July 20, 2009

Note to the readers:

This an academic research project performed by a group of four students of the Aerospace MBA (Toulouse Business School – France). The report presented here is the original one used for the academic project. The authors are still researching this subject, and this work is currently undergoing peer review by members of the SBSP community.

http://www.esc-toulouse.fr/en/p563_382/mba/aerospace-mba/welcome.html

Please note that the time available to work on this academic project was short. Although the process by which the work was done is deemed to be clear and correct, please consider carefully all assumptions made in the final calculation of financial and technological quantities which for the most part were based on those used by ESA (as mentioned in the paper).

The authors welcome all comments (critical and benign) on the work as presented. Feel free to contact us as indicated below:

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Financial and Organizational Analysis for a Space Solar Power System

A business plan to make Space Solar Power a reality

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A Multicultural Team Project
Submitted in partial fulfillment
For the degree of

Master of Business Administration
In Aerospace Management

At
Toulouse Business School
Toulouse, France

May/18/2009

Per Ardua Ad Astra

Through Struggle to the Stars

Abstract

One of the largest issues facing our civilization is the current world capacity for electricity generation. The expected demand for electricity worldwide is forecast to exceed the ability to deliver it. Furthermore many primary avenues of generation (coal & oil) take a heavy toll on the environment.

Space Solar Power is an old concept, but one which can offer many benefits. The main idea is to collect solar energy in space and transmit it wirelessly down to Earth where it can be sold on the energy market. This energy concept could be very beneficial, delivering significant amounts of energy with little to no environmental impact and at competitive prices.

Stakeholders for this project are identified and divided into different classifications. Consumer and Organizational interest to this concept is then gauged through the use of market and organizational surveys. Results from these surveys are used to proceed in the financial and strategic analyses.

Brainstorming was performed to identify niche applications of Space Solar Power technologies, which would be financially viable as well as assist in the research and development of the Classical Space Solar Power System. These applications are needed to generate interest and attract investors towards SSPS technology. Strategic analyses of the Classical and Niche applications were performed.

Financial analyses of the different systems provided us with economic feasibility of individual systems. The Classical system was found to be untenable and therefore could not support itself. This finding is in line with current research.

The Classical Space Solar Power organization was reworked to improve cash flows and include the production of niche applications. This new organizational structure greatly improved the financial viability of the Space Solar Power concept.

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Acknowledgements

Thanks are given to Dr. Okongwu and Dr. Morimoto who gave us guidance at the beginning of this project.

Further thanks are owed to those companies that supported our analysis and theories:

i.	EADS Astrium;	*Pierre Parrot*
ii.	European Space Agency;	*Leopold Summerer*
iii.	Ontario Power Generation;	*Howard Grant*
iv.	Space Energy Inc.;	*Peter Sage & Amaresh Kollipara*

Special thanks are given to Aude Vives and Danielle Reilles who provided immeasurable motivational and logistical support.

Thank you to all of our friends and colleagues who provided assistance during our survey period. Finally, last but not least, we greatly thank our families for their relentless support and understanding during the long hours and days dedicated to this project.

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1.0 Introduction and Business Concept

Introduced by Peter Glaser in 1968, Space Solar Power is an idea which promises clean, cheap, and limitless energy. At the same time Space Solar Power is a means for oil reliant countries to afford a measure of strategic security by freeing them of their need for foreign energy suppliers.

The concept is in theory very simple: collect energy in space through solar panels or mirrors where the Sun's energy is strongest, and redirect it to Earth through wireless energy transfer. The potential for energy collection is unlimited in terms of our consumption, and the effects on the environment are marginal at worst.

The idea originally received significant government attention due to its proximity to the 1973 oil crisis. As the price of oil fell back to pre crisis levels in 1974 however the attention on Space Solar Power waned. This has been the story of Space Solar Power, enjoying waning and waxing interest as the strategic needs of countries and the will of populations fluctuate.

At this time the world faces a financial crisis, a looming energy crisis, and perhaps above all an environmental crisis. In the face of so many problems it is easy to become paralyzed by choice; or fear.

Given the many problems faced by our modern civilization, and the promises made by the idea of Space Solar Power, it seems logical that the time to act is very much at hand. There are several companies around the world which, at this time, are already fully poised to go ahead with the Space Solar Power concept.

It is the intention of this project to add value to the concept of Space Solar Power in three ways.

In **Part 1** of this report we perform a strategic and financial analysis of Space Solar Power, as well as a market survey of consumers and potentially interested organizations. The purpose of this is to gauge the difficulty of the original concept while comparing it to current market trends and interest.

In **Part 2** of this report we perform strategic and financial analyses of several smaller scale niche applications for Space Solar Power technologies. The purpose of this is to determine the potential market for these applications, as well as to determine at what point they become financially viable.

In **Part 3** of this report we amalgamate the Classical and Niche applications. As a consequence of merging these ideas together we propose an organizational framework which can capitalize on both, and suggest ways in which to optimize the revenue stream.

Part 1: Introduction to Classical SSPS

2.0 Classical SSPS Strategic Analysis

The following section will analyze the SSPS concept from a strategic point of view. The purpose of this analysis will be to determine what constitute the primary impacts on this project. A brief discussion of these impacting items will follow, and how they could potentially help or hurt the final concept.

2.1 Space Solar Power System PEST

For the classical SSPS, we have decided to perform a PEST analysis to set the tone for the project as well as the environment in which it resides. The PEST analysis allows us to look at the proposed SSPS idea and brainstorm different conditions, good and bad, which affect the system.

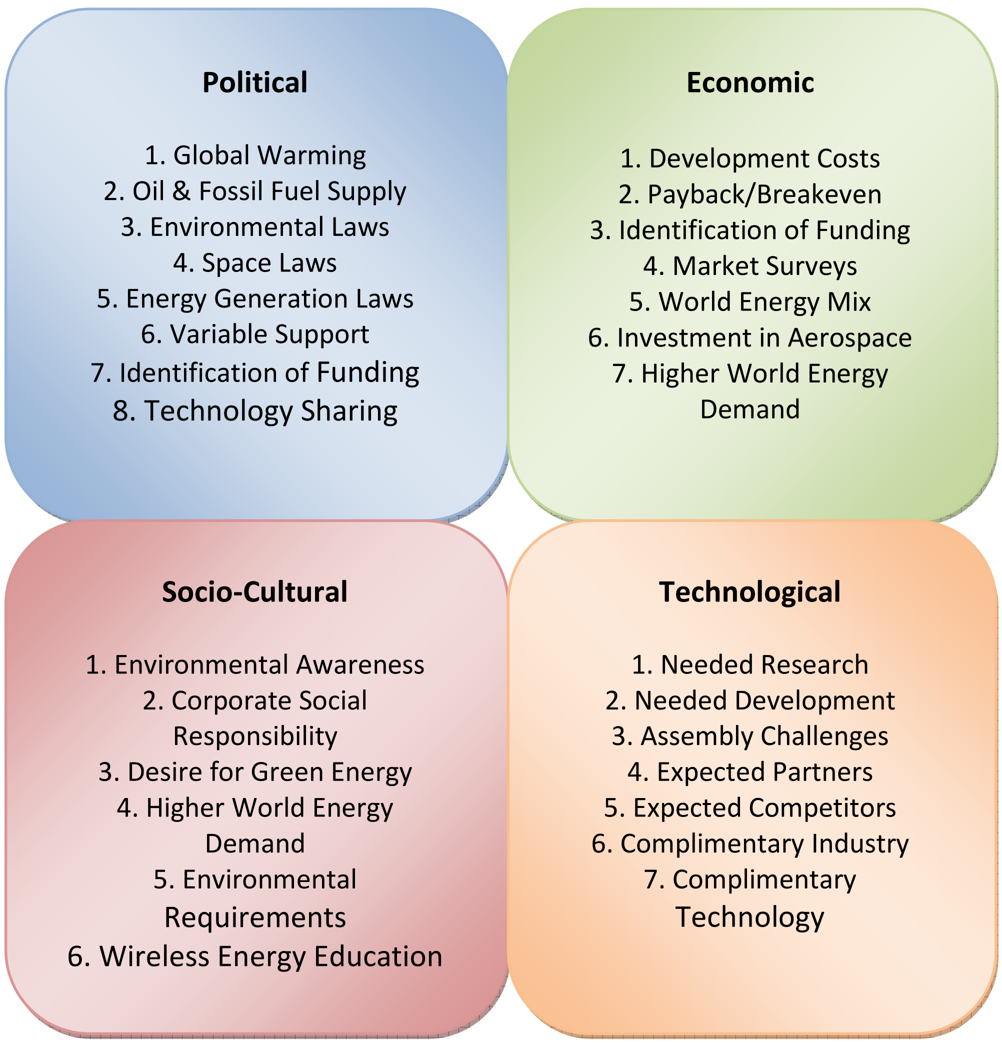


Figure 1 - PEST Analysis for Classical SSPS

The influences on the system are classified into four areas: Politics, Economics, Society, and Technology. Once the brainstorming is completed it is possible to prune the ideas down into a more concise format. The draft brainstorming template used for its execution can be found in Appendix A. The top level PEST analysis is presented above in Figure 1.

PEST Analysis Summary

The following sections summarize in limited details the top level items presented in Figure 1. Several of the ideas presented here are developed in much further detail in subsequent sections. It is important to note that some items reappear in more than one section of the PEST analysis, and are therefore explored separately from each vantage.

2.1.1 Political

Global warming

The idea of global warming and the need to take action has finally started to take a serious hold in the culture of world governments. A fundamental paradigm shift from previous decades, governing bodies the world over have started to pass laws and regulations in support of the growing green movement.

Examples of international agreements and initiatives include the IPCC[i], the Kyoto Protocols[ii], EU Emissions Trading Scheme[iii], EU Climate Change Program[iv], etc. Perhaps the most famous of such agreements, the Kyoto Protocol, can be seen to have faltered since only 63.7% of countries that signed it have actually ratified its contents into their own political system. Furthermore none of these countries have managed to meet the targets that were to have been met by 2005.[v]

Despite this difficult first step, many governments have indicated a strong redoubling of interest in the environment, and have begun to shape their domestic policies to suit. For example many national (and regional) governments have begun to offer incentives and frameworks which encourage citizens and businesses to work towards a greener future.

Examples of this are the growing wind energy industry in Germany & China[vi], as well as the ability for ordinary Canadian citizens to build their own renewable generation projects which can be fed into the normal consumer power grid.[vii]

The main idea here is that governments are finding themselves more and more inclined to work towards a green future, and that they are more willing to work towards mitigating climate change than ever before in the past.

Oil

World reliance on oil from children's toys to aircraft and motor vehicles is indisputable; however what many people perhaps do not realize is the extent to which fossil fuels, specifically oil and coal, are used to feed the global demand of electricity.

According to the International Energy Association (IEA) [viii], combustible fuels currently account for 64% of the electricity generation mix for OECD (Organization for Economic Cooperation and Development) countries as measured in 2007 and 2008[ix]. The heavy reliance on this form of energy indicates just how susceptible the world economy is to the fortunes of oil and coal, to say nothing of their environmental impact.

This can affect an SSPS system in different ways. Certainly it is conceivable that the current established industry of fossil fuel energy production will offer up different kinds of roadblocks, but also that many governments may still be reluctant to shift their generation mix to other things due to costs and concerns about strategic positioning despite the growing green movements.

One thing that needs to be considered is the long heralded arrival of "Peak Oil". Peak Oil is the point when the production of oil worldwide reaches its maximum and thereafter begins a slow decline. Since not all of the world's oil reserves have yet been identified, it remains unclear when Peak Oil may occur. Still, optimists and pessimists alike have placed it sometime between 2010 and 2030[x].

Considering the reliance of the world on oil, the eventual scarcity and then disappearance of this energy source will cause incredible worldwide problems if no replacement can be found. It is conceivable that there will be considerable strife and conflict over these remaining resources, and that it would certainly be in our best interest to find alternatives.

Environmental Laws

The use of a SSPS would suggest the creation of many new rules and regulatory bodies that will rise to govern its effects on the environment. Some specific areas of concern are the effects of microwave and laser beams on people, animals, flora, and the atmosphere.

In the case of microwave effects on people, there are already regulations in place that are applicable for terrestrial uses of the technology, specifically in terms of microwave ovens. Due to their commonality in people's homes, requirements for energy exposure had to be set and enforced to prevent any harm to the general population.

As an example, the Canadian Centre for Occupational Health and Safety has defined an exposure limit of 1 mW/cm^2 over a period of 6 minutes. Exposure of the general population to a microwave or laser based system would likely need to offer an energy exposure below this magnitude before even being considered for general use[xi].

It will also be important to consider environmental assessments that must be done before the construction of any project can be approved by local and national governments. The purpose of this assessment is to determine the net positive or negative environmental impact of the project, and therefore whether it can be approved or not. These processes are not necessarily complicated however they can be long in duration[xii].

Space Treaties

The SSPS will be subject to many different international legal frameworks that may not up until that point have had any common ground. Not only will a SSPS answer to regulations enforced by the UN Committee on the Peaceful Uses of Outer Space (COPUOUS)[xiii], but in the event of a geostationary SSPS it will also be subject to the oversight of the International Telecommunications Union (ITU)[xiv].

In either case significant consultation with these governing bodies will be required, and also with bodies that have yet to be defined. The governing United Nations space treaties under COPUOUS will be explored further in the chapters on organizations and legal treaties.

Energy Generation Regulations

The SSPS will be subject to energy generation requirements such as those faced by “normal” modern day generation systems. However since the SSPS covers a significant amount of unexplored territory, there may be some questions regarding how best to regulate it.

With the exception of rules faced by the space segment of the SSPS, it will be interesting to see how regulations on this subject evolve. Once the electricity is received and processed by a ground station, it is not expected that there will be any difference between the ways in which this electricity is shared throughout the power grid compared to other sources.

Furthermore the SSPS will be at the whims of an energy market which can swing between free market price and capped market prices depending on where and when the energy is being delivered. Although market projections suggest significant opportunities to supply energy, the whole SSPS system might be derailed by energy prices that are “too low”. [xv]

Variable Political Support

Political favour is a fickle beast whose attention sways, by necessity, between different groups and agendas. In many cases large capital intensive projects live or die by the support that they receive from their home governments. Furthermore many large aerospace projects and agencies are untenable without constant funding from government sources.

The SSPS can be framed as either a green or strategic (or both) objective. This means that politicians who support the green movement can find reason to support it, and politicians who support strategic initiatives can support it.

However with the green movement not far away from its infancy, and more pressing strategic issues often taking the spotlight, the likelihood of funding is not (and never has been) assured. An example of variable political support for a green project can be found in Canada's "ecoAuto" program which affected the price of automobiles based on their environmental impact. This initiative underwent mixed support and has since been cancelled[xvi].

Given the highly volatile nature of government spending, it may be critical to find other means of support for the SSPS. Such means will be investigated elsewhere in this document.

Technology Sharing

The SSPS will most likely require cooperation from different countries and corporations from around the world. As with any large aerospace project there will be limitations on who can work on what, and what can be sent where. Also of importance will be the division and sharing of new technologies that emerge through this project. Does everyone benefit from participation, or only a few key players?

Considering present day controlled goods initiatives and trade restrictions by the United States against certain countries, it is certain that moving forward on a large project like the SSPS will require dedicated and rigorous negotiations between partners to ensure it comes to fruition[xvii].

2.1.2 Economic

Development Costs and Payback Period

Although the technologies needed to build the SSPS are not new, and no "breakthrough" moments are required, it still carries with it a steep development cost and subsequently a distant breakeven point. Once it is operational the costs to maintain it will be significantly lower, if current satellite business models are any indication (long life, no aftermarket service).

Once the SSPS is built and operational, it theoretically produces massive amounts of energy and therefore revenue. Despite this amount of "free money" it is important to include the costs of development and construction which to date have proven to be obstacles[xviii]. These costs push any potential breakeven point into the distant conceivable future; although subsequent systems can rely on this ground work and will not need to share the bill.

Until this point however it remains to be seen how much exactly this system will cost and where this money will come from. The economic aspect is a critical limiting factor in this project.

Funding

With the exception of government funding as indicated in the Political section, there are different ways in which a SSPS project could receive money. Depending on how the SSPS project is structured, sources of income other than the government could include business partners, private investors, income from related activities, or even income related to the sale or transfer of technologies discovered during the development phase.

Although at first the question of funding may seem to be a very difficult obstacle, with a little creative thinking it could prove to be very beneficial.

Market Surveys

An important dimension to the SSPS project is the market into which it will be delivered. What is the current composition of the market, and how will it evolve in the future? Certainly it will need to be compared against direct competitors such as nuclear, coal, and oil generation; however it will be prudent to consider the end customer as well.

Does the source of electricity matter ultimately to the end customer, the everyday consumer? Or are the majority of people satisfied knowing that the light turns on when they hit the switch? Are the end consumers concerned with the effects of energy generation on the environment, and if so how much influence can they leverage over state and privatized energy generators?

World Energy Mix

According to the International Energy Agency, the burning of fossil fuel currently accounts for about 64% of world electricity production. Economically this is not a bad proposition, since the technology to do so is very old and the fuel sources are still fairly cheap and easily accessible. Conversely renewable energy sources make up only 2% of the world energy mix; partially due to questions of capacity and base load energy delivery[xix].

At first glance it might seem that such a small market for renewable energy is a hindrance. However the potential market for the SSPS is not limited to that of green energy, but instead the entire electricity market as a whole.

Although it can be argued as a green energy source, the SSPS in fact differs from current renewables since it is possible for it to become a base load system. As a result it becomes a direct competitor to standard generation sources such as nuclear and coal and therefore a credible contender for the future growing energy market[xx].

Investment in Aerospace

A correctly funded SSPS would have many knock on effects to the aerospace industry by supplying investment in and encouraging development of both new and existing technologies. Some areas which could receive direct benefits from such a project would be satellite integrators, OEM's, defence companies, robotics research, and launcher companies.

For instance as has been mentioned before, one of the limiting factors in the SSPS model is the cost of launching materials into orbit. It is argued that for the SSPS to be built there needs to be a significant reduction in the cost per kilogram. However on the other hand the only way to stimulate such a large drop in prices for launchers is to fund a project which will require launchers in bulk and therefore drive down the costs; a project like the SSPS. This conundrum has been likened to the story of the chicken and the egg.

Increasing World Energy Demand

The current level of electricity generation is nowhere near the amount of electricity expected to be demanded in the future. As the per capita consumption of energy in the developing world is expected to climb sharply, the current level of generation will not be able to cope. Add to this also the fact that much of the current electrical infrastructure is old and soon in need of replacement[xxi]. If the problem is not sufficiently handled, the cost of electricity could become astronomical.

If we consider the amount of new energy sources that need to be added to compensate for growing demand and ageing infrastructure, we can see that there is a significant market potential. We are also presented with an interesting opportunity to phase out old polluting and difficult to operate power stations with clean energy supplied by a SSPS.

2.1.3 Social

Environmental Awareness

The ideas of global warming and climate change have been around for a long time, and although awareness of this condition has been growing in the public eye steadily, it is not until recently that it has begun to have serious traction.

As the public becomes more aware of the impact of their actions, the actions of governments, and the actions of corporations, they begin to demand more responsibility from all parties. This is easily seen in the rise of environmental or “green” parties in global political systems such as in Canada and Germany.

Thanks to the media and certain outspoken celebrities[xxii,xxiii], the public has become more aware of their impact on the rest of the planet. If the SSPS can be shown to be an environmentally friendly power source, these developing consumer attitudes will become arguments in its favour.

Corporate Social Responsibility

Environmentally consumers are beginning to demand more from the providers of their food, their automobiles, and their governments. More and more people are choosing products from responsible corporations that are concerned for not just the environment but for the social conditions of the communities in which they live and work.

Companies should be dedicated to sustainable development and to the elimination of negative externalities on the environment and places where they operate. Organizations that adopt these strategies refer to them as “PPP” strategies which mean that they are concerned for People, the Planet, as well as Profits.

These emerging corporate and social attitudes could mean a fertile ground for the arrival of a SSPS system.

Higher World Energy Demand

The standard of living in developing countries is expected to grow at a very rapid pace in the coming decades. The consumption of energy is very much linked to the living standard of a population, and so as it starts to improve, the per capita consumption of energy per person will rise as well[xxiv].

Simply multiplying currently used energy generation sources by what will be needed in the future is not good enough. Considering the harm currently caused by these methods, multiplying their effects could prove to be catastrophic. The SSPS is therefore a way of moving forward to meet the growing energy needs of the planet without causing any more harm to the environment.

As an example, depending on the kind of technology used, a SSPS could at worst lose 11% of its energy to heat in the atmosphere during inclement weather[xxv]. For a sample system which provides 100KW of energy, this amounts to 11KW of thermal energy which is diffusely added to the biosphere.

By comparison, this SSPS system which operates (worst case) at 89% efficiency is bested only by a nuclear power station which can operate at 98% efficiency. Modern day coal fired plants produce electricity at only ~32% efficiency, meaning that 68% of the energy released during the combustion of fuel is lost to heat and other forms of energy which also end up in the biosphere.

Wireless Energy Education

When the idea of wireless energy transfer via microwaves or lasers is presented, the question that comes first is whether or not such a technology is safe. There is a perception, though not entirely unfounded, that there are many possible negative side effects of this proposition such as space to space weapons, space to Earth weapons, and also of cooking people and animals that get too close to the transmission zone.

What seems less obvious to many people is that wireless energy transfer is used all the time with significant regularity. Cell phones, wireless internet, and even radio are forms of wireless energy transfer. In fact if you consider the range of microwaves in the electromagnetic spectrum, each of these applications are already using microwave energy and have been determined to be very safe for human use[xxvi].

In essence then the natural fear that accompanies such a proposition will certainly prove to be a hindrance. Perhaps the best way to overcome this is with education. For instance if people are made more aware that the technologies that they use on a day to day basis are the same that would enable a wireless energy transfer, then familiarity and acceptance of the project will be much easier to accomplish.

2.1.4 Technological

Research

Having first been proposed in the 1960's and studied ever since, the idea of a SSPS is not uncommon. Furthermore the technologies and systems behind its use are extremely well understood, enough so that there really is no scientific limitation to its construction[xxvii].

This being said research stills need to be done on some of the finer points involved, such as power management, construction and assembly in space, and also the transmission of energy through the atmosphere.

Many studies have been done with respect to the effects of a SSPS on the Earth. They have concluded that if constructed correctly, there will be either no or marginal impacts to humans, animals, 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[xxviii].

Development

As with any large project, the development of the SSPS will be a long and expensive undertaking. Although the technology is understood, it will still take time to bring the idea from concept to reality.

One of the most important steps in this development phase would be the creation and operation of demonstration systems which help to show that the technology is working and worth further investment. Each of the SSPS proposals to date have all made allowances in their roadmaps for demonstration projects, whether on Earth, space to space, or even space to Earth[xxix,xxx].

Construction

The initial concept regarding space construction of the SSPS involved a very heavy, rigid structure that was constructed by hundreds of astronauts on orbit, with components lifted directly to GEO. Perhaps this idea seemed remotely feasible during the space race when the United States Government provided near limitless funding for space activities, however these days such a project is out of the question.

Since launch costs are still very much limiting factors when it comes to placing things in orbit, design and construction considerations are generally made around this point. Keeping this in mind, any future construction of a large project such as the SSPS will likely use lightweight flexible/inflatable structures, be built by robots only, and be lifted to LEO instead of GEO with some kind of low energy inter orbital assistance to place it in LEO thereafter.

Expected Partners

The aerospace industry is large in terms of turnover, but small in terms of community and the number of people that work in it. As a result there is often a lot of “cross pollination” between companies when large projects are in the works. If we can consider the European space industry as an example, there are many layers of companies who are at once cooperating on some levels and competing on others.

What this means is that no single industry or government will be able to pursue the SSPS concept on its own. It can be expected that there will be significant internal and cross industry cooperation for such a project including academic institutions, government agencies, and other aerospace companies. Furthermore it will be interesting to integrate power delivering companies such as EDF[xxxi] or OPA[xxxii] into this mix, since the SSPS is a project which will involve them as well.

Competitors

Considering that the SSPS would be a newcomer to the energy generation market, it may face serious hurdles from well established competitors. The level of this competition could vary depending on market forecasts. For instance if the projected market were bigger than any one competitor could fill, the amount of resistance would be much lower than if the market were very tight.

It will be very important for the SSPS operator to properly set itself apart from these competitors, whether it be in environmental impact, cost, or both.

Complements

The SSPS concept will cut across many different fields and industries. This will be a benefit, since it will allow for many synergistic relations with companies that would like to develop similar technologies as well as greatly ease the problem of technology transfer. Below is a non exhaustive list of different industries and technological fields which could benefit from the development of the SSPS.

Industries

a. Energy industry
b. Terrestrial solar
c. Communications
d. Launchers
e. Satellite integrators
f. Academics
g. Defence

Technologies

a. Photovoltaics
b. Communications
c. Power management
d. Material sciences
e. Robotics & automation

Figure 2 - Complementary Industries and Technologies

3.0 Stakeholder Analysis

Stakeholders are defined as those people and organizations which play a crucial role in the outcome of a given project. Although it is easy to understand that a large multinational corporation working on an international project would have to answer to stakeholders, so too does the small family owned business.

In essence a stakeholder is any single person or organization which holds a vital interest in the outcome of the project. These stakeholders can include customers, governments, media, competitors, or even employees[xxxiii]. Stakeholder interest could vary between passion, indifference, and animosity. Furthermore stakeholders can have different levels of influence as well, determining to what level their interest can shape the organization.

For the SSPS we determined that it was very important to determine who the stakeholders might be, as well as to determine their level of influence. For this we perform a stakeholder analysis which allows us to quantify and position those parties which have an influence on the SSPS. Due to the high level of cost and risk involved in this project, we can expect that many partners will be needed to help divide them into more manageable pieces.

It is important to perform this analysis with any kind of project since it will give the foresight to know who to include in the work, who to keep informed, and who to watch out for. The SSPS has many obstacles: it is necessarily an international project, it has a very large scope, it will be very expensive, and finally it has never been done before. All of these combined together make the SSPS very susceptible to problems and outright failure unless the project gets the right people, the proper financing and the adequate marketing, among other factors.

3.1 Stakeholder Analysis Methodology

To identify the stakeholders that would be involved in our project, we first needed to decide on the scope of the project. With this it would be possible to break the SSPS into several unique segments and from there identify which stakeholders would be involved at which point. It is important to clarify at this time that stakeholder analysis will first be done to identify groups of relevant entities. For example “Academia” might be considered a stakeholder group, and it should be understood that this group concerns universities or other educational establishments.

After a brainstorming period, we were able to identify six unique project segments which would come into play during the course of the SSPS lifecycle. These six segments have been defined as:

1. Research and Development
   The research and development phase consists of overall research into the technical aspects of the SSPS. This segment would also include the construction and utilization of small demonstration satellites to showcase the technical feasibility to scientists, governments, and eventual end users. A significant majority of the basic research has already been completed, although research into reducing launch costs and constructing large space structures should be performed.

2. Ground Construction
   An operational SSPS will of course require an operational ground segment. Regardless of the ultimate design choice, the ground segment will consist of environmental surveys and the physical construction of ground sites. Since the technologies needed to harness an SSPS are very well understood and pose no significant hazards to human health or the environment, the construction of a ground station will be very simple relative to others such as nuclear and coal fired generation stations.

3. Space Construction
   Orbital construction of such a system will involve many high level players such as governments, the ITU, and the United Nations, not to mention large aerospace firms. The construction segment would likely require a combination of astronauts and advanced robotics such as the Canadarm 2[xxxiv] or the Mobile Servicing System[xxxv] (MSS) currently attached the International Space Station.

4. Operations and Electrical Distribution
   The operation of the SSPS as well as the ultimate distribution of energy to the end consumers is crucial. This segment assumes that the SSPS will be operated through a ground segment as is standard for satellites, taking into account the necessity for on orbit servicing. Energy will be fed into the consumer power grid and distributed normally as per the domestic rules of the customer country.

5. The End User
   Consumers of electricity are the end users of the SSPS. Consumers often take electricity for granted and therefore are satisfied so long as their lights come on when the switches are thrown. It is however becoming very important for consumers to see that the energy they receive is coming from green sources or their effects being offset. This concept will be explored through market surveys.

6. Financial Sector
   No project can exist without some interaction with the financial sector. This segment includes all transfers of money, purchases of permits, assessments, insurances needed, etc. No special needs are foreseen in this segment with the exception of an acceptable ROI.

Once the six segments had been decided on, it was possible to move ahead and determine who would be a stakeholder in each. A second major brainstorming session was held to accomplish this task as well. The six segments are illustrated in Figure 3.

For each segment, our group recorded every conceivable entity which might have an interest in the SSPS from that point of view. For instance launch service companies would have little to no interest in what happens to the end consumers, since it is not within the scope of their business. It would be possible for stakeholders to be present in more than one segment, if not all.

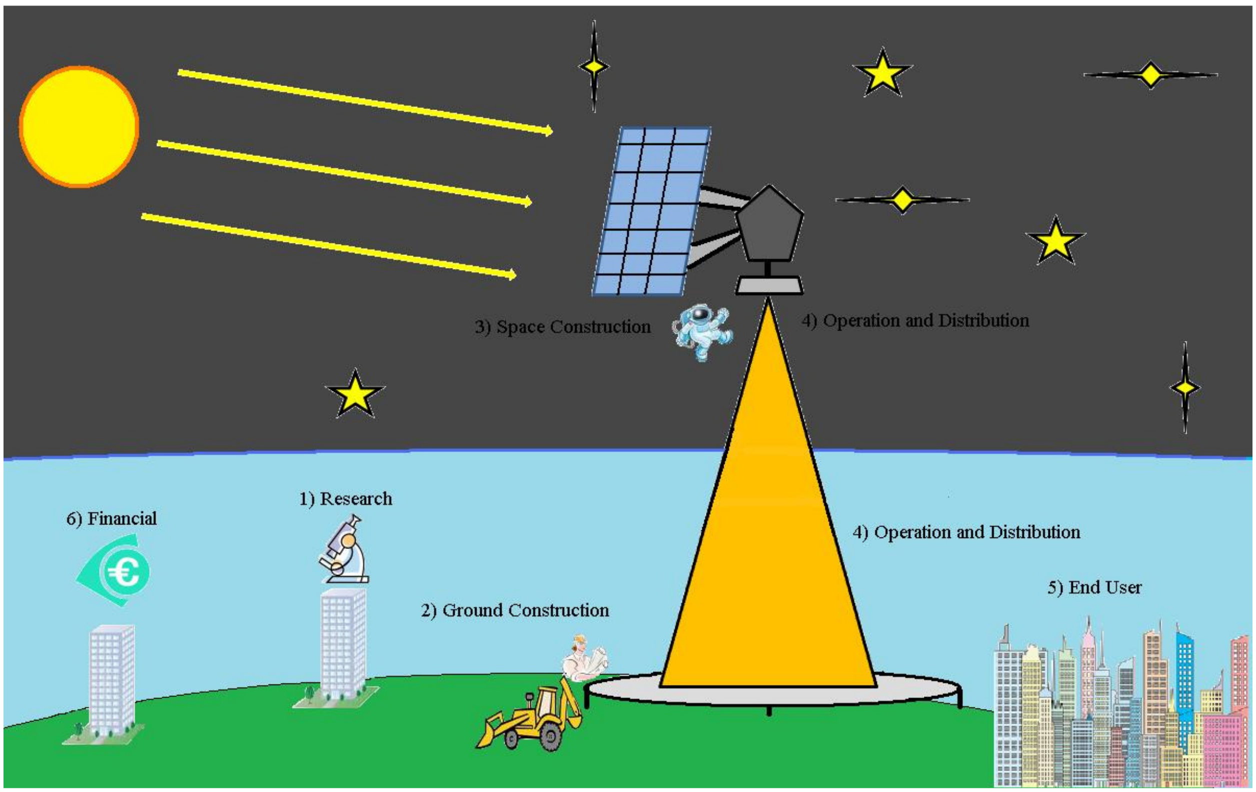


Figure 3 - The six SSPS segments

Each stakeholder group is judged and quantified against several different metrics. These metrics are used to rank them in terms of who is a key player, who is a merely to be kept informed, and who is a threat. The quantification and ranking system used here is adapted from the Toulouse Business School's Project Management course, taught by Dr. Uche Okongwu[xxxvi].

The seven metrics used to quantify stakeholders are defined below:

1. Stakeholder Type
    a. Regulatory – The stakeholder is primarily associated with the issuing of laws, regulations, frameworks, etc. Governing bodies such as the United Nations would fall into this category.

    b. Organizational – The stakeholder is part of any number of different frameworks such as corporations or unions.
    c. Community – Stakeholders which fall under this classification are organizations that do not fall under the aforementioned kinds. City populations and special interest groups might fall into this category.

2. Segment Type
   The segment numbers are the same as those defined above.

3. Commitment Level
   The level of commitment for the stakeholders is measured on a 6 point scale shifting from best to worst. This commitment varies from 1 (will make it happen) to 6 (will prevent it from happening).

4. Interest Level
   The interest level is measured in terms of magnitude from 1 to 4, where 1 is a high level of interest and 4 is total indifference.

5. Interest Type
   This indicates the sense in which a particular stakeholder views their involvement in the SSPS project and affects what they expect to get out of it, if anything.

    a. Technological – Focused on research and development.
    b. Environmental – Focused on environmental effects.
    c. Economic – Focused on economic factors (wages, ROI).
    d. Political – Focused on the politics or personal agendas.
    e. Normative – Concerned with regulations, laws, and enforcement.

6. Influence
   Relative to other stakeholders, the strength of influence of a particular entity is measured on a four point scale from 1 (strong) to 4 (none).

7. Relationship
   This defines which kind of relationship the stakeholder is viewed to have with the SSPS organization, divided into cooperative, neutral, and antagonistic.

Once all of the stakeholders within the segments have been identified, we will produce two tables for each segment which indicate for example who is a key player and who is not. These tables will compare the influence vs. relationship and commitment vs. interest, respectively. Examples of these tables are illustrated below in Figure 4 and 5 respectively.

For the purposes of our project, we identified key stakeholders as those who appear in the upper right quadrant of both graphs for a given segment.

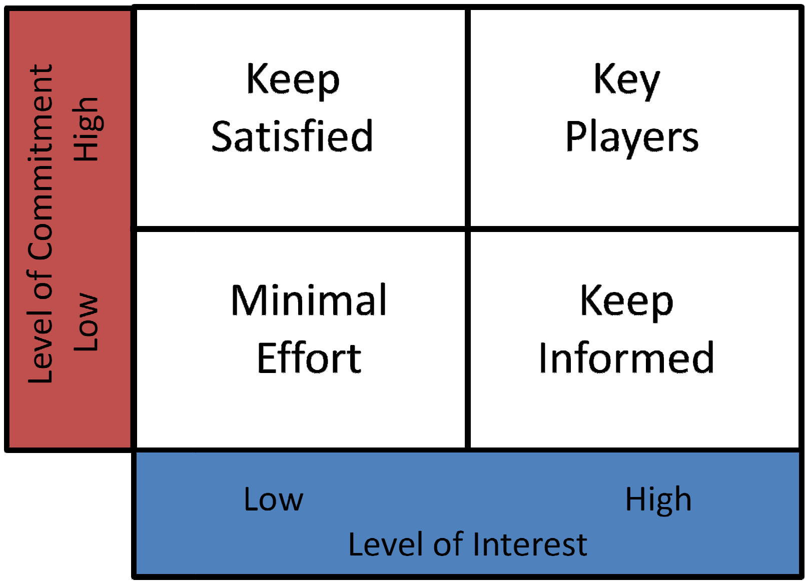


Figure 4 - Stakeholder Mapping; Commitment vs. Interest

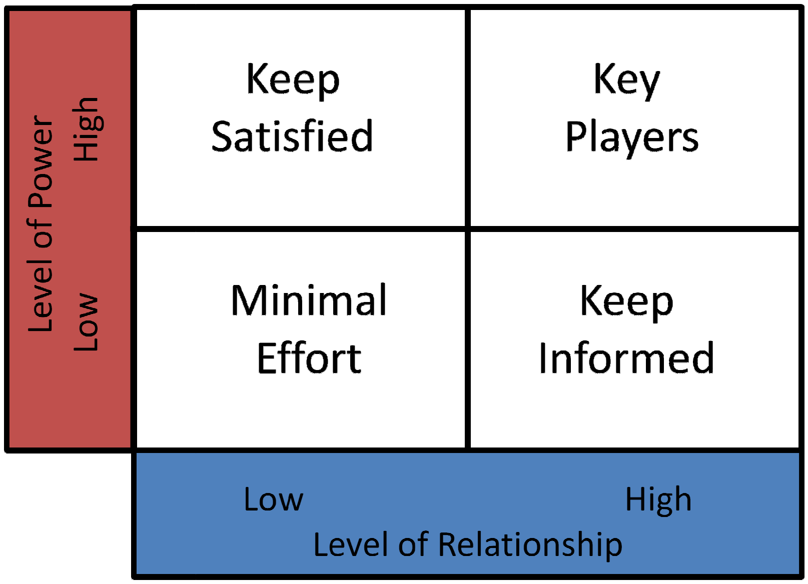


Figure 5 - Stakeholder Mapping; Influence vs. Relationship

The full spectrum of stakeholder analysis and results will be presented in Appendix B. For our purposes we will now list only those stakeholder groups who have been determined to be key to the success or failure of the SSPS project.

There are a total of 13 unique key stakeholder groups which have been identified within the six project segments. These groups are indicated below in Table 1. Identification of individual organizations within these groups was then performed to identify more precisely potential participants to the project. The list of potential individual stakeholders is provided in Appendix D.

Stakeholder Groups by Segment					
Segment 1	Segment 2	Segment 3	Segment 4	Segment 5	Segment 6
Defence Firms	Governments (local)	Governments (national)	Governments (local)	Power Utility	Defence firms
Launch Services	Governments (national)	Launch Services	Governments (national)	End Consumer	Governments (national)
National Defence	Renewable Energy Company	Satellite Services	Power Utility		Power Utility
Satellite Services	SSPS Generator	Space Agencies	Renewable Energy Company		
Space Agencies	Utility Company	United Nations	SSPS Generator		

Table 1 - Key Stakeholder Groups by Segment

3.2 Stakeholder Surveying

To get a better understanding of the shape of the industry as it pertains to the SSPS, it was clear that market surveys and interviews needed to be done. This would allow us to create a "state of the industry" picture concerning the technologies and opinions needed to advance the SSPS concept. The market surveys would be sent to the individual potential stakeholders as indicated in Appendix E with one exception.

All of the stakeholder groups with the exception of the End Consumer group can be broken down further into individual organizations. The End Consumer group however is an aggregate collection of people who use electricity; specifically the general population.

For this reason we have chosen to create and distribute two kinds of surveys, organization specific surveys and more general consumer surveys. Furthermore due to the international nature of the SSPS project, each survey is written in 5 languages: Chinese, Spanish, German, French, and English for a total of 10 unique surveys.

Each of the surveys were be uploaded onto the internet, and invitations to participate were distributed. The use of internet survey sites was crucial to ensure that all of the data was collected together consistently and in one place. This was intended ensure quick and accurate analysis after the survey period had concluded.

3.2.1 Consumer Surveys

The consumer surveys were designed to first gauge the participant's opinion of certain generic subjects regarding energy generation, and then in terms of the SSPS project. Public education on the question of wireless energy transfer is crucial to the success of the SSPS, since a lack thereof would put the general public at odds with the project and result in its imminent failure.

Since the issue of clean (green) energy is becoming central to many people's beliefs, we determined that the survey would be presented as a survey on green energy generation. Considering that the SSPS produces energy with no pollution or side effects, this was considered to be an accurate description.

The survey measures people's awareness of energy generation techniques, their inclination towards green energy, and even if they are willing to pay more for electricity that comes from green sources. After a small description of a space solar power system, the survey repeats some of the previous control questions but in terms of the SSPS specifically.

The consumer surveys were distributed through the personal networks of the team members, including faculty and staff of Toulouse Business School. Soft copies of the surveys can be found in Appendix E. Results of these consumer market surveys can be found in the Market Analysis section of this report.

The website used to administer the online surveys was: www.voycer.de

3.2.2 Organizational Surveys

The organizational surveys were sent to those entities which were identified as belonging to our key stakeholder groups. The purpose of this survey was to determine whether the organization in question was:

a) Aware of the concept of space solar power
b) Interested in addressing the concept of space solar power
c) If they were interested, under which framework would they operate

The survey suggested some discussion points at the conclusion, to indicate to the participant some of the points that we would like to discuss with them if they were interested in doing so. The reason for this is that answers to questions we needed to ask could not easily be obtained through simple survey questions and scales; they needed to be explored more fully through conversations. Appropriately the survey concludes with an invitation for further contact on the matter.

Invitations to participate in the organizational surveys were sent uniquely to each one of the entities that were identified within the key stakeholder groupings. Soft copies of the surveys can be found in Appendix E. Results of these organizational surveys can be found in the following section, Stakeholder Requirements.

The website used to administer the online surveys was: http://freeonlinesurveys.com/

4.0 Space Solar Power System Technologies

At its simplest a SSPS is a conduit for capturing otherwise unused energy from the sun and redirecting it to where it is more useful. The technologies needed to build this have been around for many decades, although having undergone significant improvements[xxxvii].

Advances in solar cell efficiency, robotics, and material sciences have for instance reduced the cost and weight of the originally proposed system to a fraction of its original value. Pursuant to this the cost of launching things into space has also decreased, although not to the same degree. Despite the improvements in all areas, launch costs still remain the most crucial factor behind the implementation of the SSPS.

This section will provide an overview of key technologies that could be used to build an SSPS, as well as a discussion on launcher options and costs. For this section we will define the following operational segments for the SSPS:

1) On Orbit Energy Collection
2) Satellite Energy Transmission
3) Terrestrial Energy Reception

4.1 Energy Collection

One of the main reasons why the SSPS is so advantageous is due to the amount of free energy available in space. Specifically this is in reference to the amount of solar energy, or solar flux, which may be referenced in terms of watts per square meter (W/m^2).

