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Alternatives for Power Generation Systems, Connectivity, and Environmental Testing

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Sponsored by the Costa Rican Foundation for Sustainable Development

July 4, 2000

Dr. Juan Barrios Arce
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Dear Dr. Juan Barrios Arce:

Enclosed is our report entitled "Alternatives for Power Generation Systems, Connectivity, and Environmental Testing." It was written at Entebbe, the Costa Rican Foundation for Sustainable Development during the period March 20 through July 4, 2000. Preliminary project work was completed in Worcester, Massachusetts prior to our arrival in Costa Rica. Copies of this report are simultaneously being submitted to Professors Angel Rivera and Roberto Pietroforte for evaluation. Upon faculty review, a copy of this report will be catalogued in the Gordon Library at Worcester Polytechnic Institute. We appreciate the time you dedicated to us.

Sincerely,

Anthony C. Durand

Kevin Caudill

Elionex B. Rodríguez

Report Submitted to:
Professor Angel Rivera
Professor Roberto Pietroforte

Costa Rica, Project Center

By

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In Cooperation With
Juan Barrios Arce, Lincos Project Director
Entebbe, Costa Rican Foundation for Sustainable Development

Alternatives for Power Generation Systems, Connectivity, and Environmental Testing

July 6, 2000

This project is submitted in partial fulfillment of the degree requirements of Worcester Polytechnic Institute. The views and opinions expressed herein are those of the authors and do not necessarily reflect the positions or opinions of the Costa Rican Foundation for Sustainable Development or Worcester Polytechnic Institute.

Abstract

The Costa Rican Foundation for Sustainable Development works to improve human development, economic balance, and the respect for environment through the promotion of technology. The Foundation utilizes Lincos containers, a shipping container that includes multiple information technologies, as a tool to further sustainable development. To help the Foundation meet the global demand for Lincos, we found alternatives for power generation systems, connectivity methods, as well as chemical substance tests to be included in the environmental testing kits for the containers.

Authorship

Consisting of three main parts, this project was authored by Anthony C. Durand, Kevin Caudill, and Elionex B. Rodríguez. Anthony C. Durand contributed to this project by concentrating on the power generation system component. Kevin Caudill contributed by concentrating on the connectivity method component. And Elionex B. Rodríguez contributed by concentrating on the environmental testing kits component. The remaining portions consisted of equal contribution by the three authors.

Executive Summary

Many impoverished communities around the world do not have the technology and necessary knowledge for improving their way of life. The way some communities have tried to develop caused much damage to their environment with only moderate success in human development and the economy. The Costa Rican Foundation for Sustainable Development works to help them develop sustainably or improving human development, economic balance, and respect for the environment through the promotion of technology.

One of the Foundations' four initiatives designed to further this type of development includes the Lincos Program. The Foundation has designed a shipping container, called the Lincos container, equipped with multiple information technologies on board. Based on these technologies the applications are configured to promote sustainable development. The applications include a computer lab, an information center, a media center, and a health and environmental center.

Because there is such a great demand for the Lincos container, the Foundation is interested in making these containers suitable for all geographical locations around the world. In particular, three components of the container have become issues that the Foundation must solve before the container can be effectively deployed.

The first issue was power generation systems or the method in which power is supplied to the electronic devices. As a local power grid may not be available for a particular site, it is important that a reliable source of energy be found to power the equipment. Since one of the Foundation's objectives is to facilitate respect for the environment, renewable sources of energy, such as hydropower and solar power, must be researched.

The second issue was the method of connectivity. Since many of the applications, such as the computer lab and information center, are dependent on a connection to the outside world. There are various locations throughout the world that are interested in placing a Lincos container that may not be wired with a local communications grid. For these sites, a wireless method of connectivity, such as satellite communications, can be used. For the locations with a local telecommunications grid, wired solutions, like digital subscriber line and cable modem technologies, must be researched.

The last issue deals with the environmental testing kits. Before the official testing kits can be deployed with the Lincos container, the optimal combination of the chemical tests included in the environmental testing kits must be found for providing the most useful results.

The objectives of our project were to find the alternatives for power generation systems, connectivity methods, and chemical substances to be included in the environmental testing kits. In terms of power generation systems, we found five alternatives: hydropower, wind power, solar power, fuel-based power, and hybrids. The first three alternatives that were researched are based on renewable sources of energy. Although fuel-based power, like diesel generators, is not based on renewable sources, it was included as a cost-effective alternative. Finally, we researched hybrid technologies and found it to be dependent on the energy resources available at a particular site. Each of these technologies was researched by using the parameters of power output, cost, and environmental impact.

The next component of this project was finding efficient connectivity methods. For the wireless connection, we located the following satellite service providers: Intelsat and Esatel. We researched four different wired solutions: digital subscriber line (DSL), cable modem, integrated services digital network (ISDN), and frame relay. These alternatives were found based upon the parameters of bandwidth, cost, supported services, and services offered.

The last issue we covered was the environmental testing kits. Researching many different tests for soil and water, we have found a set of chemical substances to be tested for. For water, our team identified pH, hardness, sodium, bacteria, chlorine, lead, nitrates/nitrites, arsenic, and ammonia tests for inclusion in the Lincos testing kits. For soil testing, we determined that pH, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, salinity, and aluminum tests should also be included.

Although more background information must be gathered on the power and connectivity infrastructure, as well as obtaining information from geological surveys for each particular site of interest for the Lincos container, these results help to address the key issues of power generation, connectivity, and environmental testing. By improving the ability of the Foundation to reach more locations around the world, marginalized communities around the world can benefit from the Lincos container through the human development, economic balance, and respect for the environment.

Acknowledgements

We would like to thank our liaison, Dr. Juan Barrios Arce, and our advisors, Professors Angel Rivera and Roberto Pietroforte, for their guidance and support during this project.

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1.0 Introduction

There are many underdeveloped communities in the world where the people do not have access to new technologies and the information that they need to improve their living conditions. The ability to establish worldwide communication and the capability to access the necessary technologies should permit people to better themselves, their economy, and the relationship they have with their environment. In doing so, they will have taken the first steps towards sustainable development. According to José Figueres, former President of Costa Rica, "sustainable development" is defined as the process of human development, a balancing of the economy, and the promotion of respect for the environment. Coined in the late 1960's, sustainable development became the basis for the environmental movement of the 1970's as many people tried to explain how society can sustain its existence while improving its state of being by "...achieving economic development to secure rising standards of living...to protect and enhance their environment..." (United Kingdom Secretaries of State for the Environment et al., 1994).

There are foundations that have been established to promote sustainable development in developing countries. Entebbe, the Costa Rican Foundation for Sustainable Development, is one such organization. They have implemented many different types of programs to promote the idea of sustainability for all regions of the world, including Costa Rica. These programs include Centaire, their clean air initiative for improving the air quality management; the APVE (Association to Promote Electric Vehicles); the Networks for Sustainability; and the Lincos Program, the main concentration of this project.

To further sustainable development, the Lincos Program was designed to provide the access to technology that is not available to marginalized communities. This access is brought to these communities in the form of a modified shipping container that "integrates multiple information technologies into a single [container]" (Entebbe, 1999). This container features four main applications: the computer lab, the information center, the video-conferencing center, and the health and environment center. By providing these applications and technologies, the Lincos container allows the community to become more aware of the world around them and give them the tools to develop through sustainable means.

Since its creation, there has been a large demand for the Lincos containers from underdeveloped communities around the world. The Foundation wants to prepare the Lincos program for global deployment. As environmental conditions vary around the world, three main areas of the Lincos container are directly affected: a source of power of the container, a connectivity method for the telecommunications system, and the environmental test kits used for testing water sources and farming lands. Because a power grid may not be available for use in a particular site, alternatives to plugging the Lincos container into a power grid needed to be studied. Since the method for connecting the container also depends on the location of the site, the Foundation needed to find alternatives to the standard satellite connection. The Foundation wanted to determine if any wire-based connections were viable solutions. And lastly, they were not sure if the chemical substances that the environmental testing kits included in the Lincos container test for, would be effective for all locations around the world.

Since these issues had not been formally researched by the Foundation, the container could not be placed in locations that did not have grid-based power without the help of fuel generators. The connectivity method also was defaulted to using satellite service, because they were uncertain of the details surrounding the other wired alternatives. The Foundation was also unsure of the effectiveness of the environmental test kits for soil and water for all locations. These issues needed to be resolved before the Foundation could mount an effective deployment campaign.

To aid in their effort, this study provides information on different power generation systems, alternatives for connectivity, and a determination of the effectiveness of the environmental test kits. Because most of the applications in the Lincos container require electricity, the power generation system must be able to produce enough energy to supply all of the on-board electrical devices. Studying the power consumption of an existing container aided in determining which technology is even feasible for Lincos use. Information on different power generation technologies help to determine the most appropriate system to use for a location and ensure the operation of all the included applications. A study of different connectivity technologies help to determine what alternative would be best to implement in connecting the Lincos container. The creation of a satellite service provider reference map aids in the search for satellite service availability and a procedure for deciding on the type of connectivity to be used for the Lincos container was developed. Our team also studied environmental tests that would best determine the quality of soil and water, as well as research the methods for correcting common environmental problems. By researching the alternatives for these three components, the Foundation will be able to extend the Lincos container to reach many more communities around the world.

This report was prepared by members of Worcester Polytechnic Institute - Costa Rica Project Center. The relationship of the Center to Entebbe and the relevance of the topic to Entebbe are presented in Appendix A.

2.0 Literature Review

The Lincos Program is designed to provide people in isolated and marginalized communities with access to information technologies that will improve their way of life. The Lincos containers provide video conferencing, computer laboratory, information center, and health and environment applications (Entebbe, 1999). However, before accomplishing the multiple tasks that a container like this can perform, the Foundation needs to address several technical issues that hinders the effectiveness of the container.

One of the major areas was to explore different power generation systems. As easy access to a power grid may not be readily available for any particular location, different power generation systems needed to be considered for the deployment of the Lincos container. The types of systems our team considered are hydropower, wind power, solar power, fuel-based power, and hybrid systems.

The second issue that was addressed is connectivity of the Lincos container. Our team considered various technologies to determine the best form of connectivity. Because the containers may be placed in remote communities, Entebbe first implemented satellite technology. For communities where a local telecommunications grid is available, other connectivity alternatives may be more viable. In addition to satellite technology, our team considered Digital Subscriber Line (DSL), Integrated Services Digital Network (ISDN), Cable Modem, and Frame Relay technologies as alternatives.

The last issue dealt with the environmental testing kits, which are part of the health and environment application included within the Lincos container. These kits should provide the users with a good measurement of the quality of their soil and water, in regards to agricultural uses and drinking purposes, respectively.

These three areas contribute to the effectiveness of the Lincos containers. One can see the implications that are possible with the Lincos container to improve the quality of life of the people. As undeveloped countries work to join the information age, issues of sustainable development are becoming more important to their well being. Sustainable development can help improve the standards of living while creating a balanced relationship between people and the environment.

2.1 Sustainable Development

Sustainable Development is a term used when it is a country's goal to develop itself economically and improve the quality of life, all while causing a minimum amount of damage to the environment. The minimum amount of damage to the environment is defined as damage that doesn't significantly affect the sustainability on the environment. This means, whatever alternations are done to the environment, the environment can recover on it's own or with the adequate help from people in a reasonable amount of time. This is very difficult to accomplish because there are many factors that will determine if sustainable development is possible for a country. The difficulty in achieving sustainable development lies across the three main areas of political stability, foreign investment, and introduction of new technology. Each of those areas is dependent upon each other.

2.2 Political Stability

Political stability is the most important to sustainable development. The stability status of the country is critical because it allows for growth in the economy domestically, but most importantly attracts foreign investors. It has been shown that countries with a stable government have strong economies. A country with a strong economy promotes economic growth, which is essential in attracting foreign business. However, when political turmoil occurred, the economic growth stopped (Saeed, 1998). Also, a government that has a strong authoritarian grasp on its country may show the illusion of stability. A democratic government has limited control, but "...may help to provide long-term stability and continued commitment to the economic agenda" (Saeed, 1998, p. 243). The reason why political stability is that it's so important to the possibility of foreign investments.

2.3 Foreign Investments

The need for foreign investments in developing countries is extremely significant, especially when that country is trying to maintain the idea of sustainable development. Foreign investment draws a large amount of money that may not have otherwise been available. Many countries will help invest in a country to develop through sustainable development. This newfound pool of capital can alleviate strain on what is commonly found in these countries, and can allow for improved quality of life, which is one of the goal of sustainable development, through redirecting of funds to social programs. High levels of investments can spur an economic take-off, which can pay off foreign debts, which are common in most developing nations (Saeed, 1998). Such an example that demonstrates this is the "debt-for-nature" swap. This program was founded in August of 1987 by Costa Rica, where debt was paid off with land. The Costa Rican government would then preserve this land, and the money that was used to buy the land, would directed toward paying off debts. With the initial $5.4 million debt-for-nature swap, in the case of Costa Rica, three years later the program had grown to "...over $95 million in debt-titles have been purchased for conservation and sustainable development projects" (Erocal, 1991 p. 387). Moreover, foreign investments bring with them new opportunities for employment, and the introduction of technology to better improve the development of that country. The newly introduced technology, though, comes with some unexpected results.

2.4 Introduction of New Technology

In every country that has tried to follow the idea of sustainable development, they have all introduced new technologies to their country in the hopes of improving the quality of life, without the waste created by the old technologies (Saeed, 1998). An example is the introduction of new farming equipment and techniques. As in all newly introduced technologies, there is a period of time that is required for the people to learn to accept and be trained in how to use the new technology. Once this has occurred, there is no doubt that there will be an increase in crop yields, but there may not be any improvement in the quality of life (Saeed, 1998). In some cases, even as productivity increases, unemployment would also increases. This is caused by the technology replacing a low-skilled occupation. To offset this trend, "...the need for labor-intensive technologies to alleviate unemployment" (Saeed, 1998, p. 216). Another point is that the newly introduced technology is only dependent upon how the technology gets used. When new technologies are introduced, and there is no appropriate instruction on the use of the technologies, the new technologies will be misused and no improvements will be made in any form.

2.5 Sustainable Development and Agriculture

Most developing countries have a large agricultural sector, where the vast majority of farms are small. Agriculture is an important aspect in sustainable development for developing nations. "Sustainable agriculture development is characterized by the integration of optimal use, conservation, and maintenance, replenishment and development of environment and natural resources" (Erocal, 1991, p. 161). If sustainable agriculture is not followed, there will be a large amount of damage done to the environment, because farmers will only concerned in increased productivity. Some typical problems that arise out of this are deforestation, soil erosion, fertilizer usage, and pesticides.

2.5.1 Deforestation

When a farmer's land has become infertile due to over planting or for any number of reasons where the farmer needs more land, deforestation occurs. In many regions of the world, including Costa Rica, setting fires is an easy way to clear forestlands. While this practice is illegal in most of these countries, it is common practice (Erocal, 1991). After the clearing of the land by fire, the topsoil is destroyed, and the land needs about a year to recover. However, overtime the land will quickly not be able to support the crops. Most of the crops planted in forestlands are foreign plants. Therefore, the plants draw out the nutrients from the soil faster than it can be replaced. Eventually, the soil eventually dies and soil erosion takes place. Sustainable agricultural development utilizes new techniques and technologies that will allow farmers to plant foreign crops, without having the soil die over time.

2.5.2 Soil Erosion

Soil erosion is caused by "…deforestation, heavy rains, and inappropriate agricultural practices are already an acute problem" (Dworkin, 1974, p. 367). All of those destroy the humus level in soil. The humus level "…consists of soil organic matter which has undergone extensive decomposition" (Saeed, 1998, p. 362). The humus level is vital to the growth of plants because it makes up the structure and texture of the soil and provides a source of nutrients for the plants. The process of humification of organic matter creates humus. Humus is lost when the carbon compounds with in the humus undergoes oxidation. "As cultivation intensity rises, more soil surface is exposed to the air, which increase the oxidation rates for carbon in the organic matter and carbon in humus" (Saeed, 1998, p. 363). Once the humus layer has been destroyed, the soil is susceptible to erosion. This can be prevented by the use of the appropriate fertilizers that replenish the ground with the proper nutrients.

2.5.3 Fertilizers

Fertilizers are used when the land cannot support the crops being grown. This is caused by multi-cropping and the use of high-yield seeds. The most common and effective fertilizers are nitrogen based. There is a direct correlation between the amount of nitrogen released by the soil and crop yields, the more nitrogen in the soil, the higher the crop yields. The amount of nitrogen (N) is naturally dependent up on the release of N from decaying organic matter. Fertilizers are used to replenish the N in the soil, but this is only a temporary solution. Multiple applications are required if the land is to be able to support crops. If no fertilizers are to be used, then the land eventually because barren and is vulnerable to erosion. Also, because of the strong need for multiple applications of fertilizers, there is no real sustainability being achieved.

2.5.4 Pesticides

The introduction of certain crops causes an increase in pests that harm those crops. Thus, pesticides are used to control the level of these pests. There are many different types of pesticides that fall into the categories of mechanical, physical, natural, and chemical (Erocal, 1991). Mechanical pesticides are traps, while physical pesticides are based on temperature, and light and sound waves. Natural pesticides implement the use of natural pest predators, such as bats. However, chemical pesticides are the most effective in controlling the population of pests, but are also the most hazardous. Many developing nations have promoted to use on non-chemical pesticides, because of the health risks associated with them, such as respiratory problems. An emerging trend has developed in Indonesia concerning the use of pesticides and food crops:

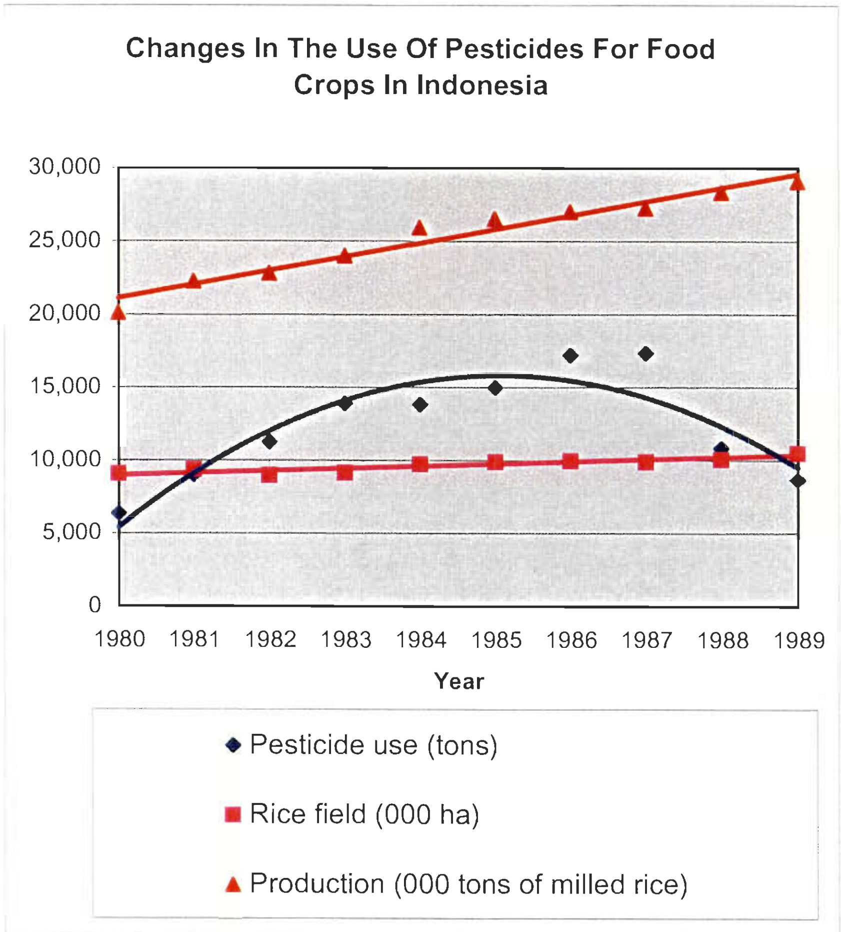
Table 1: Changes in the Use of Pesticides for Food Crops in Indonesia

Year	Pesticide use (tons)	Rice fields (000 ha)	Production (000 tons milled rice)
1980	6,366	9,105	20,161
1981	9,006	9,382	22,286
1982	11,256	8,988	22,837
1983	13,887	9,162	24,006
1984	13,816	9,764	25,933
1985	14,980	9,902	26,547
1986	17,216	9,988	27,014
1987	17,342	9,923	27,253
1988	10,840	10,090	28,340
1989	8,660	10,531	29,072

Source: Ministry of Agriculture, Indonesia (Erocal, 1991, p. 164).

