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Institute for Defence Studies and Analyses
No. 1, Development Enclave
Rao Tula Ram Marg,
New Delhi – 110 010.

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Peter A. Garretson

Overview

This paper provides a policymaker's overview of a highly scalable, revolutionary, renewable energy technology, Space-Based Solar Power (SBSP), and evaluates its utility within the context of the Indo-US strategic partnership. After providing an overview of the concept and its significance to the compelling problems of sustainable growth, economic development, energy security and climate change, it evaluates the utility of the concept in the context of respective Indian and US political context and energy-climate trajectories. The paper concludes that a bilateral initiative to develop Space-Based Solar Power is highly consistent with the objectives of the Indo-US strategic partnership, and ultimately recommends an actionable three-tiered programme to realize its potential.

Introduction

Energy security, climate security, human security and the competitiveness of one's technical and industrial base are increasingly becoming mainstream concerns for security policy-makers. As the penalties of interstate conflict have become more widespread and serious to populations, infrastructure and economies, and as the interstate system has so far succeeded in limiting the scope of such conflicts, the corresponding interconnectivity has given space to security planners to focus more on shared threats to stability and security, and initiate proactive and collective measures. When competitive national energies are subverted within an overall cooperative system--sometimes called "coopetition"--nations still pursue their security by seeking a technological edge. They do this through one of two mutually exclusive security strategies: keeping one's edge through innovation and restricted access, or technological innovation through sharing and partnership.[1] Generally, technically competitive nations seek to maximise the differential between their own industrial and military innovative capacity and those of potential competitors. They actively protect domestic markets and seek to keep jobs at home. These considerations are only rational to abandon if there are larger direct or oblique gains. This paper examines the policy mechanisms that will facilitate multiple security ends through a strategy of partnership.

While space-based solar power (SBSP) is a civil and renewable energy concept, it is also a legitimate topic of security discourse. There are several reasons for this. First, neither the citizens of a country nor its government are secure if they do not have access to a constant supply of energy. *Without a constant, predictable supply of energy, higher levels of complexity are not sustainable* – industry cannot take place, economies wither, cities die, scarcity drives conflict and instability, and populations dwindle. More importantly, a nation may not be able to defend its borders and its interests. Those charged with guarding society are keenly aware of this relationship between energy and security. This explains the second reason, which is that part of the recent expression of interest of both countries has come from within their respective defence establishments. Then one must be mindful that most space technology, particularly enabling launch technology,[2] is dual use and has defence and proliferation implications. Partnership on dual use technologies has its own security logic, as one must consider who might feel threatened or excluded. *Finally, a transition to a regime of renewable energy based upon space solar power will have very significant* *long-term implications for the international security environment, including vastly improved access to space, the need for space traffic control, space debris remediation, new regulatory institutions, vastly improved capabilities in space, as well as new equities and vital interests.*

The Indo-US Strategic Partnership is itself a "strategic" topic of security discourse, as it affects many other aspects of both nations' security, and it is important to actively nurture it. At present, it appears there is a dearth of "big ticket" ideas to continue the momentum post the "123" Indo-US Civil Nuclear Deal. Finding ideas that are relevant to agendas of both nations and help expand the partnership by enhancing cooperation in meaningful ways by linking dual-use technological and industrial bases and people-to-people contact, and familiarity between the respective bureaucracies is itself a meaningful security end. As will be discussed ahead in detail, the *SBSP is one of those ideas with a truly "big ticket" potential.*

Notes

1 *"…it is greatly in the interest of innovative nations to restrict technological access, both to limit misuse and to preserve advantage, but at the same time, it is also fundamentally in their interest to share this technology, precisely because sharing generates more innovation, more wealth and more prosperity, which in turn strengthens existing relationships and promotes stability and security."* Statement by Mark Fuller of the Monitor Group at a seminar on US Technology Transfer and International Security for the Future, September 24, 2008, American Enterprises Institute. Podcast available online at http://www.aei.org/event/1798

2 Inderfurth and Mohan have argued for Indo-US co operation on launch technologies. During presentation of this paper on October 23, 2009, my discussant, Dr. V. Siddhartha noted that the US DoD had opened the door to basic research cooperation ("6.1" research) with India, but it was currently not seeing activity. He suggested a three-way partnership between the US, Australia, and India would be possible.

Background

In thinking about policy relating to Indo-US cooperation with regard to SBSP, there are several distinct audiences which this paper tries to address. A topic as broad as SBSP has many diverse stakeholders. The primary audiences are the relevant Indian and US policymakers who are working on the various problems of the bilateral agenda, geopolitical strategy, energy security, national tech-base and climate change, and who are looking for novel and effective solutions. Secondary audiences are the potential technology suppliers and programme proposers, the US and Indian companies, universities, individual researchers and government agencies who need to better understand the opportunities in the current policy regime. Tertiary stakeholders include informed consumers and watchdog environmental groups, who need to be well informed regarding potential policy options. Each of these groups has disparate sets of knowledge and may not speak the same language. This paper seeks to explain the utility to the policymaker, the policies to the proponents and suppliers, and some of the issues to the watchdogs and regulators.

From my starting place as a strategic planner and technology scout in the US, the questions that drove my research were:

1. Whether or not the US and India's interests and amities are adequately aligned to allow forward motion for cooperation in space and energy in general and on the concept of space-based solar power specifically, and if so,

2. What an action plan toward this end would look like.

I hypothesised that the two countries were ready for an expanded agenda and that it would be possible to articulate a plan of engagement upon which policy-makers could move forward.

This paper attempts several novel contributions. First, it is the first paper to examine the topic of SBSP in the context of India's own national goals for energy security, climate change, development and space, and aligns the discourse of proponents of space solar power to the terms and existing mechanisms already in place. Second, it is the first paper to evaluate the concept of SBSP in the context of the bilateral Indo-US strategic partnership, and examine whether and how a joint programme might advance strategic partnership goals. Third, it is the first paper to consider and discuss a wide range of relevant models for bilateral cooperation and deployment of defence, space, and energy technologies.

And lastly, after examining multiple possible models, it is the first paper to provide an explicit model on how policy-makers might structure a bilateral space solar power development programme. In each case, it is also hoped that insights are gained into the underlying security challenges, the needs of the strategic partnership, and the mechanisms and models each country uses. The proposed general model might also be useful to other projects which might advance the general security and prosperity of India, the US and all nations.

Though this is the first paper to evaluate SBSP in terms of the Indo-US bilateral partnership, it is not the first to suggest it. The US Department of Defence space-based solar power study[1] in 2007 specifically identified India as a potential partner. That same year India's President, Dr APJ Kalam,[2] and the Aeronautical and Astronautical Societies of India[3] championed India's leadership in a global energy and aerospace mission. Later in August 2009, Taylor Dinerman[4] specifically suggested it in Indo-US SBSP cooperation in *Space Review*, followed by Dr. Namrata Goswami.[5]

Most recently, Air Cmde R. Gopalaswami, former Chairman of Bharat Dynamics, Ltd, presented a concrete proposal in his paper to the International Academy of Astronautics[6] to realise *a 550 GW*[7] *System-of-Systems by 2050, averting 66 billion tonnes of CO2 (Gt CO2) [17.98 GtC] by 2052*[8] *and 6 billion tonnes CO2 [1.6 GtC] every year thereafter.*[9]

In sum, this work tries to fill the role of a policy entrepreneur, as

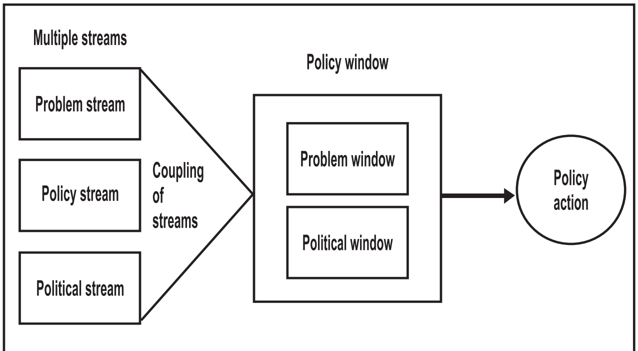

FIGURE 7.2 The Agenda-Setting Process—Kingdon's Three Streams.

Figure 1 Kingdon's Model

identified by John Kingdon in his classic work,[10] whose job is to perceive a policy window when the separate streams of problems, proposals and the political context may be joined to place an idea on the agenda, with the goal of introducing options for more expansive and ambitious thinking into Indo-US bilateral relations.

The limits of size and quantity also require the paper's scope be limited, and so there are topics which are relevant but not covered here. First among these is a thorough discussion of the technical aspects of SBSP, which is beyond the scope of this paper. Fortunately, there is a satisfactory collection of data available to satisfy anyone sufficiently curious to delve into its intricacy. While the sources are disparate, the most useful single source is the space solar power library[11] maintained by the National Space Society, which maintains over 130 key documents and studies, covering the period from 1977 to the present. Second, an in-depth and precise economic estimate[12] and cost-benefit analysis of space-based solar power is also beyond the scope of this paper, but is nevertheless a fruitful avenue for future research. Unlike the larger technical discussion, there is inadequate study of this topic, and there are reasons to be suspicious of existing estimates since they are built upon multiple levels of assumptions, and directly depend on the state of technology that has recently undergone, and is undergoing, rapid progress.

To arrive at its content and conclusions, this paper has employed several distinct research methods. This was required in part because there is no existing literature discussing organisational design for bilateral/multilateral development of space solar power or significant previous discussion, or anything so ambitious and long-term in Indo-US relations. The researcher began the paper with fairly substantial knowledge of the topic of SBSP and US technical and industrial capabilities and methods, but with very little knowledge about Indo-US relations and Indian attitudes, priorities, organisations, capabilities, policies and methods of tackling relevant problem sets. Three principal research methods were employed. The first was targeted interviews of key individuals in relevant agencies regarding policies, outlook and important stakeholders and organs relating to the Indo-US bilateral relationship. The second was a review of official statements and documents relating to the Indo-US bilateral relationship, and of Indian government documents relating to the problems that SBSP seeks to address. The final method was a series of interactive presentations across a broad sampling of Indian society and bureaucracy where the researcher presented the general topic of SBSP, and took questions and comments from the audience to access attitudes, reactions, concerns and suggestions.

Since this work is primarily for policymakers, it is important to anticipate and address their concerns. It is important then to suggest the proposed policy innovation in a language that is familiar to them. This involves understanding and articulating the political context and mandate, and helping create a policy window by coupling a proposed solution to problems considered important. Policymakers must decide upon such matters as licensing or encouraging some activity and prohibiting others, and the allocation and direction of resources. Therefore, any proposal must answer "nuts and bolts" questions of who (which agencies), what are the deliverables and what level of resourcing over what time. Any possible action usually comes with some opportunity cost. Therefore, policymakers are loathe to enter the battle for resources without a clear understanding of the attractive and detracting features, the benefits and costs, some ability to estimate risk, and an understanding of the constituencies which will support or oppose a given proposal. Policymakers do not need to understand every aspect of a technical solution, but they do need to understand how that solution will affect various constituencies, and what values to which they have attached their identity or platform will be affirmed or violated.

Notes

1 NSSO. "Space Based Solar Power: An Opportunity for Strategic Security"`, Washington, DC 2007, available at http://www.nss.org/settlement/ssp/library/nsso.htm "The SBSP Study Group concluded that should the U.S. begin a coordinated national programme to develop SBSP, it should expect to find that broad interest in SBSP exists outside of the US Government, ranging from aerospace and energy industries; to foreign governments such as Japan, the EU, Canada, *India,* China, Russia, and others; to many individual citizens who are increasingly concerned about the preservation of energy security and environmental quality. While the best chances for development are likely to occur with US Government support, it is entirely possible that SBSP development may be independently pursued elsewhere without US leadership."

2 Kalam, APJ, "The Future of Space Exploration", Boston University, April 20, 2007. "However, solar flux on earth is available for just 6-8 hours every day whereas incident radiation on space solar power station would be 24 hours every day. *What better vision can there be for the future of space exploration, than participating in a global mission for perennial supply of renewable energy from space.* Space based solar power stations have 6-15 times greater capital utilisation than equivalent sized ground solar stations. Linking space solar power to reverse osmosis technology for large-scale drinking water supplies could be yet another contribution of space."

3 AeSI 2007 Conference Recommendations, "…there is a need to generate a national consensus for the Global Aerospace and Energy Initiative, determine the sources and uses of funding, and evolve a suitable management structure and system to plan and implement the mission."

4 Dinerman, Taylor, "Should India and the US cooperate on Space Solar Power", June 8, 2009. "In Washington lots of people have complained the Obama Administration has so far not given India-US relationship the attention it deserves… one area where there seems to be movement on, though is a 'renewable energy partnership.'…Photovoltaic panels on rooftops and solar water heaters all make excellent small scale contributions to the solution, but they cannot by any stretch of the imagination fulfill the requirements of a huge growing economy like India's. *Only SSP, which operates 24 hours a day, 7 days a*

week, year after year, can hope to meet this need. Fortunately both India and the US have space programs that could, if developed together and possibly with other interested nations such as Japan, bring SSP systems into service sometime late next decade or early 2020s. With its commitment to develop a new low cost reusable space plane, the Indian Space Research Organisation (ISRO) is already working on one of the key technologies needed for an SSP system… In the near term the new Indo-US renewable energy partnership is the right place to start this collaboration. Together partners can identify what will be needed in the way of technological and scientific investments over the next decade in order to make SSP a reality."

5 Goswami, Namrata, "Committing to Continuity", at www.mainstreamweekly.net/article1577.html, August 19, 2009. "The section on 'Energy Security, Environment and Climate Change" did refer to renewable energies like solar (perhaps the most viable in terms of energy to the rural masses in India) but appears as an afterthought. The *Renewable Energy Partnership between India and the US, as currently being defined by the Obama Administration and the UPA Government, should not just deal with tactical issues of today, but include long-term advanced energy concepts such as Space-Based Solar Power* which will broadly push for strategic, rather than just tactical cooperation across a host of major dialogues." Then goes on to further discuss benefits to long-term thinking, youth, aerospace, and India's needs.

6 Gopalaswami, R., "Solar Electric Power Plants in Space: Potential Bedrock for Sustaining India's High Economic Growth Track", Hyderabad, 2007. Gopalaswami looks to supplement India's projected power shortfall with an initial installed capacity of *17 GW building to 544 GW by 2050 and a full 1000 GW (1TW) by 2065, allowing India to grow at 7 per cent vs 5 per cent resulting in an overall cumulative GDP return on investment of $103 Trillion between now and 2050.* To get there, he proposes a $10 million, 18-month expert study team, followed by a 5-7 year interim steering group growing to a Global Steering Group who will conduct a detailed study of a 550 GW System of system Space Solar Power (SSP) – Reusable Launch Vehicle (RLV) study. Following that is a five-year, Rs 500 crore (~$100M), 5-year demonstration of all critical technologies on the ground, leading into a $3-5 billion joint venture to commercially develop the necessary transportation structure spanning 2016-2025 time frame.

7 On a macro level, Mike Snead, in *The End of Easy Energy and What to Do About It*, has stated that the world will need to expand its current sustainable renewable energy capacity 24-fold to meet 2100 demands. Is such an expansion possible? *Vaclav Smil in his Energy in World History, p, 185, points out that between 1810 and 1910 oil production increased 100-fold, coal production increased 300-fold, and gas production increased 800-fold.*

8 This is very close to a "Stabilisation Wedge", or 1/7th of the solution to keep global emissions from exceeding *550 ppm*, according to Socolow, Robert, Roberta Hotinski,Jeffery B. Greenblatt, and Stephen Pacala." Solving the Climate Problem: Technologies Available to Curb CO2 Emissions", *Environment*, 46 (10), December 2004, pp. 8-19, at http://www.princeton.edu/~cmi/resources/CMI_Resources_new_files/Environ_08-21a.pdf. The authors assert that 700 GW (generating 5400 TWh, at a .9 Capacity factor) of nuclear power displacing coal would fill a wedge. *The total that must be avoided is nearly 200 billion tonnes carbon (GtC) [734 Gt CO2] by 2054,* with each of 7 wedges providing 25 billion tonnes of carbon [91.75 Gt CO2] over 25 years and avoiding 1 billion tonnes carbon [3.67 Gt CO2] annually at maturity in 2054, and all wedges providing 7 GtC [25.69 Gt CO2] avoidance in 2054. http://www.princeton.edu/~cmi/resources/Wedges/Nuclear%20power%20for%20coal%20power8.16.pdf To convert GtC to Gt CO2, multiply GtC by 3.67. The current concentration of CO2 in the atmosphere is 385 ppm, which equates to 3,105 gigatons of CO2, or 847 gigatons carbon (GtC). http://www.atmos.washington.edu/2009Q1/111/ATMS111%20Presentations/Folder%203/ChoiJ_KramerN.pdf According to www.earthpolicy.org/Indicators/CO2/2008.htm, global carbon dioxide (CO2) emissions from the burning

of fossil fuels stood at a record 8.38 gigatonnes of carbon (GtC) [30.75 Gt CO2] in 2006, which is very close to the figure of world annual emissions in 2006 were 28,431,741 thousand metric tonnes (28 Gt CO2) per http://en.wikipedia.org/wiki/List_of_countries_by_carbon_dioxide_emissions

9 Personal E-mail, R. Gopalaswami and Dr. M. Kumaravel, October 6, 2009. Actual savings would have to be reduced by approximately *1/60 per lifecycle CO2 production and launch* as per: Asakura, Keiichiroy, Patrick Collins, Kojiy Nomura, Hitoshiy Hayami, and Kanjiy Yoshioka. CO2 Emission from Solar Power Satellite through its Life Cycle: Comparison of Power Generation Systems using Japanese Input-Output Tables. Keio Economic Observatory, Keio University, Japan & Department of Environmental Policy, Azabu University, Japan, July 2000, at http://www.iioa.org/pdf/13th%20conf/AsakuraCollinsNomuraHayami&Yoshioka_LifeCycleCO2.pdf (accessed August 16, 2009).

10 See Appendix for a full summary of Kingdon's Theory of Agenda Setting and Policy Making.

11 NSS Space Solar Power Library: http://www.nss.org/settlement/ssp/library/index.htm

12 Several dated economic analyses can be found at the above library.

A Policymaker's Introduction to Space-Based Solar Power

Space-Based Solar Power is a technical concept for generating very large amounts of renewable energy and it enjoys some level of interest in both the US and India. At the time of writing this paper (2009), the concept is in a low state of technical maturity and neither the US nor India had an active funded programme to develop the technology. However, funded programmes were ongoing in both Japan's space exploration agency (JAXA) and the European Space Agency (ESA), and several companies had announced their interest in the open media (Heliosat, ManagedEnergy, PlanetPower, Powersat, PlanetaryPower, Solaren, SpaceEnergy, Space Island Group, Welsom Solar). California's largest power provider, PG&E was petitioning lawmakers to allow Solaren to provide 200MW of power by 2016.[1] It is also highly significant that during the course of writing this paper, *Japan, building on its new Space Basic Law[2] and Space Basic Plan,[3] announced on August 31, 2009, a 2 Trillion Yen ($21 billion) public-private-partnership* between JAXA,[4] Ministry of Economy Trade and Industry (METI)[5], Ministry of Science, and industrial giants such as Mitsubishi Electric, Mitsubishi Heavy Industries[6] and IHI Corp to put in place a commercial 1 GW space solar power system in geostationary orbit by 2030.

Technical Overview

In the SBSP concept, very large satellites or constellations of satellites are put into orbit around Earth to collect sunlight, turn it into electricity and then beam it to receivers on the ground, using safe, low-intensity radio or light waves optimised for transit through the atmosphere. The reason to go to space is to escape the low density and capriciousness of ground-based solar power. The sun's rays are stronger in space[7] before being filtered by the atmosphere at 1,366 W/m2 constant vs. about 1,000 W/m2 at noon in an equatorial location. There are no clouds or weather to interfere. And in space there is effectively no night in the orbits of choice, because the satellites only pass behind the Earth's shadow for brief and predictable times during equinox. That allows the same area of a solar array to collect as much as 9 times the energy an equivalent size array will collect in a temperate location on the ground.

Significance of the Concept

The significance of SBSP systems lies in its many potential advantages. These advantages address multiple contemporary problems and constituencies. *Like other renewable energy sources, SBSP systems provide a non-depletable source of carbon-neutral energy for long-term sustainable development. Unlike other renewable energy sources, it is in the nature of SBSP concepts to provide energy in a highly usable form with an exceptional capacity factor. The ability to provide 24-hour, predictable, dispatchable electric power in quantities appropriate for base-load cities* (by 2039, as much as 50 to 60 per cent of India's 1.6 billion population will reside in cities[8]), and industrial processes means that it can fill the same roles as nuclear power, hydroelectric power, natural gas and coal.[9] Therefore, the concept can address both immediate concerns regarding the need to displace carbon producing plants with cleaner power and longer term needs to replace the very substantial investment and dependence on coal and other fossil fuels as they are depleted. *The importance of a base-load and urban capable renewable power source cannot be understated.* The nature of the satellites and their receiver also means that much intermediate and costly transmission infrastructure can be dispensed with and a single satellite can service multiple receiving stations, augmenting peaking loads as necessary. A second key advantage of SBSP is its scalability. Experts calculate that *the exploitable energy in orbit exceeds not just the electrical demand of the planet today, but the total energy needs of a fully developed planet with over 10 billion people.*[10] Because of the strong coupling between electrification, human development and gross national product (GNP) / gross world product (GWP), the addition of new, non-polluting highly-usable energy has a highly beneficial effect on poverty alleviation and creation of economic opportunity and wealth.[11] The very large size of the market[12] also means that a successful space solar power industry will create many jobs, much wealth and significant tax revenues for the state, and have a highly stimulatory effect on space and high tech industry and national tech base.[13]

Environmental Overview

While no energy source is entirely benign, the SBSP concept has significant things to recommend it for the environmentally conscious and those wanting to develop green energy sources. An ideal energy source will not add to global warming, produce no greenhouse gasses, have short energy payback time, require little in the way of land, require no water for cooling and have no adverse effects on living things.

Space solar power comes very close to this ideal. Almost all of the inefficiency in the system is in the space segment and waste heat is rejected to deep space instead of the biosphere.[14] SBSP is, therefore, not expected to impact the atmosphere. The amount of heat contributed by transmission loss through the atmosphere and reconversion at the receiver-end is significantly less than an equivalent thermal (fossil fuel), nuclear power plant, or terrestrial solar plant, which rejects significantly more heat to the biosphere on a per unit (per megawatt) basis.[15] The efficiency of a Rectenna is above 80 per cent (rejects less than 20 per cent to the biosphere), whereas for the same power into a grid, a concentrating solar plant (thermal) is perhaps 15 per cent efficient (rejecting 85 (per cent) while a fossil fuel plan is likely to be less than 40 per cent efficient (rejecting 60 per cent to the biosphere). The high efficiency of the receivers also means that unlike thermal and nuclear power plants, there is no need for active cooling and so no need to tie the location of the receiver to large amounts of cooling water, with the accompanying environmental problems of dumping large amounts of waste heat into rivers or coastal areas.

Environmental: Water, CO2, and Land Usage

Water is a significant problem for India. India already suffers from acute water shortage, with 68 per cent of its area prone to drought and 33 per cent chronically drought–prone. The expected shrinking of Himalayan glacier ranges will drastically cut down future water availability in Uttar Pradesh and Bihar, and the United Nations Framework Convention on Climate Change (UNFCC) projects one-fourth of Gujarat and 60 per cent of Rajasthan are likely to experience acute physical water scarcity, as are the Mahanadi, Pennar, Sabarmati and Tapti river basins. Not requiring huge amount of water is a significant competitive advantage for space solar power in comparison to coal and nuclear fuel cycles, which require more water. In fact, a 554 GW SBSP system can potentially save India as much as 935,234 GL/annum in withdrawals and 14,958 GL/annum in water consumption.[16]

On a life cycle basis, a SBSP system contributes less than 1/60th the carbon-dioxide as an equivalent coal plant.[17] The energy payback time, even including the energy cost of installation by rockets is quite short, roughly equivalent to a ground-solar plant and in the order of a couple years.

The receiver itself is large, roughly the order of a municipal airport. The scaling laws of optics mean that the economics improve with the amount of power transferred for a given area, so most designs have used quite large loads, from 1GW (about the size of a single large nuclear plant) to 10GW.

As the receiver converts with much higher efficiency than any current or forecast solar cell and receives constant energy over the full 24-hour period rather than less than a quarter of the day, the energy productivity of the land is several times higher than if power is from terrestrial solar or wind. *Also, because the rectenna effectively stops all incident energy from the satellite but is highly transparent to sunlight, the underlying land is still available for agricultural and pastoral uses.*

Environmental: Transmission

The beam used to transmit the power has, in past studies, been selected at frequencies similar to modern wireless networks, a non-ionising (non-cancer causing), low energy wavelength and at peak intensities several times less intense than peak sunlight. *NASA, DOE, and EPA have conducted extensive experiments to assess if there were ill effects to biological life or the upper atmosphere due to such beams. None of the studies conducted so far suggest that there is any significant detrimental effect.*[18] Many times people, without a background in optics, erroneously believe that the beam can be concentrated at levels that will allow a space to ground weapon—it cannot.[19] However, modern electronic beam steering does convey an additional benefit. A single power satellite can serve many different receivers across a very large geographic area, making possible both significant redundancy and easy movement of energy between peaking load centres, without costly and intervening long-distance transmission lines.

Drawbacks

The primary downside to SBSP is its low state of maturity, given its business model that is highly dependent upon multiple significant technical successes and the high investment required to achieve those technical accomplishments. This makes it vulnerable to attack by entrenched and competing interests, who see it as a zero-sum game where any outlay incurs an opportunity cost. A secondary liability for policymakers is the relative obscurity and what appears to the public as an unfamiliar, and hence fantastic and perhaps, threatening technology. The answer to the first requires a broader vision that recognises that all the elements of a SBSP system serve other goals and so the true opportunity cost is low. The answer to the second will require a consistent and sustained strategic communication with the public to establish credibility and dispel erroneous information.

Unknowns

Policymakers should be aware that there are significant unknowns that are only likely to be answered within the context of a directed programme. *Specifically, there are a number of technically viable approaches though at present, there is no universal agreement on the best satellite design or major component selection, or on launch methodology.* Since no directed programme exists to examine and select between these approaches, precise cost estimates for the satellite,[20] ground receiver, launch system and cost of delivered electricity cannot be given with satisfying precision, nor can a clear answer be given on the magnitude of non-recurring developmental costs. However, this will be true of any major new energy programme in a comparable state of immaturity.

It is important to point out that there are strong precedents for programmes to demonstrate the basic capability (nuclear fission and fusion), as well as to specifically bring expensive technology down into commercially viable ranges, such as India's National Solar Mission.

State of Maturity

At the time of writing this paper (2009), the concept was at a pre-commercial, pre-pilot project, pre-demonstration level. *The concept is, however, considered to be "engineering ready,"*[21] meaning that it is based upon well understood principles[22] and sub-components and that a programme can be immediately initiated to do systems-level design. It is significant to call attention to this fact as it contrasts significantly with other potentially revolutionary energy concepts, like fusion where fundamental questions of science and understanding still must be answered.

Suitability for India

The Government of India has articulated a four-point criteria of suitability and viability of various energy sources: "There are four criteria on which to assess the suitability and viability of different energy sources: (i) scalability, (ii) environmental impact (iii) security of source;[23] and (iv) cost."[24] As can be seen from the discussion above, SBSP competes very well in terms of scalability and environmental impact. With respect to security of source, the Indian government also has provided a definition of energy security,[25] which acknowledges supply risk, market risk and technical risk.[26] *A mature SBSP system is expected to be significantly lower in such risks than other major sources of energy.*[27] The sole area where SBSP cannot currently compete is cost. A similar situation exists with respect to terrestrial solar,[28] and the Indian government, already recognises the importance of developing new sources that are currently economically unviable but increase energy security in harmony with the environment.[29] *It would appear, therefore, that the SBSP concept largely satisfies the Indian government's criteria for a suitable energy source to be developed to economic viability.*

Notes

1 Funded programmes were ongoing in both Japan's space exploration agency (JAXA), and the European Space Agency (ESA), and several companies had announced their interest in the open media (Heliosat, ManagedEnergy, PlanetPower, Powersat, Solaren, SpaceEnergy, Space Island Group, Welsom Solar). California's largest power provider, PG&E was petitioning lawmakers to allow Solaren to provide 200MW of power by 2016.

2 See discussion in http://ukinjapan.fco.gov.uk/resources/en/pdf/5606907/5633988/The_Bill_of_Basic_Space_Law.pdf and translation at http://translate.google.com/translate?hl=en&sl=ja&tl=en&u=http%3A%2F%2Fwww.shugiin.go.jp%2Fitdb_gian.nsf%2Fhtml%2Fgian%2Fhonbun%2 Fhouan%2Fg16601050.htm

3 http://sciencelinks.jp/content/view/936/241/

4 http://www.bloomberg.com/apps/news?pid=20601080&sid=aF3XI.TvlsJka list of Japanese papers on Space Solar Power Systems (SSPS) can be found here: http://www.google.com/search?hl=en&lr=&q=SSPS+site:jaxa.jp&start=30&sa=N

5 http://www.meti.go.jp/committee/materials2/downloadfiles/g90624b22j.pdf

6 Mitsubishi has had an historical interest in SBSP, called Solarbird, at http://global.mitsubishielectric.com/bu/space/rd/solarbird/index.html

7 1,366 W/m2 constant, vs about 1,000 W/m2 at noon in an equatorial location

8 India is rapidly urbanising, and soon will no longer be a primarily rural nation. That *imposes limits on the "small is beautiful/decentralised power" model,* impacts what type of energy options are appropriate.Per India 2039 Report, p 43" According to UN projections, *about half the total population of nearly 1.6 billion will be living in cities by 2039; others believe the share could be as high as 60 percent.* The absolute numbers are even more staggering. There will be *at least 400–500 million more urban dwellers by 2039."*

9 But it would also allow very profound changes. *For instance, electricity on this scale would allow electrification of the ground transportation network, reducing noise, and eliminating a major source of pollution, allowing an accompanying increase in air quality.* Transportation is also the largest consumer of liquid hydrocarbons, which are themselves a significant percentage of global transportation (in supertankers, etc.); electrification would allow a substantial decongestion of sea traffic. As fossil fuels and traditional biomass are replaced, there would also be substantial health benefits.

10 Snead, James M. ISDC 2009 Presentation noted that at *10 per cent slot use, geostationary orbit could hold 6,620 satellites each at 5 GW, or that at 100 per cent slot use, could hold 66,200 Sats for a total of 331,000 GW or 331 TW, and estimates a mature global system would comprise 1,8505-GW SSP systems needed to close the world 2100 dispatchable electrical power shortfall = World SSP - 9,240 GW* (dispatchable power generation), or which 2505-GW SSP systems needed to close the US 2100 dispatchable electrical power shortfall = US SSP - 1,220 GW (dispatchable power generation). A similar estimate comes from Harry G. Stine: "How many SPS units could be placed in GSO? *If all SPS units are placed in the equatorial geosynchronous orbit at a distance of 35,890 km (22,400 miles) from Earth, if each SPS unit occupies an area of 50 square km in that orbit, and if we allow for a spacing of 15 km between SPS units, it's possible to place 17,700 SPS units in GSO. That would supply a total space power capacity of 177,000 gigawatts."* Available at: http://www.nss.org/settlement/ssp/spacepower/spacepower06.html

11 See discussion on GWP in Garretson, Lieutenant Colonel Peter (2008) "Viewpoint: The Next Great White Fleet: Extending the Benefits of the International System into Space", *Astropolitics*, 6 (1), pp, 50-70, at http://dx.doi.org/10.1080/14777620801921419

12 SBSP also represents a significant business opportunity. Global spending on energy, according to http://sufiy.blogspot.com/2009/05/lithium-and-rare-earth-elements-new.html is *approximately $6 trillion.* That checks with back-of-the-envelope-calculations. Assuming the world spends a similar percent share of GDP on energy as the *US (9.8*

per cent share of GDP at its peak in 2008, www.eia.doe.gov/oiaf/aeo/economic.html), then 9.8 per cent of $79.62 trillion would be $6.9 trillion. The total electricity produced in 2006 was 16,830,000,000,000 KWh at an average price of $0.12 means *the world currently spends upwards of $2 trillion on electricity*. Coal production was 751,932,139,000 short tonnes at an average 2008 price of $111.5, suggesting the world spends upwards of $0.75 trillion on coal. The world produced 104 trillion cubic feet of natural gas at an average price of $2.32 per thousand cubic feet, or $0.24 trillion. *And the world consumed 31.1 billion barrels of oil, each at about $75, spending $2.3 trillion on oil.* Taken together, before value additions in refining, transportation, and other sources of energy not covered (biofuels, off-grid renewables, CO2 mitigation, green buildings, local pricing differences), *this would mean the world was spending in excess of $5.29 trillion on energy. Carbon trading worldwide reached $126 billion in 2008. Experts are predicting the carbon market will reach $2 - $10 trillion in the near future* (http://www.transworldnews.com/NewsStory.aspx?id=104031&cat=12), with the US alone reaching $600 billion in pollution credits by 2015 and the global carbon trading reaching $1trillion by 2020, http://www.newscientist.com/article/dn13325-greening-us-likely-to-create-huge-carbon-market.html)

13 For a discussion of which industries benefit, see Xin.

14 "As the beam passes through the atmosphere from geostationary orbit, a loss of no more than 2 per cent of total beam powers predicted. In abnormal circumstances, such as simulations in the ionosphere ring cells in the troposphere, the power loss may be temporarily greater." Xin, p. 45. "A SSPS could *at worst lose 11 per cent of its energy* to heat in the atmosphere during the weather. For a simple system which provides 100 kW of energy, this amounts to 11 kW thermal energy which is usually added to the biosphere." X in, p. 14." *The energy transmitted by SSPS from space to Earth is five orders of magnitude less than the total solar radiation reaching the earth* (i.e. the power density of the beam is weaker than the power density of sunlight). The total energy used on Earth is only 1/7000 of the amount of solar energy reaching the earth. Therefore, SSPS will not worsen global warming problems. Since for 10 efficiencies are very high, very little of the total energy is lost as heat. *SSPS does not generate CO2, change atmospheric chemistry or contribute to climate change."* Xin, p.45. "The effects of powerful microwave some stratosphere have been studied, mostly to study the effects of ozone- destroying pollutants in the troposphere or to create an artificial ozone layer by interaction with high- energy electromagnetic waves. The field strength necessary to do this is much higher than power densities that would be used by SSPS systems. *SSPS is therefore not expected to impact the atmosphere."* Xin, p. 45.

15 The efficiency of arectenna is above 80 per cent (rejects less than 20 per cent to biosphere), whereas for the same power into grid, a Concentrating Solar Plant (thermal) is perhaps 15 percent efficient (rejecting 85 per cent), and a fossil fuel plant is likely to be less than 40 percent efficient (rejecting 60 per cent to biosphere).

16 Water is a significant problem for India. As per the IDSA report on Climate Change, p. 79, India already suffers from acute water shortage, with 68 per cent of its area prone to drought and 33 per cent chronically drought-prone. The shrinking of Himalayan glacier ranges will drastically cut down water availability to Uttar Pradesh and Bihar, and UNFCC projects one-fourth of Gujarat and 60 per cent of Rajasthan are likely to experience acute physical water scarcity, as are the river basins of Mahi, Pennar, Sabarmati and Tapi. As per Institute for National Strategic Studies. Global Strategic Assessment 2009. America's Security Role in a Changing World. NDU Press: Washington, DC 2009, p. 3: "In India, urban water demand is expected to double and industrial demand to triple by 2025." And per U.S. Department of Energy. The Final Proceedings of the Solar Power Satellite Program Review. Lincoln, Nebraska: 1980. http://www.nss.org/settlement/ssp/library/1981DOESPS-Final Proceedings Of The Solar Power Satellite Program Review. pdf, p. 609, "The coal and nuclear fuel cycle require several orders of magnitude more water than any of the photovoltaic technologies [PBSP]. Water pollution is a relatively insignificant problem with the steam technologies but evaporation losses are critical and

limit the siting of coal and nuclear power plants in water short areas… the development of SPS considerably reduces the estimated quantity of water required to produce electrical energy – by more than currently used today to produce electrical power. Hence, SPS offers large potential benefits to water short areas; the same areas for which it is also advantageous for other reasons (i.e., high isolation, the presence of large continuous land areas, and the relative availability of lower quality land)." Keeping in mind that India will have significant water shortage problems, and that it is simultaneously pushing a huge expansion in nuclear power, it is important to have a sense of scale. Per EPRI (http://mydocs.epri.com/docs/public/000000000001006786.pdf), *a nuclear power plant may withdraw between 1,893-227,124 litres/MWh, and may consume between 1,514 to 2725 litres/MWh in evaporation depending on cooling technique* (once-through, pond cooling, or cooling towers). For a 1,115-1,150 MW Advanced Pressure Water Reactor (AP1000), the DOE has stated it would require between 450,000-750,000 gallons per minute [1,703,435-2,839,058 Liters/minute, or 1.7-2.8 ML/min]. Annually, whereas a fossil fuel plant will withdraw 663 megalitres/MW, and consume 10 ML/MW, a nuclear once-through will withdraw 829 ML/MW and consume 13 ML/MW and return the rest at 11-17 deg C warmer; pond cooling withdraws 17 ML/MW and consumes 13ML/MW, tower cooling withdraws only 27 ML/MW, but consumes 24 ML/MW (http://www.aph.gov.au/library/pubs/rn/2006-07/07rn12.pdf). In DAE's 2052 world where Nuclear has an installed capacity of 275 GW generating 2,044 TWh would require a withdrawal between 3,869,292 and 464,241,456 ML/annum, and consume between 3,094,616 and 7,425,000 ML/annum through evaporation. *That is a potential withdrawal of 38.7 per cent of the annual flow of the Ganges-Brahmaputra system just for 25 per cent of India's power needs!* (http://www.mdbc.gov.au/subs/eResource_book/index.htm : The river system discharges 38ML/sec x 365 days x 24 hours/day x 60 minutes/hr x 60 sec/min = 1,198,368,000 ML/annum), and an evaporation of 0.6 per cent. *And a 554 GW SBSP system could potentially save India as much as 935,234 GL/annum in withdrawals and 14,958 GL/annum in water consumption.* The same IDSA report, p. 129, states that the annual runoff in the Brahmaputra basin is likely to be reduced 14 per cent by the year 2050 due to climate change.

17 Asakura, Keiichiroy, Patrick Collins, Kojiy Nomura, Hitoshiy Hayami, and Kanjiy Yoshioka. CO2 Emission from Solar Power Satellite through its Life Cycle: Comparison of Power Generation Systems using Japanese Input-Output Tables. Keio Economic Observatory, Keio University, Japan & Department of Environmental Policy, Azabu University, Japan, July 2000. Available at http://www.iioa.org/pdf/13th%20conf/Asakura Collins Nomura Hayami & Yoshioka_LifeCycleCO2.pdf (accessed August 16, 2009).

18 Xin et all contains an excellent discussion of various studies in section 5.3, however the key sentences for policymakers are: "Many studies have been done with respect to the effects of a on the earth. *They have concluded that if constructed correctly, there will be either no or marginal impacts to humans, animals come and the environment as a result of a SSPS' operation. This cannot be said for many state-of-the-art electricity production methods currently in use."* Xin, p. 16.

19 "The only demonstrated biological effect of microwave exposure, which is, to date, heating. *To put 30 mW/cm2 in perspective, the energy generated by a typical kitchen microwave oven is approximately 1,000 mW/cm2. So such peak power densities and vision for SSPS could never even come close to 'cooking' birds or aircraft in flight."* Xin, p. 16.

20 Individual Space Solar Power Systems (Satellite, Rectenna) *Costs for a 1 GW system range between a low $5.1 billion to $23.12 billion high after an R&D investment of $35-100* billion. Wingo, Dennis, Unpublished Manuscript. Xin et all also have an excellent discussion of development costs and Net Present Value calculation in Section 9.2 as well as niche market applications in section 10. They list higher development costs ranging from 132.5 billion based on earlier NASA studies to 265 billion based on ESA studies.

21 Mike Snead in Space Review, "The Vital Need to Develop Space Solar Power." May 4, 2009, at http://www.thespacereview.com/article/1364/1

Sky's No Limit

22 While such common concerns as safety of humans, wildlife, ionosphere, aircraft, large satellite and ground receiver vulnerability seem to be well answered at the basic level, they certainly deserve more study, particularly with reference to policymaker equities. Additional concerns, such as management of space traffic, debris, maintenance and repair, effect on low-flying satellites, and effect of this new space and terrestrial infrastructure on human habitation and commerce patterns, while not as prominent, also need further elaboration in the language useful to policymakers.

23 Note that whereas the security of India's hydrocarbons does not extend past 25 years, and its coal beyond 45 years, and its entire store of uranium and thorium just hundreds of years (if it had to take over for coal), our Sun is projected to be secure as a source for at least a billion years, making SBSP over 1,000,000 times more source secure.

24 National Solar Plan, p. 1.

25 IEP, pp. 54-57: "We define energy security as follows: we are energy secure when we can supply lifeline energy to all our citizens irrespective of their ability to pay for it as well as meet their effective demand for safe and convenient energy to satisfy their various needs at competitive prices, at all times with the prescribed confidence level considering shocks and disruptions that can be reasonably expected." The paper discusses three types of risk: supply risk (meaning some external disruption in supply or availability either globally or specifically to India), market risk (meeting a sudden increase in the price), and technical risk (implying internal failure of some kind of the various distribution systems)."

26 IEP, p. xxiv: "Ensuring energy security requires dealing with various risks. The threat to energy security arises not just from supply risks and the uncertainty of availability of imported energy and also from possible disruptions and shortfalls in domestic production… even if there is no disruption of supply there can be market risk of sudden increase in energy prices. Even when the country has adequate energy resources technical failures may disrupt the supply of energy to some people. Generators could fail transmission lines of a trip or well-publicised elite. One needs to provide security against such technical risks."

27 The principle risk of an SBSP system is technical, but in practice a large number of satellites would have significant redundancy and load-sharing capability that would likely reduce this risk. Since the satellites are likely to be owned by governments or their corporations, or via an international legal entity like COMSAT/INTELSAT, supply risk and market risk is likely to be much less volatile than fossil fuel sources that depend upon spot prices, extractive capability, and foreign nation stability. *Various thinkers have examined the question of terrorist or deliberate national attack, but the most vulnerable segment of the system is on the ground where power is collected for transmission, the same as a nuclear power plant.* For an in-depth discussion of security issues, see NSSO report on Space Solar Power, the OTA Report, and the Vajik Report, available at http://www.nss.org/settlement/ssp/library/index.htm

28 National Solar Plan, p. 1: "India is endowed with vast solar energy potential… solar energy scores on an environmental impact (close to 0)… solar is currently high in absolute costs compared to other sources of power like coal. However, the mission's *objective would be to drive down costs as rapidly as possible, to Rs 4-5/kWh by 2017-2020* timeframe (2009 as base year), making solar very competitive with respect to other fossil fuel-based power sources."

29 Energy Sector R&D Working Group, p. ix: "Research and development in the energy sector has to be aimed at achieving energy security while ensuring harmony with the environment. To meet the ever-increasing demand in the country for environment friendly and sustainable manner, one has to look for clean coal technologies, safe nuclear and innovative solar. In the Indian context, some of the steps one could consider

for taking up in the 11th year plan are the following: intensification of exploration for all energy sources; developing *methods for exploiting energy sources currently considered unviable*; increasing the share of hydro, nuclear and *renewable sources* in the energy mix; looking for breakthrough technologies for exploiting renewable sources, *particularly solar* which is very high potential in the country; strengthening power delivery infrastructure so as to ensure quality... and provide for large interregional transfer."

