants are high. It is estimated that 20 million kWh/yr is required for full-time backup operation of the City of Santa Barbara's desalination plant in order to produce 3,000 acre-feet/yr (AFY) of water. This is 11,000 m³ per day at a daily energy cost of around 2.3 MW. In contrast, the energy needed to pump over twice that amount of water (7,500 acre-feet/yr) from the Colorado River Aqueduct or the State Water Project to the Metropolitan Water District of Southern California is approximately the same energy cost, i.e., up to 26 million kWh/yr. These energy requirements are more than the energy use of small-sized industrial facilities such as refineries, small steel mills, or large computer centers, which typically use 75,000 to 100,000 kWh/yr⁶.

The cost can vary, depending upon technology and capitalization expenses. In fact, high costs of capitalization and electricity are two reasons often cited why conventional seawater desalination can be prohibitively expensive. However, compared



to new sources of fresh water, the CCC estimates that the cost of seawater desalination rapidly becomes equal to or less than other sources. We described an energy source below that can reduce amortized power costs for desalination.

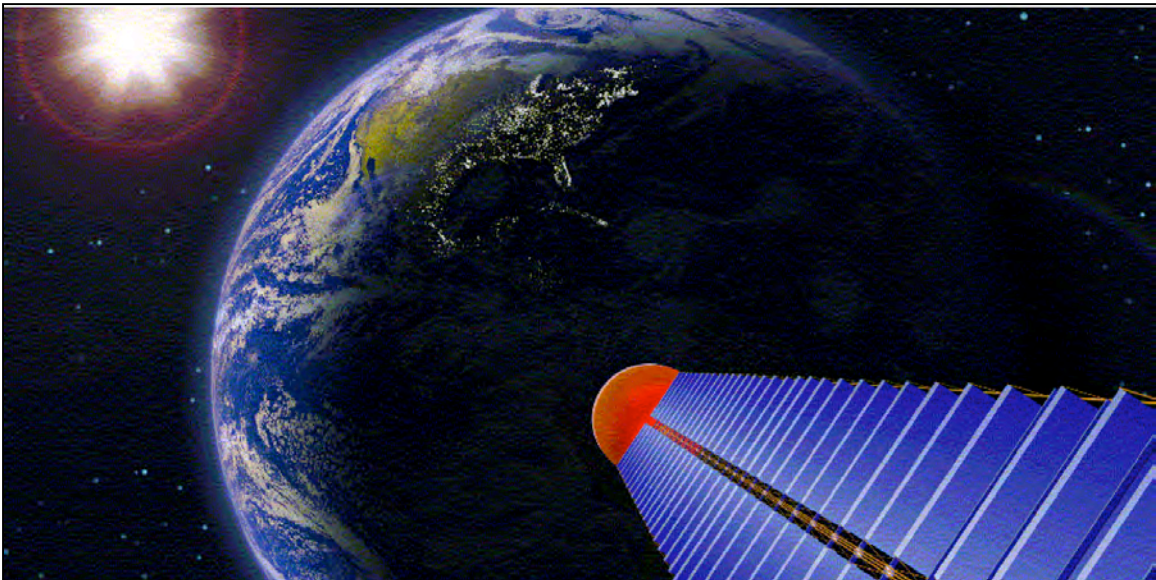
5.2 Solar Array Power can be Used for Fresh Water Production

The use of solar arrays to generate power for seawater desalination is not a new idea nor is the idea of using heat flow tubes as part of the distillation process. Solar arrays are coupled with seawater desalination and are used in the eastern Mediterranean and Persian Gulf regions. The prime disadvantages of using solar arrays are that solar energy is limited to approximately half a day (no solar power at night) and seasonal Sun angles can further reduce solar array efficiency. In addition, clouds reduce power from solar arrays.

If fresh water production were implemented using an offshore platform, solar arrays are the best method to generate electrical power for either RO or distillation processes. We describe below a way in which solar arrays can be augmented on offshore oil and gas platforms to achieve efficiency in fresh water production.