To compare the amount of solar energy in space relative to the absolute maximum solar energy available on the Earth, at the equator, and on a clear day is:

Solar flux available in geostationary orbit is: $1360W/m^2$
Solar flux available on the surface of Earth is: $600W/m^2$

It is important to note that the value of solar flux given here for the surface of the Earth is available only at midday. The amount fluctuates daily based on the time of day, weather, and also the season. The reason for this large difference between the two maximum values is due to energy being lost in the atmosphere.

This is best illustrated in Figure 6, which clearly indicates the amount of flux available based on location and time of day.

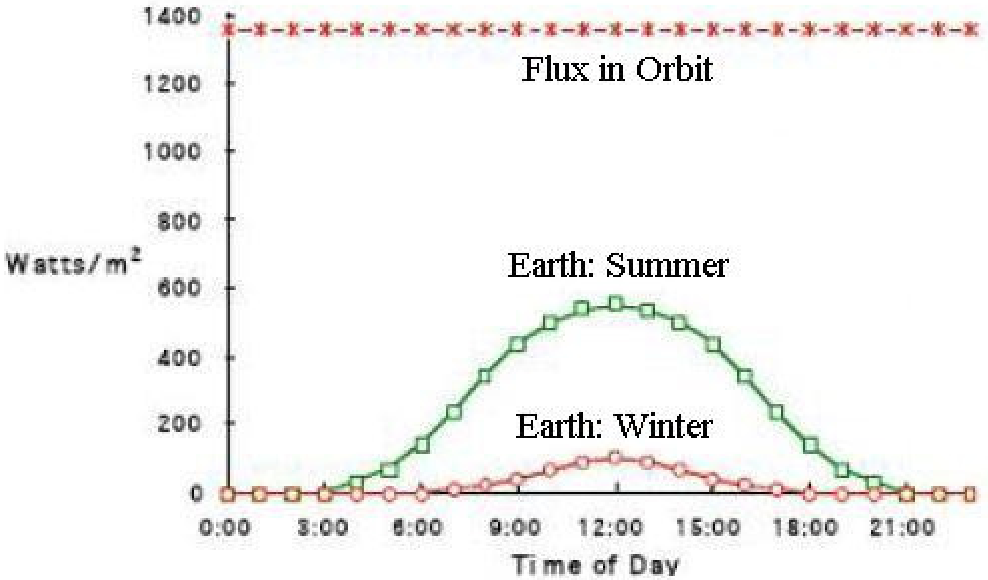


Figure 6 - The differences between solar flux in different locations[xxxviii]

There are three main ways in which this energy may be collected. They will be summarized below.

4.1.1 Space Mirror

A very simple method of collecting solar energy and directing it back to Earth is with a giant mirror. This mirror could redirect and focus additional solar flux from orbit down to a specific area of the Earth.[xxxix]

The advantages to such an arrangement are its simplicity and lack of energy conversion losses that are present in other kinds of systems. For instance in the case of a solar panel collection system there would be losses on conversion from solar flux into electricity, and then again during conversion from electricity to transmitted energy.

A space mirror would be able to direct sunlight back to Earth at all hours. In terms of electricity generation the space mirror's only use would be to augment the collection rate of solar panels during the day, and provide a limited measure of energy during the night.

There are drawbacks however since this form of energy transfer is completely susceptible to weather effects, energy losses due to solar panel collection on ground, and could potentially have negative effects on the environment. If it is a very large system it could for instance affect the lifecycles of animals or change weather patterns.

In terms of energy generation it will be more valuable to provide electricity in a more useful and controllable form than simply redirecting raw solar energy to Earth.

4.1.2 Space Mirror and Black Body / Solar Panels

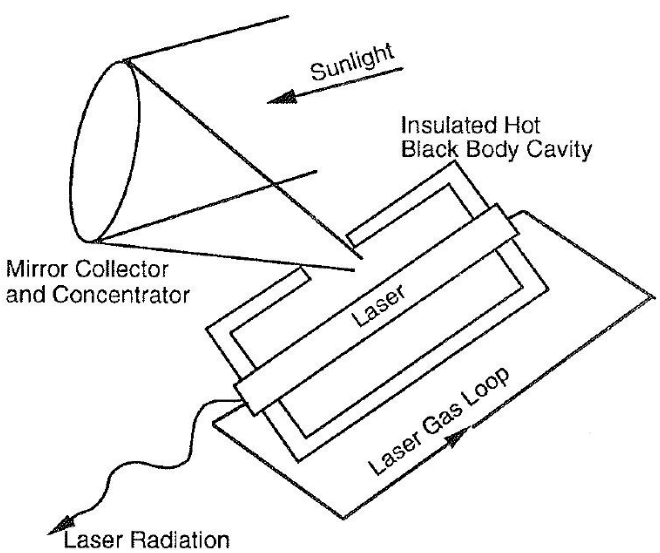
In combination with other technologies the space mirror becomes more effective. One of the problems with the pure space mirror application is the difficulty with which its energy can be harnessed.

One way in which to overcome this is by using the space mirror to focus energy into a blackbody, which is defined as a theoretical object which absorbs all radiation that falls on it[xl]. In practice there is no such perfect object, however reasonable artificial blackbodies can be made.

The energy collected in the blackbody can then be converted into electricity and fed into a transmission system. This methodology would ensure a high level of efficiency in terms of energy capture and subsequent transmission; although due to heat rejection there would be a need for significant cooling of the system[xli].

Although the space mirror and black body combination could work for any transmission system, it is ideally suited to use with those based on lasers[xlii].

Alternatively a space mirror arrangement could be used to focus a large amount of the sun's energy onto a smaller area. Specifically this energy would be concentrated into an array of solar panels, effectively acting as a solar concentrator. Since solar panels are generally limited only by the amount of energy focused on them, this could increase the collection potential and reduce overall system mass – depending on the mass of the mirrors.



Indirect Solar Pumped Laser. [Walbridge, 1980]

Figure 7 - An example of a blackbody & laser system[xliii]

4.1.3 Solar Panels

Perhaps the most obvious method to collect this energy is through the use of solar panels. This method of power generation is already in use on satellites, and so is therefore space proven; no special considerations need to be made for its use. Solar panels in space work the same as those on Earth by converting the solar flux directly into electricity; the main difference being the magnitude of solar flux.

The most important characteristics of solar panels used for space applications are its energy per mass and cost per energy ratios. For the majority of current space applications, energy to mass ratios of about 70W/Kg are not uncommon[xliv]. The efficiency of the solar panel is also very important since it not only determines the amount of energy that a given panel can provide, but it directly determines the amount of energy which will be lost in terms of heat.

Some different examples of available solar panels are listed below[xlv,xlvi]:

	GaInP2/ GaAs /Ge	Silicon	ISS Array	Boeing 702 Satellite	Entech SLA	Neuchatel Univ.
w/kg	70	100	30	80	378	4300
					*250	*2000

Notes:

a. "Entech SLA" refers to a company named Entech which has developed a lightweight solar panel called the "Stretched Lens Array". This offers a higher W/Kg over most of the other presented items.
b. The University of Neuchatel in Switzerland has developed a revolutionary new form of solar cell which can obtain up to 4300w/Kg. This technology will clearly have a significant impact on both the terrestrial and space solar panel industry as it matures.
c. Both the Entech and Neuchatel technologies were referenced without any accounting for necessary structure or power management mass. For this reason we have assumed lower values to account for this lack of information.

Despite the higher efficiencies promised by the Entech and Neuchatel technologies, there is still room for improvement. The main factor affecting efficiency for transforming captured sunlight into electricity is heat rejection; energy loss in the form of heat radiated back to space. Regarding this subject it would be interesting to perform more technical research on how to leverage thermoelectric conversion effects for the benefit of the SSPS[xlvii].

4.2 Transmission

There are two leading theories on how to transfer energy from space to power grids located on the Earth: lasers and microwaves. Each of these methods has their advantages and disadvantages which will be explored briefly in this section[xlviii]. Both of these methods make use of different parts of the electromagnetic spectrum as illustrated below.

Shared equally between both theories is the danger of causing environmental damage and loss of life to both people and animals. These transmission systems could easily fall within the scope of space weapons and would therefore be outlawed in accordance with the laws outlined by the United Nations and ratified by space faring nations[xlix].

In each case however the system can be designed with safety in mind such that the energy received on ground is unable to harm the environment or the animals. This would be true in case something accidentally wanders into the path of the beam, or the beam accidentally drifts away from the receiver.

The effects of laser and microwave energy will be explained in Section 5 of this report.

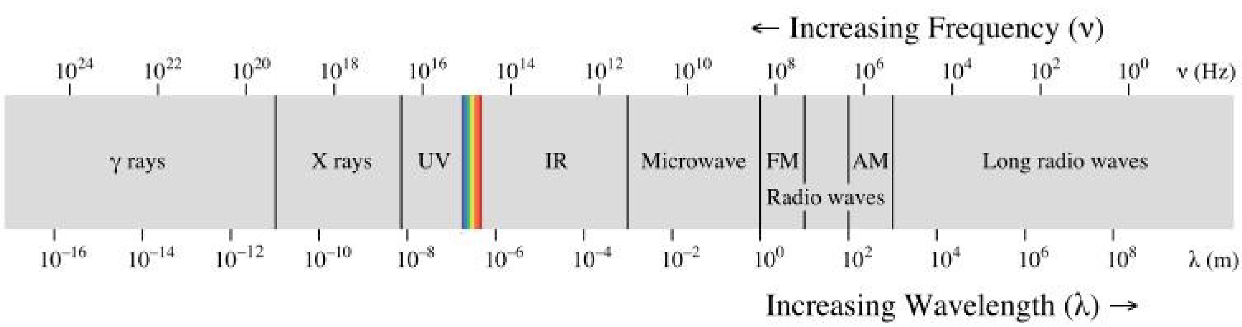


Figure 8 - The Electromagnetic Spectrum[l]

4.2.1 Laser Transmission Systems

Although often associated with visible light, lasers can in fact be produced from any level of energy in the spectrum. Theoretically transmitting energy in laser form would be the most effective due to its accuracy, small required receiver area, and coherence of energy. Although there are many different kinds of laser technologies that can be used, the main candidates are electric discharge lasers, solar pumped lasers, and free electron lasers[li].

One of the biggest hurdles facing laser transmission systems is the inefficiency of the laser during transmission. Most laser concepts considered for use in space have efficiencies approaching 20%; this means that for every 100W of energy fed into the laser, 20W are transmitted and 80W are turned into heat which must be managed by the satellite. Such low efficiencies have direct ramifications in terms of mass allocations for extra collection and heat management equipment.

For the main laser technology candidates, the next big hurdle is the atmosphere. Although it is expected that there will be little effect on the laser as it passes through the upper atmosphere, as it reaches the ground however it is possible that all of the energy is absorbed (blocked) by clouds and other weather. This makes the reliability of the system very low and therefore undesirable. A solution to this obstacle would be to place the receiving site for the laser at high altitudes where there is little interference from weather.

Finally laser systems are disadvantaged when it comes to receiving energy on the ground. There are several different ways in which this can be done, however they will be outlined further on in this section.

4.2.2 Microwave Transmission System

Microwaves are situated on the electromagnetic spectrum with frequencies ranging from 0.3 to 300 GHz. Microwaves suffer from certain disadvantages when compared to lasers. Specifically since the energy transmitted by a microwave is very diffuse, the receiving area must be very large when compared to the transmitter. Furthermore microwaves tend to lose a portion of their energy to side beams which come out of the antenna. Side beams, also called lobes, can be mitigated to a certain extent through the shape of the antenna[lii].

The use of microwaves to transmit energy from space down to Earth is an attractive option due to its interaction with the atmosphere. Although for the most part microwaves receive significant interference from water and oxygen, there are certain frequency windows in which these interactions are minimized.

What we can see from these frequency windows is that there is a minimum of atmospheric signal attenuation in the range of 2.45-5.8GHz, and also 35-38GHz. Specifically we might expect losses of 2-6%, and 8-11% respectively for these two microwave signal ranges. At all points in between there is a sharp rise in signal losses due to the presence of water and oxygen. This means that any signals being transmitted at those frequencies would be considerably susceptible to the effects of weather, if not outright blocked.

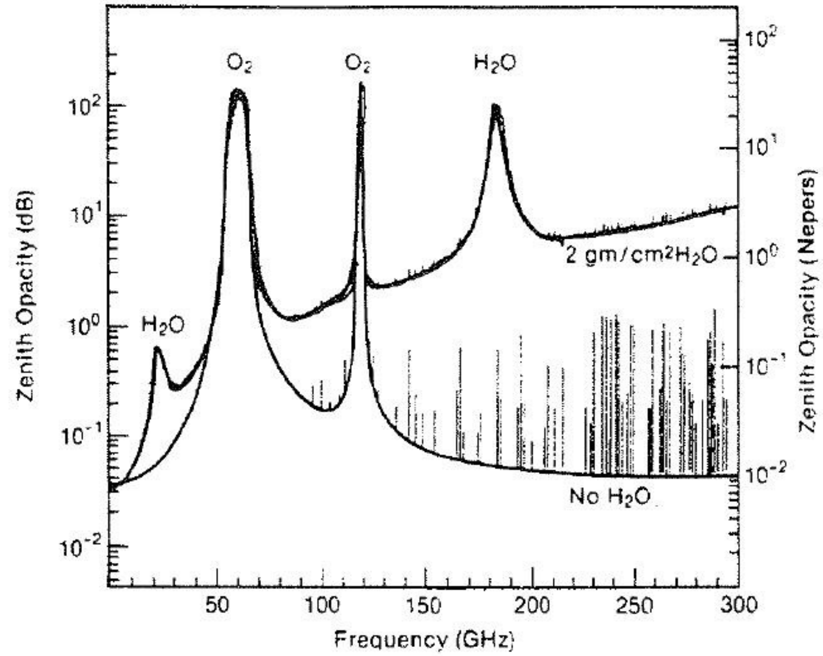


Figure 9 - Microwave signal attenuation based on frequency[liii]

Depending on various factors such as the amount of energy required and the size of the rectifying antenna, each of the two ideal transmission windows provides different benefits. Although the lower window will be able to convey energy with fewer losses, the higher frequency window could convey the same amount of energy into a smaller receiving site.

4.3 Reception

Based on the type of transmission system chosen there are different kinds of energy receiving stations that can be used. This section will briefly discuss the options available for both laser and microwave transmission reception.

4.3.1 Laser Reception

As mentioned in the previous section, one of the many problems with current day laser technology is the efficiency of its reception on ground. Different methods of laser reception have been proposed which would necessarily affect the overall kind of system used. These methods are normal solar panels and thermodynamic concentrators.

Since a laser is simply a form of light, the most straightforward way to collect it would be through the use of solar panels. In many places around the world large solar farms are being setup to offset pollution created by other means of electricity generation, and so it is conceivable that these pre-constructed solar farms could be used as reception sites for an orbital collection system[liv].

In a case like this the SSPS would in fact be using its transmission to augment the energy already being collected by the farm through normal exposure to solar energy. Energy transmitted to a terrestrial solar farm in this way would also be able to produce energy during the night, since although it is night on the ground the sun is always shining in space. This would therefore decrease the downtime of terrestrial solar power plants as well as reduce the overall system cost for a SSPS since no additional ground support stations would need to be built.

Similar to the standard solar panel concept is that of a thermodynamic concentrator. The primary difference between these two is that the concentrating array focuses incoming energy to a working fluid, where it is then used to run a turbine to generate electricity[lv]. The efficiency of such a system is could be as high as 98%[lvi], which is significantly higher than the expected 20% conversion rate of the solar panel. Since turbines are a very common technology being used in almost all modern day energy plants, there would be no significant hurdles in its implementation.

An interesting example of a solar concentrator is the solar tower, which uses air as its working fluid and natural convection as its means of energy transfer to drive turbines. A solid example of this technology is being produced by the Australian company EnviroMission[lvii].

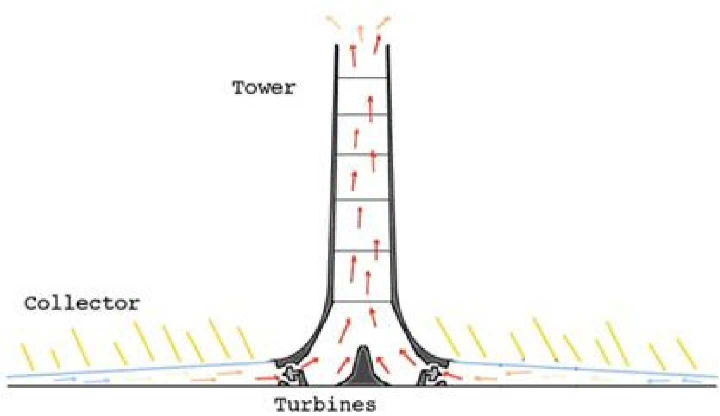


Figure 10 - Example operation of a concentrating solar tower

The above laser receiving technologies are not without drawbacks unfortunately. Both solar panels and thermodynamic concentrators suffer from waste heat either due to an inability to convert the energy or from necessary cooling. As a result each will incur severe heat rejection as a measure of operation, and could potentially have a moderate impact on the environment in which they are built.

4.3.2 Microwave Reception

In the event that a microwave transmission system is used, the only way of receiving the energy is through the use of a rectifying antenna, also known as a rectenna. The process of rectification is one in which a wave is converted back into direct current. A simple example of wave rectification is given below. The efficiency of such a conversion is significantly higher than that of solar flux on a solar panel, and if designed correctly can theoretically reach just under 100%[lviii].

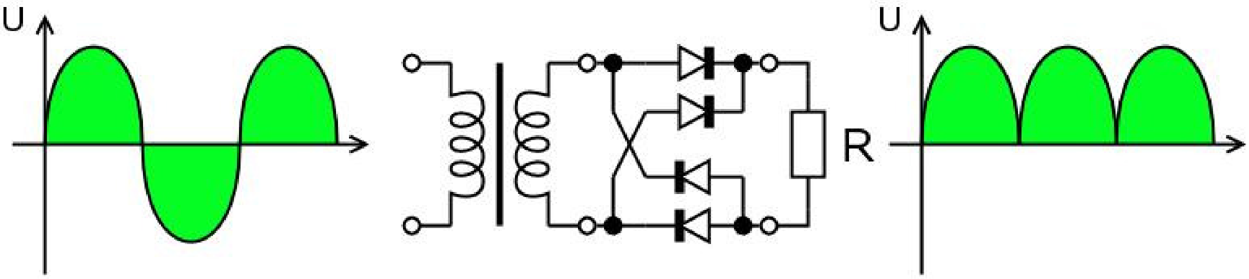


Figure 11 - An example of a waveform being rectified into a positive electrical signal through a Gratz bridge[lix]

Given the very high efficiency of a rectenna, there would need to be little consideration for losses at the receiving site or else for the same level of heat rejection experienced by the laser reception transmission options. Losses between the transmitter and receiver would therefore be limited to atmospheric attenuation which as stated before would range between 2% and 11% of the total energy transmission, dependent on the frequency of the transmission and only marginally on the weather.

Since transmitting energy via microwave results in a very diffuse energy profile, the primary drawback of the microwave option is the size of the rectenna required to receive the energy. Specifically the antenna to rectenna relation can be given by the following equation:

$$D_r = (2.44 \bullet H \bullet \lambda) / D_t \qquad (1)$$

Where:
D_r = the diameter of the rectifying antenna (m)
D_t = the size of the transmitting antenna (m)
H = the distance between the two antennas (m)
λ = the wavelength of the transmitted energy (m)

Also the relation between λ and Hz is given by:

$$f = c / \lambda \qquad (2)$$

Where:
f = the measured frequency in (Hz)
λ = the wavelength of the transmitted energy (m)
c = the speed of light at $3E10^8$ m/s

From this relation we can understand that the larger the size of the transmitting antenna, the smaller the necessary rectifying antenna. Furthermore since there is an inverse relation between frequency and wavelength we can see that the higher the transmission frequency, the smaller the necessary rectifying antenna size.

A common example using equation (1) with a frequency of 2.45GHz and a transmitting antenna of 1km in diameter leads to a needed rectifying area with a diameter of 10.5km.

A further consideration for the diffuse energy transmitted via microwave is its areal energy density. Unlike a laser which has a very consistent energy density over a small space, the rectifier needs to be large to accommodate the low energy density of the microwave. Since this energy is well understood but not uniform. Over a 10km^2 receiving site, the microwave energy profile would look like that shown below in Figure 12 [lx].

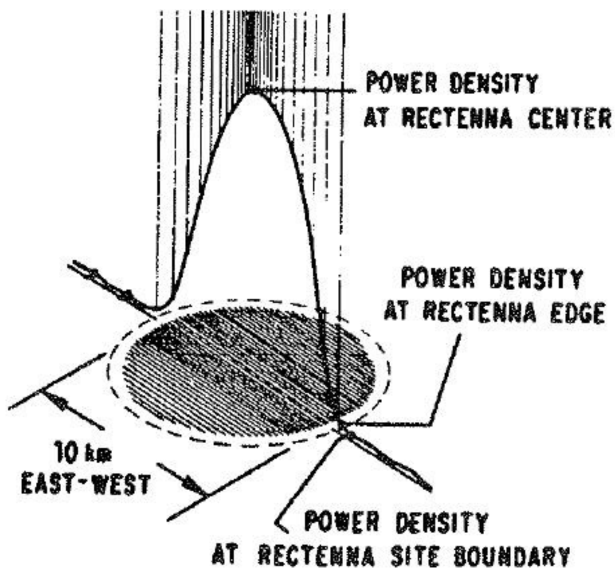


Figure 12 - Example microwave power density at rectenna

The energy profile as shown in Figure 12 can be normalized and graphed based on bore sight energy density and rectenna size, where "bore sight" is defined as the central axis of the energy beam. This is of course the point of maximum energy density.

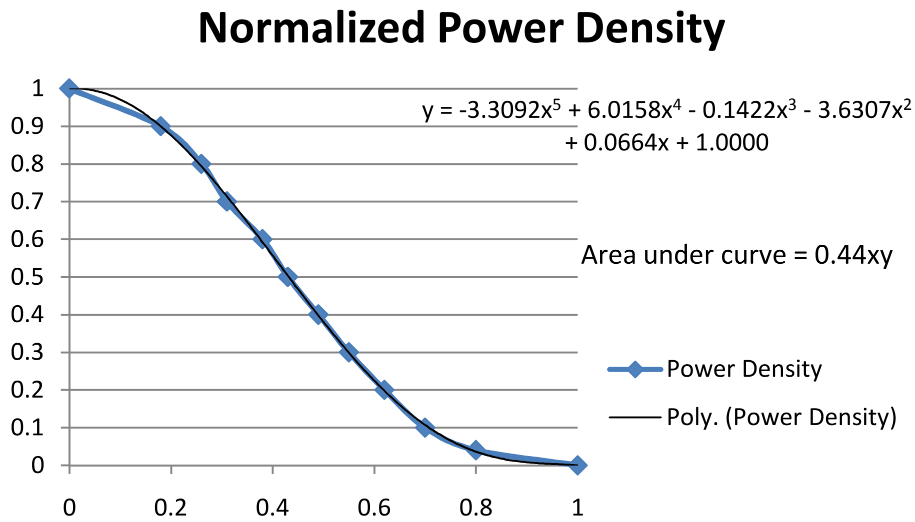


Figure 13 - Normalized power density curve for a microwave receiving site

The normalized energy density from bore sight to the rectenna limit can be defined by the equation defined in Figure 13. Note that the equation is only valid on the range of x between 0.0 and 1.0; where x = 0.0 refers to bore sight and x = 1.0 refers to the edge of the rectifier. The value of y = 1.0 corresponds to the peak energy in the centre of the rectenna.

The energy profile illustrated here can help SSPS designers determine the energy density of the microwave beam. This information is a critical factor which will determine whether the proposed microwave system is safe relative to defined human and environmental exposure limits[lxi].

4.4 Energy Collection, Transmission, and Reception Conclusions

The following conclusions can be made regarding the available technologies for developing a SSPS. Although not accounted for in our calculations, thermoelectrics can be a way to increase the overall system efficiency

Collection
For all SSPS modelling efforts during the course of this report we shall assume a mature version of this Swiss solar panel technology is available with at least the minimum w/Kg ratio as indicated in the Collection section.

Transmission
Since the laser options are not ready for space to Earth power transmission at this time, all SSPS modelling will be done using data for microwave antennas.

Reception
Although all of the options for energy reception are reasonable, the current unsuitability of the laser transmission option limits us to the use of microwave antennas, and therefore rectennas.

4.5 Launchers

Due to the necessarily large quantity of mass which must be put into orbit, launch costs have always been considered to be the most critical element in the financial analysis of a SSPS. At their current levels launch costs are in fact restrictive, and prevent the SSPS idea from moving forward.

The question of launch cost however presents an interesting problem. As is the case with any other economy of scale, the cost of production of an item decreases as the demand and therefore the production of said item increases. This is very much the situation faced by the space industry.

In its current form there are only a handful of space launches every year; the United States for example can account for about only15 per year. This is a far cry from the number of launches which may be required to build a fully functioning SSPS, which has sometimes been estimated to be in excess of 120[lxii].

The conundrum therefore is that for launch costs to decrease significantly in the near future, there needs to be a much greater demand today. On the other hand in order to create such demand today we need to begin constructing a full scale SSPS which can only begin once launch costs have decreased.

This chicken and egg scenario has been referenced many times and is a source of frustration[lxiii]. This is not to say that the SSPS is impossible by today's launch costs, but that it would be very difficult to fund and operate without making a financial loss.

Many current launch systems have been considered, and only a select few will be presented below. It should be noted that the original cost data for the Ariane 5 and the Soyuz launch vehicles are approximately 15 years old. However since the present day price of the Ariane 5 has been confirmed as identical to the older data, the cost of the Soyuz is assumed to have kept up with inflation as well.

Table 2 - Cost comparison for selected launch vehicles

	Launch to LEO			Launch to GEO		
Launcher	Launch Cost (USD)	Mass (Kg)	USD/ Kg	Cost (MillUSD)	Mass (Kg)	USD/ Kg
Ariane 5	$ 100,000,000.00	20000	$ 5,000.00	$ 100,000,000.00	10000	$ 10,000.00
Falcon 1	$ 7,900,000.00	420	$ 18,809.52	Note 1	420	*
Falcon 1e	$ 9,100,000.00	1010	$ 9,009.90	Note 1	1010	*
Falcon 9	$ 36,800,000.00	9900	$ 3,717.17	$ 36,800,000.00	4640	$ 7,931.03
Falcon 9H	$ 94,500,000.00	29610	$ 3,191.49	$ 94,500,000.00	11500	$ 8,217.39
Soyuz	$ 30,000,000.00	6855	$ 4,376.37	*	*	*

Note 1: In these cases the customer is required to supply their own GEO kick motor as part of their mission payload.

From this table of select launcher data we can see that the Falcon 9H from Space X provides the best cost to orbit of all the selected launchers. Although Space X is currently a newcomer to the launcher arena the time by the time significant investment in a SSPS is made, the launch technology will be sufficiently mature to be as reliable as the Ariane 5.

In the future it is conceivable that the Indian GSLV or Chinese Long March 5 booster families may be selected, especially if other systems are unable to keep up with the necessary tempo of launch and deployment. It is interesting to consider that both the Chinese and Indian space industries growing quickly and are in need of new “business”. Considering their use for the SSPS project would them faster development and a chance to catch up with the traditional space powers. SSPS may be very interesting subject from their perspective.

For all SSPS modelling efforts during the course of this report we shall assume a mature and reliable version of the Falcon 9H with listed payload capacity.

5.0 Environmental, Health and Safety Impacts

5.1 Introduction

Considered as a potential clean and sustainable power supply option, the great advantage of SSPS, is that, once in place and operating, its contribution to greenhouse gases in the atmosphere is zero. But the consumer survey, showed that most consumers care more about health, safety and environment issues when thinking about using electricity produced by SSPS. So Environmental, health, and safety issues have been recognized as essential concerns to be addressed as early as possible in a program to develop SSPS technology, with particular emphasis on public awareness and public perception. These results can be seen in Figure 14.

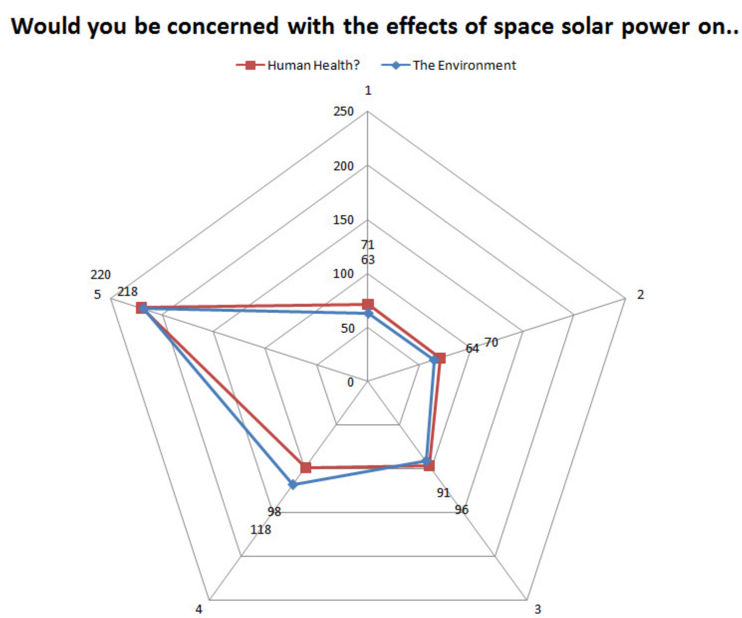


Figure 14 - Result of consumers survey concern with the effects of SSPS

Environmental factors include any significant effects on the space surrounding the satellite in orbit, on the media through which power is transmitted, and on the neighbourhood of the receiving station. These effects generally include contamination of the environment in the form of communications interference, generation of debris in orbit, or possible effects on the atmosphere (i.e., power transmission to Earth receiving sites). [lxiv]

Health and safety factors include any health hazards to Earth biota associated with power beaming, whether in the form of microwave, and if this kind of microwave beams associate with SSPS could be used as weapons. [lxv]

The effects of power beaming are primarily a function of the frequency and the energy density of the beam. SSPS would utilize a 2.45 or 5.8 GHz microwave signal to provide power to the ground. In a typical SSPS system, the beam transmitting the energy from space would be approximately 2 to 4 kilometres wide. The strength of the beam is highest in the center and rapidly decreases to very low levels at the periphery of the beam. The peak power density at the center of the beam at it intersects the rectenna is on the order of 300 watts per square meter (W/m2) or 30 milliwatts per square centimeter (mW/cm2). The center of the beam's Gaussian distribution is planned for energy densities of about 23 mW/cm2 [lxvi]. Additionally, any residual energy outside the rectenna's protective fence would be far below current microwave safety standards, between 0.01 and 1 mW/cm2 [lxvii].

Based on this power density, we will discuss the effects of SSPS and MPT in the following sections.

5.2 Environmental Factors

5.2.1 Impact on atmosphere and climate

As the beam passes through the atmosphere from geostationary orbit, a loss of no more than 2% of total beam power is predicted. In abnormal circumstances, such as scintillations in the ionosphere or rain cells in the troposphere, the power loss may temporarily be greater.[lxviii]

The effects of powerful microwaves on the 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.[lxix]

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 the Earth is only 1/7000 of the amount of the solar energy reaching the Earth. Therefore, SSPS will not worsen global warming problems. Since rectenna 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.[lxx]

SSPS doesn't affect the atmospheric chemistry, the ozone layer, and more generally on the climate.

5.2.2 Orbital Effects

Concerns are very real about the effect of the orbital debris environment on large space structures in LEO. The problem is not just the present orbital debris population, but the worsening evolution of this debris population, increased perhaps by SSPS operations. The orbital debris pollution in both LEO and GEO will remain and worsen. Research is currently under way to model the orbital debris environment more accurately and predict its increase in time. In addition, testing of hypervelocity impacts on spacecraft materials is ongoing. Also, methods of collision avoidance are being developed to aid spacecraft in avoiding collision with mid- to large sized debris that can be tracked.[lxxi]

Present usage in GEO is to move satellites above GEO by several hundred km following end of life. Most parts of SSPS, however, should be used multiple times in further SSPS generations. If technically feasible, as much mass as possible should be brought back to the Earth.

SSPS may cause space debris, but not huge. On the contrary space debris may damage the SSPS

5.3 Health and Safety Factors

The impact on public health is one of the major aspects of SSPS development because public concerns about radio wave exposure of SSPS.

As we know, the only demonstrated biological effect of microwave exposure, which is, to date, heating. To put 30 mW/cm2 in perspective, the energy generated inside a typical kitchen microwave oven is approximately 1000 mW/cm2. This means the power density at the center of an SSPS beam is only 3% as strong as a typical countertop microwave oven. So such peak power densities envisioned for SSPS could never even come close to 'cooking' birds or aircraft in-flight. [lxxii]

Other studies have shown that at 25 mW/cm2, some birds exhibit behaviours suggesting they might be able to detect microwave radiation. If true, some migratory birds, flying above the rectenna, might suffer disruption of their flying paths. At higher ambient temperatures, larger birds, having greater body mass and thus absorbing a relatively greater amount of microwave radiation, could tend to experience more heat stress than smaller ones. No doubt birds would learn to avoid areas of the sky associated with transient local heating. Research has been done on bees and birds exposed to microwave radiation at twice the dose expected for a creature flying through a typical microwave power transmission beam. Results to date indicate that there is no effect, at least on the animal's directional flying ability.[lxxiii]

Other testing has been performed on monkeys and is now under way with humans exposed to low-level microwave radiation. Results to date from this testing indicate that such exposure apparently does not render the subject sterile or result in cataracts or any other deleterious effects.[lxxiv] [9]

No evidence has been found that continuous power densities from 1 to 50 mW/cm2 (at 2.45 GHz) have any biological effects on honey bees. This subject may seem irrelevant, but since bees are the main pollinators in nature, any impact on these insects may have catastrophic outcomes for agriculture.

We have to discuss the microwave (over GHz) effect on human health imposed by the SPSS system. The corresponding limits for IEEE standards for maximum permissible human exposure to microwave radiation, at 2.45 or 5.8 GHz, are 8.16 or 10 mW/cm2 averaged over six min, and

1.63 or 3.87 mW/cm2 averaged over 30 min, respectively, for controlled and uncontrolled environments. The specific absorption rate (SAR) threshold for the most sensitive effect considered potentially harmful to humans, regardless of the nature of the interaction mechanism, is used as the basis of the standard. The SAR is only related to a heating problem, which is regarded as the only microwave effect on human health. [lxxv]

The SSPS power density of the microwave beam is within the safe level at the perimeter of the rectenna site, but at the center of the rectenna site, which is above the safe level. This area should be strictly controlled. During normal operations microwave intensity in the area above the rectenna (and perhaps even around the rectenna in some circumstances) exceeds the human exposure standards, access would need to be carefully controlled to ensure environmental safety and health standards are maintained.

Except for maintenance personnel, human exposure would normally not be permitted in these areas. However, in the case of occupationally required presence, the only protective measures required to reduce exposures to permissible levels are simple personal protective equipment such as glasses, gloves and reflective garments.

Microwave beams associated with SSPS operations could never be used as weapons. Microwave weapons, if they are ever developed, will use very high-power pulses at short ranges. Their design is quite different from that projected for SSPS.

5.4 Other Health and Safety Issues

Although once in operation the SSPS system essentially generates power with zero pollution, the pollution produced during the construction and deployment of an SSP system (i.e., multiple space launches) must be within acceptable levels.

The SSPS microwave downlink will need to be monitored continuously to ensure tightly tuned phased-array techniques and that the beam control are functioning properly (perhaps by utilizing a ‘pilot signal’ from Earth). Should a loss of beam focusing control occur, beam defocusing techniques would be required to automatically disperse the power from the beam, resulting in a widely dispersed beam of very low intensity.

The anticipated power densities at the center of the beam does exceed US Federal Aviation Administration (FAA) RF exposure standards for aircraft even though the passengers would not be affected. This area should therefore be placed ‘off limits’ to air traffic control.

Finally the SSPS may interfere with communications and radio astronomy.

5.5 Health and Safety Conclusion

Base on our present knowledge, the SSPS is safe and has more positive effects in environment and health of human, animals and plants.

6.0 Classical SSPS Market Analysis

6.1 Future World Energy Demand

There are three major parameters that have to be considered in connection with the energy system for the 21st century.

(1) The twentieth century was undergoing an extraordinary population growth. During this time, world population increased from 1.65 billion to 6 billion and experienced the highest rate of population growth averaging 2.04 per cent per year.[lxxvi] The world population growth rate has fallen to around 1.3 per cent today. Nonetheless, world population will continue to increase during the twenty-first century. As seen in Figure 15, the United Nations projected in their medium fertility scenario that world population will stabilize at nearly 10 billion persons after 2200.

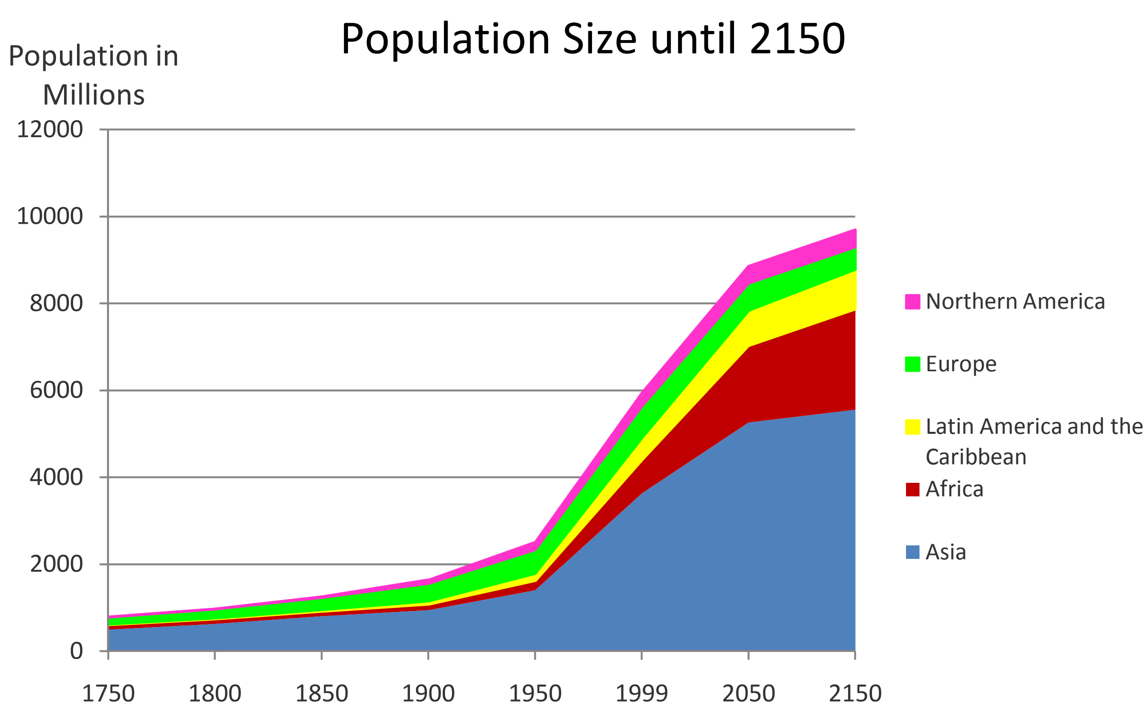


Figure 15 - Evolution of Population Size until 2150[lxxvii]

According to past experience and all current projections, the global energy demand will continue to rise in close connection with the increasing world population. Energy is the basis for of the industrial civilization. Approximately 1.6 billion people do not have access to electricity.[lxxviii] As seen in Fig xx in 2006, total worldwide primary energy consumption was 491.5 Exajoule and it increased by 34% in the last 16 years.[lxxix] From 1990 to 2006, energy consumption increased by 117% in China and 77% in India.[lxxx]

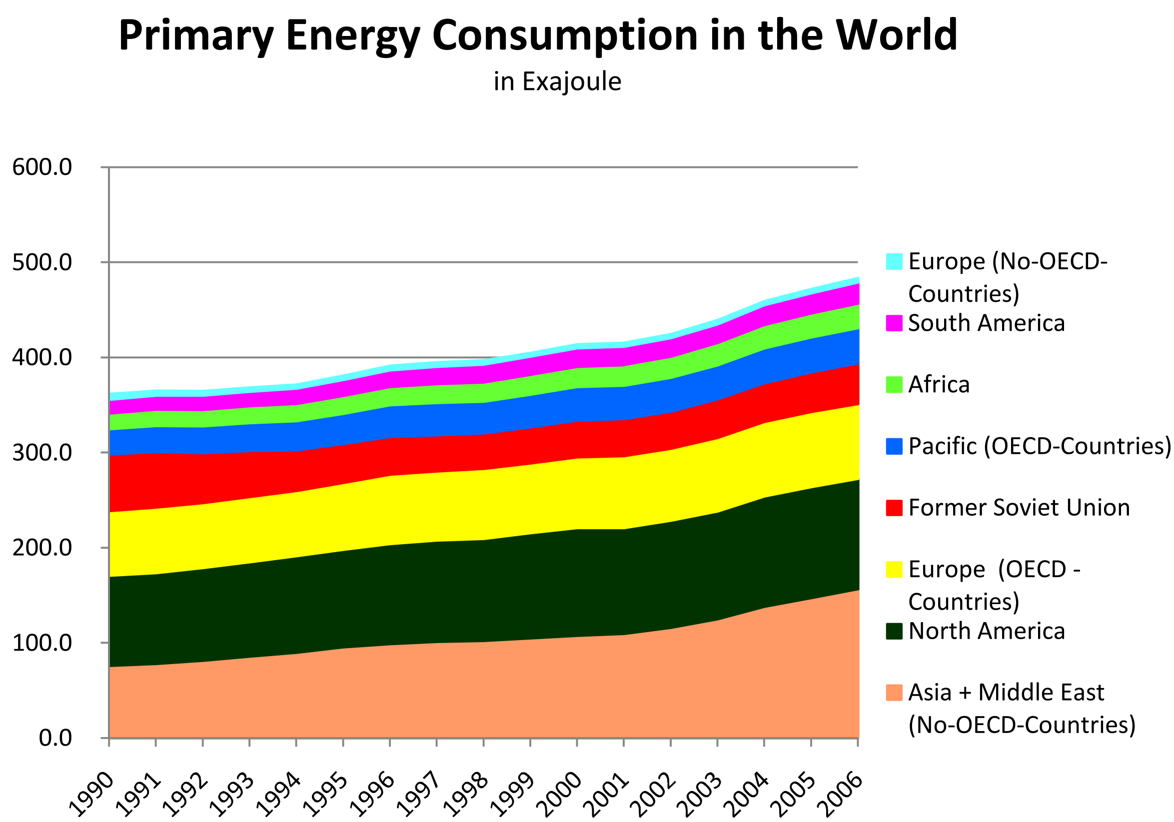


Figure 16 - Primary Energy Consumption[lxxxi]

Economically, China and India will surpass Japan and the United States within the next 30 years. Both China and India have emerged rapidly from deep poverty to become dominant players on the world's economic and political scene. India's economy is predicted to surpass Japan's by 2032, and China could surpass the U.S. economy by 2039.[lxxxii] World energy demand will increase dramatically. Experts predict that energy demand will rise by 60% between 2002 and 2030 and will require about $568 billion in new investments every year.[lxxxiii]

(2) Access to energy services is fundamental to human activities and their opportunities for economic development and growth. As seen in Figure 17, primary energy consumption per capita is currently more than 5 times higher in North America (265.1 GJ per capita) than in China.[lxxxiv] The most populated and fastest increasing parts of the world, Africa and Southeast-Asia, consume nearly 50% less than China.[lxxxv] Therefore, if the increase of the global power consumption due to population development should be accompanied by an increase of average level standards in developing regions of the world. Global energy demand will increase accordingly faster.