An Evaluation of Space-Based Solar Power In The Context of Current Important Problems on the Policymaker's Agenda

This chapter examines the extent to which a policy proposal of space solar power is responsive and relevant to the US and Indian domestic agendas, as well as to their shared bilateral agenda, and suggests there is presently an open window of action for policy innovation.

SBSP in the US Political Context

Key themes in the US 2008 Presidential election, which became prominent in national debates, included the need to respond adequately to the global financial crisis, the need to find viable strategies to achieve US national ends in Iraq and Afghanistan, the degree, kind, tone and emphasis of international engagement, the degree of multilateral engagement, the creation and maintenance of high quality jobs to ensure competitiveness in a globalised world, US energy policy, and the US position on climate change. The election of Barack Obama affirmed the US electorate's preference for a less aggressive and unilateralist foreign policy, an affirmation of the regulatory and activist role of government in the economy, a mandate and expectation of effective action on US energy security,[1] and proactive and effective international leadership on climate change. To be effective, President Obama must be able to show the effectiveness of an inclusive, engaging international diplomacy. He must visibly strengthen international partnerships in ways that are perceived to positively affect security and stability with respect to terrorism, Afghanistan, and Iraq, as well as allow forward movement on climate change and effective action toward an international economic recovery that will be felt at home in US jobs and the domestic economy.

The US is looking for effective policy solutions that allow it to make friends, solve its energy problems and mitigate climate change problems. Given the scale of the problems and timescales to bring about change, these are likely to continue be persistent and important issues in US foreign policy for several administrations to come. President Obama has already committed significant resources toward these ends, stating in his first major science address that "We will not just meet, but we will exceed the level achieved at the height of the space race, through policies that invest in basic and applied research, create new incentives for private innovation, *promote breakthroughs in energy* and medicine, and improve education in math and science." President Obama said finding a solution to the country's

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energy and economic problems may prove more daunting than the space race challenge that forced the last massive increase in science spending. "The fact is, there will be no single Sputnik moment for this generation's challenge to break our dependence on fossil fuels…In many ways, this makes the challenge even tougher to solve – and makes it all the more important to keep our eyes fixed on the work ahead." President Obama stated that his administration will devote more than 3 per cent of the US GDP to R&D, provided details of what his administration will be doing through the economic stimulus law and other budget resolution increases, including $21.5 billion for R&D in the 2010 budget with over $150 billion over 10 years for renewable energy research, $75 billion to make the research and experimentation tax credit permanent, $777 million to support 46 energy frontier research centres, and $400 million in initial funding of Advanced Research Projects Agency-Energy (ARPA-E) projects for breakthrough technologies in energy and a joint Department of Energy/ National Science Foundation (DOE/NSF) programme to urge students to pursue careers in science engineering and entrepreneurship related to clean energy. [2]

A lesser issue, but one related to this topic, concerns the future direction of America's space programme. The Obama Administration inherited an ambitious, but underfunded,[3] 'Vision for Space Exploration (VSE)',[4] which has received significant criticism both in its goals and in its implementation, and is now in a sensitive period following the negative review by the Augustine Commission. This administration will be looking for new directions to differentiate itself and there are a number of advocates for Space Solar Power connected to the administration.[5] SBSP, therefore, appears to be well-aligned with the overall mandate and agenda of the current US administration.

SBSP in the Indian Political and Developmental Context

The most compelling political problem for India is inclusive growth for development. Maintaining such growth is important to accomplishing India's moral purpose and goals, as well as maintaining internal cohesions and political stability.[6] Despite very significant gains and with the strongest global GDP rates and middle class growth, 27.5 per cent of Indians live below the poverty line and 44 per cent are without electricity.[7] As many as 300 million Indians have an income of monetary resources below Rs 545 ($11) per month; 51 per cent of the children are still undernourished; more than 350 million Indians suffer from illiteracy; 318 million do not have access to safe drinking water; 250 million do not have access to basic medical care; and 630 million lack acceptable sanitation.[8] As of

2000, 84 million households, 12 per cent of urban and 57 per cent of rural (44.2 per cent of total households), lacked electricity, and as of 2006, 125,000 villages were still without electricity.[9]

There is remarkable consistency across all the government documents analysed for this report in recognising this fundamental priority.

A clear summary of India's present political context and priorities is contained in President Patil's address to Parliament following the 2009 elections, which establishes inclusive growth as the central theme and an overall plan to enable it through infrastructure, public private partnerships (PPP), enabling regulation, *integrated energy policy (that hopes to add 13 GW of power a year), emphasis on renewables, stimulation of science and technology and emphasis on innovation, a space programme that pays rich dividends to society, proactively addressing climate change (through a variety of missions, including a National Solar Mission), the positive transformation of the Indo-US relationship,* and affirming India's role as a responsible member of the international community to work on areas of common concern, such as international terrorism, the global economic crisis, climate change, and energy security.[10]

The themes discussed above are directly reflected in India's planning and implementing documents: The Planning Commission's Eleventh Five Year Plan (2007-2012) "Inclusive Growth", Integrated Energy Policy (IEP), National Action Plan on Climate Change (NAPCC), National Solar Plan (NSP), and supporting Report on the Working Group on R&D in the Energy Sector for the formulation of the Eleventh Five Year Plan (2007-2012) (ESWG).

It would appear that the SBSP concept is well matched to several major items on the Indian agenda, so much so that it might fit in well as a new flagship programme under the new government. India's specific need for space solar power is discussed later on.

SBSP in the Context of the Needs of the Bilateral Strategic Partnership

Early in his Presidency, President Obama articulated that India "had no better friend in the world than the US" and that the two nations "shared belief in democracy, liberty, pluralism and religious tolerance", and suggested that scientists of both countries should solve the environmental challenges together.[11] The high level visit by Secretary of State Hillary Clinton in July 2009 showed great continuity with the previous administration's Next Steps in Strategic Partnership (NSSP),[12] which had laid out intended steps to be taken in "energy and environment", "democracy and development", and "high technology and space" and then set up high-level dialogues in energy, civil space, and defence cooperation. The official press release of the Department of State articulated the following pillars of the strategic partnership[13] following Secretary Clinton's visit:

i. Strategic Cooperation: working groups will address non-proliferation, counter-terrorism and military cooperation;
ii. Energy and Climate Change: working groups will continue our successful energy dialogue and begin discussions on actions to address the challenge of global climate change;
iii. Education and Development: working groups will enhance our partnership in education and initiate discussions about women's' empowerment;
iv. Economics, Trade and Agriculture: working groups will continue and strengthen our discussions on business, trade and food secu rity; and
v. Science and Technology, Health and Innovation: working groups will explore new areas for cooperation in leading technologies and in addressing global health challenges.

And the US-India Joint Statement of July 20, 2009, likewise articulates sustainable growth and development, education, space, science and technology, high-tech cooperation, energy security, environment and climate change as important areas of mutual interest in cooperation.[14] More specific to SBSP, when Prime Minister Manmohan Singh's Special Envoy on Climate Change Mr. Shyam Saran met the US President at the White House at an official reception, Obama, whose administration is focusing on alternative sources of energy so as to reduce dependence on fossil fuel, was quick to remind him of the conversation he had in this regard with Singh in London early in April about building an Indo-US renewable energy partnership. Saran reported, "In that context he (Obama) said that we are very much looking forward to what had been agreed upon during that meeting that *India and the US should seek to build up a renewable energy partnership," which will end up benefiting not only the two countries, but also the entire world.*[15] *It would thus appear that the SBSP concept can be well matched with the articulated agenda and emphasis on energy, environment, space, and high technology. Given that there is still an active search for a major item to keep the momentum going after the civil nuclear deal, and to appear to be taking significant action on energy and climate change, it would appear that there is currently an open policy window of action.*

In fact, Inderfurth and Mohan's[16] well-timed piece arguing that space should be put at the heart of US-India relations as it can literally "lift relations to a higher orbit", seemed to find a strong echo in the Singh-Obama Joint Statement, which within a broader context of assuring each other (and answering concerns of neglect[17]) that their fundamental strategic goals were convergent under the new administrations,[18] said, "They agreed to collaborate in the application of their space technology and related capabilities in outer space and for development purposes."[19]

Does India Need Space-Based Solar Power?

Space-Based Solar Power is directly relevant in the context of the Indian vision on energy, development and climate, as there are no suitable solutions yet that have emerged. As Nitin Desai recently remarked at the release of the Report of the IDSA Working Group on Climate Change, *"there is no fossil fuel future for India."*[20]

India's Energy-Climate Situation

A country's total energy demand or usage is measured as primary energy,[21] which is the raw energy input to the system and is usually measured in millions of tonnes oil equivalent (MTOE),[22] quadrillion BTUs (Quads or Q-BTU),[23] Exajoules (EJ),[24] or gigawatt-years (GW-yrs).[25] Primary energy is further divided into non-commercial energy sources that are collected from nature and used directly, and commercial energy, which is traded and supplied as a commodity (measured as total primary commercial energy supply or TPCES).[26] In 2002-03, India consumed 18.96 EJ (453 MTOE, 601 GW-Yr, 17.97 Q-BTU[27]) of total energy, of which 71 per cent (13.46 EJ, 12.77 Q-BTU, 321 MTOE, 426.82 GW-Yr) was commercial, and 29 per cent (5.49 EJ, 5.2 Q-BTU, 131.2 MTOE, 174.1 GW-Yr) non commercial.[28,29] The non-commercial portion consists mainly of traditional biofuels like wood and cow dung,[30] which cause severe indoor pollution, health problems and disproportionately affect women,[31] with an estimated annual health and economic opportunity cost of $6 billion to the nation.[32] The total primary commercial energy supply (TPCES) for 2003-04 had the following share breakdown: 51.07 per cent coal (mostly for electricity), 36.39 per cent oil (mostly for transportation fuels), 8.87 per cent natural gas, 2.14 per cent hydro, and 1.53 per cent nuclear.[33] DAE estimates that as of 2002, India used approximately 13.46 EJ of primary commercial energy, of which 6.75 EJ (214 GW-Yr, 161.2 MTOE) or 57 per cent of primary energy went to producing 638 TWh of electricity[34] and this share was increasing.

Electricity As of August 31, 2009, India had an installed capacity of 152 GW, with the following breakdown: 64.3 per cent thermal (fossil fuel), and 35.7 per cent nuclear and renewables, with the following contributions in descending order: 52 per cent coal (80.28 GW), 24 per cent hydro (36.9 GW), 10.8 per cent gas (16.38 GW), 8.7 per cent renewable (12.24 GW), 2.7 per cent nuclear (4.1 GW), and 0.8 per cent diesel (1.2 GW)[35].

However, the actual contribution depends not just on nameplate power but on the percentage of time the plant is in operation or the plant load factor (PLF).[36] For instance, in 2002, a total installed capacity of 138.73 GW produced 638 TWh (614KWh per capita). While coal[37,38] was listed as 51.84 per cent of capacity, it actually produced 66.69 per cent (425.74 TWh) of actual generation; hydro, which was 20.02 per cent (65.66 TWh) of capacity produced just 10.29 per cent of actual generation, and nuclear, which was 1.96 per cent of capacity produced 3.01 per cent (19.25 TWh) of generation, and non-conventional renewable (wind and solar), *which was 2.52 per cent of capacity produced only 0.42 per cent of actual generation.*[39]

As of 2006, India is the fifth largest producer of CO2 emissions after China, the US, the EU, and Russia at 1,510.351 million tonnes (5.3 per cent of global emissions),[40] *with emissions in the consumption of energy accounting for the largest share, 85.6 per cent or 1,293.169 million tonnes*[41] followed by industrial processes being the next largest sector.[42]

Development Status

Despite the magnitude of the above figures, India's energy economy is severely underdeveloped. Compared to Japan, a country with similar population density, and an overall enviable energy and carbon intensity of only 4,469.576 BTU per Dollar GDP, India was required 24,224.427 BTU per Dollar GDP, in 2006.[43] While Japan's carbon intensity is only 0.244 metric tonnes of CO2 per thousand Year 2000 dollar, India's is 1.801. In fact, Indian citizens overall enjoyed only one-eighth or 12.7 per cent the level of energy available to Japanese citizens (512.5 kgoa/a[44] India vs. 4,040.4 kgoa/a Japan) in 2003.[45] For electricity, the Indian citizen's average power per capita in watts is only 5.8 per cent or 1/17th[46] of their Japanese counterparts as recently as 2005. While there has been some recent improvement, as of 2003 the average electricity consumption per capita was 553 kWh,[47] with 44 per cent of its citizens being without any electricity.

For those Indians who have access and pay for electricity, the fast growth in demand[48] coupled with adequate investment in infrastructure and supply[49] has meant significant shortages,[50] with an average electricity shortage of 10 per cent and a peak power demand shortage of 15 per cent.[51] Given the high AT&C losses of 40 per cent,[52] India's citizens paid significantly more per capita in terms of purchasing power parity for a unit of energy than other countries.[53]

Despite India's extremely small per capita greenhouse gas (GHG) emissions, it already accounts for 5.3 per cent of global emissions[54] of which to over 85 per cent of CO2 comes from energy. India currently uses 0.16 KG[55] oil equivalent per dollar GDP PPP[56], in part because 56.4 per cent of India's workforce is engaged in agriculture which contributes 21 per cent of India's GDP.[57] With an overall net energy import dependence of just below 30 per cent (22 per cent according to some[58]), India currently depends on imports[59,60] for 72 per cent of its oil[61], with demand growing at 5.7 per cent per year[62] and that growing dependence exposes it to shocks.[63,64]

India's Energy Strategy
Growth First

Indian planners recognise the strong correlation between energy and human development,[65] and the critical dependence of economic growth on energy availability.[66] They acknowledge that *for India to meet its developmental goals to emerge from poverty, it must grow at 8-9 per cent*[67] *for at least 25 years,*[68] *and that power and water are likely to be the most difficult problems that will constrain growth.*[69] Water problems may be solvable with desalination but this solution is quite energy intensive.[70] The policies acknowledge the problem of import dependence and inadequate domestic sources.[71] Indian planners acknowledge the reality of climate change[72] and warming,[73] its anthropogenic cause,[74] and recognise the economic, social and security costs of climate change.[75]

Although India seeks to act as a responsible and enlightened member[76] of the global community,[77] it recognises that climate change is a collective problem that involves externalities.[78] Ultimately, while India acknowledges climate change can be costly, it prioritises growth[79] and poverty elimination over GHG mitigation,[80] seeking solutions that advance both development, and energy / environmental goals in concert. No specific costs for climate change to India were found, however the Grantham Institute for Climate Change reviewed various estimates, which range from $4-109 billion *per annum* for low income Asian countries and noted that the UNFCCC report, which saw $27-66 billion per annum cost for developing countries, was most likely a substantial underestimate.[81]

Renewable R&D in India's Strategy

The 11th Plan reflects the importance of the environment[82] and a strong appreciation of the importance of renewables,[83] and the importance of R&D to develop new sources[84]. India's NAPCC[85] and Solar Mission[86] acknowledge the importance of an ecologically sustainable path[87] and the need to shift from activity based on depleting fossil fuels to reliance on renewable sources of energy, with particular emphasis on solar[88] because of its abundance[89] in India, its clean nature, low environmental impact,[90] and renewables' positive effect on energy security and displacement[91] of fossil fuels.[92] Therefore, India's R&D community believes that now is an ideal time[93] to invest in renewables and that given their long-term benefits, subsidies are justified.[94] However, as reviewed above, renewables are a small proportion[95] because: "Renewable energy generation systems…were considered less economical than fossil fuel plants as they entailed high capital costs, inconstant energy supplies causing highly volatile energy outputs and need for backup systems for deviation control purposes. Also from the security point of view, most analysts agree that electricity available on a predictable basis is far more valuable than that which is dependent on nature's whims."[96] Solar is currently significantly more expensive[97] than other forms of power and also suffers from cyclical variations that require hybridisation or storage, with storage beyond 12 hours appearing uneconomic.[98] There is also a recognition and concern that solar energy requires significant amounts of land[99], on the order of 5 to 6 acres of land per megawatt [20.23 to 24.28 sq km / GW (4.498 km to 4.92 km per side)][100] and impairs aesthetics.[101] Nevertheless there is a clear policy in the IEP,[102] 2005 New and Renewable Energy Policy,[103] NACC, and NSP to develop renewable sources and conduct R&D to reduce costs, and has already begun taking some action.[104]

India's $19 billion, 30-year National Solar Plan, to be launched on November 14 of this year,[105] which aims to install 20 GW of capacity by 2020,[106] is at once extremely ambitious[107] and also just a small drop in the bucket, given that the estimated additions are not in the tens, but hundreds of gigawatts.

India's Projected Energy-Climate Future

India plans to grow at 8-10 per cent to eradicate poverty and meet its developmental goals[108], and that requires it to increase its primary energy by 4.3-5.1 per cent to a level 3 to 4 times above 2006 levels to reach 1351-1702 MTOE[109] (56.52-71.2EJ, 55.39-69.78Q-BTU, 1,792.25-2,257.75TW-yr) and electricity must grow 5-7 times over 2006 levels by 2032[110], adding 600 GW over the next 25 years[111] to reach 778-1207 GW by 2032[112] and generate 3,880-4,806 billion kilowatt hours. Even in 'scenario 11'[113], the most energy efficient scenario, with forced hydro (addition of 63 GW)[114], maximum nuclear, and a 40-fold[115] increase in renewables, India's future population of 1.468 billion people require 1,536 MTOE[116] and coal remains dominant[117] at 61 per cent[118] having grown between 5.9 and 6.3 per cent to be consumed at 3.6 to 4.1 times its 2004 levels.[119] To put that in perspective, China's current consumption is 1100-1200 MTOE and the US is 2400-2500 MTOE. On a per capita basis, after 25 years of aggressive development, India will still only be consuming at current levels in China and 15 per cent of current US levels.[120] *It should be noted that all this requires very significant capacity additions that historically have never been met*[121] *(sometimes falling as much as 70 per cent below target*[122]*) and will require investment of the order of $2-2.2 trillion, inclusive of related infrastructure.*[123]

By 2032, nuclear power's contribution is only expected to be 9 per cent or 98 GW. Even that modest goal assumes a growth of nearly 20-fold despite acknowledgments that nuclear power's growth may be constrained by multiple factors,[124] including workforce challenges and unproven waste disposal at large scale.[125]

If, however, all parts of India's 3-phase programme work as planned, thorium will be a significant factor after 2050,[126] and nuclear power might supply as much as 20 per cent of generating capacity (275 GW), producing 26 per cent of electrical power in 2052, when the total generating capacity is seen at 1,344 GWe and 7,957 TWh to deliver 5,305 kWh[127] per capita vs. today's 704.2 kWh. However, *even then, coal is projected to be 46 per cent of installed capacity and 47 per cent of all generation*. The need to address fundamental long-term questions therefore remains compelling.[128]

An Evaluation of India's Energy-Climate Strategies

Will India's impressive plans for a massive ramp-up in hydro-electric, nuclear and renewables make it more secure in terms of energy security and the environment? Unfortunately not. *Despite what can only be termed as heroic efforts, India's total annual carbon emissions in 2032 are likely to be 4-6 times what they are today, between 3.9 and 5.5 billion tonnes and roughly equivalent to the contribution of the US today.*[129, 130]

Imports and Fossil Fuel Dependency

India is likely to become significantly more dependent on fossil fuel imports, requiring 4-5 times what it imports today,[131] and moving from the current 30 per cent dependence to 40-45 per cent (even as high as 59 per cent in some scenarios) of its commercial energy requirement.[132] India's hydrocarbon resources[133] are grossly inadequate,[134] with oil and gas expected to be completely exhausted in 23[135] (~2029) and 38 (~2044) years, respectively.[136, 137] This gigantic increase in demand will take place against a background of increasingly constrained global supply[138] and stagnant outputs[139] and uncertain global supplies.[140]

Limits of Sustainable Energy Contribution

On the current course, India will be neither more climate nor energy secure. The country's Integrated Energy Policy contains the following disturbing paragraphs that put the problem in perspective:

"Even if India succeeds in exploiting its full hydro potential of 100-150,000 MW, the contribution of hydro energy to the energy mix will only be around 1.9-2.2 per cent (primary energy). Similarly, even if a 20-fold increase takes place in India's nuclear power capacity by 2031-32, the contribution of nuclear energy to India's energy mix is also at best expected to be 4.0-6.4 per cent."[141]

"With a concerted push in a 40-fold increase in their contribution to primary energy, renewables may account for only 5 to 6 per cent of India's energy mix by 2031-32."[142]

"A disturbing fact that emerges from the study of various scenarios is that even if India somehow succeeds in raising the contribution of renewable energy by over 40 times by 2031-32, inclusive of a renewable power capacity of 100,000 MW (compared to 6161 MW as of March 2005); the contribution of renewable store energy mix will not go beyond 5.6 per cent of total energy required in 2031-32." [143]

"The integrated analysis of various energy resources and supply options reveals that *even under aggressive growth assumptions for hydro (5 times current levels) and nuclear (20 times current levels), the contributions of the two together cannot exceed 8-10 per cent of commercial energy supply in 2031-32*… renewable energy, even when it rises to 40 times its current level will, at best, meet only about 5 to 6 per cent of India's commercial energy demand by 2031-32. Fossil fuels maintain their domination in India just as in other parts of the world. The share of coal varies between 41 per cent and 54 per cent, and that of oil and gas together between 32 per cent and 41 per cent of energy. Abundant thorium and solar resources might become important sources for India beyond 2050 provided we promote R&D now to be able to realise this potential in the future. Under the most optimistic scenarios for hydro, renewable and nuclear growth, the domestic supply levels for coal (3.8 times current levels), oil (three times current levels) and gas (more than five times current levels), *India's import dependence for commercial energy in 2031-32, would range from a low of about 29 per cent in the* *most energy-efficient scenario to about 59 per cent in the most energy intensive scenario.* Realistically speaking, it is likely that India would need to import some 40 to 45 per cent of its commercial energy requirement compared to the current level of under 30 per cent. Domestic commercial energy supplies will then need to rise four times on aggregate over the next 25 years if import dependence for commercial energy is not to exceed 40 per cent."[144] As stated in India 2039, "More fundamentally, the current policy is driven mainly by India's geopolitical negotiating stance rather than by what is good for Indian citizens and what is in India's long-term self-interest. This basic mindset must change. Neither the draft policy on the environment nor the pattern of development that underlies it is sustainable. Even under optimistic forecasts for nuclear and hydro power projects, coal-fired power plants are expected to generate 60 per cent of India's electricity in 2030."[145]

Optimal Performance in Doubt

There is even reason to doubt that the plan will be successful in meeting India's development goals, as past capacity additions have historically not been met and been disappointing[146] as a result of a number of factors. Energy and water are the biggest constraints to India's growth[147], as affirmed by Chief Negotiator for the US-India Civil Nuclear Deal and now Special Envoy for Climate Change, Mr. Shyam Saran, *"For us to make certain that energy does not become a constraint on our growth, we have to literally expand every source of energy that is available to us. And even then, there may be a wide gap between demand and supply of energy."*[148] If the necessary projections in supply additions cannot be assured, India will not be able to grow at 8 per cent[149] with resulting constraints on growth and competitiveness.[150] Gopalaswami's study suggests that *there are real impediments* to capacity addition, and that a "business as usual approach" cannot result in a growth rate higher than 5 per cent, resulting in an opportunity cost of $103 trillion in Indian GDP between now and 2050.[151] He echoes the words of the father of India's nuclear programme, Homi Bhabha, who famously noted that "No power is costlier than no power."

Limits of Nuclear Power and Coal in the Long Term

Even the long-term DAE study, which projects an extremely aggressive growth via India's three phase nuclear programme, says India will only achieve 25 per cent of the electrical requirement (not total energy) with nuclear power,[152] and will continue to rely on coal for half of its power needs.[153] That is *particularly disturbing because* the Indian Government estimates state that at the current rate of production, India's coal reserves will last 80 years[154], but at the projected growth of 5 per cent a year[155] (actual estimate is between 5.9 and 6.3 per cent)[156], *they will be completely exhausted in 45 years(~2051).*[157] Indian coal may not even last that long, as it faces problems of deterioration.[158] Further, there is reason to doubt the market availability to supply India's need with imports, as the Energy Watch Group predicts a peak in global coal supply at only 30 per cent above current levels by 2025-2030.[159]

The Need for Green Electricity

All of this points to the need expressed by Tom Friedman in 'Hot, Flat and Crowded': "Our challenge today, as individual nations, and as a civilisation, is to develop a clean energy system that can do exactly that—enable ordinary people to do extraordinary things—in terms of generating clean electrons, steadily improving our overall energy and resource efficiency, and promoting conservation. This is our biggest challenge because only such a system will enable us to grow as a world economy—not only without exacerbating energy supply and demand issues, petrodictatorship, climate change, biodiversity loss, and energy poverty, but while actually reducing them at the same time…*No single solution would defuse more of the energy-climate era's problems at once than the invention of a source of abundant, clean, reliable, and cheap electrons…Give me abundant, clean, reliable, and cheap electrons,* and I will give you a world that can continue to grow without triggering unmanageable climate change. Give me abundant, cheap, reliable, and cheap electrons, and I will give you water in the desert from a deep generator-powered well. Give me abundant, cheap, reliable, and cheap electrons, and I will put every petrodictator out of power. Give me abundant, cheap, reliable, and cheap electrons, and I will end deforestation from communities desperate for fuel and I will eliminate any reason to drill in Mother Nature's environmental cathedrals. Give me abundant, cheap, reliable, and cheap electrons, and I will enable millions of the world's poor to get connected, to refrigerate their medicines, to educate their women, and to light up their nights. Give me abundant, cheap, reliable, and cheap electrons, and I will create networks where people all over the world will start contributing their energy innovations like programmers creating shareware on the World Wide Web…The ability to generate clean electrons is not a solution to every problem, but it is the enabler of solutions to more problems than any other single factor I can think of…And that is why job number one of the clean energy system is to stimulate innovation. Because no one has yet come up with a source of electrons that meets all four criteria: abundant, clean, reliable, and cheap."[160]

R&D

Indian planning documents acknowledge R&D in the energy sector is critical for augmenting sources to raise their energy security,[161] *and that indigenous research must be supported by the government and considered a public good, especially where benefits are not seen in 3-5 years.*[162] It affirms support from basic R&D to achieve conceptual breakthroughs, to pilot plants to commercialisation[163] and the long gestation times required for energy projects to come to fruition[164] and acknowledges that to be successful, it must be sustained over decades[165] and supplied with adequate skilled manpower.[166, 167] The policy documents acknowledge the importance of provenness and the need to mature pre-commercial technologies with early interaction with users,[168] to facilitate demonstration projects attractive to customers.[169] India already has a vision to be a global leader in power plant equipment,[170] and is now seeking to move into renewable technologies with the main R&D objective to reduce costs,[171, 172] and certain thrust areas already identified. Both the IEP[173] and the Energy Sector R&D Group[174] recommended a National Energy Fund, as well as long-term (20+ year) financing, and an apex body on energy under the Prime Minister, and an annual report on progress in renewables,[175] and an amount of $1.06B to be dispersed on energy research through the DAE.[176]

India has a developed philosophy for R&D[177] that involves three approaches, "development missions that require coordinated research and development at all stages of the innovation chain to reach a targeted goal such as in the departments of atomic energy and space research; technology rollout missions to develop and roll out commercial or near commercial technology such as the missions to provide rural telephony; and broad-based R&D support to research institutions, universities and others through project funding."[178, 179, 180]

The US' Energy-Climate Situation

While US energy problems and policy are generally well known and debated, a short summary is provided for comparison with the expanded discussion on the Indian energy-climate situation above.

In terms of size, the US energy economy is five times that of India's in terms of consumption (100 vs 18 Quads), but services only approximately one-third the number of citizens (308,798,000 vs 1,177,803,000[181]), and puts out roughly four times as much CO2 (5,752,289 vs 1,510,351) in current annual emissions.[182]

US citizens consume approximately 15 times as much energy per capita (7,794.8 kgoe, or 327 GJ or 10,381 Watts) as current day Indians

(412 kgoe or 21 GJ or 682 Watts)[183], and emit nearly 16 times as much CO2 per-capita (19.1 vs 1.2)[184], with an energy intensity (GDP dollars per tonne of 2,291 for the US compared to 579 for India), or in PPP terms 2,291 vs 1,770.[185]

Structurally, the US energy economy spends about 27.2 per cent of its energy on transportation, 33.4 per cent in the Industrial sector (including no-fuel use of energy stocks), and the largest share, 39.4 per cent going to residential / commercial. Residential is also the leading source of GHG emissions, putting out 2206 MMT, followed by industrial at 1850 MMT, and then transportation at 1674 MMT.[186]

Like India, coal figures prominently in US energy. Coal accounts for 22.9 per cent of total energy resource consumption (39.2 per cent Petroleum, 23.7 per cent natural gas and 8.4 per cent nuclear), but over 50.9 per cent of electricity generation, with the balance being made up of nuclear 20.6 per cent, natural gas 15.9 per cent and hydro 6.5 per cent.[187] Coal is also the largest GHG contributor, at 2070 MMT, followed by petroleum at 2453 MMT and natural gas at 1203 MMT.[188]

The US energy sector is much more developed and less dynamic. While India's primary energy demand will surge to 3-4 times by 2032, US energy demand is only expected to grow 15 per cent (from 100 to 115 Quads) by 2035 (despite an increase in population of almost 28 per cent).[189] Electricity, rather than growing at 7 per cent annually in India, is only growing at approximately 1 per cent annually.

Although the plan forwarded by the Obama-Biden "New Energy for America Plan" envisaged the US reducing its energy demand by 15 per cent by 2020 and getting a quarter of its energy from renewables by 2025, current EIA projections suggest that energy demand will likely grow and the share of renewables is only likely to be 5.5 per cent even 10 years later, with the breakdown being: 32.5 per cent petroleum, 22 per cent coal, 22.2 per cent gas, 8.2 per cent nuclear, 8.1 per cent biomass, 2.6 per cent hydro, and 2.9 per cent other renewables. A bright side of the story is that energy related carbon emissions will have grown very modestly from 5,814 MMT to 6,320 MMT, and the energy intensity of thousand BTU per year 2000 dollar GDP improves from 8.59 to 5.12.[190]

However, the US also faces similarly compelling challenges in the long run. Analysts like Mike Snead point out that by 2100, the US population will have almost doubled (from 307 million to 560 million), and it will require approximately 1.6 times the energy (28 billion Barrels of Oil Equivalent vs 17) required today. *Today 85 per cent of US energy* *comes from non-sustainable sources* (oil, coal, and natural gas). To meet the 2100 need, sustainable energy production must expand by a factor of about 11, effectively meaning that today's total energy production capacity of nuclear, hydroelectric, geothermal, wind, ground solar electric, and land biomass would have to be added every decade through the end of the century.

Snead's analysis suggests that even with very optimistic assumptions about expansion (nuclear from 101 GW today to 175 GW by 2100, hydro expanding from 78 GW to the estimated practical maximum of 108 GW, geothermal from 3 GW to 150 GW, adding 390 square km for land and off-shore wind power[191] and 153,000 square km for ground solar photovoltaics[192] in the southwest desert states, and 1.3 billion tonnes of land biomass), these expanded sustainable energy sources will provide only about 30 per cent of the US' needed 1,750 GW of 2100 dispatchable electrical power generation capacity and about 39 per cent of the needed 17 billion BOE of 2100 annual fuels production. *Snead argues that the shortfall of some 1.200GW of dispatchable power generation and 11 billion BOE annual fuel requirement can be met using space based solar power.*[193]

Notes

1 See Dadwal, p. 6: "Hence, to cut down the US' growing dependence on energy imports, President Obama has devoted a tenth of the $787 billion to be spent under the stimulus bill to energy and the environment, with technologies such as renewables (windmills, solar panels, carbon capture and storage, advanced batteries, 'smart' electrical grids and plug-in hybrid cars all receiving substantial cash incentives."

2 http://www.eenews.net/gw/2009/04/27

3 At its high point in 1966, NASA received 5.5 per cent of the Federal Budget in that year because it was perceived as important to National Security to be pre-eminent in space. *If a proportional commitment existed today for SBSP, that would amount to $219.89 billion. At present, because exploration is no longer considered vital to national security, NASA only receives less than $19 billion, a mere 0.52 per cent of federal budget and proportionally less than a tenth of its high point.* See http://en.wikipedia.org/wiki/NASA_Budget

4 The author has argued elsewhere that what is needed more than a VSE is a Vision for Space Development (VSD): Garretson, Peter, "Elements of a 21st Century Space Policy", *The Space Review*, 3 August 2009, at http://www.thespacereview.com/article/1433/1

5 For instance, NASA Deputy Director Lori Garver, Alan Ladwig, and George Whitesides (both appointed "senior advisors to the NASA administrator") have all previously been supportive of SBSP, http://www.spaceislandgroup.com/pdf/Soft%20Power.pdf and the following white paper was one of the first 10 released for comment by the transition team, http://change.gov/open_government/entry/space_solar_power_ ssp_a_solution_for_energy_independence_climate_change/ and http://www.newscientist.com/blogs/shortsharpscience/2008/12/will-obama-pursue-space-based.html

6 "The collapse of the socialist empire has also altered the range of economic alternatives. The argument…between socialism and the market, is for the moment decisively settled in favor of the market…the challenge of the global economy is ceaseless. The routine

viability of India's democracy will therefore come to be tied more closely to its economic performance, assessed in terms of stability, growth and distribution. Rulers and those who elect them will together have to devise effective practical responses to the opportunities and hazards of the international marketplace. How they respond, what decisions they take about how to exploit or protect India's natural habitat, will also determine the prospects for future generations on the subcontinent…But ultimately, the viability – and most importantly, the point – of India's democracy will rest on its capacity to sustain internal diversity, on its ability to avoid giving reason to groups within the citizen body to harbour dreams of having their own exclusive nation states. Such dreams of partition and domestic purity are animated by the fantasy that all problems begin and end at the border; they do not. There is no ideological or cultural guarantee for a nation to hold together. It just depends on human skills." Khilnani, Sunil. *The Idea of India*. London: Penguin Books, 2004, pp. 206-207.

7 NAPCC, p. 13: "Economic reforms, implemented since 1991, have resulted in faster growth of the Indian economy. GDP growth rates have averaged roughly 8 per cent during 2004-2008. However, 27.5 per cent of the population still live below the poverty line in 2004-05 and 44 per cent are still without access to electricity."

8 Murthy, N.R. Narayana, *A Better India A Better World*. New Delhi: Penguin Books/Allen Lane, 2009, p. xv.

9 Integrated Energy Policy, p. xxvii.

10 "In 2004 my Government had set before the country a vision of an inclusive society and an inclusive economy. It worked diligently towards translating this vision into policies and programmes. My Government sees the overwhelming mandate it has received as a vindication of the policy architecture of inclusion that it put in place. It is a mandate for inclusive growth, equitable development and a secular and plural India…High growth is necessary to provide the government the capacity to expand opportunities for employment. It is necessary to provide resources to increase outlays in education, health care and infrastructure to meet the needs of all regions and all people. My Government will ensure that the growth process is not only accelerated but also made socially and regionally more inclusive and equitable. The yearning of our people for inclusiveness - economic social and cultural — and the rejection of the forces of divisiveness and intolerance that my Government spoke of in 2004 continues as both its inspiring vision and its unfinished business… My Government was able to accelerate growth substantially in the last five years to a record five-year average of 8.5 per cent. This produced an impressive expansion in high quality jobs and also gave us the capacity to guarantee rural employment and expand social and economic infrastructure in an unprecedented manner… All these initiatives were possible because high growth generated more resources. It is therefore imperative that our growth momentum is resumed…Infrastructure is a fundamental enabler for a modern economy and infrastructure development will be a key focus area for the next five years. Public investment in infrastructure is of paramount importance. Bottlenecks and delays in implementation of infrastructure projects because of policies and procedures, especially in railways, power, highways, ports, airports and rural telecom will be systematically removed. Public-private partnership (PPP) projects are a key element of the strategy. A large number of PPP projects in different areas currently awaiting government approval would be cleared expeditiously. The regulatory and legal framework for PPPs would be made more investment friendly… Coordinated action for energy would be guided by the integrated energy policy. The effort would be to see that at least 13,000 MW of generating capacity is added each year through a mix of sources -coal, hydel, nuclear and renewables…My Government will ensure that our space programme which has achieved wide recognition continues to bring rich dividends to society in agriculture, tele-medicine, tele-education and by providing information to rural knowledge centres, besides contributing to telecommunication, television broadcasting and weather forecasting. Several innovative initiatives commenced by government in the science and technology sector in the last five years and now under implementation will be further

strengthened…My Government is proactively addressing issues of climate change through eight national missions. Of these the National Solar Mission, the National Water Mission, the National Mission on Energy Efficiency, the National Mission on Sustainable Agriculture and the National Mission on Sustainable Habitat will be launched by the end of this year…The momentum of improvement of our relations with the major powers will be maintained. The transformation of our partnership with the United States of America will be taken forward. Our strategic partnership with Russia has grown over the years, and we will seek to further consolidate it. With countries of Europe and Japan my Government will continue the sustained diplomatic efforts, which have produced qualitative changes in our relations since 2004. The multi-faceted partnership with China will be expanded…As a responsible member of the international community, India will work with other countries in tackling issues of common concern such as international terrorism, the global economic crisis, climate change, energy security and reform of multilateral institutions to reflect contemporary realities…Honourable Members, my Government believes that in the knowledge society in which we live today, creativity, innovation and enterprise hold the key to people and nations realizing their potential…My Government will ensure that its policies for education and science and technology are imbued with a spirit of innovation so that the creativity of a billion people is unleashed. The next ten years would be dedicated as a Decade of Innovation." Address by the President of India, Shrimati Pratibha Devisingh Patil, to Parliament, New Delhi, June 4, 2009.

11 President Obama's Statement, Republic Day 2008: "As the people of India and people of Indian origin in America and around the world celebrate Republic Day on January 26, I send the warmest greetings of the American people to the people of India. Together, we celebrate our shared belief in democracy, liberty, pluralism, and religious tolerance. Our nations have built broad and vibrant partnerships in every field of human endeavor. Our rapidly growing and deepening friendship with India offers benefits to all the world's citizens as our scientists solve environmental challenges together, our doctors discover new medicines, our engineers advance our societies, our entrepreneurs generate prosperity, our educators lay the foundation for our future generations, and our governments work together to advance peace, prosperity, and stability around the globe. It is our shared values that form the bedrock of a robust relationship across peoples and governments. Those values and ideals provide the strength that enables us to meet any challenge, particularly from those who use violence to try to undermine our free and open societies. As the Indian people celebrate Republic Day all across India, they should know that they have no better friend and partner than the people of the United States. It is in that spirit, that I also wish Prime Minister Singh a quick recovery."

12 http://www.globalsecurity.org/military/world/india/nssp.htm or http://www.dae.gov.in/jtstmt.htm

13 http://www.america.gov/st/texttrans-english/2009/July/20090720155526xjsnommis0.423515.html

14 US-India Joint Statement, July 20, 2009, Major headings of cooperation are: "Advancing common security interests, defence co-operation, seeking a world without nuclear weapons, civil nuclear co-operation, global institutions, pursuing sustainable economic growth and development, education, space, science and technology and innovation, high technology co-operation, energy security, environment and climate change, global issues."

15 http://www.ndtv.com/news/world/obama_wants_renewable_energy_partnership_with_india.php and http://www.ndtv.com/news/world/obama_wants_renewable_energy_ partnership_with_ india.php, "The Obama Administration has already announced a $150-billion, 10-year renewable energy initiative. In fact, it was a solar energy company–by the name of Namaste–in Denver Colorado, where Obama and Vice President Joe Biden together announced the administration's renewable energy initiative in February 2009."

16 Mohan, Raja and Karl Inderfurth, "Put space at the heart of US-India relations", *Financial Times*, November 22, 2009, at http://www.ft.com/cms/s/0/87161d80-d794-111de-b578-00144feabdc0.html

[17] Ganguly, Sumit and S. Paul Kapur, "The End of the Affair?" *Foreign Affairs*, 2009.

[18] Tellis, Ashley J., "More Than Just Symbols", New Delhi: Indian Express, 2009. See also http://www.carnegieendowment.org/publications/index.cfm?fa+view&id=24288

[19] Joint Statement by President Obama, Indian Prime Minister Singh. Washington, DC: The White House, Office of the Press Secretary, November 24, 2009. at http://www.america.gov/st/texttrans-english/2009/November/20091125115540eaifas0.3806574.html

[20] Nitin Desai, Former Under-Secretary-General for Economic and Social Affairs, at release of IDSA's report on the Security Implications of Climate Change for India, September 2009.

[21] "Primary Energy is the energy found in nature that has not been subjected to any conversion or transformation process. Primary energy is energy contained in raw fuels and any other form of energy received by a system as input to the system…[and] includes non-renewable and renewable energy." Source: Wikipedia.

[22] 1 MTOE = 0.418 EJ = 1.327 GW-Yr = 0.040 Q-BTU = 11.623 TWh

[23] 1 Q-BTU = 1.055 EJ = 25.211 MTOE = 33.449 GW-Yr = 293.017 TWh. 1 Quad = 1 Q-BTU = 10^15 or 1,000,000,000,000,000 BTUs = 1,055.056 joules or the thermal energy of 172.4 million barrels of oil, roughly 100 supertankers (from Snead). 1 Quad = 293,074.56 GW-hrs

[24] 1 EJ = 23.9 MTOE = 31.71 GW-Yr = 0.948 Q-BTU

[25] 1 GW-Yr = 0.0315 EJ = 0.7537 MTOE = 0.030 Q-BTU = 8.76 TWh

[26] As used in the IEP and measured as Total Primary Commercial Energy Supply (TPCES), is that subset of Primary Energy that is bought and sold, as opposed to Traditional Biomass collected from nature and directly used.

[27] Most recent figure from EIA puts India's Total Primary Energy Consumption at 17.475 Q-BTU and total Primary Energy Production at 12.399 Q-BTU in 2006. In that same year, Total Electricity Installed Capacity was 143.773 Gigawatts (101.896 Conventional Thermal, 32.326 GW Hydro, 6.191 Non-Hydro Renewables, 3.36 GW Nuclear) for a Total Net Electricity Generation was 703.316 Billion Kilowatt Hours, total Electrical Net Consumption was 517.21 Billion Kilowatt hours, and Electrical distribution losses of 188.916 GW. See https://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=44&pid= 44&aid=1

[28] DAE Paper 10. Also 15 EJ (79.1 per cent) was domestically supplied and 3.96 EJ (20.8 per cent) of total was imported (about 30 per cent of India's commercial energy is imported).

[29] IEP, p. 89: "An examination of India's primary energy bill shows that renewables account for about 32 per cent of primary energy consumption in 2003-04. Of this major contributor is traditional biomass mainly used in cooking followed by electricity generation from large hydro plants. The actual share of modern renewables in India's energy mix is significantly lower (about 2 per cent of total)."

[30] Energy Sector R&D Working Group, p. 107: "Currently, the Indian economy is dependent on the complex energy mix. This includes around 30 per cent of non-commercial energy sources that are being used in an extremely inefficient way to imported petroleum products."

[31] IEP, p. 6: "A majority of India's people use traditional fuels such as dung, agricultural wastes and firewood for cooking food. These fuels cause indoor pollution… the use of traditional fuels in cooking with the attendant pollution and cost of gathering them imposes a heavy burden on people, particularly women and girls. The need to gather fuels may deprive a young girl for schooling. Over time, the use of such fuels increases the risks of eye infections and respiratory diseases. Lack of access to clean and convenient sources of energy affect the health of women and girls disproportionately as they spend more time indoors and are primarily responsible for cooking. Women's micro enterprises

are heat intensive, labor-intensive, and or light intensive. The lack of adequate energy supply— and other coordinated support— affects women's abilities to use these micro enterprises profitably and safely."