Here, we can see that towards the late 1980's, there was a dramatic reduction in the use of pesticides, all the while with an increasing crop production and land area. On the next page is a graphical representation of this data.

Figure 1: Changes in the Use of Pesticides for Food Crops in Indonesia



The reduction in the use of pesticides was caused by the correctly implemented natural pesticide techniques.

Sustainable Development is an extremely complex idea that requires a global involvement. For a country to try sustainable development just on its own will more than likely fail. There are organizations around the world that have been created to help countries to achieve sustainable development. One such organization is Entebbe. The Foundation that is sponsoring this project, is trying to fulfill the idea of sustainable development through various projects implemented all over Latin America that are focused on improving the quality of life of the people, without damaging the environment in the process. As with all forms of development, educating the public about certain problems will inherently allow for an easier transition to sustainable development. Currently, the Foundation has instituted the Lincos project to help facilitate spread of information in remote and marginalized areas.

2.6 Lincos (Little Intelligent Communities)

Entebbe, the Costa Rican Foundation for Sustainable Development, is an organization that promotes sustainable development through technology. It campaigns for access to technology for all those who do not have such access. The Lincos Program, short for Little Intelligent Communities, brings a variety of technologies to remote and marginalized communities (Entebbe, 1999). The Lincos container is a 20-foot ISO shipping container outfitted with equipment for telecommunications, information services, education, environment, and health applications (Entebbe, 1999).

Forms of telecommunication that are implemented in the Lincos containers are electronic mail, satellite phone, and voice and video conferencing. Long distance communications are difficult in remote areas, so a self-sustaining Lincos container must be able to replace the need for laying expensive communication lines. Not only a more cost-effective alternative but also is able to support electronic mail, voice and video conferencing, which are quickly becoming the communications format of choice. More day-to-day business and personal communications are being conducted through electronic form. In that reason connecting the people of these remote and marginalized communities with the global community is the goal of the telecommunications application.

Education is another topic of interest to Entebbe. As former President Figueres did during his presidency, the Lincos project aims to better educate the public by providing Internet access to those with none (Costa Rican Information Site, March 28, 2000). Through the Internet, Lincos plans to use virtual classrooms to teach both young students and adults alike (Entebbe, 1999). By raising awareness of global affairs and a different way of thinking, the people of these remote communities can make better-informed decisions on the issues surrounding their current situation and ultimately improve their standard of living.

Another application of the Lincos container is providing information about health and environment. Entebbe is looking into telemedicine to facilitate better awareness of health issues from the remote locations of the containers. And it is looking into environmental tests, such as soil and water analysis, to better inform the community members about the state of the surrounding environment (Entebbe, 1999).

2.7 Power Generation Technologies

There are different types of power generation technologies. In the interest of sustainable development, the majority of technologies under investigation use renewable energy sources as not to be harmful to the environment. Hydroelectric, wind, and solar power all have been extensively researched and are in use around the world.

2.7.1 Hydroelectric Power

One of the power options being considered is hydroelectric power. It uses a renewable source of energy, generates a sufficient amount of energy for the Lincos container, and is easily maintainable.

Hydroelectric power is "electricity produced from generators driven by water turbines that convert the potential energy in falling or fast-flowing water to mechanical energy." (Britannica, 2000) By using the force of water to force a mechanical motion, electrical energy can be converted from the motion of a nearby stream, river, or waterfall.

There are three main types of hydroelectric systems. Impoundment power is based on large dams that direct water from a reservoir onto a set of water turbines. Diversion power channels a river into a canal, which is directed onto a water turbine. Pumped storage uses excess energy generated from the falling water to pump water into an elevated reservoir for later use.

In the mid-19th century, water turbines were used to drive sawmills and textile mill equipment. The first hydroelectric station was built in 1882 in Appleton Wisconsin and generated 12.5 kilowatts. By the 1930's, hydroelectric plants around the world were capable of delivering over 100,000 kilowatts. From the 1940's to the early 1970's, interest in hydroelectric plants declined as fossil-fuel plants provided a more cost-effective solution to power generation. It was the oil crisis of the 1970's that brought the rehabilitation of a few smaller plants that were shut down due to fossil-fuel competition. However, as of the late 1980's, hydroelectric generation accounted for about 13 percent of the total demand for electrical energy in the US. (Britannica, 2000)

Considering Entebbe's mission for sustainable development, hydroelectric generation systems can achieve a balanced relationship with the environment. Depending on the power requirements of the Lincos container, the size of the hydroelectric generator may cause problems for the surrounding water's ecosystem. For example, creating dams to set up the power system may upset breeding patterns of salmon, which swim up-river to lay their eggs. (Britannica, 2000) However, there are hydroelectric generation systems that do not require major alteration to the ecosystem. Although they do not convert as much energy, these systems do not require the use of large dams, but use smaller redirection systems. The use of hydroelectric systems in the Lincos unit is dependent on the power requirements, the cost of the installation (which becomes quite expensive the larger the system), and environmental impact.

2.7.2 Wind Power

Another power option being considered is wind power. It also uses a renewable source of energy, can generate a sufficient amount of energy for the Lincos container, and is easily maintainable. Using the movement of air across the Earth's surface, wind generators convert the kinetic energy into electrical energy. There are two types of wind turbines, vertical axis and horizontal axis.

Vertical axis machines are positioned with the plane of rotation of the blades parallel to the ground. The most recent type of vertical wind generator is based on machine patented in 1931 by French engineer G.J.M. Darrieus. Sandia National Laboratories in New Mexico built a Darrieus wind generator in 1980 that generated 60 kilowatts in a 30 mile-per-hour wind.

Horizontal axis generators "consist of a rotor, which may have up to 20 essentially flat sheet-metal blades and a tail vane that keeps the rotor facing into the wind by swiveling the entire rotor assembly. Governing is automatic and over speeding is avoided by turning the wheel off the wind direction, thus reducing the effective sail area while keeping the speed constant" (Britannica, 2000). While early wind generators could produce 1 kilowatt of electrical energy in 1930, more recent horizontal axis machines are able to generate much more. A two-bladed turbine with a rotor diameter of 122 meters was installed in Hawaii in 1976 that was rated for 6,200 kilowatts, enough to power a few small homes, at a wind speed of 30 miles per hour.

Only requiring a windy location, wind generators do not emit pollutants nor take up much space at the installation depending on the amount of energy required. Although the only concern with this type of system is its danger to birds, the Foundation's goal of a harmonious relationship with the environment can still be achieved with this alternative. In addition, the wind generator is capable of producing a multitude of output levels that are enough to power the Lincos unit.

2.7.3 Solar Power

Another power generation option for the Lincos container is to use solar power. One alternative to laying down power lines to each Lincos site is harnessing the sun's energy to power the equipment onboard the container. This solution allows remote communities access to the Lincos equipment while using a renewable source of energy for power generation. Since the Foundation expressed an interest in this form of power generation, we looked more in depth into this technology.

2.7.3.1 History

The first efforts to convert the sun's solar energy into storable electrical energy began with Antoine Cesar Bequerel in 1839 when he observed the action of light on an electrode in an electrolyte solution. About forty years later, a pair of scientists found a similar property of selenium. Further work on the phenomenon of photoconductivity followed under the application of photographic exposure meters. By the year 1914, selenium based photovoltaic cells had energy conversion efficiencies of one percent.

It was not until 1954 that the basis for modern solar cell technology evolved out of previous solar technology. Researchers at Bell Laboratories, Pearson, Fuller, and Chapin, created an array of silicon strips that converted six percent of solar energy into electrical form. Since then, the silicon single-crystal photovoltaic cell has become the prototype of all homo-junction cells and has been the prime focus of research and development for many years (Bube & Fahrenbruch, 1983, p. 9).

2.7.3.2 Current Technology

Photovoltaic cells make reliable energy collection possible, because the sun provides a virtually limitless source of energy. Photovoltaic technology currently has two major types of material: thick crystalline and thin-film. Thick crystalline cells are four to seven millimeters thick and can reach conversion efficiencies of thirteen percent in commercial modules. Thin-film cells are much thinner (several microns thick), but have commercial efficiencies around six percent (Real Goods, 1996).

Three major commercial production technologies currently prevail in the photovoltaic cell market: single crystal, multi-crystalline, and amorphous. The single crystal production technique is the most expensive and oldest, but still produces the most efficient solar cells (13 percent). The multi-crystalline technique is less exacting than single crystal (and therefore less expensive to manufacture), but produces slightly less efficient cells than single crystal methods. Lastly, the amorphous technique features the lowest manufacturing cost for photovoltaic cells, but yields the lowest efficiency cells (six percent). Early amorphous cells were known to fade in output (up to 50 percent) before becoming stable, but newer technology has reduced output fade (Real Goods, 1996).

Original solar cells (most likely single crystalline) launched into space to power satellite equipment in the early 1960's are still operating perfectly despite harsh space conditions, so the question of durability has been answered. It will take a few more years of observation to accurately determine the durability of photovoltaic cells. As solar cell technology is closely related to transistor technologies, which have at least a 20-year life span, it is estimated that photovoltaic modules will last as long as 60 to 80 years with a six to eight hour per day duty cycle. Even so, solar cell manufacturers typically provide ten to twenty year warranties (Real Goods, 1996).

Despite the claim of a virtually free energy source, photovoltaic cells do have their drawbacks. The wattage rating on commercial solar cell modules are given under ideal conditions. Unfortunately, two factors govern the effectiveness of solar cells: percentage of full sun and temperature. Full sun (bright and shadow free) depends on the weather conditions. The Real Goods Staff (1996) states, "If you are not getting bright enough sun to cast fairly sharp-edged shadows, then you do not have enough sun to harvest much useful energy". Any slight cloud cover will reduce effective output of the photovoltaic cells. A slight shadow covering any portion of the solar array will also decrease the output. Temperature, an issue of significant importance in tropical climates, degrades solar cell output if the ambient temperature rises above 80□F. It is important to ventilate the solar cells if the climate features warm temperatures. Typically, warm temperatures will decrease the output by 15 percent. Reduction in output can climb as high as 30 percent if the collected energy is applied concurrently. This factor must be considered when designing the system

Another drawback to solar power is a high initial cost. Although it takes a sizable amount of capital to purchase and install a system, the solar cells start to repay themselves as soon as the system is started. It is estimated that a photovoltaic array can pay back its cost within 1.4 to 10 years. (Real Goods, 1996).

Once power is generated, a system is required to store the converted energy for use when sunlight is not abundant. The most common type of battery used for this purpose is deep-cycle. Unlike shallow-cycle batteries such as the ones found in a typical car, deep cycle batteries maintain a long life and discharge a smaller current. For slow discharge applications like the Lincos container applications, deep-cycle batteries are the best option. To regulate the discharge of the batteries, solar stations usually use charge controllers. Although charge controllers make photovoltaic systems more expensive, they ensure the batteries are not overcharged or drained too much. The lengthened battery life saves money by increasing the time between battery replacements (Aldous, 2000).

The following table summarizes the advantages and disadvantages of solar technology.

Table 2: Solar Living Sourcebook Photovoltaic Summary

Advantages	Disadvantages
1. No moving parts	1. High initial cost
2. Ultra-low maintenance	2. Only works in direct sunlight
3. Extremely long life	3. Sensitive to shading
4. Non-corrosive parts	4. Lowest output during shortest day length
5. Easy installation	5. Low-voltage output difficult to transmit
6. Modular design	
7. Universal application	
8. Safe low-voltage output	
9. Simple controls	

Source: Real Goods, p. 95

Solar energy conversion is a viable alternative to other methods of power generation for the Lincos project, because photovoltaic systems can be placed anywhere in the world and provide environmentally friendly, clean power. With the correct setup, solar panel systems of the appropriate size can provide energy for running the container's equipment at minimal cost for as long as the Lincos container is installed at a particular site. However, because of its high initial cost, the option may not be financially viable.

Once a viable photovoltaic power system is established, it will be possible to run Lincos containers anywhere the sun shines. This will allow the remote communities, where these containers are deployed, to run the equipment without paying the heavy cost of running power lines out to their locations.

2.8 Connectivity

The second area that needs to be researched is that of connectivity for the Lincos container. Various types to connectivity will be looked in order to determine the best form of connectivity for the Lincos unit. Currently, connectivity is being established through a satellite connection. To expand upon this, a reference source will be developed in order to provide information about satellite service providers for countries around the world. Satellite connectivity is the best way to connect to the outside world, because of the ability to make a connection between any two points on the surface of the world regardless of the local telecommunications systems. In places where there is access to a telecommunications system, different connectivity systems will be investigated.

2.8.1 Satellite Communications

One of the main goals of this project is to find a reliable way to connect the rural areas of Costa Rica to the Internet and other marginal communities via satellite. This will allow access to a variety of information, as well as to provide a way to communicate by videoconferencing, telephone, or email. There are two satellite systems that meet this demand. Both have their advantages and disadvantages.

The most commonly used VSAT system is the Interactive Two-Way star configuration (Everett, J. 1992). This involves the use of a central Hub (ground transmitter) that controls the remote VSAT's. The central hub is located on the ground, surrounded by the remote stations that have the VSAT units. It relays and boosts the signals from the VSAT's to the satellite, which is in geo-synchronous orbit. The benefits of this system are central network control and less interference upon transmission to the satellite. The central Hub's dish ranges in size from 5m to 11 m and this increase in size allows the transmission of a signal over a larger distance and clearer than the VSAT's dish, which ranges in size from 0.45m to 1.2m (Everett, 1992). Another advantage is that you can have multiple networks using the same Hub. The disadvantage of the star configuration is the cost of this type of system, "Earth terminals of this type are expensive, costing between $300,000 and $5,000,000 (at 1991 prices) depending on features and performance" (Everett, 1992, p 4).

The other VSAT Interactive Two-Way system is the mesh configuration. This configuration allows each VSAT to act as its own Hub. This results in quicker response time from terminal to terminal, than the star configuration, "...(typically 0.25s compared with 0.5s for the star configuration) which is especially advantageous when the link carries voice traffic" (Everett, 1992, p.3). Another benefit to the mesh configuration is that there is no need for an expensive central Hub Unit, and the VSAT as the acting earth terminal cost's only $12,000 (Everett, 1992). The disadvantage to this setup is the quality of the signal being transmitted to the satellite. With the VSAT's small dish, the signal will be more greatly effected by interference than signal coming from a larger dish, because a large dish can supply more power to boost the signal. However, recent developments have made the signals from a VSAT unit, to be received by a satellite with less interference.

2.8.1.1 History

The need for satellite communications/connectivity came about when people needed to transmit information over the horizon. Within a large country, relay antennas were used for this purpose, but what large bodies of water? Relay stations cannot span an ocean. Instead wires are laid along the sea floor. The problem with that, however, is maintenance and cost of adding or replacing new lines. Also, there are limits on the signals that can pass through a wire. These limits constrain the rate of transmission. To overcome these obstacles, something had to be developed that would allow for over-the-horizon communications, be expandable, and be able to transmit over large areas and at "real-time" speeds. For these reasons, the telecommunications satellite was developed.

The first telecommunications satellites had a design lifetime of just 1.5 years and cost large amounts of money to develop and to put into orbit. Yet even with these obstacles, these first few satellites proved that it was possible to communicate information around the world at "real-time" speeds. Their applications grew, as better technology was developed to expand the capabilities of satellites, and lower their costs. To give an idea of the cost to develop and launch a satellite, "the construction and launch costs of the Canadian Anik-E1 satellite, in 1994 in Canadian dollars, was $281.2 million dollars" (Roddy, 1996, P.1). This does seem like a lot of money, but when you realize that millions of customers use a satellite and pay for its services, the cost gets driven down. Also, today's satellites have a design lifetime of 10 to 15 years (Roddy, D. 1996). A satellite communications system becomes reasonable to develop if "...the system is in continuous use and the costs can be reasonably spread over a large number of users" (Roddy, 1996, p 1).

2.8.1.2 Applications

Satellite applications vary greatly. The most common use is telecommunications. An entire industry has developed because of this type of communication, for example Direct TV. Over time, a new area for satellite development is the Internet Service Provider (ISP). Using their extremely fast transfer rates and broadband frequencies, a satellite can directly transfer information from an earth station to the computer in your house, reaching data transfer rates ranging from 76.8 kbps to 40 Mbps (Gilat, 2000). The type of satellite system that dominates the ISP area is the VSAT (Very Small Aperture Terminal). VSAT is intended for use where there are not a lot of people using the terminal, preferably 3-8 users at the same time when the dish used to receive and send information is roughly between 0.55m and 1.2m (Gilat, 2000). These systems work in any location and, depending on their users' needs, can handle anything from basic Internet use, to TV and telephone use and "real-time" videoconferencing, which requires a reliable and fast connection.

2.8.2 Alternatives to Satellite

Whenever applicable, alternatives to satellite connectivity will be investigated at as a viable means of connectivity. Such methods of connectivity are: DSL cable, ISDN, frame-relay, ATM, and basic computer modems. These forms of technology offer some if not all of the qualities of satellite connectivity, but each system is dependent upon the current technology being used in the local telecommunications system.

DSL (Digital Subscriber Line) uses a digital connection to transfer data. This system can only work if the local telecommunication system has a digital infrastructure. DSL has the ability to run at different speed settings, depending on the needs of the user. Data transfer rates vary from 64 kb/s, to 6MB/s. This type of connectivity is not without it's faults. As of now, it is only available in urban and suburban areas. The digital nature of DSL makes it vulnerable to interference, and companies will only guarantee service at a range of 18,000 ft from the local telephone exchange (Everything DSL, 2000).

Cable connectivity utilizes the cable service in an area to provide connectivity. This method of connectivity has a top speed of 1 Mbps. However, the bandwidth per user is lower when more users connect using the cable method because the bandwidth is shared between all users in that area. The cost for installation, the cable modem and service is at or under $50 for all three areas.

ISDN stands for Integrated Services Digital Network. This is another digital connectivity system, but is more reliable the farther away from the local exchange than DSL. The equipment for such a system is rather expensive, and it is not able to handle the demands of video-conferencing if running other Internet applications (Andrews & Arnold, 2000). It has maximum bandwidth of 128 Kbps, and utilizes the existing telephone lines to make its connection (www.microsoft.com, 2000).

Frame-relay architecture is based on the efficient switching of data packets over a shared digital network. These circuits operate at a committed information rate (CIR) and can burst to high-end rates, taking advantage of the network's available bandwidth" (Eclipse, Eclipse Frame Relay, 2000). Frame relay is a digital telecommunications system, which has a date transfer rate of up to 1.544 MB/s. This is more than acceptable for the Lincos container for the speed requirement. However, there is a high cost for installation, and usage. Overall cost varies with equipment and services selected, but the average installation cost of a 512 kb/s is approximately $2500 with hardware, and a monthly fee of approximately $750 (Eclipse, 2000).

Asynchronous Transfer Mode is a type of connectivity such is used as the backbone for the Internet in many countries, including the United States. The speed of an ATM network range from Megabits to Gigabits. However, this type of system is used to support whole networks. Special equipment is also needed in order to establish such a communication system (ESRF, 2000).

The basic computer modem is widely available and is relatively cheap compared with other forms of connectivity. Today's computer modems have a maximum bandwidth of 56 Kbps. However, these modems are prone to interference, and their connection is not as reliable as other forms of connectivity. They use the existing telephones lines to establish a connection through the local telephone exchange.

2.9 Environmental Testing

The last area of research is environmental testing. One of the ways the Lincos container helps to further sustainable development is through facilitating respect for the environment. This is done by allowing the users to effectively measure the quality of the environment. It is important that the environmental testing kits include chemical substance tests that provide the most useful information. Before we can look at specific tests it is important to understand why these tests must be performed.