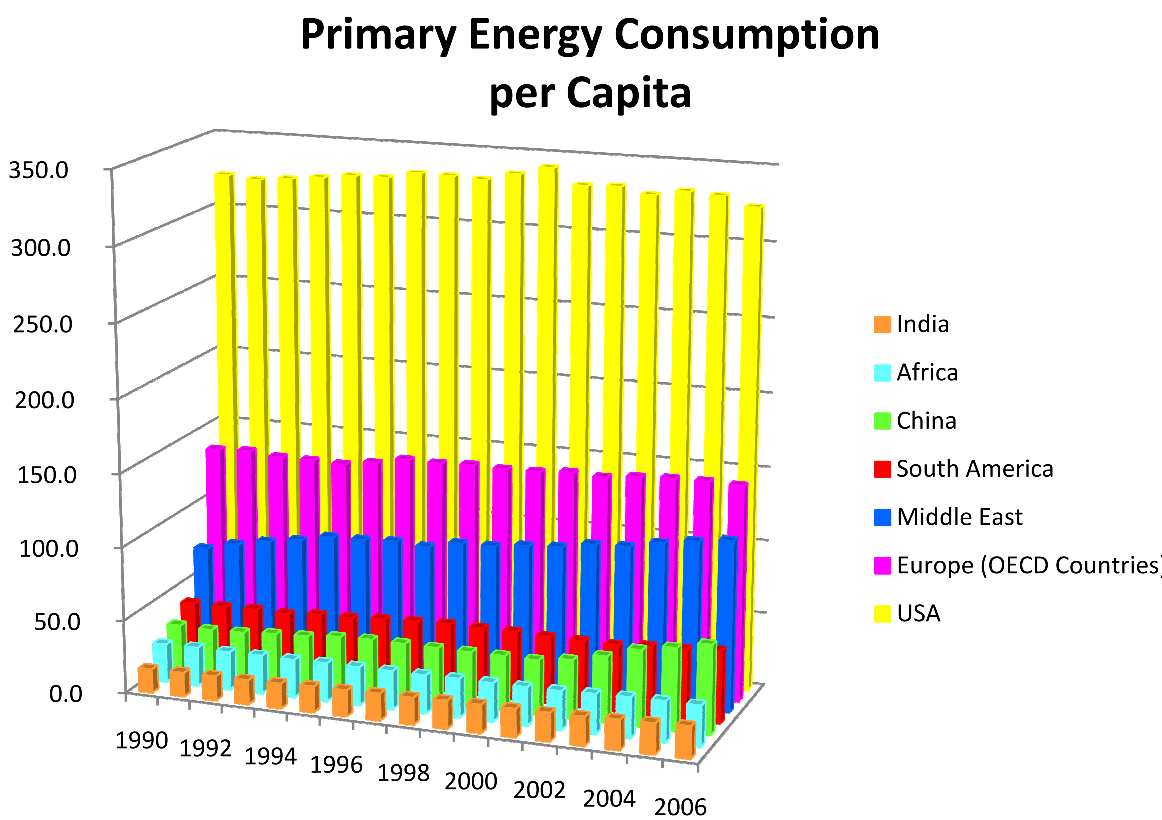


Figure 17 - Primary Energy Consumptions per Capita[lxxxvi]

Power plants have been built for 30 to 40 years. Without thinking of the increase of energy demand old power plants have to be replaced. International Energy Agency estimates that the required investment will be 531 B€ until 2020 to replace the ageing power plants in Europe.[lxxxvii]

(3) Humanity will continue to produce more carbon than oceans or forests can naturally absorb.[lxxxviii] As seen in Figure 18 energy-induced CO2 emissions have a significant part of the global emission of green house gases. Global energy-related CO2 emissions are projected to rise from 30 to 41 Gt in 2030 – an increase of nearly 40%.[lxxxix]
Emissions of greenhouse gases, created by human activities, are mostly coming from the production and use of energy, and are altering the atmosphere. There is strong evidence that most of the warming observed over the last fifty years is attributable to human activities and that significant climate change would result if twenty-first century energy needs were met without a major reduction in the carbon emissions of the global energy system.[xc]

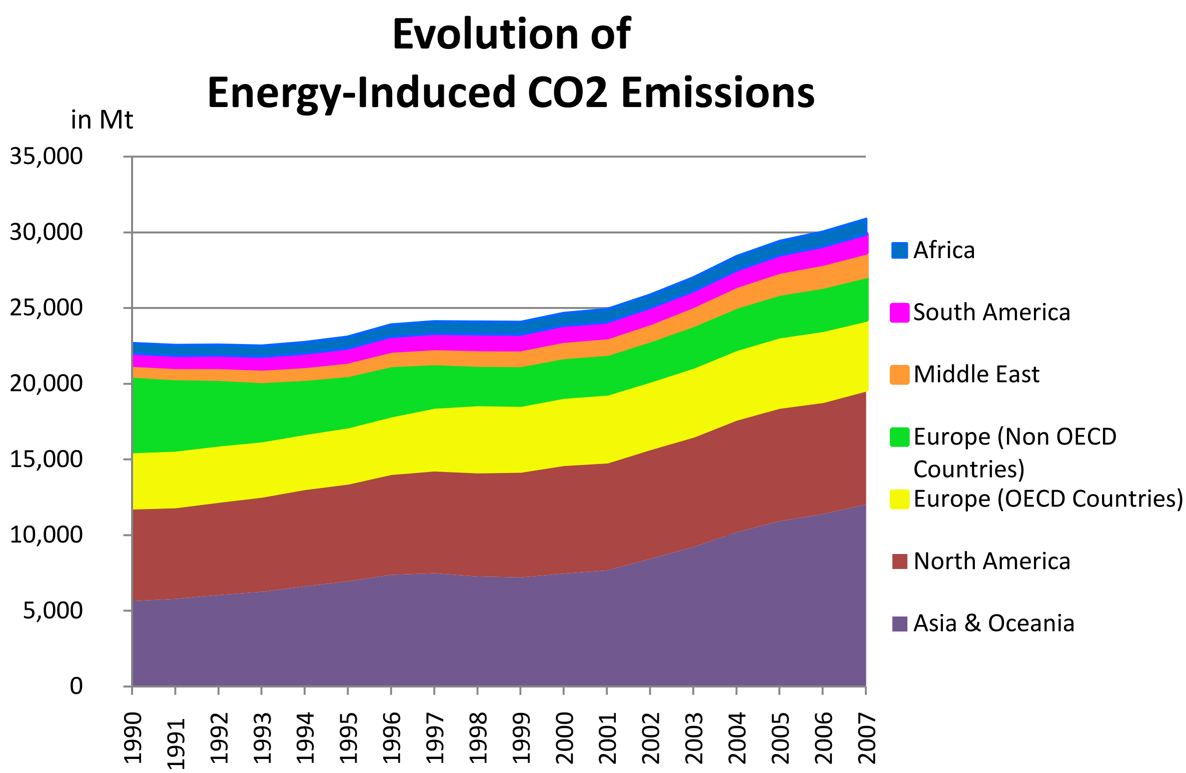


Figure 18 - Evolution of Energy-Induced CO2 Emissions[xci]

The Organization for Economic Cooperative Development (OECD) is an organization which brings together states that are willing to work together towards democracy and a free market economy around the world.

Three-quarters of the projected increase in energy-related CO2 emissions arises in China, India and the Middle East, and 97% in non-OECD countries as a whole. Emissions in the OECD reach a peak soon after 2020 and then decline. Only in Europe and Japan are emissions in 2030 lower than today. The bulk of the increase in global energy-related CO2 emissions is expected to come from cities, their share rising from 71% in 2006 to 76% in 2030 as a result of urbanization. City residents tend to consume more energy than rural residents, so they emit more CO2 per capita.[xcii] As seen in Figure 19, without changing policies the world is on a path for a rise in CO2 emissions and therefore a rise in global temperature of up to 6°C.[xciii]

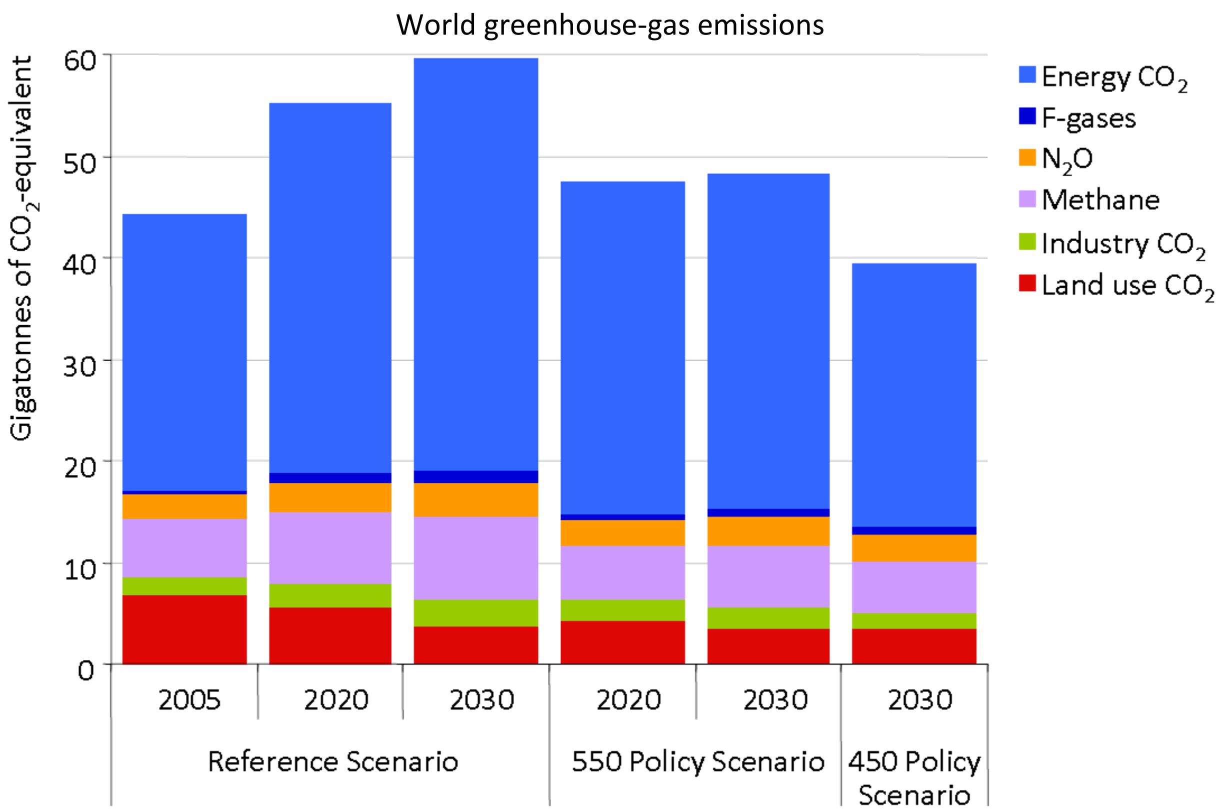


Figure 19 - World greenhouse-gas emissions[xciv]

6.2 The Current Electricity Market

Around 65 countries have goals for their own renewable energy futures.[xcv] Renewable energy supplies count for only 12.9% of the global primary energy use in 2006 according to the German Federal Ministry of Economy and Technology.[xcvi] Figure 20 gives a breakdown of the source composition of energy.

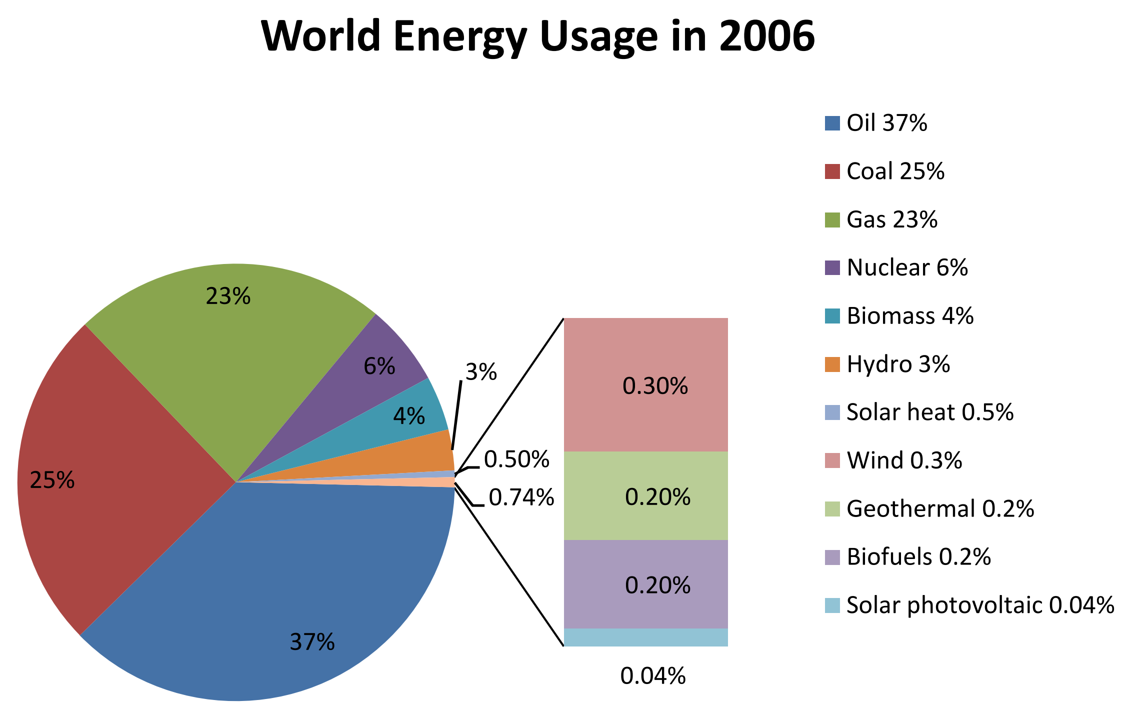


Figure 20 - World Energy Usage in 2006[xcvii]

According to the World Energy Outlook 2008 the demand for fossil fuels will increase much faster compared to other renewable sources.

Continued rising of global consumption of fossil fuels, as seen in Figure 21, is still set to drive up greenhouse-gas emissions and global temperatures, resulting in potentially catastrophic and irreversible climate change.

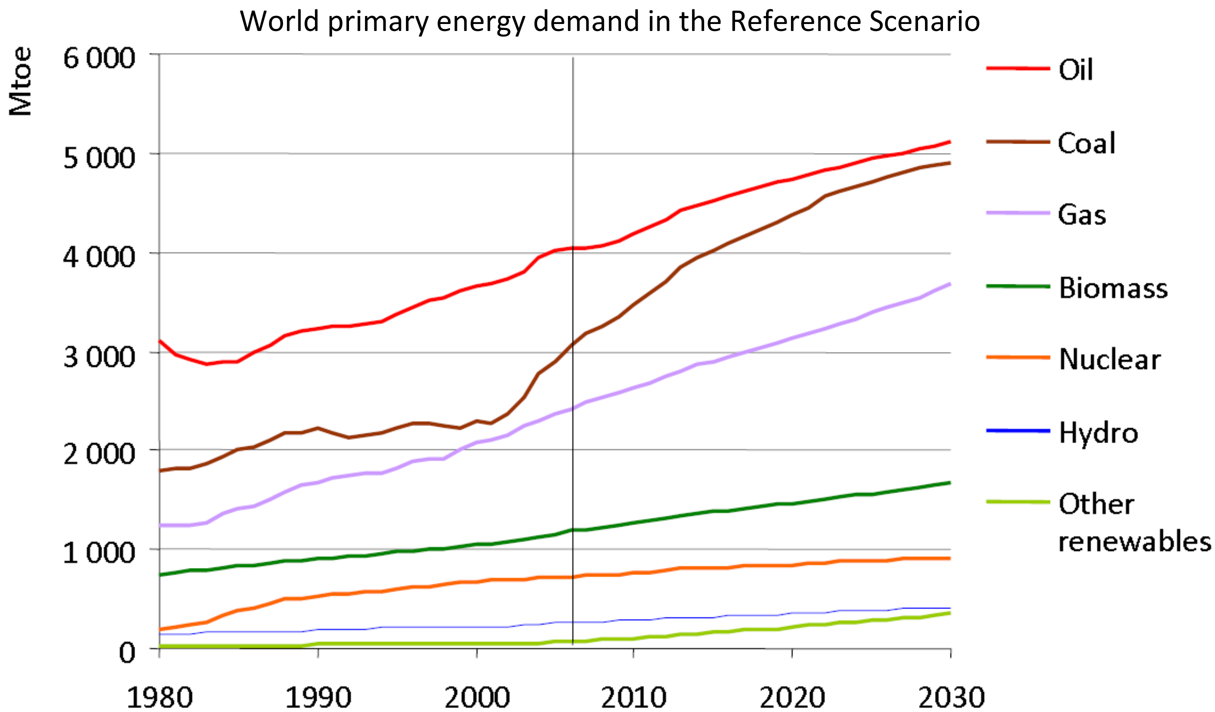


Figure 21 - Energy Reference Scenario[xcviii]

Energy choices will make or break Chinese and Indian economies. Heavy reliance on fossil fuels, particularly coal, could undermine the investments that China and India have made in growing their economies. New pushes towards developing the rich potential of solar and wind energy systems over the next 10 years could help these countries leapfrog ahead of the West, according to the Worldwatch Institute.[xcix]

Current energy development trends are not compatible with sustainable development objectives. Increasing the reliance on renewable energy sources and accelerating development and deployment of new energy technologies is a must.

6.2.1 Direct Competition to SSPS

Combustion of fossil fuels is continuing to dominate the global energy market that is striving to meet the ever increasing demand for heat, electricity and transport fuels.[c] Cost of renewable energy varies significantly according to the resource base and the technology used, but generally the cost still exceeds the conventional energy sources at present time.[ci] Energy access for the growing population will require availability of basic and affordable energy services using a range of energy resources and innovative conversion technologies while minimizing green house emissions, adverse effects on human health, and other local and regional environmental impacts.[cii]

The efficient use of primary energy in the power generation process is a key point for contributing to CO_2 emission and heat value. Energy efficiencies in power plants, as seen in Figure 22, are relatively low.

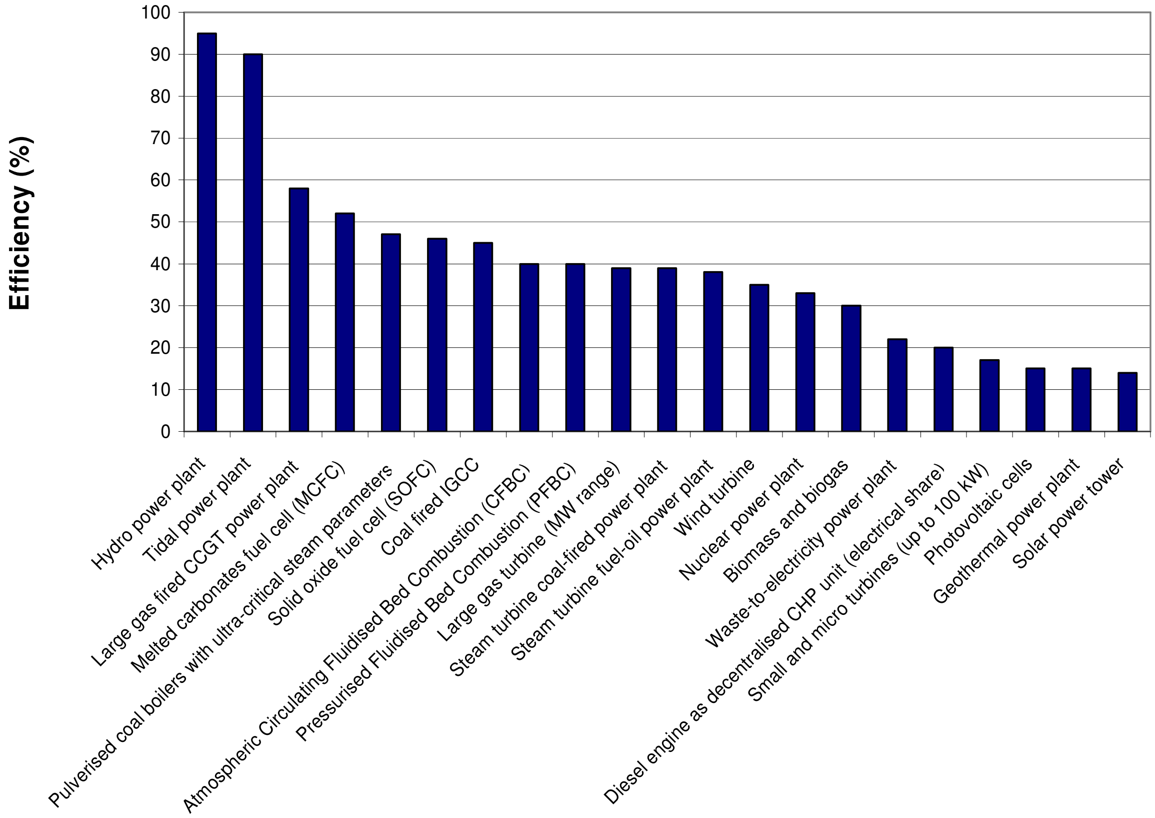


Figure 22 - Efficiency in Electricity Generation[ciii]

Inefficiencies are generally lost to other forms of energy like sound, heat and motion. Space solar power has a heat loss in the atmosphere of about 2-10%, depending on the frequency.[civ]

6.2.2 Electricity Providers

Depending on the country the provider for the classical SSPS system can be the energy generator and/or the energy operator or the government itself. Providers for green electricity like the German company Lichtblick can sell this kind of power. Looking to the future, the capacity for non-polluting energy systems like wind power, biomass or solar system on earth are not that huge. Energy providers have to find other possibilities to expand their portfolio. In order to expand their renewable capacity power generator, as for example E.ON, can also become a provider for space solar power. They have set an ambitious emission-reduction target in order to become the European energy industry leader in climate protection and to support the EU's climate policy. To get there, they are investing billions in climate-friendly generating units.[cv]

Governments must take responsibility for setting up an enabling framework to promote renewables. European leaders, for example, signed up in March 2007 to a binding EU-wide target to source 20% of their energy needs from renewables. On 23 January 2008, the Commission put forward differentiated targets for each EU member state, based on the per capita GDP of each country.[cvi] The additional renewable energy deployment needed to achieve the 20% target will reduce annual CO2 emission by approximately 700 Mt in 2020.[cvii]

6.3 Consumer Survey Results

In order to understand the consumer's perceptions and their concerns with the SSPS project, our group designed a consumer questionnaire in which we briefly introduced the concept of the SSPS project. We asked 9 questions from different aspects related to green energy, the environment, health, energy price, awareness of SSPS and so on.

We translated the survey into 5 languages (English, Chinese, French, German and Spanish) and we put it on web sites or sent it by email. We received significant feedback, having received a total of 557 survey answers. The respondents are from 25 different countries and regions, of different ages, occupations, salaries, and different academic backgrounds. The results of the consumer survey were universal and representative, so we think the results are true and credible.

Through statistic and analysis of survey results, we can clearly see that more than 88% of consumers expressed concern about the impact of existing energy generation on the environment and health, while at the same time they are highly concerned about effects of the SSPS project on the environment, personal health and safety fields.

It is worth mentioning that 88% of consumers are willing to use the green and clean energy to replace the existing energy generation systems which are harmful to the environment. Similarly 77% of consumers are willing to pay from 1% to 5% more on top of their current electricity bills for green energy, some of them even more. More than 55% of consumers believe that energy generated by the SSPS project will be a green energy source and it should be worthwhile to invest. All of these answers indicate that the SSPS project makes sense.

In short, the survey results are positive and helpful to increase the feasibility of the project. However, we still should be clearly aware that due to the project's complexity and high cost, approximately 37% of consumers uncertain on the feasibility of the SSPS project. Another thing is only 29% of consumers know the concept of SSPS from the TV , newspapers, magazines, professional books or other channels, indicating the majority of people do not know and understand the concept of SSPS.

According to the survey, data shows that this project should publicize the SSPS’s concepts and benefits to the people through multiple channels in the future in order to raise public awareness and understanding. Simultaneous, different approaches should be adopted to reduce costs and deploy more research work about the effects on environment, personal health and safety of SSPS, to avoid generating new environmental hazards, physical health and safety issues and risks in the process of putting the SSPS project into practice.

The details of consumer survey results are shown in Appendix E.

7.0 International Space Treaties

The human race has had access to space for several decades, generally considered to have started with the symbolic launch of the Russian satellite Sputnik in 1957. Gaining momentum during the cold war human space activities began to expand considerably by encompassing various military, scientific, and commercial activities.

Recognizing the emerging importance of Outer Space, the United Nations (UN) sought to create a set of guiding principles and set them into international agreements. These principles would help to direct the rising space faring nations as well as to encourage peaceful use of Outer Space for all of humanity. The age of space law therefore began in 1963, with the adoption of the "Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space".

Despite having now been around for over four decades, space law is still very much considered to be in its infancy. Since use of space and its resources has not generally progressed beyond sending satellites into orbit or probes to other worlds, the laws that governed these actions have not needed to change.

As the commercialization of space increased, small changes and amendments have periodically been made to the original agreements. The meaning and scope of these treaties have therefore evolved with time[cviii].

However as the commercialization of space begins to hasten due to new businesses like space tourism, space solar power systems, and perhaps even exo-planetary resource extraction the current set of rules will certainly need to undergo significant changes.

If the utilization of space is to reach its full potential, it needs to be developed economically and sustainably. Private businesses will provide some of the best impetus for this to occur, and the UN framework on space law needs to evolve to reflect this inevitability.

7.1 Treaty Summaries

There are five primary legal documents which refer to the use of space and space resources. Each of these treaties has been proposed and ratified under the banner of the United Nation's Committee on Peaceful Uses of Outer Space (COPUOUS). Once a treaty is approved by the United Nations it is up to member states to ratify them and bring them into law.

These five primary treaties are presented below in no particular order.

1) Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (19 UST 7570; 672 UNTS 119)[cix]

2) Convention on International Liability for Damage Caused by Space Objects (24 UST 2389; 961 UNTS 187) [cx]

3) Convention on Registration of Objects Launched into Outer Space (28 UST 695; 1023 UNTS 15)[cxi]

4) Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (16 UST 2410; 610 UNTS 205)[cxii]

5) Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (18 ILM 1434)[cxiii]

Treaty 5) does not appear to bear any special consideration for the SSPS project, since it is not envisioned at this time to use resources from any celestial body other than the Earth. This treaty will therefore not be explored any further in this section.

The United Nations has further defined an International and Intergovernmental organization to coordinate the use of telecommunications efforts around the world. This organization is known as the International Telecommunications Satellite Organization (INTELSAT), and is defined by the following agreement:

1) Agreement Relating to the International telecommunications Satellite Organization, and Operating Agreement Relating to the International Telecommunications Satellite Organization (23 UST 3813)

This agreement outlines a framework for an international organization that bears the same responsibilities and liabilities as any state when it comes to space law. Other organizations that choose to work under these auspices have greater flexibility in terms of operations, however since many governments (or their designate agencies) will likely be shareholders, very interesting shareholder interactions will arise. Nonetheless any organization which seeks to work within this framework must have the approval of the United Nations.

Nonetheless this framework opens up a new and interesting avenue of existence for a SSPS organization, if it does not want to work solely under the direction of a single country's regulations.

7.2 Treaty Descriptions

Appendix F describes those United Nations treaties which are relevant to the SSPS concept. All of the information in this section has been paraphrased from official United Nations documentation[cxiv]. Information in this section will be presented in point summary for simplicity.

7.3 Relevance of United Nations Treaties on SSPS

Under the current set of treaties outlined above, private companies are not governed by United Nations regulations or agreements without special permission. Governments therefore bear ultimate responsibility for the actions of companies and organisations registered in their jurisdictions.

In terms of a privately held SSPS organization, there would therefore be little direct interaction with the space laws as set out by the United Nations. This is not to say that the SSPS organization would be absolved of any responsibilities, since it will still be answering directly to the authorities in the country in which it is registered. If this country is a contracting party to the aforementioned space agreements, the SSPS organization will indirectly be a party as well.

Perhaps the most important aspects of these space treaties are the articles that are in reference to space weapons. Specifically, weapons in space are not allowed under any circumstances since this would violate the principle of utilizing Outer Space for peaceful reasons only.

In theory a working SSPS can be considered as a large directed energy weapon in orbit of the Earth. The effects of lasers and microwaves on people, animals, and flora are fairly well understood however[cxv], and so such a system can be (and will need to be) designed so that all of the energy it transmits is well within defined safety limits. Furthermore these systems will need to be designed in such a way that their energy output can never be changed either accidentally or on purpose, to induce a harmful effect.

8.0 International SSPS Organizational Framework

A project of the scope of the SSPS will necessarily be international by nature, and it is therefore important that its framework reflect this as best as possible. The existence of a top level organization will be crucial, since no single government or private company will be able to easily pursue such a project on its own.

In this section we will discuss the major kinds of organizational frameworks and choose which is best for the application of the SSPS.

There are in essence three different kinds of organizational structures that are available for such a project[cxvi]. These are:

1. Government Organizations
2. Private Organizations
3. Combination Government / Private

Depending on the expected scope of the organization and its objectives, one organizational structure may be more relevant than another. If we take for example the company Space Energy which endeavours to pursue a privately funded SSPS[cxvii,cxviii], the private international organization is best. If we consider however an organization that functions directly through states and the international framework set out by the United Nations, a combination of private and public is best; this is the case with INTELSAT[cxix].

In the case of INTELSAT we have an organization that is made up of an international and an internal segment.

At the international level states who wish to participate in the organization ascribe to it by signing the appropriate engagement treaties. These states continue to operate in the international arena as sovereign nations, making policy decisions as they normally would but also paying attention to their involvement in the international organization[cxx].

At the internal level the organisation is made up of several layers much akin to a normal corporate entity.

It is difficult to quantify the motivations of individual states when it comes to a project as large as the SSPS, and therefore it becomes equally difficult to identify the kinds of incentives that will make them interested and keep them interested over the life of the project. Private companies on the other hand are governed by the need for profits, and so their incentives are clear.

Since sovereign states are not private companies, they do not necessarily look for profit per se, but rather something that is beneficial to their nation. The idea of low cost environmentally friendly energy is certainly something which should attract the interest of all nations who take the health of their population and the planet seriously, however it may not be enough.

States who participate in the SSPS organisation may instead receive advantageous positioning in regards to the awarding of technical contracts required for the project, equal to their level of investment. This would allow the state in question the benefit of contributing to the project while receiving direct benefits for its own industries[cxxi].

For our analysis we will base one proposed framework for the international SSPS organization on that held by INTELSAT, since it is a reasonable combination of international and individual domestic laws, operating under the rules outlined by the United Nations space treaties. We will discuss different aspects of this organization presently, drawing from the outline presented in the International Asteroid Mission Report published by the International Space University[cxxii].

8.1 Organizational Levels

This proposal for the SSPS organization will be made up of three different bodies, defined as the assembly, the board of directors, and the executive body[cxxiii]. These are defined in short here.

The Assembly

The assembly is made up of all the states which are a party to the organization. Each state has assigned one operator to be their designate within the assembly, and procedural matters are voted upon within the assembly where a two thirds majority rules. The relationship between the states and their designates is based wholly on the domestic laws of that state. The assembly ensures that the organization works within the rules and regulations outlined by the United Nations[cxxiv].

The Board of Directors

The designated operator(s) of a state are represented within the corporate framework by a governor, whose voting power on the board is equivalent to that state's investment in the project. The function of the Board of Directors is to then decide on operational, development and design, and construction policies[cxxv].

Executive Body

The executive body takes care of the day to day management operations of the organization, in much the same way as the executive body in a normal corporation. The people within the executive body are taken from the organizations member states and answer to a director who in turn answers back to the Board of Directors. The executive body should be focused on outsourcing technical work to contractors within member states so as to minimize the size of the organization[cxxvi].

8.1.1 Organizational Membership and Withdrawal

Membership to the organization is initially defined at the outset, based on which states have agreed to sign on. This is not an exclusive club however; as it is possible for new member states to become involved as the project evolves, subject to approval from the existing members. Furthermore states are free to withdraw from the organization at their preference. In the event that a state withdraws from the organization, all operators, governors, and contractors of that state are immediately withdrawn as well[cxxvii].

8.1.2 Investment Sharing

The investment share of each state is revised annually by the board of governors, based solely on the financial contributions of that state over the course of the previous fiscal year. Currency is not the only item considered however, since “in kind” contributions such as land or launchers may be considered as financial equivalents. The investment share of each state directly affects the voting power of the representative governor[cxxviii].

8.1.4 Research and Development Contracting

As stated previously it shall be the goal of the organization to outsource as much technical work as possible, so as to minimize the size of the international workforce that it must maintain. Contracts can only be awarded to firms within participating states, and may be assigned according to two different methodologies[cxxix]. These two methods are best represented by:

a) Each contract is awarded based on the best tendered offer. Only firms based in participating states may submit bids for contracts.
b) Contracts are awarded on a “per investment” basis. This methodology is similar to the methodology used by ESA, which awards contract quotas or work share based on the size of contributions by member states.

In practice it would be best to make use of both kinds of contract awarding, based on the incentive package that best suits the participating state.

8.1.5 Technical Ownership and Intellectual Property

All assets produced for the purposes of the organization shall remain the property of the organization, including land and assets offered to the organization “in kind”, unless otherwise arranged.

In terms of intellectual property there will be a significant amount of research that will be done over the course of this project, and so a significant amount of intellectual property will also be generated. There are two ways in which the issue of intellectual capital may be addressed[cxxx].

a) All intellectual property produced by contracting parties will remain the property of the organization, to do with as it sees fit.
b) All intellectual property produced by contracting parties will remain the property of the contracting party, however the organization shall uniquely maintain unrestricted and royalty free use of the intellectual property indefinitely.

Option a) clearly allows for the organization to maintain strict control over who uses the technology and for which purpose. Option b) however is more useful in terms of motivating states and firms to participate since it allows them the chance to work with the organization as well as develop technologies and systems which will be beneficial to their own long term goals. This kind of arrangement will sponsor greater interest in participation, and therefore greater competition among bidding parties.

8.1.6 Dispute Settlement

It is unreasonable to assume that all parties will work in unison for the entire life of the organization, since there will be differences in opinion and interpretation relating to cultural and legal factors. It should be specified at the outset of the organization that all parties are to attempt amicable resolution of conflicts, since this will be in the spirit of the international nature of the organization and is already a common feature in many business contracts.

In the event that an amicable resolution cannot be met, participants agree that they will undergo and be bound by third party arbitration. In this case each party shall choose one arbitrator of their preference, and these two arbitrators together choose a third. This three member arbitration board will then make a ruling on the conflict, to which both parties agree to be immediately bound[cxxxi].

8.2 Discussion and Comparison with Private Organization

In comparison to the framework mentioned above if the organization is set up as a privately held company it would be more streamlined and simpler to control. The whole of the company would have the same objectives, and operations could be much more streamlined than that in the mixed organization.

The company would be free to choose its own locations and business partners, and as necessary be able to choose contracting firms according to its own priorities. The organization could also ensure that all of its contracts and dealings are performed under a consistent legal framework.

Partially this would be based on the country of incorporation of the organization, but also on the chosen jurisdiction for contractual dealings. In the case of the private company Space Energy, it has been incorporated in Switzerland to capitalize on their neutral world standing as well as the frequent use of Swiss jurisdictions for contract negotiation[cxxxii]. Furthermore since Switzerland has ratified all of the United Nations Space Treaties, with the exception of the treaty pertaining to the use of moon, Space Energy can still work within the United Nations framework[cxxxiii].

Drawbacks to this method are that it may be very difficult to arrange the correct parties to work together with each other. For instance if the private organization seeks to work with experts from scientific organizations as well as military ones, the partners may not be willing to work together for any number of different reasons. This is the case with ESA, which expressed a desire to avoid working with military agencies[cxxxiv].

Furthermore a privately held company would likely face the full extent of export controls if it counts the United States among its partners / countries, limiting its ability to do business in certain markets. In the mixed organization such problems could likely be mitigated to a certain extent due to high level negotiation; a private company could avoid these problems altogether by selecting technologies in which the United States has had no input. The Chinese Long March and the Indian GSLV launch families are examples of key technologies that have been developed independently of the United States[cxxxv].

8.2.1 Choice of Final Organizational Framework

The best perceived framework to move forward with the SSPS organization is a combination of the international framework used by INTELSAT and a private company in the format indicated above.

Specifically we would use the framework for INTELSAT, with the exception of the inclusion of participating states. The SSPS organization is ultimately a business and is not ascribing to anything higher than the generation of profits, albeit over a very long time frame with a secondary objective to mitigate climate change. Using the full framework of INTELSAT may prove disadvantageous, since it in not geared specifically towards profit[cxxxvi].

The SSPS organization would therefore act as prime contractor towards the final completion of a working SSPS. The Governing Board of the SSPS organization will maintain sole discretionary rights over the progression and direction of the project.

At different stages throughout the SSPS plan, the organization will be working with different companies and government agencies from around the world. The organization will negotiate contracts on a case by case basis, likely using Swiss jurisdiction for the settlement of all contract disputes due to its neutrality.

The SSPS organization will be free to award contracts as it sees fit on a per contract basis. Whether this is based on the best tendered offer or through other agreements, it will remain at the discretion of the private organization.

Intellectual property developed by partners and contractors will remain the property of said partners and contractors. The SSPS organization will uniquely maintain unrestricted and royalty free use of the intellectual property indefinitely. This is viewed as the best kind of incentive since it will encourage participation while minimizing costs (cost sharing between the organizations).

Ultimately it is believed that this amalgamation of private and international agreement frameworks will best suit the SSPS organization. Unless stated otherwise this framework shall be assumed to be in force throughout the rest of this report.

9.0 Classical SSPS Financial Analysis

9.1 Description of Technical SSPS Model

In order to perform a financial calculation for the SSPS system it was first necessary to build a technical model which would allow us to determine systems characteristics such as costs, mass, and deliverable energy.

The model was designed using Microsoft Excel with several variables which would be used to change the final design. Since there were several variables involved in our calculations it was not easy to optimize for just one. After the framework of the model was completed it was important to assign limitations to certain values during use, in order to obtain meaningful results for the others.

An important quantity for a given SSPS system is the energy density of the beam on ground. As we have seen in different areas of this report the density of the delivered energy is a critical factor for human and environmental safety. Since the rectifying antenna site would be restricted in terms of public access, the energy density of the beam is most important around the edge of the employed territory. An analysis of the beam density is provided in the SSPS Technology section (Section 4) of this report.

A benefit to the energy density analysis is that we can see the level of energy at all points along the length of the rectenna. In some cases of small power applications the energy density will be below safety standards at all points, making it possible to build the rectenna site much smaller than needed according to this normalized distribution curve. The use of smaller sites means a reduction of the footprint and cost of the ground station.

There were many quantities which were not easy to determine for this model, specifically these were: the mass of the satellite aside from solar panels, the cost of the satellite components, production costs of the rectenna, and finally the operational and maintenance costs of operating the system.

For these quantities we studied the values used by ESA in their own SSPS research papers and were able to make some educated assumptions based on the information provided[cxxxvii]. From this we were able to determine the following quantities which were used in our models:

Satellite Mass	3137Kg/Tm*
Satellite Cost	580.00$/Kg
Rectenna Cost	45.00$/m^2
Maintenance	20.57$/Kg/a

Figure 23 - Crucial satellite quantities

The unit of measurement for the satellite mass is given in Kg per metre of diameter for the transmitter.