32 IEP, p. 6: "Total economic burden of dirty biomass fuel was estimated to be Rs 299 billion [$6b] using a wage rate of Rs 60 per day, comprising of opportunity cost of gathering fuel, working days lost due to eye infections and respiratory diseases, and cost of medicine." *Note also that Total cooking requirements 1.5B is only 55 MTOE [72.97 GW-Yr, or 639.2 TWh which is about half of all the electricity produced in India in 2006] (IEP, p. xxvii), and would only require 73 GW of installed capacity to service India's entire cooking demand.*

33 IEP, p. 29.

34 DAE paper 10, Table 8. Note also that the share of electricity to primary is growing, and expected to grow from 57 per cent to 64 per cent by 2052.

35 Highlights of Power Sector, www.cea.nic.in/power_sec-reports/Executive_Summary/2009_08/1-2.pdf Excellent discussion of CEA Report at http://www.gauravblog.com/?p=516

36 See DAE Paper 10, Table 7, p. 46 for typical Plant Load Factors. IEP lists Nuclear as 68 per cent, Coal is 67 per cent, but Hydro is just 30 per cent, Wind just 20 per cent, and Solar a mere 17.5 per cent. DAE uses the term Capacity Factor (CF) and lists Nuclear as 0.80, Thermal as 0.70, Hydro as 0.38, and Non-Conv Renewable as 0.14.

37 IEP, p. 11: "Coal has been the mainstay of India's energy supply for many years. Coal consumption increased from 140 Mt in 1984 to over 400 Mt in 2004 with a growth rate of 5.4 per cent. Thermal power plants using coal today account for 57 per cent of our total generation capacity."

38 IEP, p. ixv: "Coal will remain India's most important energy source till 2031-32 and possibly beyond… coal accounts for over 50 per cent of India's commercial energy consumption and about 78 per cent of domestic coal production is dedicated to power generation. This dominance of: India's energy mix is not likely to change till 2031-32."

39 DAE Paper 10, Tables 9 and 10.

40 http://en.wikipedia.org/wiki/List_of_countries_by_carbon_dioxide_emissions

41 Total CO2 emissions from Consumption of Energy were 1,293.169 million metric Tonnes from all sources (1.164 metric tonnes CO2 per person) in 2006, with from Coal alone contributing 66.7 per cent (862.934 million metric tonnes) and Oil contributing 25.7 per cent (332.332 MTM) in 2006. Only one year later, coal was contributing 949.717 MMT in 2007. Energy Intensity, or Total Primary Energy Consumption per GDP was 24,334.427 BTU per Year per 2000 US dollars, and Carbon Intensity was 1.801 metric tonnes of CO2 per Thousand Year 2000 US dollars with a population figure of 1.11171 billion. https://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=44&pid=44&aid=1.

42 NAPCC, p. 22: "As for the national greenhouse inventory, the direct CO2 emissions from industrial sources accounted for nearly 31 per cent of the total CO2 emissions from the country. The CO2 emissions from industrial sector can be broadly categorised into two halves, i.e. process related emissions, and omissions due to fuel combustion and industries. Of the total estimated 250 million tonnes of direct CO2 emissions from the industry in 1994, nearly 60 per cent were counted by energy use." The UNFCC National Greenhouse Gas Inventory can be found at: http://unfccc.int/resource/docs/2007/sbi/eng/30.pdf but does not include India. For a detailed breakdown of Indian CO2 emissions, see India's Initial Communication to UNFCCC: http://unfccc.int/resource/docs/natc/indnc1.pdf which is further discussed in the following papers: http://www.ias.ac.in/currsci/feb102006/326.pdf, p. 328 or http://www-cger.nies.go.jp/publication/I067/I067.pdf, p. 27 or http://www.whrc.org/Policy/climate_change/ActionPDF/WHRC9.2-India.pdf, p. 6.

43 Japan 6,495.913 vs India 7,391.482 in BTU per 2000 US Dollar Purchasing Power Parity. https://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=44&pid=44&aid=1

44 kgoa/a = Kilograms of Oil/annum. The IEP, p. 1, offers a slightly lower figure: "As of 2003, India's citizens consumed only 439 kg of oil equivalent (kgoe) per capita of primary energy compared to 1,090 in China, 7,835 in the US, and the world average of 1,688" Note that per Smil, Energy in World History, p. 211: *"No country whose annual primary commercial energy consumption averages less than the equivalent of 100 kilograms of oil per capita [0.7 BOE] can guarantee even basic necessities to all of its inhabitants....As the rate of energy consumption approaches the equivalent of 1 tonne of oil [7.3 BOE or 1000kg], industrialisation advances, incomes rise, and the quality of life noticeably improves... Widespread affluence requires, even with efficient energy use, the equivalent of at least 2 tonnes [14.6 BOE or 2000kg] of oil per capita per year."*

45 http://en.wikipedia.org/wiki/List_of_countries_by_energy consumption_per_capita

46 http://en.wikipedia.org/wiki/List_of_countries_by_electricity_consumption

47 2009 per capital electricity consumption is now listed as 704.2 kWh per the Central Electrical Authority's monthly Highlights of the Power Sector report www.cea.nic.in/power_sec-reports/Executive_Summary/2009_08/1-2.pdf also of note, the average cost of power supply and average realisation 276 paise/ kWh and 227 paise/kWh including agriculture, and all-India thermal PLF was 76.65 per cent,

48 IEP, p. 4: "Power capacity has risen at a rate of 5.87 per cent per annum over the last 25 years. The total supply of electrical energy has risen at a rate of 7.2 per cent per annum over the same period. This reflects a gradual improvement in the average plant load factor (PLF) thermal plants (which stood at 74.8 per cent in 2004-5)…. aggregate technical and commercial (AT&C) losses which include theft, non-billing, incorrect billing, inefficiency and collection, and transmission and distribution losses exceed 40 per cent of the country as a whole."

49 11th Plan, p. 255 "Infrastructure— deficit and 11th plan physical targets: power deficit 13.8 per cent peeking deficit; 9.6 per cent energy shortage; 40 per cent transmission and distribution losses; absence of competition. 11th plan targets add 78577MW; access to all rural households."

50 IEP, p. 3: "In 2004-05, the peak shortage of varied from 0 to 25.4 per cent of all-India average of 11.7 per cent. Similarly, energy shortage also varied from 0 to 20.1 per cent against an all-India average of 7.3 per cent."

51 DAE paper 10.

52 IEP, p. 110: "At the national level AT&C losses still exceeded 40 per cent in the year 2004-5 (CEA 2005). The ratio of energy build energy available was a little less than 60 per cent in 2004-05."

53 IEP,p. 5: "For example, in 2002, industries in India paid 47 US cents per unit as opposed to 20 cents in China, 17 cents in Brazil, 12 cents in Japan, 5.5 cents in the US and five cents in Germany in terms of PPP."

54 11th Plan, p. 206 lists the earlier figure pre 2006 with a very different attitude unappreciative of expected growth: "With a share of just 4 per cent of global emissions, and the amount of mitigation by India will not affect climate change"

55 IEP, p. xx: "Currently we consume 0.16 kg of oil equivalent (kgoe) per dollar of GDP expressed in purchasing power parity terms. India's energy intensity is lower than the 0.23 kgoe of China, 0.22 kgoe of the US and the world average of 0.21 kgoe."

56 IEP, p. 48: "In 2003 in the consumed 0.16 kg of oil equivalent per dollar of GDP expressed in purchasing parity terms. This compares to 0.23 in China, 0.22 in the US and a world average of 0.21."

57 NAPCC, p. 35: "Contributing 21 per cent of the country's GDP, accounting for 11 per cent of total exports, employing 56.4 per cent of the total workforce, and supporting 600 million people directly or indirectly, agriculture is vital to India's economy and livelihood of its people."

58 Briefing by Dr. Rajiv Kumar, ICRIER, September 16, 2009.

59 In 2005 India's Total Imports of Refined Petroleum Product by 220.44 Thousands of Barrels per Day, Total Imports of Dry Natural Gas 281 Billion Cubic Feet, Imported 2.811 total Net Billion Kilowatthours (or 0.00959 Q-BTU), 13,516 Thousand Short Tons of Coal.

60 IEP, p. v: "We depend to the extent of 70 per cent on imported oil, and this naturally raises issues about energy security."

61 IEP, p. 9: "In 2004-05, net of imports, India consumed 120.17 Mt of crude oil products including refinery fuel… not only has domestic production stagnated, well reserves hovered between 700 Mt in 750 Mt during this period… the proved reserves nonproduction (R/P) ratio was 23 in 2004-05. We now import 72 per cent of our consumption in our import dependence is growing rapidly. This raises serious concerns about India's energy security, our ability to obtain the oil we need and the impact of constrained supply and consequent increase in oil prices on our economy."

62 IEP, p. 10, "The total consumption of petroleum products grew at the rate of 5.7 per cent per annum between 1980-81 and 2003-04. However, growth in consumption has moderated to 2.95 per cent per annum over the last four years (2000-01 to 2004-05)."

63 IEP, p. xxiv: "However, it is also necessary to recognise that India's growing dependence on energy imports exposes its energy needs to external shocks."

64 11th Plan, p. 16: "The pricing policy for petroleum products will pose a major challenge in the 11th plan, given the sharp increase in international oil prices which is yet to be passed on to consumers."

65 NAPCC, p. 14: "A strong positive correlation between energy use in human development is well recognised. It is obvious that India needs to substantially increase its per capita energy consumption to provide a minimally acceptable level of well-being to its people... India has a well-developed policy or legislative, regulatory, and programmatic regime for promotion of energy efficiency, renewable energy, nuclear power, fuel switching, energy pricing reforms, and addressing GHG emissions in the energy sector."

66 See 11th Plan, p. 14: "Rapid economic growth cannot be realised if energy is not available at reasonable costs. Electricity is crucial in this context."

67 *India's economy today per the CIA Fact Book (www.cia.gov/library/publications/the-world-factbook/geos/in.html) is $1.21 trillion* (2008) GDP in official exchange rate, and estimated to be $3.297 trillion at GDP Purchasing Power Parity and $2,900 GDP Per Capita PPP, with a growth rate of 7.4 per cent in 2008, and 9 per cent and 9.7 per cent for 2007 and 2006, respectively. According to Goldman Sachs, India is capable of growing 10-40x by 2050 to $25-43 trillion (>3x the current size of the US economy, $14.25 trillion). "Ten Things for India to Achieve its 2050 Potential", atwww2.goldmansachs.com/ideas/brics/ten-things-doc.pdf

68 As per Nilekani, *Imagining India*, p. 483, at 8-9 per cent growth and 1.5 per cent population growth, income doubles every nine years, whereas at 3.5 per cent growth and 2 per cent population growth, it takes 45 years for income to double.

69 IEP, p. 48: "India cannot deliver sustained 8 per cent growth over the next 25 years without energy and water, and these two together shall, in turn, pose the biggest constraints to India's growth."

70 NAPCC, p. 33, "Since *desalinisation is an energy intensive process (the energy requirement may vary from 3 kWh to 16 kWh for separating 1000 L* depending on the type of process used), the application of desalination technology for increasing regional water supplies strongly links to energy issues and thus GHG emissions."

71 See 11th Plan, p. 15: "We are short on oil and gas resources and this is certain to continue. More than 70 per cent of our oil needs are met by imports."

72 11th Plan, p. 204 "Global Climate Change due to rising levels of GHGs in the atmosphere is one of the most serious environmental concerns of our time. The Panel [IPCC] has

concluded that the fact of global warming is unequivocal and there is enough evidence to indicate this is due to anthropogenic reasons. Although some of these conclusions have been disputed, the assessment of the IPCC represents a broad and growing consensus in the scientific community worldwide. The current level of atmospheric CO2 is estimated as 379 parts per million (ppm) compared with the preindustrial level of only 280 ppm…. climate change is noted in the IPCC assessment reports include recession of glaciers, filed for permafrost, lengthening of mid-to high latitude growing seasons, pull word and attitudinal shifts of plant and animal ranges, decline in some plants and animal populations, early flowering of trees, and changes in insect populations and egg laying in birds… changes in the severity and frequency of extreme heat and cold, and floods and droughts, and local air pollution and aero allergens may result in changes in infectious disease occurrence, and local food production and also cause undernutrition, leading to impaired shall development. There will also be health consequences of population displacement and economic disruption. For India, the risks of malaria in heat stress related mortality have been projected by IPCC. Increase in flooding and droughts are associated with increased risk of drowning, diarrheal and respiratory diseases, and hunger and malnutrition…"

73 NAPCC, p. 2, "The fourth assessment report of the intergovernmental panel on climate change concluded from direct observations of changes in temperature, sea level, and snow cover in the Northern Hemisphere during 1850 to the present that warming of the Earth's climate is unequivocal. The global atmospheric concentration of carbon dioxide has increased from a preindustrial value of 280 ppm to 379 ppm in 2005. Multi-model averages show that temperature increases during 2090-2099 relative to the 1980 – 1999 may range from 1.12 6.4° C and sea level rise from 0.18 to 0.59 m. This could lead to impacts on freshwater availability, ocean acidification, food production, flooding of coastal areas and increased burden of vectorborne and waterborne diseases associated with extreme weather events."

74 11th Plan, p. 206: "There is no doubt that the accumulation of GHG, which is the cause of global warming, has occurred overwhelmingly due to the missions of industrial countries and is therefore entirely appropriate that the burden of mitigation falls on them."

75 11th Plan, p. 205: "Global warming will affect us seriously for South Asia warming has been projected to be above the global mean in Southeast Asia equal to the global mean… the serious consequences of climate change, including especially the consequences for India, lead naturally to the question of what should be our response. Two types of responses need to be considered. The first relates to adaptation, i.e., measures that have to be taken given the very high likelihood that climate change will occur it will have adverse effects. The second relates to mitigation, i.e. steps taken that might reduce the extent of climate change."

76 NAPCC, p. 1: "Finally our approach must be compatible with our role as a responsible and enlightened member of the international community, ready to make our contribution to the solution of a global challenge, which impacts humanity as a whole."

77 NAPCC, p. 13: "This document... also describes India's willingness and desire, as a responsible member of the global community, to do all that is possible for pragmatic and practical solutions for all, in accordance with the principle of common but differentiated responsibilities and respective capabilities."

78 11th Plan, p. 206 "An optimum approach to mitigation from a global perspective is only possible if all countries cooperate to facilitate collective action. This is because mitigation actions are characterised by the classic problem of externality— the benefits of action of any one country do not accrue only to the country itself but to the entire global community, while the costs of mitigation are fully internalised… the challenge lies in determining the basis for collective action which is fair, provides equitable entitlement to the global environmental space with burden sharing in a manner which recognises

the very different levels of development and also the very different degrees of historical responsibility for causing the problem in the first place."

79 NAPCC, p. 2: "Maintaining a high growth rate is essential for increasing living standards of the vast majority of our people and reducing their vulnerability to the impacts of climate change.... deploying appropriate technologies for both adaptation and mitigation of greenhouse gases emissions extensively as well as at an accelerated pace... engineering new and innovative forms of market, regulatory involuntary mechanisms to promote sustainable development... welcoming international cooperation for research, development, sharing and transfer of technologies enabled by additional funding in the global IPR regime that facilitates technology transfer to developing countries under the UNFCCC."

80 NAPCC, p. 1: "India is faced with the challenge of sustaining its rapid economic growth while dealing with the global threat of climate change. This threat emanates from the accumulated greenhouse gas emissions and the answer, anthropogenic regenerated through the long-term intensive industrial growth and high consumption lifestyles in developed countries... India's path is based on its unique endowments, the overriding priority of economic and social development and poverty eradication, and its adherence to its civilisational legacy that places a high value on the environment and maintenance of ecological bounds."

81 Grantham Institute. Assessing the Costs of Adaptation to Climate Change: A Review of the UNFCCC and Other Recent Estimate, "The UNFCCC report concluded that total funding need for adaptation by 2030 could amount to $49-171 billion per annum globally, of which $27-66 billion would accrue in developing countries (Table 2) (note that all references to dollars in this report are to US dollars unless otherwise specified). By far the largest cost item is infrastructure investment, which for the upperbound estimate accounts for three-quarters of total costs… A re-assessment of the UNFCCC estimates for 2030 suggests that they are likely to be substantial under-estimates…UNFCCC figures for additional investments needed to adapt infrastructure to climate change risks in 2030…Low- and middle-income nations in Asia (including Middle East) 2.0 – 33.5 US$ Billions." Available at: http://www.iied.org/pubs/pdfs/11501IIED.pdf

82 11th Plan, p. 191: "Protection of the environment has to be a central part of any sustainable inclusive growth strategy…More recently, the issue assumes special importance because of the accumulation of evidence of global warming and associated climate change that is likely to bring."

83 See 11th Plan, p. 16: "The importance of renewable energy in the country arises from a number of factors— it increases energy security, it provides energy at local levels, improving energy security at these levels and it also involves little or no greenhouse gas emissions. Appropriate policies will be pursued to encourage renewables by linking subsidies, worth required to outcomes rather than outlays. The Eleventh Plan will follow an integrated energy policy to incentivise appropriate choice of fuels and technologies. Most of the programmes for renewable energy development would continue to be promoted with a maximum of providing subsidies or incentives which are linked to outcomes rather than capital expenditure. This is important to preserve incentives for not just setting up capacities, but also operating them in encouraging cost-reduction and technology development. Some of the areas which would be pushed strongly or wind power, solar applications, biomass gasification, bio-fuels development and other clean technologies."

84 See 11th Plan, p. 17: "We need R&D and a number of areas to augment our energy resources and provide cleaner energy. Considering the threat of climate change and the need to find clean sources of energy missions in the following areas should be mounted: [of 5 total] solar photovoltaics and solar thermal electricity…Apart from these, rigorous R&D programme will encourage development of new sources, more efficient utilisation and improvement of efficiency applications."

85 NAPCC, p. 3: "The eight national missions which form the core of the national action plan, representing multipronged, long-term and integrated strategies for achieving key goals in the context of climate change... a national solar mission will be launched to significantly increase the share of solar energy in the total energy mix well recognising the need to expand the scope of other renewables and nonfossil options such as nuclear energy wind energy and biomass... another aspect of the solar mission would be to launch a major R&D programme, which could draw upon international cooperation as well, to enable the creation of more affordable, more convenient solar power systems, and to promote innovations that enable the storage of solar power for sustained long-term use."

86 *"Our vision is to make India's economic development energy efficient. Over a period of time we must pioneer a graduated shift from economic activity based on fossil fuels to one based on non-fossil fuels and the reliance on nonrenewable and depleting sources of energy to renewable sources of energy. In this strategy, the sun occupies centre stage as it should be literally the original source of all energy.* We will pour scientific, technical and managerial talents, with sufficient financial resources, to develop solar energy as a source of abundant energy to power our economy and to transform the lives of our people. Our success in this endeavor will change the face of India it will also enable India to help change the destinies of people around the world." Dr. Manmohan Sign, June 30, 2008, launching India's National Action Plan on Climate Change, quoted in National Solar Plan

87 NAPCC, p. 1: "In charting out a developmental pathway which is ecologically sustainable, India has a wider spectrum of choices precisely because it is at an earlier stage of development. Our vision is to create a prosperous, but not wasteful society, an economy that is self-sustaining in terms of its ability to unleash the creative energies of our people and is mindful of our responsibilities to both present and future generations."

88 IEP, p. 106: "Solar technology is often seen as relevant for niche applications. Given that solar energy is one of our major energy sources and the only renewable energy source with sufficient potential to meet almost all our energy needs, we should give a high priority to development of solar technology for large-scale development. A technology mission should be mounted to break the barriers to wider use of solar thermal and for bringing down the cost of solar photovoltaic by a factor of five as soon as possible."

89 NAPCC, p. 20, "The country receives about 5000 trillion kilowatt hour per year equivalent energy through solar radiation. In most parts of India, clear sunny weather is experienced 250 to 300 days a year. The annual global radiation varies from 1600 to 2200 kWh/meter squared, which is typical of the tropical and subtropical regions. *The average solar insolation incident over India is about 5.5 kWh per meter squared per day. Just 1 per cent of India's land area to meet India's entire electricity requirements till 2030."*

90 IEP, p. 130: "Energy from renewable sources is generally viewed as involving lower environmental impacts than that based on fossil fuels, nuclear and large hydropower. The main environmental benefits of renewable energy sources is that they avoid the air pollution emissions from fossil fuels and the catastrophic risks associated with nuclear plants."

91 NAPCC, p. 20, "The national solar mission would promote the use of solar energy for power generation and other applications.... solar-based technologies are an extremely clean form of generation with practically no form of commissions appointed generation. They would lead to energy security through displacement of coal and petroleum."

92 *Authors note: To replace the India's share of fossil fuel contribution with solar at the 2050 level (800 GWe or 5,000 TWh) at a capacity factor of 0.17 would require a nameplate capacity of 4,705.9 GWe not accounting for the additional overcapacity needed to compensate for the inefficiency of storing power for the 16 hours when the plant is producing no or low power. At 22 sq km per GW, that would require 103,529 sq km or 1/31st or 3.2 per cent of India's total land area of 3.28 million square kilometers (28 times the land area of Goa, India's smallest state).*

93 Energy Sector R&D Working Group, p. 107: *"Global investment in renewable energy sector rose from $30 billion in 2004 two $39 billion in 2005....* from long-term perspective is now an ideal

time to advance this clean power and energy for decades to come and set our goals for short-term and long-term achievements. Therefore, we must expand and accelerate the research, design and development (RD&D) efforts of renewable energy technologies so we can secure supply of low-cost, clean and sustainable energy sources. RD&D carried out during the last 10 years has been somewhat inadequate to make a dent on indigenous commercial production as a bulk of this research was carried out at research institutions and universities with out adequate inter-linkages with industry. Outputs of RD&D projects need to be clearly established beforehand and funding needs determined in relation to those outputs and the effort required to attain those outputs."

94 Energy Sector R&D Working Group, p. 108: "India's endowed with enormous potential of renewable energy resources to meet its energy needs. However, in spite of large potential, high cost and need for storage or some of the major barriers in large-scale diffusion of renewable energy technologies. It is recognised that there is a downward trend in the cost of renewables and reliability is gradually improving... the long-term benefit of renewable energy technologies and associated social environmental gains justify subsidy for renewables."

95 See Dadwal, p. 7: "Yet when one looks at the future plans for energy in the us as well as other developed countries, it is interesting to note that all of them are based on fossil fuels, as well as nuclear power, with renewable energy comprising only a small proportion of the energy mix. The reason for this is... no commercially viable substitutes have been found for fossil fuels, yet."

96 See Dadwal, p. 7.

97 NAPCC, p. 21: *"The investment cost of solar PV-based power systems are in the range of Rs 30-35 cr/MW… the unit cost of generation is still in the range of Rs 15-20 Rs/kWh, but may fall significantly for thin-film-based systems."*

98 NAPCC, p. 21: "The cyclical (diurnal, annual) and episodic (cloud cover) variations of solar insolation, and the impossibility of regulating the solar flux mean that in order to ensure steady power supply, meet peaking requirements, as well as ensure optimal utilisation of steam turbines and generators, it is necessary to either hybridise solar thermal systems with alternative means of raising steam or provide for high temperatures will energy storage. The former may be cumbersome or hybridisation with conventional fuels, or by biomass combustion systems. The latter may be accomplished by insulated storage of molten salts; however, in their case the rate of heat loss may be significant, and storage of more than 10-12 hours is uneconomic. *The investment cost of standalone (i.e. without hybridisation) solar thermal power plants are in the range of Rs 20-22 cr/MW... the estimated unit cost of generation is currently in the range of 20-25 Rs/kWh.*

99 IEP, "Given the limited amount of domestic conventional energy sources, renewable energy resources gain significance in the Indian context…. It may be noted that many renewables require land. The potential energy generated is assessed independently for each option. If all such options are developed together the combined potential may be less than the sum due to a paucity of available land for energy generation as other competing land uses may dominate."

100 National Solar Plan, *"Typically a solar power plant would require 5 to 6 acres of land per megawatt."*

101 IEP, p. 130: "Large arrays of photovoltaic panels with considerable demand on land and impair aesthetics."

102 NAPCC, p. 18: "The integrated energy policy was adopted in 2006. Some of its key provisions are: promotion of energy efficiency in all sectors; emphasis on mass transport; emphasis on renewables including biofuels plantations; accelerated development of nuclear and hydropower for clean energy; focused R&D on several clean energy related technologies."

103 NAPCC, p. 19: "The new and renewable energy policy, 2005, promotes utilisation of sustainable, renewable energy sources, and accelerated deployment of renewables through indigenous design, development and manufacture."

104 11th Plan, p. 207: "India is already taking a number of initiatives in clean energy including renewable energy and action to increase energy efficiency and conservation. One of the objectives of the 11th Plan is to reduce the energy intensity per unit of GHG by 20 per cent from the period 2007-08 to 2016-17."

105 http://timesofindia.indiatimes.com/news/india/Highlights-of-PMs-Independence-Day-speech-/articleshow/4895904.cms See full text of Prime Minister's Speech at: http://pmindia.nic.in/speech/content.asp?id=808 Note "India wishes to tackle the problem of climate change in partnership with other countries of the world. We have taken a decision to constitute 8 National Missions. We are committed to meet the challenge of climate change through these 8 Missions. To increase the use of solar energy and to make it affordable, we will launch the Jawaharlal Nehru National Solar Mission on 14th November of this year." And, "Restoring our growth rate to 9 per cent is the greatest challenge we face. We will make every necessary effort to meet this challenge – whether it is for increasing capital flows into the country, or for encouraging exports or for increasing public investment and expenditure."

106 See: http://www.nature.com/news/2009/090804/full/news.2009.774.html "India's prime minister Manmohan Singh has approved a US$19 billion plan to make the country a global leader in solar energy over the next three decades. The ambitious project would see a massive expansion in installed solar capacity, and aims to reduce the price of electricity generated from solar energy to match that from fossil fuels by 2030."

107 For instance, per http://beta.thehindu.com/sci-tech/energy-and-environment/article1568.ece *"Although the country has virtually no solar power today, the plan is to generate 20 gigawatts (GW) from sunlight by 2020. According to the International Energy Agency, global solar capacity is predicted to be 27GW by then — meaning that India expects to be producing 75 per cent of this within 10 years."* India also historically has had trouble executing funds even when present. According to http://www.indianexpress.com/news/india-shining/499456/0 "According to the CAG, our solar energy centre in the renewable energy ministry, which is meant to link government, institutions, industry and consumers, sent back 44-76 per cent of its budget between 2002-7. There was practically no headway in research or tech, or any productive relationships with industry."

108 IEP, p. xiii: "India needs to sustain an 8 per cent to 10 per cent economic growth rate, over the next 25 years, if it is to eradicate poverty and needs human development goals. To deliver a sustained growth rate of 8 per cent through 2031-32 and to meet the lifeline energy needs of all citizens, India needs, at the very least, to increase its primary energy supply by 3 to 4 times and its electricity generation capacity/supply by 5 to 6 times but they are 2003-04 levels. With 2003-04 as the base, India's commercial energy supply would need to grow from 5.2 per cent to 6.1 per cent per annum while its total primary energy supply would need to grow at 4.3 per cent to 5.1 per cent annually. By 2031-32 power generation capacity must increase to nearly 800,000 MW [800GW] from the current capacity of around 160,000 MW [160GW] inclusive of all captive plants…. the demand must be met to save, clean and convenient forms of energy at the least cost in a technically efficient, economically viable and environmentally sustainable manner… meeting this vision requires that India pursue all available fuel options and forms of energy both conventional and nonconventional. Further India must seek to expand its energy resource base and seek new and emerging energy sources."

109 IEP, p. 45: "Based on the various scenarios developed the total commercial energy requirement for India in 2031-32 varies from a low 1351 Mtoe to a high 1702 Mtoe. This level of commercial energy requirement entails an annual growth of 5.2 per cent to 6.1 per cent over the commercial energy supply level in 2003-04 to sustain an 8 per cent growth rate of GDP. The total primary energy requirement and 2031-32 varies from a low 1536 Mtoe to a high 1887 Mtoe. This yields an annual growth in total primary energy requirement of 4.3 per cent to 5.1 per cent over the 2003-04 level to sustain a GDP growth of 8 per cent per annum."

Sky's No Limit

110 Energy Sector R&D Working Group, p. 107: "India needs to sustain an annual economic growth rate of 8-10 per cent for quite some time to be able to meet its economic and human development goals. Such a growth rate would generate progressively increasing demands for energy. To sustain the growth rate of 8 per cent up to 2032, India would, in the very least need to increase its energy supplies by 3 to 4 times, and electricity supply by 5 to 7 times of today's levels."

111 IEP, p. 113: *"…projected power capacity additions over the next 25 years are more than 6,00,000MW [600GW], there is no danger of pre-empting future competition or limiting technology options by such bulk purchases."*

112 IEP, Table 2.5 projections for electricity requirement based on falling elasticities, projects: Total electricity energy requirement in the 2031-32 timeframe ranges between 3880 and 4806 billion kilowatt hours at 8 per cent and 9 per cent growth respectively, with a projected peak demand of 592 two 733, and the corresponding installed capacity requirement of 778 two 960 GW assuming a system load factor of 76 per cent. The Ministry of Power projects higher requirements of 4793 to 6036 billion kilowatt hours and required installed capacity of 962 two 1207 GW by 2031-32.

113 IEP, pp. 41-46: "In scenario 11, maximal use of hydro and nuclear, plus forced natural gas for 16 per cent electrical generation, a 15 per cent reduction in electricity demand by demand side management, an increase in thermal efficiency of future coal plants to 30 to 40 per cent from the present 36 per cent, an increase in the freight share of railways from 32 to 50 per cent, a 50 per cent increase in all motor vehicles, and 33.2 GW of on and off-shore wind power 10 GW solar power and 50 GW biomass power, 10 Mt of bio diesel, and 5 Mt of ethanol by 2031-32. Results in an energy mix in 2031-32 (assuming 8 per cent growth), the 41.1 per cent (632GW) for coal, 22.8 per cent (350GW) for crude oil, 12 per cent (185 GW) for noncommercial, 9.8 per cent (150 GW) for natural gas, 6.4 per cent (98GW) for nuclear, 5.6 per cent (87GW) for renewables, and 2.2 per cent (35GW) for hydro, 51.2 GW for biomass gasification and combustion for electricity. The balance is supplied by 270 GW of coal a plant load factor of 67 per cent, 69.8 GW of natural gas, 27.8 GW coal bed methane, 22.2 GW in situ coal gas, 3.1 GW IGCC pet coke."

114 IEP, pp. 38-40: India's total potential hydropower is 150 GWe Installed nameplate power (of which 32.3 GW is already installed) which is a historical 60 per cent load factor provides the equivalent of 84GW. India's high estimate for total potential onshore wind power of 65 GWe nameplate provides 13 GW or 10 Mtoe/yr at an expected future capacity factor of 20 per cent.", and "In the case of Hydro, in his full potential of 150,000 MW is taken as exploited by 2031-32. Nuclear capacity of 63,000 MW is assumed to be realised by 2031-32."

115 Energy Sector R&D Working Group, p. 109: "The integrated energy policy report, prepared by the Planning Commission, has recognised that "from a long-term perspective and keeping in mind the need to maximally develop domestic supply options as well as the need to diversify energy sources, renewables remain important to India's energy sector. It would be not out of place to mention that solar power could be an important player in India attaining energy independence in the long run. With a concerted push and a 40 fold increase in their contribution to the primary energy, renewables may account for only 5-6 per cent of India's energy mix by 2031-32. While this figure appears small, the distributed nature of renewables can provide many socioeconomic benefits."

116 IEP, p. 49, "The most energy-efficient scenario from our model shows an aggregate energy requirement of 1536 Mtoe in 2031. This scenario is 19 per cent more efficient than the most energy intensive scenario. With a projected population of 1.468 billion, the per capita total primary energy supply (TPES) in the most energy-efficient scenario comes to 1046 kgoe/yr. This is comparable to China's per capita TPES in 2003."

117 IEP, "It is seen that even under scenario 11, coal was the dominant fuel with the share of 51 per cent and in electricity generation and the share of over 41 per cent in the energy mix. Gas-based generation only contribute 11 per cent of electricity generation capacity in scenario 11."

118 Table 2.7 sources of electricity generation 2031-32401 BkWh Hydro 375 bkWh Nuclear 24 Bkwh Renewables, 2828-3693 BkWh thermal energy. This assumes exploitation of full hydro potential of 150,000 MW in the country, the capacity addition of 63,000 MW of nuclear power sources and 14,000 MW capacity from wind farms. As a result of these assumptions share of coal-based electricity drops from 72 per cent to 61 per cent . (22) assuming 8 per cent GDP growth in the would move from 553 kWh in 2004 to 2471 kWh by 2032 (32).

119 IEP, p. 28: "In the same scenario hydro would've grown up 5.9 per cent annual compounded growth to be 3.7 times its 2004 level, nuclear would've grown 11.2 per cent to be 14.6 times its current level, coal would've grown between 5.9 and 6.3 per cent to be 3.6 to 4.1 times its 2004 level; oil would've grown between 5.1 and 5.6 per cent in the 2.9 to 3.4 times; natural gas 7.2 per cent to 8 per cent in the 5.2 to 6.3x 2004 levels, and the total primary commercial energy would grow between six and 6.4 per cent to be 3.7 to 4.1 times its 2004 level."

120 IEP, p. 69: "Putting India's likely energy demand in the 2031-32 in a global perspective, one sees that China's current energy consumption is 1100-1200 Mtoe in the USA's current consumption is 2400- 2500 Mtoe. In comparison to India consumed about 348 Mtoe of commercial energy in 2004-05…. what this means is that India per capita basis consumes under 6 per cent of what the US consumes in under 41 per cent of what China consumes and will by 2031-32, consumed just under 15 per cent of current US consumption levels and equal China's current per capita consumption."

121 IEP, p. 4: "Historically plan targets have never been met, and even in the 10th Plan, the likely capacity addition will actually be under 20,000 MW (20GW). Further, the generation capacity does not have the desired mix of peaking, intermediate and bracelet stations. Finally, the history of emphasis on investment in power generation results in loading more and more power on inadequate transmission and distribution (T&D) network. Since T&D investments have not kept pace with investments in generation, power cannot be easily moved from surplus to deficit areas."

122 See http://timesofindia.indiatimes.com/Business/India-Business/Power-cuts-have-cost-India-Inc-Rs-43000-crore/articleshow/4585676.cms of this year, which says, "The government fell 70 per cent short of the target to build new power plants in 2008-09, even as businesses across the country lost an estimated Rs 43,000 due to supply disruptions as well as voltage fluctuations...only 3,453 mw capacity was added in 2008-09 against a target of 11,061 mw. This is a mere 30 per cent of the goal...Yearly targets have been missed during the first two financial years of the 2007-12 plan period, which envisages addition of a whopping 78,000 mw. Overall, the UPA added 25,583 mw during 2004-05 against the NDA's 13,878 mw between 2000-01 and 2003-04. Between the NDA and UPA rules, per capita power consumption increased from 592 Kwh in 2003-04 to 707 Kwh in 2007-08 but peak shortage has also gone up to 16 per cent. Capacity addition has lagged during the last five years due to tendering tangles, delayed statutory clearances, disjointed fuel supply chains and a severe shortage in facilities to manufacture power equipment."

123 IEP, p. 50: "Apart from the challenges of physically supplying different forms of energy discussed above, the investment requirement also shows a need for purposes of action. *Electricity generation, transmission and distribution sector alone is estimated to require an investment of at least Rs. 60 trillion in 2005 rupees [$1.2 trillion]. The total energy sector investment could well amount to Rs. 100-110 trillion in 2005 rupees [$2-2.2 trillion] inclusive of related infrastructure."*

124 IEF, p. 35: "India's poorly endowed with uranium. Available uranium supply can fuel only 10,000 MW pressurised heavy water reactors (PHWR)… Indian nuclear fuel [is] 2-3 times costlier than international supplies. The substantial for reserves can be used but that requires that the fertile thorium be converted to fissile material… the pace of nuclear power is constrained by the rate at which plutonium can be bred and thorium converted to fissile material. (35) 61,000 tonnes of Uranium-Metal provide 330 GWe-Yr in PHWR, or 42,220 GWe-Yr in fast breeder reactors. 225,000 tonnes of Thorium-Metal 150,000 GWe-Yrs. (Table 3.3, page 36). DAE estimates that by 2030 nuclear power could

supply 48-63 GWe of power, and by 2050, 208-275 GWe. (Table 3.4, p. 37)" *[Note: 150,000 GW-Years sounds like an infinitely long time, but in fact it is meaningfully finite, 150,000 GW-years would be just under 1000 years of India's current total electrical demand, but only about 111 years of India's total electrical (only) energy demand in 2050.]*

125 IEP, p. 130: "While significant technological development has been made in the area radioactive waste disposal and decommissioning, they are yet to be proven at large enough scale to satisfactorily resolve economic issues. However, despite these risks, global data suggests that of all the conventional energy options, nuclear energy poses the least risks in terms of mortality per billion megawatt hours of generation."

126 IEP, p. 63: "Thorium based reactors requires sustained R&D effort. Success in these efforts could deliver some 250,000 MW nuclear power by 2050 and much more thereafter."

127 DAE Paper 10, Tables 8 and 9.

128 IEP, p. 13: "From a long-term perspective a number of issues need to be addressed: (a) how much energy do we need over the long run? Given our resources what should be our strategy to meet the growing demand? (b) how do we promote the efficient allocation of various fuels and energy forms to different users? What should be their relative prices? (e) what is the role renewables in our energy supply? How we promote the development? (f) How should we increase India's known energy resources? What new technologies are relevant for India's future? How do we promote their development? What should be our R&D strategy? …(h) how do we ensure energy security?... how do we reduce dependence on imported energy? (i) how do we encourage an energy system that keeps air pollution within acceptable limits? The growing global concern over the threat of climate change requires that India continues to increase its energy supply and responsible manner without compromising its energy growth imperative. Long-term energy strategy must take this into account."

129 IEP, p. 50: "The carbon emission implications of our scenarios are therefore significant annual CO2 emissions could rise from 1 billion tonnes at present to 5.5 billion tonnes per year by 2031-32 in the high coal use scenario and 3.9 billion tonnes in the low coal and renewable common scenario. In the US, emissions today are in excess of 5.5 billion tonnes of CO2. In per capita terms, however, India's carbon emissions in 2031-32 will be 2.6 to 3.6 tonnes of CO2 compared to the 2004 level of over 20 tonnes in the US and the global average of 4.5 tonnes in 2004."

130 India 2039 report, p. 49, "On its current trajectory, India's call on the world's energy resources in 2039 would increase to about 3,100 million tonnes of oil equivalent, and its contribution to carbon emissions, to 6.5 gigatonnes—unsustainable for India and unacceptable for the world."

131 IEP, p. 48: *"If we assume no dramatic new finds of oil in the country, our oil imports will be around 315 to 451Mt in 2031-32. This is about 4 to 5 times what we import today… India's imports will constitute 7.9 to 11.3 per cent of global trade."*

132 IEP, p. 69: "Realistically speaking, it is likely to India would need to import some 40 to 45 per cent of its commercial energy requirement compared to the current level of under 30 per cent. Domestic commercial energy supplies will then need to rise four times an aggregate over the next 25 years is import permits for commercial energy is not to exceed 40 per cent."

133 See 11th Plan, p. 15: *"We are short of most energy resources. Even coal, which is our most abundant resource, may run out in 40-50 years."*

134 IEP, p. 51: "Comparisons of our energy requirements and a resource base suggests that our hydrocarbon resources would be grossly inadequate to meet our needs. From a longer-term perspective we need to take a number of actions: undertake a solar technology mission to make solar power using photovoltaics or solar thermal economically attractive; undertake R&D for fusion to keep open the option for unlimited power."

135 IEP, p. 34: "The reserves of crude oil are merely 786Mt. These can sustain the current level of production for 23 years and are less than only seven years worth of our current

level of consumption in 2004-05."

136 IEP, p. 17: "India's currently known oil and gas reserves will be exhausted in 23 years and 38 years, respectively, at current production levels." For an excellent comprehensive discussion of India's Energy Resources, see Raju, Dhana R. "Introduction to Energy Resources: Atomic Minerals and Fossil Fuels". Hyderabad, India. Available at: http://nsdl.niscair.res.in/bitstream/123456789/667/4/Final+-_Atomic+Minerals.pdf

137 *Even in the transportation and liquid fuels sector, Space-Based Solar Power can still provide energy security solutions. Aviation can be serviced by highly productive algae-based JP8 as part of a dual-use rectenna / land usage (see discussion in Snead).* Ground transportation can in principle be entirely electrified, with Flex-Fuel Plug-in-Hybrid Electric Vehicles (PHEVs) as the obvious desirable interim step. Further, it is desirable to begin converting the ground transportation fleet to electric power even now, since a direct comparison between the emissions of gasoline-fed Internal Combustion engines emit nearly twice as much as grid-powered electric vehicles even if entirely powered by coal (0.141 kg CO2/km for electric vehicles vs 0.258 kg CO2/km for gasoline powered automobiles). http://en.wikipedia.org/wiki/Electric_car#Carbon_dioxide_emissions. Such vehicles can charge at night when loads are low, and can also serve as a kind of buffer for peaking demand. *Further, the demand on the electrical grid is quite reasonable, as 464 GW generating 4,064.078 TWh/annum is sufficient to power the entire current global vehicle fleet through its 26 trillion kilometers/per annum at the listed rate of 0.155 kWh/km, and would cut the global emission of transportation from 6.765 Gt CO2 to 3.697 Gt CO2.* (Based on Socolow's future of 22 per cent of total emissions from transportation and *www.earthpolicy.org/Indicators/CO2/2008.htm*Estimate of global emissions at 8.38 Gigatons of carbon (GtC)[30.75 Gt CO2] from 2006.) This would provide both significant security of source, and market price stability, as predictably generated electricity does not exhibit large price fluctuations.

138 IEP, p. 51: "World energy supplies are becoming increasingly constrained. India needs to grow its energy share in a market with sluggish growth in supply and rising prices. It is assumed that the world's fossil fuel supplies grow by 2 per cent per annum. Then India share of the world supplies of fossil fuels in 2031-32 would rise from a level of 3.7 per cent to a low 7.6 per cent in the most energy-efficient scenario to 10.9 per cent in the most energy intensive scenario."

139 IEP, p. 70: "Irrespective of the final level of demand, India's growing demand for commercial energy supply has to be seen in the context of a tightening global energy market with rising prices and stagnant outputs. The world oil demand is expected to grow from the current level of 81 to 82 million barrels per day to 110 million barrels a day by 2020 at a growth rate of 1.8 per cent per annum… the US production of oil peaked in 1970 and North American gas production is widely believed to peaked in 2000. The world oil and gas production are expected to peak in 2010-2015 and 2015-2020 timeframe is respectively… even if this is considered a pessimistic outlook, India should be prepared for it."

140 See Dadwal, p. 4: "These concerns arise partly from concerns over the rapid depletion of fossil fuels – particularly oil into lesser extent, gas reserves – and partly due to the policies adopted by some of the energy producing countries. The concerns regarding adequate supplies arise from the fact that most of the sources of oil supply that are accessible to the developed countries in the international oil companies (IOCs), have reached or are close to, their peak production capacity. For instance, the US'proto-Bay block, and the North Sea's largest giant fields such as Ekofisk, Brent, Forties, Statfjord, Gullfaks, Heidrun and Oseberg, have all peaked, as well as some of the older giant fields of West Asia. According to a report by *Financial Times*, quoting the International Energy Agency's (IEA) World Energy Outlook, *output from the world's oil fields is declining faster than previously thought. Without more investment to raise production, the natural annual rate of output decline is 9.1 per cent.* The report said that the world struggled to produce enough oil to make up for steep declines in existing mature fields, such as those in the North Sea, Russia and Alaska, to meet long-term demand... in fact, according to the US Energy Information

Administration (EIA), *80 of 84 oil and gas exporting countries have reached a point where there is fuel reserves have reached a plateau in production is decreasing."*

141 IEP, p. xxii.

142 IEP, p. xiii.

143 IEP, p. 48.

144 IEP, p. 69.

145 India 2039, p. 38.

146 11th Plan, p. 14: "The performance during the Tenth Plan in adding capacity was disappointing. Against the target of 41110 MW [41GW], only 21080 MW [21GW] were commissioned, out of which only 18000 MW [18GW] were actually made fully operational."