The two types of tests the Foundation are considering are tests for soil and water. Because some of the communities interested in acquiring a Lincos container are most commonly located in isolated regions, they depend on agriculture as a way of life. So it is important to identify any trends and changes in the soil that may affect this way of life. Essential to all communities is safe drinking water. Due to all the impurities and their effects, it is important to have water tested, even though the signs of contamination are not always obvious. Testing soil and water for every chemical substance is possible, but it is very expensive and not necessary. It is more important to test on a regular basis for a few indicators and to maintain a record of soil and water quality. The greatest benefit is obtained when results are plotted on graphs over a period of time. This helps to identify any trends and changes in the soil, and sources of contamination in the water.

2.9.1 Soil

The type of soil the land contains is important to know because it influences how well nutrients and moisture will be maintained by the soil. There are two basic extremes in soil texture – sand and clay. Sandy soil has large, gritty particles and will feel coarse like beach sand. Sandy soil is loose enough to allow for good airflow through the soil, but does not hold moisture or nutrients very well. Clay soil has small, fine particles and will feel smooth. Clay soil holds moisture and nutrients well, but can be difficult to dig or till during garden preparation because of its tendency to clump. Most garden soils will be a combination of sand and clay.

For growing plants the ideal combination of sandy and clay soil is referred to as loam. Loam combines the beneficial properties of each soil type and provides you plants with the best growing environment. Loam is sandy enough to allow for drainage and air circulation but also contains enough clay to retain adequate levels of moisture and nutrients.

2.9.2 Water

The natural environment and all life are dependent on water. It exists in nature in many forms- clouds, rain, snow, ice, fog, lakes, rivers, and oceans; however, strictly speaking, chemically pure water does not exist for any appreciable length of time in nature. Water is a chemical substance that has very peculiar properties, one of them is its great power as a dissolver, for that reason it is call the "Universal Solvent". Even while falling as rain, it picks up small amounts of gases, ions, dust, and other small particles from the atmosphere. Then, as it flows over or through surface layers of the earth, it dissolves and carries with it some of almost everything it touches.

The added substances may be classified as biological, chemical (both inorganic and organic), physical, and radiological impurities. They include industrial and commercial solvents, metals and acid salts, sediments, pesticides, herbicides, plant nutrients, radioactive material, decaying animal and vegetable matter, and living microorganisms. These impurities may give water a bad taste, color, odor, or cloudy appearance, and cause hardness, corrosiveness, staining, or foaming. They may damage growing plants, cause health effects, and corrosion.

> Pure water means different things to different people. Homeowners are primarily concerned with domestic water problems related to color, odor, taste, and safety to family health, as well as the cost of soap, detergents, "softening," or other treatments required for improving the water quality.

> Chemists and engineers working for industry are concerned with the purity of water as it relates to scale deposition and pipe corrosion. Regulatory agencies are concerned with setting standards to protect public health. Farmers are interested in the effects of irrigation waters on the chemical, physical, and osmotic properties of soils, particularly as they influence crop production; hence, they are concerned with the water's total mineral content, proportion of sodium, or content of ions "toxic" to plant growth. (Shelton, 2000)

Considering the nutrients in soil and contaminates in water, there are many types of tests that can be performed for both soil and water. Currently, there are only four different types of elements that the Foundation tests. These tests were determined by our liaison Dr. Juan Barrios Arce. The four elements tested for water are pH, hardness, chlorides, and bacteria. For soil, pH, nitrogen, potassium, and phosphorous are tested. A more detailed discussion of these tests can be found in section 4.3, Data and Analysis.

After testing for the various elements, one would be aware of what is in the soil and water. This information can be used to inform the communities of what needs to be done to improve the quality and ultimately the quality of the communities' environment.

3.0 Methodology

To best achieve the objectives for this project, methodologies or procedures for each portion of the project were developed.

3.1 Power Generation System Methodology

3.1.1 Establish Power Requirements

Since there are many different types of power generation systems for all needs and at varying power output ratings, it was necessary for our team to define the power requirements of the Lincos container. To establish the power requirements of the Lincos containers, we ascertained the average and maximum power consumption of the container. This information helped to determine how much energy the power generator must be able to produce.

To find the average power consumption, our team took measurements of the electrical devices on board the Lincos container in San Marcos. To determine the average rate of power consumption a device uses, our team used a clamp meter to determine how much current the device drew from the power outlet during normal use. Since each device had power cords plugged in different locations around the Lincos container, our team found it easier to use the power cables connected to the power lines to measure the entire Lincos power consumption. We first took a base measurement (measuring amperage) with the device turned off (drawing no electrical current). Then, we took a measurement with the device turned on. By taking the difference between these two measurements, our team found the amount of current each device drew. We also measured voltage of the power outlets at the Lincos container using the voltmeter feature of the clamp meter. Finally, our team observed the usage patterns of the electrical devices to determine how much each device was used on a daily basis. We accomplished this by recording the daily activities that were scheduled in the container. Our team assembled the data gathered from both the measurements and the observations into a table and later tabulated this data to produce a rating for average power consumption of the Lincos container. (Refer to Appendix B)

To determine the maximum power consumption, our team researched the specification documentation for each of the electrical devices on board the container. By investigating through the World Wide Web, studying the device manuals, and taking actual measurements, the maximum rate of energy that the Lincos container uses was determined. For devices whose manual Entebbe did have (see Table 3), the rating was found in the power specification portion. For the devices which Entebbe did not have a manual, our team used the clamp meter from the average power consumption measurement to look at the peak wattage the device consumed while the device was on. For example, the ventilation fans for the server equipment consumed energy at a constant rate while the fans were in motion. However, if the fans were off, the rate of energy that it took to start the fan blades turning was much larger. This peak energy rating was measured and recorded as the maximum rate. For the devices we could not get access to in San Marcos, our team used the Internet to download its operation manual. The maximum rating for those devices were found in these downloaded documents. Having found all this data, our team compiled and tabulated it to determine the maximum power consumption of the Lincos container. (Refer to Appendix B)

With both maximum and average power ratings, our team made a decision on how much energy is necessary for the Lincos container. We used the device usage observations along with the average and maximum consumption rates to calculate the total amount of energy (both average and maximum) that was consumed by the Lincos container per day. (Refer to Appendix B) With this figure, our team determined a rating for the power generation system to charge the battery so there is no interruption in service.

3.1.2 Research Alternatives that Fit Requirements

Once the power consumption of the Lincos container was determined, solutions for power generation must be identified and researched. Since, the Foundation is interested in sustainable development, power generation solutions using renewable resources are of prime interest for this project.

To identify which power generation technologies to concentrate on, a combination of interviews with the employees of Entebbe and research on the Internet was performed. In particular, our team consulted with the director of the Lincos Program, Dr. Juan Barrios Arce, to determine on which power generation technologies Entebbe is interested. Our team also searched the library at Instituto Technologico de Costa Rica in Cartago for information, but we were unable to find usable data about the different technologies. Since many organizations and firms dealing with energy generation systems have websites on the Internet, our team found much information about each of the renewable technologies from these sources.

Once the alternatives were determined, we researched each alternative on the Internet. Since there are associations and groups that promote these technologies, our team contacted representatives from several groups for information regarding the parameters of the research (namely power output capacity, cost, and environmental considerations). Also, we requested the same information from manufacturers and distributors of the equipment through electronic mail, because it was the quickest method of communication.

3.1.3 Compile Data

Once all the data was collected, our team generated an evaluation matrix. Each technology, which is hydropower, wind power, solar power, fuel-based power, and hybrids, is listed in this matrix. We have listed the resulting data, in terms of the parameters of power output, cost, and environmental impact, to each corresponding technology. (Refer to Table 8 in Section 4.1.1) By compiling the data in this fashion, our team gives the reader the ability to quickly reference the parameters for each technology and allows them to make an educated decision about the type of power generation system to be utilized by the Lincos container.

3.1.4 Develop Conclusions

Finally, our team produced a recommendation for the improvement to the Lincos container in terms of power consumption and a method for selecting a type of power generation system for any particular location. The recommendation and method are presented in Section 5.1, Conclusions and Recommendations. Our team decided to make the recommendation by studying the results in Section 4.1.1, Power Generation Systems Data and Analysis. In the interest of convenience, our team produced the selection method by combining data we found in this study into a website that can be served in the internal network at the Foundation. This site is outlined in Figure 7, Section 5.1 and included in Appendix B.

3.2 Connectivity Methodology

Similar to the alternate power generation solutions for different locations all over the world, connectivity solutions must also by developed. The end result of the connectivity methodology is to provide a resource on satellite service providers, and to produce a procedure for deciding on the method of connectivity for the Lincos container.

3.2.1 Satellite Service Provider Reference Map

In order to establish a satellite service provider reference map for the Lincos container, the first thing that was needed was to establish a method of selecting satellite service providers. This method became the following parameters: bandwidth, costs, service area, and equipment needed. These parameters were established with the aid of our liaison Dr. Juan Barrios. Once the parameters have been created, the search for satellite providers began.

3.2.2 Search For Satellite Service Providers

The search for satellite providers began on the Internet because of the Internet search capabilities. This is the quickest way to locate potential satellite service providers, and allows a means of establishing contact through e-mail or telephone call. However, all of the potential satellite service providers are outside of Costa Rica, and to make numerous international phone calls would be too expensive. We used e-mail as the main means of contacting the satellite service providers, and if no replies were received, phone calls would be necessary to make contact. Phone communication will only be made on the approval of Entebbe. After contact has been made, and information gathered, the creation of the Satellite Service Provider Reference Map was created. Nevertheless, others sources were looked into as well. We attempted to utilize the library at Entebbe; however, the content of that library was on the different governmental policies of Latin America, and other countries. We also visited the library at TEC in Cartago, however, due to time constraints, we were unable to locate any useful information.

3.2.3 Creation of Satellite Service Provider Reference Map

The Satellite Service Provider Map will be presented in web page format in order to be attached to Entebbe's intranet. This is to provide easy access to the reference map, and to aid in searching for satellite service providers. This will assist Entebbe in the search for which acceptable satellite service providers for the Lincos containers. However, the reference map will not recommend one satellite service provider over another, it will only present information on each satellite service provider. The decision of a satellite service provider for the Lincos unit will be determined by an Entebbe employ.

3.2.4 Alternatives to Satellite

In looking for the best method of connectivity for the Lincos container, the location of the container will ultimately determine the type of connectivity. In areas where there is an existing telecommunications system, it may be possible to supply the Lincos container with the appropriate form of connectivity through the established landlines. There are many types of connectivity systems available for landlines, and so to narrow down the search, parameters were developed. These parameters are similar to the parameters developed for satellite connectivity, because they both have to provide the same service. The parameters are: bandwidth, costs, availability factors, and equipment needed. These parameters will help determine which alternate connectivity systems are best for the Lincos container.

3.2.5 Researching Alternatives

The alternatives to satellite connectivity are DSL, ISDN, Cable, and Frame-Relay. All of these types of technologies will be researched on the web for bandwidth, costs, availability factors, and equipment needed. An interview with Mr. Richard Elizondo Giangiulio, an employee of the local Internet service provider RACSA, provided information on the different types of connectivity. Mr. Richard Elizondo Giangiulio was appointed to us by RACSA to provide the information that we were looking for. After the interview, we had received pricing information and what types of systems are used for different requirements.

3.2.6 Connectivity Selecting Procedure

After researching these alternatives, and any others that we may come across, the information has been assembled in such a way so that the selection of connectivity will be determined by the limitations of the local telecommunication system. The limitations of the local telecommunications system are the requirements for the different types of connectivity. This information is being developed in a decision tree in web page format, to be attached to Entebbe's intranet for easy access. This will provide a method for deciding which connectivity system is best for the Lincos containers in their given location and accessibility to a local communications grid.

3.3 Environmental Testing Methodology

3.3.1 Research Acceptable Composition

To help find the chemical substances that provide the most information about soil and water, we first determined what makes good soil and water. To do this, our team identified knowledgeable individuals from various organizations and educational institutions by consulting with our liaison and through research on the World Wide Web. By searching for soil and water resources through Internet search engines, such as Altavista, Yahoo, and Google, we found organizations and universities, such as U.S. Environmental Protection Agency (EPA) and the University of Georgia, who have aided in our search for information. All these sources provided valuable background information on general properties of soil and water, and specific chemical tests. From these sources, our team determined the composition of good soil and water. For soil, we studied the acceptable amounts of nutrients and other elements. For water, our team examined the parameter of acceptable levels of contaminants.

3.3.2 Identify the Most Informative Chemical Substances

To identify the key indicators of quality, our team studied the information gathered from researching the acceptable composition of soil and water, as well as suggestions from various knowledgeable individuals from the previously mentioned organizations. In the case of soil, we examined elements that have the greatest impact on plant growth by looking at general plant nutrient requirements as well as elements that may be harmful to plants and animals. In the case of water, our team looked at contaminants that pose the most risk to humans. Along with researching the composition and effects of soil and water, we also considered the recommendations of knowledgeable individuals, such as Doctor Paul F. Bendrell from the Feed and Environmental Water Lab of the University of Georgia and Robert Cantilli from the U.S. EPA, to determine the substances that should be tested for. During our visit to San Marcos, we also spoke with Rodrigo Jimenez, a local agriculture engineer, about tests that he considered as most important. The information gathered from the above procedures is further discussed in section 4.3, Data & Analysis.

3.3.3 Produce Recommendations

From researching the acceptable compositions and identifying the most informative chemical substances we recommended specific tests that should be included in the environmental testing kits. To help improve the effectiveness of these tests, our team produced a reference for the Lincos users about when to perform these test. In addition, we also developed the structure of a database to help record and interpret the test results. These topics are discussed in section 5, Conclusions and Recommendations.

4.0 Data and Analysis

From the methodology described in Section 3, the following data was gathered. Although each component of the project resulted in different data, the combination of the results together help to further the Foundation's goals by providing important information about deploying the Lincos containers around the world.

4.1 Power Generation Systems Data and Analysis

There are four different configurations of the Lincos container: standard, educational, expansion, and reduced. Each configuration of the unit is designed for a different purpose. The standard configuration of the standard includes a computer lab, information center, video conferencing center, and the health and environmental center. The energy consuming devices in this setup consists of six desktop machines, two servers, the entertainment equipment, and an FM transmitter station. The educational configuration includes eight desktop computers, two servers, and the entertainment equipment and is designed only for computer lab and videoconferencing use. The expansion configuration contains 10 desktop machines and is designed to supplement an existing container with additional computers. And finally, the reduced configuration contains all except the health and environmental application. In addition to equipment for any given configuration, a lighting and security system are standard in all containers.

As discussed in the methodology, each device was measured for its contribution to the total power consumption. Each device was initially shut off to get a base measurement. The device was then turned on and the average amperage was observed. A burst in the draw of current was observed as some devices started up. This was recorded as the maximum rate. Although most equipment did not jump past the average figure measurement, devices with induction coils (i.e. ventilation fan) did take a significant jump in amperage to start. The following table presents the measurements taken from the Lincos container in San Marcos. These measurements were combined with the rest of the data to generate a figure for the power consumption.

Table 3: San Marcos Lincos Equipment Measurements

Device	Ave Amps	Max Amps
Outdoor Light	1.40	1.40
Indoor Light	0.40	0.40
Fluorescent Light	0.30	0.30
Ventilation Fan	0.75	1.50
Client PC	0.40	0.70
Client Monitor	0.50	1.00
Printer	0.10	*0.43
Television	0.70	*0.78
Receiver	0.15	*2.00
CD/DVD Player	0.10	0.10
VCR	0.10	0.10
Tape Player	0.10	0.10
Server PC	0.40	0.70
Server Monitor	0.50	1.00

* - Calculated from specification documentation

Table 4 shows measurements and estimates for the equipment that was not accessible for measurement. The container we visited had only opened for eight days before our arrival. Only the computer lab and the video conferencing equipment were available for exact measurement. The staff at San Marcos did not allow our team to turn off the satellite transceiver or the security system. Also, the uninterruptible power supplies were not measured, because they supplied power to systems that we were not able to shut down. The following data was gathered from measuring equipment in the offices at the Foundation as well as studying device documentation. This information contributed to the final power consumption figure.

Table 4: Inaccessible Equipment Measurements (Entebbe, June 2000)

Device	Ave Amps	Max Amps
Hub	0.10	0.35
Notebook PC	0.2	0.40
FM Transmitter	0.44	0.44
Zip Drive	0.075	0.1
UPS	0.35	1.4
Satellite Transceiver Security System	2.6	7.0

Before the final power consumption rating can be calculated, another consideration was taken: the duration of use of the electrical devices. The power consumption of the container not only depends on the amount of continuous energy the included devices consume. It also depends on the amount of time that each device is in use. By observing the usage of the Lincos container in San Marcos, the following figure was generated. (Figure 2)

In terms of the power consumption of the equipment, our team observed that most of the devices consumed energy at a steady rate. Even though the desktop computers were used the most during the day, peaks in power consumption of the computers were negligible compared to their idling rate. Some equipment remained on at all times of the day: the server computer, server monitor, Ethernet hub, satellite transceiver, and battery backup system were never shut down. These devices also consumed energy at a constant rate. Also, the florescent lights were used to illuminate the computer stations during the day and the internal incandescent lights as well as the external floodlights were turned on at nightfall. As the consumption rate of these devices did not fluctuate much, it made the estimation of the daily amount of energy consumed easier to calculate.

Figure 2: Lincos Daily Schedule

Time	Activity
8:00	Setup
9:00	Class
10:00	
11:00	
12:00	
13:00	
14:00	Open Lab
15:00	
16:00	
17:00	Class
18:00	
19:00	
20:00	Shut Down
21:00	
22:00	
23:00	
0:00	
1:00	
2:00	
3:00	
4:00	
5:00	
6:00	
7:00	

During most of the day, the computers were used for class material, electronic mail, word processing, and general web searches. In between classes, several videos were presented. The television, video cassette player (VCR), and stereo receiver were used to play these videos. This application only consumed energy for three hours per day. Although the Lincos container was also designed to provide entertainment in the form of movies, the television and VCR were solely used for the educational videos during our team's visit.

Upon observing the daily usage of the electrical devices, the number of hours each device was in use for were calculated. The total amount of energy used per day by the Lincos container was determined with these figures.

Although the lights only illuminated in and around the Lincos container, they contributed a significant amount to the power consumption. We observed that the fluorescent lights (indoor) were left on during operating hours for about 12 hours. The incandescent lights (indoor) were turned on for about four hours during the evening. The floodlights (outdoor) were only used after dark for approximately 12 hours. As evident from the tables in Appendix B, the lighting system consumes a large portion of the total power.

Table 5: Daily Usage of Electrical Devices

Item	Hours/Day
Outdoor Light	12
Indoor Light	4
Fluorescent Light	12
Ventilation Fan	12
Client PC	12
Client Monitor	12
Printer/Scanner/Fax	12
Laser Printer	12
Television	3
Stereo Receiver	8
Tape Player	0
CD/DVD Player	8
VCR	3
Satellite Transceiver	24
Security System	24
Server PC	24
Server Monitor	24
Battery Backup	24
Info PC (Notebook)	12
FM Transmitter	12
Zip Drive	12

The desktop computers were also a large component of the power consumption. They were turned on when Lincos opened and turned off when the container closed. Although the monitors had energy saving capabilities, the power saving feature was largely unused as the computers were used all day long.

In addition to the desktop computers, the stereo equipment was used for the majority of the day. Although the stereo receiver was used to provide the videos with sound, it was mainly used to play music from the compact disc player. The only exception was the tape player, which was not used. However, having measured the power consumption of the stereo equipment, the contribution of energy usage was very small compared to the larger energy consuming components.

All equipment that was left on 24 hours a day included the server computer and monitor, the battery backup system, the satellite transceiver, and the security system. The server equipment, which supports the desktop computers, may also serve web pages and other internet-related services, so it is required that it be on all the time. The battery backups protect the server from interruptions in power and the satellite equipment support the telecommunication connection. Lastly, the security system is left on to protect the container from theft. Although these devices draw power continuously, they are necessary to effectively support the operation of the Lincos container.

Even though some of the devices were not implemented in the container at San Marcos (i.e. Zip Drive, laser printer, etc.), their usage patterns were estimated based on the application the device was designed for. It was important to consider their usage, as these devices will also be included in the various configurations for other Lincos containers. For example, the Zip Drive is used to store data onto removable media and would be in use when the desktop computers are on. Therefore, it is estimated to be on about 12 hours a day. The laser printer, information PC (notebook), FM transmitter, and Zip Drive were among those that were not present at the San Marcos site.