Assumptions

The following assumptions have been made in our technical model:

1) As indicated in the SSPS Technology section we have used a new kind of solar panel in our model
2) ESA had assumed a cost of 22 EUR per square meter of land purchased. This cost seemed very high and so we searched out land prices in Europe (France) and Canada (Ontario). The prices for land came out to be marginal at 0.60 EUR and 0.11 CAD per m^2 respectively. Since these land costs are so low they have been disregarded in our calculations[cxxxviii].
3) The satellite will have an expected lifespan of 30 years.
4) The satellite components will be lifted to LEO to optimize the capacity of the launchers
5) The satellite components will be transported to GEO via a low energy orbit, possibly using ion thrusters.
6) We will use a transmission frequency of 38GHz since this allows us to transmit the most energy into the smallest space, even when accounting for transmission losses.
7) We will use a transmitter diameter of 141m.
8) The combination of transmitter size and frequency result in a relatively small rectenna diameter when compared against the ESA reference system of 11x14km[cxxxix].

The following table indicates only a selection of the possibilities that we have considered for our financial analysis. A sample system calculation is provided in Appendix K.

Classic Applications										
Case	Ideal MW	Transmitter Diameter (m)	Rectenna % of Ideal	Rectenna diameter (Km)	Rectenna Area (km^2)	Received Energy (MW)	Border Density (mW/cm^2)	Number of Launches Needed	Expected Total Cost (B.USD)	Cost per kW/h (USD)
1	1000	141	75	3.67	10.56	989.0	1.07	44	5.37	$ 0.02
2	1000	141	85	4.16	13.57	997.7	0.29	44	5.53	$ 0.02
3	1000	141	100	4.89	18.78	1000.0	~0.00	44	5.77	$ 0.02
4	5000	141	100	4.89	18.78	5000.0	~0.00	160	18.7	$ 0.01

Figure 24 – Four different Classic SSPS Combinations

These values are based upon a non discounted cash flow and also do not take into account the development costs assumed by ESA and NASA. Interesting to note is the transmitter diameter of 141m. Perhaps as a result of the Excel model characteristics, the transmitter diameter of 141m was found to be the point of least cost for all combinations of variables input. Further examination in this area would be helpful.

9.2 Description of SSPS NPV Calculation

Key values from the technical analysis have been transplanted into the NPV calculation for the classical SSPS system. Using the information above as well as some of the following data / assumptions, we can create a basic NPV valuation for the system.

Assumptions

1) ESA had assumed a total development cost for the SSPS of 265 billion USD, with a note that this was more than twice the cost of suggested the NASA DOD example. For our case we will assume that the cost of development of the SSPS is equivalent to that suggested by NASA[cxl].
2) ESA has assumed a progress rate of 0.8 in terms of launch costs, based on each doubling of launch mass. We will make our first calculation assuming no volume benefits[cxli].
3) The cost of capital for the system will be taken as 7.51%, which is the cost of capital for the aerospace and defence industry as of January 2009[cxlii].
4) The market price for electricity of 0.08 EUR[cxliii] shall be used in the NPV calculation, not the cost per kW/h as indicated in Figure 24.
5) We can use tax shields to mitigate cash flow losses.

Resulting NPV Calculation Set #1

Of the three basic NPV calculations for the SSPS, Case #1 as presented in Figure 24 is the best choice for a 1GW system. This is a relative term however since the final NPV for this system is -72 billion USD. Note that the actual NPV data sheets for all calculations will be provided in Appendix I.

As a point of comparison a basic NPV calculation for a 5GW system using the same constraints as above is -59 billion USD. This reinforces the benefits of an economy of scale, in that building more of something generally leads to a better price. This is Case #4 as indicated in Figure 24 above.

Despite this improvement NPV is still negative, although it is a small wonder considering the cost of the anticipated development costs. We will now take some further assumptions under consideration which will affect the NPV calculation.

Further Assumption #1*:* We will now take into account the progress rate of 0.8 as indicated above. Based on the doubling of launch mass the cost per multiple of launch cost will be given by the curve given in Figure 25.

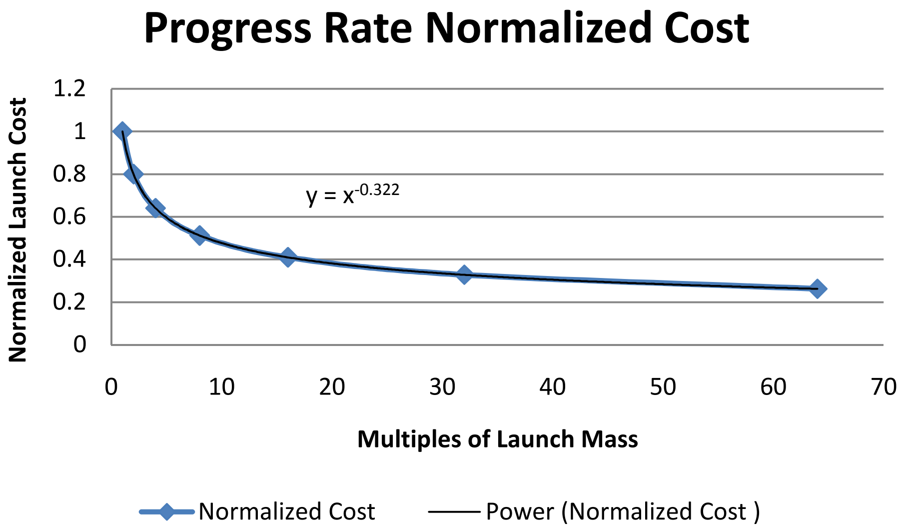


Figure 25 - Cost curve based on progress rate of 0.8

From this curve we can see that there will be reductions in the total launch cost based on volume of launches.

Further Assumption #2*:* We will now take into account some of the information provided to us during our market surveys. As we have seen in the results presented in the market Analysis section, 79% of those surveyed said that they would be willing to pay more if they could be guaranteed a green energy source, and 57% felt that investing in a SSPS would be a good choice.

Since the SSPS is currently not available, these people are not able to contribute any extra money to its cost. However there is another approach. Currently EDF[cxliv] has a "green tariff" program, in which people willingly donate a small amount of extra money onto their energy bill in order to help fund green energy sources[cxlv].

Taking this existing model into consideration, we could assume that a partnership with a utility company such as EDF or Vattenfall[cxlvi] would be able to levy a small amount of money to act as token income during the SSPS development. This would not be a large sum, but it might be enough to offset some of the costs.

For our assumption we will use EDF's customer base and our market survey results to build our donation value:

Quantity	Comments
30.00 €	Cost per customer per month
360.00 €	Cost per year
2.5%	Percent extra cost
369.00 €	New end of year bill
9.00 €	Cost Delta
28,000,000	Number of customers in France for EDF[cxlvii]
79%	Percent of those surveyed who would pay more for electricity
20%	Percent of those surveyed would choose to pay to help the system in advance
15.80%	Total percent of customer base willing to pay extra (79% x 20%)
4,424,000	The number of customers who would be paying the premium in advance
39,816,000.00 €	Proposed cash flow per year to assist in SSPS
0.736	USD:EUR exchange rate[cxlviii]
$ 54,000,000.00	Proposed cash flow per year to assist in SSPS

Therefore we will add in a line in our calculations to account for a small income of 54 million USD. Furthermore as the SSPS begins to generate electricity, we will implement a cost increase of 2.5% on top of the market price to account for consumer willingness to pay more for green energy sources.

Resulting NPV Calculation Set #2

We can see in the following figures the change in NPV for SSPS Case #1 and Case #4 in their original and modified forms.

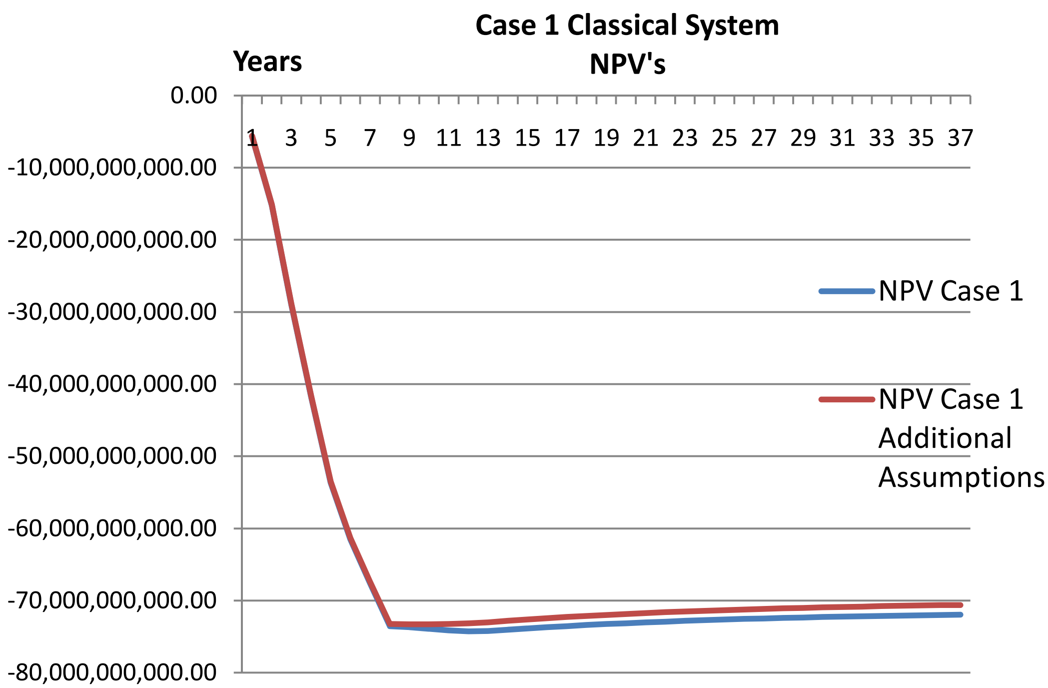


Figure 26 - NPV for SSPS Case #1

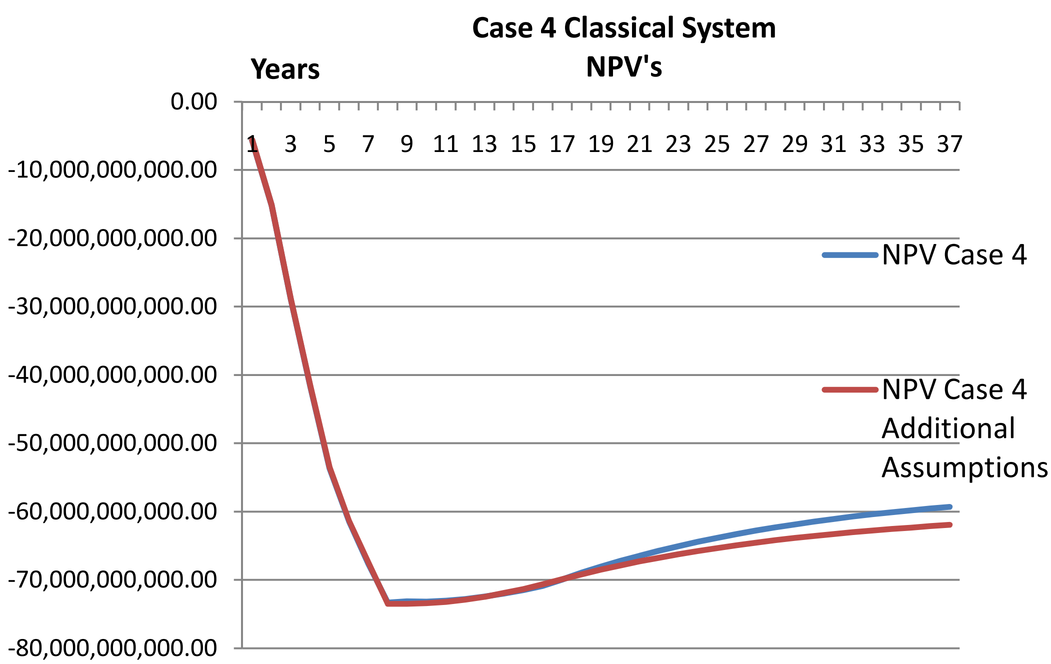


Figure 27 - NPV for SSPS Case #4

With addition of further assumptions #1 and #2 above, we can obtain new NPV calculations for both the 1GW and 5GW classical systems. From these results we can see that the cost for the 5GW system has not improved. This is attributed to our financial model which used the launch costs to determine value, and from which depreciation was then calculated. With lower launch costs there is less depreciation, and therefore the shielding effect is reduced.

9.4 Conclusion and Discussion

As we have demonstrated in this section the cost of building a SSPS is incredibly expensive, and at this time cannot offer a reasonable NPV or ROI. Financial data was calculated for two different classical systems based on the following criteria:

I. Utilization of a new kind of solar panel technology.
II. Land costs have been disregarded due to their low prices.
III. The SSPS will have an expected lifespan of 30 years.
IV. The SSPS components will be lifted to LEO to optimize the capacity of the launchers.
V. The SSPS components will be transported to GEO via a low energy transfer orbit, possibly via ion thrusters.
VI. We will use a transmission frequency of 38GHz.
VII. Satellite Mass 3137Kg/Tm
VIII. Satellite Cost 580$/Kg
IX. Rectenna Cost 45$/$m^2$
X. Maintenance 20.57$/Kg/a
XI. Transmitter size of 141m offers the lowest cost for our applications.
XII. Development costs of 132.5 B.USD will be used.
XIII. A progress rate of 0.8 shall be used for volume purchases of launchers.
XIV. The cost of capital will be 7.51%.
XV. A market price of 0.08 Euro per kW/h will be used.
XVI. A premium of 2.5% will be added onto all energy sold based on market feedback.
XVII. An optional green tariff of 54 M.USD will be received each year in donations.
XVIII. Use of tax shields to mitigate financial losses

With the above information we have seen that the best NPV for a 1GW and 5GW system that we could obtain were -71 B.USD and -59 B.USD, respectively.

There are three main limiting factors in this analysis. The first limiting factor in this calculation was the cost of the launchers. This statement is not new, and our results merely indicate that it is still very much an obstacle.

Linked to the cost of the launcher is the needed mass of the system. The satellite mass value of 3137Kg/Tm used in our calculations added a considerable amount of mass for larger transmitter diameters, leading us to select a higher frequency of transmission (38GHz).

This choice allowed us to afford a smaller antenna / rectenna combination, however substantially increased energy transmission density. The diffuse energy density offered with a 2.45GHz system required a massive increase in rectenna size, and offered no benefits in terms of cost.

The development cost was perhaps the most limiting of the three factors. Starting from a deficit of 132.5 B.USD (or 265 B.USD as estimated by ESA), it is very difficult to obtain a positive economic value without either a significant increase in the expected system life, the cost of consumer energy, or alternate forms of income to offset costs. Data concerning the nature of these development estimates could not be reliably obtained for analysis.

For our calculations we assumed a single driving organization which involved different stakeholders at appropriate times throughout the product lifecycle. At this point however we can conclude that the Classical SSPS is not financially viable in terms of this single organization.

Part 2: SSPS Niche Applications

10.0 Introduction to Niche Applications

10.1 What is a niche application?

Before answering this question the term "niche" it should be defined. This word has been widely used in biology and it refers to the specific position a species or living being occupies with respect to others, "The particular area within a habitat occupied by an organism"[cxlix].

In the world of economics the usage adopted implies a very specific and focused product, service, or market. In terms of a small specialized business model: "A special area of demand for a product or service"[cl], "a specialized and profitable part of a commercial market; a narrowly targeted market"[cli].

Therefore the term niche refers to particular characteristics instead of general, narrow instead of broad, and focused instead of diffused. In this sense and for the purpose of the present work, a niche application is that derived of a product, technology or service with a general and broad reach in terms of possible users, but by its distinguishing features is targeted at highly focused markets.

In the case of SSPS the general application would be power generation for mass consumption and the niche applications would be power generation for small scale consumption within specific conditions: Remote locations without access to the power grid. Difficulty to use conventional power generators, such as those based on fossil fuels. Need for rapid deployment and retrieval. In the case of the recharging mobile devices the remote location does not necessarily apply, this will be explained in the following sections of this report.

10.2 Are niche applications required?

Space has become increasingly a business environment; several companies are ready to sell commercial space products to anyone who can meet their price. The types of services for sale include photographic imagery down to 1.0-meter resolution (soon to be 0.5-meter resolution), infrared detection, radar scanning, communications, Global Positioning System (GPS) receivers, and access to refined weather data[clii].

This business model started as technologies with a very specialized and narrow demand, niche markets. The ever growing demand for such products and services has created a "virtuous cycle" in which demand offers incentives to enhance technological capabilities and better performance attracts more users. The key factor is which technologies and applications are prone to be adopted by a wide base of users.

Such is the intention when devising niche applications for SSPS, to maximize both the uses and profit derived from the development and application of such technology. A broader range of profitable business models will make this technology more attractive from the economic point of view. Therefore, it will be easier to obtain funds for its development and more complementary technologies or applications will be developed, thus creating an economical inertia that will help reducing the required time frame for its full implementation.

Additionally offering some niche applications helps to promote public awareness, as well as support and research for the whole SSPS technology. By proposing and developing niche applications, some of their profits can be reinvested in the development of a full SSPS or to scale up the capacities of smaller applications.

10.3 Cost "Premiums" and niche markets.

"Premiums" are factors that contribute to make a market more desirable from the economic perspective. Four premiums related to SSPS applications have been identified during the development of the present work: Remote, Green, Military and Peak Load. For the purpose of the niche applications only the first three will be discussed.

Remote Premium: Some people are willing (and often have no choice) to pay more for energy in remote places, since generation in place is either difficult or expensive and given population density and distance to the power grid setting up the infrastructure to get interconnected results in prohibitive costs.

Therefore, the idea is offering SSPS in-situ power generation at comparatively lower costs because of the logistics implied (no required fossil fuel transportation and storing or wired power transmission infrastructure), as well as environmentally friendly (no fossil fuel burning, water dams flooding terrain, or highly spaced wind turbines affecting landscape and wild life, among others). Some examples of regions where the stated conditions exist and such a concept would work well are isolated towns or villages in Siberia, Africa, Alaska, China, India, the Amazon region, Antarctica and medium size islands and archipelagos.

The concept of this premium is associated with small stationary applications which are explained in their corresponding section. According to the "space solar power program, final report" paper of the International Space University of Kitakyushu, Japan, written in 1992, a reasonable price per kW/h at remote locations can be set up between US$ 0.22 and US$ 0.55, depending upon factors such as transportation costs for fuel and power output of the generator. At this time Antarctica is the place with the highest price per kW/h. Such values are derived from direct operation costs; environmental costs due to the impact of burning fossil fuels (Diesel as the main one) haven't been accounted for. Therefore any power provider that intends to be competitive in such market type must offer costs within this range.

Green Premium: For research purposes two sets of surveys were developed, details and results are explained in the Market Research section of this report as well as in Appendix E. One of the surveys was designed for common consumers and among other results it was found that people are willing to pay a surcharge of 1-5% of their regular electricity bill for the option of buying pollution free energy, such as SSPS. A 2.5% addition to the total electricity bill of potentially hundreds of thousands of households would provide an important economic incentive to develop green energy sources. A portion of this can be devoted to payback the investments made to develop a commercially viable SSPS. This finding, along with the fact that "only about 12% of the daily energy production on earth comes from renewable sources[cliii], show that there is a huge potential for a successful business model based on the SSPS concept".

Military Premium: The military is highly interested in this concept, since it would allow operation without being hindered by logistical and security constraints. The so called Fuel Tether, as was labelled by Lieutenant General James N. Mattis[cliv], when he said "unleash us from the tether of fuel"[clv]. According to the paper "More Capable War fighting through Reduced Fuel Burden" produced by the Defence Science Board in 2001[clvi], "over 70 percent of the tonnage required to position today's U.S. Army into battle is fuel[clvii]". Once the forces are positioned 25% of that fuel is used for electrical power by generators, "Generators used to cool, heat and light bases constitute the largest single consumer of fuel on the battlefield"[clviii].

Such dependency on fuel represents one of the greatest weaknesses and threats not only for the US military but for any Armed Force in the world since it implies a heavy and long logistics chain that can be attacked much more easily than any other military objective. This has been the case during the Iraq war for the coalition led by US Forces or in Afghanistan for NATO Forces.

http://www.armytimes.com/xml/news/2009/02/ap_iraq_exit_routes_022109/022109ap_iraqexit_800.JPG

A study by the Air Force Research Laboratory –AFRL– showed that the "Fully Burdened Cost of Fuel" as defined by the Office of the Deputy Under Secretary of Defence for Acquisition & Technology (FBCF is the commodity price plus the total lifecycle cost of all people and assets required to **move** and **protect** fuel from the point of sale to the end user)[clix] of 1 MW per year in the battle field is equivalent to US $134M, this implies that the real cost per kW/h for the US Military is US $23.9. To see a more detailed explanation of how such FBCF was obtained see Appendix J.

Figure 28 – Cummins Generator

Later on, the same DoD Office adopted a more conservative figure for FBCF of US $42 per gallon of Diesel for the generators if it is transported by air and of US $15 by truck, according to the testimony of March 13, 2008, by Mr. Chris Dipetto before the House Committee on Armed Forces[clx]. Taking as reference a Cummins Diesel Generator as shown in Figure 28[clxi], Model DGDK, rated at 100 kW, every kW/h generated would have a FBCF of US $ 1.14 with this new figure. Still much more than the US $ 1.03 a kW/h would cost with an SSPS providing 6.77MW. The Future Military Power Requirements Conference held in Washington DC on July, 2008, hosted by the AFRL, defined that a Forward Operating Base require between 3 to 5 MW of power, which would be provided by between 438 to 730 diesel generators (extrapolating the AFRL calculation for 1 MW).

Besides the real costs for the military of transporting and securing the fuel required to power their generators, increased public awareness and concern upon the environmental impact of military activities need to be accounted, much of such negative environmental impact is caused by the use of fossil fuels to get the forces moving and operating, this has been acknowledged also in the Defence Science Board document which states "Following the Kosovo operation, a number of organizations conducted official and private investigations of the environmental fallout of the air campaign"[clxii] a clear example of this can be seen in http://academic.evergreen.edu/g/grossmaz/schrinrj.htmlp.

11.0 Stationary Small Scale SSPS Applications

11.1 Description of Small Stationary Applications

According to the International Energy Agency (IEA) 25% of the world population lives without electricity, in most cases there is no way to deliver the energy.[clxiii] Markets are changing and the demand for green energy is very high. The deployment of renewable technologies for small-scale applications has large possibilities for the future.

Energy can be generated from different natural resources, such as sunlight, wind, water and geothermal heat. Stationary small-scale applications must be applicable for all kinds of geographical classifications. To come to the fore only wind and solar will be examined in this context.

Airflows can be used to produce electricity with wind turbines. This technology is growing at an average annual growth rate of 25%.[clxiv] This requires large amounts of land; particularly in areas of high wind resources. The strength of the wind varies from zero to storm force. Wind turbines do not produce the same amount of electricity all the time. There will be times when they produce no electricity at all. Efficiency is depending on the region where it is running. Land limitations make it even more difficult to install more systems. Lots of people think the landscape should be left in its natural form for everyone to enjoy. Wind turbines are also very noisy and they can generate the same level of noise as a family car travelling at 100 km/h.

Solar power is most available energy source on earth, capable of providing many times of the current energy consumption. Electricity can be generated by means of photovoltaic cells or heat engines. Photovoltaic cells were originally developed for the use in space, where repair is expensive, if not impossible. But it still powers nearly every satellite in orbit because it operates reliably for a long period of time with virtually no maintenance.

Solar power on earth is however an unsteady energy source, with energy production relying on the sun and therefore depending on day/ night cycles and alternatively the weather conditions. Some days it may not produce power at all, which could lead to energy shortage. As seen in Figure 29 only about half of the incoming solar energy reaches the Earth's surface.

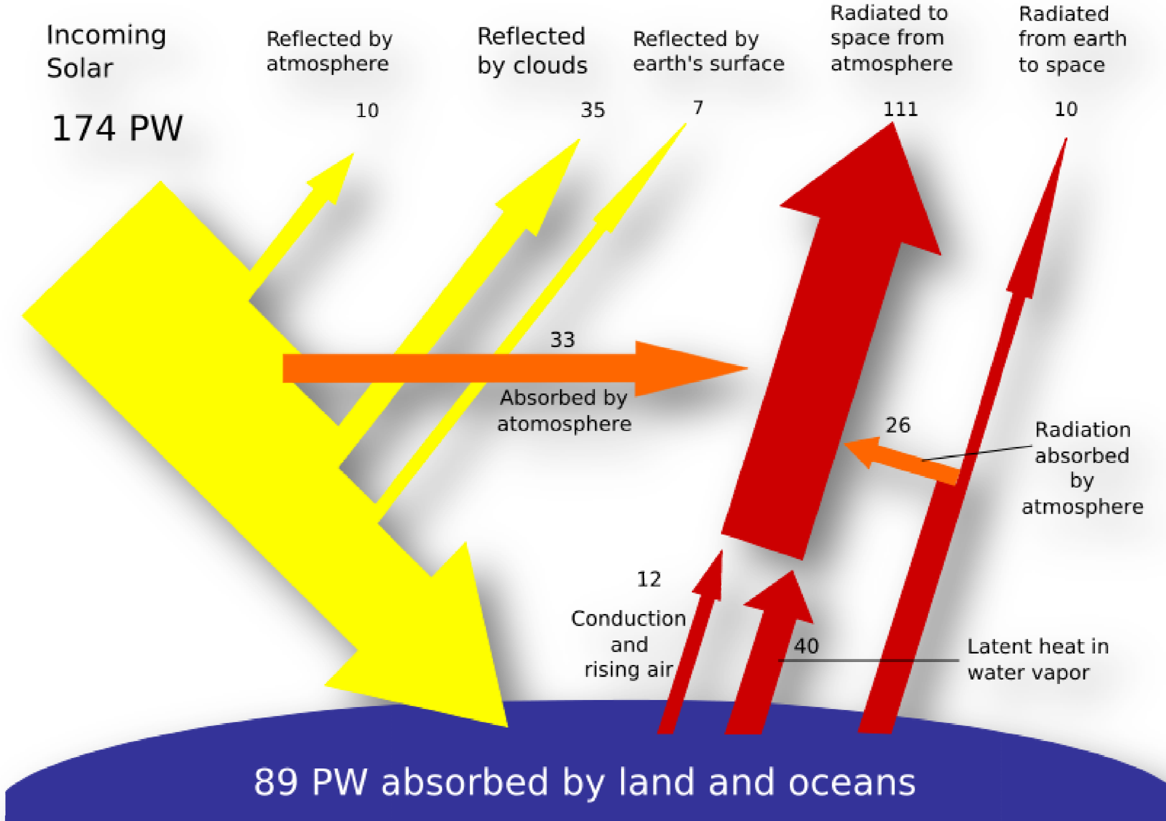


Figure 29 - Solar Energy on Earth[clxv]

Unlike terrestrial solar and wind power plants, space solar power is available 24 hours a day, 7 days a week, in huge quantities. It works regardless of cloud cover, daylight, or wind speed.

11.2 SWOT Analysis for Stationary Applications

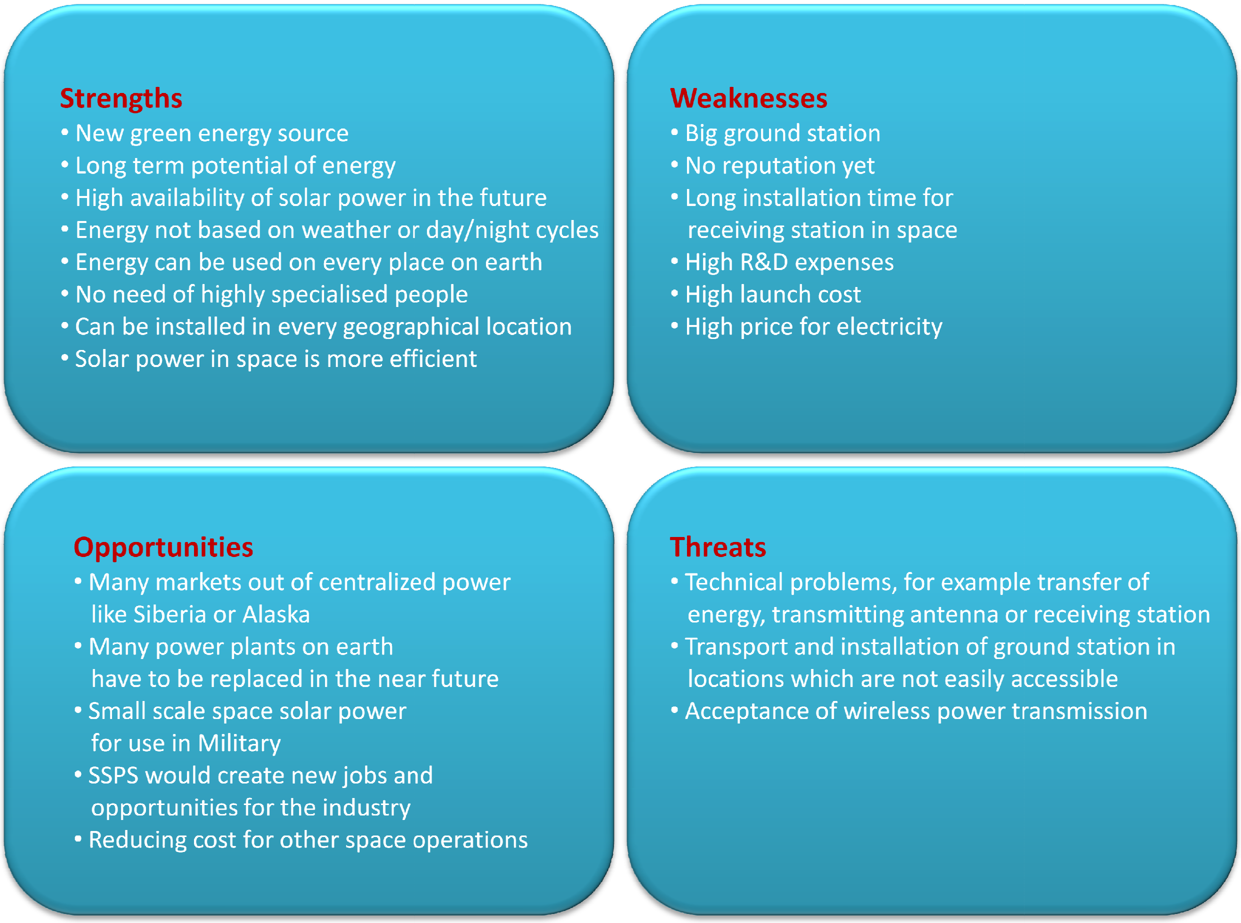


Figure 30 - SWOt Analysis for stationary applications

11.3 Market Analysis for Stationary Small Scale Applications

Small-scale applications come not only into play when people generate their own electricity with devices on their houses or in their gardens. Isolated regions like Alaska or Siberia can use small-scale applications to provide electricity to a whole village or small towns.

In countries like Russia 2/3 of territory is out of centralized power supply.[clxvi] Russia shows an intensive economic development in areas with weak or absent power infrastructure and even there are infrastructure constraints in the areas of centralized power supply. In 2007 2.3 GW of the total requests for new load connections were rejected.[clxvii] Huge renewable resources are needed because current technologies have many limitations.

Remote locations represent also research centers in Antarctica and small islands or group of islands. Some are located at high latitudes with harsh environmental conditions. The power demand reaches per location from 100 to 1,200 KW and more.[clxviii] This segment is relatively stable, since a certain amount of people will live in these places.

Remote locations with an increasing energy demand are found in developing countries. The current energy use as well as availability is small.[clxix] Providing energy to these locations seems to give direct benefits to the population like drinking water, cooking and telecommunication and not to mention the importance of environmental benefits. Using wood as main fuel resource leads to deforestation. The power demand can range from 10 KW to 10,000 KW and market is predicted to grow in developing regions.[clxx]

Growing trend in small-scale applications is also seen in other parts of the world like China, India and even the United States. The trend in the U.S. is towards smaller power generation units and therefore the small-scale energy market is expected to rise at an average annual growth rate of 16.6%.[clxxi]

Space-based solar energy will have lots of opportunities in the small-scale power supply market.

11.4 NPV for a Small Scale SSPS

Analysis of the NPV of space solar power in small scale applications is based on the assumptions taken in the 2nd set of the financial analysis of the classical system. The calculation of this NPV can be found in Appendix I.

Figure 31 provides the payback time and value of the system.

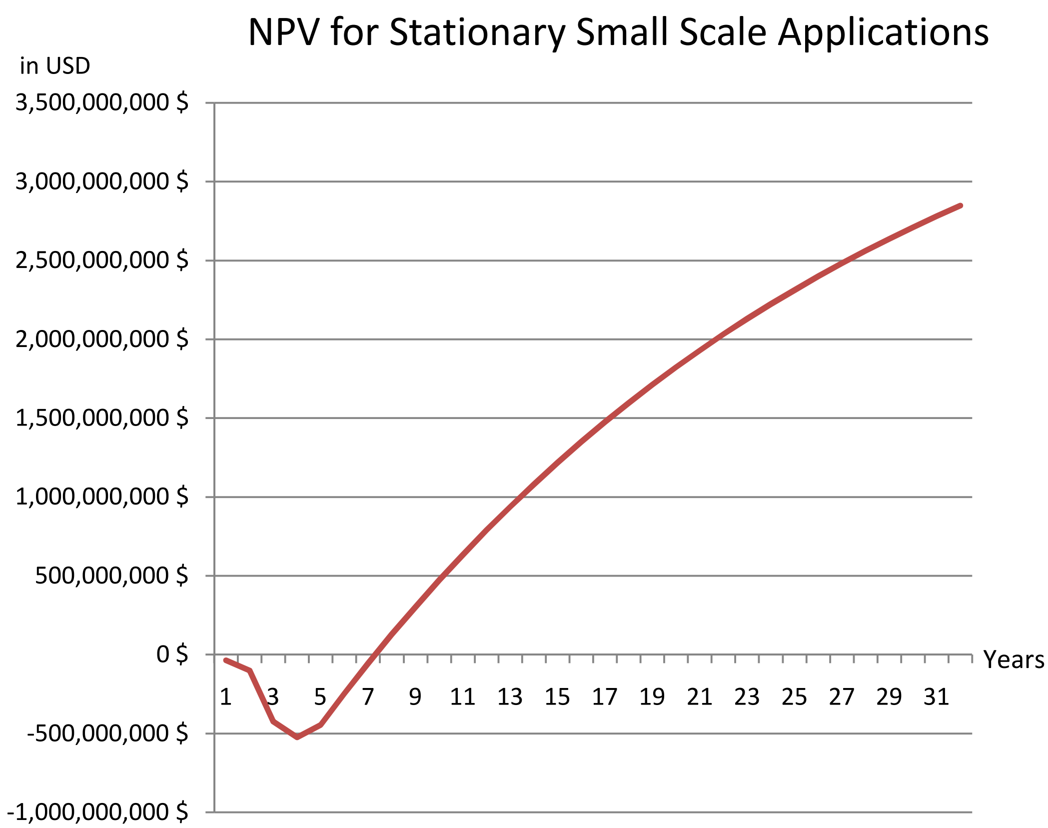


Figure 31 - NPV for Small Scale Applications

11.5 NPV for a Remote SSPS System

Analysis of the net present value (NPV) of space solar power in remote applications is based on the assumptions taken in the 2nd set of the financial analysis of the classical system. The calculation of this NPV can be found in Appendix I.

Figure 32 provides the payback time and value of the system.

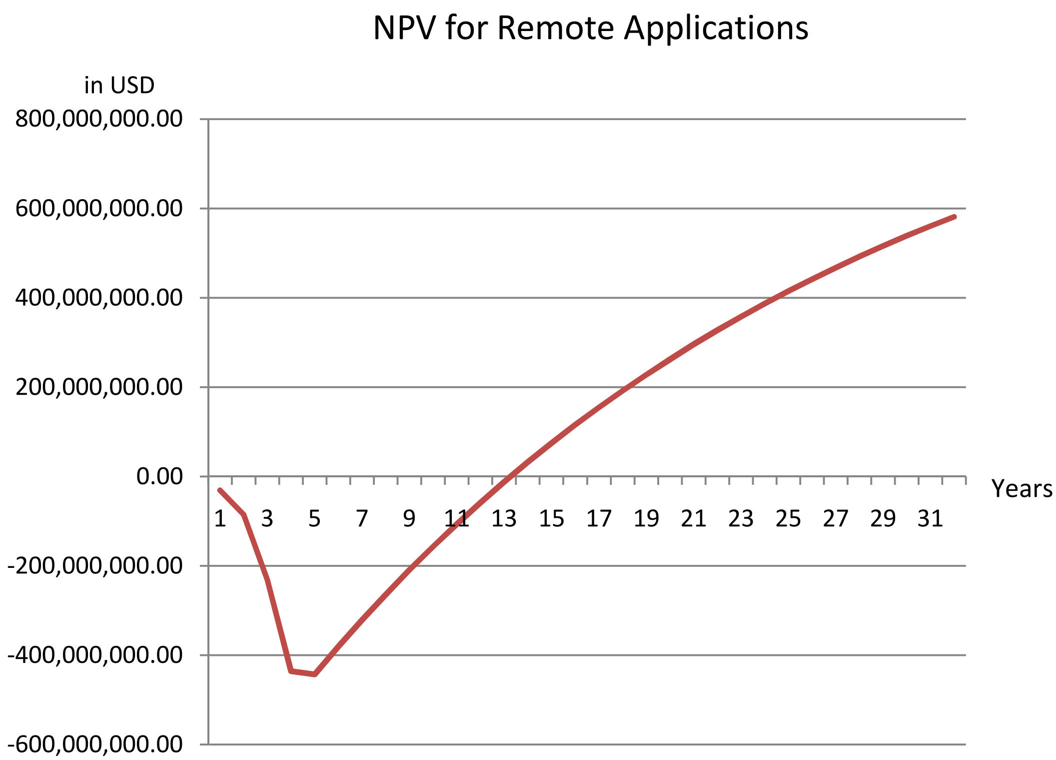


Figure 32 - NPV Remote Applications

11.6 Comparison to Various Generation Sources

Renewable energy systems generally generate small amounts of energy and therefore the competition in this segment is high. Table 3 lists all kinds of power generation technologies with their characteristics and typical cost.

Table 3 - Status of renewable energy technologies, characteristics and cost[clxxii]

Technology	Typical Characteristics	Typical Energy Costs (U.S. cents/kWh)
Power Generation		
Large hydro	Plant size: 10 megawatts (MW)–18,000 MW	3–4
Small hydro	Plant size: 1–10 MW	4–7
On-shore wind	Turbine size: 1–3 MW	5–8
	Blade diameter: 60–100 meters	
Off-shore wind	Turbine size: 1.5–5 MW Blade diameter: 70–125 meters	8–12
Biomass power	Plant size: 1–20 MW	5–12
Geothermal power	Plant size: 1–100 MW Type: binary, single- and double-flash, natural steam	4–7
Solar PV (module)	Cell type and efficiency: single-crystal 17%; polycrystalline 15%; amorphous silicon 10%; thin film 9-12%	15 - 22
Rooftop solar PV	Peak capacity: 2–5 kilowatts-peak	20–80[1]
Concentrating solar thermal	Plant size: 50–500 MW (trough), 10-20 MW	12–18[2]
power (CSP)	(tower); Types: trough, tower, dish	
Hot Water/Heating		
Biomass heat	Plant size: 1–20 MW	1–6
Solar hot water/heating	Size: 2–5 m2 (household); 20–200 m2	2–20 (household)
	(medium/multi-family); 0.5–2 MWth	1–15 (medium)
	(large/district heating); Types: evacuated tube, flat-plate	1–8 (large)
Geothermal heating/cooling	Plant capacity: 1–10 MW; Types: heat pumps, direct use, chillers	0.5–2
Biofuels		
Ethanol	Feedstocks: sugar cane, sugar beets, corn, cassava,	25–30 cents/liter (sugar)
	sorghum, wheat (and cellulose in the future)	40–50 cents/liter (corn)
		(gasoline equivalent)
Biodiesel	Feedstocks: soy, rapeseed, mustard seed, palm,	40–80 cents/liter
	jatropha, or waste vegetable oils	(diesel equivalent)

Technology	Typical Characteristics	Typical Energy Costs (U.S. cents/kWh)
Rural (off-grid) Energy		
Mini-hydro	Plant capacity: 100–1,000 kw	5–10
Micro-hydro	Plant capacity: 1–100 kW	7–20
Pico-hydro	Plant capacity: 0.1–1 kW	20–40
Biogas digester	Digester size: 6–8 cubic meters	n/a
Biomass gasifier	Size: 20–5,000 kW	8–12
Small wind turbine	Turbine size: 3–100 kW	15–25
Household wind turbine	Turbine size: 0.1–3 kW	15–35
Village-scale mini-grid	System size: 10–1,000 kW	25–100
Solar home system	System size: 20–100 watts	40–60

Note: Costs are economic costs, exclusive of subsidies or policy incentives. Typical energy costs are under best conditions, including system design, siting, and resource availability. Optimal conditions can yield lower costs, and less favourable conditions can yield substantially higher costs. Costs of off-grid hybrid power systems employing renewables depend strongly on system size, location, and associated items like diesel backup and battery storage.

([1]) Typical costs of 20–40 cents/kWh for low-latitudes with solar insolation of 2,500 kWh/m2/year, 30–50 cents/kWh for 1,500 kWh/m2/year (typical of Southern Europe), and 50–80 cents for 1,000 kWh/m2/year (higher latitudes).

([2]) Costs for trough plants; costs decrease as plant size increases.[clxxiii]

11.7 Providers of Small Scale SSPS

Provider for small scale space solar power could be general energy provider of renewable energy as for example Vattenfall Europe**.** Vattenfall's vision is to be a leading European energy company and our main products are electricity and heat. Their mission is to enhance our customers' competitiveness, environment and quality of life through efficient energy solutions and world-class service.[clxxiv]

Research bodies with research centers in regions with no access to electricity can be a possible provider.