147 IEP, p. 48: "India cannot deliver sustained 8 per cent growth over the next 25 years without energy and water, and these two together shall, in turn, pose the biggest constraints to India's growth."

148 "For us to make certain that energy does not become a constraint on our growth, we have to literally expand every source of energy that is available to us. And even then, there may be a wide gap between demand and supply of energy....This has really opened up a huge opportunity for India in terms of international cooperation with the rest of the world in nuclear energy and technology...while this is a high scale of opportunity in terms of at least partially meeting our energy security, nobody is arguing that this is the be all or the end of dealing with our energy challenge...So, I think we should NOT hype this to the extent that the nuclear energy deal means that our problems are solved. They are not. We must be realistic about how much we can actually scale up nuclear energy say up to 2020 or up to 2050 to meet a significantly growing part of our energy needs. There have been various figures that have been talked about. and I do not know what Dr. Kakodkar has said, but he has mentioned earlier that opening of the nuclear trade will enable us to add up to 40,000 MW of nuclear generated electricity by 2020. There have also been figures mentioned that we will have 60,000 MW by 2030. So we are looking at a very major and accelerated programme for expansion of the nuclear industry...based on some very important presumptions…We do not have enough reprocessing facilities in the country...the kind of human resources that we will require, the kind of capacity building that we require is again going to be something very ambitious. And the sooner we address that issue, the better it is....the Atomic Energy Act has so far not been amended to allow for private sector participation in nuclear power plant operations...This is itself a huge opportunity...*sometimes in India there is, what I consider to be a somewhat distorted contradiction that is placed between technical collaboration with foreign companies and what we need to do indigenously...It is not as if one is a substitute for the other...there is a certain technology cycle. Even if we look at our atomic energy programme or our space programme, we must not forget that the initial base was built with international collaboration. It did not come out of thin air. That is what enabled us to put in place a certain infrastructure for the development of these industries. It enabled us to benefit from training, from access to higher education, in science, and that is what enabled us to absorb the modern technology and then be able to internalise if and then use it for further development. But this is not a one-time or a one-off event. It is a process. You keep upgrading yourself with foreign collaboration that enables you to build up your own capacities from where you move up to a higher level of collaboration. You start off being a recipient and end up being a partner. That is the pathway you need to follow. So I would caution people from putting the development of indigenous technology as somehow being divorced from what needs to be done in terms of collaboration with other advance countries. These things go very much hand in hand. And to the extent we are living in a highly globalised, interconnected world, to think in terms of autocratic types of policies is not the right way. We should really have an open mind and we should have an open regime for absorbing technology and sharing what we develop with others, so that there is a creative interaction that is constantly taking place with the rest of the world*...I would also like to point out something that people have missed that this particular agreement while it may seem to be about nuclear energy, its ramifications are actually much wider. In 1974, when there was a response to

our nuclear test, much of the technology denial and the limitations of the sanctions that were placed on us were nuclear specific. They related to the transfer of nuclear plants, its technology, and the nuclear components. But as time passed a number of dual use technologies were added to this list...if there was a super computer we wanted for weather forecasting but could also be used for making calculations for nuclear purpose, we were denied such items...a very large number of dual use technologies, which had little to do directly with the nuclear sector and had perfectly legitimate uses in our civilian industry for development and upgradation of our industry , were denied to us. And this list kept on becoming larger and larger as time passed. So essentially we have been facing a technology apartheid and what this agreement has done,...that a very large number of these dual-use technologies...have now become available to us. This I think, is a huge opportunity, and a very big challenge for India. But this means that the private industry also needs to proactively get involved. They have to take advantage of such items are now available. The benefit of this goes far beyond just the nuclear industry." Shyam Saran, Special Envoy to Prime Minister on Indo-US Nuclear Deal (IEF Newsletter, January-February 2009).

149 IEP, p. 68: "To fuel a sustained 8 per cent annual growth or energy scenario faces major challenges. Even the conservative projection of India's energy needs to fuel this level of economic growth requires the basic capacities in the energy sector related physical infrastructure such as rail, Port, roads and water grow by factors of 3 to 7 times by 2031-32 alongside a 20 fold increase in nuclear and a 40 fold increase in renewable energy. If we cannot assure supply and even the conservatively projected levels of commercial energy we will not be able to grow 8 per cent per annum."

150 IEP, "An integrated energy policy is needed to ensure that energy costs and availability do not constrain India's economic growth and competitiveness."

151 See Gopalaswami.

152 Ultimately though, if nuclear must replace not only coal but hydrocarbons because of global peak and decline in supply, it will not be a permanent solution. To understand the scale, the ultimate potential with thorium is quite high, expected to supply 275GW in 2050. *If nuclear had to supply all of India's energy needs in 2050, India's total nuclear fuel resources would last approximately only 217 years* (see table 4 and figure 1 of attached DAE Study.): 61,000 tonnes Uranium in Fast Breeders = 1,027,616 TWh (thermal) 2,25,000 tonnes Thorium in Breeders = 3,783,886 TWh (thermal) Conversion efficiency of Thermal to Electricity in nuclear power plants = 0.36 Total Thermal Potential of Indian Nuclear Fuel = (1,027,616 TWh + 3,783,886 TWh) x 0.36 = 1,732,140.72 TWh (electric) Annual Electricity demand in 2050 = 8,000TWh/Yr Total Electrical Potential of Indian Nuclear Fuel = 1,732,140.72TWh(e) / 8,000TWh(e)/yr = 216.5 Years

153 Energy Sector R&D Working Group, p. 3: "Installed electricity generation in India has grown more than 100 times since independence in 1947. To sustain the projected GDP growth rate, the energy production levels must be stepped up to 1350 GWe by 2050. It is thus clear that, every source of energy needs to be exploited with adequate attention to the commercial viability and environmental aspects.... a recent study by DAE estimates approximate percentage contributions of various sources towards electricity generation in the year 2050 to be 49 per cent by coal, 3.8 per cent oil, 11.8 per cent gas, 8.3 per cent, hydro, 2.4 per cent nonconventional renewable and 24.8 per cent nuclear.... it is estimated that electricity investment from 2001- 2030 would be approximately US$10 trillion (based on $ cost of 2000). This excludes fuel cost. India's investment in electricity in this period is estimated to be approximately US$665 billion." Original DAE study, "Document 10: A Strategy for Growth of Electrical Energy in India", available at www.dae.gov.in/publ/doc10/.

154 IEP, p. 33: "Proved reserves of coal, the most abundant energy resource, at the current level of consumption can last for about 80 years. If all the inferred reserves also materialised and cool and late night could last for over 140 years at the current rate of extraction of course, coldly by consumption will increase in the future in the reserves

would last for four fewer years. *If domestic coal production continues to grow at 5 per cent per year, the total (including proven, indicated and inferred) extractable reserves service will run out and about 45 years."*

155 IEP, p. xxii: "At a growth rate of 5 per cent in domestic production currently extractable coal resources will be exhausted in about 45 years."

156 IEP, p. 17: "The current levels of production growth, the known extractable resources will be exhausted in less than 45 years. A large part of India's coal reserves may not be extractable with current mining technologies."

157 IEP, p. 71: "Coal emerges as the most important energy source in India accounting for not less than 41 per cent of our energy mix under any scenario and potentially reaching 54 per cent of the energy mix under certain scenarios. Even at 41 per cent level, India would need 1.6 billion tones (about four times current production). At a higher share requirement could rise to 2.5 billion tones (over six times the current production) of coal from domestic sources. Depending upon the level of increase in domestic coal production to meet growing demand, India's currently known reserves of extractable coal will not last beyond 45 years. Plus we have to stretch our energy resources as much as we can by promoting energy efficiency and conservation. To augment or energy sources we should also promote the development of new sources of energy."

158 Note that the IEP, p. 47 says that it takes eight years to develop a coal mine, and the quality of Indian coal is deteriorating progressively, and a 5% deterioration of the next 25 years would raise the core requirement from 2555 Mt to 2689 Mt.

159 Energy Watch Group. *Coal: Resources and Future Production*. Ottobrun, 2007. http://www.energywatchgroup.org/fileadmin/global/pdf/EWG_Report_Coal_10-07-2007ms.pdf "Production profile projections suggest the *global peak of coal production to occur around 2025 at 30 percent above current production in the best case*… The fastest reserves depletion worldwide is taking place in China with 1.9 percent of reserves produced annually. The USA, being the second largest producer, have already passed peak production of high quality coal in 1990 in the Appalachian and the Illinois basin. Production of sub-bituminous coal in Wyoming more than compensated for this decline in terms of volume and – according to its stated reserves – this trend can continue for another 10 to 15 years. However, due to the lower energy content of sub-bituminous coal, US coal production in terms of energy has already peaked 5 years ago – it is unclear whether this trend can be reversed. ...This analysis reveals that global coal production may still increase over the next 10 to 15 years by about 30 percent, mainly driven by Australia, China, the Former Soviet Union countries (Russia, Ukraine, Kazakhstan) and South Africa. Production will then reach a plateau and will eventually decline thereafter...while the IEA reference scenario assumes further increasing coal consumption (and production) until at least 2030. According to our analysis, this will not be possible due to limited reserves."

160 Friedman, Tom. *Hot Flat and Crowded*, Farrar, Straus and Giroux, 2008, pp. 186-87.

161 Integrated Energy Policy, p. xxv: "Research and development (R&D) in the energy sector is critical to augment our energy resources, to meet our long-term energy needs and promote energy efficiency. Such R&D would go a long way in raising our energy security and delivering energy independence over the long-term. R&D requires sustained a continued support over a long period of time."

162 Energy Sector R&D Working Group, p. 110: "It is recognised that the long-term interest of the country in developing and harnessing the renewable energy technologies would be better served when indigenous RDD efforts are encouraged and supported by the government. The government needs to take a liberal approach to developing emerging technologies and processes. The risk in developing new and emerging technologies, where the benefits of the technology development or not to be necessarily visible in the next 3-5 years, the risk must be covered largely by the government.... the overall approach of the R&D support in renewable energy sector should aim at achieving

significant reduction in the cost and improving the product life and reliability."

163 Integrated Energy Policy, "Energy related R&D has not got the resources it needs. India needs to substantially augment the resources made available for energy related R&D and to allocate the strategically. To take an innovative idea to its commercial application involves many steps. Basic research leading to fundamental breakthrough may open up possibilities of applications. R&D is needed to develop conceptual breakthroughs improve their feasibility. This needs to be followed up by working, laboratory scale model. Projects that show economic potential should then be scaled up as pilot projects, while keeping in mind cost reductions that could be achieved through better engineering and mass production. Demonstration projects, further economic assessment and more R&D then go into making the project acceptable and attractive to customers before commercialisation and diffusion can take place."

164 IEP, p. 13: "Many energy projects involve large investments in a long gestation lags. An integrated policy needs to provide a framework of development in the strategy of transition to the desired energy future. In particular, R&D for new technologies and new sources maybe most successful with long-term commitment and support. Setting priorities among alternative R&D missions and to finding an optimal R&D strategy require an integrated perspective on the future of the energy system."

165 IEP, p. 103: "While coordinated effort is desirable for all R&D in all links of the innovation chain, it becomes critical to place such a coordinating role under a commercially oriented entity, with well identified targets, when one needs to roll out already commercial or near commercial technologies in a time bound manner. Funding for specific projects in our universities and R&D institutions as a part of such a programme should be routed through the coordinating agency for time bound outcomes. In either approach, it is emphasised that R&D requires sustained support over long periods of time."

166 Energy Sector R&D Working Group, p. 113: "Is recognised that no research and technology development can be sustained without specialised and skilled manpower to undertake the work… the IIT's and other engineering colleges need to be pursued to design and develop specialised courses in renewable energy."

167 11th Plan, "The low entry of talent into the S&T streams is one of the most serious challenges facing S&P systems in the country. Therefore, during the 11th Plan period and beyond, a new scheme under the title 'Innovation in Science Pursuit for Inspired Research' (INSPIRE) would be initiated to attract and foster talent in scientific research."

168 Energy Sector R&D Working Group, p. 93: "Provenness is a key factor for selection of technology in most industries... in this regard, it is proposed that tax incentives e.g. excise duty waiver or reduction etc. should be given to the refinery for the first time implementation of an indigenous technology or commercial scale/semi-commercial scale... research and development for new technologies requires imported many sophisticated equipment and pilot plant. It is proposed that to encourage the R&D centers of commercial organisations particularly PSUs (DSIR recognised), the wavering customs duty to be given like CSIR laboratories and academic institutions.... for such cases were technology development is mature at pre-commercial launch levels, it is important that the matters taken up at higher level in the government for evolving simplified procedures to encourage indigenously research products, especially when the government is the buyer or is funding the projects.... new/emerging technologies can be undertaken turning them at the conceptual stage itself to the requirements of the users. A few such technologies can event pages to the economy, can be concentrated upon by users and technology providers.... indigenous technology/product's development itself can be sponsored by users of the products. This practice is quite common in the Japanese and Korean industries woes in China."

169 IEP, p. xxv: "Demonstration of such projects, economic assessments and further R&D to make the new technology accessible and attractive to customers could follow, before finally leading to commercialisation and diffusion… much R&D can be considered a public good. It is thus better financed by the government. Initially an allocation of Rs

1,000 crore [$0.2 billion] should be made for energy R&D excluding atomic energy."

170 Energy Sector R&D Working Group, p. 4: "Vision of the initiative: to set the world-class consortium for energy with select facilities for development of advanced materials for power generation in making India a global leader for the manufactured export of power plant equipment... to develop advanced materials at lower cost and make India a global leader in the export of manufactured components required by the power sector."

171 Energy Sector R&D Working Group, p. 108: "R&D objective: the main objective of R&D during the 11th Plan and beyond is to reduce the costs, improve the performance efficiency, reliability and life of systems for energy in attendance of the country through clean and sustainable renewable energy technologies."

172 NAPCC, p. 21: "The R&D effort should be directed mainly at reducing costs of production and maintenance, and include both production design and fabrication/ assembly techniques. In addition, R&D should cover a balance of systems issues involved in hybridisation…"

173 IEP, paraphrase of p. xxvi: The integrated energy policy recommended that a national energy fund (NEF) be set up with priorities based on the dynamic strategic vision to support a number of technology missions for developing near commercial technologies and rolling out new technologies in the time bound manner to encourage coordinated research in all stages of the innovation chain to reach a targeted goal using the existing model of atomic energy and space research from a broad base of research institutions, universities and even individuals.

174 Energy Sector R&D Working Group, p. x: "The working group supported the creation of a National Energy Fund. The working group also felt the need for "directed" basic research to be promoted in the energy sector. "Directed" basic research may be in an area where knowledge generation would benefit Indian society in the long term court may be in an area where the results of the research would benefit Indian industry in the long term. "

175 IEP, p. 71: The integrated energy policy committee supports the planning commission's 10th plan proposal for the creation of an apex body on energy under the chairmanship of the Prime Minister. They further suggest that central and state governments as well as leading lending institutions see the market for long-term 20+ years that the finance all infrastructure particularly energy infrastructure using capital market-based instruments twenty-year repayment schedules during keys for later maturities built-in refinancing every five years and partial risk guarantees. They also suggest an annual renewable energy report should be published providing details of actual performance in different renewable energy technologies at the state and national levels the Department of Science and Technology is a technology business incubators for entrepreneurs for renewable energy and energy efficiency and rule energy. However, entrepreneurs also need finance. Financial institution should be encouraged to set up venture capital funds for energy entrepreneurs. DST should monitor actual success on the ground and reshape its programme based on actual results/feedback.

176 Energy Sector R&D Working Group, p. x: "An amount of Rs. 5,310 crore [$1.06 billion] is projected as the requirement for addressing the energy R&D needs brought out in this report, over and above the plan budgets (for the 11th Five-Year Plan.) Of the ministries and departments dealing with R&D in the energy sector... the amount... will be dispersed to the Department of Atomic Energy by creating a board of research in energy science and technology (PREST) operated on the same lines as the board of research and nuclear sciences (B. or NS). That amount will be used for supporting inter-institutional and interministerial/interdepartmental research areas like energy related materials, combustion initiative, etc., mentioned in District Court and for setting up centers of excellence in universities/national academies/mission oriented agencies in the energy sector. A notional figure of about 2 per cent of the projected Rs. 5,310 crore could be generalised to the office of the principal scientific advisor to the Government of India."

177 Energy Sector R&D Working Group, p. 110: "Elements of research: i) establish a research portfolio broad enough to encompass basic science, to technology development, to prototype development; ii) establish research priorities based on market opportunities; iii) attract and involve the best and brightest brains were ever available to get the work done; iv) ensure synergy throughout the process between government, academia, research labs and industry so that all issues of policy, funding, technology and marketing are comprehensively addressed."

178 IEP, p. 103: "At each stage appropriate support needs to be provided for R&D. The nature of supporting the attendant institutional arrangements will differ. India has used three approaches; technology development missions that require coordinated research and development at all stages of the innovation chain to reach a targeted goal such as in the departments of atomic energy and space research; technology rollout missions to develop and roll out commercial or near commercial technology such as the missions to provide rural telephony; and broad-based R&D support to research institutions, universities and others through project funding."

179 IEP, p. 103: "Technology missions are the most appropriate mechanism, particularly when it requires coordinated action in a number of different areas which may involve different government ministries, departments or levels and the private sector. A technology mission whether for development or rollout not only brings a single point focus to dispersed initiatives in the relevant field but also provides support to research projects in universities and research institutions with the aim of delivering the mission objectives. Technology missions must cover areas that are of critical importance to India's long-term energy needs."

180 IEP, p. xxv: "Research and development (R&D) in the energy sector is critical to augment our resources, to meet a long-term needs, to promote efficiency, to attain energy independence and enhance our energy security... Energy R&D has not got the resources it needs. We need to substantially augment the resources for energy R&D and allocate the strategically. To take an innovative idea to a commercial application involves many steps. Basic research leading to fundamental breakthrough may open up possibilities of applications. R&D is needed to develop any new concept and to prove its feasibility. This needs to be followed up by a working model at laboratory scale. Scaling up to a pilot project files if the economic potential is attractive keeping in mind cost reductions that could be achieved through better engineering and mass production. Demonstration projects, further economic assessments and more R&D than go into making the project acceptable and attractive to customers before commercialisation and diffusion can take place. At each stage appropriate support needs to be provided for R&D. The nature of supporting the attendant institutional arrangements will differ. India has used three approaches; technology development missions that require coordinated research and development of all stages of the innovation chain to reach a targeted goal such as in the departments of atomic energy and space research; technology rollout missions to develop and roll out commercial or near commercial technology such as the missions to provide rural telephony; and broad-based R&D support to research institutions, universities and others through project funding. Technology missions are the most appropriate mechanism, particularly when it requires coordinated action in a number of different areas which may involve different government ministries, departments or levels in the private sector."

181 http://en.wikipedia.org/wiki/List_of_countries_by_population

182 http://en.wikipedia.org/wiki/List_of_countries_by_carbon_dioxide_emissions

183 http://en.wikipedia.org/wiki/List_of_countries_by_energy_consumption_per_capita

184 http://en.wikipedia.org/wiki/List_of_countries_by_carbon_dioxide_emissions_per_capita

185 http://en.wikipedia.org/wiki/List_of_countries_by_ratio_of_GDP_to_carbon_dioxide_emissions

[186] Kaiper, Gina V., US Energy Flow Trends—2002, https://netfiles.uiuc.edu/mmazzocc/shared/DOE%20Energy%20Flow%20EED%20LLNL%20GOV%20llnl%20ucrl-tr-129990-02.pdf for updates, see: https://publicaffairs.llnl.gov/news/energy/archive.html

[187] 2010 Annual Energy Outlook Early Release Overview http://www.eia.doe.gov/oiaf/aeo/overview.html

[188] Kaiper, Gina V., US Energy Flow Trends—2002, https://netfiles.uiuc.edu/mmazzocc/shared/DOE%20Energy%20Flow%20EED%20LLNL%20GOV%20llnl%20ucrl-tr-129990-02.pdf

[189] Annual Energy Outlook Early Release Overview, at http://www.eia.doe.gov/oiaf/aeo/overview.html

[190] Annual Energy Outlook Early Release Overview, at http://www.eia.doe.gov/oiaf/aeo/overview.html

[191] *This gives a nameplate capacity of 2,024 GWe, but low capacity factor and variability mean only 101.2GW of dispatchable power generation, providing only 5.6 million GW-hrs of annual electric power. Snead,* "End of Easy Energy", p. 40.

[192] Giving a name plate capacity of 13,400GWe, but because of low capacity factor and variability, producing only 29 million GW-hrs of annual electricity. Snead, "End of Easy Energy", p. 41.

[193] Snead, James M. (Mike), "The vital need for America to develop space solar power", Monday, May 4, 2009, at http://www.thespacereview.com/article/1364/1

Is True Cooperation On Strategic Technologies Possible?

The Objections of Sceptics

There remains at the time of writing a significant amount of scepticism on both sides regarding the degree to which India and the US can and will engage in meaningful technical cooperation in meaningful dual-use technology like space.[1]

Asymmetrical Capability

Discussions with policymakers and implementers on the US side see the obstacles principally in terms of structural and asymmetric capability. First, they complain of an understaffed and under-empowered, and often opaque bureaucracy, where few people even have the authority to schedule a meeting, that pushes decisions upward and is often "unwilling to sign paper" that sets up the mechanisms that are required to provide US agencies freedom of action. Second, they complain that their perception of Indian desires for cooperation often sounds more like one-way transfer, or "give us stuff," where the US seeks a trade off that is equal or better. The US also often requires significant end-use monitoring to make sure its huge investment and technological edge is not compromised by reverse engineering or passing the technology on to others.

Technology Control Regimes (ITAR & MTCR)

Discussions with policy-makers and implementers on the Indian side base their scepticism chiefly on what they see as the US's own self-defeating technology control regimes, specifically the International Trafficking in Arms Regulations (ITAR),[2] which governs civilian satellite and launch, and the Missile Technology Control Regime (MTCR),[3] both of which, it is felt, impede meaningful cooperation and are not particularly effective in preventing proliferation but are quite effective in losing business for the US. India also has concerns that it could relax its stance on autonomy and become dependent on US technology only to come under sanctions or a technology control or denial regime at some later time. India also has active technical partnerships with other technically advanced countries that it has strong incentives to preserve.

Further, both the US and India protect their strategic (meaning dual-use) industries like launch and satellite manufacture, and India in particular sees its space programme as a crown jewel of autonomy. Each domestically has a stake in not becoming interconnected and interdependent.

Evidence for Cooperation

Despite the concerns of sceptics, the Indo-US strategic partnership seems to rest on very sound fundamentals that are not likely to change over several decades. First, is a shared cultural history in colonialism, with the attendant struggle for freedom, and the important influence of the enlightenment thought, British political organisation, commerce and trade routes and prominence of the English language in matters of science, state-craft and commerce. Second, the significant and growing bilateral trade. Third is the asymmetric but aligned economic needs–where India needs investment today to maintain a high rate of growth for development and cohesion, and the US is looking for high growth places to invest, and places that provide both a market for its own goods and a cost-competitive manufacturing base to manufacture the ideas it conceives and finances. Fourth is the large and politically active diaspora that is actively seeking to build closer ties. Fifth is a shared interest in limiting the damage of those extremists that undermine pluralism and sew extremism and violence. Finally, both wish to take part in the the economic rise of a vibrant Asian market where a normative rule set prevails that allow all members to benefit from the use of global commons and work on collective problems and human security is possible. Within this framework, both nations see the need to make space for and engage China as it evolves as a responsible stakeholder with greater transparency, but to ensure that accommodation takes place respecting important equities of themselves and their neighbours, and is free of any element of coercion.

Steady Progress and Momentum

Further, the strategic partnership has exhibited steady momentum and upward direction across changes in administration in both countries. A change in the orientation of the countries began at the end of the Cold War with the 1991 Kicklighter Memo under President George H.W. Bush, and was followed by the Agreed Minute on Defence Cooperation in 1995. The momentum slowed following India's decision to conduct nuclear testing ("Operation Shakti") in 1998, but was resumed in the wake of the Al Qaeda attacks on the US on September 11, 2001 ("9/11"). Since then, despite changes in ruling parties on both sides, there have been a list of important accomplishments, including the signing of a General Security of Military Information Agreement (GSOMIA) in 2002, the formal designation of India as a "Friendly Foreign Country" for cooperative activity in research and development, and participation in the Foreign Comparative Testing (FCT) programme, the inking of the 2003 Master Information Exchange Agreement (MIEA), the 2004 Joint Statement laying out the Next Steps in Strategic Partnership (NSSP) and the New Defence Framework and Umbrella Research Development Testing and Evaluation agreement (RDT&E) agreement, both signed in 2005, the Maritime Security Cooperation Framework in 2006, and quite recently the Civil Nuclear Agreement ("123") in 2008. With the NSSP, the two countries set up important and regular dialogues on energy, space, high-tech cooperation, defence and defence research cooperation, and aviation cooperation. Most recently, in 2009, a new high-level strategic dialogue was announced, as well as special engagement on climate change and an emphasis on a "renewable energy partnership." More concretely, India and the US agreed to a standard end-use monitoring (EUM) language, a technological safeguards agreement, a side letter allowing the launch of civil US satellites and components, and set up an endowed science and technology fund.

Ongoing Technical Cooperation

These were necessary procedural precursor steps, and clearly show an increased trust to cooperate in dual use and high tech areas. In fact, *all the necessary components are now finally in place for a much expanded technical collaboration.* There are already a significant number of information exchange agreements (IEAs) that are active or in the process, and one active project agreement (PA) on Toxicity Evaluation of Engineered Nanomaterials (TEEN). There are many more active collaborations between Indian researchers and US basic research agencies; for example, the National Science Foundation (NSF), the Asian Office of Aerospace Research and Development (AOARD), or the Office of Naval Research (ONR) Global. Non-governmental, completely civilian, collaboration in both industry and academia is many times deeper, with dedicated multi-national research institutes such as the General Electric Jack Welch Center (GE-JWC).

Why India, and Does India Have Anything to Offer?

While most Indian audiences encountered by the researcher did not seem to challenge the reasons for why India might want the US as a partner in such a high tech space endeavour, a frequent line of questions posed during interactive sessions was "Why India and does India really have anything to offer? Why shouldn't the US and its companies just go it alone? Why not choose as a primary partner Japan or the European Union, or 'cash-rich China', which is easier to work with than our complicated democracy and bureaucracy?"

This researcher sees no reason to argue why the US or India or both together should not seek collaboration with these other partners, but there is significant momentum in the Indo-US strategic partnership, and strong reasons for the US to consider India.

Firstly, *India is the only major state where a Head of State has not only suggested space solar power as a goal for its space agency,* but also expressed an interest in international cooperation. Second, as already noted above, *there is considerable momentum in the Indo-US strategic partnership,* with key components–space, energy, climate change, high tech, aviation, and dual-use strategic technologies and defence cooperation–already in place with vibrant dialogue. Third, *India's need for power and development is acute, likely considerably more acute than other potential partners* which makes it potentially a more motivated partner, and a linked effort also promises a tremendous ultimate market potential. Fourthly, the success of space solar power will depend partly on low-cost manufacture. *In the time frame when space solar power will come of age, perhaps 15 years in the future, even as other manufacturing and labour markets age and face decline, India is projected to be in the midst of its demographic dividend, with the largest working age population of any country on earth.*[4]

Finally, and significantly, in a breakthrough project like space solar power where an international regulatory framework is required, the influence of a historically normative power representing the developing world and its equities is a powerful enabler, and *without such a partnership a go-it-alone attitude might find the environment and the markets considerably less permissive.*

Further, the case for technical cooperation with India is quite strong. As already remarked, *over the course of nearly a decade, there has been significant momentum to the technical cooperation aspect of the Indo-US strategic partnership and we have finally put in place all the necessary precursor elements for institutional research and development.*

Cooperation today is principally at a low level because bureaucracies still are not familiar with each other,[5] and trust is earned incrementally over time. In the course of this research, there was no indication that there was reason to doubt that such trust and familiarity will be the natural course.

India already contributes the largest number of foreign technical students in the US and its diaspora contributes substantially in high tech. As multinationals and successful Indian diaspora choose to return, India is likely to see a significant expansion in the number and type and competence of technical capabilities.

India is today a very competent space power, being one of a very small club of nations with heavy launch, launch to GEO, and moon-mission capability, and it is only going to become more so. For a project like this, one must consider not just the current level of a country's tech base, but its likely trajectory. Investments being made now in satellite design, low-cost re-usable Two Stage to Orbit (TSTO) systems at ISRO and Single Stage to Orbit (SSTO) through DRDO's International Space Plane Programme are likely to evolve relevant technologies even while the US launch programme has taken a diversion into large expendables. Particularly in an immature project like space solar power where there are very few technologists with a level of competence in the subject, in the course of a five-year technology and workforce development project, India's technical schools can easily multiply the number of competent technologists by multiple factors. That rapid addition of intellectual workforce at competitive costs provides yet another multiplier for rapid progress.

Is MTCR or ITAR an Insurmountable Obstacle?

A frequent concern encountered in structured discussions was the obstacles posed by the MTCR and ITAR.[6] Do these, in fact, pose an insurmountable obstacle? They do not. There is currently a strong current suggesting ITAR may get a re-look to become more permissive with respect to space cooperation. But even if there is no change, ITAR is not a prohibition, just an onerous procedure for approval, which can be navigated by a dedicated, expert cadre. It is also possible that if policymakers are convinced that the success of larger ends is at stake, that special legislation (like the Counter Terrorism Technical Support Organisation[7]) or an executive order could streamline some types of technical interchange. An example exemption already exists for COMSAT.[8]

Further, MTCR is not an absolute prohibition. It specifically states that it is not meant to constrain cooperation in civil space programmes.[9] In practice, however, it is difficult to find a meaningful distinction between peaceful launch and missile technologies. Even in the case of unambiguously military technologies, countries are at liberty to transfer such technology, provided they receive adequate assurances from the recipient country. One interesting idea that came up in discussion was the idea of a controlled international facility for space-planes, patterned after the IAEA model for controlled international nuclear facilities.[10]

ITAR

There is also significant criticism of ITAR's effect on US strategic position with respect to advantage in space,[11] and the need for the US to be more open in space cooperation. For instance, the recent Augustine Commission report summary of key findings said "space exploration has become a global enterprise…Actively engaging international partners in a manner adapted to today's multi-polar world could strengthen geopolitical relationships, leverage global resources, and enhance the exploration enterprise…The US can lead a bold new international effort…If international partners are actively engaged, including on the 'critical path' to success, there could be substantial benefits in foreign relations and more resources overall could become available."[12] Even more critical is the National Security Space Office's (NSSO), the policy office that coordinates between US military, intelligence and civil space programmes (see description under stakeholders), recent Space Transportation Roadmap, which says: "In order to achieve needed sub-orbital and/or orbital space transportation capabilities through the 2025 time frame, what international cooperation will be required?'…Industry and government stakeholders generally responded that the International Traffic in Arms Regulations (ITAR) serves as one of the most significant obstacles to US progress and competitiveness in space. Implemented at a time when the US benefited from an asymmetric technological advantage that enjoyed a wide margin, its goal of safeguarding US national security and furthering US foreign policy objectives were rational. The risks of international space partnerships and enterprises, and of foreign investment or technology sharing in commercial space endeavours, were obvious, even on balance with lost opportunities….However, today's globalised, multi-polar world has changed the dynamics, and the balance of that risk. The Department of State's strictly bureaucratic enforcement of ITAR fails to recognise the global and egalitarian shifts in technological advantages placing a self-insulated US at great risk in terms of both commerce and national security. Profitable technology and investment opportunities are missed on all fronts, as the US becomes evermore blind to the actual state of the art. In fact, certain foreign technologies are evolving to the asymmetric advantage of our competitors, all the more so because ITAR prohibits the sort of commercial teaming that would permit our deeper insight. The reality today is that US national security benefits from a deep insight of the space technologies of international commercial competitors just as much as those competitors benefit from understanding ours. In fact, in the realm of advanced technologies generally, not just those that are space-related, it is difficult to imagine any that are not dual and multi-purpose. *In conclusion, with respect to ITAR, there was a government and industry consensus that ITAR regulations need to be substantively revised in a way that recognises that broader international space partnerships are in our national security interest."*[13]

Peter A. Garretson

Notes

1 For instance, in presenting this paper, Science reporter Pallava Bagla noted that while India had opened the door to participation in Chandrayaan-1, it almost didn't happen because the US found it difficult to participate with the US bureaucracy and its rules posing an obstacle and time sink.

2 See an excellent discussion of ITAR and its effect on India in Bommakanti, Kartik, 2009, pp. 12-14, 'Satellite Integration and Multiple Independently Retargetable Reentry Vehicles Technology: Indian-United States Civilian Space Cooperation',*Astropolitics*,7 (1), January 2009, pp. 7-31, available at http://dx.doi.org/10.1080/14777620902768859

3 From Dr. G Balachandran, Unpublished Manuscript, Chapter II on Space Cooperation: *"Cooperation in civilian space related activities offer the greatest scope for expanded Indo-US high tech transfers and joint activities* with some exceptions. The Indian Space Research Organisation's (ISRO) primary programs are in the areas of satellite development and operation, space propulsion and space applications. Of these three, space propulsion is one area where there can be only limited or little joint activities or transfers of equipment or related technologies. The MTCR regime as well as US domestic laws would place some restrictions on such activities. However, in the area of satellite technology, especially communication satellites, and space application the opportunities are great. ISRO would be a major beneficiary of the NSSP if it matures to its full potential."

4 Nilekani, *Imagining India*, p. 51, India's demographic dividend will not peak until 2035. By 2035, India will have added over 270 million people to the working population.

5 Synthesis of numerous conversations with officials on both sides.

6 Balachandran, G, Unpublished Manuscript: "The equipment and related technologies that ISRO may need or would prefer to source from US fall within the ambit of both the US Commerce Control List (CCL) and the US Munitions List (ML). The former is licensed by the Department of Commerce and the later by the Department of State. In general items figure in the US ML if they are specifically designed or modified for military application. Commercial communication satellites, scientific satellites, research satellites and experimental satellites are designated as Significant Military Equipment (SME) and are included in the ML only when the equipment is intended for use by the armed forces of any foreign country. It is most likely that ISRO requires export licenses for items under both the USCCL and USML. EAR99 items being items of common nature not usually requiring licenses do not fall in the category of items specifically designed or modified for military use and do not figure in the ML. The current licensing environment is not conducive to such an operation. Some new mechanism has to be found. Fortunately the US has already in place a regulatory regime that allows for such a contingency.*[COMSAT, discussed below]."*

7 See CTTSO Website http://www.cttso.gov/international-partners.html

8 Balachandran, G, Unpublished Manuscript, "The FY 2000 Foreign Relations Authorisation Act, passed in 1999, required the Department of State to 'establish a regulatory regime for the licensing for export of commercial satellites, satellite technologies, their components, and systems which shall include expedited approval, as appropriate, of the licensing for export by United States companies of commercial satellites, satellite technologies, their components, and systems, to NATO allies and major non-NATO allies.' The Department of State published implementing regulatory changes in May 2000 establishing a special regime for licensing commercial communication satellite components, parts, accessories, attachments, associated equipment and certain associated technical data. The focus of the regime was on two areas: i) supply of satellite components and associated technical data and ii) technical data for use in plant visits, responding to bids and request for quotes, acceptance of testing equipment and the like and for marketing complete satellites. The primary feature of the regime was the freedom of US suppliers of such items to submit license applications for multiple permanent and temporary exports and temporary imports of such articles for expeditious consideration without meeting the

documentary requirements concerning purchase orders, letters of intent, contracts and non-transfer and end use certificates, or the documentary requirements of concerning approval of re-exports or retransfers, when all of the following requirements were met: The proposed exports concern exclusively one or more foreign persons (e.g., companies or governments) located within the territories of the countries identified as being eligible for the regime, and one or more commercial communications satellite programmes included within a list of such persons and programmes approved by the U.S. Government for purposes of this section, as signified in a list of such persons and programmes that will be publicly available through the Internet Website of the Office of Defense Trade Controls and by other means. The proposed exports or re-exports concern exclusively one or more countries of the North Atlantic Treaty Organisation and/or one or more countries which have been designated as a major non-NATO ally. The regulations did, however, require the exporter to report complete shipment information to the concerned authority within 15 days of shipment including description of the item, the quantity and end user and end use. At present, the COMSAT regime is applicable only for NATO and major non-NATO allies (MNNA). It is an interesting fact that while currently Pakistan, as a MNNA, is eligible for COMSAT benefits but cannot make use of them because of the absence of technical capability to undertake such a task, India which has both the capability and potential US partners to make use of COMSAT benefits, cannot do so since it is neither a member of NATO nor a MNNA. *However, given that the NSSP has been billed as an unique arrangement between US and India, unlike any other agreement that US has with other countries, and given that it is about strategic partnership, it should not be difficult to extend COMSAT benefits to India as well.* Fortunately there is a precedent on how to achieve this objective…under Section 2350a, Title 10 United States Code, the Secretary of Defense was authorised to enter into memorandum of understanding (or other formal agreement) with one or more major allies (member countries of NATO or MNNA) of the United States or NATO organisations for the purpose of conducting cooperative research and development projects on defense equipment and munitions. However, this section was amended in 2001 to include "Any friendly foreign country" (defined as being other than the NATO, a NATO organisation, member country of NATO and a major non-NATO ally) as well. India was designated as such a "Friendly Foreign Country" (FFC) by the Secretary of Defense in late 2001 and that designation has since then been maintained by the Secretary of Defense. *Therefore, in a similar manner, Section 1309 (a)(1) of the Foreign Relations Authorization Act for FY 2000 which currently is applicable only to member countries of NATO and major non-NATO allies, can be amended to include the category of "any friendly foreign country" as well. Since India has been already designated a FFC, nothing further needs to be done.* And since the language of the amendment is not India-specific, it would not attract any adverse attention from non-friendly members of the US Congress. Further it would restore a semblance of parity in matters of U.S. high technology-relations with India and Pakistan. *An alternate approach to the issue would be an amendment to Part 123.27- Special licensing regime for export to U.S. allies of commercial communications satellite components, systems, parts, accessories, attachments and associated technical data- to include India in the Special licensing regime.* There is a precedent for such an action. In May 2000, the US announced the Defense Trade Security Initiative (DTSI) announced at the NATO Ministerial in Florence, Italy. These initiatives reforming the US defense trade export control system was made available made available to NATO Allies, Japan and Australia, were intended to improve the efficiency and competition in defense markets. In July 2000, the State department published regulations to implement the initiatives. In July 2001, Parts 124, 125 and 126 detailing the implementation of DTSI were amended to make these reforms available with respect to Sweden as well. *In a similar manner Part 123.27 can be amended to include India in the special COMSAT licensing regime.* Which of these would be the optimal approach requires to be examined further. If that is done, then ISRO can be included in the COMSAT list of approved persons and the communication satellite programmes of ISRO listed in the COMSAT list of approved programmes. Such a move will enable ISRO to compete for satellite procurement bids by third parties either alone or in collaboration with US firms with mutual benefits to both US and India. It will also help

ISRO's own communication satellite programmes. If this were to be done, the facilities of COMSAT regulations which cover items controlled under US ML can be extended to include as well Department of Commerce licenses for the COMSAT approved programmes to ISRO. Such an approach will not in any manner dilute the control the US government has over licensing of items for communication satellite programmes or the conditions which it may impose on such transfers. It will merely make the commercial transactions that much simpler and transparent and enable ISRO to operate in an internationally competitive environment."

9 The aim of the MTCR is to restrict the proliferation of missiles, complete rocket systems, unmanned air vehicles, and related technology for those systems capable of carrying a 500 kilogram payload at least 300 kilometres, as well as systems intended for the delivery of weapons of mass destruction (WMD)… The MTCR Guidelines specifically state that the Regime is *"not designed to impede national space programs or international cooperation in such programs as long as such programs could not contribute to delivery systems for weapons of mass destruction."* http://www.mtcr.info/english/guidelines.html

10 Round-table discussion with AeSI community, Hyderabad, India.

11 http://csis.org/files/media/csis/events/060921_sat_export_controls.pdf

12 Summary Report of the Review of U.S. Human Space Flight Plans Committee, www.nasa.gov/pdf/384767main_SUMMARY%20REPORT%20-%20FINAL.pdf

13 National Security Space Office. Space Transportation Technology Roadmap In Support of the Small Unit Space Transport and Insertion (SUSTAIN) Capability, and Other Expressed Government and Industry Space Transportation Needs, Washington, DC, September 14, 2009.

A Discussion And Evaluation of Various Responsible Agencies And Stakeholders; of Various Models for International Cooperaton, Space, Energy And Infrastructure Development

This paper incorporates a fairly comprehensive discussion of the important stakeholders, technology providers and relevant models in formulating a policy approach to SBSP. This is a major portion of the contribution of the paper and should be quite useful to someone in the US trying to understand the Indian system, or someone in India trying to understand the complexities of the US energy/space/defence/dual-use/export control system, as well as to policy entrepreneurs, who are seeking useful models of bilateral/multilateral cooperation, or infrastructure/energy development. However, to appeal to a broader audience, who may not desire to read through this survey, I have moved those sections to the appendix section. The various stakeholders and models discussed ahead can be further referenced in detail there.

Judgements of the Researcher

First, a programme like space solar power is strategic in that it crosses many bureaucratic lines of authority and requires broad and different expertise, and many benefits are external to the organisation. However SBSP is currently weak in terms of an organised constituency. The lens through which it is seen matters greatly—is this a space project, an energy project, a climate-change / geo-engineering project, a strategic cooperation technology project? While it is all these things, *it is my judgement that it is best framed as an energy security/renewable energy/climate security project. Therefore, those agencies responsible for energy and climate should be in charge, with space and defence as suppliers.*

Corporations[1] try to maximise their payback in a short time with minimal risk. The low technical readiness, high development costs, accompanying technical and financial risk, long-payback time, and present lack of anchor customers are substantial barriers to entry, and mean it is unlikely for corporations interested in SBSP to be able to enter the market and be successful. Corporations will shrewdly look to the government to reduce the risk.[2]

Government provided incentives, such as solar feed-in tariffs, transferrable tax credits, and anchor customer contracts such as the Ultra-Mega-Power Plant scheme will certainly raise corporate interests, but recent business case analysis suggest that it is unlikely a corporation can absorb the very large non-recurring development costs and be able to close the business case.[3]

A multilateral COMSAT-like consortium is a significant investment that will probably not seem justifiable before there has been significant, technological risk reduction, technology demonstration and an assured business plan is in place.

The criteria I will establish for moving to a for-profit international consortium is when there is a demonstrated business plan, a clear consensus on international regulatory regime, and a relevant demonstration of the technology in a sub-scale but directly scaleable manner, in its native environment, over the actual distances, at the actual frequencies, with meaningful levels of power and power density.

An international demo project is within reach of present engineering and mega-science budgets, and can be done with existing launch vehicles, but needs to be preceded by a process to arrive at a design consensus.

The US and India have demonstrated via a number of recent steps that they are ready for a deeper partnership inclusive of sensitive and strategic technology in space, energy and R&D.

MTCR is not insurmountable in the longer term, but an early concentration on launch is likely to be more difficult than an early concentration on satellite design.

Mechanisms do exist for cooperative military R&D and both military R&D establishments have displayed some level of interest and utility for power beamed to forward and remote bases. *The military technical* base should definitely be leveraged, but an exclusively military focus will detract from other meaningful bilateral goals and not fully capture the potential benefits for the bilateral relationship.