To calculate a usable figure for determining the energy requirements of the container, the daily amount of energy consumed must be calculated. This amount is measured in kilowatt-hours. To calculate this for a single device, the rate of consumption (watts = amps*115 volts) is multiplied by the number of hours the device is in use. For the Lincos container, the daily amount of energy for each device must be added up to determine the total amount. Table 6 illustrates this process. The detailed calculations for each of the configurations for both the average and maximum power consumption are included in Appendix B.

Table 6: Sample Power Consumption Calculation

Item	Quantity	Ave Amps	Hours/Day	Watts Hrs Used/Day
Outdoor Light	4	1.40	12	7728.0
Indoor Light	6	0.40	4	1104.0
Fluorescent Light	8	0.30	12	3312.0

From the above calculations, our team determined the amount and maximum rate of energy that the power generation systems must be able to generate. The amount of energy (in watt-hours) determines the size of the battery bank (described in the literature review, Section 2.13) the system must include. As the usage patterns of the Lincos container may vary from day to day, the total amount of energy used per day must be estimated. From this information, a suitable capacity battery can be determined. Another consideration is the power generation systems' ability to handle the Lincos container's peak wattage. As each electric device continuously draws a certain amount of energy per time, running multiple devices will add an additional load on the power generation systems linearly. If the system cannot provide enough wattage that the Lincos container requires, then a shortage in power will occur. This will cause many electrical devices to shut down. By determining the maximum wattage or peak wattage of the system, an appropriately chosen power generation system will be able to reliably provide the Lincos container with energy. The results of these calculations are presented in Table 7 for each of the Lincos configurations.

Table 7: Power Consumption for Lincos Configurations

Lincos Configuration	Ave Wattage (kW)	Max Wattage (kW)	Ave kWHrs/Day	Max kWHrs/Day
Standard	2.8	4.9	33.9	64.1
Education	3.0	5.1	35.3	66.8
Expansion	2.5	3.9	28.8	48.1
Reduced	2.8	4.9	33.9	64.1

The average wattage figures suggest that the power generation system should be able to generate just over 5kW at all times the Lincos container is open. Although the average is around 3kW, the container may use up to 5.1 kW if all devices are consuming energy at peak rates. However, it is unlikely that a 5.1-kilowatt spike would ever occur even under heavy use. An acceptable system must be able to supply the peak wattage (5kW) so that no power shortages occur.

The kilowatt hour per day figures are especially important for renewable energy systems as power may only be generated at certain times of the day. For example, solar power is dependent on the availability of full sun. Given five hours of full sun per day and a requirement of 35kWHrs per day (average), a suitable solar power system must be able to generate 35kWHrs in the five-hour timeframe for full sun. This suggests that the solar panels must generate 8kWHrs per hour (or a rate of 8kW). For other energy systems that generate power in a larger timeframe, the power rating for the system will decrease. This is the case of hydroelectric systems. These systems generate power continuously as rivers or waterfalls do not stop flowing. This type of system only needs to produce energy at a rate of 1.5kW. Again, these energy figures must be considered when designing a power generation system.

With the power consumption figures from Table 7, the selection of an appropriate power generation system can be performed. The system must be able to support a rating of 5kW peak wattage and the ability to generate around 40-65kWHrs per day. The following table presents the results of the research performed for systems capable of powering the Lincos container.

Table 8: Power Generation Systems Results

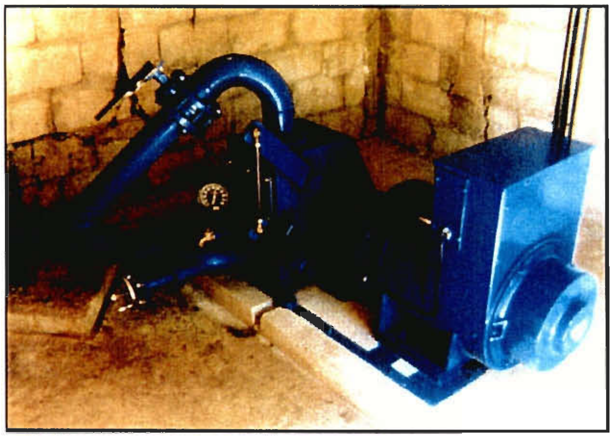
Technology	Power Output	Cost (US$)	Environmental Impact	Advantages	Disadvantages
Hydro	1000's kW	15,000	Water ecology	Always on, little to no maintenance, endless renewable energy source	Expensive initial cost, water ecology impact from dam (if necessary)
Wind	3kW	8,000	None	Little to no maintenance, endless renewable energy source, simple expansion	Unreliable energy source
Solar	10 kW	50,000	None	No maintenance, endless renewable energy source, simple expansion	Expensive initial cost, large physical size may be required
Gas	50kW	15,000	Air and noise pollution	Inexpensive system, extremely reliable	Air and noise pollution

4.1.1 Hydropower

Although usually installed for providing utility-grade electricity, hydroelectric systems are well suited to supply the amount of power required by the Lincos container provided that the head and flow rate of the river or waterfall is sufficiently large. Standard hydropower systems are generally rated over 30kW. The other type of hydroelectric systems, called small or micro-hydropower systems, generate up to 30kW of power. Since the Lincos container only requires 5kW peak wattage, the micro-hydropower systems are the most appropriate.

Since the hydroelectric system needs only to supply at most 5kW, the cost of the system is much more reasonable than the larger systems, which can cost several million dollars. The smaller scale systems (5kW) have been found at $15000, making this alternative very viable. The following figure shows an example of a slightly larger system.

Figure 3: Canyon Technologies 14kW Water Turbine



Although commonly believed to be safe and environmentally friendly method of producing electricity, hydroelectric power can adversely effect the environment. The hydro-ecology of a river can drastically change if a hydroelectric dam is installed. Migratory patterns of fish, like salmon, can be interrupted. Small fish migrating downstream can be killed if caught in the hydro turbines. These dams can also alter the quantity and quality of the water downstream from the installation. Spillage of water over the dam can also cause a super saturation of the water with gases from the air. The water is mixed with gases from the air that are not typically found in the water. These gases can be deadly for fish absorbing the water downstream. Also, depending on the size of the power system, tree clearing for the installation can cause soil erosion and landslides that can clog up streams closing entire hydro-ecosystems. Flooding of vast areas of land can destroy forests or agricultural settlements. The reservoirs can change a well-aerated river into an unsafe body of water in which many species of fish cannot survive.

As a capable power generation system, hydropower systems should not be overlooked. However, with the cost of installation, it is a very expensive alternative to implement for the Lincos container alone. Hydropower systems should be considered for the long run as the high initial costs are balanced out with time.

Another consideration for hydropower systems is the inclusion of another application for Lincos: electric utility supplier. With a sufficiently large hydroelectric generation system, the excess energy generated can be sold to the nearest power grid or directly to the community. The revenues generated from this application can help to offset the cost of the hydropower installation and Lincos container itself.

4.1.2 Wind Power Systems

Current applications of wind power range from charging small battery to providing utility grade electricity. The lower power wind generators produce up to 500 watts, while larger generators can produce well into the kilowatt range. Large wind power systems usually include a number of wind power generators working in tandem. For the Lincos container, these generators will provide enough power as long as there is sufficient wind. Most commercially available wind generators provide peak power at around 25 miles per hour, which is more easily attained with a tower to elevate the generator. However, the average wind speed must be measured at the intended site to more accurately determine the expected power output.

Southwest Windpower and World Power Technologies are two large companies manufacturing wind turbines. Southwest Windpower manufactures smaller generators from 50 watts to 500 watts with optimal conditions. Considering these are only peak ratings, at least six Southwest Windpower's top of the line Windseeker turbines (5-foot rotor) would be necessary to power the Lincos unit 24 hours per day under ideal wind conditions. Although this is an option, World Power Technologies manufacturers even larger turbines capable of up to 4.5 kilowatts. These turbines, with a 15-foot rotor, also produce peak power at 25 miles per hour. One generator alone would be sufficient to support the Lincos container. The Whisper 4500 model could even support the Lincos container without the help of a battery system, but it is dependent on the reliability of the wind to gust at optimal speed. The following figure illustrates the Windseeker model.

Figure 4: Southwest Windpower's Windseeker 500 Series Wind Turbine

At around \$900 to \$1000, the Windseeker is a possibility. However, to compensate for a lower average wind speed, roughly six to ten turbines will be necessary to power Lincos. In addition, the costs of the towers and other components can easily add to over 10,000 dollars.

The Whisper 4500 costs around \$7000. With the additional equipment, World Power Technology's larger system may save \$2000 to \$3000 over Southwest

Windpower's system. The same amount of energy produced from six to ten Windseekers can be generated through fewer, larger power Whisper wind turbines.

Although wind power does not have any major impacts to the environment, there are studies that suggest wind turbines are a danger to birds. Wind power generates no byproducts or waste, nor consumes any non-renewable energy sources. If chosen as the power generation system for a particular site, careful monitoring and care of the bird population will help ensure their survival.

4.1.3 Solar Power Systems

Solar power is another option as a renewable energy source. Even though solar panels have a low wattage yield per panel, combinations of panels together can produce several kilowatts. Since the hours of full sun is very important to the output of the photovoltaic system, the number of sun hours in a day for a particular site must be accounted for. Given five hours of full sun, a system requiring 50kWhrs must produce 10kW. Only a very large solar power system can provide this much energy. Since the Lincos containers are long-term installations (ten or more years), this technology is viable for supplying energy even if the system requires a permanent installation. In considering the transportation and setup of the solar power system, the solar panel's size may be greater than the top of the container. But since the installation is one-time and the container will not move, the size of the solar panels is not an issue. Also, because photovoltaic cells are sensitive to heat and percent of full sun, Lincos sites located in warm or cloudy regions or require a slightly larger system to counteract the effects of decreased efficiency in the solar panels. Since the container is a long-term installation, the size of the solar power system is less of an issue as that of the cost. The following figure illustrates a solar power generation system.

Figure 5: Solar Power Generation System

There are many manufacturers who design and build solar power systems. The systems, capable of generating the minimum of 8kW, cost upwards of $50,000 according to the Big Frog Mountain Company. Although the initial cost of the solar power system is great, the amount of energy it creates over time can be used to help pay for the initial investment when considering selling electricity.

In comparison to the previous alternatives, solar power does not have any negative impact to the environment. Photovoltaic cells do not consume any energy, nor does it produce any harmful by-products. As a completely clean source of energy, solar power is a good option for powering the Lincos container if the initial costs of the system can be absorbed.

4.1.4 Fuel-based Systems

Fuel-based power generation systems have long been used as power supply and backup systems. Manufacturers produce fuel generators at all different sizes. Because there are a large number of products that can produce a large range of energy per day, an appropriate system to power the Lincos container that requires 40-60 kilowatts per day can easily be found. The following figure illustrates an example of a fuel-based power generation system.

Figure 6: Honda EX5500SK1 Quiet Gas Generator

The price of a fuel-based generator is much cheaper in comparison to the other alternatives when looking at initial costs. For example, an industrial 5.5kW diesel generator costs only $4000 compared to the cost of a solar power system. A gas generator of the same size is priced under $3000. Although the initial costs are low for fuel-based systems, they require a non-renewable source of energy. In running these types of generators, a constant supply of fuel is required. This is not the case with solar, wind, or hydropower systems. Although fuel generators make a good option for locations not suitable for any other kind of power system, running this alternative adds an on-going cost to the operation of the Lincos container.

Three environmental issues appear when considering fuel generators: air, noise, and ground pollution. In considering air pollution, it is important to note that there are two types of fuel most commonly used in these types of systems: diesel and gas fuel. Although diesel fuel generators use a more stable fuel for storage, its exhaust is more polluting than that of a gas generator. Given that manufacturers do provide filters to reduce the amount of harmful exhaust, fuel generators still produce a significant amount. To combat noise pollution, manufacturers also produce silent models. These models feature an enclosure that cuts down on noise from the engine. Also, since diesel fuel generators use less fuel than gas generators, it costs less to run diesel generators. Provided that the transportation of the fuel is done safely and carefully, the issue of ground pollution becomes insignificant. However, depending on the amount transported (whether fuel is delivered daily or monthly dictates the size of the shipment), contamination of the ground water and soil may be an issue. Diesel fuel can also be stored for up to three years with the appropriate additives while gas can only be stored for up to six months. Although an inexpensive alternative to renewable energy sources, fuel-based power generation should be avoided (in the interest of the environmental aspect of sustainable development) as long as the above technologies are available and affordable.

4.1.5 Hybrid Systems

There are many different variations of hybrid systems commercially available. However, most systems are simply two different types of generators both charging the same battery system. Therefore, combining any of the previously mentioned technologies together can be considered a hybrid system. Depending on the conditions at a particular site, a custom system can be designed that takes into account typical wind, sun, and water conditions. For example, adding a fuel generator as backup or a supplement to a solar power system would be considered a hybrid system. Since most battery systems used by these power generation systems accept multiple charge sources, implementing other power generation systems to the existing system is easy.

The cost of a hybrid system depends on the different components in the system. Estimating the price of a system depends heavily on the conditions and equipment that is necessary to generate the required amount of power. In the solar power system mentioned recently, the addition of the fuel generator would only add $3000 to $4000 to the cost of the system. However, consulting a renewable energy systems specialist is the best course of action for determining the cost of a hybrid system.

The environmental impact of hybrid systems also depends on the different components in the system. Each component's impact still effects the environment the same as an entire system made up only of that component.

Although there are many power generation systems to choose from, an in-depth study of a site of interest will reveal the most appropriate technology to use. Recommendations on how to make the decision for a particular site are presented in Section 5, Conclusions and Recommendations.

4.2 Connectivity Data and Analysis

4.2.1 Satellite Provider Reference Map

In order to create the satellite provider reference map, parameters were established to select acceptable satellite service providers for the Lincos container. These parameters were created with the help of our Liaison and they are: bandwidth, service areas, compliance with Lincos systems, and reduced costs for developing countries. With these parameters in place, we began to search for satellite service providers and found Intelsat, Panamsat, and Esatel. All are global satellite service providers, and offer a wide range of bandwidths from 64Kbps to 45 Mbps. They also offer Internet access, as well as voice, data, and video-conferencing. However, Intelsat additionally offers television quality video-conferencing. Exact setup and operational costs are currently unavailable; nevertheless approximated costs can found in Charts 1, 2, 3, and 4, in Appendix B. All of this information gathered from Intelsat and Esatel has been compiled into the Satellite Service Provider Reference Map.

The purpose of our team's proposed Satellite Service Provider Reference Map is to allow for easy access to a list of satellite service providers for Entebbe to choose from, for a given country. The best way to present this information was to make it web-based, and to attach it to Entebbe's intranet for better accessibility. The reference map work by clicking on the particular region of the world where the country of interest lies within. Then after clicking on the country, a list of satellite service providers appears. Clicking on the providers will send you to a page with contact information, as well as some information about their services. There is also a link to the provider's web page. Intelsat's information page contains a link to a list of signatories for that particular country in order to obtain equipment and cost information.

The Satellite Service Provider Reference Map is to provide information on available satellite service providers; nevertheless, it does not recommend which satellite service provider to use. To recommend which satellite service providers to use for every country is complicated and time-consuming project and it is contingent to the specific needs of the region. Therefore, the decision on which satellite service provider to be used should be conducted after a specific site/country has been identified. Contacting the satellite service providers and obtaining financial costs will be the ultimate step in the decision process between satellite service providers. The reference map is just one part in the process for deciding what method of connectivity should be used in the Lincos containers, no matter where they are deployed.

4.2.2 Alternate Methods of Connectivity

Depending on the location of the Lincos containers, different methods of connectivity, other than satellite, may be possible. In order for the Lincos containers to utilize alternate methods of connectivity, the Lincos containers must have access to a local communications grid.

The different methods of connectivity are DSL (Digital Subscriber Line), Cable, ISDN (Integrated Services Digital Network), and Frame Relay. DSL is a digital based form of connectivity that utilizes the existing telephone lines as its connection. It operates on the frequencies above that of normal telephone service, so both services can be provided at the same time with no interruption (http://www.dlsreports.com, 2000). Cable connectivity is done through the existing cable service in the area; so, a cable modem is needed to establish the connection. ISDN is another digital connectivity method that also utilizes the existing telephone lines in the same manner as DSL. Both DSL and ISDN share the characteristic only being effective within 18,000 feet from the local telephone exchange, because the digital signal degrades over distance due to interference from other electronic sources. Frame-Relay is based on sending small packets of information through a network to get to a designated site (http://www.alliancedata.com, 2000). All of these methods meet the bare minimum bandwidth requirement, however, there are certain areas in which the particular methods excel over each other. The areas have been divided into speed or bandwidth, monthly cost, equipment costs, installation costs and advantages and disadvantages of each system. All of these comparisons can be seen in Appendix B. In the speed chart, satellite is the fastest with 45 Mbps. For the comparison of monthly cost, DSL and cable have to lowest maximum value. With the comparison of equipment costs, cable has the lowest maximum cost. Both DSL and cable have to lowest maximum charge for installations costs. A connectivity comparison chart and the advantages and disadvantages are given in Appendix B. These methods of connectivity are the types of connectivity that allows the Lincos containers to meet their full potential to service the communities in which they are placed.

Other forms of connectivity were researched as well. Telephone modems and ATM (Asynchronous Transfer Mode) were investigated, and our team determined that such systems didn't meet the requirements of the Lincos containers. Telephone modems are in use throughout the world, and are cheap to buy and install and use, but they are lacking the necessary speed to support the applications of the Lincos containers. ATM is an extremely fast form of connectivity, with a top speed of 150 Mbps. However, such a system is intended to support and extend the Internet backbones of continents, i.e. the North American backbone. Internet backbones are the main pathways for transferring data around the world. The overall cost for such a system just for the Lincos containers would run into the tens of thousands of dollars a month.

All of the information on acceptable methods of connectivity has been compiled into a decision platform that is web-based, which is to be apart of Entebbe's intranet. This final product is to aid in deciding which method of connectivity is best for the Lincos container given its location and accessibility to a local communications grid.

4.3 Environmental Testing Data and Analysis

From performing the methodology the following data was found.

4.3.1 Units of Measurements

Water test results express the concentration of most contaminants in either "parts per million (ppm)" or "million grams per liter (mg/l)." Although the terminology is different, 1 part per million is the equivalent of 1 milligram per liter. Pesticide concentrations, meanwhile, are frequently reported in "parts per billion (ppb)" or "micrograms per liter (µg/l)." A part per billion is 1/1000 of a part per million.

For other compounds, the results of a water analyses may be expressed in different forms of measurement. For instance, water hardness may be expressed in "grams per gallon," while the corrosion index simply estimates whether water is corrosive or not corrosive.

4.3.2 Soil

From the research that our team performed, we found that there are 16 nutrient elements required to grow crops. Plants absorb three of these essential nutrients, namely carbon, hydrogen, and oxygen, through the air and water. The other 13 nutrients are taken up from the soil. They are commonly divided into macronutrients and micronutrients. Macronutrients are the nutrients required in large quantities, and micronutrients are required in smaller amounts. Table 9 lists these macronutrients, micronutrients, and other tests along with their acceptable ranges.

4.3.2.1 Macronutrients

Nitrogen

Nitrogen promotes rapid growth, increases leaf size and quality, hastens crop maturity, and promotes fruit and seed development. Because nitrogen is a component of amino acids, which are required to synthesize proteins and other related compounds, it plays a role in almost all plant metabolic processes.

Nitrogen is an essential part of chlorophyll manufacture through photosynthesis. Photosynthesis is the process through which plants take light energy to convert atmospheric carbon dioxide into carbohydrates. Carbohydrates (sugars) provide energy required for growth and development.

Phosphorus

Without phosphorus normal plant growth cannot be achieved. It is a component of nucleic acids, most importantly ATP. It activates coenzymes for amino acid production used in protein synthesis. Phosphorus decomposes carbohydrates produced in photosynthesis and it is involved in many other metabolic processes required for normal growth, such as respiration, fatty acid synthesis, and as mentioned before photosynthesis. It enhances seed germination and early growth, stimulates blooming, enhances bud set, and hastens maturity.