Governments of countries could become an provider because they want to support their goals for their own renewable energy futures. Also the army or the air force of a country would be able to support their stationary base in other regions in the world where they don't have access to the central power system.

Even telecommunication companies like for example Safaricom which use only green energy technologies for their telecommunication systems could become a provider for small scale space solar power.

11.8 Stakeholders Involved

- Renewable Energy Company
- Telecommunication Firms
- Defence Firms
- National Defence
- United Nations
- Environmental Groups
- Local Population
- Government (national)
- Government (local)
- Local Authorities
- SSPS Generator
- System Operators
- Utility Company
- Academia
- Financial Institutions
- End User

12.0 Mobile SSPS Applications


Figure 33 - Field Power Distribution Unit

Mobile Space-to-Ground Solar Power Station MSGSPS: This will be a deployable system consisting of a self propelled truck with two trailers. Every major component will have the proper dimensions to fit in a C-130 Hercules cargo bay (12.3*3*2.7 m^3 – length/width/height). The trailers would carry, in 2 parts, the rolled multilayer rectenna (wire mesh type), and the poles required to deploy it. The truck will carry a crane to raise the poles and extend among them the rectenna, as well as the power distribution hub which contains the transformers and multiple sockets for the AC/DC outputs required to distribute power. The system will have the flexibility, by using multiple trucks together, to deliver as much power as required within the capacities of the SPS. But the basic unit will provide at least 1 MW; in other words, the system will be modular and scalable. Another characteristic of the system it will be its interoperability with other power generator systems. The rectenna will have the possibility of being used as a passive camouflage device for military applications, given the fact that the energy density over the rectenna will be below safety limits for human health. Figure 33 illustrates a field power distribution unit[clxxv].

Explaining in more detail: The reason for designing the system in modules that can be loaded into a C-130 is because this airplane is the main tactical airlifter in the world: “More than 2,100 C-130/Hercules aircraft have been built, and they are flown by more than 60 nations worldwide”[clxxvi]. The Hercules also exists in 3 civilian variants. Any load fitting in a C-130, fits more comfortably in a Boeing C-17 Globemaster or the future Airbus A-400M. This design feature would make the system available worldwide to many national and international users such as military forces and humanitarian organizations, among others.

Figure 34 - C-130J Hercules 1[clxxvii]

The type of truck recommended as the base for the system would be the Oshkosh HEMTT A3 (Heavy Expanded Mobility Tactical Truck) especially the model M977, which is a Cargo Truck with Incorporated Crane, it has an hybrid diesel-electric propulsion system and is by itself a back up Diesel Power Generator: “the onboard generator can deliver more than 100KW of military-grade AC power for external operations”[clxxviii]. Additionally, this truck has the advantage that when the MSGSPS is fully deployed most of the trucks can be used in other military applications, such as C4ISR (Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance centers), cargo transport and handling, troop movement, etc.

Figure 35 - Oshkosh HEMTT A3[clxxix]

The reason for the minimum 1 MW power delivered on ground, is purely economical, since technically is perfectly feasible but the cost per kW would make it unpractical.

The calculated cost for the basic system (1 MW of delivered power) is as follows:

Rectenna (490 m diameter)	8,454,446.00
Oshkosh HEMTT A3 with Crane (US $135.000 x 7)	945,000.00
Trailer (HEMAT M989 A1 at US $69.000 x 14)	966,000.00
Field power distribution unit (US $20.000 x 10)	200,000.00
Poles (US $2000 x 415)	830,000.00
1 MW Cost	11,395,446.00

Distribution of rectenna in the HEMAT trailer (15 panels)

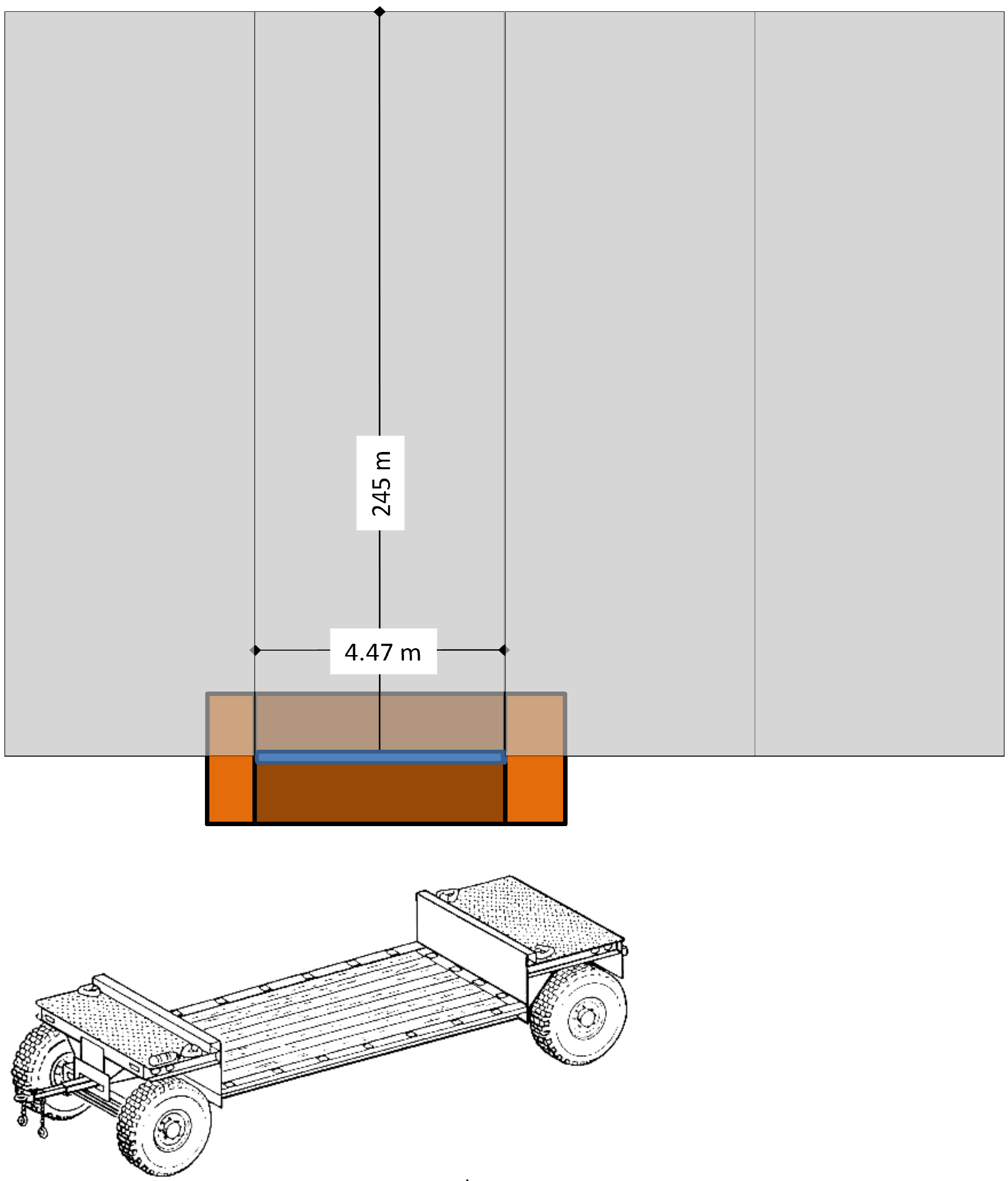
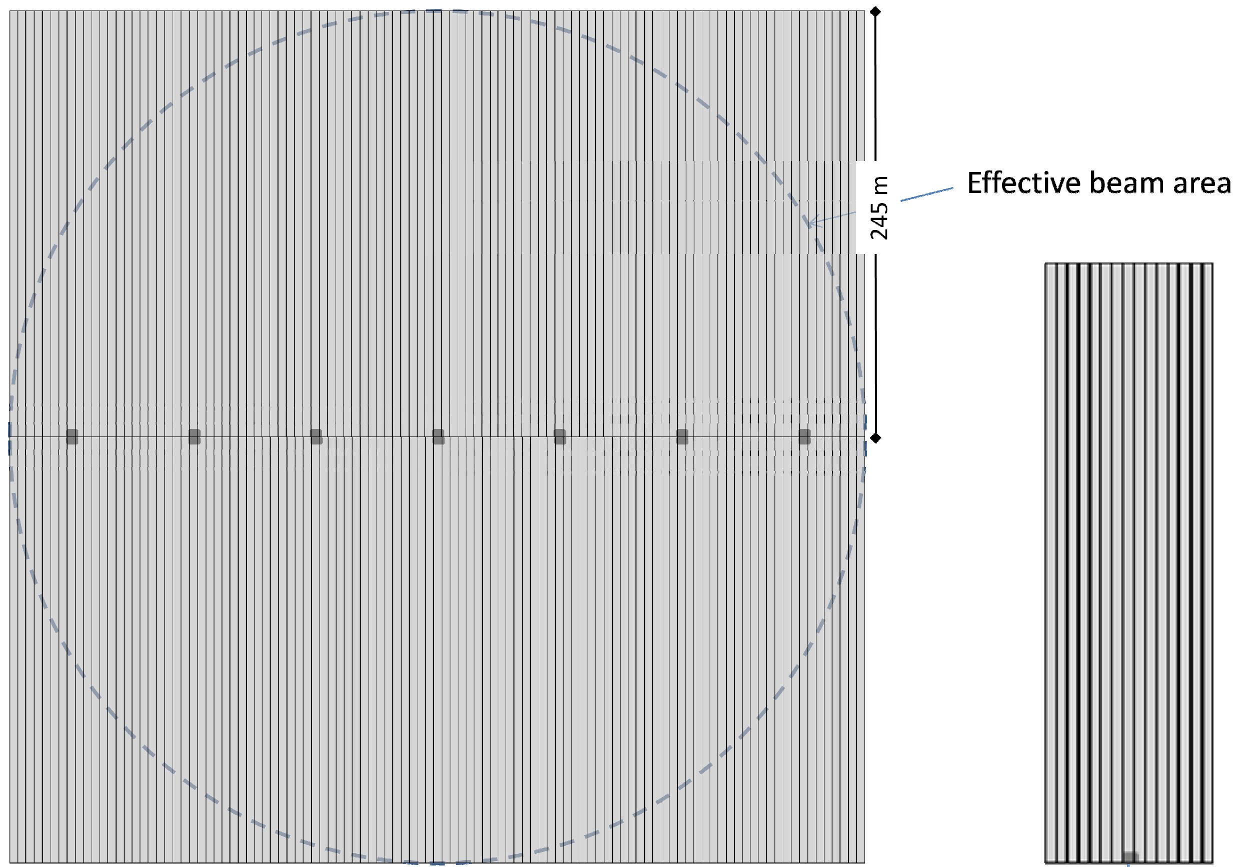
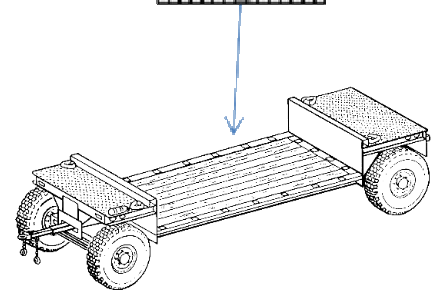


Figure 36 - Rectenna transport trailer[clxxx]





12.1 Market Analysis for Mobile Applications

Any “Out of the grid” non-permanent medium or big size operation such as Humanitarian Aid (Famine, Disaster Relief), certain commercial enterprises (Mining, prospecting,), and Rapid Deployment Military Forces or Non-Permanent Military Units, such as a Forward Operations Base, face the logistical, economical and even security drawbacks of their isolation and distance from usual power sources.

“When disaster strikes, electric power is usually the first critically important service to be lost. And the effects can be devastating”[clxxxi] worsening even more the conditions for survivors. Therefore, one of the first tasks of survivors and emergency teams is to restore power. Usually the only way to do this in a quick manner is by means of fossil fuel gen-sets. But this brings its own problems; noise, pollution and danger. “In the wake of a major disaster such as a flood, tornado, earthquake, hurricane, or fire, newspapers often report incidences of fires, burns, fuel explosions, and even asphyxiations caused by the improper use of a generator”[clxxxii]. And then there's the problem of transporting and storing the fuel needed by those generators, without which they would be useless.

Not as dramatic, but of great economical impact, operations performed by different industries in search of new resources in isolated, underdeveloped or offshore regions need to count on reliable and constant power. But they have to deal with significant increase in cost because difficulties to transport and store the fuel used for generating that power.

As was clearly explained previously, military services which need to deploy and stay for a moderate period of time in one position, face not only the difficulties of transporting and storing fuel for their generators, but also they need to protect their supply lines from attacks by the opposing forces. Such situation produces a skyrocketing cost structure, reduces the operational effectiveness of the forces because they need to dedicate personnel, equipment and time to escort and safely store the fuel, and makes the force vulnerable to attacks in a highly sensitive part of its logistic chain.

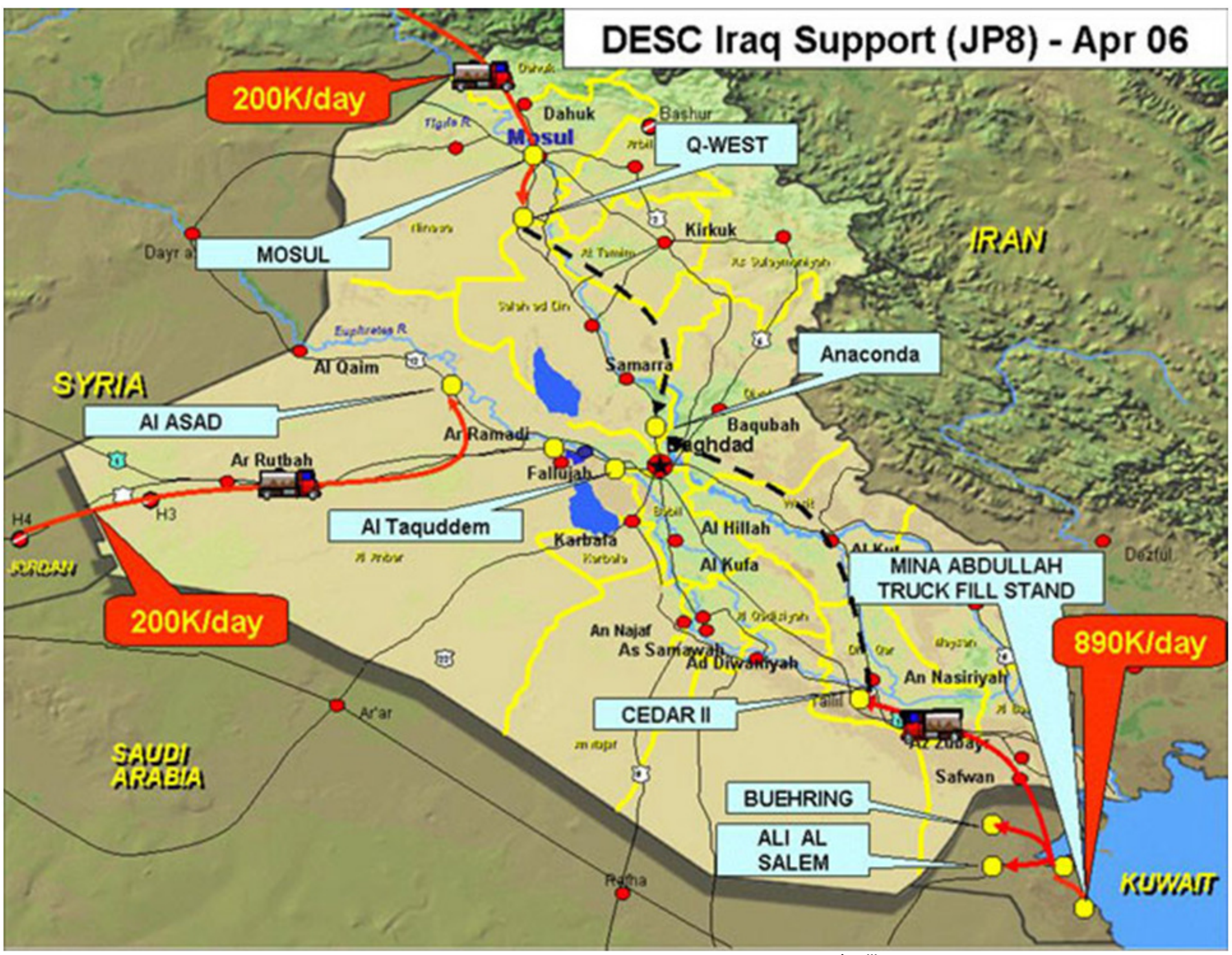


Figure 37 - Support structure of US forces in Iraq[clxxxiii]

Given the previously stated situations, why hasn't the market produced a viable solution? Reasons include high dependency on oil and on the infrastructure around its energy chain (production, transportation, and consumption), entire industries and even economies that exist around oil (powerful vested interests). High upfront development costs for replacing technologies with no guarantee of adoption (no concerted effort) since there are various energy chains that can be used to replace the traditional ones of Fuel Oil and Diesel Oil, some are: Natural Gas, Biomass, Coal, Enriched Uranium (Nuclear energy), Geothermal, Wind, Tidal, Gravitational, Thermo electrics and Solar both as Photovoltaic and as Microwaves as proposed by SSPS.

But the costs of keeping the actual answer to the needs posed by being "out of the grid" are very high and problematic. Such situation it will worsen in the foreseeable future. Non-renewable energy sources are being depleted with consequent scarcity and price increasing. Concerns over the impact on the environment and on human health, the so called external costs (the monetary quantification of its socio-environmental damage, as defined by the Directorate General for Research of the European Commission[clxxxiv]) grow in amplitude and strength. And the taxation and normative restrictions becomes heavier as time passes.

As can be seen in the following Graphics of the study "External Costs: research results on socio-environmental damages due to electricity and transport" developed by the Directorate General for Research of the European Commission, the alternatives to replace Fuel and Diesel Oils are either very new, not constant (scarce and unreliable) or have high impact in terms of pollution and/or green house effect. In the study Solar was considered as a "very clean technology at the use stage, but has considerable life cycle impacts" that's why it wasn't included in the graphic.

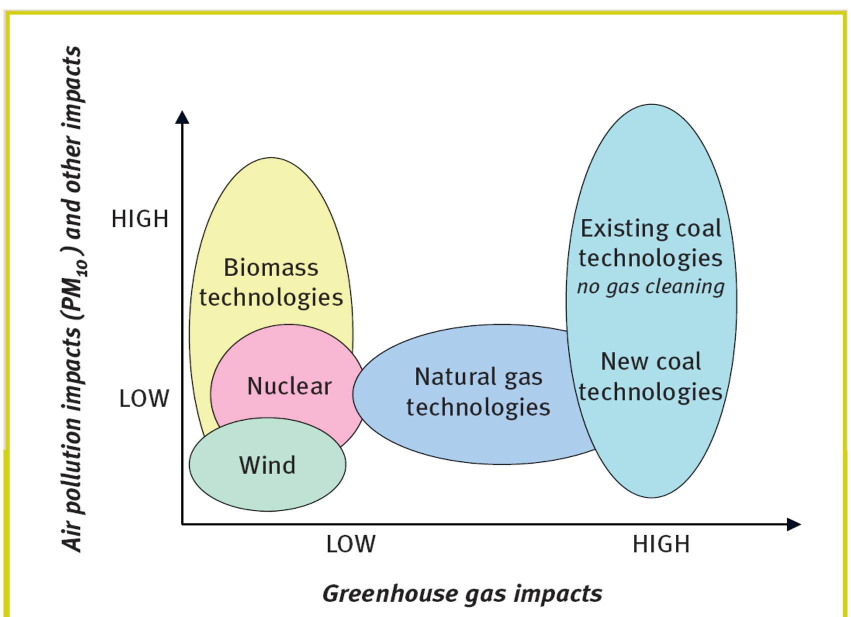


Figure 38 - Comparison of various generation technologies[clxxxv]

Analysis of the NPV for Military SSPS application is based on the assumptions taken in the 2nd set of the financial analysis of the classical system. Figure 39 provides the payback time and value of the system. The price per kWh is adjusted to reach a positive NPV. The calculation of this NPV can be seen in Appendix I.

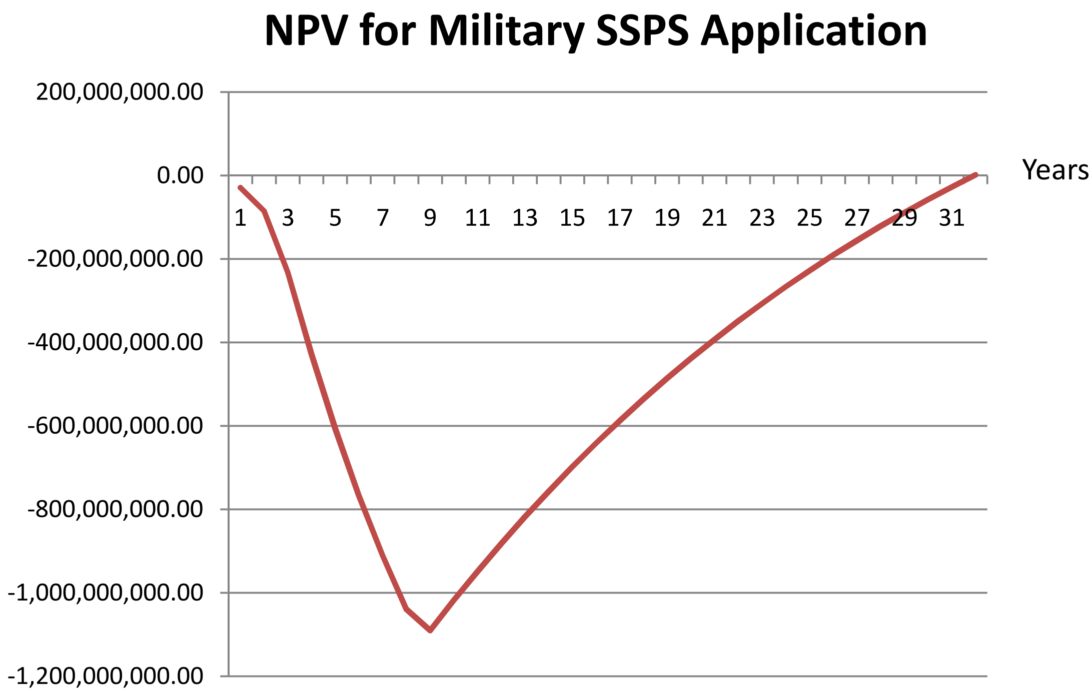


Figure 39 - NPV for Military SSPS Application

Figure 40 - Various cost figures for electricity production[clxxxvi]

EXTERNAL COST FIGURES FOR ELECTRICITY PRODUCTION IN THE EU FOR EXISTING TECHNOLOGIES[1] (IN € CENT PER KWH*)

Country	Coal & lignite	Peat	Oil	Gas	Nuclear	Biomass	Hydro	PV	Wind
AT				1-3		2-3	0.1		
BE	4-15			1-2	0.5				
DE	3-6		5-8	1-2	0.2	3		0.6	0.05
DK	4-7			2-3		1			0.1
ES	5-8			1-2		3-5**			0.2
FI	2-4	2-5				1			
FR	7-10		8-11	2-4	0.3	1	1		
GR	5-8		3-5	1		0-0.8	1		0.25
IE	6-8	3-4							
IT			3-6	2-3			0.3		
NL	3-4			1-2	0.7	0.5			
NO				1-2		0.2	0.2		0-0.25
PT	4-7			1-2		1-2	0.03		
SE	2-4					0.3	0-0.7		
UK	4-7		3-5	1-2	0.25	1			0.15

* *sub-total of quantifiable externalities (such as global warming, public health, occupational health, material damage)*
** *biomass co-fired with lignites*

QUANTIFIED MARGINAL EXTERNAL COSTS OF ELECTRICITY PRODUCTION IN GERMANY[2] (IN € CENT PER KWH)

	Coal	Lignite	Gas	Nuclear	PV	Wind	Hydro
Damage costs							
Noise	0	0	0	0	0	0.005	0
Health	0.73	0.99	0.34	0.17	0.45	0.072	0.051
Material	0.015	0.020	0.007	0.002	0.012	0.002	0.001
Crops	0	0	0	0.0008	0	0.0007	0.0002
Total	0.75	1.01	0.35	0.17	0.46	0.08	0.05
Avoidance costs							
Ecosystems	0.20	0.78	0.04	0.05	0.04	0.04	0.03
Global Warming	1.60	2.00	0.73	0.03	0.33	0.04	0.03

[1] *Global warming is valued with a range of damage cost estimates from € 18-46 per ton of CO_2*

[2] *Median estimates; current technologies; CO_2 emissions are valued with avoidance costs of € 19 per ton of CO_2*

12.2 Stakeholders Involved

As part of the stakeholder analysis done for the purposes of this study, six segments were defined in terms of type of involvement regarding SSPS technology. For the specific case of Mobile Applications, only those with High levels of Commitment/Interest or Influence/ Relationship are listed, those with a (-) sign indicates and opposing position against this technology:

- SSPS development company
- National Defence
- Defence Firms
- Satellite Services
- Electronics and related devices manufacturers
- Space agencies
- Launch services
- Peace Activists (-)
- Fossil Fuel Energy Generator (-)

12.3 SWOT Analysis for Mobile Applications

Strengths
- Lower development cost
- Flexibility
- Responsiveness
- Interoperability
- Enabled by existing technology
- Sturdiness of components
- Low operating costs
- Reliability
- Autonomy
- Cleanliness
- Modularity
- Scalability

Weaknesses
- Weight of ground component
- Size and Area of rectenna
- Dependence on SSPS development
- Medium-High development price
- High cost of generated power

Opportunities
- Many potential customers
- Ever growing demand for energy and non-polluting energy
- Scaled up replacement of traditional energy sources
- New business area
- Access to space technology and applications for remote or undeveloped areas
- High % of population without permanent energy supply
- Interesting subject from the media perspective

Threats
- Availability and price of alternative energy sources
- Strong opposition from peace activists regarding military applications
- Opposition from fossil fuel energy generators
- Bad perception on impact over human health

Figure 41 - SWOT Analysis for mobile applications

13.0 Recharging Wireless Devices

With the rapid development of information technology and people's living standards, portable consumer electronic devices have become an essential part of life. At the end of 2008, the global mobile phone users have more than 4.1 billion; the popularization rate reached 61.1% and sustained growth, particularly developing countries, such as China, India and Africa, the volume of mobile phone users have increased rapidly. Other digital cameras, notebook computers, MP3 and PDA products users also continue to grow.

These consumer electronic devices rely mainly on their internal embedded battery-powered. As the battery has run out of its power, it needs a fixed power connection to recharge it.

This is very inconvenient to use in our travel and business trip, we often have to carry other spare batteries, charger, power adapter and other accessories to ensure that these devices work normally. Even if doing so, we will often encounter a number of special environment which has no fixed power connection and unable to charge cell phones and other equipment, leading to some unexpected results, such as no communicating with the outside world in the emergent situation, the important data loss.

At the same time charging equipment increase additional volume and weight, inconvenient to carry, purchase and maintenance costs increase, battery scrap also become a source of environment pollution. So finding a wireless charging method for mobile devices which is sustainable and reliable, wherever and whenever, environment friendly and no harmful to the human’s health and will be significant market opportunities and competitive advantage.

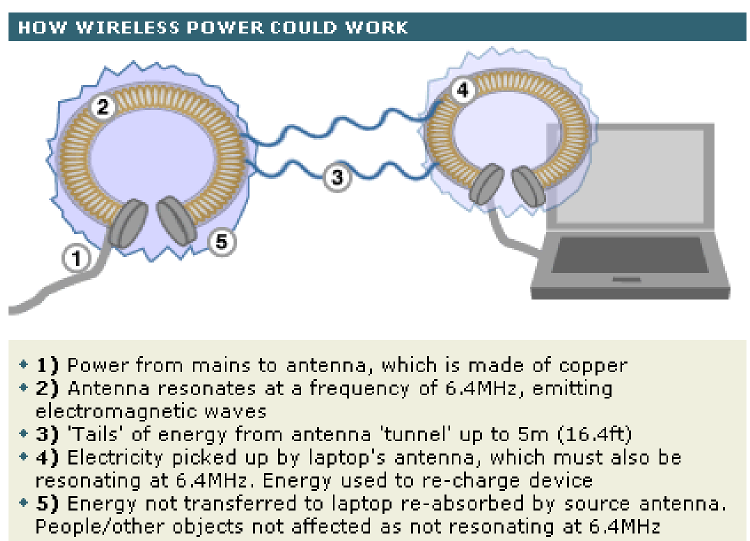


Figure 42 - Example of how wireless power could work

Generate electricity using wireless power to provide energy for these mobile devices could be a good option. Wireless power is becoming a popular concept in the consumer segment since there is a huge need for a more convenient way of powering portable devices and eliminating the hassle of several chargers and wires. Now many organizations and companies have carried out the research of this technology, and have achieved a breakthrough in the development of a variety of portable wireless charging devices, which mainly transmit radio frequency (RF) power energy to receiver and recharge your cell phone[clxxxvii, clxxxviii].

13.2 Niche application

As we mentioned in previous section, utilize RF wireless energy transmission to charge the mobile phone is feasible in future. Figure 43 show us the functional block diagram inside mobile phone. Now we need redesign a new type of mobile phone, named “QX5”, to meet this application. Our idea is to use the present antenna of mobile phone to receive the signal, which is RF wave, and carry the electricity power, redesign and add a new part to separate the signal and amplify the power to recharge the mobile phone, as Figure 43 show.

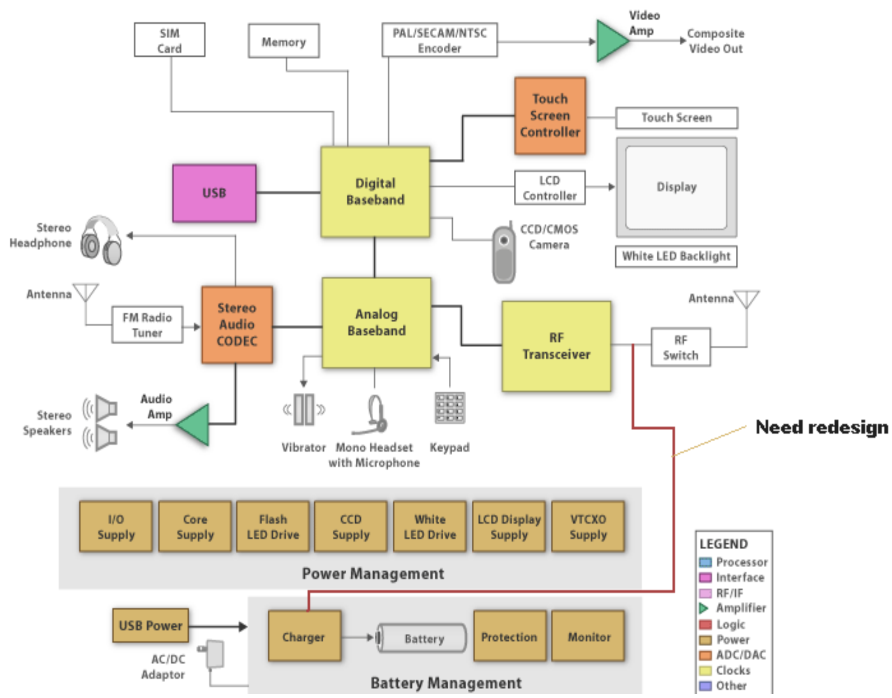


Figure 43 - Internal functional block diagram of mobile phone

We issue this niche application in order to make people more convenient with wireless energy and try to make profit to fund the SSPS project in future.

The QX5 cell phone can receive RF signal via antenna from Terrestrial-based signal transmit and receive tower, another way is that receive directly from communication satellite.

Our criteria to choose RF transmit source is:

- Utilise the present communication network as much as possible.
- No more technology change and cost added for main stakeholders.
- Cover the most personal mobile communication user.

13.3 Transmission Comparison

From the analysis indicated in Appendix G, we can see that there are advantages and disadvantages of three different transmission methods. According to the selection criteria, we summarize and give the grade each factor as follows:

The Assessment of Three RF Transmission Methods			
Main Factors	GEO Communication Satellite	LEO Communication Satellite constellations	Terrestrial-based cellular phone systems
Network in existence	YES	YES	YES
Coverage	GLOBAL	GLOBAL	Main area(depends on amount of base tower)
User amount	Not suitable for personal mobile communication	SMALL	HUGE (4.2Billion at the end of 2008,and increase 20% per year)
Technology change	BIG	SMALL	SMALL
Cost added	R&D cost is highest(QX5 need another antenna to receive different frequency)	No enough users and now operators(e.g.iridium,globalstar) lose money , operational cost is very high.The usage charge high and user cann't affordable and accept in short-term	R&D cost lower than GEO and LEO methods,because QX5 just need to R&D a small part)
Feasibility	Low	Low	High

Table 4- Assessment of RF Transmission Methods

So we prefer to utilize terrestrial-based cellular phone system to realize the QX5 project.

13.4 SWOT analysis of QX5 application

In this section, we use the SWOT analysis tools to indentify the probably project's strengths, weaknesses, opportunities and threats in different aspects, such as market, finance, environment and so on.

Then we can know where we are now and what we need to do. The result of SWOT analysis is presented below in Figure 44.

Figure 44 - SWOT Analysis for QX5

13.5 Business Model

In this application, we use the GSM terrestrial-based cellular phone systems at present, and as we mentioned earlier we could use 900MHz frequency, the same with GSM's radio frequency, to recharge the QX5 cell phone. So for the mobile operator, they would not need to reinvest or change anything. On the other hand mobile phone manufacturers only need to develop a new type of receiver which can convert radio frequencies into electricity to charge the phone. Perhaps manufacturers have not imagined this idea; or else their own R & D costs for this idea are too high.

Our vision of the "QX5" application is to make people more comfortable with the idea wireless power energy; in addition we make profit from this idea and help to fund the SSPS.
So we prefer to develop new enabling technology through investment in R&D and have fostered competition by broadly licensing the rights to use our patented technology. Further, we provide customers the opportunity to easily and quickly develop and introduce their products by providing chipset solutions that integrate our technology.

"Imagination is more important than knowledge."

- Albert Einstein

Einstein's words ring true today, because intellectual property (IP), and its innovative implementation, is driven by the power of imagination.[clxxxix]

As we know, QUALCOMM embraces this philosophy of using imagination and innovation to drive technological advances that benefit end users. According to Dr. Irwin Jacobs, one of QUALCOMM's founders and its chairman, "We started QUALCOMM with the idea that we would try to be innovative – look for an idea that could make a significant difference."[cxc]
For more than 20 years, QUALCOMM has invested significantly in research and development (R&D), which has resulted in thousands of innovative ideas, methods and products that have changed the wireless world.

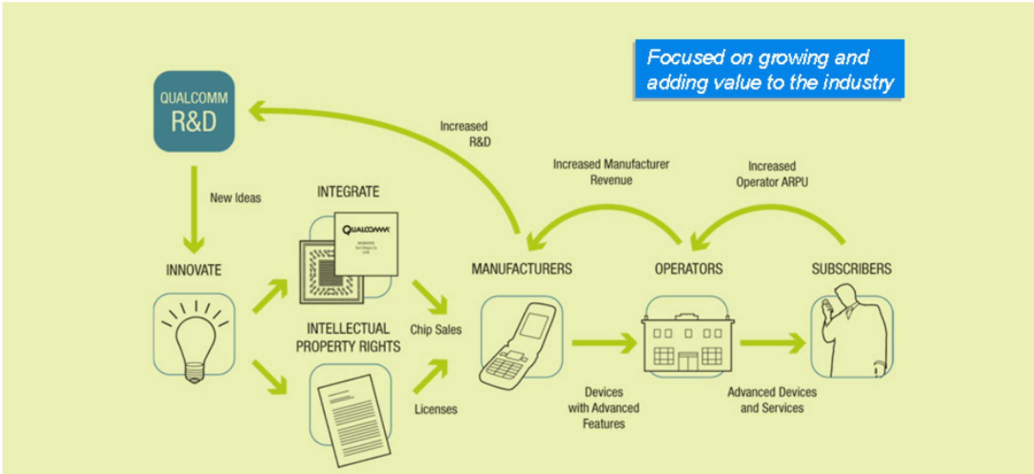


Figure 45 - QUALCOMM Business Model - Technology Enabler

As illustrated in Figure 45, QUALCOMM has pioneered a new business model, based on accelerating and focusing its Internal R&D, in addition to selling chipsets and patent, license, which enable system and device manufacturers to get to market faster and at lower costs than if they conducted all their own R&D and integrated their own chipset and software solutions.

By driving invention, broadly licensing the innovations and providing equipment vendors with complete chipset and software solutions, QUALCOMM is enabling suppliers to bring infrastructure, test equipment and mobile devices to market more quickly and at lower cost. It is enabling operators to offer richer and more compelling services to subscribers at a lower cost. Equally important, it is enabling end users to gain access to mobile communications and the Internet at a rate inconceivable only five years ago.[cxci]

Qualcomm's business model has gained a great success, our idea in "QX5" application is very similar with this model, so we will refer to and adopt Qualcomm's business model. We invested significant amounts in R&D, protected its innovations with patents, commercialized the new technologies by incorporating them in its chipsets, and broadly licensed its technologies to expand the number of vendors participating in the market.

13.6 Market and Financial Analysis

13.6.1 Market Analysis

Mobile phone subscribers worldwide had hit the four billion by the end of 2008, reached 4.1 billion, 60% of the world's citizens have access to mobile phones. This is according to a recently released UN report. Most of the increase in cell phone usage will be from the rapidly developing economies of Brazil, Russia, India, and China, which altogether account for over 1.3 billion mobile phone subscribers by year-end.[cxcii]

Now the GSM cell phone users are up to more than 80% of total users, base on iSuppli[cxciii] corporation's forecast ,the global mobile phone market shipments will reach 1.22 Billion in 2009 and from 2010-2012,the total shipments will reach 4.22 Billion. Another forecast is the duration of update a new cell phone is 8 months. Although the sales of mobile phone are in temporary downturn due to financial crisis, it will recover by 2011.

By analyzing, we can see that the global mobile phone users will continue to grow. Despite the financial crisis, the handset manufacturers have lowered the expected shipments, but the mobile phone sales remained at a high level and will increase after 2011. Therefore, the mobile phone market has good prospects. R&D will get the cell phone charging standard, which use the GSM RF signal, produce the chipsets in three years, then sell the chipsets and through patent license and technology transfer profits can be made.

13.6.2 Financial Analysis and NPV Calculation

We adopt the Qualcomm's business model and we invest in R&D of GSM RF signal recharge QX5 standard and produce the ASIC chipsets, we earn the profit by three ways：

- Patent license to mobile phone manufacturers.
- Sell chipsets to mobile phone manufacturers and charge fee from the revenue of mobile phone manufacturers.
- Charge fee from mobile communication operator. Because if the mobile phones have sustainable electric power, the users can make more phone calls, so the revenue of operator can increase.

In order to calculate the NPV of QX5 application, we make assumptions according to Table 5.

Factors	Value	Note
1. Cost of capital	7.87%	Industry Average Standard, QUALCOMM is 8.85%[cxciv]
2. Tax	24%	Industry Average Standard[cxcv]
3. Depreciation Rate	10%	
4. Working Capital	30% of Revenue	Reference from Qualcomm Annual Report
5. Objective QX5 manufacturer	6	Main cell phone manufacturers
6. Number of QX5 manufacture every year	1	
7. The first three years Investment in R&D and product	100,000,000	invest 10% of Total revenue after enter market
8. IP/Patent usage fees per new QX5 manufacturer	5,000,000	1/3 of Qualcomm's patent charge standard
9. Cost of workforce per person per year	40,000	
10. Wage increase rate per year	3%	
11. Number of total worker in R&D phases	200	
12. Number of each QX5 manufacturer can sell in first year	200,000	This number increase in first 5 years. After 5 years later, The highest market share of manufacturer can sell 100,000,000 QX5,(Nokia sell 157 million GSM phones per quarter).Base on the market share (Figure 46),other manufacturers can sell related amount
13. The price of QX5	100	
14. Charge fee per QX5	3.0%	base on Qualcomm standard(2.5%-5%）
	3	
15. Charge from operator	1	
16. Cost of per chipsets	5	
17. The price of per chipsets	7	
18. Marketing per year	20,000,000	The first three years are 5,000,000 5,000,000 and 40,000,000. After R&D and enter the market is 20,000,000 per year.

Table 5- QX5 Financial Assumptions

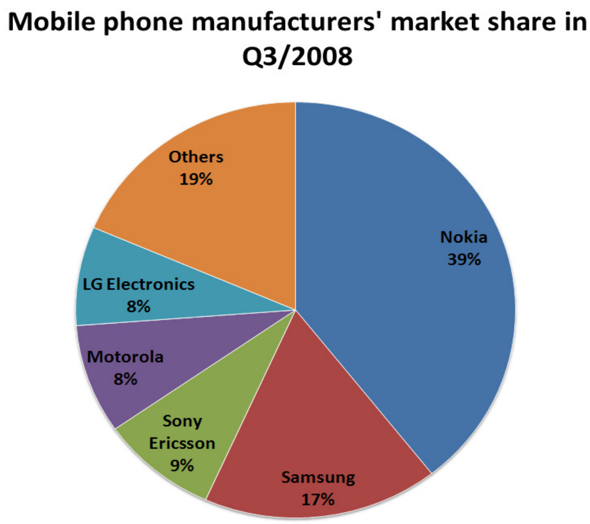


Figure 46 - Main Mobile phone Manufacturer's market share in quarter 3/2008

Based on the assumption, we calculate the NPV of QX5 application project is equal to $ 3.7B.USD and we reach the pay back point at 2014 and breakeven point at 2017.Figure 47 shows the lines of Free Cash Flow and Cumulate Discount Cash Flow.