A bilateral programme is likely to enjoy the best support if kept at the highest level. A higher level direction will also allow the leveraging of the talents and capabilities of multiple agencies.

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Notes

1 Aside from the major aerospace, energy and utility corporations in the US, Japan, China and Middle East that have expressed interest, the following list of small companies have declared interests in developing Space Solar Power:

Heliosat http://www.heliosat.com/

ManagedEnergy http://managedenergytech.com/

Packer Engineering http://www.packereng.com/services/research_development.html

PlanetPower

PowerSat http://www.powersat.com/

Solaren http://www.solarenspace.com/

SpaceEnergy http://www.spaceenergy.com

Space Island Group http://www.spaceislandgroup.com/solarsat.html

SpaceWorks http://www.sei.aero/com/projects/displayindex.php?id=1

Welsom Solar http://nextbigfuture.com/2009/02/welsome-space-consortium-solar-space.html

2 Based on conversations with major aerospace firms in the conduct of the NSSO Space Solar Power Report, and public discussions at conferences such as the Space Investment Summit, New Space Conference, and IDSA Industrial Base conference.

3 Xin et all, Wingo, Unpublished manuscript

Proposed Model for How Policymakers Might Structure A Bilateral Space Solar Power Development Programme

The programme recommended assumes that the conservative judgements of the researcher in the last section are correct and that there is no company with the requisite technology and financing today that can build space solar power satellites successfully for profit without government help; that the technology is likewise too immature to justify immediate formation of an international for-profit consortium; that the community is too small and insufficiently organised to move immediately to a mega-science scale demonstration; that a government-sponsored precursor effort to develop the underlying technology and workforce is a universal enabler; and that a low-level effort without Head-of-State visibility and commitment is neither likely to maximise benefits of a cooperative programme nor likely to achieve the necessary momentum to truly realise the goal.

The overall programme goal must be directed and specific: First, to *enable, by 2025, space-based solar power as a viable economic replacement for fossil fuel energy, and second, to position the US and Indian technical and industrial bases to enjoy a competitive edge in what is expected to be a significant and profitable market.*

Such a focus, with both a time and economic component, will ensure that the goal does not become an endless self-serving research and development programme, but is connected with a necessary degree of urgency to the larger societal and political needs.

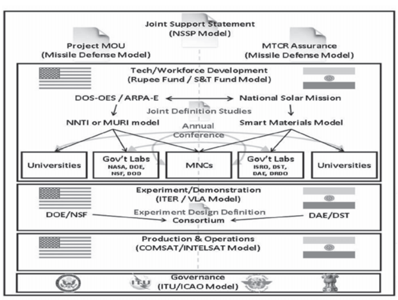

Figure 2 Proposed Model

Toward that end, *the first and most important precursor step is to capture the idea within the context of the dynamism of the Indo-US partnership with high level attention and establish top-level support and sanction.*

In the proposed model, there is an enabling government policy followed by three consecutive stages or tiers of value producing activity. Certain specified criterion of success is required for graduation to the larger investment in the subsequent stage. This maximises interim gain and minimises risk and cost.

Stage 0: Framework

An enabling bilateral framework is created to provide high level sanction,[1] resourcing, and organisation. The components of this framework are:

- Inclusion of the goal of realising the potential of green 24-hour energy from space in a joint statement.
- An enabling information exchange agreement
- An enabling project agreement
- An organisational framework for collaboration
- If there is a desire to pursue simultaneous development of low-cost access to orbit, then the Missile Technology Control Regime (MTCR) assurance document must also be signed

Stage 1: Technology Initiative and Workforce Development.

The goal of Stage 1 is to stimulate the technology base, push key enabling technologies and create a supporting work force and technical base. This stage would seek to broadly involve respective government agencies and labs, universities, and domestic and multi-national corporations.

Organisation and Functioning of Stage 1:

Due to the broad and interdisciplinary nature of the project, it is desirable to make use of the entire tech base of both nations. Therefore, the researcher has selected what is called a project or initiative model in the US and what is called a technology mission in the Indian context. In each, a central agency directs an overall research agenda and distributes funds to a number of different providers to reduce risk and cultivate expertise.

In the proposed model, the coordinating offices are kept at a high level, commensurate with the potential impact and equities of the various bilateral dialogues on climate change, energy and space, and above the level of contributing agencies.

For the US, international oversight can be managed out of the US Department of State's Office of Ocean Environment and Science (OES),[2] with the operational mechanism for project management and distribution of funds belonging to the Department of Energy's Advanced Research Projects Agency for Energy (ARPA-E).[3] ARPA-E in turn provides funding to a number of different providers, both in and out of the government, toward the directed ends specified below.

On the Indian side, the high level oversight is provided by the Prime Minister's Council on Climate Change, with the operational mechanism for project management being through the Solar Energy Centre as a special amendment to the National Solar Mission. To effectively marshal the talents and capabilities of the entire tech base, it is conceived that within the US, a multi-agency initiative, not unlike the National Nano Technology Initiative, will coordinate and leverage existing funding and related projects within government agencies, standard contracts, cooperative research and development agreements (CREDA) and other transaction authority (OTA) with cooperative corporations, and multi-disciplinary university research initiatives (MURI) to leverage and connect universities. Such procedures have similar analogues in the Indian system, with the National Solar Mission as one mechanism, and the smart materials programme being an example of multiple participating agencies, with funding distributed from a central source on a merit basis.[4] *An estimated total budget of $10-30 million might be required to fully address all desired goals of Phase 1.*

It is also desirable to construct an independent oversight to evaluate the progress toward the goal. In the US, this responsibility should be organised under the aegis of the National Research Council (NRC), and in India through the Prime Minister's Delivery Monitoring Unit, perhaps via the Principal Scientific Advisor's (PSA) office. A number of possible organisational models are possible and the researcher finds no compelling reason why it cannot be a different top agency on either side, or a slight divergence in model for fund distribution. For instance, one alternative will be simply to provide an additional "fenced off" budget within the new Joint S&T Endowment.

Phase 1 Deliverables

The key deliverables of this phase, all to be completed in less than five years are:

- A joint definition study, to include a system-of-system's level study with the minim aim of 550 GW by 2050 and 1 TW by 2065
- Identification of technology focus areas and targets
- A thorough study of the current economic delta and establishment of targets to achieve economic viability

- System-level studies
- A joint roadmap for technology development and demonstration
- An initial definition study for an ITER-level mega-science demonstration project
- Each of these would be facilitated by annual bilateral conferences for data sharing hosted in alternating countries

If the bilateral organisation succeeds in its deliverables on time (a reasonable target is five years), and is also able to articulate a viable and consensus approach toward a meaningful demonstration,[5] the broad technology and workforce development initiatives may be continued, but the focus of efforts and funding shifts.

Stage 2: Experiment / Demonstration

The goal of Stage 2 is to roll out a prototype level experiment that can directly be scaled up by industry. The key activity of this stage is to form an international consortium with a consensus experiment design where individual nations contribute their resources toward a common mega-science project. *Previous estimates for the time and cost of such a demonstration programme using existing launch capabilities is $10 billion and a timeframe of 10 years,[6] which is of the same order as the International Thermonuclear Experimental Reactor (ITER).*

This stage will likely follow the ITER model of a consortium, with national signatories,[7] and is almost certainly to be expanded to include more nations than just the US and India. In India, as in the US, this will likely mean a switch to DAE and DOE or DST and NSF to manage the much larger budget and execution through a subsidiary organisation like ITER-India.

If the experiment/demonstration is successful, and the underlying technology development efforts have been successful in retiring the major technical risk and there appears to be a convincing pathway to retire financial risk and execute a viable business plan, then the focus of efforts shifts to the next phase. *The demonstration needs to be well constructed, since there is again an order of magnitude step-function in the amount of capital required for the next phase.* It is estimated that the one-time non-recurring capital investment to achieve a full productive capacity is likely on the order of $100 billion ($35-265 billion) via a public-private partnership. *Although this level of capital is large, very large sums are not unusual in the energy sector for projects that have far less transformational effects.*[8]

Neither government nor a private company will undertake that step unless they can convince investors that the delivered power will be cost competitive in the targeted market and using standard net present value (NPV) calculations, there is a clear road to profitability.

Stage 3: Production and Operations

The goal of Stage 3 is to operate an international for-profit business consortium modelled after COMSAT/INTELSAT, with one or more legal consortium entities directly represented to UN governing bodies to deliver clean power for development worldwide within international governing rule sets. Individual nations will be at liberty to choose their signatories, whether they are private or publically held companies, or public service undertakings. An excellent discussion of how to structure such an undertaking is provided by Xin et al in Section 14.2 of the Toulouse Business School's Financial and Organisational Analysis for a Space Solar Power System: A business plan to make Space Solar Power a reality.

Space Security and Engagement with International Bodies

It is also important to note that direct engagement with UN governance bodies will be required even before the experiment / demonstration stage, to include the Committee on the Peaceful Uses of Outer Space (CoPUOS), the International Telecommunications Union (ITU), and may well require new institutions to be set up to cope with the significantly increased traffic to and from and in space. Such an institution might mirror the International Civil Aviation Organisation (ICAO) and provide a forum to disseminate safety practices and standards, and coordinate processes for space traffic monitoring (STM) and space traffic control (STC), as well as debris monitoring and active de-orbit. The space capabilities envisioned to be able to construct and maintain solar power satellites will have a significant impact on the space security regime, and the construction of a supportive regime will have to consider the potential *vulnerability of such high value space-based assets to counter-space capabilities, and the need to properly balance technical capabilities and assurances with diplomatic management of threat perceptions. Any group of nations proposing to undertake strategic cooperation in this area must be fully aware to the need to actively construct a regime that will be sensitive to the threat perceptions of others and likely expectation of regulation and assurances.*

In summary, an actionable bilateral policy framework will originate with a joint statement by the respective heads of state announcing and sanctioning the activity and signing the requisite information exchange and project agreement paperwork. An initial five-year, $10-30 million

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programme, managed in the respective executive, will develop contributing technologies and build a competent work force via the project/initiative and technology mission model, culminating in a roadmap and plan for an international mega-science project for a demonstration prototype. A second, $10 billion, 10-year phase will see the formation of an international consortium to construct a sub-scale space solar power system retiring all significant technical risk. The final stage will entail the bilateral leadership to set up an international for-profit consortium along the lines of COMSAT/INTELSAT model to provide a scalable green energy system to allow development and address energy security and carbon mitigation concerns.

Notes

1 Something like the Next Steps in Strategic Partnership (NSSP) verbiage, available for review here: http://www.dae.gov.in/jtstmt.htm

2 Others potential apex oversight groups might be OSTP or the organs OSTP manages, such as NSTC, or PCAST, or the appointed heads of the Energy Dialogue or Civil Space Working Group.

3 The policymaker might ask, why not ISRO and NASA? The answer is that the organisational cultures of both ISRO and NASA are focused on Space Exploration and have significant competing interest groups who have historically been successful in killing previous programmes.

4 During the presentation of this paper, Dr. V. Siddhartha suggested that India would need special legislation to set up a "Special Purpose Vehicle" (like was done with the Commonwealth Games) to set up an optimal organisation, and that the organisational form will have to change as the technology and its readiness changes as well. An SPV is a legal entity, usually a limited company to fulfill narrow, specific, or temporary objectives.

5 Policymakers should understand a meaningful demo to have the following criteria: It should retire all significant technical risk for a follow-on commercial architecture. It should in essence be a sub-scale demonstration in the proposed environment beaming an appreciable amount of power over the proposed distance where the components are directly scalable to a full-scale power plant.

6 NSSO, Space Based Solar Power: An Opportunity for Strategic Security.

7 Here the list of nations involved would need to expand significantly. In both discussions and presentation of this paper, there was particular concern about the geopolitical implications of this technology, and concern about it being available to all, and not being controlled by few powerful interests and possible power shifts. There was considerable interest expressed in early inclusion of China.

8 Please see Chart in Appendix to get a sense of cost, budgets and investment.

Conclusion

The problems of energy security, climate change and inclusive development are compelling, and viable long-term solutions have yet to satisfactorily emerge, and provide the challenge of our generation. India's challenges to develop, eradicate poverty, and still keep down emissions so as not to incur calamity are not hers alone but a bellwether of the future of the world. Technical solutions may exist, but they require policy entrepreneurs to translate scientific and technical proposals into the language of the problems and political agenda of the day.

This paper sought to evaluate space-based solar power, a highly scalable, revolutionary renewable energy technology, in the context of the Indo-US bilateral strategic partnership, and determine if US and Indian interests and amities were sufficiently aligned to allow forward motion on such a project, and if so, what would be an actionable form for policymakers. It is the conclusion of the researcher that SBSP does appear to be a good fit for the US domestic, Indian domestic and bilateral agendas, and there is adequate political space and precursor agreements to begin a bilateral programme, should policymakers desire it. Given that SBSP appears to fit the articulated Indian criteria for suitability of energy source and to offer a better long-term energy security solution, and that the evaluation of the current energy-climate situation is so unhopeful, with a lack of promising and scalable solutions emerging, a no-regret, due-diligence effort in space-based solar power seems a justified and strategic[1] investment. An actionable, three-tiered programme, with threshold criteria/goals, has been proposed, moving from basic technology and capacity building to a multi-lateral demo, and ultimately to an international commercial public-private-partnership entity to supply commercial power in the 2025 timeframe. The launch of such a potentially revolutionary programme can begin with a simple statement exchanged between the two heads of state,[2] or articulated in a joint statement.

An aggressive bilateral space solar power programme, at its minimum, will create a forum and networked cadre for discourse on advanced energy, space and climate technologies that can be recycled to nearer term problems, while visibly demonstrating an interest in global challenges. But at its maximum, such a programme might be a way out of India's (and the world's) climate-energy dilemma, as well as a $103-trillion opportunity and opportunity for India to use its successful space programme to transcend the middle income trap[3] while shaping a future peaceful space regime. It will certainly constitute not only a "big ticket item"[4] that will link the technical bases of the world's largest democracies, but also become one of the grandest and most ambitious humanitarian and environmentalist causes that will be sure to excite a generation as did the Apollo programme in the worthy purpose articulated by the founder of the Indian Space Programme Dr. Vikram Sarabai, "*we must be second to none in the application of advanced technologies to the real problems of man and society*." In what more meaningful way can two of the space-faring democracies contribute to the challenges of this generation than finding a solution to energy and climate security "in the third dimension", and capturing it within the dynamism of their strategic partnership?

Notes

1 Dr.Scott Pace, Director of the Space Policy Institute and former Associate Administrator for Program Analysis and Evaluation at NASA, speaking at an NDU Space Power Theory Seminar has remarked, "We know something is strategic if we can't fit it into any one bin…if we can say it is 'just' this or 'just' that. strategic capabilities touch multiple fields and cannot be accurately limited to any one area" SBSP certainly fits that criteria, as it crosses many lines and communities of authority and responsibility—it is a climate change and development solution that is based on energy; it is an energy project that is based on civil space technology; it is civil space technology that may be advanced by defense cooperation and competence in defense labs, it is a technology that if successful would change the world and require new governing regimes—that necessarily requires a larger view and more strategic discourse.

2 As recommended by Air Cmde Gopalaswami: *"....President Obama complimented Prime Minister Manmohan Singh for launching India's visionary national solar mission, and suggested it might be timely for India to initiate a comprehensive Feasibility Study for a Space Power Satellite and its enabling technologies within India, with US participation if needed…."*

3 India 2039 Report, "That is the middle income trap—unable to compete with low income, low wage economies in manufacturing exports and unable to compete with advanced economies in high skill innovations.", "The middle income trap refers to countries stagnating and not growing to advanced country levels" The report dramatises the difference: "The payoff to the marathoner is huge: per capita income of over $20,000 by 2039, four times what the sporadic sprinter [trapped in the middle income trap having not pursued tech development strategies] can expect to achieve.", and then provides a prescription, calling for India to become a "globally competitive economy" by enhancing its competitiveness, moving from lower to higher productivity activities by "climbing up the global technology ladder" as Japan (specifically citing MITI) and South Korea have, specifically through spending 9-10 per cent of GDP on infrastructure vs. the current 5-6 per cent, including *crash programmes to eliminate power shortages and accelerate completion of rural electrification and national highways*, increasing R&D spending from 0.8 per cent of GDP to 3 per cent (mostly in the private sector vs today's 70-80 per cent in the public sector which is narrow in scope, has low outputs and is disconnected from the market) to create a "technology and innovation system" pursuing frontier, strategic and inclusive innovation, enhancing commercialisable research and development and creating a foundation to diffuse and encourage the absorption of new technologies "innovation ecosystem comprising an integrated science, technology and innovation policy, facilitative intellectual property regime, responsive infrastructure early-stage and venture capital, and science and technology parks and incubation centres with clusters of higher education and research and development institutions. • Provide support for basic and

applied research and technology diffusion through tax credits, matching grants, loan guarantees, technology rewards and training support." and "Launching a Revolution in Energy" seeking "progress in energy efficiency and significant use of renewable and nuclear technologies", recognising that "*Launching an energy revolution for energy security and competitiveness* India will not be alone. The world will collectively go through an energy revolution or carbon revolution in the next three decades—a revolution that will create for India as much opportunity as challenge. The international community recognises that the global carbon emissions target cannot be achieved without India's cooperation. India could thus count on an effective partnership and a global compact with the global community, which would bring with it substantial technological and financial support in return for pursuing an energy strategy in India's self-interest.", "Establish a crash programme for developing clean energy technologies—particularly solar, clean coal and carbon capture technologies under public private partnerships.", "an energy pricing policy that provides financial incentives for timely investments and for the transfer and *Global leadership in advanced energy technologies* Worldwide", and "a much greater degree of openness to drawing on international experience and advances. And the modes of research and development support should ensure much more reliance on the private sector for technology imports and adaptation."

4 *Assuming a total non-recurring investment of $200 billion and a production cost in the neighborhood of $15B per 10GW satellite / rectenna system and fifty five 10-GW satellites (55 x $15B = $820 billion) are required to achieve 550GW to ensure 7 vs 5 per cent GDP growth per Gopalaswami, then the Return on Investment (ROI) in the Indian GDP Scenario alone exceeds 100:1 ($103,000 billion/$1,020 billion) even before the full lifetime revenue payback of all the satellites.*

Appendices

Appendices

Appendix A

A Discussion And Evaluation of Various Responsible Agencies and Stakeholders

In discussions in India, both with Industry and Government it was apparent that for a project like SBSP, it would fall to the government to take the lead, as the capacity and self-direction of industry R&D was still far behind government, and along with the universities, highly dependent on it for resources and direction. But a persistent problem (not unique to India), was the question of "Who will take a decision?" on this, since it crosses so many boundaries and organisations. It is at once, a energy project (MNRE, DAE), a Climate Change mitigation project (MoEF), a space project (ISRO), a science & technology project (DST, DSIR), a dual-use defense cooperation project (DRDO), and an international project (MEA)—who has the preponderance of expertise, who is best positioned for cooperation, and should own, lead and champion it?

This section is designed to give a high level introduction to the organs that may have some role in the development of SBSP. It is written to have a broader utility, to any policy entrepreneur interested in Indo-US collaboration in the fields of energy, space, climate, or other strategic / dual use technologies. As such it aims to provide an introduction of both Nation's respective policy and technology organs, as well as the existing bilateral interfaces. The organisation I have chosen for this section is to first discuss high level national organisations that provide sanction, oversight and broad direction, then to discuss executing bodies with expertise and funding, then facilitating bodies that form bi-national touch-points, and finally regulatory bodies, both national and international that may have orthogonal or opposed ends, such as frequency management, non-proliferation, or trade protection that must be addressed.

Indian Stakeholders

PM's Committee on Climate Change (GOI)

A coordination committee chaired by Prime Minister called the Prime Minister's Council on Climate change was constituted in June 2007 to coordinate national action for assessment, adaptation and mitigation of climate change. The first meeting of the Council was held in July, 2007 and the second meeting of the Council was held in November 2007.

One of the important decisions, has been to prepare a National Document compiling action taken by India for addressing the challenge of climate change and the action that it proposes to take, India's National Report on Climate Change.[1]

Planning Commission (GOI)

With no analog in the US, the GOI's Planning Commission is charged with "making assessment of all resources of the country, augmenting defiant resources, formulating plans for the most effective and balanced utilisation of resources and determining priorities."[2] As a practical matter, the planning commission now builds "a long term strategic vision of the future and decide on priorities of nation…works out sectoral targets and provides promotional stimulus to the economy to grow in the desired direction…plays an integrative role in the development of a holistic approach to policy formulation in critical areas of human and economic development." The Prime Minister is the Chairman, which works under the overall guidance of the National Development Council. The Chairman, Deputy Chairman and full time Members (8), as a composite body, provide advice and guidance to the subject Divisions (34 total, of which Power & Energy is #22 and Science and Technology is #26) for the formulation of Five Year Plans, Annual Plans, State Plans, Monitoring Plan Programmes, Projects and Schemes.[3] National Priorities, key targets, and budget allocations for all non-defense matters are set forth in Five-Year Plans.

Space Commission (GOI)

The Chairman of this Commission is also the Chairman of ISRO, and the Secretary of the Department of Space.

PSA to GOI

The Office of the Principal Scientific Advisor to the Government of India is primarily responsible for evolving policies, strategies, and missions for generation of innovations and support of multiple applications and generating science and technology tasks in strategic, economic, and social sectors in partnership with Government departments, institutions and industry. The tasks of the PSA's Office involve creation of missions and multi-departmental, multi-institutional projects in strategic, technology and other areas of economic/social relevance. The PSA is also the Chairman, Ex-officio of the Scientific Advisory Committee to the Cabinet (SAC-C), which includes some 51 members from IIT, IIS, TIFR, BARC, Ministry of Communications and Information Technology, Center for High

Energy Physics, National Physical Laboratory, medical centres and Industrialists.[4] Chief Advisor to the Prime Minister of India for Science and Technology, is a separate position, but also may have significant equities with respect to an SBSP programme.[5]

MOD Science Advisor to Minister of Defence (GOI)

The Department of Defense Research and Development is headed by a Secretary who is the Science Advisor to the Defence Minister ("SA to RM"). It is the Job of the SA to RM to advise the Government on scientific aspects of military equipment and logistics and the formulation of research, design and development plans for equipment required by the services.[6]

ISRO (GOI, Department of Space)

The Indian Space Research Organisation (ISRO)[7] is a civil space organisation under the Department of Space that reports directly to the Prime Minister. Its closest analog is NASA. It presently has a budget of approximately $1-1.5 billion.[8] While ISRO at present has no extant programme in SBSP, its overall purpose and vision are quite consonant: "The guiding vision for the Indian Space Programme, from the very inception of the programme had been to *be 'second to none' in the development and applications of space technology to the solution of the real problems of society*. India was among the first few countries to realise the importance of space technology to solve the real problems of man and society and took initiatives to develop the space technology for the benefit of the nation. The emphasis on Self-reliance has been an important component of the vision, with which India undertook development of satellites, launch vehicles and associated ground segment indigenously in a progressive manner. Today, India's *core competence in space is its ability to conceive, design, build and operate complex space systems* and use them in various frontiers of national development. Space holds immense potential to accelerate the development process in the country and offers enormous opportunities to understand the universe. In the context of rapidly transforming India into an economically prosperous, socially secure and culturally rich nation, Space technology is an inevitable tool. The *thrust of the space programme in future will have to be on large scale applications of space technology in the priority areas in the context of national development*. The future directions for Space Programme have to *take into account needs of the country* in the context of emerging international environment and the potential that India holds for human development."[9] The major objectives of India's Space Programme are self-reliant space services for large scale applications of priority to national development.[10] Consonant with the above discussion on India's priorities, "The overall *thrust* of the space programme will be to sustain and strengthen the already established space based services *towards socio-economic development* of the country. The programme profile will be based on the emerging requirements in the priority areas of national development and security requirements and will take cognizance of the policy framework and global trends. " Further, ISRO's thinking already reflects an appreciation of the underlying technologies and future potential contribution in energy," Material processing, building large space systems like space stations, servicing and refuelling of satellites in space and the potential of space to *augment our energy resources* will be of increasing importance in the days to come" including a space logistics concept very similar to that articulated in the NSSO Report on Space Solar Power, recognizing the "*moon and its potential to augment our energy resources* have been initiated in the recent years. Building up *large space systems like space stations, servicing and refuelling of satellites in space and material processing* are promising greater *economic benefit* to the nation." Aside from the above emphasis, ISRO acknowledges the importance of reducing launch costs and reusability[11] , and already has active programs in Two-Stage-to-Orbit (TSTO), and air breathing Single-Stage-to-Orbit[12] ISRO's long-term planning and vision effort is led by its Scientific Secretary[13] . ISRO has an office for international cooperation.

Antrix Corporation (GOI-controlled)

Antrix is a government owned company, established in 1992 to market Indian Space Products and Services,[14] and serves as the business and marketing arm of Indian Space Research Organisation (ISRO). The name "Antrix" is an anglicised version of Antarriksh, the Sanskrit word for "Space". Antrix markets a range of products and services including spacecraft systems (such as various precision subsystems for spacecraft, including solar array deployment mechanisms, camera control, spacecraft power systems and power electronics, transponders and attitude control systems), propulsion components (propellant tanks, liquid apogee motors, thrust control mechanisms, transducers, etc.), Remote Sensing services (selling satellite imagery from the Cartosat, IRS, Oceansat and other remote sensing satellites that ISRO operates), Transponder leasing services on the INSAT series of communication satellites, Launch services on board ISRO's PSLV and GSLV launch vehicles, Ground support services (supply, install, integrate and operationalise ground tracking stations for satellites in orbit), Spacecraft testing services (access to test facilities for satellites and launch vehicles). Antrix has successfully launched several Commercial Satellite Launches of Kitsat (Korea), Tubsat (DLR - Germany), BIRD (DLR -Germany), PROBA (Verhaert, Belgium) aboard the ISRO's Polar Satellite Launch Vehicle (PSLV), and supplied reliable satellite systems and sub-systems to customers such as Hughes, Matra Marconi, World Space, etc.[15]

DAE (GOI)

Reports directly to the Prime Minister through the Atomic Energy Commission.[16] The mandate of the DAE is to develop and deploy technologies for the production of nuclear power and to harness applications of radiation and isotope technologies for societal benefits, and to increase the share of nuclear power through indigenous and other proven technologies, and support to basic research in nuclear energy and the frontiers of science.[17] Their vision is to empower India through technology, creation of more wealth and providing a better quality of life to its citizens. Its activities include the design, construction of nuclear power and research reactors and supporting fuel cycle technologies covering exploration, mining, and processing of nuclear materials, production of heavy water, nuclear fabrication, fuel processing and nuclear waste management. It is also developing advanced technologies which contribute to national prosperity, and human resource development for Indian industry. Like the U.S. DOE, DAE's broad technology base has branched out and DAE is now pursuing other technologies such as solar thermal, alternate energy conversion,[18] nanotechnology, MEMS, microelectronics, plasmas, high power RF, lasers, high precision manufacture, robotics and automation, and has a history of fruitful international collaboration, such as with CERN, KEK, Fermilab.[19] Its mandated functions and duties also include accelerators, supercomputers, advanced materials, and instrumentation.[20] DAE is also the funding agency for ITER-India, contributing to the multi-lateral effort to achieve fusion energy.[21]

MNRE (GOI)

The Ministry of New and Renewable Energy (MNRE) is the nodal Ministry of the GOI for all matters related to new and renewable energy. The broad aim of the Ministry is to develop and deploy new and renewable energy for supplementing the energy requirements of the country.[22] Its mission is to ensure: Energy Security (reducing oil imports through development of alternate fuels), increase the share of clean power for electricity generation, energy availability and access, energy affordability (cost-competitive, convenient, safe, and reliable new energy supply options), and energy equity (per-capital energy consumption at par with the global average by 2050 through a sustainable and diverse fuel mix).[23] It has a vision to develop new and renewable energy technologies, processes, materials, components sub-systems, products and services and to make the country a net foreign exchange earner.

SEC (GOI)

The Solar Energy Center (SEC)[24] is a specialised centre under the Ministry of New and Renewable Energy. The National Solar Plan envisions a significant expansion of the SEC to a centre of excellence for R&D and Apex research institution for a network of Indian solar research centres.[25]

DST (GOI)

The Department of Science & Technology (DST) was established in May 1971, with the objective of promoting new areas of Science & Technology and to play the role of a nodal department for organising, coordinating and promoting S&T activities in the country. Its mandate includes: the Formulation of policy statements and guidelines, Co-ordination of areas of Science & Technology in which a number of Institutions & Departments have interests and capabilities, Support to basic and applied research in National Institutions; Support minimum Infrastructural facilities for Testing & Instrumentation Technology Development and Commercialisation; Popularisation of Science & Technology; Socially oriented S&T interventions for rural & weaker sections; and Fostering International Cooperation in S&T, as well as promoting development and S&T in the States, and scientific surveys and services through Survey of India and National Atlas and Thematic Mapping Organisation (NATMO), and management of Information Systems for Science & Technology. Its activities include, the formulation of policies relating to Science and Technology, particularly on matters relating to the Scientific Advisory Committee of the Cabinet (SACC), and the promotion of new areas of Science and Technology with special emphasis on emerging areas; Research and Development through its research institutions or laboratories in co-ordination with the concerned Ministry or Department; Support and Grants-in-aid to Scientific Research Institutions, Scientific Associations and Bodies; Futurology; Coordination and integration of areas of Science & Technology having cross-sectoral linkages in which a number of institutions and departments have interest and capabilities, and all matters concerning the Science and Engineering Research Council and Technology Development Board, National Council for Science and Technology Communication; National Science and Technology Entrepreneurship Development Board; International Science and Technology Cooperation including appointment of scientific attaches abroad (These functions shall be exercised in close cooperation with the Ministry of External Affairs); matters regarding Inter-Agency/Inter-Departmental coordination for evolving science and technology missions; and matters concerning domestic technology particularly the promotion of ventures involving the commercialisation of such technology other than those under the Department of Scientific and Industrial Research.[26]

DSIR / CSIR (GOI)

The Department of Scientific and Industrial Research (DSIR) is a part of the Ministry of Science and Technology. The primary endeavour of DSIR is to promote R&D by the industries, support a larger cross section of small and medium industrial units to develop state-of-the art globally competitive technologies of high commercial potential, catalyse faster commercialisation of lab-scale R&D, enhance the share of technology intensive exports in overall exports, strengthen industrial consultancy & technology management capabilities and establish user friendly information network to facilitate scientific and industrial research in the country. It also provides a link between scientific laboratories and industrial establishments for transfer of technologies through National Research Development Corporation (NRDC) and facilitates investment in R&D through Central Electronics Limited (CEL). Programmes and activities under the scheme are centred around promoting industrial R&D, development and commercialisation of technologies, acquisition, management and export of technologies, promotion of consultancy capabilities, etc.[27] The 11th Plan also establishes specific objectives for DSIR.[28]

CSIR (GOI)

The Council of Scientific & Industrial Research (CSIR) is the premier industrial R&D organisation in India was constituted in 1942 by a resolution of the then Central Legislative Assembly. It is an autonomous body registered under the Registration of Societies Act of 1860.CSIR aims to provide industrial competitiveness, social welfare, strong S&T base for strategic sectors and advancement of fundamental knowledge.

CSIR is one of the world's largest publicly funded R&D organisations having linkages to academia, R&D organisations and industry. CSIR's 37 laboratories not only knit India into a giant network that impacts and add quality to the life of each and every Indian but CSIR is also party to the prestigious Global Research Alliance with the objective of applying global knowledge pool for global good through global funding. CSIR's R&D portfolio embraces areas as diverse as aerospace, biotechnology, chemical, the full ABC-Z of Indian Science.[29] CSIR accounts for many as 62 per cent of all US patents granted to Indians[30], has experience in public-private partnerships[31], and has been given responsibilities per the 11th Plan that have a bearing on renewable energy and may support SBSP.[32]

DRDO (USG)

The Defence Research & Development Organisation (DRDO) is a network of 50 labs (5000 scientists and 25,000 supporting personnel) that work under the Department of Research and Development of the Ministry of Defense (MOD), and is "dedicated to working toward enhancing self-reliance in Defence Systems, and undertakes design and development leading to production of world class weapon systems and equipment according to the needs laid down by the three services," and is conducting work in SBSP related areas such as aeronautics, missiles, materials, and electronics.[33] DRDO has an International Space Plane Programme aimed at achieving a Single-Stage-to-Orbit (SSTO) capability, and is currently working on a supporting hypersonics[34] test-bed.[35]

Indian Embassy Officials in DC (GOI)

Indian Embassy Officials with likely equities in an SBSP project would include the Counsellor (Space) [ISRO Rep] and the Counsellor (Defense Technology) [DRDO Rep].

MEA (GOI)

The Ministry of External Affairs (MEA) is the nodal agency for India's foreign affairs and diplomacy. Within MEA, the America's division (AMS), Disarmament & International Security Affairs Division (D&ISA), Investment, Technology Promotion & Energy Security Division (ITP)[36] all conceivably would have equities in a joint Indo-US SBSP programme.

MoEF (GOI)

The Ministry of Environment & Forests (MoEF) is the nodal agency in the administrative structure of the Central Government for planning, promotion, coordination and overseeing the implementation of India's environmental and forestry policies and programs, as well as the nodal agency for India for the United Nations Environment Programme and other multilateral programmes.[37]

Indian Institutes of Technology

"The Indian Institutes of Technology (IITs), are a group of fifteen autonomous engineering and technology-oriented institutes of higher education established and declared as Institutes of National Importance by the Parliament of India. The IITs were created to train scientists and engineers, with the aim of developing a skilled workforce to support the economic and social development of India after independence in 1947… Owing to the autonomy of the IITs, these institutes are among those few institutes (the other institutes being National Institutes of Technology or the NITs) in India that offer degrees in technology (B. Tech.) at the undergraduate level as opposed to the Bachelor of Engineering (BE) degrees awarded by most other Indian universities… Each IIT is an autonomous university, linked to the others through a common IIT Council, which oversees their administration. They have a common admission process for undergraduate admissions, using the Joint Entrance Examination (popularly known as IIT-JEE) to select around 4,000 undergraduate candidates a year. Postgraduate Admissions are done on the basis of the GATE, JMET, JAM and CEED. About 15,500 undergraduate and 12,000 graduate students study in the IITs, in addition to research scholars…The seven IITs are located in Kharagpur, Mumbai, Madras, Kanpur, Delhi, Guwahati, and Roorkee. With the plan to setup eight more IITs in the states of Bihar (Patna), Rajasthan, Andhra Pradesh (Hyderabad), Himachal Pradesh, Orissa (Bhubaneshwar), Madhya Pradesh (Indore), Gujarat (Gandhinagar) and Punjab (Rupnagar), and the conversion of IT-BHU to an IIT, the total number of IITs will be increased to 16.[3] Six of the eight proposed new IITs, namely IIT Patna, IIT Rajasthan, IIT Hyderabad, IIT Bhubaneswar, IIT Gandhinagar and IIT Punjab, are functional as of June 2008 and have admitted students for the 2008-09 academic year while IIT Indore and IIT Himachal Pradesh are set to operate from the 2009-10 academic year. All IITs are autonomous universities that draft their own curricula, and they are members of LAOTSE, an international network of universities in Europe and Asia. LAOTSE membership allows the IITs to exchange students and senior scholars with universities in other countries.…IIT Kanpur was established in 1959 in the city of Kanpur, Uttar Pradesh. During its first 10 years, IIT Kanpur benefited from the Kanpur–Indo-American Programme, where a consortium of nine US universities helped to set up the research laboratories and academic programmes."[38]

Notes

1 http://india.gov.in/sectors/environment/climate.php

2 http://planningcommission.gov.in/aboutus/index.html

3 http://planningcommission.gov.in/aboutus/orgn.html

4 http://psa.gov.in

5 www.news.colostate.edu/Release/3588

6 http://mod.nic.in/aboutus/body.htm

7 www.isro.org

8 11th Plan inputs for Space, http://planningcommission.gov.in/aboutus/committee/wrkgrp11/wg11_subspace.pdf "The total expenditure of the Department during the 10th Plan period would come to Rs 13,242 crore [$2.65 bilion over five years] approx. comprising of a Plan component of Rs 11,502 crore and non-plan component of Rs

1,740 crore. In the first four years of the Plan period 2002-06, the Department has maintained budget utilisation of more than 99 per cent of the final approved grant. (Budget utilisation has been in the range of 99.67 per cent to 99.88 per cent in the first four years). The indicative plan outlay for the Department for 10th Plan is Rs 13,250 crore." Note: This is exceptional considering how much is not executed on MOD and the services and is returned.

9 11th Plan inputs for Space, http://planningcommission.gov.in/aboutus/committee/wrkgrp11/wg11_subspace.pdf

10 See 11th Plan, p. 174: "The major objectives of the Space Programme are to establish self-reliant operational space services in the areas of satellite communications, satellite based information for management of natural resources and satellite meteorological applications…The emphasis of the space programmes will be on large-scale applications of space technology in the priority areas of national development. The already established space-based services for socioeconomic development of the country will be sustained and strengthened. The future directions of the space programme will take into account the needs of the country in the context of emerging international environment and the potential that India holds for human development. Technology advancement, which is essential to maintain competitive relevance, will be an important trust for space endeavors."

11 Ibid, "All leading countries in space are pursuing many promising options for cost reduction and higher speed to cut journey time. Today's expendable launchers have effectively reached a technology plateau. Novel solutions are required to reduce the cost of access to space. Reusability appears a key area of focus. Development of newer materials like composites, smart materials, structures and propulsion systems such as nuclear, laser, microwave, antimatter, plasma, electric and the magnetic rail launching system are in the anvil. The air breathing propulsion option is being pursued by most of the advanced nations to achieve higher aviation speed… The application of re-usability will be initially to the ISS and then on to the Moon, Mars and Beyond."

12 Ibid, "Air breathing propulsion system related technologies being developed will feed into RLV program. With the above, an intermediate Two-Stage-To-Orbit (TSTO) vehicle may be the path for realisation by about 2025 which could take us towards a Single-Stage-To-Orbit (SSTO) vehicle beyond this period."

13 Conversation with ISRO personnel at LCPM-8 Conference, 2009.

14 http://www.antrix.gov.in/

15 http://en.wikipedia.org/wiki/Antrix_Corporation

16 www.dae.gov.in/sectt/daeorg/images1/daeorg.htm

17 GOI DAE Citizen's Charter

18 11th Plan, p. 174: "In addition, the project on energy conversion technologies will study of alternate energy conversion technologies will be strengthened." [DAE]

19 www.dae.gov.in/publ/doc11/index.htm

20 www.dae.gov.in/sectt/ria/daeria.htm

21 Presentation given by Dr. P.M. Raole at IITb Materials Research Conference. See also www.iter-india.org

22 http://mnes.nic.in/history.htm and http://mnes.nic.in/mission.htm and http://mnes.nic.in/vision.htm

23 http://mnes.nic.in/mission.htm

24 http://mnes.nic.in/sec/sec-contact.htm

25 NSP, p. 17. "The basic strategy to support research and development would include: transforming the Solar Energy Center (SEC) into a centre of excellence for R&D in solar energy and the apex research Institute for solar energy that will coordinate a network of solar research centres as well as the focal centre for international cooperation on solar

research. The SEC will select and fund other academic and research institutions, encourage industry to undertake performance that research while providing partial financial support (25-50 per cent), support pilot plants to demonstrate the viability of new technologies and innovative ideas; encourage research groups from other countries to undertake joint projects with Indian academic and research institutions and utilise and create an industrial base in India, and pursue leapfrog technologies."

26 http://dst.gov.in/about_us/intro_DST.htm

27 http://www.dsir.gov.in/aboutus/intro.htm

28 11th Plan, p. 181: "The avowed objectives of the department of scientific and industrial research (DSIR) are to promote industrial research, technology development and transfer in its utilisation, with a view to making Indian industry globally competitive. During the 11th Plan, the focus would be on promoting creativity and innovation among individuals; promoting and supporting industry for development of new products, processes and technologies; attracting venture capital funding; developing the consultancy profession; promoting commercialisation of technologies in India and abroad; and creating awareness about the latest IPR regime. The focus of CSIR would be on finding holistic and optimal solutions to the pressing problems of the country by deploying technologies ranging from the simplest to the most sophisticated ones. Innovation in all spheres of activities, ranging from science, technology, management and financing, would be supported. The thrust would be on the adoption of three-pronged approach to: (i) conceptualise, plan and work, and network mode, an R&D of relevance both nationally and globally to align it with the public, private, strategic or social needs as the case may be ; (ii) forge a viable, defined and scientifically challenging R&D projects in super institutional mode to make each laboratory a cohesive and close-knit unit. This would help in aligning and reinforcing the core competency of the laboratory ; and (iii) build within each laboratory, Centres of Sustainable Growth, a kind of magnet to attract scientists /technologists of Indian origin, industry (both national and foreign) and a large number of trainees. Such centres would aim to be creative think-tanks to look at the future with a clear vision."

29 http://www.csir.res.in/External/Utilities/Frames/aboutcsir/main_page.asp?a=topframe.htm&b=leftcon.htm&c=/external/heads/aboutcsir/about_us.htm

30 11th Plan, p. 183: "CSIR was granted 667 US patents during the 10th Plan, 62 per cent of the total US patents granted to Indians excluding, NRIs and foreign assignees, belong to CSIR. As a result of the research carried out the national laboratories, over 13,000 basic research papers were published in internationally peer-reviewed journals. The average impact factor per paper of nearly 2.01 has been achieved during 2005-06. The extra cash flow from contract research was nearly Rs 1,500 crore [$0.3 billion]."

31 11th Plan, p. 182: "CSIR operated a new millennium Indian technology leadership initiative (NMITLI) scheme in PPP mode through which 42 projects were developed involving 65 industrial partners and 222 research groups for capturing global technology leadership position."

32 11th Plan, p. 184: "CSIR laboratories will seek to leverage their unique scientific and technological capabilities through a series of: Supra-institutional project wherein the laboratory will have at least one flagship project in which a majority of the groups within the laboratory participate and synergize the in-house capabilities to optimize outputs; enter laboratory network mode projects started during the 10th plan which will be further strengthened with a sharp focus on developing products/processes and knowledge; network mode with institutions/agencies outside CSIR to develop advanced technologies/products/prototypes/knowledgebase that requires multidisciplinary inputs and synergies; and major national facilities which will be created in frontier areas to help in the generation of competitive knowledge capabilities at par with international standards of future relevance...Supra-institutional projects: technology development and R&D initiatives in aerospace... focus on major earth processes, natural resources and the geo-environment.. competencies in clean coal initiative and energy conservation technologies. Network projects: uncertainty reduction, or ability impact assessment, mitigation policy

Sky's No Limit

intervention and capacity building for global change; programme on climate change; hydrogen energy initiative— overcoming materials challenges for generation, storage and conversion of hydrogen using fuel cells; design and fabrication capabilities for very high power, high efficiency and very high frequency microwave tubes… development of advanced lightweight metallic materials for engineering applications… nano material and nano devices. "

33 www.drdo.org

34 India has previously proposed hypersonics in past Joint Technical Group (JTG) meetings as per conversations with DRDO officials.

35 Brief by DRDO at AeSI Aerospace Luminary Lecture, Hyderabad, 2009.

36 http://meaindia.nic.in

37 http://moef.nic.in/modules/about-the-ministry/introduction

38 Wikipedia, October 10, 2009.

US Government Stakeholders

OSTP (USG)

The Office of Science and Technology Policy in the US President's Office of Executive Service. The Office of Science and Technology Policy (OSTP) is part of the Executive Office of the President (EOP) and advises the President on the effects of science and technology on domestic and international affairs. The office serves as a source of scientific and technological analysis and judgment for the President with respect to major policies, plans and programs of the Federal Government. OSTP *leads* an interagency effort to develop and implement *sound science and technology policies* and budgets. The office works with the private sector to ensure Federal investments in science and technology contribute to *economic prosperity, environmental quality, and national security*.[1] In recent years the OSTP has played a central role in coordinating the Presidential Directive establishing National Space Policy. It is not a funding or project agency.