Potassium

Potassium has many functions in plant growth. It is essential for photosynthesis, activates enzymes to metabolize carbohydrates for the manufacture of amino acids and proteins, and facilitates cell division and growth by helping to move starches and sugars between plant parts. It also adds stalk and stem stiffness, increases disease resistance, increases drought tolerance, gives plumpness to grain and seed, improves firmness, texture, size and color of fruit crops, and increases the oil content of oil crops.

Calcium

Calcium is a component of cell walls and is involved in production of new growing points and root tips. It provides elasticity and expansion of cell walls, which keeps growing points from becoming rigid and brittle. It acts as a base for neutralizing organic acids generated during the growing process, aids in the movement of carbohydrates and nitrogen absorption. Without calcium cell manufacture and development would not occur.

Magnesium

Magnesium is a component of the chlorophyll molecule, which is the driving force of photosynthesis. It is also essential for the metabolism of carbohydrates. It is an enzyme activator in the synthesis of nucleic acids (DNA and RNA). It regulates uptake of other essential elements, serves as a carrier of phosphate compounds throughout the plant, facilitates the movement of carbohydrates, and enhances the production of oils and fats.

Sulfur

Sulfur is an essential component in the synthesis of amino acids required to manufacture proteins. It is also required for production of chlorophyll and utilization of phosphorus and other essential nutrients. Sulfur ranks equal to nitrogen for optimizing crop yield and quality. It increases the size and weight of grain crops and enhances the efficiency of nitrogen for protein manufacture. Crops that have high nitrogen requirement must have adequate Sulfur to optimize nitrogen utilization. Sulfur increases yield and protein quality of forage and grain crops along with production and quality of fiber crops.

4.3.2.2 Micronutrients

Boron

Boron is an enzyme activator and is involved in the production of starch required for production of cellulose. The major function of boron is in sugar transport to meristem regions of roots and tops.

Chlorine

Chlorine is involved in the plant's respiration and in the photosynthesis.

Copper

Copper is involved as an enzyme activator and is thought to be involved in chlorophyll formation and in protein synthesis.

Iron

Iron is involved in the synthesis of chlorophyll.

Manganese

Manganese acts as an enzyme activator for nitrogen assimilation. It is essential for the manufacture of chlorophyll.

Molybdenum

Molybdenum is required in small amounts for protein synthesis.

Zinc

Plants require zinc because it activates enzymes.

The following table lists the essential nutrients for plants in soil along with their acceptable ranges.

Table 9: Acceptable Measurements of Nutrients in Soil

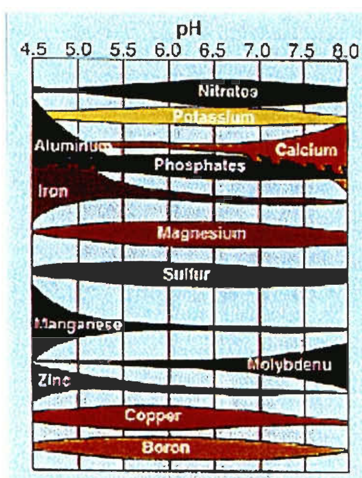
Nutrients	Acceptable Ranges (ppm)
Nitrogen	8.0 – 100.0
Phosphorus	10.0 – 40.0
Potassium	200.0 – 300.0
Calcium	50.0 – 250
Magnesium	200.0- 300.0
Sulfur	7.0 – 12.0
Boron	0.5 – 1.0
Copper	1.0 – 20.0
Iron	10.0 – 50.0
Manganese	5.0 – 50.0
Molybdenum	0.2 – 50.0
Zinc	3.0 – 15.0

4.3.2.3 Other Indicators

pH

pH is not a nutrient; it is a measure of soil acidity or alkalinity. The pH level of soil determines how well the plants are able to use nutrients in the soil. So if the pH is too high or too low plants are not able to use the nutrients in the soil efficiently. Figure 7 illustrates the relationship between pH and all the nutrients.

Figure 7: pH - Nutrient Relationship



Salinity - (Electrical Conductivity, ECe)

Salinity indicates the amount of soluble salt in soil. High salinity levels inhibit seed germination and plant growth.

Aluminum

Aluminum is not an essential nutrient for plants. At elevated levels it can be extremely toxic to plant roots and limit the plant's ability to take up phosphorus.

Toxic Heavy Metals

Lead and cadmium are toxic to both plants and animals at elevated levels.

The following table lists the other indicators of soil along with their acceptable ranges.

Table 10: Acceptable Measurements of Other Indicators for Soil

Other Indicators	Acceptable Ranges
PH	6.0 – 7.5
Salinity	0.5
Aluminum	5.0 –50.0 (ppm)
Lead	<150 (ppm)
Cadmium	<1 (ppm)

4.3.2.4 When to Perform Soil Tests

Nutrient levels can vary over a growing season for several reasons. Plants use up nutrients in the soil as they develop. Nutrients are also affected by weather influences along with the weathering of the soil. From our research we have developed the following list that describes when soil should be tested to improve the effectiveness.

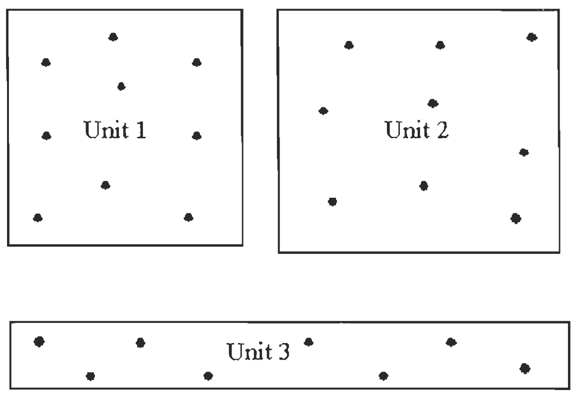
1) **Before any planting is done.** This is to make sure the soil contains the necessary nutrients.
2) **Every four weeks during the growing season.** This is to verify that nutrient levels are still adequate. These periodic checks will allow the users to catch any

deficiencies and make the necessary adjustments. This is much more effective than waiting for deficiencies to become apparent in the growth pattern of the plants.

3) **After the growing season.** This is to better prepare the soil for the next growing season.
4) **Suspicion of nutrient deficiency or contamination.** This is to determine the cause of any problems.

A minimum of five to ten samples should be collected throughout a given plot of land. Figure 8 illustrates sample areas of where to test.

Figure 8: Sample Soil Test Areas



4.3.3 Water

Based on his medical background, our liaison, Dr. Juan Barrios Arce, selected a set of tests for contaminants in water. These test include: pH, hardness, chloride, and bacteria. Although these contaminants are important, our research has found many other impurities that should be considered for the environmental testing kits. The following section lists and explains these impurities.

pH

pH indicates the ratio of hydrogen ions to hydroxyl ions on a logarithmic scale from 0 (pure acid) to 14 (pure alkaline). Pure water is 7.0, meaning that there is an equal balance of hydrogen ions and hydroxyl ions. (Note the logarithmic scale means that there are 10 times as many hydroxyl ions at 3.0 as at 2.0). In other words it pH is a measure of "acidity". Acidic water is typically corrosive, which dissolves metal that can be toxic. Alkaline water is associated with hardness. pH is also a substance to test for in soil.

Hardness

Hardness is the total of the calcium and magnesium (expressed as calcium carbonate). While Hardness minerals are generally considered to be beneficial to human health, excessive levels can cause damage to plumbing systems, especially where the water is heated, which can release toxic metals. Bitter taste and a strong unpleasant odor are associated with hard water.

Sodium

Sodium is the main component of salt. At high levels gives water its salty taste. It is a concern for people with heart conditions.

Bacteria

Bacteria in water can be a serious health problem. It indicates that the water supply is unsanitary and may contain disease-causing organisms. It may also identify presence of soil and plant material contamination.

Lead

Lead is a harmful metal. It has been connected with many health problems from lead poisoning to a reduction in intelligence quotient (IQ) scores.

Arsenic

Arsenic is a naturally occurring element and is widely distributed in the environment. Everyone is exposed to low levels of arsenic. Also the main use of arsenic is for pesticides. Weed killers, for example use it as their active ingredient. There are many health risks associated with skin abnormalities and if ingested it increases the risk of caner.

Sulfur

Hydrogen sulfide is a naturally occurring gas that is produced by sulfate reducing bacteria. The rotten-egg smell is a result of this gas. These bacteria are not known to cause disease. If not accustomed it may produce a laxative effect. Sulfur at high levels will produce an undesirable taste and may cause corrosion in plumbing.

Iron

Iron is a mineral that enters water naturally. While it is generally considered a beneficial mineral, excessive levels of Iron contributes to water hardness. It can cause a bad taste and stain laundry and plumbing fixtures.

Ammonia

Ammonia is a component of many chemical fertilizers used to enhance crop growth. It is the most toxic nitrogen compound.

Calcium

Calcium is a natural element found in soil. It contributes to water hardness. It is usually not harmful in small concentrations. However, it affects the taste, odor, and appearance of water.

Chlorine

Chlorine is used as the primary disinfectant to eliminate potentially harmful bacteria. It is usually not harmful in the amounts diluted in water used as disinfectant. It does have a distinctive odor.

Copper

Copper found in water usually comes from the pipes. At high levels, short-term exposure can cause gastrointestinal distress. Long-term exposure can contribute to liver and kidney damage.

Fluoride

Fluoride is added artificially to water supplies and occurs naturally in many private supplies. It is effective in preventing dental cavities. As with chlorine, it helps kill bacteria. But too much can damage teeth, cause cancer, impair brain function, and can make bones brittle.

Magnesium

Magnesium is a natural element that contributes to water hardness.

Manganese

Manganese is a natural element that contributes to water hardness and acts similar to iron.

Nitrates/Nitrites

Nitrate is one of the components of the nitrogen cycle. There are numerous sources including natural deposits, fertilizers, decaying organic material. Excessive nitrates causes serious a serious and sometimes fatal blood disorder. (nitrite is the toxic form of nitrate)

The following table lists all these components of soil along with their acceptable ranges.

Table 11: Maximum Contaminant Level in Water

Contaminants	Maximum Contaminants Level
pH	6.5 – 8.5
Hardness	100.0
Sodium	6.0
Bacteria	None
Lead	0.015
Arsenic	0.05
Sulfur	250.0
Iron	0.3
Ammonia	0.1
Calcium	15.0
Chlorine	250.0
Copper	1.0
Fluoride	2.0
Magnesium	8.0
Manganese	0.05
Nitrates/Nitrites	10.0

4.3.3.1 When to Perform Water Tests

Our research indicates that water should be tested once a year. In addition, water should be tested if the following situations arise:

1) If family members or houseguests have recurrent illness.
2) If household plumbing contains lead pipes, fittings, or solder joints.
3) If you are buying a home and wish to assess the safety and quality of the existing water supply.
4) If a water softener is needed to treat hard water.
5) If want to monitor the efficiency and performance of home water treatment equipment.
6) If water stains plumbing fixtures and laundry.
7) If water has an objectionable taste or smell.
8) If water appears cloudy, foamy, or colored.
9) If pipes or plumbing show signs of corrosion.
10) If water leaves scaly residues and soap scum, and decreases the cleaning action of soaps and detergents.
11) If water supply equipment (pump, chlorinators, etc.) wear rapidly.
12) If repairing, replacing, or installing pipes.
13) Following a rainy period.
14) After flooding.
15) If a new baby is expected; pregnant women, women anticipating pregnancy, or infant under six months.
16) If water source is in an area of intensive agricultural use.
17) If near a coal or other mining operation.
18) If near gas drilling operation or abandoned gas station or buried fuel storage
19) If near dump, junkyard landfill, factory, or dry cleaning operation.
20) If near seawater, a road salt storage site, or a heavily salted roadway and it is noticed that the water tastes salty or signs of corrosion appear on pipes.

    Logical observations can be made by the water's appearance, odor, and taste.

The chemical substances presented in this section should be included in the kits, but it is not necessary to test for them all. A few of these tests can be removed from these lists, because they can be accounted for in other tests. An abridged list is presented in the conclusions and recommendations section.

5.0 Conclusions and Recommendations

Based on the research documented in this report, a series of conclusions and recommendations have been made regarding the efforts to globally deploy the Lincos container. Each component of this project deals with a different aspect of the Lincos container, but together strengthens the Foundation's tools for furthering sustainable development. By helping to introduce technology in isolated and marginalized communities, human development can be improved through access to the wealth of information found on the Internet, communication with other communities in the area and around the world, and access to tools that aid the monitoring of soil and water.

5.1 Power Conclusions and Recommendations

There are three recommendations our team would like to make regarding the Lincos container's power generation system: reducing energy consumption, using our intranet web site to help select a power generation system, and considering electric utility as an application for the Lincos Program.

The first suggestion comes from the study of power consumption. There are a few electronic devices in the container that can be replaced with more power efficient counterparts. For example, the computer monitors used in the container are based on cathode ray tube (CRT) technology. Our team recommends that the Foundation use liquid crystal (LCD) displays instead. Also, the incandescent lighting system can be replaced with low-power fluorescent lighting. Because the container consumes roughly 40,000 kilowatt-hours per day, the replacement of the lights and monitors can reduce the consumption by 6,000 to 10,000 kilowatt-hours. This power consumption reduction can significantly reduce the price of the power generation system. For example, the price of wind generators can decrease by roughly $2000. Although these alternatives consume much less energy, they are also less cost effective, so additional research must be performed on the feasibility of these options. However, the additional cost spent on energy efficient devices will help save on the cost of a larger power generation system.

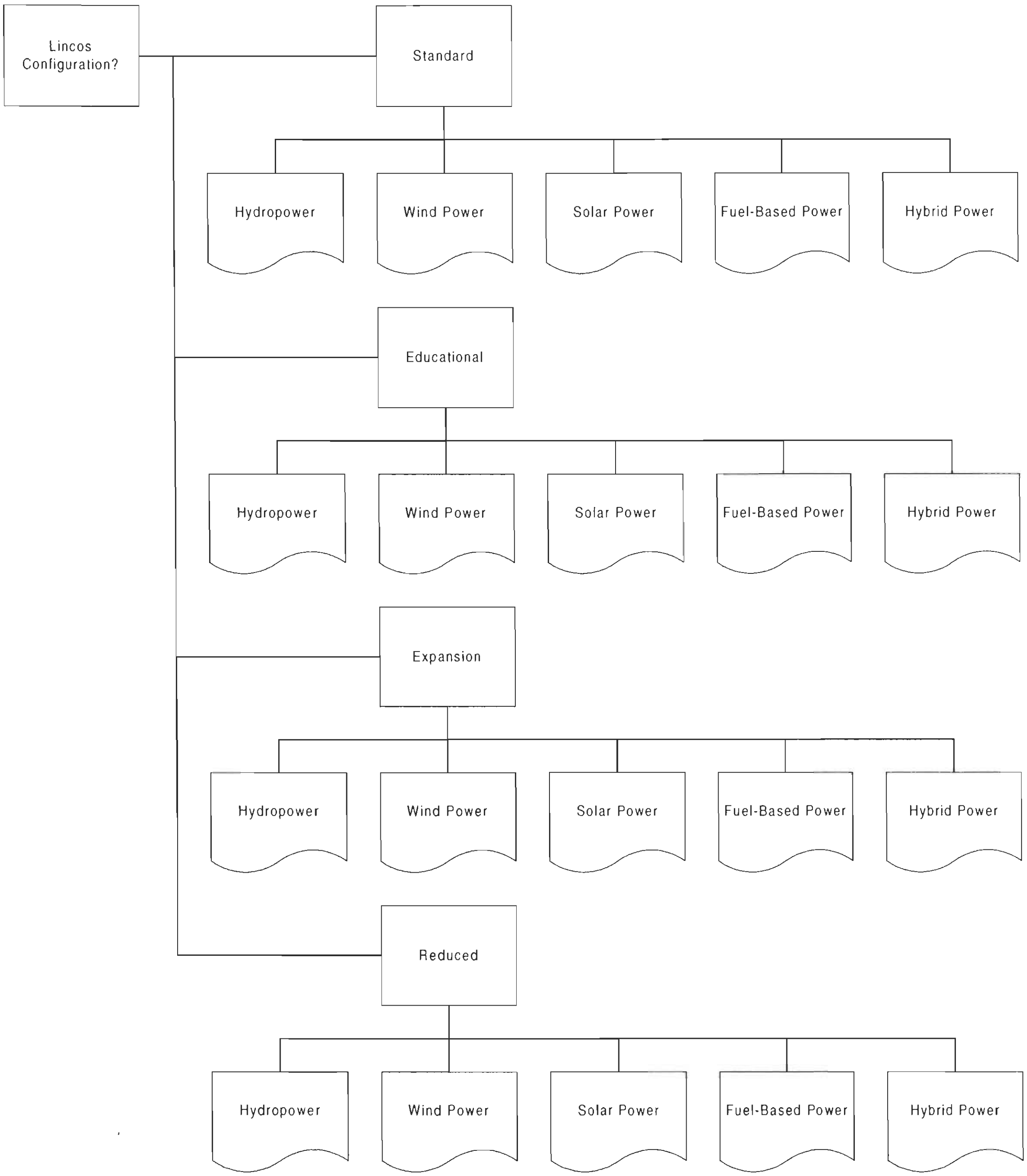
Our second recommendation for the power generation systems is that the Foundation performs an in-depth study of the energy-producing assets of a site intended for Lincos container deployment. To aid in this effort, we have created an informational intranet website to help the Foundation ultimately choose a suitable power generation system. The user of the website first chooses a Lincos configuration of interest. The link then loads a web page that provides power consumption information about that configuration and a list of power generation technologies. The user then selects the technology they are interested in and another web page loads with specific information about the technology. This page contains information on history, description, environmental impact, and estimated pricing. Also included are Internet links to manufacturers and distributors of the power generation system. The structure of the web site is presented in Figure 9 and is included in Appendix D on floppy disk.

Lastly, we recommend that the Foundation consider the addition of another application in the Lincos container: electricity utility provider. As some sites may contain an abundant source of energy, such as a large waterfall or constant high-speed wind, the power generation system may be able to produce more energy than the Lincos container requires. This excess energy may be sold to the nearest power company to help financially sustain the container. For areas without a local power company, the Foundation may consider selling the excess power directly to the community. Although purchasing a larger power generation system and laying power lines directly to the community may cost more, the revenues generated from the sale of energy would offset the added cost. We recommend that a study be performed on the feasibility of adding this application to the Lincos container.

To summarize these recommendations, we present the following list to recapitulate the previous points:

- Reduce energy consumption through energy-efficient devices
- Use intranet web site to aid in power generation system selection
- Consider adding electric utility as an application for the Lincos container for sites with a large energy source

Figure 9: Power Generation System Website Structure



5.2 Connectivity Conclusions and Recommendations

The second set of recommendations comes from the study of connectivity dealing with the development of a satellite service provider reference map, and a procedure for deciding on connectivity for a Lincos container.

5.2.1 Recommendations For The Satellite Service Provider Reference Map

Currently, satellite connectivity is being used as the primary connectivity method. This has uncovered the need for a reference of satellite service providers for every county in the world. Therefore, we recommend the creation of a satellite service provider reference map that should contain the following:

- The reference map should be made as a website in order to provide easy access and to allow for upgrades to take place.
- The satellite service provider reference map flow in same manner as Figure 10 on the next page.
- The website should contain information on services offered and contact information as well.
- A model of this website has been put onto a disk, located in Appendix D, entitled "Connectivity Selection Process", with the file name entitled "sat_ref.htm".