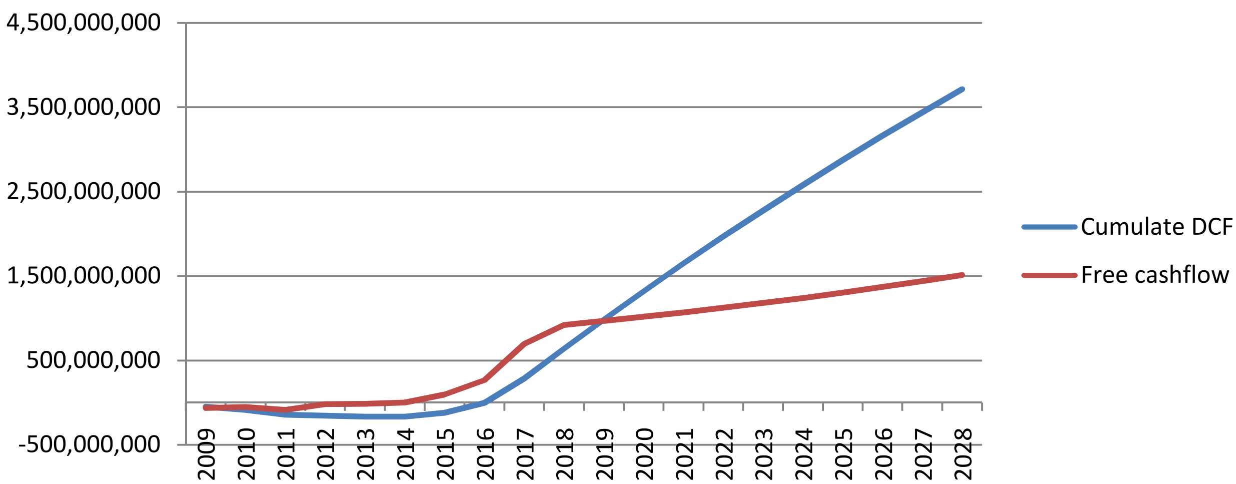


Figure 47 - NPV of QX5 application project; assuming 2009 as year zero

13.7 Main Stakeholders

According to our business model, we use the stakeholder assessment standards[cxcvi] to identify and classify the main stakeholders of this QX5 application project and their interest, relation and influence to the project. The main stakeholders of this application have been defined as:

1) Academia
2) QX5 Manufacturers
3) Electronic Manufactures
4) Operator
5) End QX5 User
6) Other Wireless Power Recharge Technology Company
7) Financial Agency
8) WIPO: World Intellectual Property Organization
9) ISO: International Standards Organization
10) ITU: International Telecommunications Union
11) WHO: World Health Organization
12) Governments

We can see from this list that the operators, chipset manufacturers, mobile phone manufacturers and end-user are the main stakeholder of this QX5 application project.

- **Mobile phone manufacturers:**
  They hope that through the use of new technologies and at a lower cost to increase product innovation, promote the competitive advantage. By increasing the mobile phone shipments to increase market share then increase the company's revenues and profits, realize the sustainable development.

- **Electric chipsets manufacturers:**
  As the main supplier's partners of the project, they really want to lower chip costs and increase revenue through economies of scale.

- **Mobile communication operators:**
  They hope that does not change the ground base station and the signal transmission frequency, so as not to increase the company's new investment and operating costs. The achievement of QX5 project can increase the use time of mobile phone users, they may make more phone calls and send more SMS, so that can increase the operator's income. At the same time because the phone can be assured by enough power energy, which operators can provide high value-added services to reap greater profits. After Operators make profit and earn more money, they could construct more ground base stations to improve coverage. This is sustainable development circle.

- **End mobile phone users:**
  Under the case of not increasing the charges, ensuring personal safety and health, the users really want to have convenient experience which bring about by high-tech features and new services ,improve the quality of life.

The key stakeholders can benefit from the project, while the level of their co-operation, participation and commitment to the project has important impact. Therefore the project should pay attention to these key stakeholders and meet their needs. Also we should not lose sight of other stakeholders, and try to do sufficient communication and coordination with them, so that they can understand the benefits of projects, to enhance their positive support and influence the project. Thus we can mitigate the risks of QX5 program.

13.8 Conclusion

Through studying the existing mobile communications and RF transmission charging technology, we select to use the frequency of GSM signal, which using the base station tower transmission based on the ground. By redesigning the mobile phone receiver, amplifying and rectifying the RF wave signal to recharge the QX5 mobile phone.

Use of our business model, which refers to Qualcomm's model , we should invest in research and development this kind of wireless power energy, establish the technical standards and integrate them into chipsets, through charging the fee of patent licenses and technology transfer fee from the handset manufacturers, mobile communication operators ,we can earn the income and profit. We analyze the cell phone market over the next few years and mobile phone manufacturers' shipments of mobile phone.

Based on reasonable financial assumptions, we calculate the NPV of the project QX5.The result shows that this project is profitable and available in the next 20 years; it can help to provide the SSPS projects for a total of more than 3.5 billion of funds.

Meantime, for main stakeholders, QX5 applications can increase the convenience of end-users, also the mobile phone manufacturers can increase revenue and market share, and mobile communication operators can increase functionality and new services to increase revenue and profits. This application will be a win-win project.

Therefore, we can conclude the QX5 application is feasible.

Part 3: Alignment of Classical and Small Scale SSPS Applications

14.0 New Vision for SSPS

This section will focus on combining the results of the classical SSPS system with the results of the niche applications as defined previously in sections 11 through 13. Once this has been completed we will suggest changes to the current organizational framework as outlined in section 8. These changes will seek to find a more effective way for the SSPS concept to move forward and become a reality.

14.1 Classical SSPS Results

As we have seen in section 8, a single organization operating as a prime contractor cannot succeed on its own due to the immense front end cost of the research and development phase. Furthermore the small improvements caused as a result of the voluntary green tariff program and 2.5% electricity bills, although helpful, were not able to make a significant difference.

The best NPV's that could be obtained for SSPS Case 1 and Case 4 in this organizational model were -71 and -59 billion USD respectively.

Combination of Classical and Niche Applications

In Part 2 of this report we explored different niche applications of SSPS technology which might serve to help the classical SSPS come to life. Specifically these niche SSPS applications were intended to perform the following functions:

1. Share the development cost through technological synergy with similar products.
2. Educate the public in regards to wireless energy transfer.
3. Provide a revenue stream to help offset the large development costs.

The different variations to the SSPS concept that we considered were:

1. Small scale fixed location use, such as for remote locations or individual cities.
2. Applications for mobile military and humanitarian missions which could operate much more effectively if relieved of their heavy reliance on fossil fuel.
3. The self charging cell phone QX5.

Individually without taking into account the large research deficit faced by the classical system, each of these applications is almost guaranteed to be a profitable venture. Indeed as seen in Part 2, they were.

Since the niche applications would hypothetically be easier to construct (and certainly are cheaper) we can assume that they can be built faster and started sooner in the research curve then the classical SSPS. If we assume that the company which is producing the SSPS is also producing these niche applications, we expect that the profitability of the company would increase towards a positive NPV.

We will now take into account such an operation. Presuming that the SSPS organization is building one of each of the proposals including a full operation of QX5 class cell phones, we calculate the NPV to be significantly improved. From Figure 48 below, we can see that with the addition of all applications the NPV becomes “only” -7.7 billion USD. This is still a negative NPV however it at least one order of magnitude better than the previous results.

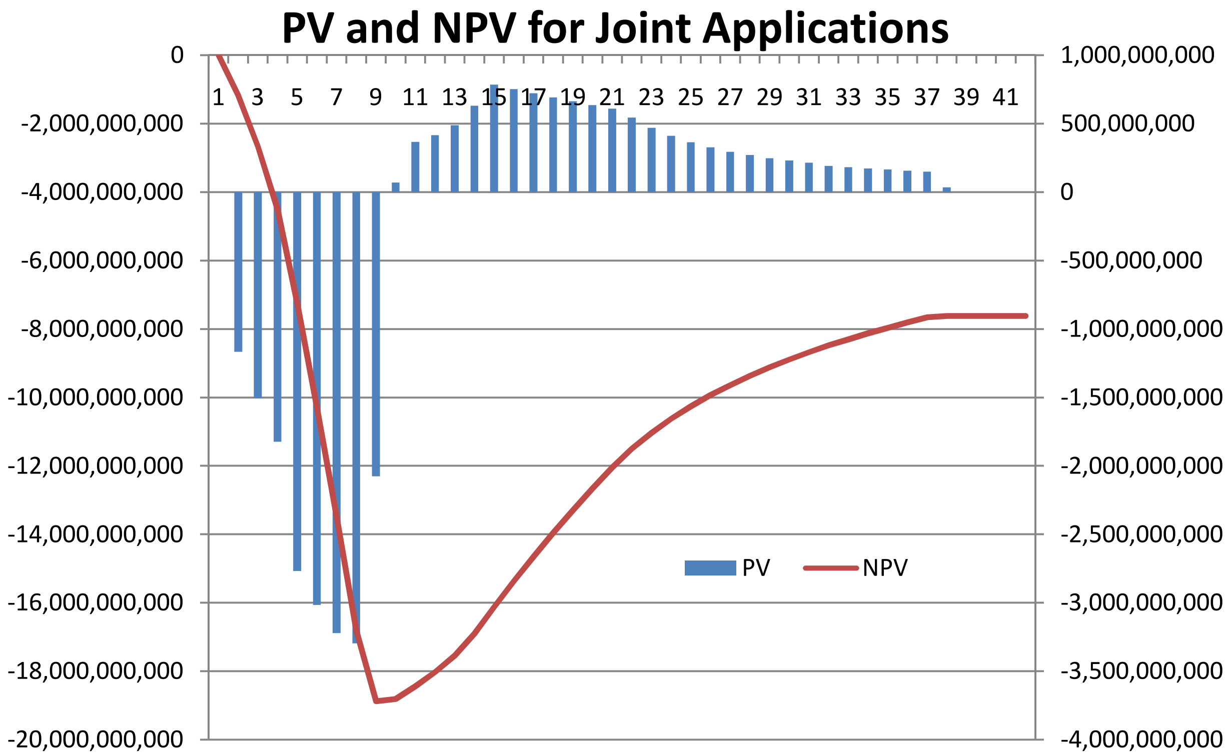


Figure 48 - NPV (left) and PV (right) for a combination of classical and niche applications

This particular calculation consists of the following products:

1) 1x Military satellite selling energy at 11.45USD per kW/h
2) 1x Lifecyle NPV for QX5
3) 1x A small scale satellite providing energy to a remote site at 0.58$ per kW/h
4) 1x A small scale satellite providing energy to an urban site at 0.08$ per kW/h
5) 1x A single classical system providing energy to the electricity grid at 0.08$ per kW/h.

14.2 Discussion of Results

The lesson from this exercise is not that a certain combination of these products will create a magic elixir and therefore a positive NPV. The lesson is instead that a volume of products delivered, as early as possible, will in fact shift the NPV from a negative value to a positive value.

As an example if we increase the number of small scale urban satellites (#4 above) to three, the NPV changes to +351 million USD. Certainly this is a slim margin; however it shows that it is nonetheless possible to obtain a positive result. This calculation does also take into account staggered production of the satellites, since a significant learning curve will initially apply.

We can clearly see here that delivering more products in a shorter period of time is better than delivering a single product, however much better, after a long period of time. In the next section we will discuss how to further improve the feasibility of the SSPS project.

14.2.1 Potential for Framework Improvement

To come to a positive NPV it will be necessary for our proposed SSPS organization to produce and sell a volume of satellites instead of just a single very large satellite. Considering some of the many constraints on the space industry such as the difficulty to build satellites and the limited number of orbital positions, it would be unreasonable to consider a "volume" of satellites as anything greater than 10 or 20.

Furthermore comparing the size of the energy market and the generation capacity of these small scale satellites (20 x 200 MW = 4 GW), we will also need to consider the possibility of replacing or "building on" to existing satellites to make room for larger systems as the market demands it.

At this point however we will only consider that our SSPS Organization must be arranged to make a volume of satellites to break even.

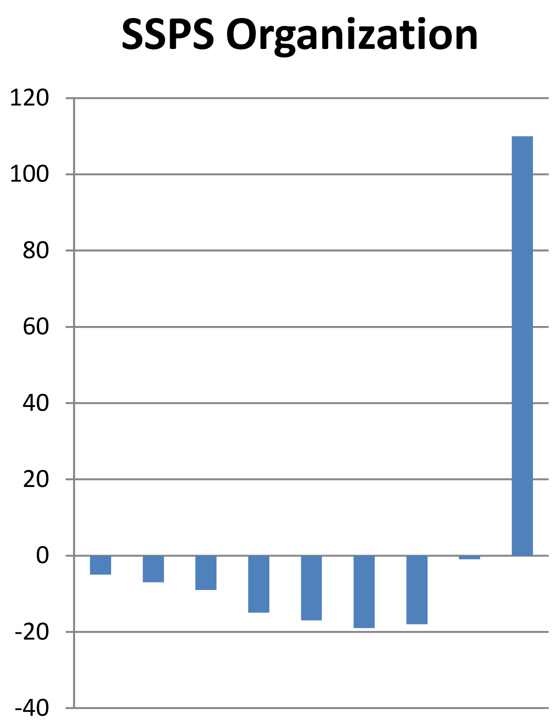
A subsequent obstacle with building and operating the SSPS is that the payback revenue occurs over a very long period of time. Thanks to the effects of inflation and the discounted cash flow, it becomes impossible to recuperate the spent funds in a reasonable amount of time. The SSPS organization needs to earn money faster on its future rate of return, but how is this possible?

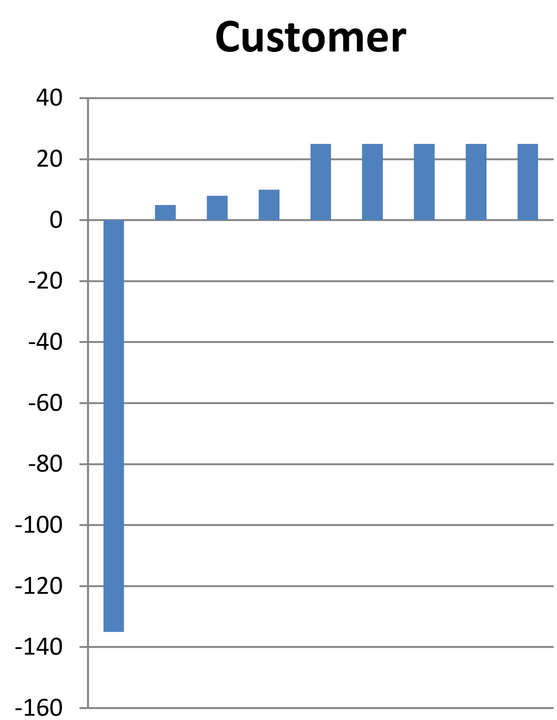
The answer to this question is simpler than expected: sell the completed system to independent operators.

The act of selling a complete SSPS system creates a massive influx of revenue in a single accounting period, instead of a large amount that gets discounted over an expected life of 30 years. Therefore the SSPS organization can receive the revenue from the completed system right away, adding billions of dollars in present day revenue, not discounted revenue. If several systems are sold in this manner, the breakeven point for the SSPS improves visibly.

The customer of this system will find the accounting to be much simpler than the SSPS Organization. As far as the customer is concerned, it makes a single large investment at t=0, and then earns profit from energy generation activities for the life of the system.

In this sense, the SSPS organization benefits since it receives its money faster. The customer benefits since they are not saddled with the massive cost of research, development, and production. Example Organization and Customer cash flows for this proposition are indicated below with non representative, token amounts.





There is a close analog to this proposed system in the air framer industry. Our suggestion of a researcher/producer and a customer which buys the resulting system is the same as the Boeing – Airline or Airbus – Airline combination. Clearly there are differences in technology and certainly of capacity, however it helps to take a fresh point of view on the SSPS question.

Thinking of the SSPS organization in this manner opened up different avenues of thought for our group. It has allowed us to suggest an easily understandable (and universally accepted) form of business structure. The subject is then moved closer to the realm of possibility than the realm of science fiction.

14.2.2 Final Proposed SSPS Framework

The proposed framework for the future SSPS Organization is that of a satellite researcher and manufacturer, but not as an ultimate operator. The operation of the satellite will be left to the customer who has decided to purchase one of the SSPS'. It should be noted that this framework is in addition to the framework put forward in Section 8, not in exclusion.

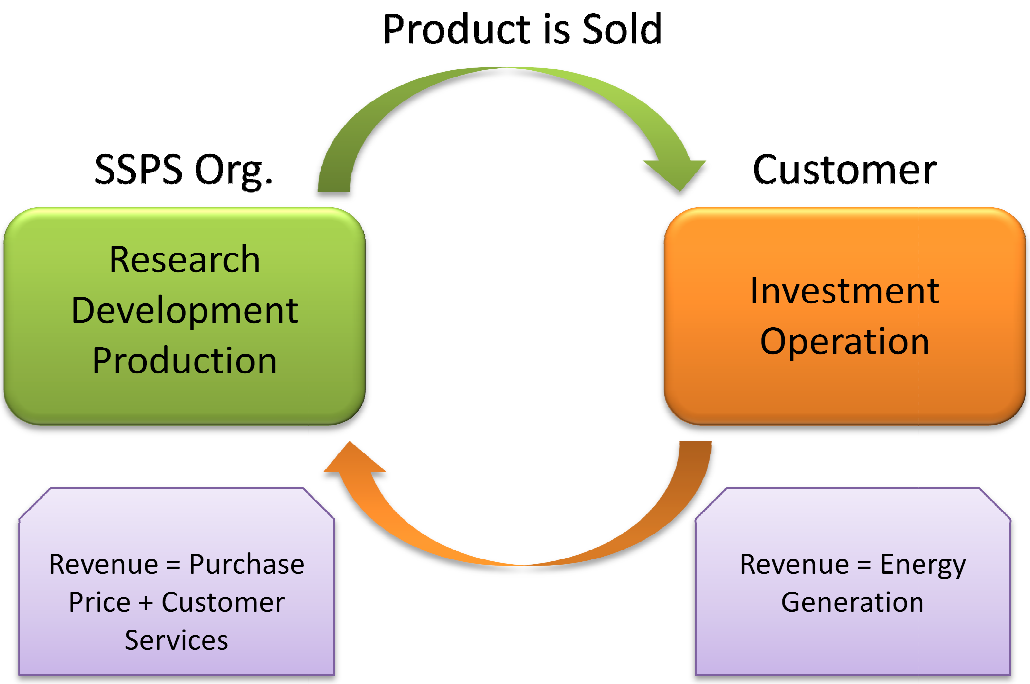


Figure 49 - Proposed SSPS Business Framework

From this proposed framework we can now consider different elements which would improve the financial standing of both the SSPS Organization, as well as the customer. Ultimately these suggestions can be used to improve the value proposition to the customer, and investors in the SSPS Organization.

SSPS Organization

i. The Organization will seek to share research as much as possible. Research and development costs can be shared among different organizations including government agencies and private institutions. Universities can provide a significant amount of research at little to no cost to the organization. Intellectual property concerns shall be addressed in the manner described in section 8.

ii. The Organization will seek to share energy research with government agencies. Many industrialized nations spend billions of dollars on energy research every year. Countries wishing to encourage the green energy market might find it beneficial to provide research assistance to the SSPS organization. Either money or in kind support would directly mitigate the cost of R&D borne by the Organization.

iii. The Organization may seek tax assistance from its home government in the form of breaks, credits, or delays in the payment to provide some means of improvement in cash flows.

iv. The Organization produces multiple systems instead of just one system.

v. The Organization is no longer an operator of the SSPS system, and instead sells its SSPS satellites to independent operators.

vi. The Organization will provide customer support at least in the form of maintenance to operational customers. Not all customers will have the means to work in space, and so it is an opportunity for the SSPS Organization. Had the Organization been the operator, it would have incurred maintenance costs. If it is a manufacturer and providing services, it can count these costs as revenues.

Customer

i. The Customer purchases a complete and operational SSPS from the SSPS Organization. The Customer is not concerned with the costs of research and development of the system, only with the costs of owning and operating the equipment to deliver energy and obtain profit.

ii. Maintenance of the system which cannot be performed by the Customer (almost anyone who is not a government) shall be outsourced to appropriately competent authorities, such as the SSPS Organization. The Customer would consider this a normal operating cost.

iii. Many governments, especially in Europe, are interested in increasing the percentage of green energy being used by their populations. Governments may be willing to offer some limited subsidies to companies that operate SSPS generation stations, making the project more feasible.

iv. The Customer becomes well positioned to enter the carbon trading market that has been established in the European Union. Since each SSPS produces energy carbon free, it has great potential to mitigate significant quantities of carbon and therefore add value in such a market.

These suggestions for the SSPS Organization and the Customer are expected to improve the value proposition of the SSPS project to both parties. As a result the SSPS concept is moved out of the realm of science fiction and into the realm of a feasible business. It is believed that combining this organization with the production of more (but smaller) SSPS satellites will provide the impetus towards a project with a positive return on investment.

15.0 Final Conclusions on Space Solar Power

The world is coming to a crossroads in terms of energy production and consumption. As it is, forecasts indicate that the current level of energy production will not be able to meet the demand within a reasonable period of time. This is highlighted by:

1. Global increase in population, mostly in developing nations, will increase demand
2. Global increase in standard of living will increase energy demand
3. Eventual exhaustion of fossil fuel reserves (currently the primary world energy source)
4. The imminent replacement of existing aged power generation sources

These items combined indicate that there is an unprecedented level of demand for new energy sources. Increasingly people turn to renewable energy sources for their needs such as terrestrial solar, wind, hydro, geo thermal, and biomass. Unfortunately however these green sources can provide neither the capacity nor reliability that is needed for base load energy supply.

Enter Space Solar Power. This is a concept that has been around for many decades and promises to provide the needed capacity, reliability, and environmental cleanliness that consumers increasingly want.

This report has sought to analyse the financial feasibility of Space Solar Power as well as to identify stakeholders which would be crucial to its success. This was accomplished through market surveys, organizational surveys, and financial models based on research of current and historical data.

We found that although launch cost is very much a critical factor in the success of a SSPS, the most important consideration was in fact the cost of research and development. According to models by ESA and NASA the cost for developing a SSPS is between 130 and 260 billion USD. This development cost proved an insurmountable obstacle for the Classical approach of one organization and one large SSPS; despite our best efforts the net present value of this investment was -59 billion USD at its best.

Besides such direct reasons for SSPS' not being adopted until now, there are also indirect reasons as well. It is clear that the energy chains based on fossil fuels, oil and coal need urgent replacement both for economical and environmental reasons, however it is not clear what they should be replaced with. In other words, there are various options for alternative energy sources but none of them has proven any significant advantage over the others.

The possible scope of the SSPS concept is very large, and so identification and development of niche SSPS applications followed the same structure as that used for the Classical system. It was determined that these applications individually would have a positive return on investment and could therefore be profitable ventures. To do this however they would need the same research and development budget as the classical system.

Since these niche applications are smaller than the Classical SSPS, they could be built much faster and for much cheaper. Taking this into account the SSPS Organization would need to produce several of these smaller systems in order to break even and then make a profit. Given the state of the energy market and the desire for green energy this is viewed as extremely probable.

The final Organization would therefore aim to be a prime research, development, and production contractor which hands out work to sub contractors such as Astrium, Thales, Boeing, NASA, ESA, etc. The internal structure of the SSPS Organization in terms of research and development will be similar to that used by INTELSAT, as indicated in Section 8.

In terms of production and operation the SSPS Organization could be structured similarly to Airbus or Boeing. By selling completed SSPS' and services to various customers it can improve its cash flow and revenues.

While the customers would earn money from the sale of electricity, the SSPS Organization would make revenues off of the sale of the system as well as services sold to the customer such as maintenance of orbiting equipment, among others that have yet to be defined. In this way the SSPS Organization could receive a return on its investment immediately in present day dollars, not future discounted dollars.

This framework is thought to be a reasonable and financially plausible method through which the SSPS concept can be brought from science fiction into reality. Considering the state of the world energy economy and the environment, the question is not whether we should invest in Space Solar Power; the question is how soon can we start?

List of Acronyms

A	annum
AC/DC	Alternate Current/Direct Current
AFRL	Air Force Research Laboratory
ASIC	application-specific integrated circuit
B	Billion
CAD	Canadian Dollar
CO2	Carbon dioxide
COPUOUS	Committee on the Peaceful Uses of Outer Space
DOD	United States Department of Defence
EDF	Électricité de France
ESA	European Space Agency
EU	European Union
EUR	Euro
FBCF	Fully Burdened Cost of Fuel
GEO	Geostationary Orbit
GHz	Gigahertz
GJ	Giga-Joule
GPS	Global Positioning System
GSLV	Geosynchronous Satellite Launch Vehicle
GSM	Global System for Mobile communications
Gt	Giga-Tons
HEMAT	Heavy Expanded Mobility Ammunition Trailer
HEMTT	Heavy Expanded Mobility Tactical Truck
IEA	International Energy Agency
INTELSAT	International Telecommunications Satellite Organization
IP	Intellectual Property
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standards Organization
ISS	International Space Station
ITU	International Telecommunications Union
i.e.	for instance
KW	kilo watt
kW/h	kilowatt hour
LEO	Low Earth Orbit
MMS	Mobile Servicing System
PDA	Personal digital assistant
MSGSPS	Mobile Space-to-Ground Solar Power Station
Mt	Mega-Tons
NATO	North Atlantic Treaty Organization

NASA	National Aeronautics and Space Administration
NPV	Net Present Value
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
OPA	Ontario Power Authority
PEST	Political, Economic, Social, and Technological
POG	Power on Ground; delivered to rectifier after losses
PV	Present Value
RF	Radio Frequency
ROI	Return on Investment
R&D	Research and Development
SAR	specific absorption rate
SLA	Stretched Lens Array
SPS	Space Power Satellite
SSPS	Space Solar Power System
SWOT	Strengths, Weaknesses, Opportunities, and Threats
USA	United States of America
USD	United States Dollar
UN	United Nations
VS.	Versus
W	Watt
WHO	World Health Organization

Appendix A – PEST Analysis Template

PEST Analysis Template

State what you are assessing here

____

(This particular example is for a new business opportunity. Many criteria can apply to more than one quadrant. Identify criteria appropriate to your own PEST situation.)

Criteria examples	Political	Economic
Ecological/environmental issues Current legislation home market Future legislation European/international legislation Regulatory bodies and processes Government policies Government term and change Trading policies Funding, grants and initiatives Home market lobbying/pressure groups International pressure groups Wars and conflict		

Criteria examples	Social	Technological
Lifestyle trends Demographics Consumer attitudes and opinions Media views Law changes affecting social factors Brand, company, technology image Consumer buying patterns Fashion and role models Major events and influences Buying access and trends Ethnic/religious factors Advertising and publicity Ethical issues		

Appendix B – Generic Stakeholder Exercise

The following Appendix presents the results of our generic stakeholder brainstorming, sorting, and mapping exercise.

Part A. Dimensions and Factors of Stakeholders Assessment

Stakeholder Type	R - Regulatory	O - Organizational	C - Community			
Segment Type	1 - Research	2 - Ground Construction	3 - Space Construction	4 - Operation and Distribution	5 - End User	6 - Overall / General
Commitment	1 - will make it happen	2 - will help happen	3 - will let it happen	4 - there could be many groups for or against	5 - don't want it to happen	6 - will prevent
Interest Level	1 - high	2 - medium	3 - low	4 - indifferent		
Interest Type	T - Technology	En - Environment	Ec - Economic	P - Political	N -Normative	
Influence	1 - strong	2 - medium	3 - weak	4 - none		
Relationship	1 - cooperative	2 - neutral	3 - antagonistic			

Part B. Stakeholders Assessment of Each Segment type

1. Research

Stakeholder	Stakeholder Type	Commitment	Interest Level	Interest Type	Influence	Relationship	Comment
Space Agencies	R	2	1	T	1	1	NASA, ESA, CSA, JAXA, CNES, CAST
Academia	R	2	1	T	2	2	School systems, University
Launch Services	R	3	2	T	2	1	
Satellite Services	R	3	2	T	2	1	e.g. Thales
Gov. Military Organizations	R	2	1	T	1	1	Launcher / Directed Energy
Renewable Energy Company	R	2	1	En	2	1	
Nuclear Energy Generator	R	3	4	Ec	2	2	
Fossil Fuel Generator	R	5	2	Ec	2	3	
Electronic Manufactures	R	3	4	Ec	3	2	
Telecommunication Firms	R	3	3	T	3	1	Microwave
General Industry	R	3	3	T	3	2	Laser technology for manufacturing, for example
Governments (national)	R	2	3	P	1	1	
Defence Firms	R	2	1	T	1	1	northrop grumman, boeing, etc
Space Advocacy Groups	O	3	1	N	3	1	

2. Ground Construction

Stakeholder	Stakeholder Type	Commitment	Interest Level	Interest Type	Influence	Relationship	Comment
Environmental Groups	C	4	1	En	2	2	there could be many people for and against at the same time
Local Population	C	6	1	P	1	3	
Construction Companies	R	3	2	Ec	3	1	
Builders (people)	O	3	3	Ec	4	1	
Air Traffic Management Authority	R	5	1	N	1	2	
Government (national)	R	1	1	P	1	1	
Government (local)	R	2	1	P	2	1	
Local Authorities	R	3	2	N	4	2	police, fire, ambulance
SSPS Generator	R	1	1	Ec	1	1	
System Operators	O	3	2	Ec	4	1	
Utility Company	R	2	1	Ec	2	1	
Academia	R	3	3	T	4	1	School systems, University
Subcontractors	R	3	2	Ec	3	1	
Insurance Companies	R	3	4	Ec	4	2	
Renewable Energy Company	R	2	1	En	2	1	
Nuclear Energy Generator	R	3	4	Ec	2	2	
Fossil Fuel Energy Generator	R	6	1	Ec	1	3	
Peace Activists	C	6	1	P	3	3	space weaponization

3. Space Construction

Stakeholder	Stakeholder Type	Commitment	Interest Level	Interest Type	Influence	Relationship	Comment
Government (national)	R	2	2	P	1	1	
Gov. Military Organizations	R	1	1	P	1	1	
Defence Firms	R	2	1	Ec	2	1	Northrop Grumman, Boeing
Space Advocacy Groups	C	2	1	N	3	1	
United Nations	R	2	1	P	1	1	application of space law / treaties
Builders (people)	O	3	3	N	3	1	either astronauts or else robotic operators
Launch Services	R	2	1	Ec	1	1	
Satellite Services	R	2	1	Ec	1	1	
Space Agencies	R	2	1	N	1	1	NASA, ESA, CSA, JAXA, CNES, CAST
Subcontractors	O	3	2	Ec	3	1	
Academia	R	3	2	T	3	1	School systems, University
Telecommunication Firms	R	3	1	T	2	1	
Insurance Companies	R	3	4	Ec	4	1	

4. Operation and Distribution

Stakeholder	Stakeholder Type	Commitment	Interest Level	Interest Type	Influence	Relationship	Comment
Power Utility (dc)	R	1	1	Ec	1	1	
SSPS Generator	R	1	1	Ec	1	1	maybe runs the array
Government (national)	R	2	1	P	2	1	
Government (local)	R	2	2	P	2	1	
Environmental Groups	C	4	1	En	3	2	
Local Authorities	R	3	4	N	4	1	
Renewable Energy Company	R	2	1	En	2	1	
Nuclear Energy Generator	R	3	4	Ec	2	2	
Fossil Fuel Generator	R	5	3	Ec	2	3	
Gov. Military Organizations	R	3	3	P	3	1	

5. End Users

Stakeholder	Stakeholder Type	Commitment	Interest Level	Interest Type	Influence	Relationship	Comment
End Consumer	O	3	2	Ec	1	1	
Power Utility	R	2	1	Ec	2	1	
Government (local)	R	2	3	Ec	2	1	
Local Authorities	R	3	4	N	4	2	police, fire, ambulance

6. Overall/General

Stakeholder	Stakeholder Type	Commitment	Interest Level	Interest Type	Influence	Relationship	Comment
Government (national)	R	1	2	Ec	1	1	
Government (local)	R	3	2	Ec	2	1	
Power Utility (dc)	R	2	2	Ec	2	1	
Financial Institutions	R	4	3	Ec	2	2	
Defence Firms	R	2	2	Ec	2	1	
United Nations	R	3	2	Ec	2	1	COPOUS
Renewable Energy Generators	R	2	2	Ec	3	1	
Environmental Groups	C	3	1	Ec	3	1	

Part C. Stakeholders Sorting and Mapping

I. Stakeholders Sorting

Stakeholder	Segment	Interest	Need(s)	Can Offer	Expects in Return	Comment
Academia	1, 2, 3	Academic & Technological	Opportunities to perform cutting edge research. Ideally would like funding.	Research	Recognition, opportunities for students, funding if possible	School systems, University
Air Traffic Management Authority	2	Normative	What will be the effects of wpt on aircraft? Passengers? Where will these receiving stations be located?	Nothing (will direct aircraft away from sites)	To be kept in the loop	
Builders (people)	2, 3	Economic	Work	Labour	Wages	
Construction Companies	2	Economic	Work to bid on	Builders	Contracts	
Defence Firms	1, 3, 6	Economic	Opportunities to perform cutting edge research and development, contracts to bid on	Experienced high technology workforce, considerable resources, market presence	Recognition, opportunities to expand, leverage workforce, and experience	Northrop Grumman, Boeing, etc
Electronic Manufactures	1	Economic	Work to bid on	Relevant skill sets	Contracts	
End Consumer	5	Economic	Clean and safe electricity	nothing	Clean and safe electricity	
Environmental Groups	2, 4, 6	Environmental	To be kept in the loop regarding environmental, health, and safety aspects of the SSPS	support if in favour, obstacles if not	Clean and safe electricity	there could be many people for and against at the same time
Financial Institutions	6	Economic	Investment opportunities	Capital	Decent ROI	
Fossil Fuel Energy Generator	1, 2, 4	Economic	To be kept in the loop regarding environmental, health, and safety aspects of the SSPS	Nothing; competitor	Nothing; competitor	
General Industry	1	Technological	Low cost energy, green if possible; industrial applications of SSPS technologies	Limited support for research that is of interest (financial or in kind)	Benefits of research	Laser technology for manufacturing, for example
Gov. Military Organizations	1, 4, 3	Political & Technological	Means to improve projection of power (weapons or supporting technologies)	Healthy research and development funding for approved projects	Weapons or supporting technologies	Launcher / Directed Energy
Government (local)	2, 4, 5, 6	Economic & Political	Local jobs, to be kept in the loop regarding environmental, health and safety aspects of the SSPS	Reduced taxes, local workforce, land, access to local infrastructure	Employment of local population, benefits of non polluting energy source, local reinvestment.	

Stakeholder	Segment	Interest	Need(s)	Can Offer	Expects in Return	Comment
Government (national)	1, 2, 3, 4, 6	Economic & Political	National jobs, to be kept in the loop regarding environmental, health and safety aspects of the SSPS, strategic energy security, environmental sustainability, to meet the energy needs of its population in the best way possible	Reduced taxes, development credits (governmental assistance programs) educated workforce, access to national infrastructure	Employment of national population, strategic energy independence, safe clean and reliable energy source, national reinvestment.	
Insurance Companies	2, 3	Economic	Nothing	Insurance	Business	
Launch Services	1, 3	Technological & Economic	Reason to be in business, investment to develop better launchers and lower future system costs	Launch vehicles	Launch contracts; assistance in developing better launchers	
Local Authorities	2, 4, 5	Normative	To be kept in the loop regarding environmental, health, and safety aspects of the SSPS	nothing (but need to know if special safety training and response measures are needed)	To be kept in the loop	police, fire, ambulance
Local Population	2	Political	Clean and safe electricity	consumers	Clean and safe electricity	
Nuclear Energy Generator	1, 2, 4	Economic	To be kept in the loop regarding environmental, health, and safety aspects of the SSPS	Nothing; competitor	Nothing; competitor	
Peace Activists	2	Political	To be kept in the loop regarding environmental, health, and safety aspects of the SSPS	support if in favour, obstacles if not	To be kept in the loop	space weaponization
Power Utility	4, 5, 6	Economic	Electricity to supply to its markets	A market	Safe & reliable electricity	
Renewable Energy Company	1, 2, 4, 6	Environmental & Economic	Electricity to supply to its markets	A niche market	Safe, clean, & reliable electricity	
Satellite Services	1, 3	Technological, Economic	New business opportunities, investment to develop better satellites technologies and lower future system costs	Highly skilled workforce, cutting edge technology, satellite production experience, the capacity to invest in new markets, market presence	Recognition, opportunity to expand, leverage workforce and experience. New business opportunities for sustained growth	e.g. Thales
Space Advocacy Groups	1, 3	Normative	A chance to have their opinions heard; To be kept in the loop regarding environmental, health, and safety aspects of the SSPS	Considerable tacit knowledge among space enthusiasts and professionals alike. Passionate about space development	SSPS; investment in other space related technologies and activities	
Space Agencies	1, 3	Technological & Normative	New areas of research to explore, practical and commercial applications of research that has already been done	Highly skilled and experienced research and development workforces. Considerable tacit and explicit knowledge of science and engineering. Passionate about space development	Recognition, opportunity to explore new avenues of science and research, opportunity to apply research that has already been completed.	NASA, ESA, CSA, JAXA, CNES, CAST
SSPS Generator	2, 4	Economic	Cooperation, support, funding	SSPS development framework	A chance to develop SSPS	

Stakeholder	Segment	Interest	Need(s)	Can Offer	Expects in Return	Comment
Telecommunication Firms	1, 3	Technological	New business opportunities, investment to develop better communication technologies and lower future system costs	Experience in operating satellites, communications equipment, microwave transmission technologies	Opportunity to develop better technologies and share costs. Opening up of new markets.	Microwave
United Nations	3, 6	Normative & Political	International cooperation, responsibility, and accountability	International political regulatory framework and treaties	Safe peaceful uses of space	COPOUS

II. Stakeholders Mapping

SEGMENT 1: RESEARCH			
	STAKEHOLDER MAPPING: COMMITMENT/INTEREST		
LEVEL OF COMMITMENT	**High**	Renewable Energy Company Governments (national)	Space Agencies Academia Launch Services Satellite Services National Defence Defence Firms Space Advocacy Groups
	Low	Nuclear Energy Generator Electronic Manufactures Telecommunication Firms General Industry	Fossil Fuel Generator
		Low	**High**
	LEVEL OF INTEREST		

SEGMENT 1: RESEARCH			
	STAKEHOLDER MAPPING: POWER/RELATIONSHIP		
LEVEL OF INFLUENCE	**High**	Academia Nuclear Energy Generator Fossil Fuel Energy Generator	Space Agencies Launch Services Satellite Services National Defence Renewable Energy Company Governments (national) Defence Firms
	Low	Electronic Manufactures General Industry	Telecommunication Firms Space Advocacy Groups
		Low	**High**
	LEVEL OF RELATIONSHIP		

SEGMENT 2: GROUND CONSTRUCTION			
	STAKEHOLDER MAPPING: COMMITMENT/INTEREST		
LEVEL OF COMMITMENT	**High**		Governments (national) Governments (local) SSPS Generator Utility Company Renewable Energy Company
	Low	Builders (people) Academia Insurance Companies Nuclear Energy Generator	Environmental Groups Local Population Construction Companies ATM Authorities Local Authorities System Operators Subcontractors Fossil Fuel Energy Generator Peace Activists
		Low	**High**
	LEVEL OF INTEREST		

SEGMENT 2: GROUND CONSTRUCTION			
	STAKEHOLDER MAPPING: COMMITMENT/INTEREST		
LEVEL OF INFLUENCE	**High**	Environmental Groups ATM Authorities Nuclear Energy Generator Fossil Fuel Energy Generator	Governments (national) Governments (local) Local Population SSPS Generator Utility Company Renewable Energy Company
	Low	Local Authorities Insurance Companies Peace Activists	Construction Companies Builders (people) System Operators Academia Subcontractors
		Low	**High**
	LEVEL OF RELATIONSHIP		

SEGMENT 3: SPACE CONSTRUCTION			
	STAKEHOLDER MAPPING: COMMITMENT/INTEREST		
LEVEL OF COMMITMENT	**High**	National Defence Defence Firms Space Advocacy Groups	Governments (national) United Nations Launch Services Satellite Services Space Agencies
	Low	Builders (people) Insurance Companies	Subcontractors Academia Telecommunication Firms
		Low	**High**
	LEVEL OF INTEREST		

SEGMENT 3: SPACE CONSTRUCTION			
	STAKEHOLDER MAPPING: COMMITMENT/INTEREST		
LEVEL OF INFLUENCE	**High**		Governments (national) National Defence Defence Firms United Nations Launch Services Satellite Services Space Agencies Telecommunication Firms
	Low		Space Advocacy Groups Builders (people) Academia Subcontractors Insurance Companies
		Low	**High**
	LEVEL OF RELATIONSHIP		

SEGMENT 4: OPERATION AND DISTRIBUTION			
	STAKEHOLDER MAPPING: COMMITMENT/INTEREST		
LEVEL OF COMMITMENT	**High**		Power Utility (dc) SSPS Generator Governments (national) Governments (local) Renewable Energy Company
	Low	Local Authorities Nuclear Energy Generator Fossil Fuel Energy Generator National Defence	Environmental Groups
		Low	**High**
	LEVEL OF INTEREST		

SEGMENT 4: OPERATION AND DISTRIBUTION			
	STAKEHOLDER MAPPING: COMMITMENT/INTEREST		
LEVEL OF INFLUENCE	**High**	Nuclear Energy Generator Fossil Fuel Energy Generator	Power Utility (dc) SSPS Generator Governments (national) Governments (local) Renewable Energy Company
	Low	Environmental Groups	Local Authorities National Defence
		Low	**High**
	LEVEL OF RELATIONSHIP		

SEGMENT 5: END USER			
	STAKEHOLDER MAPPING: COMMITMENT/INTEREST		
LEVEL OF COMMITMENT	**High**	Governments (local)	Power Utility (dc)
	Low	Local Authorities	End Consumer (dc)
		Low	**High**
	LEVEL OF INTEREST		

SEGMENT 5: END USER			
	STAKEHOLDER MAPPING: COMMITMENT/INTEREST		
LEVEL OF INFLUENCE	**High**		End Consumer (dc) Power Utility (dc) Governments (local)
	Low	Local Authorities	
		Low	**High**
	LEVEL OF RELATIONSHIP		

SEGMENT 6: Overall/General			
	STAKEHOLDER MAPPING: COMMITMENT/INTEREST		
LEVEL OF COMMITMENT	**High**		Governments (national) Power Utility (dc) Defence firms Renewable Energy Company
	Low	Local Authorities	Governments (local) United Nations Environmental Groups Press and Media
		Low	**High**
	LEVEL OF INTEREST		

SEGMENT 6: Financial			
	STAKEHOLDER MAPPING: COMMITMENT/INTEREST		
LEVEL OF INFLUENCE	**High**	Financial Institutions Press and Media	Governments (national) Governments (local) Power Utility (dc) Defence firms United Nations
	Low		Renewable Energy Company Environmental Groups
		Low	**High**
	LEVEL OF RELATIONSHIP		

Appendix C – Key Stakeholder Interviews

This Appendix contains a collection of information gained via discussion with certain key stakeholders. Unless otherwise mentioned, the information provided here should not be considered the official views of the organization for which these individuals work.