NSTC

The National Science and Technology Council (NSTC) was established by Executive Order on November 23, 1993. This Cabinet-level Council is the principal means within the executive branch to coordinate science and technology policy across the diverse entities that make up the Federal research and development enterprise. Chaired by the President, the membership of the NSTC is made up of the Vice President, the Director of the Office of Science and Technology Policy (OSTP), Cabinet Secretaries and Agency Heads with significant science and technology responsibilities, and other White House officials. A primary objective of the NSTC is the establishment of clear national goals for Federal science and technology investments in a broad array of areas spanning virtually all the mission areas of the executive branch. The Council prepares research and development strategies that are coordinated across Federal agencies to form investment packages aimed at accomplishing multiple national goals. The work of the NSTC is organised under four primary committees: Science, Technology, Environment and Natural Resources and Homeland and National Security. Each of these committees oversees subcommittees and working groups focused on different aspects of science and technology and working to coordinate across the federal government.[2]

National Space Council (USG)

In the past, the US total space enterprise was overseen by a National Space Council chaired by the Vice President. At the time of this writing, no such organisation existed, however some analysts have speculated that the new administration will reconstitute this body. If so, this would become the apex body for consideration of a large, multi-national project like SBSP. The Missions of the National Space Council per the existing statute (Executive Order 12675) were to: Establish broad goals and objectives for the US space programmes; Establish strategies to implement these goals and objectives through an integrated nation-wide set of activities; Monitor the implementation of these strategies; Resolve specific programme or policy issues arising from ambiguities or disagreements in implementing the strategies[3] . The National Space Council was a cabinet-level body within the Executive Office of the President of the United States, which existed from its creation 1989, during the administration of George H.W. Bush. It replaced the earlier National Aeronautics and Space Council (1958-1973). The Council was chaired by Vice President, and consisted of The Secretary of State; The Secretary of the Treasury; The Secretary of Defense; The Secretary of Commerce; The Secretary of Transportation; The Director of the OMB; The Chief of Staff to the President; The Assistant to the President for National Security Agency; The Assistant to the President for Science and Technology; The Director of Central Intelligence; and The Administrator of the National Aeronautics and Space Administration. In 1993, the National Space Council was disbanded and all of its functions were absorbed by the National Science and Technology Council (NSTC)[4] though the NSTC website shows neither a dedicated committee or subcommittee for space.

PCAST

President's Council of Advisors on Science and Technology (PCAST) is an advisory group of the nation's leading scientists and engineers who directly advise the President and the Executive Office of the President. PCAST makes policy recommendations in the many areas where understanding of science, technology, and innovation is key to strengthening our economy and forming policy that works for the American people. PCAST is administered by the Office of Science and Technology Policy (OSTP).[5] PCAST represents leaders from many scientific disciplines. President Obama has also specifically tasked PCAST: *"I will charge PCAST with advising me about national strategies to nurture and sustain a culture of scientific innovation."*

NSSO (USG)

The NSSO has been the most vocal agency recently on the subject of Space Solar Power, having released a report in 2007 suggesting a high-level national programme and openness to international collaboration.

The role of the NSSO is to facilitate the integration and coordination of defense, intelligence, civil and commercial space activities. They are the only office specifically focused on cross-space enterprise issues and provide direct support to the Air Force, National Reconnaissance Office, other Services and Agencies, Joint Staff, Office of the Secretary of Defense, Office of the Director of National Intelligence, White House, and Congress, as well as other national security space stakeholders.[6] The NSSO is not a funding or project agency, and principally provides advice and facilitates coordination.[7] NSSO has published a favourable report on SBSP.

OSD AT&L (IC, DDR&E) (USG)

The Office of the Undersecretary of Defense for Acquisition, Technology and Logistics contains two directorates that have equities in Indo-US SBSP. Director, International Cooperation (AT&L(IC)) which contains the Director, Pacific Armaments Cooperation, and the Director, Defense Research & Engineering (DDR&E), which contains the Deputy Under Secretaries of Defense for Science & Technology, Advanced Systems & Concepts, International Security Technology, Laboratories & Basic Sciences, Assistant Deputy Under Secretary of Defense, Joint Capability Technology Demonstration (JCTD), and the Director, Defense Advanced Research Projects Agency. While the DDR&E itself is not a significant funding agency, its subordinate offices (such as DARPA & JCTD) are and may look to DDR&E for guidance.[8] Director, International Cooperation, Office of the Under Secretary of Defense (Acquisition, Technology and Logistics) is the US co-chair for the Joint Technical Group (JTG).

OSDP (USG)

The Office of the Under Secretary of Defense – Policy's mission is to consistently provide responsive, forward-thinking, and insightful policy advice and support to the Secretary of Defense, and the Department of Defense, in alignment with national security objectives[9] . OSDP contains two sub-offices[10] with equities in Indo-US cooperation in Space Solar Power: The Office of the Assistant Secretary of Defense for Asian and Pacific Security Affairs (APSA) is responsible for U.S. security and defense policy in the Asia-Pacific region, with its subordinate Office of the Deputy Assistant Secretary of Defense for South and Southeast Asia having specific responsibility for DoD policy with respect to India, and the Office of the Assistant Secretary of Defense for Global Strategic Affairs (GSA) with its subordinate Office of the Deputy Assistant Secretary of Defense for Space & Cyber Policy. OSDP also oversees the two offices, DSCA and DTSA that balance cooperation with export control[11] discussed below.

NASA (USG)

The National Aeronautics and Space Administration (NASA), per the National Space Act, exercises control over aeronautical and space activities sponsored by the US, except weapons systems and military operations. Its activities relevant to SBSP include: the improvement of usefulness, performance of aeronautical and space vehicles, preservation of U.S. leadership in aeronautical and space science and technology in the conduct of peaceful activities outside the atmosphere, cooperation by the U.S. with other nations and groups of nations in peaceful application.[12] NASA has in the past conducted SBSP related activities,[13] with an active programme until 2006 when it refocused on a new direction, and was contemplating a small in-space wireless power beaming demo as recently as December of 2008.[14] NASA's FY2010 budget request was for $18.686 Billion.[15] NASA maintains both an international office and a Pacific liaison in Tokyo, and participates with India through the Civil Space Working Group.

DOE (USG)

The US Department of Energy's overarching mission is to advance the national, economic, and energy security of the United States; to promote scientific and technological innovation in support of that mission. It aims to promote America's energy security through reliable, clean and affordable energy.[16] The DOE in the past has been involved in Space Solar Power through joint studies with NASA.[17] Within DOE, ARPA-E, National Renewable Energy Laboratory (NREL),[18] specific laboratories with contributing technologies, and DOE/EERE[19] at headquarters may have equities in a Space Solar Power Program. DOE's FY2010 budget request is for $26.4 billion, not including some $16.8 billion in the Recovery act for renewable energy sources.[20]

ARPA-E (USG)

ARPA-E is a newly created arm of the DOE, whose mission is to provide access to funding needed to bring next generation of energy technologies to fruition by focusing on high risk, high payoff concepts (not basic research)—technologies promising true energy transformations, in order to enhance U.S. economic security by identifying technologies with the potential to reduce energy imports from foreign sources; reduce energy-related greenhouse gas emissions; and improve energy efficiency across the energy spectrum, and ensure the U.S. remains a technological leader in developing and deploying advanced energy technologies.[21] ARPA-E is presently funded at $400 Million for FY2010[22].

NSF (USG)

The National Science Foundation (NSF) is an independent federal agency whose mission is to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense. NSF has an annual budget of about $6B, and funds about 20 per cent of all basic research conducted in US colleges and universities across the full range of possible subjects, as well as "high-risk, high pay-off" ideas, novel collaborations, and numerous projects that "may seem like science fiction today, but which the public will take for granted tomorrow."[23]

NSF participated and provided funding in a collaborative effort with NASA on Space Solar Power (SSP) Exploratory Research and Technology (SERT) programme conducted in 1999-2000. NSF has had a cooperative program[24] with India's Department of Science & Technology since 1997[25] and more than 75 bilateral projects have been supported.

DARPA (USG)

The Defense Advanced Research Projects Agency (DARPA) mission is to maintain the technological superiority of the U.S. military and prevent technological surprise from harming our national security by sponsoring revolutionary, high-payoff research bridging the gap between fundamental discoveries and military use.[26] DARPA has historically funded significant programmes in space, and continues to today, including programs that may advance necessary technologies for space solar power[27] such as low-cost space access, innovative satellite technologies, autonomous servicing, etc. DARPA's annual budget is approximately $3.2 billion of which more than $0.2 billion was on space.[28] DARPA also has an active international collaboration programme.

AFRL & NRL (USG)

Significant expertise and funding for space technology development exists in the US Air Force Research Laboratory (AFRL)[29] and US Navy's Naval Research Laboratory.[30] Post the NSSO report, AFRL hosted two workshops and published a report. NRL also examined SBSP and released its own report.[31] AFRL and NRL have also both been active in funding basic research in India through AOARD[32] and ONR Global,[33] as well as collaborating with DRDO on aerospace materials, power and energy. Such cooperative Information Exchange Agreements (IEAs) and Project Agreements (PAs) are coordinated through the JTG, OSD/AT&L, SAF/IA, and ODC.

AOARD (USG)

AOARD's mission is to support the US Air Force S&T community by identifying foreign technological capabilities and accomplishments which can be applied to Air Force needs; by providing liaison with members of the scientific and engineering community in Asia and Pacific Rim Region Countries; by encouraging open communication between Air Force scientists and engineers and their counterparts within the AOARD area of responsibility, and by supporting Asian research projects of interest to the Air Force. AOARD's primary focus is on basic research with a secondary interest in applied research. To facilitate interaction, AOARD invites prominent Asian scientists to AF R&D organisations to present their work (Window-on-Science), supports conferences in Asia to promote networking between AF scientists and Asian scientists (CSP), and administers contracts to Asian R&D organisations for continuing technical interactions. AOARD solicits proposals for research through various AFOSR Broad Agency Announcements (BAAs). The office is collocated with the Office of Naval Research Global and the US Army International Technology Center – Pacific in Tokyo, Japan.[34]

ONR Global (USG)

The Office of Naval Research (ONR) coordinates, executes, and promotes the science and technology programmes of the United States Navy and Marine Corps through schools, universities, government laboratories, and nonprofit and for-profit organisations. It provides technical advice to the Chief of Naval Operations and the Secretary of the Navy and works with industry to improve technology manufacturing processes. ONR plays a critical role in advancing scientific knowledge to support the generation of naval technology with a vision focused on future capabilities, hedging against the uncertainty of warfare. ONR Global, as an international presence for ONR, actively seeks opportunities to promote science and technology collaboration of mutual benefit between the US and researchers around the globe and maintains offices in Tokyo and Singapore.[35]

SAF/IA (USG)

SAF/IA's mission is to build, sustain, expand, and guide relationships that are critical enablers to US expeditionary air and space forces conducting global operations and fighting the war on terror. They serve as the source of pol-mil and international affairs expertise for the US Air Force and on aerospace matters for the DoD, providing political-military assessment, security assistance, International Arms cooperation, foreign disclosure and export control, comparative weapons analysis, and international professionals development.[36] As a practical manner Air and Space Cooperation is typically routed through SAF/IA. SAF/IA also coordinates the ICR&D and Coalition Warfighter Programs,[37] each with specific space cooperation budgets (programme currently funded at approximately $5 million with one-fifth specifically for space-related R&D) which request proposals in March, due typically in mid June, with winners being announced in July to receive funding the subsequent[38] fiscal year.[39] SAF/IA would be the window through which any aerospace related information exchange and project agreements would be negotiated between US and Indian defense research establishments.

DSCA (USG)

DSCA's mission is to lead, direct, and manage security cooperation programs and resources to support US national security objectives that: build relationships that promote U.S. interests; *build* allied and *partner capacities* for self-defense and coalition operations; and promote peacetime and contingency access for U.S. forces. DSCA fosters Security Cooperation programs vital to U.S. national security to build trust and influence in peacetime, to have access to regions of the world during times of crisis, and to ensure interoperability with coalition partners during times of conflict. Security Cooperation programs provide financial and technical assistance; transfer of defense materiel, training and services to friends and allies; and promote military-to-military contacts. DSCA works with friendly countries and U.S. allies worldwide to: Build partner capacities for internal security and self–defense; Promote human rights and civilian control of the military; Support international victims of natural or manmade disasters.

They partner with the U.S. State Department, the Military Departments, other U.S. Government organisations, U.S. industry, and foreign government customers to provide: Foreign Military Sales (FMS); Foreign Military Financing; International Military Education and Training; Excess Defense Articles; Humanitarian Assistance; Humanitarian Civic Assistance; Mine Action Training (Awareness and Removal Techniques); Other Security Cooperation programs DSCA manages more than: $36 billion in new sales each year, 49,000 international military students from over 156 countries; 723 security assistance personnel in 117 countries; $296 billion in open FMS cases; $31 billion in customer operating funds; and $113 million in Humanitarian Assistance and Mine Action funds; $95 million for the Regional Centers for Strategic Studies.[40]

DTSA (USG)

The Defense Technology Security Administration (DTSA) administers the development and implementation of Department of Defense (DoD) technology security policies on international transfers of defense-related goods, services and technologies. It works to ensure that critical U.S. military technological advantages are preserved; transfers that could prove detrimental to U.S. security interests are controlled and limited; proliferation of weapons of mass destruction and their means of delivery is prevented; diversion of defense-related goods to terrorists is prevented; military interoperability with foreign allies and friends is supported; and the health of the U.S. defense industrial base is assured. DTSA Monitors technology transfer related to integration and launch of U.S. space technology on foreign launch vehicles (mandated by 1999 National Defense Authorization Act [NDAA]), it develops and advocates technology security policy recommendations consistent with national military strategy and security cooperation guidance, develops and adjudicates positions that address U.S. technology security concerns, reviews Commodity Jurisdiction Requests, Enforcement Support, Advisory Opinions, Retransfer Requests, and reviews and coordinates 30,000 export licenses annually and other actions related to export of controlled hardware and technology and provide DoD position to the Departments of State or Commerce.[41]

ODC (USG)

The Office of Defense Cooperation is an office in the US Embassy to facilitate defense cooperation, including R&D. Its mission is, as directed by the Ambassador, Secretary of Defense, and the Commander United States Pacific Command, to manage and execute security assistance and cooperation programs in the Republic of India to strengthen Indian-U.S. relationships that support and promote mutual national security objectives and interests. Additionally, ODC works with the DATT (Defense Attaché Office) on military-to-military engagement programmes, within policy and resource limitations, that advance mutual interests of the U.S. and host country.[42]

US Embassy Officials in Delhi (USG)

Various US Embassy Officials may have equities in an SBSP programme, including the Environment & Science Officers, Econ officers, USAID officers for bilateral and SARI-E, Commerce Officers, Federal Aviation Administration Liaison, and the Office of Defense Cooperation discussed above.

Department of Commerce (NOAA/OSC) (USG)

The Office of Space Commercialisation is the principal unit for space commerce policy activities within the Department of Commerce. Its mission is to foster conditions for the economic growth and technological advancement of the U.S. commercial space industry. It focuses on several sectors of space commerce industry including satellite navigation, commercial remote sensing, space transportation, entrepreneurial "New Space" activities,[43] and space-based solar power.[44]

Department of State (Export Control) (USG)

The Directorate of Defense Trade Controls (DDTC), in accordance with 22 U.S.C.2778-2780 of the Arms Export Control Act (AECA) and the International Traffic in Arms Regulations (ITAR) (22 CFR Parts 120-130), is charged with controlling the export and temporary import of defense articles and defense services covered by the United States Munitions List (USML).[45]

Department of State (ISN) (USG)

The Bureau of International Security and Nonproliferation (ISN) spearheads efforts to promote international consensus on WMD proliferation through bilateral and multilateral diplomacy, leads diplomatic efforts against proliferation challenges and threats, and works closely with other multilateral institutions such as the IAEA.[46]

Department of Commerce (BIS) (USG)

The Bureau of Industry and Security's mission is to advance U.S. national security, foreign policy, and economic objectives by ensuring an effective export control and treaty compliance system and promoting continued U.S strategic technology leadership.[47]

USTR (USG)

The Office of the U.S. Trade Representative is part of the Executive Office of the President, and is responsible for developing and coordinating U.S. international trade, commodity, and direct investment policy, and overseeing negotiations with other countries. The head of USTR is the U.S. Trade Representative, a Cabinet member who serves as the president's principal trade advisor, negotiator, and spokesmen on trade issues.[48]

Department of State (OES) (USG)

The Bureau of Oceans and International Environmental and Scientific Affairs (OES) mission is to advance sustainable development internationally through leadership in oceans, environment, science and health.[49] This includes partnerships and initiatives that advance broad development goals of economic growth, social development, environmental stewardship, and includes energy and climate change. The Office of Space and Advanced Technology (OES/SAT) ensures that U.S. space policies and multilateral science activities support U.S. foreign policy objectives and enhance U.S. space and technological competitiveness, leads interagency coordination on all civil space related international agreements implementing important NASA, NOAA, and USGS cooperation with other space partners, and plays a key role in implementation of National Space Policy focused on dual-use space applications. It is also the primary U.S. representation to the United Nations (UN) Committee on the Peaceful Uses of Outer Space (UNCOPOUS).[50] The Office of Science and Technology Cooperation (OES/STC) pursues establishment of binding bilateral and multi-lateral science and technology agreements, in high priority areas including environment and energy research.[51] OES works closely with the US Special Envoy for Climate Change.

FAA/AST (USG)

The Office of Commercial Space Transportation (AST) is the only Space-related line of business in the Federal Aviation Administration (FAA). It exists to regulate commercial space transportation industry, ensure compliance with international obligations of the U.S. and protect the public health and safety, safety of property, and national security and foreign policy interests of the United States, and to encourage and facilitate and promote commercial space launches and re-entries by the private sector, as well as recommend appropriate changes to Federal statues, treaties, regulations, policies, plans and procedures, and facilitate the strengthening and expansion of U.S. space transportation infrastructure. The AST issues FAA licenses for commercial launches of orbital and suborbital rockets.[52]

EPA (USG)

The U.S. Environmental protection agency leads the nation's environmental science, research, education and assessment efforts. Its mission is to protect human health and the environment.[53]

FCC (USG)

The Federal Communications Commission (FCC) is an Independent US Government agency charged with regulating interstate and international communications by radio, television, wire, satellite and cable. The Wireless Telecommunications Bureau regulates the use of radio spectrum to fulfil the communications needs of businesses, aircraft and ship operators, and individuals.[54]

EPRI (Private)

The Electric Power Research Institute is an independent, non-profit company performing research, development and design in the electricity sector for the benefit of the public.[55]

NRC (Independent)

The mission of the NRC is to improve government decision making and public policy, increase public education and understanding, and promote the acquisition and dissemination of knowledge in matters involving science, engineering, technology, and health. The institution takes this charge seriously and works to inform policies and actions that have the power to improve the lives of people in the U.S. and around the world. The NRC is committed to providing elected leaders, policy makers, and the public with expert advice based on sound scientific evidence. The NRC does not receive direct federal appropriations for its work. Individual projects are funded by federal agencies, foundations, other governmental and private sources, and the institution's endowment. The work is made possible by 6,000 of the world's top scientists, engineers, and other professionals who volunteer their time without compensation to serve on committees and participate in activities. The core services involve collecting, analysing, and sharing information and knowledge. The independence of the institution, combined with its unique ability to convene experts, allows it to be responsive to a host of requests. Its activities include: Consensus studies/comprehensive reports that focus on major policy issues and provide recommendations for solving complex problems, and expert meetings and workshops to connect professionals and interested public to stimulate dialogue. The NRC is administered jointly by the NAS, NAE, and the IOM through the NRC Governing Board. The National Research Council (NRC) functions under the auspices of the National Academy of Sciences (NAS), the National Academy of Engineering (NAE), and the Institute of Medicine (IOM). The NAS, NAE, IOM, and NRC are part of a private, nonprofit institution that provides science, technology and health policy advice under a congressional charter signed by President Abraham Lincoln that was originally granted to the NAS in 1863. The four organisations are collectively referred to as the National Academies.[56] The NRC has twice weighed in on Space Solar Power, once in 1981,[57] and again much more favourably in 1991.[58]

USAID/SARI-E (USG)

The US Agency for International Development (USAID) runs a multilateral programme called the South Asia Regional Initiative for Energy (SARI-E). This programme is covered in greater depth in the Models section.

Notes

1 http://www.ostp.gov/

2 http://www.ostp.gov/cs/nstc Principal members can be found here: http://www.ostp.gov/cs/nstc/principal_members

3 http://www.dailykos.com/story/2008/7/10/19303/2212/978/547179

4 http://en.wikipedia.org/wiki/National_Space_Council

5 http://www.ostp.gov/cs/pcast

6 http://www.acq.osd.mil/nsso/, also see http://www.acq.osd.mil/nsso/organization/organization.htm

7 The closest equivalent to NSSO and OSDP Strategic Policy might be a prospective planning / policy function within the Integrated Defense Staff (IDS).

8 http://www.acq.osd.mil/organization.html

9 http://www.defenselink.mil/policy/

10 http://www.defenselink.mil/policy/sections/policy_offices/index.html

11 "It is greatly in the interest of innovative nations to restrict technological access, both to limit misuse and to preserve advantage, but at the same time, it is also fundamentally in their interest to share this technology, precisely because sharing generates more innovation, more wealth and more prosperity, which in turn strengthens existing relationships and promotes stability and security." Statement by Mark Fuller of the Monitor Group at a seminar on *U.S. Technology Transfer and International Security for the Future,* September 24, 2008, American Enterprises Institute. Podcast available online at http://www.aei.org/event/1798

12 www.nasa.gov/offices/ogc/about/space_act1.html

13 See multiple NASA studies at www.nss.org/settlement/ssp/library/index.htm

14 www.nasawatch.com/archives/2008/12/canceling_somds.html

15 www.nasa.gov/pdf/344612main_Agency_Summary_Final_updates_5_6_09_R2.pdf

16 www.energy.gov/about/index.htm

17 www.nss.org/settlement/ssp/library/doe.htm

18 www.nrel.gov

19 http://www.eere.energy.gov/

20 www.cfo.doe.gov/budget/10budget/Content/Highlights/FY2010Highlights.pdf

21 http://arpa-e.energy.gov/

22 www.cfo.doe.gov/budget/10budget/Content/Highlights/FY2010Highlights.pdf

23 http://www.nsf.gov/about/

24 http://www.nsf.gov/od/oise/anesa-dst-india.jsp

25 http://www.indousstf.org/fullstory.aspx?storyheadline=History&prevmytitle=About IUSSTF&sectionid=S150

26 www.darpa.mil/mission.html

27 www.darpa.mil/sto/space/index.html and www.darpa.mil/tto/programs/index.htm

28 www.darpa.mil/budget.html

29 www.afrl.af.mil

30 www.nrl.navy.mil

31 http://www.nss.org/settlement/ssp/library/2008-NRLSBSP-PossibleDefenseApplicationsandOpportunities.pdf

32 www.tokyo.afosr.af.mil

33 www.onrglobal.navy.mil

34 http://www.wpafb.af.mil/library/factsheets/factsheet.asp?id=9477

35 http://www.onr.navy.mil/onrg.asp

36 http://www.safia.hq.af.mil

37 www.acq.osd.mil/ic/cwp.html

38 Personal E-mail, ICR&D manager, 2009.

39 *Note that the Indian Fiscal Year runs from April 1 to March 31, with budget preparations beginning in September, and budgets released in March (unless delayed as in 2009 by an election to July) by the Ministry of Finance (http://finmin.nic.in) whereas the US Fiscal Year runs October 1 to September 30, with budget preparations beginning in March, and submitted in August , with and budgets released in May by the Office of Management and Budget (OMB) (www.whitehouse.gov/omb/budget/) and begin executing on October 1. Travel for US Government personnel usually becomes difficult close to the close of the fiscal year.*

40 http://www.dsca.mil/PressReleases/dsca_trifold_compatible.pdf

41 http://www.defenselink.mil/policy/sections/policy_offices/dtsa/index.html

42 Personal e-mail, Director, Defense Cooperation in Armaments (DCA), ODC, New Delhi.

43 www.space.commerce.gov/about/

44 www.space.commerce.gov/power/

45 www.pmddtc.state.gov

46 www.state.gov/t/isn/

47 www.bis.doc.gov/about/index.htm

48 www.ustr.gov/about-us/mission USTR also serves as vice chairman of the Board of Directors of the Overseas Private Investment Corporation (OPIC), and is on the Board of Directors of the Millennium Challenge Corporation, and is a non-voting member of the Export Import Bank Board of Directors, and a member of the National Advisory Council on International Monetary and Financial Policies.

49 www.state.gov/g/oes/

50 www.state.gov/g/oes/sat/index.htm

51 www.state.gov/g/oes/stc/index.htm

52 www.faa.gov/about/office_org/headquarters_offices/ast/about/

53 www.epa.gov/epahome/aboutepa.htm

54 www.fcc.gov/aboutus.html

55 http://my.epri.com

56 http://sites.nationalacademies.org/NRC/index.htm

57 Electric Power from Orbit: A Critique of a Satellite Power System. National Research Council of the National Academy of Sciences, 1981.

58 Laying the Foundation for Space Solar Power: An Assessment of NASA's Space Solar Power Investment Strategy. National Research Council of the National Academy of Sciences, 2001.

Joint Organs

Civil Space Dialogue

As a part of Next Steps in Strategic Partnership (NSSP), which proposed expanded engagement on civilian nuclear activities, civilian space programmes and high-technology trade based on a series of reciprocal steps, an Indo-US Working Group on Civil Space Cooperation (JWG) has been established. The JWG endeavours to build closer ties in space exploration, satellite navigation and launch in the commercial space arena. The JWG identified new and expanded areas for civil space cooperation, including negotiating of the Memorandums of Understanding to place two instruments provided by the US National Aeronautics and Space Administration (NASA) on India's Chandrayaan-1 lunar mission, negotiations on space launch agreements, and discussions on promoting interoperability between Indian and US civil space-based positioning, navigation and timing systems.[1]

US-India Energy Dialogue

U.S. – India Energy Dialogue was launched on May 31, 2005. It is chaired by the US Secretary of Energy and the Deputy Chairman of the Planning Commission, India.[2,3] It established five Working Groups along with a Steering Committee to provide oversight. The goals of the Dialogue are to promote increased trade and investment in the energy sector by working with the public and private sectors to further identify areas of cooperation and collaboration. Building upon the broad range of existing cooperation, it is hoped that this effort will help mobilise secure, clean reliable and affordable sources of energy. The five Working Groups are: Oil and Gas, Coal, Power and Energy Efficiency, Civil Nuclear, and New Technologies and Renewable Energy. *The New Technology and Renewable Energy Working group will promote the development and deployment of clean, new and renewable energy and technologies leading to enhanced energy security and stable energy markets that will support desired levels of economic growth with appropriate concern for the environment.*[4]

High Tech Cooperation Group (HTCG)

High Technology Cooperation Group (HTCG) formed between India and US, which is chaired by Under Secretary, Department of Commerce, USA and Foreign Secretary, Ministry of External Affairs, Government of India. HTCG focuses towards building knowledge economy through public-private participation in the areas of biotechnology, nanotechnology, defence and information technology.

Joint Technical Group (JTG)

The JTG is the high-level group which coordinates and approves joint technical projects and information exchange. It sits below the Defense Planning Group (DPG) which provides overall guidance. The JTG is co-chaired by the Director, International Cooperation, Office of the Under Secretary of Defense (Acquisition, Technology and Logistics) and a Chief Controller Research & Development, Defence Research and Development Organisation (DRDO).

US-India Aviation Cooperation Programme

This programme is a US-Public-Private Partnership to do capacity building in Aviation in India. This programme is covered in the models section.

Notes

1 http://www.indousstf.org/fullstory.aspx?storyheadline =History&prevmytitle=About IUSSTF&sectionid=S150

2 http://www.pi.energy.gov/documents/IndiaUSEnergyDialogueJointStatement.pdf

3 The US-India Energy Partnership Summit, October 1, 2009,was also attended by Indian ministers Farooq Abdullah (MNRE) and Jairam Ramesh (MoEF). It aimed at contributing to the ongoing high-level India-US dialogue areas such as renewable energy, climate change and technological innovation, see http://www.thaindian.com/newsportal/business/farooq-ramesh-to-take-part-in-india-us-energy-dialogue_100252151.html

4 http://www.indianembassy.org/press_release/2005/July/16.htm

International Stakeholders

ITU (UN)

The International Telecommunication Union is the second-oldest international organisation still in existence, established to standardise and regulate international radio and telecommunications. It was founded as the International Telegraph Union in Paris on 17 May 1865. Its main tasks include standardisation, allocation of the radio spectrum, and organising interconnection arrangements between different countries to allow international phone calls — in which regard it performs for telecommunications a similar function to what the UPU performs for postal services. It is one of the specialised agencies of the United Nations, and has its headquarters in Geneva, Switzerland, next to the main United Nations campus.[1] The ITU also coordinates orbital slots for Geostationary Satellites, which because of their small transmitting antennas must be spaced at large intervals to prevent interference.

UNCOPUOS (UN)

The Committee on the Peaceful Uses of Outer Space was set up by the General Assembly in 1959 (resolution 1472 (XIV)) to review the scope of international cooperation in peaceful uses of outer space, to devise programmes in this field to be undertaken under United Nations auspices, to encourage continued research and the dissemination of information on outer space matters, and to study legal problems arising from the exploration of outer space.[2]

Notes

1 http://en.wikipedia.org/wiki/ITU

2 http://www.oosa.unvienna.org/oosa/COPUOS/copuos.html

Non-Government Stakeholders

Lobbies (Private)

There are a number of India-related lobbies, of which USINSPAC is considered the largest. USINPAC's mission is to impact policy on issues of concern to the Indian American community in the United States. USINPAC provides bipartisan support to candidates for federal, state and local office who support the issues that are important to the Indian American community. These issues include: Strengthening US-India bilateral relations in defence, trade, and business; Promoting a fair and balanced policy on immigration; Ensuring protection from hate-crimes; Advocacy for appointments of Indian Americans in the Executive and Judicial branches of Government (Equal Opportunity); Ensuring equal protection under the law (Civil Rights), and protection of rights; Advocacy for issues such as small business. USINPAC's activities focus on strengthening a grassroots network to work on issues concerning the community. These activities include: Monthly scheduled breakfast events on Capitol Hill; Monthly luncheons with Chiefs of Staffs or Legislative Directors of key committees (International, Small Business, Finance, Immigration) on Capitol Hill, and quarterly Capitol Hill days to petition for / against key issues and legislation. Through its USINPAC's grassroots advocacy campaign, participation in Congressional Hearings and conduct of high-level briefings, regular meetings with key lawmakers and senior staff, educating and building awareness on a diverse range of issues, providing guidance in a crisis, acting as the go-to resource with a consistent message and 24/7 Washington presence, USINPAC has had a number of notable achievements related to the strengthening of the US-India Strategic Alliance, including support for the successful passage of the US-India Civilian Nuclear Cooperation from the 2006 Hyde Amendment to the 2009 approval of 123, Support of expanded US-India defence cooperation and US defence sales to India in 2005, 2006, 2007, and 2008, and the launching of the US Senate Caucus on India and Indian Americans in 2004.[1]

CII (Private)

CII is a non-government, not-for-profit, industry led and industry managed organisation, playing a proactive role in India's development process. The Confederation of Indian Industry (CII) works to create and sustain an environment conducive to the growth of industry in India, partnering industry and government alike through advisory and consultative processes. CII undertakes extensive research, interacts with key government officials and disseminate information through publications, seminars and events, including on Space Security, Defense, and Energy. Through a large network of offices (64 offices in India, 9 overseas), CII tracks policy issues in detail at the regional level and interacts closely with Members of Parliament - the policy makers - across political parties to raise awareness about the need for reforms, the need for change to keep up with in an extremely competitive global economy. Founded over 114 years ago, CII claims the title of India's premier business association, with a direct membership of over 7800 organisations from the private as well as public sectors, including SMEs and MNCs, and an indirect membership of over 90,000 companies from around 385 national and regional sectoral associations. CII seeks to catalyse change by working closely with government on policy issues, enhancing efficiency, competitiveness and expanding business opportunities for industry through a range of specialised services and global linkages. It also provides a platform for sectoral consensus building and networking. Partnerships with over 120 NGOs across the country carry forward initiatives in integrated and inclusive development, which include health, education, livelihood, diversity management, skill development, water and energy. CII also has a Defence Division which works proactively with the Ministry of Defence, Armed Forces and Defence Research and Development Organisation towards promoting Industry's participation in Defence production and towards strengthening the capabilities of Indian Industry in defence Production by steering policy formulation, defence market development and facilitation of joint ventures / technology tie-ups. CII maintains an office in the USA, and has previously partnered with USIBC on Nuclear energy and Green Business, and the Aspen Institute for broad Indo-US relations.

USIBC (Private)

The U.S.-India Business Council is the principal interlocutor for industry operating in the U.S. and Indian marketplace, playing a critical role supporting U.S. Government initiatives that include the U.S.-India Economic Dialogue (CEO Forum), the U.S.-India High Technology Cooperation Group, U.S.-India Energy Dialogue, the Defense Procurement & Production Group, and the U.S.-India Trade Policy Forum.

USIBC formulates an annual work plan that targets specific issues important to its member-companies, compiled from input derived from the 12 Executive Committees and Working Groups that meet regularly to assess progress on-the-ground and to devise strategies and prepare representations to advance sector-specific reforms in India. In addition, USIBC's Executive Committees organise industry missions to India to present to counterparts and the Government of India a united front to forge policy reform advances. USIBC claims the tile of the premier business advocacy organisation representing America's top companies investing in India, joined by global Indian companies, promoting economic reforms with an aim to deepen trade and strengthen commercial ties. Its primary mission is to serve as a direct link between business and government leaders, resulting in increased trade and investment. USIBC organises major policy and business development conferences in the U.S. and India. USIBC facilitates for its members key meetings with Indian Industry and Government of India officials to provide business leaders with direct access to top Indian decision-makers.

USIBC was formed in 1975 at the request of the government of the United States and India to involve the private sectors of both countries to enhance investment flows between the United States and India. USIBC is partnered with the premier industry & trade associations in India, including the Confederation of Indian Industry (CII), the Federation of Indian Chambers of Commerce and Industry (FICCI), the American Chamber of Commerce in India (AmCham India), National Association of Software and Service Companies (NASSCOM), The Indus Entrepreneurs (TiE), and the Indo-American Chamber of Commerce (IACC). These relationships provide USIBC-member companies with invaluable expertise and contacts throughout the U.S. and India. Day-to-day operations at USIBC are conducted from its headquarters at the U.S. Chamber of Commerce in Washington, D.C. To serve its members effectively, USIBC has established a presence in New York through the Manhattan-India Investment Roundtable, as well as a West Coast presence in California and in New Delhi. [2]

UNDOUSSTF (Private)

This organisation promotes and catalyses Indo-US bilateral collaborations in science, technology and engineering. It is covered in depth in the Models section.

Space Enterprise Council (Private)

The Space Enterprise Council was founded in 2000 to represent businesses with a commercial interest in space. Over the past eight years, the Council has grown to represent all sectors of the industry including commercial, civil, and military space. As a forum for space-related companies, the council brings the collective power of its affiliation with TechAmerica and its diverse members into a single, unified voice that is used in advocating member interests to policymakers. Prior to becoming a part of TechAmerica in 2009, the Council was affiliated with the U.S. Chamber of Commerce. Significant in its membership diversity, the Council provides U.S. companies a unique opportunity to take a principle role in developing and advocating policies and programs that ensure that the U.S. continues to be a leader in the space marketplace. A respected authority in the space community, the Council uses its influential leadership role to create a better business environment for space companies.[3] The Space Enterprise Council published a policy recommendation on Space Solar Power.[4]

SSAFE (Private)

The Space Solar Alliance for Future Energy (SSAFE) is a coalition of thirteen leading research organisations and space advocacy groups advocating investment in Space-Based Solar Power to address the planet's future energy needs. Its membership includes the National Space Society (NSS), Space Frontier Foundation, Space Power Association, Aerospace Technology Working Group (ATWG), Marshall Institute, Moon Society, ShareSpace Foundation, Space Studies Institute (SSI), Spaceward Foundation, AIAA Space Colonization Technical Committee, ProSpace, Space Enterprise Council, and Space Generation Foundation.

Notes

1 http://www.usinpac.com/mission_objective.asp

2 http://www.usibc.com/usibc/about/default and http://www.uschamber.com/usibc/about/default

3 http://www.techamerica.org/space

4 http://www.nss.org/settlement/ssp/library/2008-SECSpaceBasedSolarPowerWhitePaper.pdf

Appendix B

A Discussion And Evaluation of Various Models For International Cooperation, Space, Energy And Infrastructure

"We have working models of cooperation and cross-border technology movement" Jairam Ramesh, MNRE Minister[1]

Numerous models exist which are relevant for study with respect to a mega project like Space-Based Solar Power, and it is would be understandable if policymakers determining bilateral agendas were not familiar with even the major ones. For this study the researcher has reviewed several major models which India or the US or the two nations together have found successful. They cover the range of major projects and methods used to promote infrastructure, energy, mega-science, and space. Models vary in the mix and role of government and private industry, the involvement of defense research dollars or facilities, the desired end state (tech stimulus, pre-commercial prototype, commercial/for-profit), the degree of internationalisation (national, bilateral, multi-lateral), the degree of high-level visibility, and the degree of resourcing, and the assumed level of technical maturity. Of these various models, the following deserve special attention because they were referred to by my interviews with Indian and US colleagues. I have organised the models from small-scale projects & technology push models to larger-scale demonstration and commercialisation models, interspersing space, energy, and infrastructure.

Chandrayaan-1

Chandrayaan-1 was India's indigenously developed, indigenously launched unmanned space craft that put India in the small club of powers who have reached the Moon, and showcased ISRO's ability to do ambitious missions at very low cost and on a tight schedule (675 kg, 1.5 meter cubic, $80Million).[2] It received awards from the US based National Space Society (NSS), and American Institute for Aeronautics and Astronautics (AIAA), and is credited with the discovery of water on the Moon of sufficient quantity to open the door for more ambitious human presence and industrialisation. It was also a model of international collaboration, with the heavily instrumented probe (11 total) carrying 5 Indian and 6 hosted international payloads, one from Bulgaria, three from ESA (UK, Poland, Sweden), and two from the US (mini-SAR from JHU/APL, and M3 from NASA/JPL). In concert with the NASA Lunar

Reconnaissance Orbiter (LRO), it performed a bistatic radar experiment where pulses from Chandrayaan -1 were pointed at Erlanger crater for four minutes and received by both Mini-SAR on Chandrayaan-1 and Mini-RF on LRO.[3] Chandrayaan-1 is significant because it was the first Indo-US space cooperation after the door was opened with the 2004 Next Steps in Strategic Partnership (NSSP) articulated by Prime Minister Vajpayee and U.S. President George W. Bush, and the subsequent removal of Indian government run subsidiaries from the US.S Commerce Department's Entities List allowing export of dual-use items to ISRO headquarters, and the removal of licensing requirements for low-level dual-use technologies (EAR99 and XX999 items) and the "presumption of approval" of items not on the Nuclear Suppliers Group (NSG) export list. ISRO had announced the mission in 2003 prior to the NSSP agreement, and it was only in May of 2006 that ISRO and NASA signed a Memorandum of Understanding (MOU) to carry the two scientific payloads aboard Chandrayaan-1.[4] Chandrayaan-1 represents a successful cooperative project and the first instance of ISRO and NASA getting to know each other since their early collaboration in the 1950s,[5] 1960s through the 1980s.[6] *Chandrayaan-1 will certainly* establish the reference point for future Indo-US space collaboration, and may be useful as a model for very small scale proof of concept demonstrations (below the prototype level) such as was contemplated by NASA in 2008.

Smart Materials Model

In the Smart Materials programme, all five major Scientific Departments, DST, CSIR, DAE, DOS, and MOD participate in a push in a strategic technology area, in this case, smart materials. The programme began with a detailed proposal made to the MOD, and after scrutiny was sanctioned by the MOD. The overall programme goals are to establish Human Resource Development (HRD) and Research Facilities within Academic Institutions for a given field (in this case Smart Materials), and takes place in two phases. Initially "Community Sensitisation" takes place through workshops & training. Then funding is distributed for creation of basic components that contribute to hands-on human resource development and the exercise of such facilities to gain expertise in producing devices and microsystems, as well as fund specific applications in Aerospace, Automotive and Bio, with the condition that they result in productionisable products. Interagency equities are coordinated via an apex body, where all five departmental heads constitute the board. The board receives an annual budget from MOD of approximately Rs 2 billion [$40 million], and is distributed via a single eminent individual in consultation with the board. The programme is not an open R&D

programme with requests for proposals, but distributes funding to known good performers. The size of the grants is variable depending on the project, with 2-3 years for product oriented projects.[7] *This model might serve as a model for SBSP broad-level technology development and workforce creation.*

National Mission in Nano Science (Government Sponsored Tech Push)

As per the 11th Plan, "The national mission in nano science and technology would be a major new programme, designed to enable India to become a significant player in the global race by tapping the potential applications of nano science and technology. The proposed nano science and technology mission would focus on basic research, infrastructure development for quality nano science and technology research, human research development, forging international collaborations and most importantly, promoting PPP in the area of nano science and technology."[8]

National Nanotechnology Initiative (Government Sponsored Tech Push)

The US also has a multi-agency programme to align various nanoscience, called the National Nanotechnology Initiative (NNI). The National Nanotechnology Initiative (NNI) provides a multi-agency framework to ensure US leadership in nanotechnology that will be essential to improved human health, economic well being and national security. The NNI invests in fundamental research to further understanding of nanoscale phenomena and facilitates technology transfer. The NNI was established in 2001 to coordinate Federal nanotechnology research and development, and provides a vision of the long-term opportunities and benefits of nanotechnology and a framework for a comprehensive nanotechnology R&D programme by establishing shared goals, priorities, and strategies, and it provides avenues for each individual agency to leverage the resources of all participating agencies. The goals of the programme are to: Advance a world-class nanotechnology research and development programme; Foster the transfer of new technologies into products for commercial and public benefit; Develop and sustain educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology; Support responsible development of nanotechnology. By serving as a central locus for communication, cooperation, and collaboration for all Federal agencies that wish to participate, the NNI brings together the expertise needed to guide and support the advancement of this broad and complex field. The NNI consists of the individual and cooperative nanotechnology-related activities of 25 Federal agencies (all the major Scientific Departments, and most of the other major Federal

Departments and Agencies) with a range of research and regulatory roles and responsibilities. Thirteen of the participating agencies have R&D budgets that relate to nanotechnology, with the reported NNI budget representing the collective sum of these (about $1.5 billion in 2009[9]). The NNI as a programme does not fund research; however, it informs and influences the Federal budget and planning processes through its member agencies. The NNI is managed within the framework of the National Science and Technology Council (NSTC), the Cabinet-level council by which the President coordinates science, space, and technology policies across the Federal Government. The Nanoscale Science Engineering and Technology (NSET) Subcommittee of the NSTC coordinates planning, budgeting, programme implementation and review to ensure a balanced and comprehensive initiative. The NSET Subcommittee is composed of representatives from agencies participating in the NNI. To support the interagency coordination activities of NSET Subcommittee, a National Nanotechnology Coordination Office was established in 2001.[10] *NNI might serve as a model for SBSP broad-level technology development.*

BIRD (Government Conditional Grants for Joint Endeavours)

IDSA's Dr. Cherian Samuel, had proposed BIRD as a potential model for deepening Indo-US technological collaboration. BIRD is an acronym for Israel-U.S. Binational Industrial Research and Development, established by the U.S. and Israeli governments in 1977 to generate mutually beneficial cooperation between the private sectors of the U.S. and Israeli high tech industries, including start-ups and established organisations. The BIRD Foundation's mission is to stimulate, promote and support industrial R&D of mutual benefit to the U.S. and Israel. BIRD provides matchmaking services between Israeli and American companies in the field of Research and Development, as well as funding covering up to 50 per cent of project development and product commercialisation costs but takes no equity in the joint projects and all services are free of charge. BIRD supports approximately 20 projects annually (Up to 35 full-scale projects (>$400,000 project budget) and 20 mini-projects may be approved each year) with a total investment of around $11 million per year. To date, BIRD has invested over $245 million in 740 projects, which have produced sales of over $8 billion. Since the establishment of the Foundation 30 years ago, the accumulated repayments have totalled $82 million. Any pair of companies, one Israeli and one U.S.-based, may apply jointly so long as they can demonstrate the combined capabilities and infrastructure to define, develop, manufacture, sell and support an innovative product based on industrial R&D. The companies may be simply cooperating on an ad hoc basis, linked through a corporate joint venture, or commonly owned (in whole or in part). The key criterion is that each corporate entity shall have the ability to carry out its part of the joint development and commercialisation and is willing to share in the financial risk of product development as well as in the financial gain of commercialisation. Proposals are subject to a confidential review by qualified and experienced experts from the US National Institute of Standards and Technology (NIST) and from the Office of the Chief Scientist (OCS) of Israel's Ministry of Industry and Trade. The decision to approve or reject proposals for funding full-scale projects are made by BIRD's Board of Governors, which convenes semiannually to act on proposals for full-scale projects. Project duration may be as long as 3-4 years, if deemed necessary for reaching commercial readiness. The Executive Director is empowered by the Board of Governors to allocate up to 20 per cent of annual conditional grant funds for the support of mini-projects ($200,000, or 50 per cent of actual project costs), which has proven to be a powerful and successful tool for rapid and relatively low-risk involvement of U.S. and Israeli companies in relatively small but meaningful product developments of a cutting edge technology. Grants are conditional, meaning that if a Project fails, BIRD will claim no repayments. Therefore, BIRD is a major risk-sharer with the Project partners. If commercialisation succeeds, BIRD is entitled to repayments of a maximum of 150 per cent of this Conditional Grant tied to actual revenues linked to US Consumer Price Index, and repayments are made at the rate of 5 per cent of each dollar of reported sales (to third parties) revenue, or at the rate of 30 per cent of the revenue earned from extending licensing rights to the technology, or at the rate of 50 per cent from the outright sale of the technology to any third party. Other advantages of BIRD besides major risk sharing is that BIRD does not become involved in the formulation of the relationship between partnering companies, its professional review provides a seal of approval, and BIRD acquires neither equity nor any rights to intellectual property in BIRD-funded Projects, and its grant is a form of off-balance sheet financing. Grant payments are usually recorded as pre-tax expenses, a reduction of R&D expenses, and grant repayments are recorded as a royalty expense. Because both transactions are not recorded as a liability, they do not have any impact on the balance sheet.[11]

Such a model would clearly have a stimulatory effect on Indo-US tech collaboration, but since it is focused on commercializing products in a short time span, it probably could not provide either sufficient capital, nor the right focus for SBSP. Nevertheless, the concept of a Government conditional grant of 50 per cent without an equity or intellectual stake to develop a commercial technology would almost certainly interest the several companies who wish to bring Space Solar Power to market.