Figure 10: Satellite Service Reference Map Structure

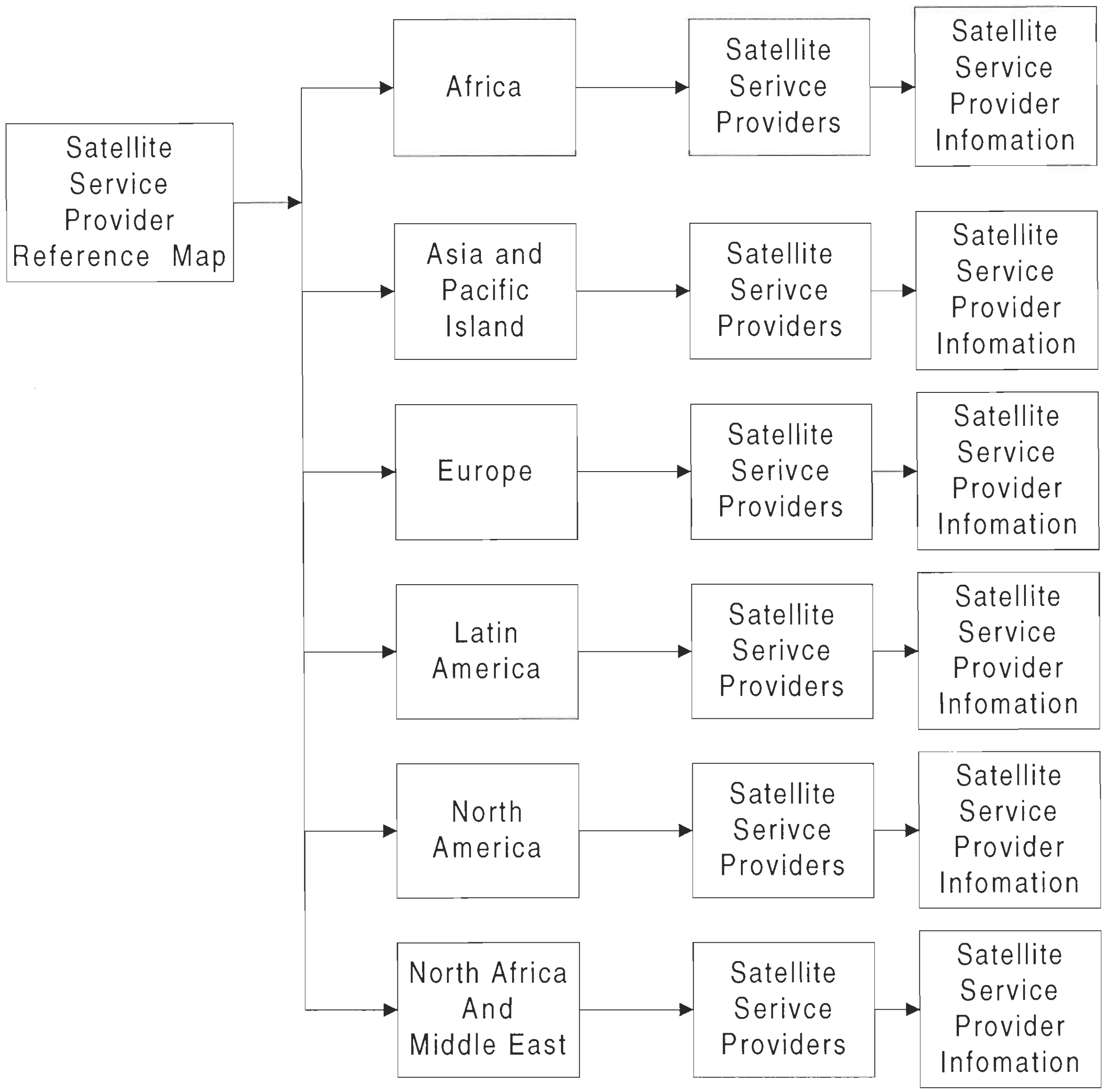


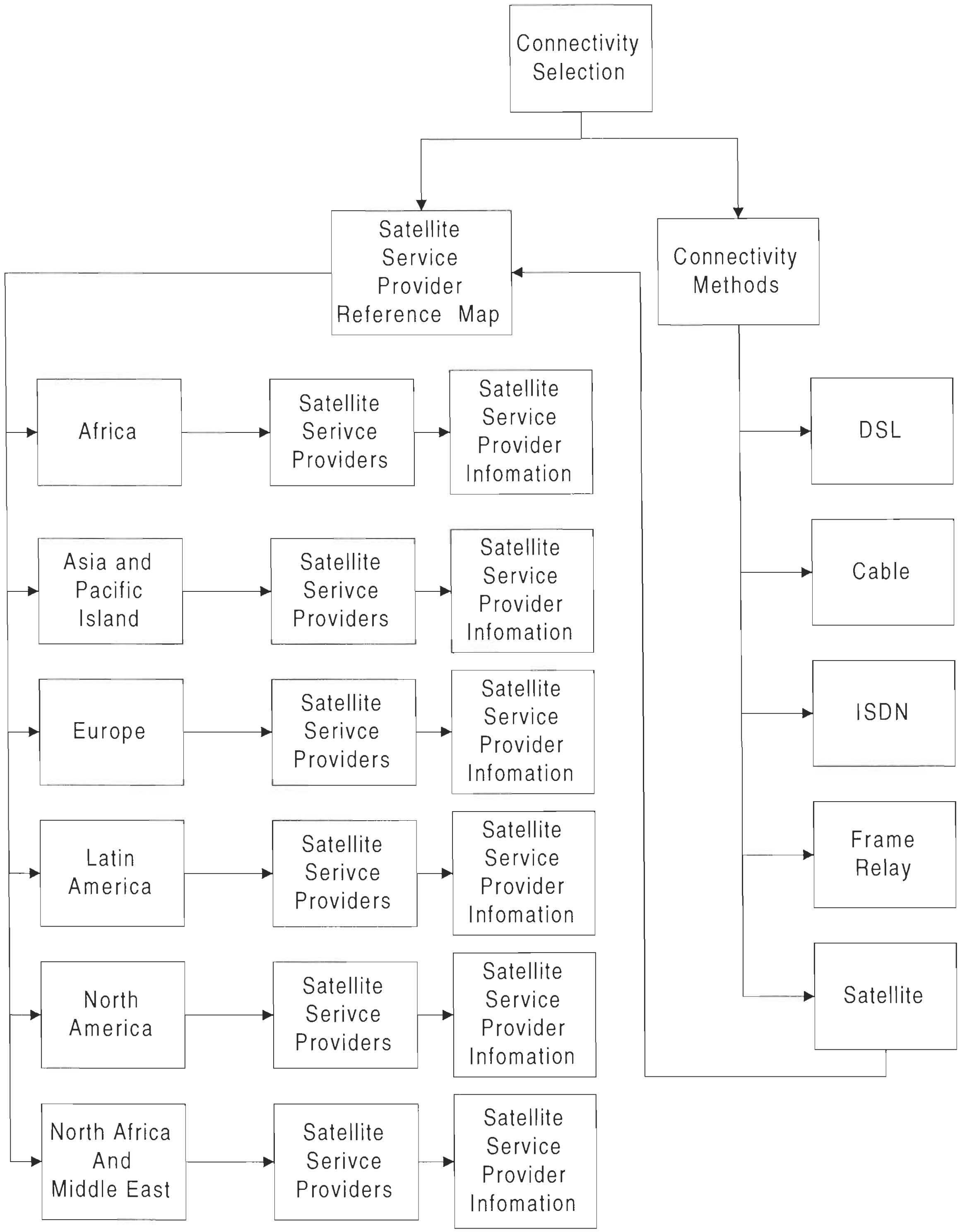
Figure 10 is a simple model of the proposed website based satellite service provider reference map. The proposed model starts out with a map of the world with regions of the world highlighted in different colors. These regions are links to a list of countries within the corresponding regions of the world. Every country listed is a link to its list of satellite service providers. The names of the Satellite service providers are links to information on those providers. The type of information that will be displayed is contact information, and services available. We also recommend that the site should be updated whenever a new satellite service provider is found, and every 6 months or a year for information that is already contained within the site.

5.2.2 Recommendations For Connectivity Selection Process

A need for a procedure to determine the most effective method of connectivity for a Lincos container was also found. In order to meet this need we recommend that the Foundation develop a procedure for selecting connectivity. We also recommend that the process include the following:

1. The connectivity selection process should be made as a website in order to provide easy access and to allow for upgrades to take place.
2. The connectivity selection process flow in a similar manner as in Figure 11 on the next page.
3. The website should contain information on the different methods of connectivity such as, bandwidth and costs.
4. The proposed model of this website has been put onto a disk, located in Appendix D, entitled "Connectivity Selection Process". The name of the file is entitled "Connectivity_Selection.htm".

Figure 11: Connectivity Selection Structure



The proposed model follows a similar layout to the figure above. The model has a homepage that contains a question about accessibility to the local communications grid with a "No" and "Yes" answer to click on. Clicking on "No" bring you to the satellite service provider reference map. Clicking on "Yes" brings you to a page that contains the alternate methods. The page contains the connectivity methods of DSL, Cable, ISDN, Frame-Relay, and Satellite. These are the only viable connectivity methods that will allow the Lincos containers to reach its full potential on communicating with the out side world in the forms of the Internet, telephony, and video-conferencing. Clicking on the different methods brings you to another question relating to whether or not the appropriate technology is available to use the alternate methods. Clicking on "No" brings you back to the list of alternate methods so that you can explore other options. Clicking on "Yes" brings you to an information page on that type of connectivity. This page contains general information on bandwidth, installation costs, equipment costs, and monthly costs, as well as a small table of advantages and disadvantages on the method of connectivity. The page that contains the list of alternatives also contains a link to the Satellite service Provider Reference Map. This is incase the alternate methods cannot be used and so satellite will be the only viable solution. We also recommend that the site be updated whenever a new method of connectivity is discovered to keep up with emerging technology.

5.3 Environmental Testing Conclusions and Recommendations

From researching the different substances that should be tested for in soil and water, we recommend that the following tests be included in the Lincos container's environmental test kits. Because some of the elements in the total list from section 4.3, Data and Analysis, can be tested for by one test, it is not necessary to analyze for each individual element. We recommend that the following substances be tested for in the environmental testing kits.

5.3.1 Soil

1) Nitrogen
2) Phosphorus
3) Potassium
4) Calcium
5) Magnesium
6) Sulfur
7) pH
8) Salinity
9) Aluminum

Only two reductions were necessary for the soil nutrients. It is not necessary to test for the micronutrients, because they all contribute to the pH. Because an imbalance in micronutrients contributes to high or low pH, these nutrients can be accounted for by testing for pH. Since lead and cadmium occur naturally and are present in low levels, it is not a major concern plant growth. Only when human contamination is suspected (i.e., from industrial waste and byproducts), is it necessary to test for these elements.

5.3.2 Water

1) pH
2) Hardness
3) Sodium
4) Bacteria
5) Chlorine
6) Lead
7) Nitrates/Nitrites
8) Arsenic
9) Ammonia

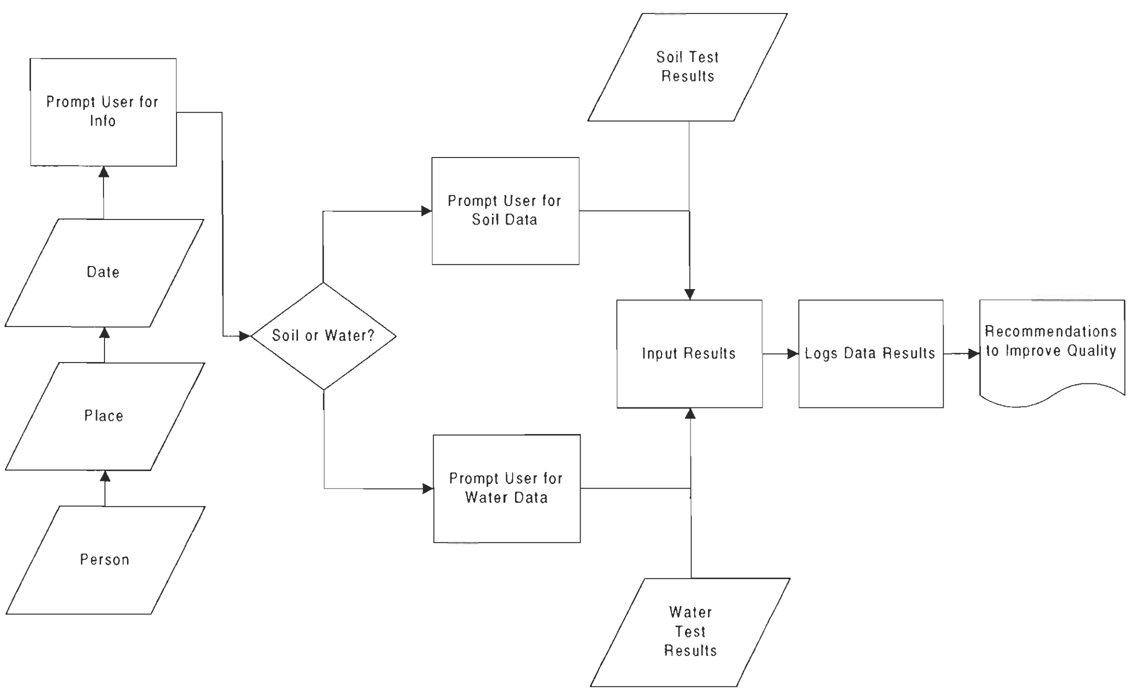
We recommended that three reductions in the test list be made from the original set in section 4.3, Data and Analysis. Our team made the first reduction by removing iron, calcium, copper, magnesium, and manganese, because they all contribute to water hardness. Various sources indicated that these elements could all be tested for by the hardness test. The second reduction was made by removing sulfur from the list, because it contributes to low pH and has a distinctive odor at elevated (and contaminating) levels. Therefore, it is not necessary to test for sulfur. We made the last reduction by removing fluoride. Although fluoride contamination almost never occurs naturally, it has been a problem where communities have used it for water treatment. However, because chlorine is more often used for water treatment than fluoride, it is not necessary to test for this element.

As the composition of soil and water may vary depending on geographical location, our team recommends that research be done on the soil and types of crops at future Lincos sites. With this background, substance tests can be added to the environmental testing kits to improve their effectiveness. For example, the types of crops in different regions of the world are not the same. Because certain types of crops may need specific amounts of micronutrients, the tests for micronutrients may need to be added to the environmental testing kits.

Our team also recommends that a reference guide be distributed with the environmental testing kits for helping the Lincos users decide when to perform these tests for soil and water. This reference guide outlines instances or events when the user should test. A sample of this guide is included in Appendix C.

The last recommendation is the construction of a database for the Lincos users. This database logs the user's test results and outputs recommendations for improving the quality of their water or soil. The following figure illustrates typical database operation.

Figure 12: Structure of Environmental Testing Database



The user inputs their name, the date, the place where the test was performed, and the results of the tests into the database and it would display recommendations for improvement. The database recommendations should be based on the information presented in Appendix C.

To summarize our recommendations, we present the following list to reiterate the previous points:

- Include the suggested soil and water tests in the environmental testing kits
- Research future Lincos sites for soil and water conditions
- Include the reference guide for when to perform the tests in the kits
- Use the structure for an environmental database to create a helpful tool for Lincos users

5.4 Closing Remarks

In researching each of the components of this project, the Lincos Program can now reach more communities than ever. Finding alternative power generation systems to power grid energy supplies extends the reach of the Lincos Program. These systems enable most of the applications, like the computer lab, videoconferencing center, and information center, to operate without restriction. The connectivity alternatives also allow the Lincos container to be placed in a wider variety of locations. Facilitating the communication process and providing Internet access make up a large portion of the applications on board the container. Another component of this project is the health and environment application. In this application, Entebbe has designed a series of tests for soil and water. With an improved set of environmental test kits, Entebbe can help communities around the world improve the quality of their soil and water. Although this information helps Entebbe further sustainable development, more research can be performed on the feasibility of these alternatives in specific locations around the world.

Nevertheless, with the Foundation's hard work and dedication, sustainable development comes slightly closer to reality.

Appendix A

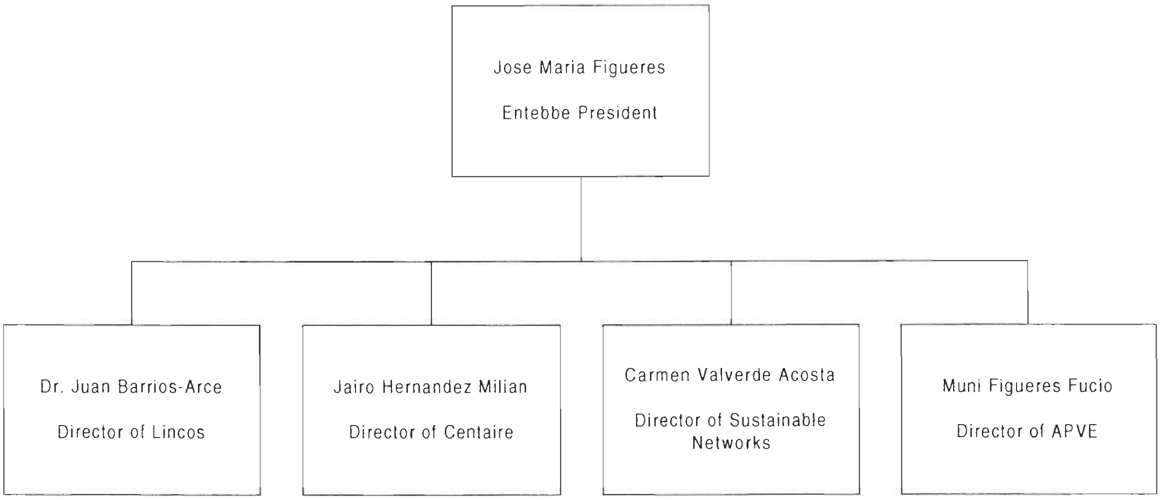
Mission and Organization of Entebbe

"To further sustainable development through improvements in individual well being, developed by the promotion of technological applications that offer greater opportunities, living conditions, and access to services, while reducing their costs and increasing time for their personal benefit and enjoyment" (Entebbe, 1999, p. 1).

Entebbe, the Costa Rican Foundation for Sustainable Development, defines sustainable development in terms of three parts. Sustainable development improves the process of human development, strengthens the balance of economy, and fosters respect for the environment. To do this, the Foundation concentrates on one of the three areas mentioned in the literature review, the promotion of new technology.

Mainly serving Latin American, the Foundation is divided into four main programs. The Centaire Program, APVE (Association to Promote Electric Vehicles), Networks for Sustainability, and the Lincos Program. A director heads each program. The liaison of this project is director of the Lincos Program. In addition, a Program Coordinator oversees each program and a director of administration heads the administrative side of Entebbe. Former President José Figueres is the Foundations' president. The following figure illustrates the structure of this organization.

Figure 13: Entebbe Organization Chart



Working on projects that are financially self-sufficient, the Foundation is a not-for-profit organization. Each project has some form of financial support from various firms around the world. The AVINA Foundation provides funding for general Entebbe overhead costs. Also, the Lincos program receives support from Hewlett Packard, Intel, Motorola, and Microsoft. Much research is performed through educational institutions by students receiving academic credit that further reduces their operational costs.

Although the Foundation is not heavily policy-based, the president sets most of the policies. However, as an organization divided into four programs, the policy for each program is set by the program directors.

This particular project was originally described by Foundation as:

> Entebbe has implemented what they call "little intelligent communities." They integrate multiple information technologies in a single portable unit that can be transported from one site to another through Costa Rica. Their intention is to make these technologies accessible to isolated and marginal communities. These units are self-sufficient from the energy power of view and have satellite connections so as to communicate with the external world. The technologies used are related to health and environment, laboratories for education in computer sciences, teleconferencing, communications, tele-banking, e-commerce, etc. Students should contribute to the "little intelligent communities" by

> conducting research on better alternatives to provide connectivity and energy to their units. Students should analyze offers made by providers in order to increase connectivity possibilities to the Internet and voice over IP. Students should also analyze offers related to the supply of energy. For all of these, students would have to take into consideration specific geographical and technology of the conditions of the region.

As the objective of the project changed to include a third area, environmental testing, the final objectives are discussed in an earlier portion of this document.

Because the Foundation's mission is to further sustainable development, the Lincos program helps to promote technology in marginalized communities with the goal of improving the communities' quality of living as well as to minimize damage to the environment that this process may incur. This project is designed to help extend the reach of the Lincos unit to the global scale by finding viable alternatives for power generation systems, connectivity, and environmental tests. The results of this work will help the Lincos staff deploy Lincos containers to any location around the world.