A brief description of each participant is given to place the conversation and information given into context for the reader.

EADS Astrium
Pierre Parrot
Mr. Parrot works in the Strategy and Business Development department within EADS Astrium. In the past he has performed significant exploratory work on the SSPS concept in terms of Astrium's objectives, and was put in touch with us as a subject matter expert. He has been extremely helpful in allowing our group to establish an understanding of the full scope of the SSPS concept.

Toulouse Business School
Raul Gomez Gutierrez
Evelyn Panier
Sun Xin
Cornelius Zund

Date: March 4th 2009

The following notes were taken during the course of the conversation with Mr. Parrot. Note that these do not represent the extent of our interaction, just the information provided during this conversation.

Leadership

1. Historically the leadership on this subject has been by technical experts, namely NASA, ESA, and JAXA
    a. Since the technical aspects of the system are now very well understood, it is good idea for a new kind of leadership to emerge (such as commercial leadership)
    b. There is still room for research projects to be done:
        i. Launchers and infrastructure

Very costly initiative

1. The classical SSPS is a very expensive undertaking
2. Smaller synergistic space projects will be able to help
3. The SSPS would be a very long term initiative
    a. Need marketing in this area
    b. Astrium has performed self funded research into this area and worked with ESA

Applications

1. Large scale power plant applications are obvious, would use either the laser or microwave technologies
2. Small scale ideas are key to help build momentum
3. Need early demonstrations to show the public what is being done
4. Public safety needs to be completely understood
5. Synergy with the energy industry is key

Best way to move forward?

1. Not clear
2. International astronautical association
3. Need to move the ideas out of the scientific community and into the business community
4. A new dedicated entity should be formed that will do this
5. The obstacles faced are analogous to those faced by the fusion energy community

Stakeholders

1. COPUOUS
    a. Space laws, treaties
    b. UN bodies are not fit to the task of commercialization
2. Energy Market
    a. Energy utilities are big policy movers and have lots of monetary weight
    b. Current big primary energy sources are nuclear and coal
    c. Institutions need to settle technology issues first before the private sector can use

Niche Applications

1. Military and telecommunications are obvious pairings
2. Need to be economically feasible otherwise there is no point
3. Need to be aligned with power utilities

European Space Agency
Leopold Summerer
Mr Summerer works as head of the European Space Agency's Advanced Concepts Team in the Netherlands. He has been a prolific writer on the subject of space solar power, and has published many papers in this area. Mr. Summerer was referred to our group as ESA's subject matter expert, and has provided us with invaluable information over the course of this project.

Toulouse Business School
Raul Gomez Gutierrez
Sun Xin
Cornelius Zund

Date: February 27 2009

The following notes were taken during the course of the conversation with Mr. Summerer. Note that these notes do not represent the extent of our interaction, just the information provided during this conversation.

Governmental Issues

1. Governments are concerned with their energy security
    a. Energy is a strategic resource
    b. Energy mix should be diversified
2. Policies affect what government will and will not invest in
    a. Environmental policies
    b. Technology and innovation policies
3. International cooperation
    a. Who are the stakeholders?
    b. Technology sharing between international partners
4. National environmental agencies
    a. Concerned with the effects of wireless power transmission on people and the environment
    b. Microwave and laser energy is non-ionizing

Regulatory Issues

1. International Telecommunications Union
    a. Controls the allocation of geosynchronous orbital slots
2. What are the allowable frequency spectrums?
    a. Some bands are reserved for different reasons (astronomy, military, etc)
3. Structural concerns
    a. Something the size of an SSPS has never yet been built
4. COPUOUS the United Nation Committee on the Peaceful Uses of Outer Space
    a. UN laws govern who has access to space, with what, and for what purpose

Miscellaneous

1. The SSPS concept is considered to be between two different industries
    a. Both the space industry and the energy industry have historically felt that SSPS' were the domain of the other.
    b. Both industries need to support each other.
2. An SSPS is many orders of magnitude larger than the largest space structure built to date, the International Space Station
3. There are still significant margins for technical improvement, for instance in the areas of weight reduction and launch cost
4. Major strides towards SSPS with the exception of demonstration units is not expected in the near future.

Space Energy
Peter Sage, Director
Mr. Sage is a highly successful entrepreneur who has to date built six different companies. At this time he is personally responsible for much of the investment funding provided to Space Energy and is also its principal director. Mr. Sage has been extremely supportive of our group project since it covers much of the same ground as Space Energy.

Amaresh Kollipara, Chief Strategy Officer & Lead Technical Liaison
Mr. Kollipara is Co-Founder and Managing Partner of Earth2Orbit, which is a global provider of satellite launch services. Earth2Orbit is working with the Indian Space Research Organization to provide commercial launch services to a variety of satellite clients. Mr. Kollipara has been able to offer us information on Space Energy's technical plans and obstacles.

Both Mr. Sage and Mr. Kollipara have provided us with invaluable real world examples of how a project such as ours would unfold.

Toulouse Business School
Raul Gomez Gutierrez
Evelyn Panier
Sun Xin
Cornelius Zund

Date: March 24 2009

The following information was received during the course of the conversation with Mr. Sage and Mr. Kollipara. Some questions numbers will be presented out of order, since this is the way in which the conversation flowed. These notes do not represent the extent of our interaction, just the information provided during this conversation.

Q.0 Can you describe the organization?

1. Concerned with climate change and energy demand
2. There are no significant roadblocks in the way; challenges are mostly commercial not technical
3. Needs to start being developed today to avoid the impending energy gap.
4. Company began 2 years ago, low profile, lot of personal funding needed to start
5. Strong commercial case is needed to "close" the business plan
6. People need to be educated

Q.1 Can you elaborate on your short – long term goals?

1. Company needs visibility for SSPS
2. Need a demonstrator in LEO
    a. High level technical plan
    b. 5kw demo, all needed components in one launch
    c. Multiple receiver stations for demo
    d. Educates non aerospace people
    e. Lots of electrical networking required
3. Some smaller scale projects are needed to improve the underlying technologies
    a. Solar cells, launch components, fairing packaging, space architecture, transmission, reception, guidance, manoeuvring, software
4. Microwave likely needs to be very large scale
5. Laser technology is not at this time ruled out

Q.2 Several satellites at once? What is the goal? What is the size?

1. Mostly TBD

2. Still identifying different experts which would like to join the team
    a. Original Peter Glaser design had problems with structural and thermal rigidity
3. Constellation of satellites is considered
4. US and EU suntower concepts are considered
5. New ideas include inflatable structures
6. Very dense solar cell packing is needed

Q.4 How do you deal with the risk of not getting enough orbital allocations?

1. Monumental challenge, UN and ITU are responsible for this
2. Have established some government contacts for information

Q.5 In what stage are you in terms of the demonstrator prototype?

1. Many advisors at the moment
2. No formal relationships at this time
3. Commercial contacts not that strong at this time
4. Have contacts with DOD and NASA

Q.6 How do you intend to address launch costs? Long March or Falcon series (for example)?

1. In discussion with different people
2. This is a fundamental hurdle
3. Cheapest are the Falcon 9, GSLV, and Long March
4. Reusable vehicles are critical
5. Possibly hundreds of billions of dollars to develop
6. Choosing a good launch partner could have many political hurdles
    a. In touch with broker for Indian launch services
    b. No foreseeable political problems with India
    c. Currently an embargo of sorts which Obama is expected to clear

Q.8 What are your plans to mitigate space debris? Avoid it or deal with it?

1. Collisions are unavoidable
2. Currently collisions can be withstood
3. Critical system points would need to be reinforced

Q.9 What magnitude of weather effects do you expect?

1. Markets are currently in India, China, Middle East
2. Effects are based on the location of the customers
3. Health effects on people must be considered
    a. NASA has shown that there would be no significant impact on people
    b. Best in rural areas to avoid psychological effects

Q.10 How do you intend to deal with Energy Storage? How much?

1. Not economically feasible at this time

Q. 11 Who are your partners?

1. Mostly still to be determined
2. Have had some discussions with Boeing, Raytheon, Thales Alenia Space
3. There will be elements of in house I.P
4. There are no formal agreements at this time, just informal discussions

Q.13 Have you discovered any applications aside from supplying electricity?

1. Individual component markets which need high W/Kg
    a. Aircraft, UAVs, cars
    b. Medical devices

2. Space to space transmission
3. This is a part of the near term plan

Q.3 What was your approach to risk analysis?

1. Dr. F. Shu
    a. Senior risk analysis expert
    b. Worked on the Columbia risk analysis team
2. Must consider costs, feasibility, ROI, packing, etc. Ongoing process

Q.14 What is your company missing, what roles must still be fulfilled?

1. Contingent on financing
2. Technical team will begin to address concerns
    a. Full dedication of team to start soon
3. Proper commercialization
    a. Lower launch costs
    b. Easily implemented robotic assembly

Q.15 How do you intend to work within the current framework of space treaties?

1. New areas of legal framework will need to be created
2. SSPS will be a catalyst to new laws and agreements
3. Communication satellites offer the basis for the international agreements
4. The NSSO has already focused on the legal framework

Q.16 Where is the company based?

1. Switzerland was chosen for the corporate head office due to beneficial international regulations
2. Skilled staff are located in the UK and the US
3. Ultimately the location of the company will be based on the location of the customers
4. Part of the business strategy is to be an international company selling to international customers

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Appendix D – List of Organisations

This Appendix contains a list of companies whose opinions on the SSPS were solicited. With the exception of the key stakeholders listed in Appendix C, we received either marginal feedback or no feedback at all.

Asociación Colombiana del Consumidor	Fachhochschule Bremen	Office National d'Études et de Recerches Aérospatiales
Astrium (EADS)	Government of Ontario Ministry of Energy	Ontario Federation of Agriculture
Boeing	HIT-Harbin Institute of Technology	Ontario Power Authority
Beijing University of Aeronautics and Astronautics	Honeywell	Ontario Power Generation
China Academy of Launch Vehicle Technology	Institut der Rheinisch-Westfälische Technische Hochschule Aachen	RWE
Canadian Aeronautics and Space Institute	Instituto de Hidrología, Meteorología y Estudios Ambientales	Ryerson University
Canadian Forces	Instituto de Planificación y Promoción de Soluciones Energéticas	Space Energy
Canadian Space Agency	ISAGEN	State Electricity Regulatory Commission of PRC
Carelton University	L-3 Communications	State Grid Corporation of China
China Academy of Space Technology	Lockheed Martin	State-owned Assets Supervision and Administration Commission of State Council,PRC
Cesaroni	MDR	Steinbeis Transfer-Zentrum Raumfahrt
China Academy of Science	Ministerio de Comunicaciones	Telesat
China National Space Administration	Ministerio de Defensa Nacional	Tsinghua University
COMDEV	Ministerio de Minas y Energía	Universidad de los Andes
Comisión Colombiana del Espacio	Ministry of Industry and Information Technology of PRC	Universidad de San Buenaventura
Deutsche Gesellschaft für Luft- und Raumfahrt	Ministry of Environment Protectiong of PRC	Universidad Distrital Francisco José de Caldas
Deutsche Luft- und Raumfahrt	Mitec	Universidad Militar Nueva Granada
Energy Bureau of China	National Research Council of Ontario	Universidad Nacional
EnviroMission	Nodo de Estudios Aeroespaciales de Colombia	Universidad Pontificia Bolivariana
EON	University of Toronto	Universität Dresden
Fachhochschule Aachen	Nanjing University of Aeronautics and Astronautics	Vattenfall
Northwestern Polytechnical University	Norsat	

Appendix E – Consumer and Organisational Surveys

Part A. Consumers Survey Questionnaire

PERCEPTIONS ON ENERGY GENERATION

English Version:

The subject of energy has become very prominent in our modern civilization. Questions of production, cost, and impacts on human health and the environment are discussed with increasing frequency. This survey is intended to measure your reactions to and opinions of certain key subjects in terms of energy generation, its effects, and the use of "green energy". For the purpose of this survey "green" energy can be defined as an energy source which is generally considered to be environmentally friendly and non-polluting.

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1. There are many ways to generate electricity, including but not limited to the burning of fossil fuels, nuclear power, wind turbines, and solar power. Are you familiar with the effects that energy generation has on the environment?

   (Y) (N) (Not Sure)

2. Are you concerned with the effects of power generation on:

a. Human Health	1	2	3	4	5
b. The Environment	1	2	3	4	5

   Where 1 is "not at all concerned" and 5 is "very concerned".

3. Assuming sufficient availability, would you select green energy sources over all others?

   (Y) (N) (Not Sure)

4. If your utility company offered you the option to buy energy only from green sources, how much more would you be willing to pay for this service?
   a. 0% (No change)
   b. 1-5%
   c. 6-10%
   d. >10%

5. Are you familiar with the concept of gathering sunlight in space and transmitting it wirelessly back to Earth for conversion into electricity?

   (Y) (N)

6. If you answered YES to the previous question, can you indicate how you have come to know about this subject? Please choose all appropriate answers.
   a. By speaking with other people

b. Through the internet
c. Watching TV
d. Reading in general press/magazines
e. Reading in technical/scientific publications
f. Other

Space Solar Power System (SSPS)

A space solar power system is a proposal that offers to capture solar energy in orbit and transfer it back to Earth wirelessly, where it will be converted to electrical energy for use by consumers.

Some benefits of this system include:

I. Solar energy collection in space is not affected by weather or day/night cycles
II. There is no burning of fuel (with the exception of launching into space) or creation of radioactive wastes
III. An operational system will generate very high energy output for a negligible expense

Some drawbacks to this system include:

A. Very high up front development costs
B. Very long development and implementation period

Please consider the following questions in terms of the space solar power system described above.

7. For this concept would you be concerned with its effects on:

a. Human Health	1	2	3	4	5
b. The Environment	1	2	3	4	5

Where 1 is “not at all concerned” and 5 is “very concerned”.

8. Would you consider this system to be a green energy source?
   (Y) (N) (Not Sure)

9. Do you think that spending time and money to develop such a system is a good idea?
   (Y) (N) (Not Sure)

Some final questions to classify your answers.

a. Age [drop down]
b. Gender [radio]
c. Country
d. Level of education [drop down] (Up to High School /Technical /Undergraduate /Master PhD.)
e. Level of income in (name currency)
   i. [give a drop down list <20000, 25000… 100000]
f. Level of employment
g. [unemployed /self employed /working full time /business owner]

Chinese Version

能源问题已经成为现代社会中日益突出的问题。关于能源产量、成本以及对人类健康和环境影响的讨论日益频繁。此项调查的目的在于衡量你在关于能源产生、效果及"绿色能源"**等主要方面的反**应和意见。为便于调查，"绿色能源"**在此被定**义为环境友好和无污染。

1. 发电的方式有很多种，包括火力发电、水力发电、风力发电、核电及太阳能发电等，你了解这些方式对环境的影响么？
   了解 ( )　　不了解（ ）　　不确定（ ）

2. **你**对发电方式对人身健康和环境的影响关心程度如何（1-5级，1为根本不关心，5为非常关心）：
   a. **人身健康**　　1　2　3　4　5
   b. 环境　　1　2　3　4　5

3. **假**设有充足的供应，你会选择使用绿色能源来代替其他能源么？
   会 ( )　　不会 ( )　　不确定 ( )

4. **如果使用**绿色能源的价格会高于其他能源，你所能承受的高出的价格范围是多少：
   a. **不**变甚至低于现在的电价
   b. 1-5%
   c. 6-10%
   d. >10%

5. **你了解通**过空间采集太阳光能之后通过无线传输的方式传回地面，并将其转换为电能这一概念么？
   了解 ( )　　不了解 ( )

6. **如果你**对第**5个**问题的回答是**"熟悉"**，**你能告**诉我们你是通过哪种渠道得知这一概念的？请选择所有你认为合适的答案：
   a. **从其他人**处得知
   b. **通**过网络得知
   c. **通**过收看电视得知
   d. **通**过阅读相关书和杂志得知
   e. **通**过阅读专业技术和科学文献得知
   f. **其他渠道**（请注明）：

空间太阳能采集与传输系统（简称SSPS）

该系统通过卫星在轨采集太阳能并通过无线传输的方式传回地面，并将其转换为电能供用户使用。

这一系统主要有以下几个优点：

IV. 空间太阳能采集不受天气和昼夜周期影响
V. 没有燃料的燃烧（除发射进入太空之外）和放射性废料产生
VI. 投入运行的系统将以可以忽略不计的代价产生非常高的能量输出

这一系统主要有以下几个缺点：

C. 非常昂贵的预先开发成本
D. 比较长的开发和实现周期

基于上面对空间太阳能采集与传输系统（简称SSPS）的描述，请回答以下几个问题：

7. 对于SSPS这个概念，你对其对人身健康和环境的影响关心程度如何（1-5级，1为根本不关心，5为非常关心）：
   a. 人身健康　　1　2　3　4　5
   b. 环境　　1　2　3　4　5

8. 你认为通过这一系统产生的电能将会是一种绿色能源么？
   是（ ）　不是（ ）　不好说（ ）

9. 你认为花费时间和金钱来开发SSPS这样的系统是一个很好的主意吗？
   是（ ）　不是（ ）　不好说（ ）

为便于我们整理归类各个问题的答案，请您根据您的意愿回答以下几个问题：

a.年　龄：（1）小于20岁　（2）20-30岁　（3）30-40岁　（4）40-50岁
（5）50-60岁　（6）60岁以上

b.性　别：（1）男　（2）女

c. 教育程度：（1）高中　（2）大专　（3）大学本科　（4）硕士　（5）博士

d.收入水平：（1）小于2000元/月　（2）2000-4000元/月　（3）4001-6000元/月
（4）6001-8000元/月　（5）8001-10000元/月　（6）一万元以上/月

e.职　业：（1）学生　（2）教师　（3）职员　（3）科技人员
（4）公务员　（5）企业管理人员　（6）其他（请注明）：

German Version

In unserer modernen Zivilisation ist Energie ein wichtiger Bestandteil des menschlichen Daseins. Fragen bezüglich Produktion, Kosten, und Auswirkungen auf menschliche Gesundheit und Umwelt werden immer häufiger diskutiert. Diese Befragung beabsichtigt die Messung aller Reaktionen und Meinungen hinsichtlich der Energieerzeugung, ihre Effekte und die Nutzung von "grüner Energie". Für den Zweck dieser Befragung wird "grüne Energie" als Energie-Bezugsquelle definiert die naturverträglich und umweltfreundlich ist.

1. Es gibt viele Möglichkeiten Energie zu erzeugen, zum Beispiel fossile Energieträger, Atomenergie, Windenergie und Solarenergie. Sind Sie vertraut mit den Effekten die Energieerzeugung auf die Umwelt hat?
(J) (N) (Nicht sicher)

2. Sind Sie beunruhigt über die Effekte von Energieerzeugung auf
a) menschliche Gesundheit 1 2 3 4 5
b) die Umwelt 1 2 3 4 5

1 = "gar nicht beunruhigt" und 5 = "sehr beunruhigt"

3. In der Annahme, ausreichende Verfügbarkeit ist gewährleistet, würden Sie "grüne Energie" über allem anderen auswählen?
(J) (N) (Nicht sicher)

4. Wenn Ihr Energieunternehmen Ihnen die Option anbieten würde die Energie nur von "grünen" Bezugsquellen zu kaufen, wie viel mehr wären sie bereit zu zahlen?
a) 0% (keine Änderung)
b) 1-5%
c) 6-10%
d) mehr als 10%

5. Sind Sie vertraut mit dem Konzept der Ansammlung von Sonnenlicht im Weltall und deren kabellosen Übertragung zur Erde für anschließende Konvertierung in Elektrizität?
(J) (N)

6. Wenn Sie die letzte Frage mit JA beantwortet haben, können Sie bitte angeben wie Sie über dieses Konzept aufmerksam geworden sind. Bitte wählen sie alle angebrachten Antworten aus.
a) Gespräche mit Freunden oder Arbeitskollegen
b) Übers Internet
c) Fernsehen
d) Zeitungen oder Zeitschriften
e) Technische oder wissenschaftliche Veröffentlichung
f) Andere

Weltraum-Solar-Energie

Bei diesem Konzept werden im Weltraum große Solarsegel angebracht, die dann im Weltraum die Sonnenenergie in Elektrizität umwandeln und sie kabellos an die Erde senden zur Nutzung für den Enduser.
Einige Leistungen die dieses System beinhaltet sind:
I. Solarenergie im Weltraum ist nicht betroffen vom Wetter oder von Tages/ Nacht Zyklen
II. Es wird kein Kraftstoff umgesetzt (außer bei Installation des Systems im Weltall) und es gibt keinen radioaktiven Abfall
III. Ein betriebsfähiges System erzeugt viel Energie für geringfügige Kosten

Einige Nachteile die dieses System beinhaltet sind:
I. Sehr hohe Entwicklungskosten
II. Sehr lange Entwicklungs- und Implementierungsphase

Die folgenden Fragen beziehen sich auf die oben beschriebene Weltraum-Solar-Energie .

7. Bezüglich dieses Konzeptes sind sie beunruhigt über die Effekte auf
a) menschliche Gesundheit 1 2 3 4 5
b) die Umwelt 1 2 3 4 5

1 = "gar nicht beunruhigt" und 5 = "sehr beunruhigt"

8. Halten Sie dieses System für eine "grüne" Energie-Bezugsquelle?
(J) (N) (Nicht sicher)

9. Denken Sie, dass es eine gute Idee ist Zeit und Geld aufzuwenden um ein solches Projekt zu entwickeln?
(J) (N) (Nicht sicher)

Einige letzte Fragen um die Antworten einordnen zu können.
a) Alter
b) Geschlecht
c) Herkunftsland
d) Bildungslevel
e) Einkünfte
f) Arbeitsverhältnis

French Version

Le sujet de l'énergie est devenu stratégique dans notre civilisation modern. Les questions de production, de coût et l'impacte sur la santé et l'environnement sont de plus en plus discutées. La raison d'être de cette enquête est d'obtenir vos opinions et vos réactions à propos de certaines idées clés : la production de l'énergie, ses effets, et l'utilisation de l'énergie « verte ». Pour cette enquête on définira l'énergie « verte » comme : une source de l'énergie qui génère très peu de pollution (ou aucune) lors de sont production.

1. Il y a plusieurs manières de produire de l'électricité :on peut citer la combustion fossile, l'énergie nucléaire, les turbines de vent et les panneaux photovoltaïques. Connaissez-vous les effets de production de ces sources d'électricité sur l'environnement?
   (Oui) (Non) (Ne Sait Pas)

2. Est-ce que les conséquences de la production de l'électricité vous inquiètent?

a. Les effets sur la santé	1	2	3	4	5
b. Les effets sur l'environnement	1	2	3	4	5

   Ou « 1 » elles ne vous inquiètent pas, et « 5 » elles vous inquiètent beaucoup.

3. Si vous avez le choix, choisiriez vous les sources vertes de production pour votre électricité quotidienne?
   (Oui) (Non) (Ne Sait Pas)

4. Si votre fournisseur d'électricité (EDF) vous donne l'option d'acheter votre énergie seulement a parti des sources vertes, combiens seriez vous prêt à payer en supplément pour ce service?
   a. 0% (Pas de changement)
   b. 1-5%
   c. 6-10%
   d. >10%

5. Connaissez-vous l'idée de capter la lumière dans l'espace, et de le transmettre à la Terre pour la convertir en électricité?
   (Oui) (Non)

6. Si votre réponse à la dernière question était OUI, pouvez vous nous indiquer comment vous avez été sensibilisé à ce sujet? Merci de choisir la / les réponses pertinente.
   a. En parlant avec d'autres personnes
   b. Par l'internet
   c. Par le télévision
   d. Journaux, revues générales
   e. Journaux, revues scientifiques
   f. Autre

Système d'Énergie Solaire Spatiale (SESS)
La notion de le système d'énergie solaire spatiale désigne la possibilité de capter l'énergie solaire dans l'espace (par les panneaux photovoltaïques ou les miroirs), et de le renvoyer à la Terre sans fil. Lorsque l'énergie arrive sur le sol, elle est convertie en électricité pour la consommation générale.

Quelques avantages de ce système :

VII. Le capture de l'énergie solaire dans l'espace n'est pas affectée par le temps ou par jour / nuit, comme le sont les panneaux photovoltaïques au sol.
VIII. Aucune combustion pendant l'opération, ou du production des déchets radioactifs.
IX. Production d'une très grande quantité de l'énergie à coût quasi nul.

Quelques inconvenances de ce système :

E. Un coût de développement très élevé
F. Le développement et l'implémentation prendront une dizaine d'années

Merci de répondre aux questions suivantes en tenant compte de la définition du SESS donnée plus haut.

7. Est-ce que les conséquences de la production de ce système vous inquiètent?

a. Les effets sur la santé	1	2	3	4	5
b. Les effets sur l'environnement	1	2	3	4	5

Ou « 1 » elles ne vous inquiètent pas, et « 5 » elles vous inquiètent beaucoup.

8. Est-ce que vous pensez que ce système peut être labellise « vert »?
   (Oui) (Non) (Ne Sait Pas)

9. Pensez vous qu'il serait positif d'investir l'argent et du temps dans ce projet?
   (Oui) (Non) (Ne Sait Pas)

Quelques dernières questions pour classifier vos réponses :

a. Age [drop down]
b. Sexe [radio]
c. Pays
d. Niveau d'education [drop down] (Up to High School /Technical /Undergraduate /Master PhD.)
e. Niveau de revenu (name currency)
   i. [give a drop down list <20000, 25000… 100000]
f. Niveau d'emploi
   i. [unemployed /self employed /working full time /business owner]

Spanish Verson

La generación de energía se ha convertido en un asunto de la mayor importancia en nuestra civilización moderna. Su producción, costos e impacto en la salud humana y el medio ambiente son temas de discusión cada vez más frecuentes. Esta encuesta busca conocer sus reacciones y opiniones sobre algunos aspectos claves en cuanto a generación de energía, sus efectos y el uso de "energías verdes". Para los propósitos de la presente, energía "verde" puede ser definida como aquella que es considerada como ambientalmente amigable y no contaminante.

PARTE I

1. Hay muchas formas de producir energía, incluyendo pero no limitado a la quema de combustibles fósiles, energía nuclear, energía eólica y energía solar. Está usted familiarizado con los efectos que tiene la generación de electricidad sobre el medio ambiente?

   (S) (N) (No Estoy Seguro)

2. Le preocupan los efectos que la producción de electricidad tiene sobre:

   a. Salud Humana 1 2 3 4 5
   b. Medio Ambiente 1 2 3 4 5

   En donde 1 es "no me preocupa" y 5 es "muy preocupado".

3. Asumiendo suficiente disponibilidad, usted escogería una fuente de energía "verde" sobre cualquier otra fuente?

   (S) (N) (No Estoy Seguro)

4. Si su compañía de electricidad le ofreciera la posibilidad de escoger su suministro eléctrico generado únicamente de una fuente "verde", estaría dispuesto a pagar una suma adicional por tal opción en porcentaje respecto a su actual factura?

   a. 0% (Sin cambio)
   b. 1-5%
   c. 6-10%
   d. >10%

5. Está familiarizado con el concepto de recolectar luz solar en el espacio y transmitirla a tierra en forma inalámbrica para su conversión en electricidad?

   (S) (N)

6. Si respondió Si a la anterior pregunta ¿puede indicar como tuvo conocimiento de dicho tema? Por favor seleccione tantas respuestas como sea apropiado.

   a. En conversaciones con otras personas
   b. En Internet
   c. En Televisión
   d. En el periódico/revistas
   e. En publicaciones técnicas /científicas
   f. Otros

PARTE II

Space Solar Power System (SSPS) – Sistema de Energía Solar desde el Espacio
El Sistema de Energía Solar desde el Espacio es un proyecto que busca captar energía solar en órbita y transferirla hacia la tierra por medios inalámbricos, donde se convertiría en energía eléctrica para su consumo doméstico e industrial.
Algunos beneficios de este sistema incluyen:

X. La recolección de energía solar en el espacio no se ve afectada por condiciones climáticas ni por los ciclos del día y la noche.
XI. No se quema ningún tipo de combustible (con la excepción del lanzamiento hacia el espacio del sistema) ni se crean desechos radiactivos.
XII. Un sistema plenamente operacional generará una gran cantidad de energía a un muy bajo costo.

Algunos inconvenientes de este sistema incluyen:

G. Muy altos costos iniciales para su desarrollo y puesta en órbita.
H. Muy largo periodo de desarrollo e implementación.

Para las siguientes preguntas considere el sistema de acuerdo a lo descrito anteriormente.

7. Le preocupan los efectos que la producción de electricidad de esta forma pueda tener sobre:

a. Salud Humana	1	2	3	4	5
b. El Medio Ambiente	1	2	3	4	5

En donde 1 es “no me preocupa” y 5 es “muy preocupado”.

8. ¿Consideraría este sistema como una fuente de energía “verde”?
   (S) (N) (No Estoy Seguro)

9. ¿Considera que invertir tiempo y dinero para desarrollar dicho sistema sea una buena idea?
   (S) (N) (No Estoy Seguro)

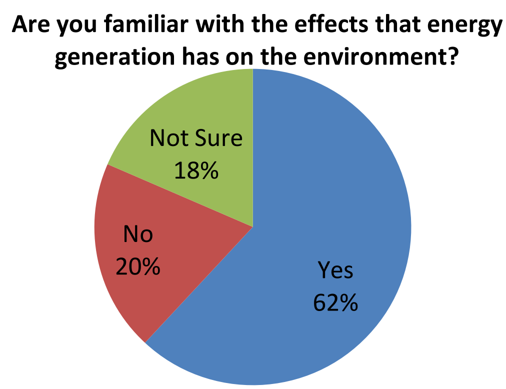
Algunas preguntas que permitirán clasificar sus respuestas.

a. Edad [drop down]
b. Género [radio]
c. País
d. Nivel de Educación [drop down] (Secundaria /Técnico /Universidad /Posgrado)
e. Nivel de ingresos (En US Dólares por la naturaleza internacional de la encuesta)
   i. [give a drop down list <20000, 25000… 100000]
f. Nivel de empleo
   ii. [desempleado /empleado/propietario]

Part B. Result Statistics

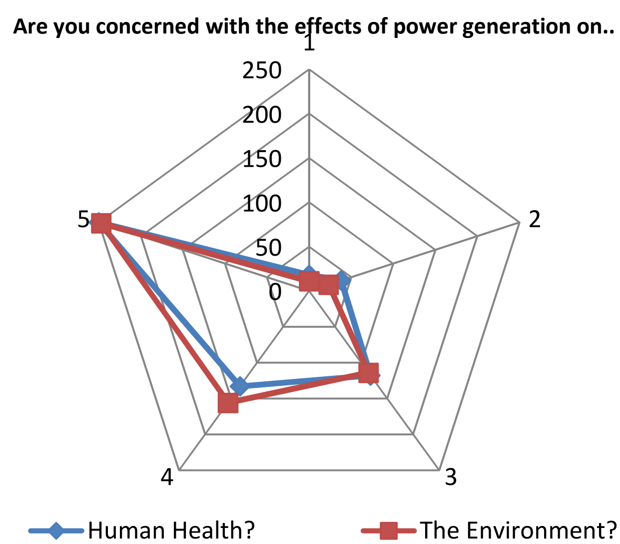
Question 1.

Yes	345
No	109
Not Sure	103



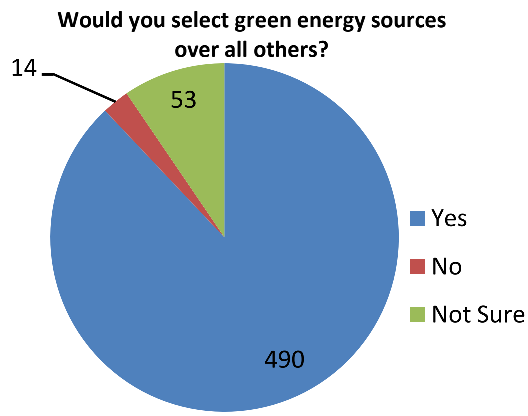
Question 2.

Human Health		The Environment	
1	18	1	11
2	38	2	23
3	118	3	114
4	133	4	156
5	250	5	247



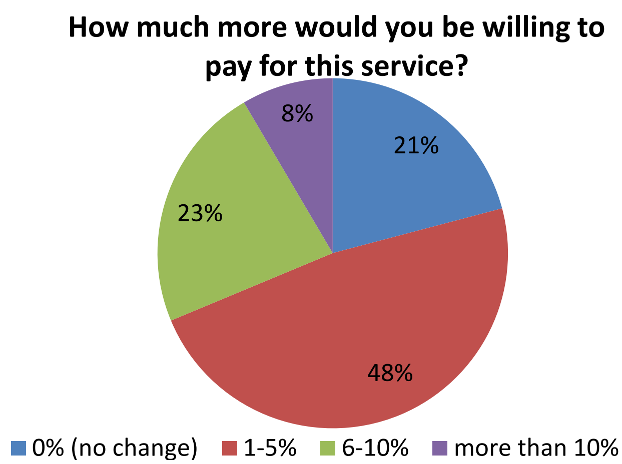
Question 3.

Yes	490
No	14
Not Sure	53



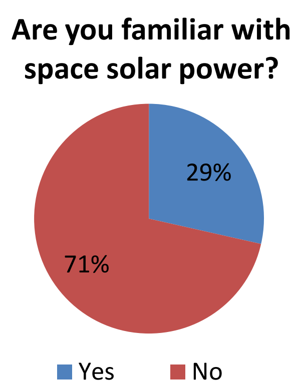
Question 4.

0% (no change)	116
1-5%	266
6-10%	127
more than 10%	47



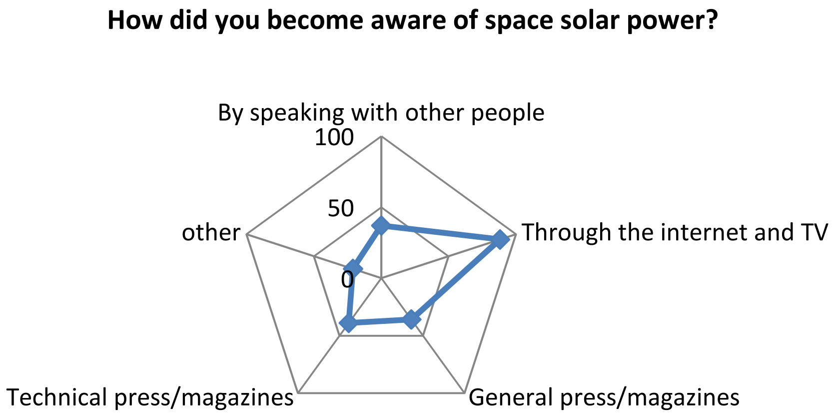
Question 5.

Yes	159
No	398



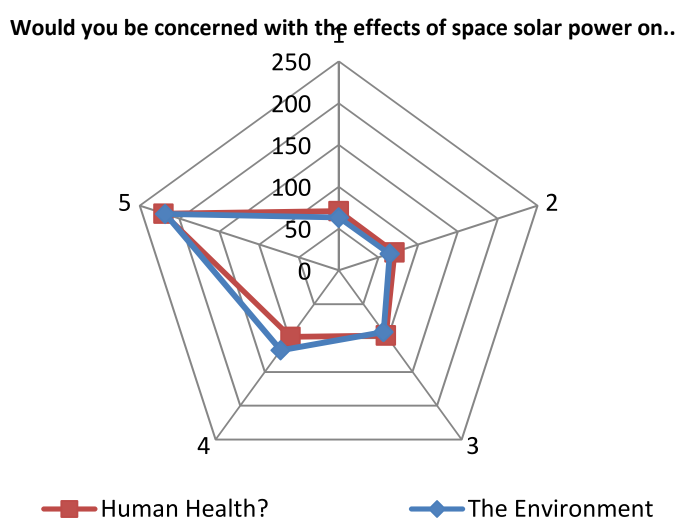
Question 6.

Q6a		Q6b+C		Q6d		Q6e			Q6f
Other people	37	TV + Internet	88	General Press	36	Technical Press	39	Y	Other



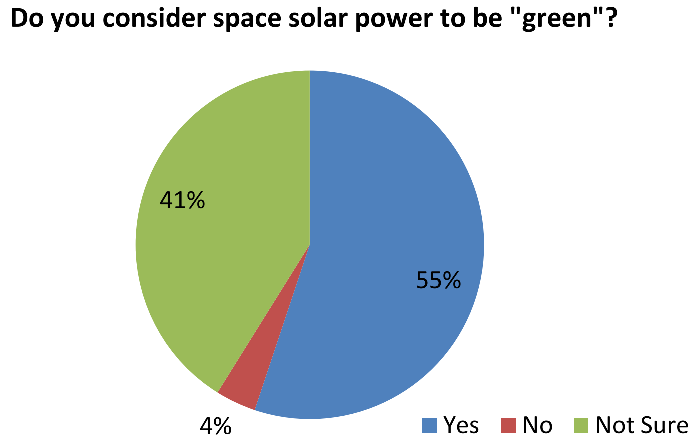
Question 7.

Human Health		The Environment	
1	71	1	63
2	70	2	64
3	96	3	91
4	98	4	118
5	220	5	218



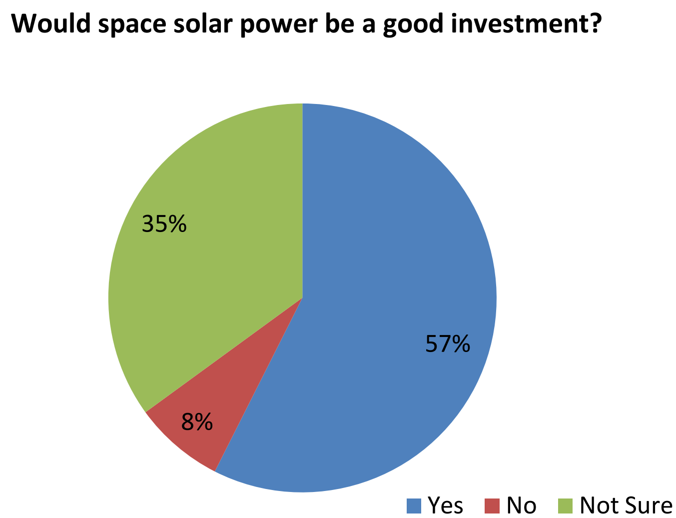
Question 8.