Sky's No Limit

US-India Endowment for Joint R&D Innovation and Commercialisation

In July of 2009, India and the US set up a $30 million[12] endowment to fund, with equal contributions from India and the US, cooperative research and stimulate entrepreneurial activity toward commercial results. The endowment is managed by a Board, who sets up a peer review committee to judge proposals which are open to government, educational, and private sector institutions. Governments retain royalty free license for government purposes.[13] At maturity, it may resemble BIRD, but it has yet to begin functioning. *Such a fund might be useful for studies and technology development related to SBSP, and might serve as a pass through vehicle for a dedicated project on Space Solar Power.*

UNDOUSSTF (Private)

A The Indo-US Science and Technology Forum (IUSSTF), established under an agreement between the Governments of India and the United States of America in March 2000, is an autonomous, not for profit society that promotes and catalyses Indo-US bilateral collaborations in science, technology, engineering and biomedical research through substantive interaction among government, academia and industry. As a grant making organisation, the principle objective of IUSSTF is to provide opportunities, to exchange ideas, information, skills and technologies, and to collaborate on scientific and technological endeavours of mutual interest that can translate the power of science for the benefit of mankind at large. IUSSTF aims to facilitate, seed and promote US-India bilateral collaborations in science, technology, engineering and biomedical research. IUSSTF strives to increase interactions among government, academia, and industry, by promoting collaborative research and development, the transfer of technology, and the dissemination of knowledge and information of common interest to the research communities in India and US by building awareness through exchange and dissemination of information, capitalising on S&T synergy on issues of common concern leading to long-term partnerships, supporting enabling S&T programme portfolios that pave the way to sustainable and potential collaboration, and nurturing context between young and mid career scientists to develop mutual trust, leadership and technopreneurship in R&D, and encouraging public private partnerships through networking. To accomplish its missions IUSSTF supports the following programmes: Bilateral workshops/ symposia/ conferences, training programmes and advanced schools, R&D joint networked centres, public-private joint networked centres, individual travel grant for sabbatical fellowships, travel grant for exploratory visits, as well as flagship initiatives, Frontiers of Science Symposium, Indo-US Frontiers of Engineering Symposium, Indo-US Research and Philanthropy Program, and solicits proposals three times a year (Feb, June, Oct with award announcements in May, Sept, Jan). IUSSTF has sponsored many events, bringing together nearly 5,000 Indian and US Scientists and catalysed much collaboration, as well as facilitated key inter-institutional MoUs, and Joint R&D centres, and supported the creation of the vision document on Indo-US Civil Space Cooperation, the International Partnership in Hydrogen Economy (IPHE), and India's partnership in the US Big Sky Regional Carbon Sequestration Program.[14] *The Forum, with its interests in collaboration, interdisciplinary subjects, space, and energy, could fund joint seminars, research fellowships and individual researcher travel in support of SBSP.*

US-India Aviation Cooperation Programme

The U.S-India Aviation Cooperation Programme (ACP), a public-private partnership between the U.S. Trade Development Agency (USTDA), the U.S. Federal Aviation Administration (FAA) and U.S. aviation companies,[15] has been established to provide a forum for unified communication between the Government of India and U.S. public and private sector entities in India. The ACP is designed to work directly with the Indian Government to identify and support India's civil aviation sector modernisation priorities. The ACP will serve as a mechanism through which Indian aviation sector officials can work with U.S. civil aviation representatives to highlight specific areas for technical cooperation. The ACP consists of both U.S. Government and private sector representatives, and its secretariat will function as the focal point for responding to Indian areas of interest by identifying appropriate training programmes and other cooperative activities. The secretariat will be responsible for managing and organising the identified training and technical cooperation activities. US-India Joint Aviation Dialogue at the Apex, with the US-India Joint Aviation Steering Committee, loosely tied to the US-India Aviation Cooperation Programme. The Steering Committee oversees Joint Working groups in Flight Standards, Air Worthiness, Air Traffic, Airports, and environment. The ACP's specific objectives are to: (i) promote enhanced safety, operational efficiency and system capacity in the Indian aviation sector; (ii) facilitate and coordinate aviation industry training and technical ties between the U.S. and India; and (iii) strengthen overall U.S.-India aviation cooperation. USTDA is providing funding for training and technical assistance programmes and the FAA and U.S. aviation companies are providing in-kind support.[16] *This model does not appear appropriate for a project like SBSP though it may provide a forum to discuss certification and air traffic control of launch vehicles.*

USAID/SARI-E (USG)

The US Agency for International Development (USAID) runs a multi-lateral programme called the South Asia Regional Initiative for Energy (SARI-E). The USAID/SARI/Energy programme promotes energy security in South Asia through three focus areas: (1) cross border energy trade, (2) energy market formation, and (3) regional clean energy development. Through these activities SARI/Energy facilitates more efficient regional energy resource utilisation, works toward transparent and profitable energy practices, mitigates the environmental impacts of energy production, and increases regional access to energy. SARI/Energy countries include: Afghanistan, Pakistan, India, Nepal, Bhutan, Bangladesh, Sri Lanka and the Maldives. SARI-E's activities include Technical Assistance, including conducting analytical studies on energy security, distribution reform, regulatory reform and energy efficiency; Training including conducting training programmes as well as developing and implementing regional workshops, seminars, conferences, and informational sessions on energy security, distribution reform, regulatory reform and energy efficiency; South Asia Utility Placement Programme, which is a capacity building programme designed to improve the technical and managerial skills of professional staff in South Asian utilities through a short-term placement at another South Asian, U.S., or overseas utility; Regional Partnerships, which bring together key energy sector participants to interact on critical issues in the areas of energy market formation, energy policy, utility management, regulatory reform, and transmission; and providing critical research data (Solar & Wind Resource Data) on regional renewable energy sources for dissemination via the SARI/Energy Programme.[17] *SARI-E might provide a forum to discuss SBSP programmatics between technology providers and utilities, and linkage to multi-lateral energy requirements.*

Project (DARPA) Model

Several thinkers have commented that the United States should have a Manhattan Project for Energy. Certainly Space Solar Power would meet that criterion. In the project model, responsibility, leadership, and funding typically flow through a single, responsible individual who is usually a strong champion of the programme. Often the funding organisation (like DARPA and now ARPA-E) has only funding and oversight, and pursues the project through other organisations whether government labs, universities, or private companies. Such models have been used both for government only uses (such as the development of the Nuclear Bomb (Manhattan Project), Nuclear Submarines, ICBM, Strategic Defense Initiative (SDI)), as well as for pre-commercial/dual use applications that ended up having tremendous public and civilian value, such as ARPA-net which became the internet. Project models are typically used to push a technology to a given criteria, though not always to a full capability. Very often such pre-competitive research serves only to retire risk, and then leaves a "valley of death" where financing or a customer is required to move things from a technological fait accompli to a fielded or commercial product. Often the project manager manages risk by having multiple performers that pursue different approaches to accomplish the same end. In matters of great public interest or cost, the programme organisation and its leadership may be detached or formed to operate autonomously so as to be able to completely control their personnel and resources and concentrate solely on the task, and for the leadership to be able to have maximum decision-making power, autonomy and the minimum levels of intervening management.[18] *The project model would seem to provide the best model for an individual nation that wished to see SBSP progress to a technological demonstration success in the minimum amount of time.*

ARPA Net (military research leads what is mainly a consumer technology)

ARPA Net, which pioneered the technologies that made possible the modern Internet, was a US Department of Defense (DoD) Advanced Research Projects Agency (ARPA, now DARPA) programme, where under the vision and direction of a programme manager, multiple contractors efforts were funded and coordinated in breakthrough technologies. The success of the DARPA model has recently led to the creation by the US Congress of an Advanced Research Projects Agency – Energy or ARPA-E.

Manhattan Project

"The Manhattan Project was the codename for a project conducted during World War II to develop the first atomic bomb. The project was led by the United States, and included scientists from Denmark, The United Kingdom and Canada. Formally designated as the Manhattan Engineer District (MED), it refers specifically to the period of the project from 1942–1946 under the control of the U.S. Army Corps of Engineers, under the administration of General Leslie R. Groves. The scientific research was directed by American physicist J. Robert Oppenheimer… Project research took place at over thirty sites across the United States, Canada, and the United Kingdom. The three primary research and production sites of the project were the plutonium-production facility at what is now the Hanford Site, the uranium-enrichment facilities at Oak Ridge, Tennessee, and the weapons research and design laboratory now known as Los Alamos National Laboratory. The MED maintained control over U.S. weapons production until the formation of the Atomic Energy Commission in January 1947…in December 1941 Vannevar Bush created the larger and more powerful Office of Scientific Research and Development—which was empowered to engage in large engineering projects in addition to research—and became its director. Vannevar Bush, the head of the civilian Office of Scientific Research and Development (OSRD), asked President Roosevelt to assign the operations connected with the growing nuclear weapons project to the military. Roosevelt chose the Army to work with the OSRD in building production plants. The Army Corps of Engineers selected Col. James Marshall to oversee the construction of factories to separate uranium isotopes and manufacture plutonium for the bomb… Vannevar Bush became dissatisfied with Col. James Marshall's failure to get the project moving forward expeditiously and made this known to Secretary of War Stimson and Army Chief of Staff George Marshall. Marshall then directed General Somervell to replace Col. Marshall with a more energetic officer as director. In the summer of 1942, Col. Leslie Groves was deputy to the chief of construction for the Army Corps of Engineers and had overseen the very rapid construction of the Pentagon, the world's largest office building. He was widely respected as an intelligent, hard driving, though brusque officer who got things done in a hurry. Hoping for an overseas command, Groves vigorously objected when Somervell appointed him to the weapons project. His objections were overruled, and Groves resigned himself to leading a project he thought had little chance of success. Groves appointed Oppenheimer as the project's scientific director, to the surprise of many."[19]

Apollo Programme

"Apollo Programme landed the first humans on Earth's moon. NASA's Apollo Programme ran from 1961 until 1975… The programme spurred advances in many areas of technology peripheral to rocketry and manned spaceflight. These include major contributions in the fields of avionics, telecommunications, and computers. The programme sparked interest in many fields of engineering… In November 1960, John F. Kennedy was elected President after a campaign that promised American superiority over the Soviet Union in the fields of space exploration and missile defense. Using space exploration as a symbol of national prestige, he warned of a "missile gap" between the two nations, pledging to make the U.S. not "first but, first and, first if, but first period." Despite Kennedy's rhetoric, he did not immediately come to a decision on the status of the Apollo Programme once he was elected President.

He knew little about the technical details of the space program, and was put off by the massive financial commitment required by a manned moon landing…required the most sudden burst of technological creativity, and the largest commitment of resources ($24 billion), ever made by any nation in peacetime. At its peak, the Apollo Program employed 400,000 people and required the support of over 20,000 industrial firms and universities… According to Steve Garber, the NASA History website curator, the final cost of project Apollo was between $20 and $25.4 billion in 1969 dollars (or approximately $145 billion in 2008 dollars)."[20]

BRAHMOS (Bilateral Government / Private Sector for-profit R&D)

In my interview with former ISRO rocket scientist, DRDO director, Principal Scientific Advisor, and finally President of India, Dr. APJ Abdul Kalam, he stated his preference for the BrahMos[21] model, and his further elaboration of it through a "World Knowledge Platform." In this model, it begins scientist-to-scientist level, where they visit each other's labs and conceive what is possible on each side. Then they mutually formulate a plan using near equal expenditure of resources, no transfer of funds, but complete sharing of data, and then provide a coordinated push to sell the idea to their respective governments for resourcing. It should be noted this model involved the government of India to private entity (company) in the other country.

World Knowledge Platform

The World Knowledge Platform is Dr. APJ Abdul Kalam's concept of extending the BrahMos model to a wider set of problems. 'World Knowledge platform' will enable joint design, development, cost effective production and marketing of the knowledge products, systems and services in various domains based on the core competence of partner nations to international market. World knowledge platform is a meeting place for science, technology, industry, management and marketing" to address water, healthcare, agriculture and food processing, knowledge products, transportation systems, habitat, and disaster prediction and management and capacity building.[22]

Technology Mission

India has a model it calls a technology mission. "Technology missions are the most appropriate mechanism, particularly when it requires broad needed action in a number of different areas, which may involve different government ministries, departments or levels in the private sector. A technology mission whether for development or rollout not only brings a single point focus to disperse initiatives in the relevant field but also provide support to research projects in universities and research institutions with the aim of delivering the mission objectives. Technology missions must cover areas that are of critical importance to India's long-term energy needs."[23]

National Solar Mission

A specific and relevant example of a Technology Mission is India's new National Solar Mission. The National Solar Mission is one of eight missions designed to respond directly to climate change and is monitored by the Prime Minister's Council on Climate Change.[24] The National Solar Mission has several goals,[25] to establish India as a global leader in Solar Energy, to establish 2-3 large solar utility scale plants, and ultimately reach 20GW of installed capacity by 2020 while displacing 42 million tonnes of C02 emission[26] as well as to establish a regulator/incentive mechanism[27], and in the long-term to deliver truly disruptive innovations.[28] Toward this end, it has articulated a comprehensive idea of how it will pursue research,[29] and has recognised both the correlated manpower needs,[30] and the utility of bilateral and multilateral agreements.[31] The plan envisions a level of required investment of approximately $17-21 billion over 30 years as well as a funding mechanism in the form of a tax on fossil fuel and fossil fuel based power generation.[32] *The National Solar Mission could either serve as a direct template for in-India SBSP, or SBSP might become one element of an upgraded National Solar Mission.*

Mega-Science Model

Another model, which was first proposed and took centre stage in my discussions at Electronics Corporation of India Limited (ECIL)[33] was the "big science" model. Here the discussion centred on the need for a meaningful international demonstration, perhaps on the order of $10 billion that in itself was not a commercial venture, but rather a large experiment. This amount was not deemed to be ridiculous, and ECIL noted that India is supporting several such projects, including ITER, Large Hadron Collider (LHC), CERN,[34] Facility for Anti-Proton and Ion Research (FAIR),[35] and Square Kilometer Array (SKA).[36] *The perception was that such large collaborative international projects were being led principally by the Europeans,* "universal technology for public good", and that the US was losing soft power and mindshare by not initiating such endeavours, and their was a perception of the rest of the world going for "universality" while the US was pursuing a path of "uniqueness" or exceptionalism and wanting to go it alone and advance alone rather than in collaboration.

Discussion also touched on whether, rather than only being a positive respondent to the initiative of others, India was ready and confident to take leadership and propose such a project. None of the discussants saw any fundamental barrier, "In principle I don't see why it should not happen." In that group it was felt that the relevant groups with the proper research facilities and long term outlook were the Indian Department of Energy (DAE) and the Department of Space (DOS), and that these should be coordinated through the Indian Principal Scientific Advisor (PSA), who could take leadership in establishing a coordinated R&D plan, and building International coalitions. "PSA is the correct authority to start to take it around…he has both Space and Atomic Energy." DST and DRDO were also mentioned, but with less prominence in this model, and it was noted that DST is principally a funding organisation without direct lab capabilities, though useful in policy and concluding international cooperation. Here they noted the FAIR project and suggested that the industry shareholding approach might work where funding, "might be conducted under the aegis of DST and they in turn channelise the funding." Participants wondered what the appropriate link would be on the US side, mentioning both OSTP and DARPA.

ITER

ITER was originally an acronym for International Thermonuclear Experimental Reactor, but that title was dropped due to the negative popular connotation of "thermonuclear," especially when in conjunction with "experimental". "Iter" also means "journey", "direction" or "way" in Latin, reflecting ITER's potential role in harnessing nuclear fusion as a peaceful power source. According to the ITER consortium, fusion power offers the potential of "environmentally benign, widely applicable and essentially inexhaustible" electricity, properties that they believe will be needed as world energy demands increase while simultaneously greenhouse gas emissions must be reduced. ITER is designed to produce approximately 500 MW (500,000,000 watts) of fusion power sustained for up to 1,000 seconds. Although ITER is expected to produce (in the form of heat) 5-10 times more energy than the amount consumed to heat up the plasma to fusion temperatures, the generated *heat will not be used to generate any electricity. The programme is anticipated to last for 30 years — 10 for construction, and 20 of operation.* ITER *was originally expected to cost approximately 10 billion (£9 billion) [US$14.5 billion]*, but the rising price of raw materials and changes to the initial design may see that amount double. The reactor is expected to take nearly 10 years to build and is scheduled to be switched on in 2018. If completed, ITER would be one of the most expensive modern technoscientific megaprojects.[37] The idea for ITER originated from the Geneva superpower summit in November 1985 where Premier Gorbachov, following discussions with President Mitterand of France, proposed to President Reagan that an international project be set up to develop fusion energy for peaceful purposes. The ITER-project subsequently began as a collaboration between the former Soviet Union, the USA, the European Union (via Euratom) and Japan. In 1988 the conceptual design work was started, followed in 1992 by engineering design. On July 21, 2001, the ITER engineering design activities were successfully completed, and the final design report was made available to the ITER Parties. The design was underpinned by Research & Development work worth $650 million, which was carried out by the ITER parties to establish the practical feasibility of the design. The process of selecting a location for ITER took a long time, and was finally successfully concluded in 2005.[38] India is already participating in the ITER consortium through an India Consortium called ITER-India funded through the DAE to provide in-kind contributions[39] equivalent to US $0.5 billion.[40] *ISRO's chairman is aware of ITER as a model for SBSP.*[41]

International Space Station (ISS)

The International Space Station serves primarily as a research laboratory and is the largest satellite ever launched into orbit. The programme itself, and the international cooperation that it represents, allows 14 nations to live and work together in space, providing important lessons that can be taken forward into future multi-national missions. Originating during the Cold War, the International Space Station represents a union of several space station projects from various nations. During the early 1980s, NASA had planned to launch a modular space station called Freedom and the Soviets were planning a replacement for Mir to be constructed during the 1990s called Mir-2. With the fall of the Soviet Union ending the Cold War and Space Race, Mir-2 was cancelled, and budget difficulties prompted U.S. administration officials to start negotiations with partners in Europe, Russia, Japan, and Canada in the early 1990s to begin a collaborative, multi-national, space station project. In June 1992, then U.S. President George H. W. Bush and Russian President Boris Yeltsin agreed to cooperate on space exploration by signing the Agreement between the United States of America and the Russian Federation Concerning Cooperation in the Exploration and Use of Outer Space for Peaceful Purposes, and in September 1993, U.S. Vice-president Al Gore and Russian Prime Minister Viktor Chernomyrdin announced plans for a new space station, which eventually became the International Space Station. On-orbit construction of the station began in 1998 and is scheduled to be complete by 2011, with operations continuing until at least 2015...The ISS is a joint project among the space agencies of multiple nations. These consist of the United States National Aeronautics and Space Administration (NASA), Russian Federal Space Agency (RKA), Japan Aerospace Exploration Agency (JAXA), Canadian Space Agency (CSA) and the European Space Agency (ESA) of ten European nations. The Brazilian Space Agency (AEB) participates through a separate contract with NASA. The Italian Space Agency (ASI) has separate contracts for various activities not done within the framework of ESA's ISS projects, where Italy is a full participant. "As a multinational project, the legal and financial aspects of the ISS are complex. Issues of concern include the ownership of modules, station utilisation by participating nations, and responsibilities for station resupply. The main legal document establishing obligations and rights between the ISS partners is the Space Station Intergovernmental Agreement (IGA). This international treaty was signed on January 28, 1998 by the primary nations involved in the Space Station project: the United States, Russia, Japan, Canada and ten Member States of the European Space Agency (Belgium, Denmark, France, Germany, Italy, The Netherlands, Norway, Spain, Sweden, Switzerland). This set the stage for a second layer of agreements, called Memoranda of Understanding (MOU), between NASA and ESA, CSA, RKA and JAXA. These agreements are then further split, such as for the contractual obligations between nations, and trading of partners rights and obligations…The most cited figure of an overall cost estimate for the ISS ranges from 35 billion to 100 billion USD. ESA, the only agency actually stating potential overall costs, estimates •100 billion for the entire station over a period of 30 years. "[42]

Government Incentivised, Pure Commercial Model

In this model, the only role of government is to create an incentive structure by way of regulation, access to capital, access to infrastructure and personnel, feed-in tariffs, anchor contracts, etc., and allow the private sector to do the rest. This model hopes to capitalise on private sector efficiencies to move fast and market forces to keep the cost of products and services low. In this model, companies do self-funded R&D also called Internal Research and Development (IRAD), take out loans for the high capital costs, and own and operate the Solar Power Satellites, using no government funding,[43] and assuming almost all risk. Generally speaking though, for very large infrastructure and power projects, regulated monopolies or public-private-partnerships (PPPs) have proven successful, since most companies look to minimise risk and maximise profit in the short term. SBSP presents very significant up-front NRE and capital investments beyond what most companies can handle, and would require active help from a government to cope with regulations and international issues.

Even in this model, India could put in place an incentive regime at no cost that would provide an optimal environment for companies that wanted to take this risk. Companies, especially large multi-nationals decide where to invest their next dollar based upon the combination of freedom & control (percent share of ownership, ease of doing business without excessive permissions), security/risk (Intellectual property rights, legal protection, government regulation and incentive stability), flexibility of labour (educated workforce, ease of hiring and firing) and opportunities for financial gain and freedom to spend it (government incentives, low-cost loans, depreciation, provided infrastructure and social benefits, ability to move funds between countries).[44]

Until recently, India was not considered to be a friendly environment for domestic of foreign energy companies, but India is beginning the right moves to make its energy market more attractive to companies and renewable energy investors which will be important to attract private sector investment in SBSP and other renewable energy technologies. Clearly there is an increased appreciation of competitive markets[45] and the design of incentives,[46] and very recently India's Prime Minister has publically invited more Foreign Direct Investment (FDI) in India's energy sector.[47]

Several of India's recent innovations could be successfully applied to SBSP even before the technology is fully mature to encourage companies to invest in the technology. They include: Public-Private-Partnerships for R&D such as NMITLI,[48] mandated share of renewable energy in power company portfolios that allow purchase of higher-cost green energy spread across many consumers, attractive feed-in tariffs, large, long-term purchasing contracts like the Ultra-mega power programme,[49] Tradable Tax Rebate Certificates (TTRCs),[50] accelerated depreciation,[51] grant support, and low interest soft loans,[52] and extending the guaranteed post-tax returns of 14-16 per cent given to Public Service Undertakings (PSUs),[53] and allowing generating stations to sell directly to high tension customers.[54]

India might be able to get even further if it allowed renewable energy investments to be eligible for the large defence offsets (30 per cent of all acquisitions) which may be as much as $10 billion by 2011,[55] and further liberalised the percentage share of ownership in defence firms.[56]

PSU / FGC (State Owned or partially State-Owned Enterprise)

An alternative to the purely commercial model, where the State sees an interest or advantage in a particular industrial activity is a state-owned/ controlled, or chartered corporation. Both India and the US have mechanisms for setting up such entities.

In India a State-owned enterprise is called a Public Service Undertaking (PSU) (company in the public sector), a company in which the government (either Union, state/territorial, or both) own a majority (51 per cent or more) share of the company equity.[57] India has a wide variety of PSUs.[58]

In the US this is called a Federal Government Corporation (FGC),[59] the first of which was chartered in 1781 and predates the Constitution. The following quotes come from Held's paper, "Spinning off Army Activities in to Federal Government Corporations": "The FGC model has a form of ownership different from the other models. It is chartered by Congress, which sets forth goals, obligations, special powers, exemptions, and composition of the board of directors. As mentioned earlier, the FGC benefits from financial freedom beyond the restrictions on federal agencies. It also offers workforce management options unavailable to government agencies. The unique characteristics of FGCs make this approach a promising candidate",

"During the first half of the 20th century, FGCs were a common instrument of national military strategy to capture the manufacturing efficiencies of the U.S. economy for both the execution of and preparations for the two world wars…During the 20th century the FGC has become a common instrument of national policy. Since World War II the Congress has created about one FGC per year, resulting in about 60 in existence today…The basis for Congress's ability to create government corporations is derived from the Necessary and Proper clause of the Constitution, Article I, Section 8, Paragraph 18." FGCs "comprises about 50 government corporations that are chartered by Congress to achieve specific national policy goals. For example, in the first Clinton Administration, when it was felt that a domestic "Peace Corps" might solve some of the problems of the inner city, the Congress at the behest of the administration created the Corporation for National and Community Service (AmeriCorps) in 1993. The most recent FGC is the Valles Caldera National Preserve and Trust, which authorises the acquisition and independent management of the Valles Grande, an enormously beautiful and undeveloped area of land in northwestern New Mexico. These organisations include such familiar entities as the Tennessee Valley Authority (TVA), the National Railroad Passenger Corporation (AMTRAK), and the Smithsonian Institution", "Since World War II, Federal Government Corporations have been used as instruments of national

Sky's No Limit

policy because of their efficiencies arising from commercial market forces, their flexibilities with regard to encumbering regulations, and their ability to access financial alternatives. The usual process for creating an FGC starts with Congress drafting a charter that sets forth the entity's goals, obligations, special powers and exemptions, and organisational structure including the composition of the board of directors. The enabling legislation can specify a federal charter or incorporation under the laws of the District of Columbia. All FGCs are created as separate and permanent legal entities. Generally, in the congressional charter the right to sue and to be sued is a provision and is considered a waiver of sovereign immunity that clearly distinguishes the FGC from other government organisations. Free market forces generally create low-cost products and services…Adherents of small government can agree that the FGC could be a first step to the privatisation of commercial government activities… FGC option creates a highly focused organisation with a well-defined national policy goal. FGCs are allowed to focus on a single product or service and on a limited customer base or constituency… FGCs are granted much flexibility with regard to the otherwise encumbering regulations that would obtain for a traditional government agency. FGCs can enter contracts for goods and services independent of the FAR. They can buy and sell assets independent of the Federal Property and Administrative Services Act of 1949. Most FGCs are exempted from Civil Service regulations on pay and employee tenure (Lilienthal and Marquis, 1941) and from government personnel ceilings. Some FGCs are even exempted from the Government Corporation Control Act (GCCA), which was created to better regulate the mix of powers and privileges granted to FGCs in their congressional charters… FGCs benefit from financial freedoms beyond the restrictions on federal agencies. FGCs have the right to borrow funds from commercial and private sources, to issue debt in the form of bonds, and to own, to acquire, and to dispose of real property plant and equipment. Generally an FGC is not subject to the year-end budget pressures forcing expenditures within a given fiscal year. They can enter into multiyear commitments based on funding that will be available in their budgets regardless of yearly expenditures. Mixed and private ownership FGCs are usually financed 'off the balance sheet' (Collender, 1997) which, in effect, excludes them from the national accounts. With such a status, the debts of such organisations do not count against the national debt and are not subject to deficit reduction goals or spending caps when Congress is operating under budget reduction measures such as the Gramm-Rudman- Hollings budget reduction process. Some FGCs are exempted from local, state, and federal taxes, and their executives are excluded from Security and Exchange Commission regulations. Federal Government Corporations can be analysed along three basic dimensions: control, cash, and customers. FGCs are categorised for legal and regulatory purposes as government-owned, mixed-ownership, and private-ownership (U.S. GAO, 1995). The strategic control of an FGC flows from the level of ownership by the federal government, the level of ownership by private parties, and by the composition of the board of directors (BOD). Operationally, the control of the FGC is in the hands of the leadership brought in to run it. These individuals report to the BOD. For a government-owned FGC, the President of the United States appoints the majority or the entire BOD, whereas for a privately owned FGC, the President appoints a minority of BOD positions. The mixed ownership FGCs are in the middle.", "FGC customers are almost always the commercial sector or the general public. Some FGCs have government customers as well. The basic theme for all FGCs is that corporations can be more efficient than governmental structures when it comes to market transactions. Whereas FGCs have existed for more than 200 years, there are significant differences in how they are structured and controlled. There is essentially no uniform legal definition of an FGC. Because Congress individually charters each FGC, the range of applicable statutes may vary widely." *Instruments such as FGC and PSUs may be considered as one form of Pubic Private Partnership that might create the right balance of risk and efficiency for a strategic project such as Space Solar Power.*

COMSAT/INTELSAT (International Mixed-Ownership For-Profit)

INTELSAT was the first successful multi-lateral shared-ownership space enterprise, establishing the first global satellite communications system and spearheading today's $7 billion satellite communications business.[60] It operated as a separate legal entity operating under Article VI authority of the Outer Space Treaty.[61]

"The Inter-Governmental Organisation (IGO) began on August 20, 1964, with 11 participating countries. On April 6, 1965, Intelsat's first satellite, the Intelsat I (nicknamed Early Bird), was placed in geostationary orbit above the Atlantic Ocean by a Delta D rocket.[62] In 1971, 85 nations (including the United States) formed the International Telecommunications Satellite Organisation "INTELSAT," a public intergovernmental treaty organisation. INTELSAT was charged with operating the world's first global telecommunications satellite system, in order to guarantee the interconnectedness of the world's communications systems and the availability of international telecommunications service to every nation on earth.[63] In 1973, the name was changed and there were 80 signatories.

Intelsat provides service to over 600 Earth stations in more than 149 countries, territories and dependencies. Since its inception, Intelsat has used several versions (blocks) of its dedicated Intelsat satellites. INTELSAT completes each block of spacecraft independently, leading to a variety of contractors over the years. Intelsat's largest spacecraft supplier is Space Systems/Loral, having built 31 spacecraft (as of 2003), or nearly half of the fleet.[64] By the mid-1990s, the INTELSAT treaty organisation consisted of 148 member nations, and operated a global fleet of 25 geostationary satellites that served virtually every populated location on earth. However, in the 1980s, separate international satellite systems inspired by INTELSAT's success began competing against INTELSAT. By 2000, more than 200 operational geostationary commercial communications satellites orbited the earth, of which only 19 belonged to INTELSAT. As competition intensified, some commentators questioned why a public intergovernmental treaty organisation was still needed to provide telecommunications services that by then were substantially provided by the private sector. Acting on such concerns as the proliferation of privately-owned telecommunications satellites and transoceanic fibre optic cables, the US Congress enacted the ORBIT Act of 2000, which mandated the privatisation of INTELSAT. The privatisation process began in July 2001, [37 years as an intergovernmental organisation] and essentially ended with the sale of INTELSAT's satellites on January 28, 2005, when INTELSAT's former satellite system was sold to private investors for $5 billion dollars.[65] "The operations of INTELSAT are now based on the INTELSAT agreement (10 ILM 909 (1971))[66] and the operating agreement relating to INTELSAT (10 ILM 946 (1971)), both completed in Washington in 1971. The former is a treaty of which eventually most states of the world, members of the international telecommunications Union (ITU), became members and the latter is an agreement opened both for states and public and private telecommunications entities designed by governments in accordance with the provisions of the INTELSAT treaty. The COMSAT[67] has been so designated by the US. Under the INTELSAT agreement membership in the organisation is open to all member states of the ITU, the ultimate goal being the creation of a single global satellite telecommunications system. The members participate in the organisation by way of investment shares determined by the percentage of utilisation of the INTELSAT space segments. The institutional structure includes the assembly of parties, the meeting of signatories, the Board of Governors, and the Executive Organ headed by the Director General. The decision-making in the board is based on a weighted voting system depending on the amount of shares held by each government, but no government may cast more than 40 per cent of the total vote. Decisions on substantive matters require either the support of at least four governors representing at least two thirds of the investment shares with the support of all but three governors regardless of the total investment shares they may represent."[68] "In the period prior to Intelsat's privatisation in 2001, ownership and investment in INTELSAT (measured in shares) was distributed among INTELSAT members according to their respective use of services. Investment shares determined each member's percentage of the total contribution needed to finance capital expenditures. The organisation's primary source of revenue came from satellite usage fees which, after deduction of operating costs, was redistributed to INTELSAT members in proportion to their shares as repayment of capital and compensation for use of capital. Satellite services were available to any organisation (both INTELSAT members and non-members), and all users paid the same rates."[69] *INTELSAT is often brought up as a model for international ownership and control of SBSP, such as the 1980 DOE Program Review: "An international organisation ala COMSAT was strongly indicated for SPS,"[70] and a draft act has already been authored by Darel Preble at the Space Solar Power Institute*[71], and a more complete treatment of how such international corporations would function is discussed in Xin et al. *While some feel such an entity should be created after a government R&D programme retires the major technical risk, others feel it would provide exactly the sort of bold, focused organisation that would best be able to take the technology to commercial viability, and provide it with both an open-line budget and ability to bring in private capital, as well as a budget partially protected from annual appropriations.*

Captive Military Model

Several studies[72] have discussed the possibility of using military requirements as a spring-board and interim step to commercial viability. These thinkers look at previous examples such as the Boeing 707, C-5 competition, ARPA-net (and many other examples), and point to the fact that the military has successfully been used to seed very important civilian technologies. Because of dual use concerns and areas of competence, *it is difficult to imagine any successful programme that does not make use of at least some military R&D capabilities*. Typically such models would focus on using military R&D resources to serve the captive market, and begin with *a constellation of systems operating in the 3-5 MW range.* The advocates point out the large budgets and competence of military R&D establishments, particularly in space, and the fact that robust cooperative agreements are already in place between the US and India.[73] Further, they point out the existing requirement of the military for power at remote and forward bases, and the extremely high cost[74] (both monetary and in lives paid to secure access) the military pays for this energy today, as well as legislative mandates for the military to secure more green power.

Such a model could work, and proceed at a much lower level of approval, provided there are advocates at the researcher level and champions above.[75] *Already the US has existing programmes specifically to encourage space cooperation with friendly countries and India is specifically named.*[76]

However, there are several considerations that are likely to be important to policymakers. First, Space Solar Power offers a very broad and exciting line of research on current problems that might make it more attractive to hold and display at a higher level than mil-to-mil R&D, and might never achieve critical mass of attention or resources. Second, *if the intent of policymakers is to fully capitalise on the range of potential benefits of a technology aimed at growth, climate change, energy security, and national tech base competitiveness enhancement, and with a long-term vision as a mass civilian application, they may find a programme principally focused on military requirements to have certain drawbacks.* While a space solar power programme addresses a logistical power requirement and not a weapons requirement, and is seen principally as a sort of proactive industrial policy, it is for, instance, conceivable that either one's own public or one's adversaries might have (or deliberately create) a different perception.

RURAL Electrification (Government Loans to Cooperatives)

One of the most successful US government programmes and large scale infrastructure projects was the 1930s Roosevelt Rural Electrification project. Within two years of enactment of the executive order to establish the Rural Electrification Administration (REA), it had helped bring electricity to some 1.5 million farms through 350 rural cooperatives in 45 of the 48 states. By 1939 the cost of a mile of rural line had dropped from $2,000 to $600. Almost half of all farms were wired by 1942 and virtually all of them by the 1950s. In the 1930s, President Roosevelt saw the solution of this hardship as an opportunity to create new jobs, stimulate manufacturing, and begin to pull the nation out of the despair and hopelessness of the Great Depression. "One of the key pieces of Roosevelt's New Deal initiatives, the REA would provide loans and other assistance so that rural cooperatives—basically, groups of farmers—could build and run their own electrical distribution systems…The model for the system came from an engineer. In 1935, Morris Llewellyn Cooke, a mechanical engineer who had devised efficient rural distribution systems for power companies in New York and Pennsylvania, had written a report that detailed a plan for electrifying the nation's rural regions…Under the REA there was no direct government competition to private enterprise. Instead, REA made loans available to local electrification cooperatives, which operated lines and distributed electricity."[77] *Today, one might imagine large, low-cost federal/central or global loans given to municipalities or groups of municipalities to allow "green electrification" via SBSP.*

Eisenhower National Highway Program

Some thinkers, like STRATFOR's George Friedman[78] *see a parallel between SBSP and the Eisenhower National Highway project. Ultimately Space-Based Solar Power is an infrastructure project of enormous scale serving populist and humanitarian goals with some added strategic benefit.* In this sense it is analogous to the Dwight D. Eisenhower National System of Interstate and Defense Highways, commonly called the Interstate Highway System (or simply, the Interstate System), which is a network of limited-access highways (also called freeways or expressways) in the United States that is named for President Dwight D. Eisenhower, who championed its formation. The entire system, as of 2006, has a total length of 46,876 miles (75,440 km), *making it both the largest highway system in the world and the largest public works project in history.* Interstate Highways, which began with the National Interstate and Defense Highways Act of 1956, receive substantial federal funding (90 per cent federal and 10 per cent state) and comply with federal standards, but they are owned, built, and operated by the states or toll authorities. Originally lobbied for by major U.S. automobile manufacturers, it was championed by President Dwight D. "Eisenhower, who was influenced by his experiences as a young Army officer crossing the country in the 1919 Army Convoy on the Lincoln Highway, the first road across America. Eisenhower also had gained an appreciation of the German Autobahn network as a necessary component of a national defense system while he was serving as Supreme Commander of the Allied forces in Europe during World War II. In addition to facilitating private and commercial transportation, it would provide key ground transport routes for military supplies and troop deployments in case of an emergency or foreign invasion. Initial federal planning for a nationwide highway system began in 1921, when the Bureau of Public Roads asked the Army to provide a list of roads it considered necessary for national defense. This resulted in the Pershing Map…By the late 1930s, planning had expanded to a system of new superhighways…About *70 per cent of the construction and maintenance costs of highways in the U.S. are covered through user fees* (net of collection costs), primarily gasoline taxes collected by the federal government and state and local governments, and to a much lesser extent tolls collected on toll roads and bridges. The rest of the costs are borne by general fund receipts, *bond issues*, and designated property and other taxes. The federal contribution is overwhelmingly from motor vehicle and fuel taxes (93.5 per cent in 2007), as is about 60 per cent of the state contribution. However, local contributions are overwhelmingly from sources other than user fees. The portion of the user fees spent on highways themselves covers about 57 per cent of costs, as approximately one-sixth of the user fees are diverted to other programmes, prominently including mass transit."[79] *Ultimately Space-Based Solar Power is an infrastructure project of enormous scale serving populist and humanitarian goals with some added strategic benefit. In this sense it may be analogous to the Dwight D. Eisenhower National System, both in scale, potential effects, and possible financing model.*

Notes

1 Speaking at IDSA's Security Implications of Climate Change Event.

2 http://www.isro.org/chandrayaan/htmls/spacecraft_description.htm

3 http://en.wikipedia.org/wiki/Chandrayaan-1

4 Bommakanti, Kartik. 'Satellite Integration and Multiple Independently Retargetable Reentry Vehicles Technology: Indian-United States Civilian Space Cooperation', *Astropolitics*, 7 (1), January 2009, pp. 7-31, at http://dx.doi.org/10.1080/14777620902768859

5 http://en.wikipedia.org/wiki/Indian_Space_Research_Organisation Both the Rangpur Observatory and the Uttar Pradesh State Observatories set up in 1954 and 1957 enjoyed the technical support and cooperation of the United States.

6 http://www.indianembassy.org/newsite/indousspaceFeb09.asp "Indo-US cooperation in the space arena dates back to the very beginning of the Indian space programme. The very first sounding rocket, a Nike-Apache launched from Thumba on November 21, 1963 was a US made rocket that carried instruments to conduct ionospheric experiments over the earth's magnetic equator that passes over Thumba. Several more such rockets were launched later for various scientific missions. India conducted the Satellite Instructional Television Experiment (SITE) in the mid-1970s with NASA. SITE involved deployment of Direct Reception TV sets in about 2400 villages across six states of India to receive educational programmes via ATS-6, covering agriculture, family planning, health and hygiene, etc. The experiment was hailed as the world's largest sociological experiment. This was followed by the establishment of the multipurpose Indian National Satellite (INSAT) System in the 1980s. All the four satellites under INSAT-1 series were built by a US Company to India's specifications and three of them were put into orbit by US launch vehicles including INSAT-1B, orbited by the US space Shuttle Challenger."

7 Personal E-mail with Dr. V.K. Aatre, head of smart materials programme and former Science Advisor to Minister of Defence, July 18, 2009.

8 See 11th Plan, p. 181.

9 http://en.wikipedia.org/wiki/National_Nanotechnology_Initiative

10 http://www.nano.gov/html/about/home_about.html

11 http://www.birdf.com/

12 http://www.indianembassy.org/newsite/indosciapr07.asp

13 Agreement Between the Government of the United States of America and the Government of the Republic of India to Establish a Board and an Endowment for Joint Research and Development, Innovation, and Entrepreneurial and Commercialisation Activities in Science and Technology. New Delhi, July 20, 2009.