5.3 Solar Power Satellites Can Increase Capacity to 24-Hour Water Production

For efficient fresh water production, a facility must be operated continuously, 24 hours a day. We propose the use of solar power from orbiting satellites (Solar Power Satellites – SPS) as a method to substantially increment the solar array power that is generated naturally from sunlight.



SPS systems have been conceived and designed for nearly 4 decades but not yet demonstrated. The design concept is straightforward – use a large solar array structure in space, collect the electrical power needed to power a microwave or laser transmitter on the spacecraft, direct the beam to a solar array receiving antenna at



the Earth’s surface that is sensitive to the beam’s microwave or laser frequency, and convert the received power at the Earth solar array into electricity. The advantage of a SPS in geosynchronous orbit (GEO) is that it is able to produce power 24 hours a day and, thus, power can be transmitted at night to the surface of the Earth. Minor outages of up to approximately an hour per day over a 2-week period occur twice a year during the spring and fall equinoxes.

Historically, SPS were envisioned for providing large-scale electricity to towns or small cities. This is based on the fact that a single kilometer-wide band of space at GEO experiences nearly enough solar flux in one year to equal the amount of energy contained within all known recoverable conventional oil reserves on Earth today. The size of an orbital solar array is still technically prohibitive to provide power for cities. However, our concept would use a satellite that is conceptually similar to existing commercial communication satellites but with a much larger solar array⁷. For comparison, the International Space Station (ISS) has a completed total power of 120 kW using 16 solar panels of approximately 5600 m². A 2 MW SPS would require approximately 16 times the number of solar panels as the ISS, i.e., a configuration that is certainly much larger and technically challenging, but not unfeasible. A single 2MW-class satellite can provide power for a Santa Barbara-class seawater distillation plant on a converted offshore platform during the night and can supplement the power for operations during the day. Inefficiencies in the system are not considered here. SPS power received at the Earth’s surface is about ½ Sun in the center of the beam, day and night. Added to the normal daily solar power, this can provide enough power to run fresh water production facilities.

The cost of a SPS at GEO is more than a communications satellite, which costs around \$100-200M. However, it should be much less than a direct linear scaling by size. The complexity is less although the structure is much larger, and this would probably require active attitude control and charging mitigation. A more realistic cost estimate needs to be determined and initially we use the figure of \$500+M for such a satellite based on existing technologies.

Table 5. Summary of gross metrics implied in this paper

ISS-class solar power satellite	Gross metric with no inefficiencies
Fresh water production	700 m ³ /day or 170,000 gal/day
Population served	3000 people
Power required	120 kW

6 Recommendations – Space Water Consensus Group

6.1 What is Needed Now

There is a convergence of many interests behind our proposed concept. First, it is an understatement to say that a strong interest exists in reducing a global carbon footprint as one part of mitigating climate change. This path includes the small com-



ponent of decommissioning oil and gas platforms off the coast of California. At the same time, there are growing demands for fresh water along coastal areas. If we additionally consider that there are technical advances towards realizing space-based solar power, and we realize that niche markets may be the best first users for new technologies, then these convergent concepts combine into a compelling argument. That argument says – *produce industrial quantities of fresh water on former offshore oil and gas platforms, use solar arrays for diurnal power, and augment it with space-based solar power for around-the-clock operation.* This argument stimulates policy makers, business communities, and the public to make novel use of mature technologies in solving 21st Century problems.

Specific actions needed now are concept studies and recommendations by government and professional sectors that require multi-level funding (federal, state, private sector). An advocate or champion for the concept at the federal level would be useful. Among U.S. agencies (DoD, DoE, DoC, NASA, NSF, EPA), funding coordination is required.

6.2 Benefits Derived from Space Water Concept

Global benefits that can be derived from this concept include:

- clean, no-carbon footprint energy legacy for centuries to come;
- solution for global fresh water production; and
- transformative solutions to global climate crisis.

U.S. benefits include:

- clean energy source for water production and electricity;
- military energy and water independence at forward bases; and
- global leadership for developing space assets in the 21st Century.

Regional California benefits include:

- unlimited fresh water source for Southern California; and
- So Cal new jobs creation in aerospace, energy, and water industries.