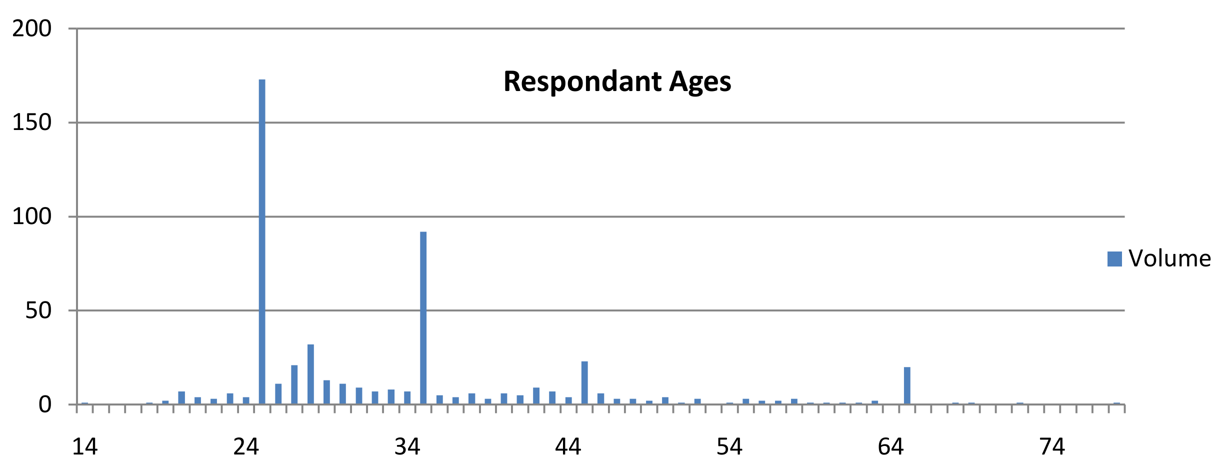
Yes	307
No	21
Not Sure	229



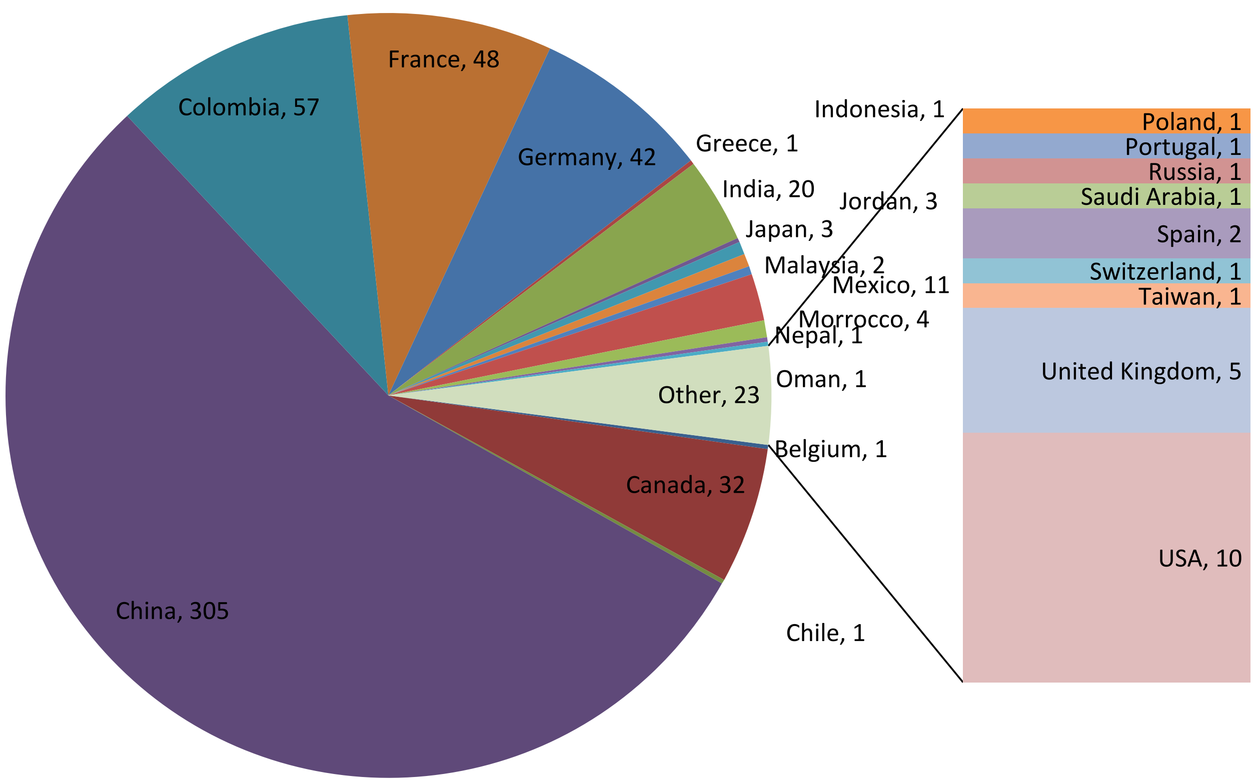
Question 9.

Yes	320
No	42
Not Sure	95





Worldwide Distribution of Survey Respondants



Appendix F – Summary of United Nations Space Treaties

The following definitions are in force:

Contracting Party: Is any state or organization which has signed and ratified the relevant document
Launching State / Authority: The state or organization to which the astronaut or equipment in question belongs.

Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (19 UST 7570; 672 UNTS 119)[cxcvii]

a. Any contracting party that bears witness to an emergency landing of another state's personnel shall immediately notify the launching authority as well as the UN.

b. If due to distress or emergency astronauts must land in a contracting parties jurisdiction, the contracting party shall take all available means to rescue and assist, as well as contacting the United Nations and the launching authority. The contracting party will work as closely as possible with the launching authority to ensure the safe return of astronauts.

c. If the personnel of a spacecraft have touched down in a neutral place, all contracting parties who have the means shall assist in search and rescue operations.

   Note: the above items apply equally to equipment and spacecraft as to astronauts.

d. Components of launched items which are found beyond the jurisdiction the launching authority after returning to Earth shall be returned to the launching authority, who must first provide identifying data before the items can be transferred.

e. Hazardous components discovered in the jurisdiction of a contracting party will be removed by the launching authority, under the supervision of the contracting party.

f. The launching authority will bear all costs incurred during the recovery of its equipment and personnel.

Convention on International Liability for Damage Caused by Space Objects (24 UST 2389; 961 UNTS 187)[cxcviii]

a. Any launching state shall be completely liable for damages caused by its space objects anywhere on the Earth or to aircraft in flight.

b. In the event that one launching state's equipment causes loses or damage to the equipment/personnel of another state's equipment/personnel at any place other than the surface of the Earth, the infringing state shall be held wholly responsible.

c. In the event of an incident between two or more launching states causing damage within a third party's jurisdiction (on Earth or in space), the offending parties shall be wholly liable.

d. States which launch space vehicles in tandem shall be jointly and severally liable for damages caused to any party by this joint launch.

e. States whose land is used for launching space objects but are not otherwise engaged in the affair shall be considered as a joint launch party.

f. Launching states cannot seek exoneration for liabilities if their actions have been outside the scope of the UN space laws.

g. These laws do not apply to damages caused against nationals of a launching state (its own people) or else foreign nationals who have been invited to participate in these actions.

h. States have one year to make a claim of damages from the incident date. If the state is unaware of the incident, it has one year from the date of discovery to make a claim. This date of discovery is based on the date that the state would reasonably be able to have noticed the damage, had due diligence been exercised.

i. International and intergovernmental organizations will be subject to these laws if they declare their acceptance of the rights and obligations as borne by participant states.

j. States which are stakeholders of independent organizations that operate within this agreement shall share liabilities with the organization if they have also accepted these laws

Convention on Registration of Objects Launched into Outer Space (28 UST 695; 1023 UNTS 15)[cxcix]

a. All items launched into space shall be logged into a registry to be maintained by the launching state. The launching state shall keep the United Nations up to date on the status of this registry as new items are added or the status of old items is changed.

b. The United Nations shall have full and unlimited access to this registry including orbital parameters of all space objects.

c. In the event of damage caused by an object which cannot be identified in a registry, those states with space monitoring capabilities shall endeavour to identify the nature of the object to the best of their ability.

k. International and intergovernmental organizations will be subject to these laws if they declare their acceptance of the rights and obligations as borne by participant states.

l. States which are stakeholders of independent organizations that operate within this agreement shall share liabilities with the organization if they have also accepted these laws

Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (16 UST 2410; 610 UNTS 205)[cc]

a. The exploration and use of Outer Space including celestial bodies shall be carried out for the benefit of all mankind and the knowledge there gained shall be the province of all.

b. Outer Space shall be free to explore and access by all states and is not subject to appropriation by any nation

c. All contracting states undertake to never place weapons of mass destruction, nuclear or otherwise, in orbit of the Earth, on other celestial bodies, or else stationed anywhere else in Outer Space.

d. The Moon and other celestial bodies shall be used exclusively for peaceful purposes. Use of these bodies for any kind of military fortification, manoeuvre, or test is completely prohibited.

e. States which are party to this treaty shall immediately inform all other states or else the Secretary General of the United Nations of any discovered phenomenon, in space or on any celestial body, which may be harmful to astronauts.

f. Actions carried out in space by nongovernmental organisations shall be done under the supervision of the relevant government; the relevant government shall bear all responsibility for the actions of this organisation. The actions of international organisations shall likewise be the responsibility of the participant nations.

g. Parties shall explore space in a cooperative manner, and shall endeavour to prevent the contamination of celestial bodies for the benefit of all other parties.

h. Parties to the treaties shall inform the United Nations as well as the public concerning the nature of all activities performed in Outer Space and on celestial bodies.

Appendix G – Orbital Signal Transmission Comparison

Signal Reception Comparison
There are three kinds of mobile communication ways which can transmit the RF signal at present:

- Provide global wireless communications is via GEO communication satellites.
- Provide global wireless communications is via LEO communication satellite constellation system.
- Terrestrial-based cellular phone systems (e.g. GSM).

We describe these three ways separately, and then compare the advantages and disadvantages in next section.

GEO satellite Communication
GEO satellite refers to the geosynchronous satellite about 36000km over the equator, which are mainly applied in field of telecommunication, broadcast and meteorology etc., with frequency band of L, S, C, X, Ku, Ka. Figure 50 shows a typical GEO satellite communication. [cci]

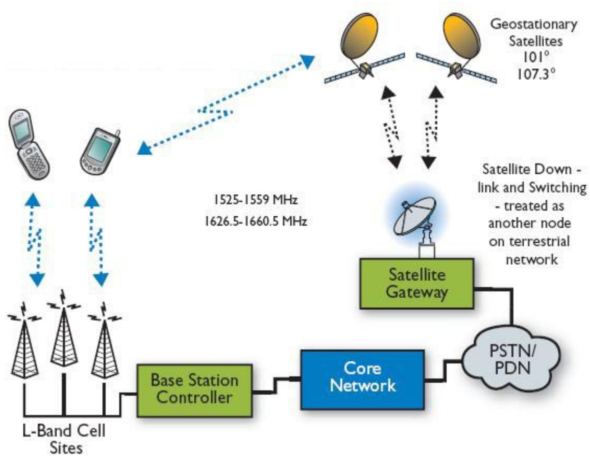


Figure 50 - A typical GEO satellites communication

A constellation formed by three GEO satellites, 120˚ apart in longitude, can provide communications coverage to anywhere on the surface of the Earth below approximately 70˚of latitude. Due to its advantage of covering the whole globe with only 3 to 4 satellites therefore, the control of constellation is simple, and remote telecommunication can be completed without tracking satellite and inter-satellite link. The deficiency is the shortage of frequency and orbit resources, unable of covering the polar areas; especially because of the longer distance between satellite and ground, it results in more link load and longer propagation delay time (at least 120ms, which is perceivable in two-way voice communications.), and causing the increased volume and costs of satellite and users' terminal, and unsuitable for application of mobile communications business. Losses along the 36,000 km long path are high, since signal strength falls off with the square of the distance between transmitter and receiver. High power transmitters and large antennas are required for the user terminals on the ground to overcome these losses. This reduces the mobility of end user terminals to the point where handheld personal devices for GEO communications are impractical. With bulky and expensive terminals, GEO systems could only win over a small group of users, typically consisting of mariners, field workers, and military personnel. As a consequence, GEO systems were unable to generate a customer base large enough to lower the cost of service significantly based on economies of scale.[ccii]

LEO Satellite Communication

A LEO communication satellite constellation system is a constellation of satellites that orbit the Earth at an altitude of about 500-1500 km and provide wireless communications also named as inverted cellular system between terminals on the ground. Figure 51 shows a typical LEO satellite communication.

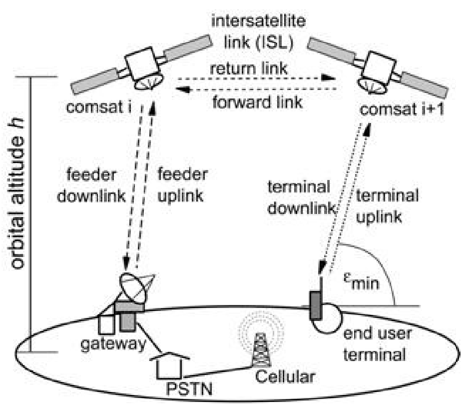


Figure 51 - A typical LEO satellite communication

LEO systems overcome the distance problem that plagues the GEO systems. Time delay for LEO systems is on the order of 10 milliseconds, negligible for voice communication. The short distance also reduces the requirement on power and antenna size.

As a result, LEO satellite phones are much more compact, which enables them to be carried by individual users. The smaller distance, however, comes at a price. While three GEO satellites can cover the entire globe below 70 degrees of latitude, LEO constellations typically require dozens of satellites to ensure continuous global coverage because the footprint of a LEO satellite is much smaller.

LEO satellites on the other hand require two-way many-too many connections, which increases the need for frequency bandwidth as well as hardware and software complexity of both space and terrestrial elements. With deficiencies like more required satellites, complicated control increases all-in costs, greater technical difficulty, and higher risks.

Terrestrial Cellular Communication

GSM (Global System for Mobile communications: originally from Groupe Spécial Mobile) is the most popular standard for mobile phones in the world. Its promoter, the GSM Association, estimates that 80% of the global mobile market uses the standard.[cciii] Its ubiquity makes international roaming very common between mobile phone operators, enabling subscribers to use their phones in many parts of the world. GSM differs from its predecessors in that both signalling and speech channels are digital, and thus is considered a second generation (2G) mobile phone system. This has also meant that data communication was easy to build into the system.

The ubiquity of the GSM standard has been an advantage to both consumers (who benefit from the ability to roam and switch carriers without switching phones) and also to network operators (who can choose equipment from any of the many vendors implementing GSM []). GSM also pioneered a low-cost (to the network carrier) alternative to voice calls, the Short message service (SMS, also called "text messaging"), which is now supported on other mobile standards as well. Another advantage is that the standard includes one worldwide Emergency telephone number, 112. This makes it easier for international travellers to connect to emergency services without knowing the local emergency number.[cciv]

The network behind the GSM seen by the customer is large and complicated in order to provide all of the services which are required. It is divided into a number of sections and these are each covered in separate articles.

- The Base Station Subsystem (the base stations and their controllers).
- The Network and Switching Subsystem (the part of the network most similar to a fixed network). This is sometimes also just called the core network.
- The GPRS Core Network (the optional part which allows packet based Internet connections).
- All of the elements in the system combine to produce many GSM services such as voice calls and SMS.

Appendix H – QX5 Stakeholder Analysis

Stakeholder	Stakeholder Type	Segment Type	Commitment	Interest Level	Interest Type	Influence	Relationship
1.Academia	R	1	2	1	T	3	1
2.QX5 Manufacturers	R	2	2	1	T/Ec	1	1
3.Electronic Manufactures	R	2	2	2	T/Ec	2	2
4.Operator	R	2	2	1	T/Ec	2	1
5.End QX5 User	R	3	3	1	T/En/Ec	1	1
6.Other Wireless Power Recharge Tech.Company	R	2	5	3	Ec	2	3
7.Financial Agency	R	4	3	4	Ec	2	2
8.WIPO*	R	5	3	2	T/N	1	2
9.ISO*	R	5	3	2	T/N	1	2
10.ITU*	R	5	3	3	T/N	2	2
11.WHO*	R	5	3	3	En/P	2	2
12.Goverment	R	5	3	2	Ec/En/P	2	1

*** WIPO-WORLD Intellectual Property Organization** ***ISO-International Standard Organization**

*** ITU-International Telecommunication Union** ***WHO-World Health Organization**

Appendix I – NPV Analysis Section

NPV for Classical System Case 1 (Through the size restrictions only selected columns are shown.)

Cost of capital	7.5%		Total mass in space (in kg)	1,297,638.61
Tax rate	24.1%		mass per launch (in kg)	29,610.00
Depreciation over 30 years			launch cost per launch	$94,500,000.00
POG (MW)	989		New launch cost	$27,972,000.00
expected kw/h a year	8,403,730,800.00		Rectenna cost	$475,562,634.00
Development cost total	$132,500,000,000		Production cost	$752,630,391.66
Total cost (value)	$2,347,073,025.66		Maintenance cost (per kg & per year)	$20.57
Total launches	44			
% Customer pays more	2.50%			
Price per kw/h	$0.08			
Voluntary green tarif	$54,000,000.00			

Year			1	6	7	8	13	14	37
Cash inflow	+	Revenue Electricity	0	0	0	$34,455,296.28	$689,105,925.60	$689,105,925.60	$689,105,925.60
		Voluntary green tarif	$54,000,000.00	$54,000,000.00	$54,000,000.00	$54,000,000.00	$54,000,000.00	$54,000,000.00	$54,000,000.00
Cash outlfow		% from total R&D	6%	12%	10%	10%			
	-	Research & Development	$7,950,000,000.00	$15,900,000,000.00	$13,250,000,000.00	$13,250,000,000.00			
		% from production cost		5%	10%	17%	5%		
	-	Production cost		$37,631,519.58	$75,263,039.17	$127,947,166.58	$37,631,519.58		
	-	Rectenna cost				$475,562,634.00			
		Launch per year				2	6		
	-	Launch cost				$55,944,000.00	$167,832,000.00		
	-	Operating cost				$1,218,155.40	$26,692,426.13	$26,692,426.13	$26,692,426.13
		Value				$772,348,359.33	$2,347,073,025.66		
	-	Depreciation				$78,235,767.52	$78,235,767.52	$78,235,767.52	$78,235,767.52
Befor Tax	=		-$7,896,000,000.00	-$15,883,631,519.58	-$13,271,263,039.17	-$13,900,452,427.23	$432,714,212.36	$638,177,731.95	$638,177,731.95
Tax amount	-		-$1,902,936,000.00	-$3,827,955,196.22	-$3,198,374,392.44	-$3,350,009,034.96	$104,284,125.18	$153,800,833.40	$153,800,833.40
After tax	=		-$5,993,064,000.00	-$12,055,676,323.36	-$10,072,888,646.73	-$10,550,443,392.27	$328,430,087.18	$484,376,898.55	$484,376,898.55
	+	Depreciation				$78,235,767.52	$78,235,767.52	$78,235,767.52	$78,235,767.52
Free Cash flow	=		-$5,993,064,000.00	-$12,055,676,323.36	-$10,072,888,646.73	-$10,472,207,624.74	$406,665,854.71	$562,612,666.07	$562,612,666.07
PV	=		-5,574,943,255.81	-7,811,614,336.61	-6,071,482,998.01	-5,871,790,203.75	158,828,221.76	204,404,760.29	38,734,354.94
NPV	=		-5,574,943,255.81	-61,304,071,622.15	-67,375,554,620.17	-73,247,344,823.92	-73,016,338,783.65	-72,811,934,023.36	-70,602,995,285.39
Final NPV		-70,602,995,285.39							

NPV for Classical System Case 4 (Through the size restrictions only selected columns are shown.)

Cost of capital	7.5%		Total mass in space (in kg)	527,881.51
Tax rate	24.1%		mass per launch (in kg)	29,610.00
Depreciation over 30 years			New launch cost	$37,233,000.00
POG (MW)	5000		Rectenna cost	$8,454,446.83
expected kw/h a year	42,486,000,000.00		Production cost	$306,171,274.32
Development cost total	$132,500,000,000		Maintenance cost (per kg & per year)	$20.57
Total cost (value)	$18,702,337,817.67		Total mass in space (in kg)	527,881.51
Total launches	160			

Year			1	6	7	8	9	16	17	37
Cash inflow	+		0	0	0	$106,215,000.00	$318,645,000.00	$3,292,665,000.00	$3,398,880,000.00	$3,398,880,000.00
Cash outlfow		% from total R&D	6%	12%	10%	10%				
	-	Research & Development	$7,950,000,000.00	$15,900,000,000.00	$13,250,000,000.00	$13,250,000,000.00				
		% from production cost		2%	4%	11%	11%	4%	2%	
	-	Production cost		$54,737,862.70	$109,475,725.40	$301,058,244.85	$301,058,244.85	109475725.4	54737862.7	
	-	Rectenna cost				$845,444,682.67				
		Launch per year				5	10	20	5	
	-	Launch cost				$472,500,000.00	$945,000,000.00	$1,890,000,000.00	$472,500,000.00	
	-	Operating cost				$3,045,388.50	$9,136,165.50	$94,407,043.50	$97,452,432.00	$97,452,432.00
		Value				$1,783,216,515.62	$3,029,274,760.47	$18,175,099,954.97	$18,702,337,817.67	
	-	Depreciation				$4,416,666,666.67	$4,416,666,666.67	$4,416,666,666.67	$4,416,666,666.67	$4,416,666,666.67
Befor Tax	=		-$7,950,000,000.00	-$15,954,737,862.70	-$13,359,475,725.40	-$19,182,499,982.69	-$5,353,216,077.02	-$3,217,884,435.57	-$1,642,476,961.37	-$1,115,239,098.67
Tax amount	-		-$1,915,950,000.00	-$3,845,091,824.91	-$3,219,633,649.82	-$4,622,982,495.83	-$1,290,125,074.56	-$775,510,148.97	-$395,836,947.69	-$268,772,622.78
After tax	=		-$6,034,050,000.00	-$12,109,646,037.79	-$10,139,842,075.58	-$14,559,517,486.86	-$4,063,091,002.46	-$2,442,374,286.6	-$1,246,640,013.68	-$846,466,475.89
	+	Depreciation				$4,416,666,666.67	$4,416,666,666.67	$4,416,666,666.67	$4,416,666,666.67	$4,416,666,666.67
Free Cash flow	=		-$6,034,050,000.00	-$12,109,646,037.79	-$10,139,842,075.58	-$10,142,850,820.19	$353,575,664.21	$1,974,292,380.07	$3,170,026,652.99	$3,570,200,190.78
PV	=		-5,613,069,767.44	-7,846,584,634.72	-6,111,839,505.39	-5,687,119,107.86	184,419,222.88	620,691,847.70	927,083,862.34	245,798,592.42
NPV	=		-5,613,069,767.44	-61,504,866,558.86	-67,616,706,064.24	-73,303,825,172.10	-73,119,405,949.22	-70,866,371,246.25	-69,939,287,383.9	-59,295,057,666.05
Final NPV		-59,295,057,666.05								

NPV for Small Scale Application (Through the size restrictions only selected columns are shown.)

Cost of capital	4,3%		Total mass in space (in kg)	613,410.07
Tax rate	30,5%		mass per launch (in kg)	29,610.00
Depreciation over 30 years			launch cost per launch	$94,500,000.00
POG (MW)	192.8		New launch cost	$35,437,500.00
expected kw/h a year	1,638,600,048.00		Rectenna cost	$357,200,378.43
Total cost (value)	$1,457,165,721.34		Production cost	$355,777,842.91
Total launches	21		Maintenance cost (per kg & per year)	$20.57
Price per kw/h	$0.22			

Year			1	2	3	4	5	6	31	32
Cash inflow	+		0	0	$85,831,431.09	$257,494,293.26	$360,492,010.56	$360,492,010.56	$360,492,010.56	$360,492,010.56
Cash outlfow		% from production cost	15%	28%	28%	24%	5%			
	-	Production cost	$53,366,676.44	$99,617,796.01	$99,617,796.01	$85,386,682.30	$17,788,892.15			
	-	Rectenna cost			$357,200,378.43					
		Launch cumulated			5	15	21			
		Launch per year			5	10	6			
	-	Launch cost			$177,187,500.00	$354,375,000.00	$212,625,000.00			
	-	Operating cost			$3,045,388.50	$9,136,165.50	$12,617,845.22	$12,617,845.22	$12,617,845.22	$12,617,845.22
		Value			$786,990,146.89	$1,226,751,829.19	$1,457,165,721.34			
	-	Depreciation			$48,572,190.71	$48,572,190.71	$48,572,190.71	$48,572,190.71	$48,572,190.71	$48,572,190.71
Befor Tax	=		-$53,366,676.44	-$99,617,796.01	-$599,791,822.57	-$239,975,745.25	$68,888,082.48	$299,301,974.63	$299,301,974.63	$299,301,974.63
Tax amount	-		-$16,260,826.31	-$30,353,542.45	-$182,756,568.34	-$73,120,609.58	$20,990,198.73	$91,197,311.67	$91,197,311.67	$91,197,311.67
After tax	=		-$37,105,850.13	-$69,264,253.57	-$417,035,254.23	-$166,855,135.67	$47,897,883.75	$208,104,662.96	$208,104,662.96	$208,104,662.96
	+	Depreciation			$48,572,190.71	$48,572,190.71	$48,572,190.71	$48,572,190.71	$48,572,190.71	$48,572,190.71
Free Cash flow	=		-$37,105,850.13	-$69,264,253.57	-$368,463,063.52	-$118,282,944.96	$96,470,074.46	$256,676,853.67	$256,676,853.67	$256,676,853.67
PV	=		-35,582,901.92	-63,695,259.81	-324,930,808.48	-100,027,183.15	78,232,552.68	199,609,208.29	70,009,183.03	67,135,771.99
NPV	=		-35,582,901.92	-99,278,161.73	-424,208,970.21	-524,236,153.37	-446,003,600.69	-246,394,392.39	2,781,643,581.01	2,848,779,353.00
Final NPV		2,848,779,353.00								

NPV for Remote Applications (Through the size restrictions only selected columns are shown.)

Cost of capital	4.3%		Total mass in space (in kg)	527,881.51
Tax rate	30.5%		mass per launch (in kg)	29,610.00
Depreciation over 30 years			New launch cost	$37,233,000.00
POG (MW)	22.5		Rectenna cost	$8,454,446.83
expected kw/h a year	191,866,776.00		Production cost	$306,171,274.32
Total cost (value)	$984,819,721.14		Maintenance cost (per kg & per year)	$20.57
Total launches	18		Total mass in space (in kg)	527,881.51
Price per kw/h	$0.58			

Year			1	2	3	4	5	6	31	32
Cash inflow	+		0	0	$30,911,869.47	$92,735,608.40	$111,282,730.08	$111,282,730.08	$111,282,730.08	$111,282,730.08
Cash outlfow		% from production cost	15%	28%	28%	24%	5%			
	-	Production cost	$45,925,691.15	$85,727,956.81	$85,727,956.81	$73,481,105.84	$15,308,563.72			
	-	Rectenna cost			$8,454,446.83					
		Launch per year			5	10	3			
	-	Launch cost			$186,165,000.00	$372,330,000.00	$111,699,000.00			
	-	Operating cost			$3,045,388.50	$9,136,165.50	$10,963,398.60	$10,963,398.60	$10,963,398.60	$10,963,398.60
		Value			$412,001,051.59	$857,812,157.43	$984,819,721.14			
	-	Depreciation			$32,827,324.04	$32,827,324.04	$32,827,324.04	$32,827,324.04	$32,827,324.04	$32,827,324.04
Befor Tax	=		-$45,925,691.15	-$85,727,956.81	-$285,308,246.71	-$395,038,986.97	-$59,515,556.27	$67,492,007.44	$67,492,007.44	$67,492,007.44
Tax amount	-		-$13,993,558.09	-$26,121,308.44	-$86,933,422.77	-$120,368,379.33	-$18,134,390.00	$20,564,814.67	$20,564,814.67	$20,564,814.67
After tax	=		-$31,932,133.05	-$59,606,648.37	-$198,374,823.94	-$274,670,607.64	-$41,381,166.28	$46,927,192.77	$46,927,192.77	$46,927,192.77
	+	Depreciation			$32,827,324.04	$32,827,324.04	$32,827,324.04	$32,827,324.04	$32,827,324.04	$32,827,324.04
Free Cash flow	=		-$31,932,133.05	-$59,606,648.37	-$165,547,499.90	-$241,843,283.60	-$8,553,842.24	$79,754,516.81	$79,754,516.81	$79,754,516.81
PV	=		-30,621,531.51	-54,814,146.67	-145,988,806.78	-204,517,248.29	-6,936,751.29	62,022,483.65	21,753,221.94	20,860,396.95
NPV	=		-30,621,531.51	-85,435,678.17	-231,424,484.95	-435,941,733.24	-442,878,484.54	-380,856,000.89	560,014,599.66	580,874,996.61
Final NPV		580,874,996.61								

NPV for Military Applications (Through the size restrictions only selected columns are shown.)

Cost of capital	4.3%		Total mass in space (in kg)	1,886,629.37
Tax rate	30.5%		mass per launch (in kg)	29,610.00
Depreciation over 30 years			New launch cost	$24,759,000.00
POG (MW)	3.5		Rectenna cost	$5,719,486.12
expected kw/h a year	29,701,962.60		Production cost	$1,094,245,033.63
Total cost (value)	$2,684,540,519.75		Maintenance cost (per kg & per year)	$20.57
Total launches	64		Total mass in space (in kg)	1,886,629.37
Price per kw/h	$11.85			

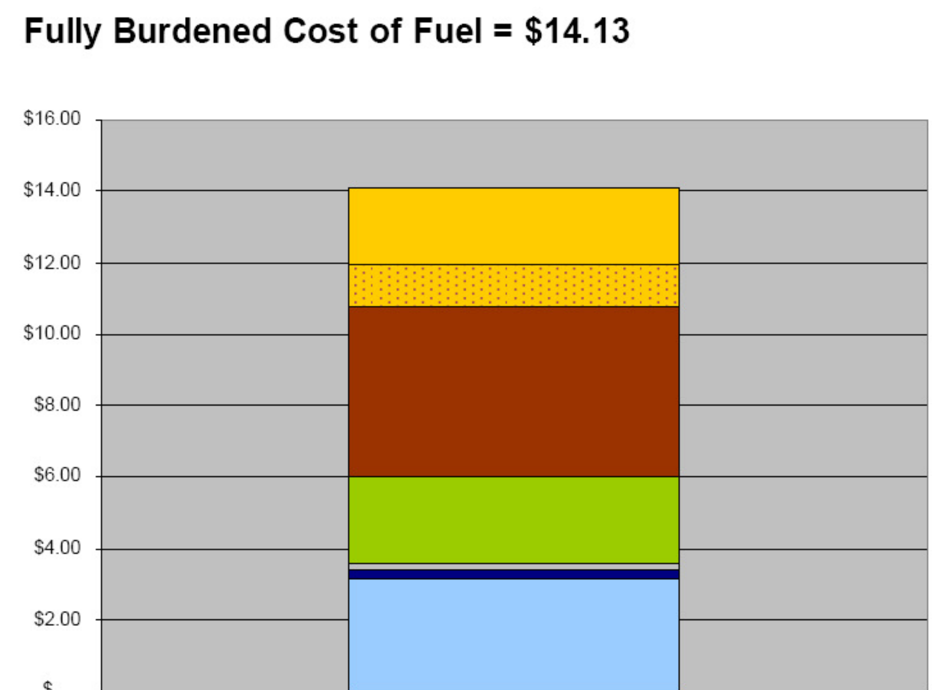
Year			1	2	3	4	8	9	10	32
Cash inflow	+		0	0	$27,497,520.06	$82,492,560.19	$302,472,720.70	$351,968,256.81	$351,968,256.81	$351,968,256.81
Cash outlfow		% from production cost	4%	8%	14%	14%	14%	4%		
	-	Production cost	$43,769,801.35	$87,539,602.69	$153,194,304.71	$153,194,304.71	$153,194,304.71	$43,769,801.35		
	-	Rectenna cost			$5,719,486.12					
		Launch per year			5	10	10	9		
	-	Launch cost			$123,795,000.00	$247,590,000.00	$247,590,000.00	222831000		
	-	Operating cost			$3,045,388.50	$9,136,165.50	$33,499,273.50	$38,807,966.11	$38,807,966.11	$38,807,966.11
		Value			$414,018,194.86	$814,802,499.57	$2,417,939,718.40	$2,684,540,519.75		
	-	Depreciation			$89,484,683.99	$89,484,683.99	$89,484,683.99	$89,484,683.99	$89,484,683.99	$89,484,683.99
Befor Tax	=		-$43,769,801.35	-$87,539,602.69	-$347,741,343.26	-$416,912,594.01	-$221,295,541.50	-$42,925,194.63	$223,675,606.71	$223,675,606.71
Tax amount	-		-$13,336,658.47	-$26,673,316.94	-$105,956,787.29	-$127,033,267.39	-$67,428,751.50	-$13,079,306.80	$68,153,957.37	$68,153,957.37
After tax	=		-$30,433,142.88	-$60,866,285.75	-$241,784,555.97	-$289,879,326.62	-$153,866,790.01	-$29,845,887.83	$155,521,649.35	$155,521,649.35
	+	Depreciation			$89,484,683.99	$89,484,683.99	$89,484,683.99	$89,484,683.99	$89,484,683.99	$89,484,683.99
Free Cash flow	=		-$30,433,142.88	-$60,866,285.75	-$152,299,871.97	-$200,394,642.62	-$64,382,106.02	$59,638,796.16	$245,006,333.34	$245,006,333.34
PV	=		-29,184,064.90	-55,972,506.52	-134,306,326.55	-169,465,780.78	-46,042,298.79	40,899,657.01	161,126,541.74	64,083,259.15
NPV	=		-29,184,064.90	-85,156,571.41	-219,462,897.97	-388,928,678.75	-746,231,260.86	-705,331,603.85	-544,205,062.12	1,723,161,353.51
Final NPV		1,723,161,353.51								

QX5 NPV Analysis

Year	2009	2010	2011	2012	2013	2024	2025	2026	2027	2028
# Workers	200	200	200	150	150	100	100	100	101	102
Salary	40,000	41,200	42,436	43,709	45,020	62,319	64,188	66,114	68,097	70,140
Number of QX5 manufacturer	0	0	0	1	2	6	6	6	6	6
Manufacturer 1								77,566,411	81,444,731	85,516,968
Manufacturer 2	0	0	0	0	217,949	30,667,573	32,200,952	33,811,000	35,501,550	37,276,627
Manufacturer 3	0	0	0	0	0	16,235,774	17,047,563	17,899,941	18,794,938	19,734,685
Manufacturer 4	0	0	0	0	0	14,431,799	15,153,389	15,911,059	16,706,612	17,541,942
Manufacturer 5	0	0	0	0	0	14,431,799	15,153,389	15,911,059	16,706,612	17,541,942
Manufacturer 6	0	0	0	0	0	5,411,925	5,682,521	5,966,647	6,264,979	6,578,228
Cost										
Invest in R&D	-30,000,000	-20,000,000	-20,000,000	-500,000	-800,000	-216,476,988	-227,300,838	-238,665,879	-250,599,173	-263,129,132
Invest in Fixed assets	-10,000,000	-10,000,000	-10,000,000	0	0	0	0	0	0	0
Depreciation	-1,000,000	-2,000,000	-3,000,000	-3,000,000	-3,000,000	0	0	0	0	0
Cost of Workforce	-8,000,000	-8,240,000	-8,487,200	-6,556,362	-6,753,053	-6,231,870	-6,418,826	-6,611,391	-6,877,830	-7,154,305
Cost of Chips	0	0	0	-1,000,000	-3,589,744	-757,669,458	-795,552,931	-835,330,578	-877,097,107	-920,951,962
Marketing budget per year	-5,000,000	-5,000,000	-40,000,000	-20,000,000	-20,000,000	-20,000,000	-20,000,000	-20,000,000	-20,000,000	-20,000,000
Total cost	-54,000,000	-45,240,000	-81,487,200	-31,056,362	-34,142,796	-1,000,378,316	-1,049,272,595	-1,100,607,848	-1,154,574,110	-1,211,235,399
Revenue										
IP/Patent	0	0	0	5,000,000	5,000,000	0	0	0	0	0
Charge fee from QX5 Manufacturer	0	0	0	600,000	2,153,846	454,601,675	477,331,759	501,198,347	526,258,264	552,571,177
Charge fee from operator	0	0	0	1,000,000	3,589,744	757,669,458	795,552,931	835,330,578	877,097,107	920,951,962
The chip Sales	0	0	0	1,400,000	5,025,641	1,060,737,242	1,113,774,104	1,169,462,809	1,227,935,949	1,289,332,747
Total Revenue	0	0	0	8,000,000	15,769,231	2,273,008,375	2,386,658,794	2,505,991,734	2,631,291,320	2,762,855,886
Total operating income	-54,000,000	-45,240,000	-81,487,200	-23,056,362	-18,373,566	1,272,630,059	1,337,386,199	1,405,383,886	1,476,717,211	1,551,620,487
Working capital	3,000,000	3,000,000	3,000,000	2,400,000	4,730,769	681,902,513	715,997,638	751,797,520	789,387,396	828,856,766
Change of Working capital	3,000,000	0	0	-600,000	2,330,769	32,471,548	34,095,126	35,799,882	37,589,876	39,469,370
Free cash flow	-66,000,000	-53,240,000	-88,487,200	-19,456,362	-17,704,335	1,240,158,511	1,303,291,074	1,369,584,004	1,439,127,335	1,512,151,118
Tax	15,840,000	12,777,600	21,236,928	4,669,527	4,249,040	-297,638,043	-312,789,858	-328,700,161	-345,390,560	-362,916,268
Total profit	-50,160,000	-40,462,400	-67,250,272	-14,786,835	-13,455,295	942,520,468	990,501,216	1,040,883,843	1,093,736,774	1,149,234,849
DCF	-50,160,000	-37,510,337	-57,795,322	-11,780,757	-9,937,806	302,538,472	294,743,444	287,138,038	279,705,237	272,455,696
Cum DCF	-50,160,000	-87,670,337	-145,465,659	-157,246,415	-167,184,221	2,577,492,872	2,872,236,315	3,159,374,354	3,439,079,590	3,711,535,286
NPV	3,711,535,286									

Appendix J – Fully Burdened Cost of Fuel

The figure of US $134 Million Dollars for 1 MW per year seems unreal or product of a miscalculation, but it corresponds to the cost of: buying the quantity of generators required to produce 1 MW (146 Gen. at US $1.7Mn total), transport this number of generators from USA to Iraq (US $ 100K by Sea or US $ 800K by Air), depreciation and maintenance (each at a cost of US $ 1.5Mn), transport the fuel required by the generators to where they are (By truck US $11Mn, by Helicopter US $112Mn) and pay the support personnel required to operate and maintain the gen-sets (12 people for one year: US $6.3Mn).



	$ Per Gallon
Force Protection (Air)	$2.19
Force Protection (Ground)	$1.20
Transport:	$4.75
Fuel Support Military Personnel in SBCT	$2.43
Fuel Support Equipment in SBCT	$0.18
Sustainment Brigade/TSC	$0.24
Fuel Commodity	$3.14

Appendix K – Sample Technical Model Calculations

MW POG	Transmitter Diameter (m)	Normalized Radius of Rectenna Built	Effective Rectenna Diameter (m)	% Of Maximum Energy	Boresight Energy Density (mW/cm^2)	Frontier Energy Density (mW/cm^2)	Structure Needed (Kg)	Mass of Solar Panel Needed (Kg)	Estimated Production Cost (USD)	Expected Number of Launches	Expected Total Cost	Energy Must be Sold at ($/kwh)
1000	600	5%	57.47	11%	296.6555553	0.310781115	1,882,352.94	855,285.67	$ 1,587,830,391.14	92.46	$ 10,381,404,826.82	$ 0.36
1000	150	25%	1149.37	53%	18.5409722	0.01942382	470,588.24	855,285.67	$ 769,006,862.24	44.78	$ 5,074,482,219.10	$ 0.04
1000	200	50%	1724.05	87%	32.96172836	0.034531235	627,450.98	855,285.67	$ 859,987,254.34	50.08	$ 5,727,677,163.03	$ 0.03
1000	500	75%	1034.43	99%	206.0108023	0.215820219	1,568,627.45	855,285.67	$ 1,405,869,606.94	81.86	$ 9,229,441,064.16	$ 0.04
1000	141	100%	4890.93	100%	16.38280304	0.017162887	442,352.94	855,285.67	$ 752,630,391.66	43.82	$ 5,766,167,307.84	$ 0.02
5000	141	5%	244.55	11%	81.9140152	0.085814435	442,352.94	4,276,428.33	$ 2,736,893,135.42	159.36	$ 17,896,012,294.70	$ 0.12
5000	141	25%	1222.73	53%	81.9140152	0.085814435	442,352.94	4,276,428.33	$ 2,736,893,135.42	159.36	$ 17,946,738,975.66	$ 0.03
5000	141	50%	2445.46	87%	81.9140152	0.085814435	442,352.94	4,276,428.33	$ 2,736,893,135.42	159.36	$ 18,105,259,853.66	$ 0.02
5000	141	75%	3668.20	99%	81.9140152	0.085814435	442,352.94	4,276,428.33	$ 2,736,893,135.42	159.36	$ 18,369,461,317.00	$ 0.01
5000	141	100%	4890.93	100%	81.9140152	0.085814435	442,352.94	4,276,428.33	$ 2,736,893,135.42	159.36	$ 18,739,343,365.67	$ 0.01
200	141	5%	244.55	11%	3.276560608	0.003432577	442,352.94	171,057.13	$ 355,777,842.91	20.72	$ 2,328,201,025.31	$ 0.40
200	141	25%	1222.73	53%	3.276560608	0.003432577	442,352.94	171,057.13	$ 355,777,842.91	20.72	$ 2,378,927,706.27	$ 0.09
200	141	50%	2445.46	87%	3.276560608	0.003432577	442,352.94	171,057.13	$ 355,777,842.91	20.72	$ 2,537,448,584.28	$ 0.06
200	141	75%	3668.20	99%	3.276560608	0.003432577	442,352.94	171,057.13	$ 355,777,842.91	20.72	$ 2,801,650,047.61	$ 0.06
200	141	100%	4890.93	100%	3.276560608	0.003432577	442,352.94	171,057.13	$ 355,777,842.91	20.72	$ 3,171,532,096.28	$ 0.06
75	141	5%	244.55	11%	1.228710228	0.001287217	442,352.94	64,146.42	$ 293,769,632.17	17.11	$ 1,922,789,273.51	$ 0.88
75	141	25%	1222.73	53%	1.228710228	0.001287217	442,352.94	64,146.42	$ 293,769,632.17	17.11	$ 1,973,515,954.47	$ 0.19
75	141	50%	2445.46	87%	1.228710228	0.001287217	442,352.94	64,146.42	$ 293,769,632.17	17.11	$ 2,132,036,832.47	$ 0.13
75	141	75%	3668.20	99%	1.228710228	0.001287217	442,352.94	64,146.42	$ 293,769,632.17	17.11	$ 2,396,238,295.80	$ 0.13
75	141	100%	4890.93	100%	1.228710228	0.001287217	442,352.94	64,146.42	$ 293,769,632.17	17.11	$ 2,766,120,344.47	$ 0.14

Note that the required costs per kW/h given in this table are based on non discounted cash flow calculations, and should not be directly compared to data for NPV calculations performed elsewhere. Note also that many supporting columns for this calculation could not be provided due to space limitations.

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