Appendix B

Charts and Tables

Power Generation System Charts and Tables

Table 12: Lincos Device Average Power Consumption Measurements at San Marcos, June 2000

Device	Amps	Watts
Flood Light (Outdoor)	1.40	161
Incandescent Light (Indoor)	0.40	46
Fluorescent Light	0.30	34.5
Ventilation Fan	0.75	86.25
Client PC	0.40	46
Client Monitor	0.50	57.5
Laser Printer	0.10	11.5
Printer/Scanner/Fax	n/a	11.5
Television	0.70	80.5
Stereo Receiver	0.15	17.25
CD Player	0.10	11.5
VCR Player	0.10	11.5
Tape Player	0.10	11.5
Ethernet Hub	0.10	11.5
Server PC	0.40	46
Server Monitor	0.50	57.5
UPS - Battery Backup	0.35	40.25
Satellite & Security	n/a	300
Info PC (Notebook)	0.2	23
FM Transmitter	n/a	50
Zip Drive	n/a	0.1

n/a - data retrieved from specifications found in device manuals

Table 13: Average Power Consumption for Standard Configuration

Item	Quantity	Hours/Day	Watts Hrs Used/Day	Continuous Power (Watts)
Flood Light (Outdoor)	4	12	7728.0	644.0
Indoor Light	6	4	1104.0	276.0
Fluorescent Light	8	12	3312.0	276.0
Ventilation Fan	2	12	2070.0	172.5
Client PC	6	12	3312.0	276.0
Client Monitor	6	12	4140.0	345.0
Printer/Scanner/Fax	1	12	138.0	11.5
Laser Printer	1	12	138.0	11.5
Television	1	3	241.5	80.5
Stereo Receiver	1	8	138.0	17.3
CD/DVD Player	1	8	92.0	11.5
VCR Player	1	3	34.5	11.5
Satellite & Security	1	12	3600.0	300.0
Ethernet Hub	1	24	276.0	11.5
Server PC	2	24	2208.0	92.0
Server Monitor	2	24	2760.0	115.0
UPS - Battery Backup	2	24	1932.0	80.5
Info PC (Notebook)	1	12	276.0	23.0
FM Transmitter	1	12	600.0	50.0
Zip Drive	1	12	1.2	0.1

Table 14: Average Power Consumption for Educational Configuration

Item	Quantity	Hours/Day	Watts Hrs Used/Day	Continuous Power (Watts)
Flood Light (Outdoor)	4	12	7728.0	644.0
Indoor Light	6	4	1104.0	276.0
Fluorescent Light	8	12	3312.0	276.0
Ventilation Fan	2	12	2070.0	172.5
Client PC	8	12	4416.0	368.0
Client Monitor	8	12	5520.0	460.0
Printer/Scanner/Fax	0	12	0.0	0.0
Laser Printer	1	12	138.0	11.5
Television	1	3	241.5	80.5
Stereo Receiver	1	8	138.0	17.3
CD/DVD Player	1	8	92.0	11.5
VCR Player	1	3	34.5	11.5
Satellite & Security	1	12	3600.0	300.0
Ethernet Hub	1	24	276.0	11.5
Server PC	2	24	2208.0	92.0
Server Monitor	2	24	2760.0	115.0
UPS - Battery Backup	2	24	1932.0	80.5
Info PC (Notebook)	0	12	0.0	0.0
FM Transmitter	0	12	0.0	0.0
Zip Drive	1	12	1.2	0.1

Table 15: Average Power Consumption for Expansion Configuration

Item	Quantity	Hours/Day	Watts Hrs Used/Day	Continuous Power (Watts)
Flood Light (Outdoor)	4	12	7728.0	644.0
Indoor Light	6	4	1104.0	276.0
Fluorescent Light	8	12	3312.0	276.0
Ventilation Fan	2	12	2070.0	172.5
Client PC	10	12	5520.0	460.0
Client Monitor	10	12	6900.0	575.0
Printer/Scanner/Fax	1	12	138.0	11.5
Laser Printer	0	12	0.0	0.0
Television	0	3	0.0	0.0
Stereo Receiver	0	8	0.0	0.0
CD/DVD Player	0	8	0.0	0.0
VCR Player	0	3	0.0	0.0
Satellite & Security	0	12	0.0	0.0
Ethernet Hub	1	24	276.0	11.5
Server PC	0	24	0.0	0.0
Server Monitor	0	24	0.0	0.0
UPS – Battery Backup	2	24	1932.0	80.5
Info PC (Notebook)	0	12	0.0	0.0
FM Transmitter	0	12	0.0	0.0
Zip Drive	0	12	0.0	0.0

Table 16: Average Power Consumption for Reduced Configuration

Item	Quantity	Hours/Day	Watts Hrs Used/Day	Continuous Power (Watts)
Flood Light (Outdoor)	4	12	7728.0	644.0
Indoor Light	6	4	1104.0	276.0
Fluorescent Light	8	12	3312.0	276.0
Ventilation Fan	2	12	2070.0	172.5
Client PC	6	12	3312.0	276.0
Client Monitor	6	12	4140.0	345.0
Printer/Scanner/Fax	1	12	138.0	11.5
Laser Printer	1	12	138.0	11.5
Television	1	3	241.5	80.5
Stereo Receiver	1	8	138.0	17.3
CD/DVD Player	1	8	92.0	11.5
VCR Player	1	3	34.5	11.5
Satellite & Security	1	12	3600.0	300.0
Ethernet Hub	1	24	276.0	11.5
Server PC	2	24	2208.0	92.0
Server Monitor	2	24	2760.0	115.0
UPS - Battery Backup	2	24	1932.0	80.5
Info PC (Notebook)	1	12	276.0	23.0
FM Transmitter	1	12	600.0	50.0
Zip Drive	1	12	1.2	0.1

Table 17: Configuration Comparison of Average Daily Power Consumption in Watt-Hours

Configuration	WH/Day	KWH/Day	5Hr Gen* (WH/Day)	24Hr Gen* (WH/Day)
Standard	34101.2	34.1	6820.2	1420.9
Educational	35571.2	35.6	7114.2	1482.1
Expansion	28980.0	29.0	5796.0	1207.5
Reduced	34101.2	34.1	6820.2	1420.9

* - watt-hours needed from power generation system to meet daily requirements

Figure 14: Configuration Comparison of Average Daily Power Consumption in Watt-Hours

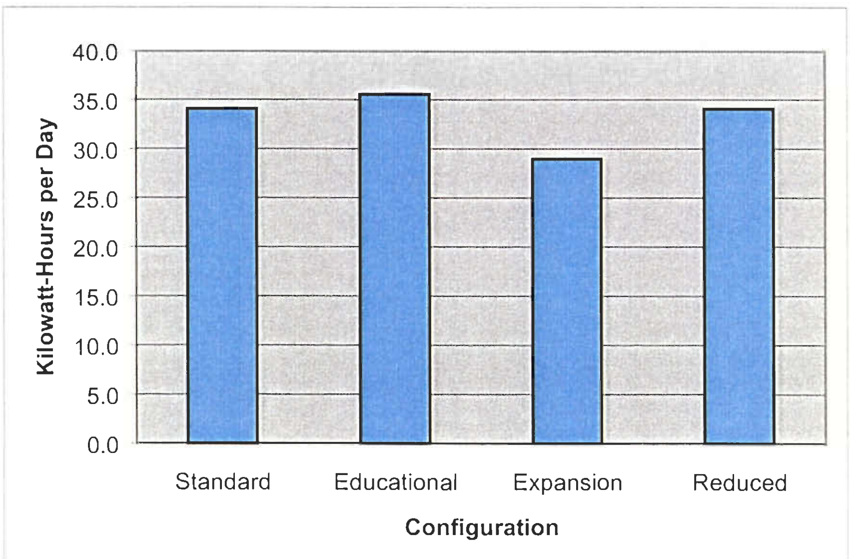


Table 18: Configuration Comparison of Average Power Consumption in Watts

Configuration	Watts	Kilowatts
Standard	2805.3	2.80525
Educational	2927.8	2.92775
Expansion	2507.0	2.507
Reduced	2805.3	2.80525

Figure 15: Configuration Comparison of Average Power Consumption in Kilowatts

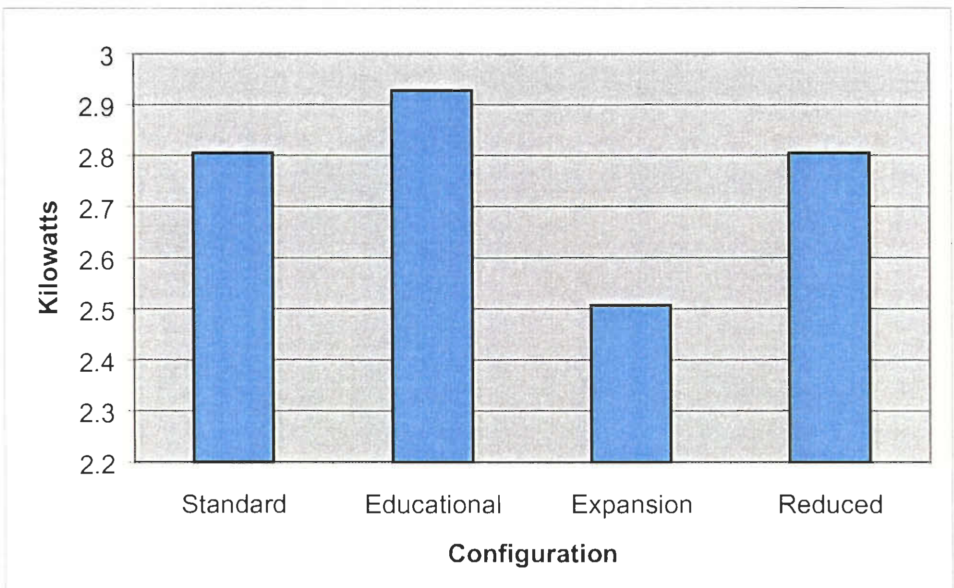


Table 19: Lincos Device Maximum Power Consumption Measurements at San Marcos, June 2000

Device	Amps	Watts
Flood Light (Outdoor)	1.40	161
Indoor Light	0.40	46
Fluorescent Light	0.30	34.5
Ventilation Fan	1.50	172.5
Client PC	0.70	80.5
Client Monitor	1.00	115
Laser Printer	0.43	50
Printer/Scanner/Fax	n/a	11.5
Television	0.78	90
Stereo Receiver	2.00	230
CD Player	0.10	11.5
VCR Player	0.10	11.5
Tape Player	0.10	11.5
Tape Player	n/a	40
Server PC	n/a	150
Server Monitor	n/a	90
UPS - Battery Backup	1.4	161
Satellite & Security	n/a	800
Info PC (Notebook)	n/a	70
FM Transmitter	n/a	50
Zip Drive	n/a	0.1

n/a - data retrieved from specifications found in device manuals

Table 20: Maximum Power Consumption for Standard Configuration

Item	Quantity	Hours/Day	Watts Hrs Used/Day	Continuous Power (Watts)
Flood Light (Outdoor)	4	12	7728.0	644.0
Indoor Light	6	4	1104.0	276.0
Fluorescent Light	8	12	3312.0	276.0
Ventilation Fan	2	12	4140.0	345.0
Client PC	6	12	5796.0	483.0
Client Monitor	6	12	8280.0	690.0
Printer/Scanner/Fax	1	12	600.0	50.0
Laser Printer	1	12	600.0	50.0
Television	1	3	270.0	90.0
Stereo Receiver	1	8	1840.0	230.0
CD/DVD Player	1	8	92.0	11.5
VCR Player	1	3	34.5	11.5
Satellite & Security	1	12	9600.0	800.0
Server PC	2	24	7200.0	300.0
Server Monitor	2	24	4320.0	180.0
UPS - Battery Backup	2	24	7728.0	322.0
Info PC (Notebook)	1	12	840.0	70.0
FM Transmitter	1	12	600.0	50.0
Zip Drive	1	12	1.2	0.1

Table 21: Maximum Power Consumption for Educational Configuration

Item	Quantity	Hours/Day	Watts Hrs Used/Day	Continuous Power (Watts)
Flood Light (Outdoor)	4	12	7728.0	644.0
Indoor Light	6	4	1104.0	276.0
Fluorescent Light	8	12	3312.0	276.0
Ventilation Fan	2	12	4140.0	345.0
Client PC	8	12	7728.0	644.0
Client Monitor	8	12	11040.0	920.0
Printer/Scanner/Fax	0	12	0.0	0.0
Laser Printer	1	12	600.0	50.0
Television	1	3	270.0	90.0
Stereo Receiver	1	8	1840.0	230.0
CD/DVD Player	1	8	92.0	11.5
VCR Player	1	3	34.5	11.5
Satellite & Security	1	12	9600.0	800.0
Server PC	2	24	7200.0	300.0
Server Monitor	2	24	4320.0	180.0
UPS - Battery Backup	2	24	7728.0	322.0
Info PC (Notebook)	0	12	0.0	0.0
FM Transmitter	0	12	0.0	0.0
Zip Drive	1	12	1.2	0.1

Table 22: Maximum Power Consumption for Expansion Configuration

Item	Quantity	Hours/Day	Watts Hrs Used/Day	Continuous Power (Watts)
Flood Light (Outdoor)	4	12	7728.0	644.0
Indoor Light	6	4	1104.0	276.0
Fluorescent Light	8	12	3312.0	276.0
Ventilation Fan	2	12	4140.0	345.0
Client PC	10	12	9660.0	805.0
Client Monitor	10	12	13800.0	1150.0
Printer/Scanner/Fax	1	12	600.0	50.0
Laser Printer	0	12	0.0	0.0
Television	0	3	0.0	0.0
Stereo Receiver	0	8	0.0	0.0
CD/DVD Player	0	8	0.0	0.0
VCR Player	0	3	0.0	0.0
Satellite & Security	0	12	0.0	0.0
Server PC	0	24	0.0	0.0
Server Monitor	0	24	0.0	0.0
UPS - Battery Backup	2	24	7728.0	322.0
Info PC (Notebook)	0	12	0.0	0.0
FM Transmitter	0	12	0.0	0.0
Zip Drive	0	12	0.0	0.0

Table 23: Maximum Power Consumption for Reduced Configuration

Item	Quantity	Hours/Day	Watts Hrs Used/Day	Continuous Power (Watts)
Flood Light (Outdoor)	4	12	7728.0	644.0
Indoor Light	6	4	1104.0	276.0
Fluorescent Light	8	12	3312.0	276.0
Ventilation Fan	2	12	4140.0	345.0
Client PC	6	12	5796.0	483.0
Client Monitor	6	12	8280.0	690.0
Printer/Scanner/Fax	1	12	600.0	50.0
Laser Printer	1	12	600.0	50.0
Television	1	3	270.0	90.0
Stereo Receiver	1	8	1840.0	230.0
CD/DVD Player	1	8	92.0	11.5
VCR Player	1	3	34.5	11.5
Satellite & Security	1	12	9600.0	800.0
Server PC	2	24	7200.0	300.0
Server Monitor	2	24	4320.0	180.0
UPS - Battery Backup	2	24	7728.0	322.0
Info PC (Notebook)	1	12	840.0	70.0
FM Transmitter	1	12	600.0	50.0
Zip Drive	1	12	1.2	0.1

Table 24: Configuration Comparison of Maximum Daily Power Consumption in Watt-Hours

Configuration	WH/Day	KWH/Day	5Hr Gen* (WH/Day)	24Hr Gen* (WH/Day)
Standard	64085.7	64.1	12817.1	2670.2
Educational	66737.7	66.7	13347.5	2780.7
Expansion	48072.0	48.1	9614.4	2003.0
Reduced	64085.7	64.1	12817.1	2670.2

* - Watt-Hours needed from power generation system to meet daily requirements

Figure 16: Configuration Comparison of Maximum Daily Power Consumption in Watt-Hours

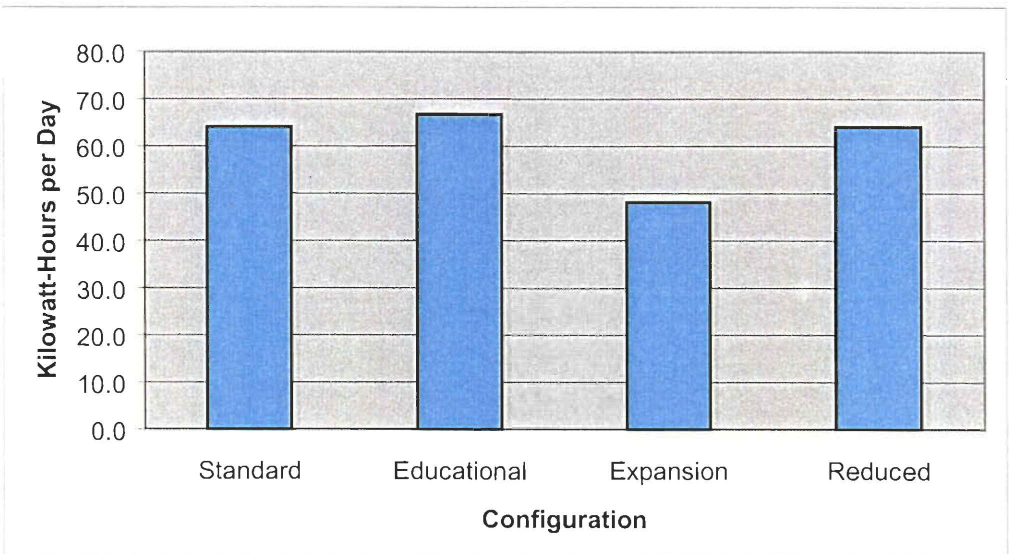
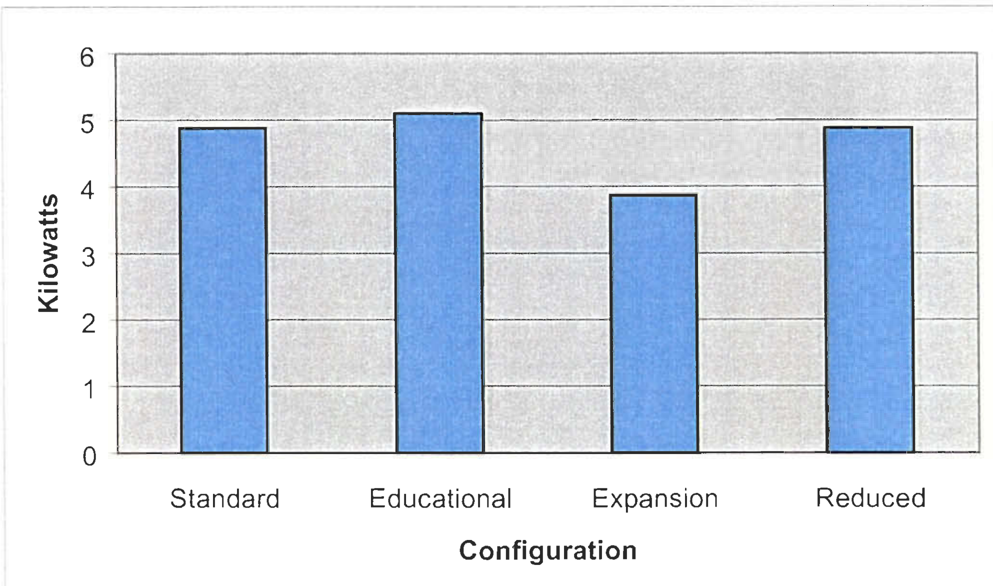


Table 25: Configuration Comparison of Maximum Power Consumption in Watts

Configuration	Watts	Kilowatts
Standard	4879.0	4.879
Educational	5100.0	5.1
Expansion	3868.0	3.868
Reduced	4879.0	4.879