Industry benefits include:

- new unlimited resources for water, power, and mineral industries;
- lease revenues and minimal-cost decommissioning for oil and gas platform owners; and
- major program development for the aerospace industry.

6.3 Feasibility Study Project Sponsorship

It is time for a feasibility study on this concept to be performed through a sponsoring organization grant. Candidate sponsors include i) the National Security Space Office (NSSO), which sponsored the 2007 *Space-Based Solar Power As an Opportunity for Strategic Security, Phase 0 Architecture Feasibility Study*⁸, also known as SBSP, ii) the California Ocean Science Trust, which issued a 2008 *Request For Pro-*



posals: Study to Provide Information Related to Oil and Gas Platform Decommissioning Alternatives in California⁹, iii) the National Research Council, iv) the National Science Foundation, v) NASA, vi) the Department of Defense, vii) the Department of Commerce, and viii) the Department of Energy. One or several of these organizations could sponsor the study in whole or in part.

6.4 Feasibility Study Project Members

In performing this study, it is important that expertise be used from organizations familiar with seawater desalination, coastal environmental and land-use policy, water and power economics, oil and gas platform operations, and solar power satellite manufacturing.

6.5 Feasibility Study Stakeholder

If an anchor “customer” or niche market is considered for this project, one might suggest that U.S. military installations along the southern California coast would benefit greatly as a first user of this system. We consider the U.S. Government a stakeholder in this concept.

7 Recommendations – Plan of Action

7.1 Short-Term Feasibility Study

We recommend that a short-term study be conducted. The topic of this study would be the feasibility of producing industrial quantities of fresh water on re-commissioned offshore oil and gas platforms, using solar arrays for diurnal power, and augmented with space-based solar power for around-the-clock operation.

As a starting point, we subjectively rate the maturity level of this architecture:

- climate change affecting the water infrastructure – relatively mature scientific understanding with prediction details still evolving;
- continued population growth in coastal areas – mature, clearly defined trend;
- use of seawater desalination as a source for metropolitan water supplies – mature technology where implementation issues are tied to energy costs;
- California coastal oil and gas platforms coming to the end of their productive lives – mature, well-defined technical and policy direction tempered by a serious concern for the tremendous costs involved in decommissioning platforms and the probable sea floor disruption that accompanies removal;
- platform re-commissioning for alternative uses – relatively mature idea but there is a continuing debate on platform re-use; the concept for a large-scale fresh water production facility has not been considered;
- solar arrays on offshore platforms to generate electrical power for desalination – mature technology but the implementation needs further study;



- efficient fresh water production requires 24 hours a day operation – mature concept but implementation is not well defined;
- solar power from orbiting solar power satellites can substantially augment the solar array power generated naturally from sunlight – mature concept but immature implementation and a SPS proof-of-concept has yet to be demonstrated; and
- production of industrial quantities of fresh water on re-commissioned oil and gas platforms, using energy from solar power satellites, is a breakthrough concept for addressing the pressing climate, water, and economic issues of the 21st Century – this is a novel combination of mature technologies in a new way to provide new solutions.

Since the least mature element of this concept is space-based solar power, we recommend that the feasibility study rely heavily on previous space-based solar power (SBSP) work to understand whether or not this path for augmented power generation is reasonable. The NSSO's SBSP study laid significant groundwork for such a study by outlining fundamental next-step SBSP tasks, including:

- the need to identify clear targets for economic viability in markets of interest;
- the need to identify technical development goals and a risk roadmap;
- the need to select the best design trades; and
- the need to fully design and deploy a meaningful SPS demonstrator.

One SBSP study finding was that the commercial sector needs the Government to accomplish three major activities to help SBSP development. These include i) removing a major portion of the early technical risks via an incremental research and development program culminating with a space-borne proof-of-concept demonstration for a SPS; ii) facilitating the policy, regulatory, legal, and organizational instruments that will be necessary to create the partnerships and relationships (commercial-commercial, government-commercial, and government-government) needed for a SPS to succeed; and iii) the need for the government to become a direct early adopter and to provide incentives for other early adopters. We recommend the proposed study include these topics for consideration.