14 http://www.indousstf.org/

15 Listed companies include Boeing, Goodrich, Matron Aviation, GE, Pratt and Whitney,

PAS, Raytheon, Cessna, WCG, FedEx, IBM, Hi-Tech, Vaughn College, Honeywell, MITRE, MOOG, Lockheed Martin, Heike, and Bell Helicopter.

16 http://newdelhi.usembassy.gov/pr042307a.html

17 http://www.sari-energy.org/

18 Personal experience as DARPA Service Chief's Intern

19 Wikipedia, October 10, 2009.

20 Wikipedia, October 10, 2009.

21 Brahmos is an Indo-Russian joint partnership to develop and market a supersonic cruise missile, see http://www.brahmos.com/

22 http://www.abdulkalam.com/kalam/jsp/display_searchcontent.jsp?content=438&columnno=0&starts=0&search_for=world knowledge platform&sublink_id=75

23 IEP, p. 103.

24 NAPCC, p. 3, "Comprehensive mission documents detailing objectives, strategies, plan of action, timelines and monitoring and evaluation criteria would be developed and submitted to the Prime Minister's Council on climate change by December 2008. The Council also periodically review the progress on these missions. Each mission will report publicly on its annual performance...In order to respond effectively to the challenge of climate change, the government has created an Advisory Council on Climate Change, chaired by the Prime Minister. The council has broad-based representation from the key stakeholders, including government, industry and civil society and sets out broad directions for national actions in respect of climate change. The council will also provide guidance on matters relating to the coordinated national action on the domestic agenda and review of the implementation of the national action plan on climate change including its R&D agenda. The council chaired by the Prime Minister would also provide guidance on matters relating to international negotiations including bilateral, multilateral programs for collaboration, research and development."

25 NAPCC, p. 22: *"The ultimate objective of the mission would be to develop a solar industry in India that is capable of delivering solar energy competitively against fossil options from the kilowatt range of distributed solar thermal and solar PV to GW scale baseload priced and dispatch CSP [concentrated solar power] within the next 20-25 years."*

26 See National Solar Plan, "The objective of the National Solar Mission is to establish India is a global leader in solar energy…Establishing 2-3 large-scale solar utility scale plants (CSP)… to demonstrate technological and economic viability… pilot project to validate business models for large-scale rural electrification projects… promotion of local manufacturing capacities across the solar value chain, from raw materials to components through the establishment of dedicated solar manufacturing and technology parks… they may be developed that out in a manner similar to the ultra mega power plant (UMPP)… pilot deployment of next-generation technologies… installed capacity to reach 20GW by 2020… the above solar power capacity addition [building to 20 GW by 2020] would also result in about 42 million tons CO2 emission reduction."

27 National Solar Plan, p. 11: "The objective of the policy would be to create an environment which enables rapid large-scale capital investment in solar energy applications and provides an incentive structure that encourages technical innovation and lowering the costs to grid parity, preferably by 2020…The key design principles underlying the regulatory/incentive mechanism include solar power purchase obligations for states mandating 1-3 per cent of power consumed within the state be generated from solar energy by 2017, feed-in tariffs paid by the central government through utilities assigned 20 year power purchasing agreements (PPAs) established through competitive bidding, 10 year tax holiday, customs duty and excise duty exemption on capital equipment and critical materials, capital subsidy or accelerated depreciation (only on solar heating applications were all applications), use of market-based price discovery to set feed in

tariffs with set reductions per annum till elimination by 2020, single window clearance mechanisms, standard lease agreement format/template for installations and government land, mandated connectivity via State transmission utilities, and setup of an Autonomous Solar Energy Authority within the Ministry of new and renewable energy to provide the necessary guidance, financing (low interest rate loans, priority sector lending), tariff setting and setup of solar technology parks. One of the mission objectives is to take a leadership role in solar manufacturing (across the value chain) of leading edge solar technologies and targeting 4 to 5 GW of installed capacity but 2017, including the setup of dedicated manufacturing capacities for polysilicon material annually make about 2 GW capacity of solar cells."

28 NAPCC, p. 21: "The national solar mission would be responsible for: (A) the appointment of commercial in your commercial solar technologies in the country; (B) establishing a solar research facility at an existing establishment to coordinate the various research, development and demonstration activities being carried out in India, both in the public and private sector; (C) realising integrated private sector manufacturing capability of solar material, equipment, cells and modules (D) networking of Indian research efforts with international initiatives with a view to promoting collaborative research in acquiring technology were necessary, and adapting the technology acquired to Indian conditions; (E) providing funding support for activities foreseen under (A) to (D) through government grants duly leveraged by funding available under global climate mechanisms and earnings from deployment of research sponsored by the nation. Policy and break the current measures for promotion of solar technologies will also be enhanced as common to all renewables-based technologies.... further the mission would aim for local photovoltaic (PV) production from integrated facilities and a level of 1000 MW per annum within this timeframe.... in the long term, but mission would direct Indian solar research initiatives to deliver truly disruptive innovations that cut across more than one approach or technology. These include: (A) getting the same electrical, optical, chemical and physical performance from cheap materials that is delivered by expensive materials; (B) developing new paradigms for solar cell design that surpassed current efficiency limits; (C) finding catalysts that enable inexpensive, efficient conversion of solar energy into chemical fuel; (D) identify novel methods of self-assembly of molecular components and functional integrated systems; and (E) developing new materials for solar energy conversion infrastructure, such as robust and inexpensive, thermal management materials."

29 NSP, p. 17: "The mission will aggressively pursue research and development in solar energy through: (i) Solicited research and identified thrust areas, including storage systems; (ii) Industrial research, for increasing efficiency and reducing cost; (iii) basic research and new materials and concepts; (iv) Consortium approach and networked R&D efforts by different ministries; (v) International cooperation in research and development."p. 18: "The research council comprising eminent experts and representatives from academic and research institutions, industry, government and civil society, will guide the overall technology development strategy."

30 National Solar Plan, p. 19: "The rapid large-scale diffusion of solar energy will require a common commitment increase in technically qualified manpower of international standard. It is envisaged that over the mission about 100,000 trained and specialised personnel would be required by 2020 for engineering, management and R&D functions. [5,000 per GW]…IITs and premier engineering colleges would be involved in the design and development of special courses in solar energy and financial assistance from the government…at B. Tech, M. Tech and PhD level. A government fellowship programme to train 100 selected engineers / technologists and scientists in solar energy in world class institutions abroad will be taken up."

31 National Solar Plan, p. 20: "Wherever feasible, cooperation through bilateral and multilateral arrangements would be facilitated."

32 National Solar Plan, p. 21: "Total anticipated funds from the Union Government for the above programme are Rs 85,000-105,000 crore [$17-21 billion] over a 30-year period

starting with Rs 5,000-6,000 crore [$1-1.2 billion]. These funds will be collected in this first hearing on lap civil solar fund in order to insulate the programme from budget related variability... the strategy should be to tax fossil fuels and fossil fuel-based power generation to mobilise additional resources at a rate of 10 paise / 1000 Kcal and 5 paise per KWh on thermal power generation, resulting in Rs 4,240 crore [$0.85 billion] annually and expected to grow annually."

33 ECIL is a public sector company and offshoot of the Department of Atomic Energy, which operates on a for-profit basis responsible to shareholders. ECIL has a number of technology capabilities under a single roof related to Space Solar Power, though not likely to take leadership without direct funding from GOI. They employ some 5,000 engineer and technical staff. Their main thrust is control instrumentation, particularly in defense and space, including antennas and receivers (including the 30m dish build for the Chandrayaan Moon mission and Deep Space Network). They build products, but also do contract work for DRDO, ISRO, DAE, and DST not unlike US defense contractors. They have expanded into a number of purely civilian areas, such as E-government voting booths, transport and railways, and control of chemical industry plants. They have done previous work on central solar receiver Heliosat including the optics and control structures. They noted that they draw sustenance from the R&D labs, and are keen to align to the overall concern in energy.

34 11th Plan, p. 175: "The DAE contributed significantly to international mega-science projects, particularly the CERN. This contribution has been recognised and lauded by the international scientific community."

35 11th Plan, p. 180: "Indian scientists were assisted and supported in accessing/utilising some of the major international research facilities like CERN (Geneva), ELETTRA (Italy), Sp Ring-8 (Japan), KEK Accelerator (Japan), national laboratory for high energy physics (Japan), synchrotron radiation sources beamline facility (Novosibirsk, Russia), FAIR (germany), Fermi Lab (United States), and synchrotron light source (Singapore), for dance training and conducting experiments in the fields of crystallography, condensed matter physics, high-energy scattering, solid x-ray spectroscopy, nuclear resonance scattering, magnetic Compton studies, and so on."

36 SKA, or Square Kilometer Array, is a international radio astronomy project in Africa to link 1,000 smaller radiotelescopes together

37 http://en.wikipedia.org/wiki/ITER (accessed April 24, 2009).

38 http://www.iter.org/a/n1/history.htm

39 http://www.iter-india.org/ see organisation here: http://www.iter-india.org/ITER-India-Org.pdf

40 See 11th Plan, p. 172: "The International Thermonuclear Experimental Reactor (ITER) is a prestigious international project which will nearly complete the scientific and technological investigations required to build a prototype demonstration reactor, based on the magnetic confinement scheme of controlled thermonuclear fusion. India's contribution to ITER, worth nearly Rs 2,500 crore [$0.5 billion] in terms of equipment to the experiment, are largely based on the indigenous experience and the expertise available in Indian industry. India will also participate in the subsequent operation of ITER and the experiments thereon. R&D efforts on fusion and plasma science will continue to strengthen domestic technologies."

41 Interview with ISRO Chairman M. Nair, pp.137-138, in Bagla, Pallava; Menon, Subhadra, *Destination Moon: India's Quest for the Moon, Mars and Beyond*, Harper Collins, 2008.

Q: But are you open to the suggestion that India can participate in using the ISS?

A: Yes, if there is a specific need, definitely one can.

Q: Do the other countries want India on board?

A: Well, the US is the main partner, and now you know Indo-US relations, they are improving quite a bit. So we'll have to wait and see.

Q: The same thing was considered with the International Thermonuclear Experimental Reactor (ITER). Now India is part of ITER. We were not part of the ITER experiments?

A: See for example, the US is participating in our Chandrayaan mission. They have sent two instruments to be flown piggyback, so that's a positive step toward improving our relationship.

Q: So are we saying that India may not be averse or allergic as it was towards the ISS? We could be participating in that experiment?

A: No, as part of international cooperation, such things (can happen) and there is no reason why we should be rejecting it.

Q: But are we also planning to put a space station kind of object in space?

A: At the moment such things are not on our horizons. But you know, some of the scientists are talking about the possibility of building a platform which can be used for generating power and then beaming it back to the earth and so on through a connection.

Q: But are these Indian scientists?

A: Yes, even foreign scientists have got some concepts on that. But there are a lot of technical breakthroughs one has to make to be successful. See, first of all the efficiency of the solar panels will have to improve to at least 50 per cent. Then, a proper system of transmitting this power from the space to the ground without it becoming a safety hazard. Such things have to be solved, only than can you include it in a proposal. But there are many things which were dreamt of 20 years back that have become reality today. So we cannot rule out the possibilities of the future.

Q: So you want to be there, prepared?

A: Naturally.

42 http://en.wikipedia.org/wiki/International_space_station

43 For instance, Space Island Group explored securing a long-term contract for a fixed rate over multiple decades and then use that to get a multi-billion dollar loan from the World Bank. Personal Conversation, Gene Myers, 2007. Solaren is attempting to get a similar long-term contract from PG&E. http://www.msnbc.msn.com/id/30198977/

44 Summary of discussions with MNC senior country representatives from Lockheed, Boeing at IDSA Future of Indian Industrial Base Conference, and outbrief from first US Solar Trade Mission in March.

45 IEP, p. xiv: The approach favored by the integrated energy policy committee seeks competitive markets wherever possible, pricing and resource allocations that are determined by market forces, transparent and targeted subsidies, improved efficiencies across the energy chain policies that reflect externalities of energy consumption, policies that rely on incentives and disincentives to regulate the marketing consumer behavior, policies that are implementable, and management reforms to create accountability in incentives for efficiency.

46 IEP, p. 16: "We must provide policies that create an enabling environment and provide incentives to decision-makers, consumers, private firms, Thomas public corporations and government departments, to behave in ways that result in socially and economically desirable outcomes."

47 http://www.indianexpress.com/news/pm-invites-more-fdi-in-energy/508855/

48 Energy Sector R&D Working Group, p. 111: "There are several funding mechanisms for technology initiatives that exist today. For example that Technology Development Board funds commercialisation of research but it focuses generally on short-term goals. Some years back, the "New Millennium Indian Technology Leadership Initiative" (NMITLI)

was announced which is a concerted approach involving the partnership of the government and private industry, technical labs, academic institutions, venture capital funds, etc., with reporters being chosen through competitive bids for different elements of the programmes. The Ministry should also adopt such successful models developed by other scientific ministries, especially the DST and CSIR, to support RDD, technology of absorption and technology transfer to facilitate R&D in renewable energy technologies. The Integrated Energy Policy has also recommended creation of national energy fund (NEF) for supporting research and energy technologies."

49 11th Plan, p. 15: "A major, new initiative for promoting competition and attracting private investment in the power sector launched in the last year of the Tenth Plan was the Ultra Mega Power Projects programme. Under this programme, the government would invite proposals on a competitive basis from the public and private sector to set up nine large power projects of 4000 MW [4GW] each. Three such projects have been successfully bid for and the remaining six are expected to be bid out in the first few years of the Eleventh Plan."

50 IEP, p. 92: "A premium on feed in tariff may not benefit a standalone plant in a remote area. For such plant a capital subsidy may be required. Such a capital subsidy, however can be linked to the amount of power actually generated if it is given in the form of tradable tax rebate certificates (TTRC). The rebate would then become payable when electricity is generated and would be linked to the amount of electricity generated."

51 NAPCC, p. 24: "Most of the energy-efficient equipment require higher upfront investment. And accelerated depreciation of up to 80 per cent in the first year on energy-efficient equipment would help in their deployment."

52 Energy Sector R&D Working Group, p. 112:: "It is proposed to provide the following additional incentives to Indian renewable energy industry i) 150 per cent accelerated depreciation to set up R&D centres in the country in renewable energy, which must be recognised as an R&D centre by the government; ii) soft loan at 2- 3 per cent annual interest rate to be repaid in 8-10 years for specified technologies, raw materials and components; iii) grant support (50 per cent) to seek international certificate for purpose of exports. iv) grant/loan to encourage industry to set up research facilities, pilot manufacturing facilities, to be identified by the Ministry from time to time. The above mentioned approach would help the Indian renewable energy industry in not only providing reliable and sustainable solutions for the growing energy needs of the country, but also help in attaining a leadership role in the world renewable energy market."

53 IEP, p. 5: "An even playing field permeates the marketplace wherein the central power sector PSUs get guaranteed post-tax returns of 14-16 per cent with full payment backed by the GOI."

54 11th Plan, p. 15: "An important innovation of the Electricity Act, 2003 is the statutory provision for open access which allows generating stations to enter the market and sell directly to high tension customers."

55 http://www.india-defence.com/reports/2262

56 USIBC has requested India to raise the cap from 26 per cent to 49 per cent, at http://www.bloombergutv.com/news/latest-business-news-us/27381/raise-fdi-cap-in-defence-sector—usibc.html and http://www.bloombergutv.com/news/latest-business-news-india/30221/lack-of-incentives-deter-fdi-in-defence-.html

57 http://en.wikipedia.org/wiki/Public_Sector_Undertaking

58 A list of Indian PSUs can be found here: http://india.gov.in/citizen/PSU.php and http://en.wikipedia.org/wiki/List_of_Public_Sector_Undertakings_in_India

59 Held, Spinning Off Army Activities Into Federal Government Corporations,

60 http://www.intelsat.com/about-us/history/

61 "Article VI: States Parties to the Treaty shall bear international responsibility for national

activities in outer space, including the Moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty. The activities of non-governmental entities in outer space, including the Moon and other celestial bodies, shall require authorisation and continuing supervision by the appropriate State Party to the Treaty. When activities are carried on in outer space, including the Moon and other celestial bodies, by an international organisation, responsibility for compliance with this Treaty shall be borne both by the international organisation and by the States Parties to the Treaty participating in such organisation." http://www.fas.org/nuke/control/ost/text/space1.htm (accessed October 3, 2009).

62 http://en.wikipedia.org/wiki/Intelsat

63 Katkin, Kenneth D. Communication Breakdown?: The Future of Global Connectivity After the Privatization of INTELSAT. Chase College of Law, Northern Kentucky University, The Berkeley Electronic Press (bepress), 2005, at http://law.bepress.com/expresso/eps/508

64 http://en.wikipedia.org/wiki/Intelsat

65 http://law.bepress.com/cgi/viewcontent.cgi?article=2561&context=expresso

66 Available as "Agreement Relating To The International Telecommunications Satellite Organization" from http://www.islandone.org/Treaties/BH585.html or http://en.wikisource.org/wiki/Agreement_relating_to_the_International_Telecommunications_Satellite_Organization a scanned original with signatures available here: http://www.eric.ed.gov/ERICWebPortal/contentdelivery/servlet/ERICServlet?accno=ED082508

67 COMSAT was a US Congress chartered, private corporation under government control.

68 Boczek, Boleslaw A., *International Law: A Dictionary*. Lanham, MD: The Scarecrow Press, Inc., 2005.

69 http://en.wikipedia.org/wiki/Intelsat

70 Societal Assessment – International Issues in U.S. Department of Energy. The Final Procedings of the Solar Power Satellite Program Review. Lincoln, Nebraska, 1980, pp. 133-134.http://www.nss.org/settlement/ssp/library/1981DOESPS-FinalProceedingsOfTheSolarPowerSatelliteProgramReview.pdf

71 Preble, Darel. President, Space Solar Power Institute. SSPI SUNSAT ACT http://www.sspi.gatech.edu/sunsat_act.html

72 See for instance, NSSO, "Space-Based Solar Power: An Opportunity for Strategic Security"; Xi et al, "Financial and Organizational Analysis for a Space Solar Power System" A Business Plan to Make Space Solar Power a Reality", Gopalaswami, "Solar Electric Powerplants in Space: Potential Bedrock for Sustaining India's High Economic Growth Track".

73 Not only in the general sense discussed above in the section on cooperation. According to the 2009 JTG, Specific Information Exchange Agreements (IEAs) already exist on Energy & Power and Aerospace Materials.

74 Xi et al, pp. 86-87: Note that *70 per cent of tonnage used in battle is fuel and 20 per cent of that fuel is used for electricity, and that based on Fully Burdened Cost of Fuel (FBCF), the US military spends $134M per Megawatt per year, and that the real cost of electricity to the military at the front lines is $23.9/kWh.*

75 Multiple interviews by the researcher suggest that on both the US and Indian side there is significant support at fairly high levels. The structure of the US side usually requires the championship of the actual researcher programme manager, which as of this time, a strong advocate remains unidentified.

76 The Unclassified February 2008 exhibit R-2, RDT&E budget item justification includes international space cooperative R&D, PE number 0603791F, with the following mission description and budget item justification: these funds will be used to implement space related international cooperative research, development, and acquisition (ICRD&A)

agreements with North Atlantic Treaty Organisation (NATO) member states and major non-NATO allies (Argentina, Australia, Egypt, Bahrain, Israel, Japan, Jordan, and Republic of Korea (South Korea), Kuwait, Morocco, New Zealand, Pakistan, Taiwan, Thailand, and the Philippines) and friendly foreign countries (Austria, Brazil, Bulgaria, Finland, India, Singapore, South Africa, Sweden, Switzerland, and Ukraine). The programme implements the provisions of Title 10 U.S. code, section 2350a NATO Cooperative research and development (R&D). The programme was established improve cooperation among NATO nations and later major non-NATO allies, and research development and acquisition. The legislation authorised funds to significantly improve United States (US) and Allied conventional defense capabilities by leveraging the best defense technologies, eliminating costly duplication of R&D efforts, accelerating the availability of different systems, and promoting US and allied interoperability or commonality.

77 http://www.greatachievements.org/?id=2990

78 Friedman, George, *The Next 100 years*, pp. 218-219.

79 http://en.wikipedia.org/wiki/Interstate_Highway_System

Appendix C

Various Figures on Costs

How much is the cost of SBSP development compared to other significant costs?

Budget / Expense	Cost in Billions USD	Reference
World GDP	69,620.00	CIA Factbook
Cost of Kyoto	40,000.00	Per Strickland / Preble Presentation to Lunar Roundtable
Investment required next 20 years to ensure adequate energy supplies (IEA)	26,000.00	http://www.worldenergyoutlook.org/docs/weo2008/WEO2008_es_english.pdf
Cost Global Warming 2 decades	20,000.00	Per Strickland / Preble Presentation to Lunar Roundtable
cost of continued reliance on coal, from today through 2030	15,900.00	http://www.greenpeace.org/usa/press-center/releases2/new-global-energy-strategy-tac Currently, the renewable energy market is worth $70 billion and doubling in size every three years
US GDP	14,260.00	CIA Factbook
World Energy Market	6,000.00	http://sufiy.blogspot.com/2009/05/lithium-and-rare-earth-elements-new.html
US Budget 2009	3,998.00	OMB
OPEC Oil & Gas Revenues 2030	2,000.00	http://www.worldenergyoutlook.org/docs/weo2008/WEO2008_es_english.pdf
Indian GDP	1,210.00	CIA Factbook
Total allocated both Wars	915.10	www.nationalpriorities.com/costofwar_home
US Stimulus Package	789.00	www.trt.net.tr/International/NewsDetail.aspx?HaberKodu=528b67d4-6b22-4a0c-bed6-118989977979
DOD (2009)	726.00	OMB
OPEC Oil & Gas Revenues 2008	700.00	http://www.worldenergyoutlook.org/docs/weo2008/WEO2008_es_english.pdf
War in Iraq	687.00	http://costofwar.com
Exxon Revenue 2008	550.00	http://blogs.moneycentral.msn.com/topstocks/archive/2008/04/28/get-ready-for-exxon-s-truly-gaudy-numbers.aspx
Global Revenue from Climate Related Businesses 2008	530.00	http://www.reuters.com/article/GCA-GreenBusiness/idUSTRE58H2FM20090918
Oil & Gas Exploration 2008	492.00	Oil & Gas Journal Sept 28, 2009, p.5

Boeing Backlog in 2008	384.00	http://seekingalpha.com/article/73644-the-boeing-company-q1-2008-earnings-call-transcript
Subsidies 20 largest non-OECD 2007	310.00	http://www.worldenergyoutlook.org/docs/weo2008/WEO2008_es_english.pdf
Gorgon LNG Projected Sales over a Decade to Asia	300.00	http://www.watoday.com.au/wa-news/australia-signs-biggest-ever-resource-deal-with-china-20090818-ep2g.html
Total Direct & Indirect Space Activity 2007	251.00	http://www.aia-aerospace.org/national_aerospace_day/strength/facts_at_a_glance/
War in Afghanistan	228.00	http://costofwar.com
Indian Budget 2008	204.20	http://indiabudget.nic.in/ub2009-10(I)/bag/bag4-2.htm
SBSP NRE (high)	**200.00**	Xi et all
Annual Cost to reduce GHG emissions to present levels by 2030	200.00	www.reuters.com/article/reutersEdge/idUSN1818479820080319
US Aerospace Sales in 2009	183.00	http://www.kiplinger.com/businessresource/forecast/archive/aerospace_s
Exxon Planned 5-yr exploration in 2009	150.00	http://www.msnbc.msn.com/id/29533364/
Annual Cost of Climate Change Global (High)	109.00	Grantham Institute
International Space Station (ISS)	100.00	http://en.wikipedia.org/wiki/ISS#Costs
Indian Arms Import Market for this decade	100.00	http://www.washingtonpost.com/wp-dyn/content/article/2009/09/25/A
Boeing Expected Revenue 2009	73.00	http://seekingalpha.com/article/73644-the-boeing-company-q1-2008-earni
Renewable Energy Market 2008	70.00	http://www.greenpeace.org/usa/press-center/releases2/new-global-energy-market is worth $70 billion and doubling in size every three years
Annual Cost Climate Change Developing Countries (High) UNFCCC	66.00	Grantham Institute
Gorgon LNG Deal (Australia & China in 2009)	50.00	http://www.watoday.com.au/wa-news/australia-signs-biggest-ever-resource
Exxon Profits 2008	45.22	http://business2press.com/2009/01/30/exxon-earns-45b-in-2008-highest-
Indo-US Bilateral Trade 08	44.43	http://fas.org/ssp/indiatrade.png
Exxon & Shell Exploration Budget	40.00	Per Strickland Presentation to Lunar Roundtable
US Sales Satellites and Related hardware 2009	40.00	http://www.kiplinger.com/businessresource/forecast/archive/aerospace_s
Global Investment in Renewables 05	39.00	Energy Sector R&D Working Group, **page 107**
The Gorges Dam (official)	37.23	www.alertnet.org/thenews/newsdesk/PEK84588.htm including resettlemer generating capacity will reach 22.5GW It has already generated 348.4 TWh, sol than a third of its project costs. By displacing 366 grams of coal for every 1kW consumption by 31 million tonnes and 1000 Million tonnes of GHG's per year

Exxon Cash 2008	31.00	http://www.msnbc.msn.com/id/29533364/
Sakhalin 5	30.00	www.atimes.com/atimes/Central_Asia/FB04Ag01.html
Amount next 5 yrs Indian military defense Upgrades	30.00	www.reuters.com/article/vcCandidateFeed1/idUSSP167929
Exxon Capital and New Exploration 2009	30.00	http://www.smartbrief.com/news/api/storyDetails.jsp?issueid=3D3C7305-283AF20AD0F7&copyid=5A306208-69B5-4CC2-AB93-C1F15F9C3BAA&ln
MOD 08 Budget GOI	28.30	http://indiabudget.nic.in/ub2009-10(I)/bag/bag4-2.htm
Annual Cost Climate Change Developing Countries (Low) UNFCCC	27.00	Grantham Institute
DOE 2009 Budget	25.90	OMB
Energy Spending 08 GOI	22.90	http://indiabudget.nic.in/ub2009-10(I)/bag/bag4-2.htm
Military Space Budget (US) in 2004	22.50	http://www.fas.org/sgp/crs/space/RL33601.pdf http://fpc.state.gov/docu
JAXA/Trade Ministry SBSP project	**21.00**	
India National Solar Plan	19.00	http://www.nature.com/news/2009/090804/full/news.2009.774.html
NASA (2009)	18.68	www.nasa.gov/pdf/344612main_Agency_Summary_Final_updates_5_6_09.
Direct Costs of Disasters in India 2005	17.50	IDSA Security Implications of Climate Change
Approx Cost 10GW SPS	**15.00**	Per Strickland Presentation to Lunar Roundtable
ITER (construction)	14.56	http://en.wikipedia.org/wiki/ITER#Funding
Boeing Cash in 2008	12.10	http://seekingalpha.com/article/73644-the-boeing-company-q1-2008-earnin
Sakhalin 1	12.00	www.atimes.com/atimes/Central_Asia/FB04Ag01.html
Ministry of Petroleum & Gas	11.50	http://indiabudget.nic.in/ub2009-10(I)/bag/bag4-2.htm
Cost of New Style Aircraft Carrier	11.00	http://yedda.com/questions/aircraft_carrier_cost_sea_sailing_35040610103
Ministry of Power	10.40	http://indiabudget.nic.in/ub2009-10(I)/bag/bag4-2.htm
SBSP Demo	**10.00**	http://www.nss.org/settlement/ssp/library/nsso.htm
Value 123 Deal to US	10.00	www.reuters.com/article/vcCandidateFeed1/idUSSP167929 of two sites of
MMRCA Fighter Contract	10.00	http://en.wikipedia.org/wiki/Indian_MRCA_competition
New Nuclear Reactor (1GW) AP1000	7.00	http://en.wikipedia.org/wiki/Economics_of_new_nuclear_power_plants
World Bank Clean Energy Fund	5.00	www.reuters.com/article/reutersEdge/idUSN1818479820080319
IPI Pipeline	5.00	www.thaindian.com_10068195.html
Large Hadron Collider (LHC)	4.40	http://en.wikipedia.org/wiki/LHC#Cost
Exxon R&D	3.50	http://manonthestreet64.blogspot.com/2008/05/exxon-mobile-reported-t
Cost of Nuclear Powered Submarine	2.50	www.rand.org/news/press.07/05.07.html

DAE 08 Budget	1.14	http://indiabudget.nic.in/ub2009-10(I)/bag/bag4-2.htm
S&T&E Spending 08 GOI	0.91	http://indiabudget.nic.in/ub2009-10(I)/bag/bag4-2.htm
Ministry of S&T	0.73	http://indiabudget.nic.in/ub2009-10(I)/bag/bag4-2.htm
ISRO 08 Budget	0.72	http://indiabudget.nic.in/ub2009-10(I)/bag/bag4-2.htm
DST 08 Budget	0.31	http://indiabudget.nic.in/ub2009-10(I)/bag/bag4-2.htm
MNRE 08 Budget	0.27	http://indiabudget.nic.in/ub2009-10(I)/bag/bag4-2.htm
DSIR 08 Budget	0.24	http://indiabudget.nic.in/ub2009-10(I)/bag/bag4-2.htm

Appendix D

Proposed Joint Statement

India - USA Joint Statement (PROPOSED SBSP Excerpt)

The following is the proposed text of Indo-US Joint statement to be issued after the delegation-level meeting between the Prime Minister, Dr. Manmohan Singh and the US President Mr. Barack Obama.

"Prime Minister Manmohan Singh and President Obama today declare their resolve to further transform the relationship between their countries and established a global partnership…..

Drawing on their mutual vision for the U.S.-India relationship, and our joint objectives as strong long-standing democracies, the two leaders agree on the following:

FOR ENERGY AND THE ENVIRONMENT, HIGH-TECHNOLOGY AND SPACE

To strengthen energy security and diversify energy sources that would have a positive impact on development and carbon mitigation, the two leaders resolve to undertake a 3-phase due-diligence effort to explore the feasibility of Space-Based Solar Power to solve the linked problems of energy security, development, and Climate Change, with the ultimate aim of putting in place a commercially viable system by 2025.

The programme will begin with three studies: a study to examine the feasibility of a global-scale (1 Terrawatt by 2065) Space Solar Power system-of-systems (including supporting infrastructure and transportation) to be completed in two years; a supporting technology roadmap to retire technical risk and achieve economic viability targets, to be completed in two years; and a study to arrive at a consensus on an ITER-scale mega-science multi-lateral demonstration / experiment within 5 years.

This programme will be addressed through [The Special Envoys for Climate Change / State/OES & PM's Committee on Climate Change / PSA/OSTP] with all help and assistance from the U.S-India Energy Dialogue, the Civil Space Joint Working Group (JWG), Joint Technical Group (JTG), the High Technology Cooperation Group (HTCG), as well as the U.S.-India Aviation Cooperation Program."

Appendix E

Summary of Kingdon's Theory of Agenda Setting and Policymaking

The theoretical construct being used by the researcher to understand the agenda setting and formulation of policy follows John W. Kingdon's classic text, *Agendas, Alternatives, and Public Policies*, which provides important insights into how subjects come to official government attention, how the alternatives are generated from which officials choose, how the government agenda is set, and helps us understand why "an idea's time" occurs when it does?

Kingdon's work builds on the earlier "Garbage Can Model" of Cohen, March, and Olsen who conceived of a chaotic system consisting a mix of problems with access to the organisation, a mix of solutions looking for problems, and a mix of participants including the demands and resources of decision-makers.

In Kingdon's conception, "The agenda…is the list of subjects or problems to which government officials, and people outside of government closely associated with those officials, are paying some attention at any given time."

According to Kingdon, agendas and alternative solutions are often influenced by "the three P's":Problems, Proposals and Politics, which operate as distinct streams according to their own logic, and having their own set of actors.

Actors working in the problem stream work on how to bring their conception of a problem to official attention and convince them to see it in their particular way, and monitor indicators, highlight focusing events, and provide or highlight other types of feedback indicate via comparison or classification a violation of values.

The politics stream is sensitive to context. The political stream is affected by election results, shift in public opinion, and other indicators of the national mood. Actors working in the politics stream work to maintain coalitions, trade provisions for support and bargain or compromise to build consensus. They work to perceive and highlight to decision makers the national mood, turnover in mandate, perceived agreement or movement on an issue. Often it takes a dramatic event, or crisis, to bring a problem to the attention of public officials. Another way to bring an issue or problem to the front of the political agenda is through the promotion of groundbreaking scientific discoveries.

The final element is the formation and refining of proposals. Participants in this stream are typically specialists who concern themselves with technical feasibility and optimisation of particular values, and continually refine pre-existing ideas to fit the context, and try to sell their ideas, but are not always sensitive to the political context. Proposals exist in a form of primordial soup where different elements are recycled and recombined and evolve. Often proposals have economic, scientific, or academic research, and must spend significant dormant time developing effective communications and respectable voices, and direct linkage to problems before coming onto the agenda.

"Any one of these processes can prompt or impede political action, promote an issue to a higher level of attention, inspire alternative solutions or knock it completely off the radar screen. Conversely, lack of public acceptance, powerful opposition, high costs or the perception that an issue is less pressing than others and competing issues may keep an item low on the public's agenda."

Each stream while obeying its own imperatives, works to help merge with the others, often with the help of a policy entrepreneur who actively attempts to link the streams. Kingdon, who introduces the concept of a Policy Entrepreneur, notes such an individual "could be in or out of government, in elected or appointed positions, in interest groups or research organisations. But their defining characteristic...is their willingness to invest their resources—time, energy, reputation, and sometimes money—in the hope of a future return (122). Such entrepreneurs can be found at any level, but they are particularly adept at reading windows and pushing their problems and proposals into prominence.

The entire system operates as an organised anarchy where there is "a collection of choices looking for problems, issues and feelings looking for decision situations in which they might be aired, solutions looking for issues to which they might be the answer, and decision makers looking for work." (85)

"Advocates hook solutions onto the problem of the moment, or push them at a time that seems propitious in the political stream." (172) Solutions come to be coupled with problems, proposals become linked with political exigencies, and alternatives get introduced when the agenda changes.

When all three streams merge, a policy window opens where action on a policy can occur by a decision-making body. Policy windows are opportunities for action when the issue is "really getting hot." Although there might be a problem stream that has identified / labelled some problem as important, and perhaps even coupled to a the policy stream where some proposal has emerged as "best" it still must happen in the window when the political stream has some mandate or need for action or delivery.

Michael Mintrom, in *Policy Entrepreneurs and School Choice* further elaborates on the role of Kingdon's the policy entrepreneur, who must be capable of "identifying problems in ways that both attract the attention of decision makers and indicate appropriate policy responses. Yet, the task of problem definition is made all the harder when individuals and groups in positions of power have previously taken care to establish and maintain a given policy image. The policy entrepreneur must define problems in ways that are not readily dismissed by those who benefit from current policy settings...Policy entrepreneurs must develop strategies for presenting their ideas in ways that will ensure they are taken seriously. This is why policy entrepreneurs spend large amounts of time networking in and around government. In doing so they learn the "worldviews" of various members of the policymaking community and make contacts that can help build their credibility. Making these contacts allow policy entrepreneurs to determine what arguments will persuade others to support their policy ideas...Frequently, policy entrepreneurs seek to assemble and maintain coalitions to support specific policy innovations...A coalition can allow a policy entrepreneur to rapidly spread the word on a particular policy innovation among a policy community....This general description...suggests that policy entrepreneurs may well play a significant part as agents for change. However, there are limits."

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Appendix F

List of Interviews and Interactive Sessions

- Mr. John Mankins, Managed Energy Technology, early March 2008
- Maj John Hanley, AF/A5XX Regional Affairs, March 12, 2008
- LTC Larry Smith, Defense and Army Attaché Sri Lanka and the Maldives, March 16, 2008
- Ambassadors Jim and Lauren Moriarty, March 16, 2008
- Nik Khanna, USIBC and Neil Chatterjee, Legislative Liaison, March 17, 2008
- Stan Mushaw, DARPA International Programs, July 10, 2008
- Raj Rajendran, Army Research Officer Program Manager, July 16, 2008
- Lt Col Andy Jouhal, Joint Staff Plans & Programs (J5) for South Asia, August 18, 2008
- Mr. Chris Clary, OSDP South Asia Policy Desk Officer, India, August 18, 2008
- Ms. Amy Irwin Secretary of Air Force International Affairs, Energy & Space, Mr. Jay Finch, Secretary of Air Force International Affairs, Space, August 19, 2008
- Ms. Melinda Tate, Mr. Jay Finch, Mr. John Lucacos, Ryan Romito, Secretary of Air Force International Affairs (SAF/IA), August 19, 2008
- Mr. Derek Litchfield, SAF/IA International Cooperation Research & Development Program Manager, August 19, 2008
- Col Steve Rust, OSD AT&L (IC), August 19, 2008
- Ms. Anne Smoot, DSCA, August 19, 2008
- Mr. Art Stern, Office of South Asia and Oceania, Department of Commerce, August 20, 2008
- Mr. Mike Beavin, Office of Space Commercialization, Department of Commerce, August 20, 2008

- Kim Wells, Aviation & Space, Department of Commerce, August 20, 2008
- Kit Rudd, Aviation & Space, Department of Commerce, August 20, 2008
- Mr. Gopal Bhushan, Counsellor (Defence Technology), Indian Embassy, August 21, 2008
- Dr. Mita Desai, DARPA Program Manager, August 21, 2008
- Garvey McIntosh, NASA International Relations, late November 2008
- Dr. Ron Sega, August 26, 2008
- Bob Ford, Senior Advisor, Department of State, August 28, 2008
- Ms. Julie Rottier, Department of State OES, August 28, 2008
- Mr. Nat Turner, Economic, Energy and Business Affairs Bureau Bilateral, US Department of State, August 21, 2008
- Mr. Stu Nozette, NASA, Mini-SAR Program Manager for Chandrayaan-1, August 21, 2008
- Dr. VK Saraswat, Chief Controller, DRDO Space & Missiles, September 14, 2008, March 3, 2009 (Aero India)
- Mr. Joe Rouge, Director, National Security Space Organisation (NSSO), September 14, 2008
- Dr. Subbarao Surampudi, NASA JPL, September 18, 2008
- Mr. Michael Cheatham, Indo-US Science and Technology Forum, November 25, 2008
- Mr. Deviprasad Karnik, Counsellor, Space, Indian Embassy, November 25, 2008
- Mark Ginsberg, DOE HQ EERE, November 26, 2008
- Dr. Satu Limaye, Director, East-West Center, December 16, 2008
- Col Tom Shearer, Chief, National Space Security Office (NSSO) Plans & Programs, late 2008
- Ms. Heather Broman, Science Officer, US Embassy, January 28, 2009

- Col Stewart Kowall, Air Attaché, late January 2009
- Cynthia Torres, Director, Coachella Valley USEAC, CS Energy Team, (Renewable Energy & Alternative Fuels Specialist), U.S. Dept. of Commerce/USFCS, March 31, 2009
- Mr. Eric Jones, Econ Section, US Embassy, June 9, 2009
- Mr. Lilienfeld, Claudio A, USTR, June 9, 2009
- Dr. G. Balachandran, IDSA, June 18, 2009
- Lt Col Michael Pettigrew, PACOM/J5, July 30, 2009
- Ms. Nira Desai, OSDP South Asia Policy Desk Officer, India, 18 Sept 2009
- US Embassy, New Delhi (Econ, Commerce, Science, Environment, DAO, ODC), Delhi January 30, 2009
- DRDO HQ International Cooperation, Delhi, Feb 20, 2009
- Indian Space Research Organization (ISRO) Satellite Center, Bangalore, March 3, 2009 (Including ISRO Director, Scientific Secretary, and ISAC Director, and ISRO Space Policy Analyst)
- Indo-US Science and Technology Forum (INDOUSTF) at the National Institute for Advanced Studies (NIAS), Bangalore, March 5, 2009 (Included two former Science Advisors to the Raksha Mantri)
- Asia International Company President and Sikkim Resident Commissioner, Delhi, March 11, 2009
- Ajay Singha, AMCHAM India office call, Delhi, March 18, 2009
- US-India Aviation Cooperation Program office call, Delhi, March 18, 2009
- One-on-one to head of India Energy Forum (IEF) office call, Delhi, March 18, 2009
- Vivek Lall, Boeing India, Delhi, March 18, 2009
- Dr. Kalam, former President of India, Delhi, March 23, 2009
- Electronics Corporation of India (ECIL), Hyderabad, April 4, 2009
- Hyderabad aerospace industry leaders and Defense Research and Development Organization (DRDO), Hyderabad, April 4, 2009

- Aeronautical Society of India (AeSI), Hyderabad, April 4, 2009
- Indian Institute of Technology Madras (IITm), Chennai, April 6, 2009
- Tata Institute for Fundamental Research (TIFR) April 8, 2009
- National Centre for Radio Astrophysics (NCRA) and Inter-University Center for Astronomy and Astrophysics (IUCAA), Pune, April 10, 2009
- Bhabha Atomic Research Center (BARC), Mumbai, April 9, 2009
- Maharashtra Institute of Technology (MIT), Pune, April 10, 2009
- Maharashtra Solar Power Manufacturers, Pune, April 10, 2009
- Centre for Airpower Studies (CAPS), Delhi, April 21, 2009
- Indian Institute of Technology Bombay (IITb) Materials Researcher Conference, Mumbai, May 9, 2009
- Ministry of New and Renewable Energy (MNRE) Solar Energy Center (SEC), Gurgaon, May 19, 2009. Attendees included Dr. P.C. Pant, Director, SEC, Dr. Rajesh Kumar, Principal Scientific Officer, Dr. Bibek Banyopadhyay, Advisor and Head, SEC.
- MoserBaer (largest thin-film PV manufacturer in India), Delhi, May 20, 2009
- PUGWASH Society at the Institute for Defence Studies and Analyses (IDSA), Delhi July 1, 2009
- Principal Scientific Advisor (PSA) to the Government of India, Delhi July 8, 2009 (with representation from Department of Science and Technology (DST),
- Department of Science and Industrial Research (DSIR), and Technology Information, Forecasting and Assessment Council (TIFAC)
- General Electric Jack Welch Centre Researcher's Momentum Conference, Bangalore, August 12, 2009
- Center for the Study of Science and Technology Policy (CSTEP), Bangalore, August 12, 2009
- Indian Institute of Technology Madras (IITm) Energy Forum, Chennai, September 22, 2009

Peter A. Garretson

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About the Author

Peter A. Garretson was a Council on Foreign Relations (CFR) International Fellow in India, and a Visiting Fellow at the Institute for Defence Studies and Analyses (IDSA) New Delhi. He is an active duty Air Force officer on sabbatical as an Air Force Fellow. He was previously the Chief of Future Science and Technology Exploration for Headquarters Air Force, Directorate of Strategic Plans and Programs, and is a former DARPA Service Chiefs' Intern, and former Los Alamos National Laboratory (LANL) Service Academy Research Associate. He is a published author on Space Grand Strategy, and is a recipient of the National Space Society's (NSS) Space Pioneer Award.

This paper provides a policymaker's overview of a highly scalable, revolutionary, renewable energy technology, Space-Based Solar Power (SBSP), and evaluates its utility within the context of the Indo-US strategic partnership. After providing an overview of the concept and its significance to the compelling problems of sustainable growth, economic development, energy security and climate change, it evaluates the utility of the concept in the context of respective Indian and US political context and energy-climate trajectories. The paper concludes that a bilateral initiative to develop Space-Based Solar Power is highly consistent with the objectives of the Indo-US strategic partnership, and ultimately recommends an actionable three-tiered programme to realize its potential.

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Institute for Defence Studies and Analyses
No.1, Development Enclave, Rao Tula Ram Marg,
Delhi Cantt., New Delhi - 110 010
Tel. (91-11) 2671-7983 Fax.(91-11) 2615 4191
E-mail: idsa@vsnl.com Website: http://www.idsa.in