Figure 17: Configuration Comparison of Maximum Power Consumption in Watts



Connectivity Charts

Chart 5: Bandwidth for Different Connectivity Methods

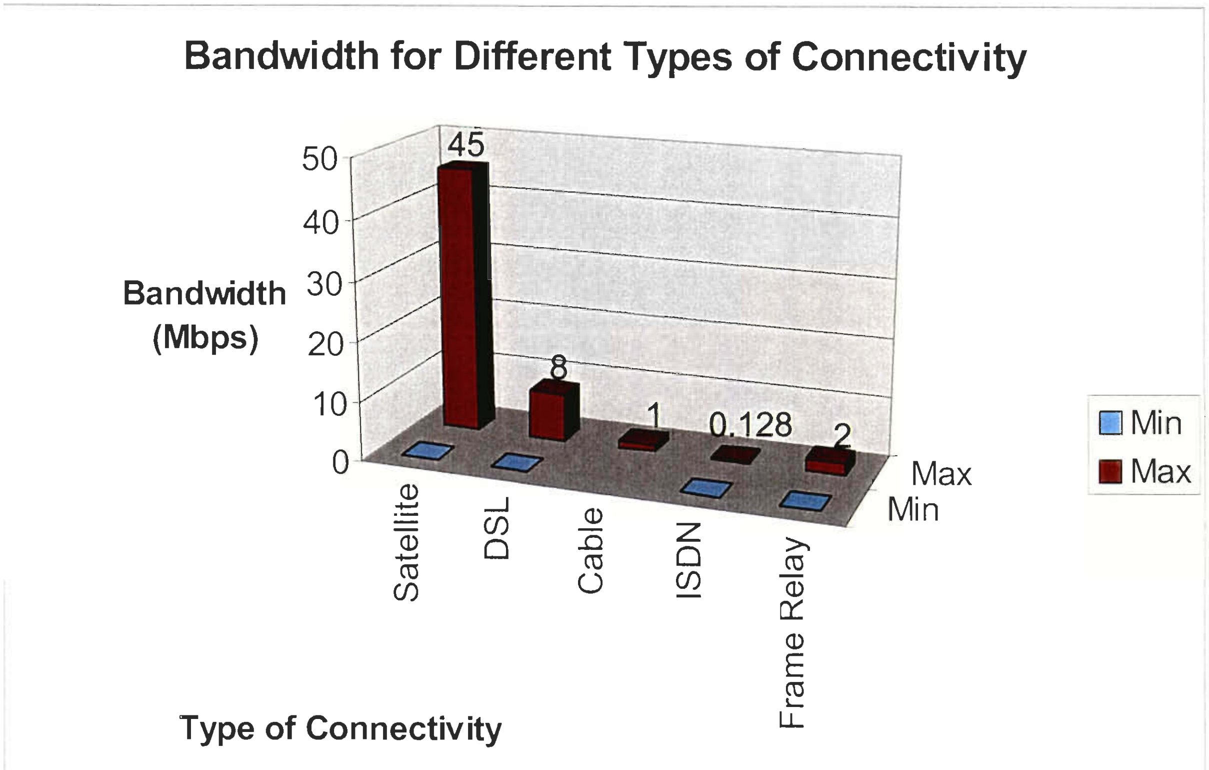


Chart 6: Monthly Costs for Different Types of Connectivity

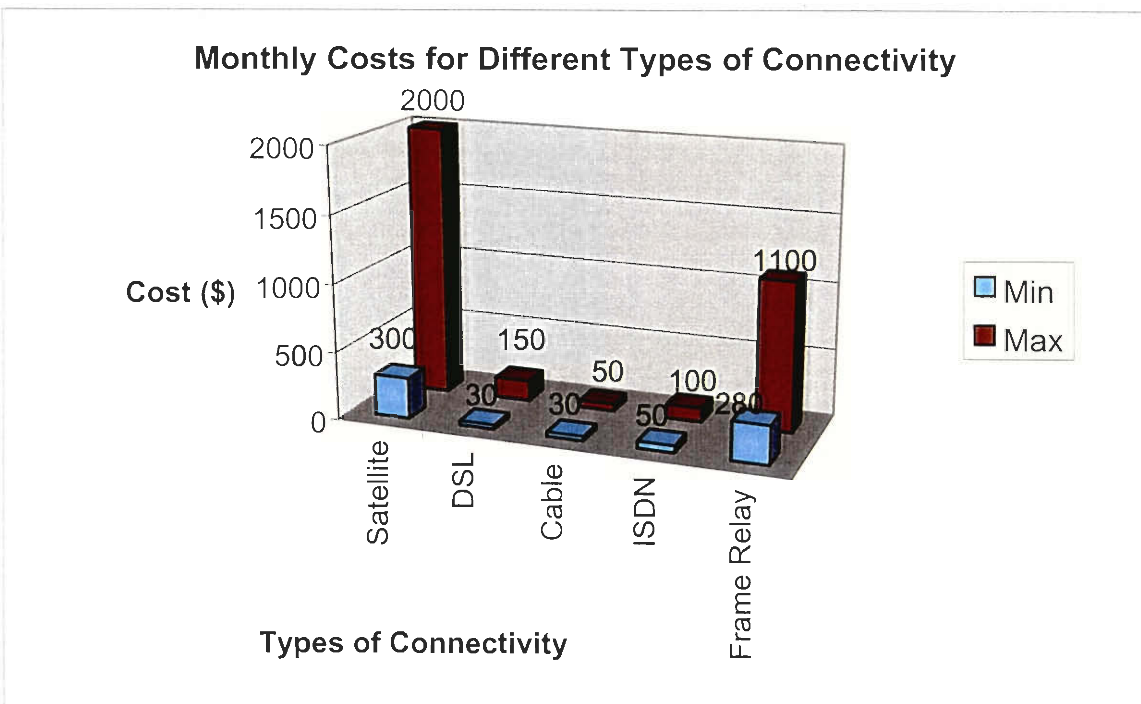


Table 26: Equipment Costs for Different Types of Connectivity

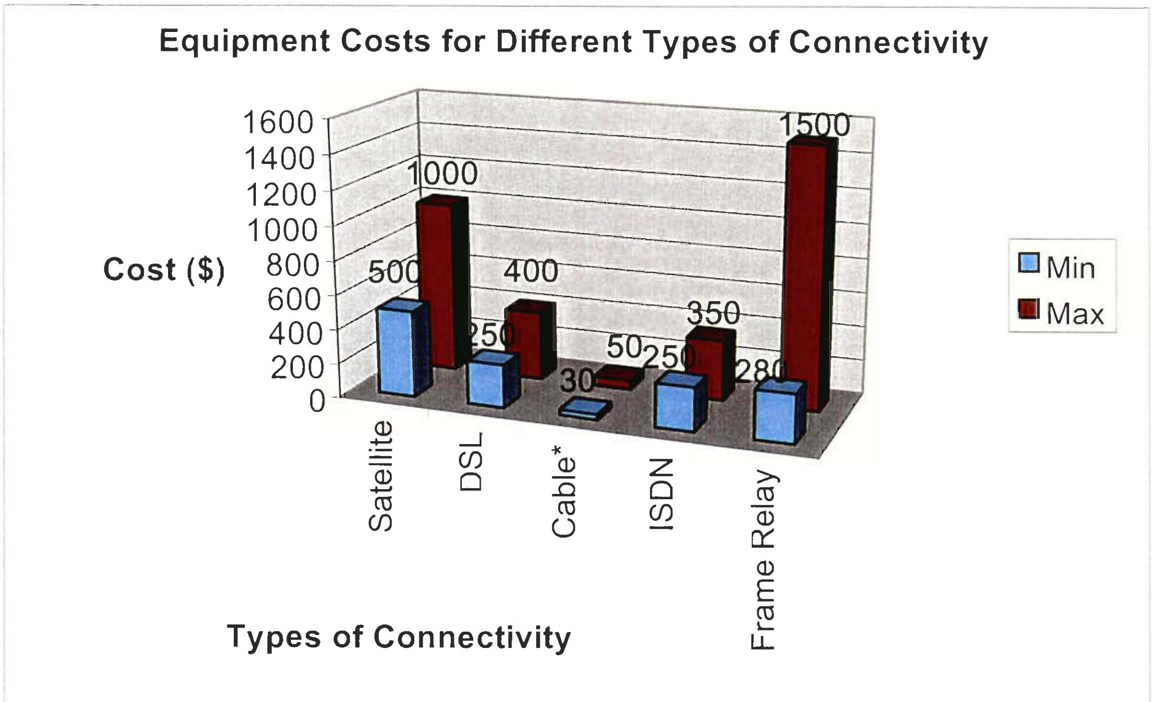
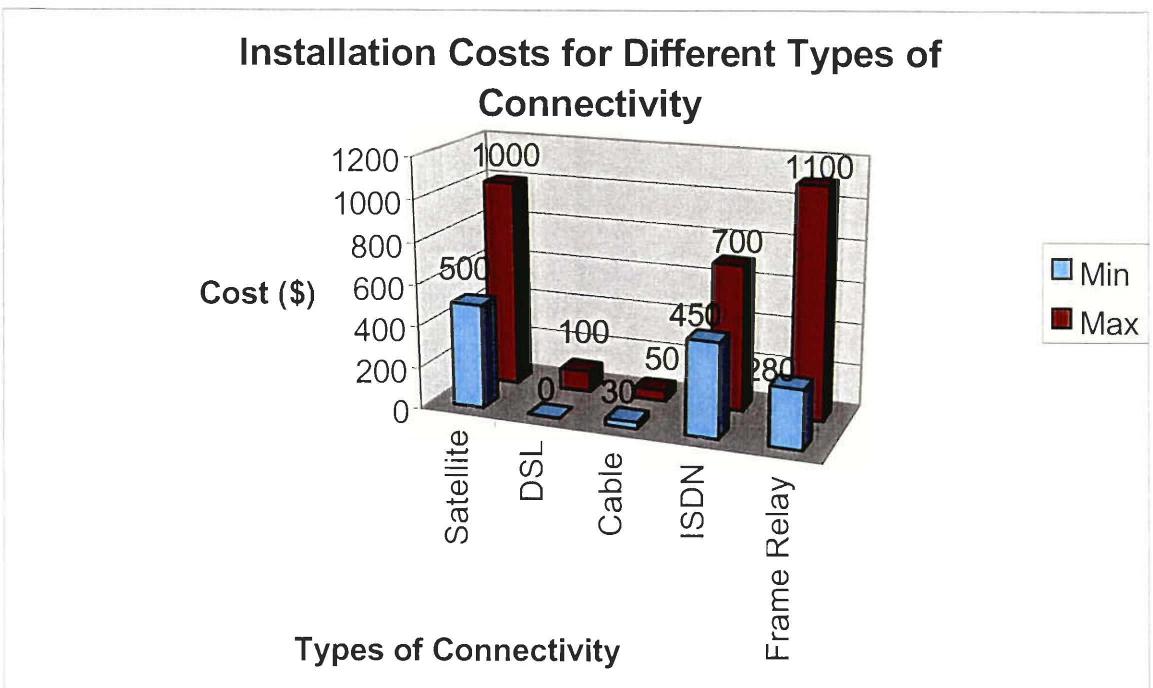


Table 27: Installation Costs for Different Types of Connectivity



Connectivity Tables

Table 28: Cost Comparison of Connectivity Methods

SYSTEM	Speed		Monthly Costs		Equipment Costs		Installation Costs	
	Min	Max	Min	Max	Min	Max	Min	Max
Satellite	64 Kbps	45 Mbps	$300	$2,000	$500	$1,000	$500	$1,000
DSL	64 Kbps	8 Mbps	$30	$50	$250	$400	$0	$100
Cable	No Value	1 Mbps	$30	$50	30*	$50*	$0	$100
ISDN	64 Kbps	128 Kbps	$50	$100	$250	$350	$450	$700
Frame Relay	64 Kbps	2 Mbps	$280	$1,100	$280	$1,500	$280	$1,100

* Price for renting out equipment

Table 29: Advantages and Disadvantages of Different Connectivity Methods

SYSTEM	Advantages	Disadvantages
Satellite	Speed: Maximum speed of 45 Mbps. Global Capability: Location is not a factor. Can connect from anywhereon the world, expect for polar regions. Perfect for locations where no local communications grid exists. Costs: Overall cost are moderate for high bandwidth rate and performance.	Costs: In comparison with other forms of connectivity, monthly costs, equipment costs, and installations costs are high. Not suited for areas with developed communications systems.
DSL	Speed: Maximum speed of 8 Mbps. Type of Connection: Uses normal copper telephone wires without interrupting phone service. Costs: Overall costs are relatively low for high bandwidth.	Location: Lincos unit can not be more than 18,000 feet from the local telephone exchange. Availability: Not available in most parts of the world, especially rural areas.

Cable	Speech: Maximum speed of 1 Mbps. Costs: Overall costs are low for the bandwidth, as long as there is cable service already in the area, and the cable company provides Internet service.	Availability: Not available in most parts of the world, especially rural areas. Shared Connectivity: The 1 Mbps is shared with other users in the local cable service area.
ISDN	Availability: Available in most parts of the world. Costs: Overall costs are lower than other forms of connectivity. Type of Connection: Utilizes the normal copper telephone wires, Without interrupting phone service.	Costs: High overall cost to bandwidth ratio. Speed: Maximum speed of 128 Kbps. To obtain this speed, an additional phone line must be installed in order to not interrupt phone service. Location: The Lincos container must be within 18,000 feet of the local telephone exchange, and itmust have the necessary equipment.
Frame Relay	Speed: Maximum speed of 2 Mbps. Reliability: Dedicated connection and is a very stable system.	Costs: Overall costs are high. Availability: Site specific, only for a specific user. This means that all equipment and lines must be bought and installed for this system.

Appendix C

Environmental Testing

Water

If the water contains any impurities there are a number of ways to treat it. Each method contains a section on the contaminants removed by the method and their limitations. To make the selection process easier the contaminants and the treatment methods are in Table 30.

Activated Carbon Filters

Contaminants effectively removed:

Volatile organic chemicals, some pesticides, radon gas, chlorine, and mercury. They also treat odors, as well as off-color and off-taste problems.

Limitations

As contaminants build up on the filter, the filter will eventually lose its ability to remove contaminants and must be replaced. If the filter is not replaced, there is the risk that contaminants on the filter will re-enter the water. If this happens, the contaminants may re-enter the water in amounts that are even more concentrated than they were originally.

Distillation

Contaminants effectively removed:

Microbiological contaminants, trace elements of heavy metals, some inorganic chemicals (nitrates, for instance), some volatile organic chemicals, salts, and dissolved iron and manganese. Distillation is the only water-purification process that removes microorganisms, such as bacteria and viruses, with absolute certainty.

Limitations

Because distilled water is essentially free of minerals, and because it absorbs carbon dioxide from the air, it is acidic and can corrode materials with which it comes into contact. Some units allow certain organic contaminants to evaporate with the water. Also, the distillation process is slow and energy costs are relatively high.

Air Stripping

Contaminants effectively removed:

Some volatile organic chemicals, radon, and gases such as hydrogen sulfide. In addition, air stripping helps treat odor and taste problems.

Limitations

The energy cost of pumping the water and running the blower can be fairly high. Also, it is possible for bacterial growth to occur in the system's holding tank. Therefore, the water tank needs to be chlorinated.

Reverse Osmosis

Contaminations effectively removed:

Bacteria, radium, heavy metals, and inorganic compounds such as calcium, nitrate, and fluoride. It also successfully treats water with high salt content, certain detergents, volatile organic contaminants, pesticides, and taste-, color-, and odor-producing chemicals.

Limitations

The under-the-sink installations are costly and require space that is not ordinarily available in small kitchens. Reverse osmosis is slow and wasteful of water.

Ion Exchange (Water Softener)

Contaminations effectively removed:

Calcium, barium, radium, and taste-, odor-, and color-producing chemicals. Treats water hardness.

Limitations

The additional sodium in softened water could cause health problems.

Mechanical Filtration

Contaminations effectively removed:

Dirt, sediment, loose scale, and insoluble iron and manganese.

Limitations

Mechanical filtration does not do much to remove harmful, dissolved organic or inorganic chemicals.

Chlorination

Contaminations effectively removed:

Bacteria, other microbiological contamination, and taste, odor, and color producing chemicals.

Limitations

This method may raise the amount of chlorine to unsafe levels, if not properly used.

Ultraviolet Radiation

Contaminations effectively removed:

Bacteria and other microbiological contaminants.

Limitations

To effectively purify water, a minimum dose of UV radiation must pass through every molecule of water. So it may not work effectively in turbid, or cloudy water.

Table 30: Treatment Methods for Water

Contaminants	Activated carbon filters	Air stripping	Chlorinatio n	Distillation	Ion exchange/w ater	Mechanical filtration	Reverse osmosis	Ultraviolet radiation
Chlorine	X							
Coliform bacteria, other microorganisms			X	X			X	X
Color (black sediment, reddish-brown)	X		X		X		X	
Inorganics, minerals, and heavy metals (lead, mercury, arsenic, cadmium, barium)	X[1]			X	X[2]		X	
Iron/manganese – dissolved		X[3]	X[4]	X	X[5]			
Iron/manganese – insoluble						X		
Nitrates				X	X[6]		X	
Odor and off-taste	X	X	X		X		X	
Some pesticides	X						X	
Radium					X		X	
Radon gas	X	X						
Salt				X			X	
Sand, silt, clay (turbidity)						X		
Volatile organic chemicals	X	X		X[7]			X	
Water hardness					X			

1. Mercury only
2. Barium only.
3. When followed by mechanical filtration.
4. When followed by mechanical filtration or an activated carbon filter.
5. When present in low concentrations.
6. Anion exchange units will remove nitrates. But cation exchange units will not.
7. Works for volatile organic chemicals with high boiling points.

Soil

If any of the nutrients are deficient then refer to Table 31, which shows the probable cause of deficiency and the method of correction.

Table 31: Nutrient Deficiency Symptoms, Cause, and Method of Correction

Element	General Deficiency Symptoms	Probable Cause of Deficiency	Method of Correction
Nitrogen (N)	Yellow leaves, stunted growth, lower leaves turn brown, leaves abort	Low soil N, leaching from the soil, in adequate N applied	Apply N fertilizer
Phosphorus (P)	Small plants, reddish-purple leaves, slow growth, loss of plant vigor	Low soil P; cool, wet soils; inadequate P applied	Apply P fertilizer
Potassium (K)	small plants, brown margins on lower leaves, small weak stems, lodging of plants, poor yield and quality	Low soil K, leaching from the soil, inadequate K applied	Apply K fertilizer
Calcium (Ca)	Small plants, deformed buds, distorted leaves, failure to grow, poor fruit development	Low soil pH, leaching from the soil, inadequate lime applied	Apply lime or Ca fertilizer
Magnesium (Mg)	Lower leaves-in severe cases, entire plants-turn yellow with green interveinal areas	Low soil pH, leaching from the soil, no Mg applied in lime or fertilizer	Apply dolomitic lime or Mg fertilizer
Sulfur (S)	Yellow plants, slow growth, low vigor, no response to applied nitrogen, low crop yield and quality	Low soil S, leaching from the soil, low organic matter content, no S fertilizer applied	Apply S fertilizer
Boron (B)	Terminal bud dies, multiple lateral branches (rosette with short internodes, older leaves thick and leathery, petioles short, twisted, and ruptured), hollow heart (in vegetables), small deformed fruit (in grapes), cork spots in (apples)	Low B, esp. on sandy soils	Apply foliar spray or add B to soil
Chlorine (Cl)	Reduced growth; stubby roots; interveinal chlorosis; nonsucculent tissue (in leafy vegetables)	Low soil Cl, esp. in soils subject to leaching	Apply Cl-containing fertilizer
Copper (Cu)	Reduced growth, leaf-tip dies back, leaf tip breaks down, leaves ragged	low soil Cu, high organic mater	apply foliar spray or add Cu to soil
Iron (Fe)	Yellowing or chlorosis of the newly emerging leaves	High levels of phosphorus or manganese, high pH	Apply foliar spray or ad Fe to the soil
Manganese (Mn)	Interveinal chlorosis of leaves, stunted plants, yellow cast over deficient areas, reduced yield and quality	Low soil Mn, high soil pH due to over liming	Lower soil pH, apply foliar spray or add Mn to soil
Molybdenum (Mo)	Reduced growth; pale green color; necrotic areas adjacent to midrib, between veins and along leaf edges; twisted stems	Low soil pH, low Mo content in soil	Inoculate seed with Mo, apply foliar spray, or add Mo to soil

Zinc (Zn)	Chlorotic leaves, slow growth, reduced vigor, white streaks parallel to leaf blade	Low Zn in soil, high soil pH, high soil P	Lower soil pH, apply foliar spray, or add Zn to soil

pH Adjustment

To raise **pH** (increase alkalinity) add:

1) Lime
2) Ground Limestone
3) Oyster Shells

To lower **pH** (increase acidity) add:

1) Alum
2) Sulfur
3) Compost
4) Manure
5) Tannic Acid

Salinity Adjustment

Different plants have different salt tolerance levels. Rain usually corrects this problem, but if levels are still to high users need to leach (wash out) their soil with moderate amounts of fresh water.

Aluminum Adjustment

Aluminum increases greatly at soil pH below 5.5. So increasing the soil's pH will lower aluminum to acceptable levels.

Appendix D

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