The above outline provides a framework for bringing the SBSP study area together with the other study areas of seawater desalination, solar array use on platforms, and policy, economic, societal impacts. We recommend that it be used as a guide for developing a proposed study agenda.

7.2 Technical, Economic, and Societal Impact Workshops

We recommend that the study team hold expert workshops on technical, economic, and societal impact issues to obtain relevant advice and material. These workshops would solicit contributions from leading experts in order to address the



fundamental tasks and the 3 major activities of required government assistance described in the section above.

7.3 Technical Feasibility Report

We recommend that the study team produce a technical feasibility report. This report will necessarily cover the identification of technical development goals, the selection of the best design trades, sizing of power needs for water production rates, the feasibility of converting offshore platforms to other than oil and gas uses, the possibility of solar array construction on offshore platforms, the method of water delivery from offshore to onshore distribution facilities, the removal and use of brine, the ability of SBSP for enabling continuous fresh water production, the design and deployment path for a meaningful space-borne SPS proof-of-concept demonstrator, and a roadmap using incremental research and a development program for removing technical risks.

7.4 Economic Feasibility Report

We recommend that the study team produce an economic feasibility report. This report will necessarily cover the need to identify clear targets for economic viability in the fresh water production market, water production versus energy trade-offs, a first user or anchor customer identification, an evaluation of niche market feasibility, an evaluation of water production costs in this concept versus conventional water sources, an evaluation of cost benefits to the oil and gas industry for converting offshore platforms rather than removing them, estimating the economic benefit of leasing, water, mineral, and cap-and-trade credit sales that could provide secondary revenue streams, an evaluation of the costs for a SPS demonstrator and who would pay for it, and a roadmap that includes the government as a direct early adopter and an agent providing incentives for other early adopters in order to help remove economic risks.

7.5 Societal Impact Report

We recommend that the study team produce a societal impact feasibility report. This report will necessarily cover the policy, regulatory, legal, and organizational instruments that would be necessary to create the partnerships and relationships, including commercial-commercial, government-commercial, and government-government, needed for this concept to succeed. There are many Federal, California, county, and municipal coastal regulations and policies related to water management, offshore platforms, and environmental concerns. There are also natural fears among the public for use of new energy technologies (laser or microwave radiation beamed from space) near their homes and work. These impacts suggest that the California coastal example is a national pathfinder for a societal impact assessment. A roadmap for addressing and removing societal risks, some of which are outlined in Table 4, must be addressed.



8 Notes

- ¹ *Climate Change and Water*, IPCC Technical Paper VI, Intergovernmental Panel On Climate Change, June 2008.
- ² *The National Academies Summit on Summary of a Meeting: America's Energy Future*, Committee for the National Academies Summit on America's Energy Future, The National Academies Press, Washington, DC, 2008.
- ³ *Population Trends Along the Coastal United States: 1980-2008*, National Oceanic and Atmospheric Administration, September 2004.
- ⁴ *Ripple Effects: Population and Coastal Regions*, Population Reference Bureau Measure Communication; www.measurecommunication.org or www.prb.org.
- ⁵ There is a strong sentiment in the oil and gas community that the platform decommissioning estimates may be even higher, reaching \$10 billion.
- ⁶ California Coastal Commission, *Seawater Desalination in California*, October 1993, <http://www.coastal.ca.gov/desalrpt/dtitle.html#TOCDesalination>.
- ⁷ Potter, S., et al., *Space Solar Power Satellite Alternatives and Architectures*, AIAA Aerospace Sciences Meeting, AIAA 2009-402, 2009.
- ⁸ *Space-Based Solar Power As an Opportunity for Strategic Security, Phase 0 Architecture Feasibility Study*, Report to the Director, National Security Space Office, Interim Assessment, Release 0.1, 10 October 2007.
- ⁹ *Study to Provide Information Related to Oil and Gas Platform Decommissioning Alternatives in California*, Request For Proposals, California Ocean Science Trust, Oakland, CA, October 31, 2008.