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An Assessement of on-Site Renewable Energy Source Consideration with Original Building Construction Procurement Efforts

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AN ASSESSEMENT OF ON-SITE RENEWABLE ENERGY SOURCE CONSIDERATION WITH ORIGINAL BUILDING CONSTRUCTION PROCUREMENT EFFORTS

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ABSTRACT

As energy resources are needed in abundance to sustain the ever evolving global economy, the world's energy dependency for good reason, is beginning to shift. Various studies have shown that although fossil fuels are still the primary source of energy for the world, the utilization of more sustainable energy resources is on the rise. However due to current competitive bidding strategies and underlying practices that typically consider sustainable features such as renewable energy sources as costly additions rather than effective options to program requirements, building construction procurement strategies have been slow to embrace this change.

In this thesis, a methodology is derived for assessing the overall benefits of utilizing a renewable energy source as a program option from the original building construction procurement effort. This methodology was developed by utilizing project procurement methods and techniques, in addition to certain life cycle costing concepts. Data from the original procurement of The Basic School in Quantico, Virginia was used to apply this methodology. The results of this application and supplemental research show that the incorporation of a renewable energy source into the original building construction procurement effort as opposed to additions that are incorporated later in the project procurement effort produced cost and schedule benefits. Furthermore, a contractor could apply this methodology to similar projects that incorporate sustainable features into its original design and cost estimates, and utilize the findings of the application in the technical components of future projects.

CHAPTER ONE

INTRODUCTION

1.1 Background on Renewable Energy Sources

The majority of the energy consumed today is produced from fossil fuels such as coal, petroleum and natural gas. According to the 2011 Global Status Report fossil fuels were used to produce just under 85 percent of the total energy consumed globally (Renewable Energy Policy Network for the 21st Century, 2011). The remaining 16 percent of energy consumed came from renewable energy sources such as biomass, hydroelectricity, small hydro, wind, solar, geothermal and biofuels.

Among the most notable forms of renewable energy sources are hydraulic, wind and solar energy sources. Leading the way in terms of capacity as of 2011, hydro power had an estimated worldwide capacity of over 900MW resulting from a number of large-scale hydroelectric dams throughout the world (Renewable Energy Policy Network for the 21st Century, 2011). Following hydro power, wind power with a worldwide capacity of over 200GW (Renewable Energy Policy Network for the 21st Century, 2011).

Coming in third in terms of available capacity, solar power had an estimated world-wide capacity of just over 70GW at the end of 2011 (Renewable Energy Policy Network for the 21st Century, 2011). Though this capacity is significantly less than the current capacities of both hydro and wind power, there is an imminent significance in the rate at which solar power, specifically energy generated from the use of photovoltaic modules is increasing.

According to the Energy Information Agency, of the three economic sectors (Commercial, Industrial, Transportation & Residential), the commercial sector accounted for roughly 50 percent of the total energy used in 2011. Of the 18,020 trillion Btu of energy consumed by the commercial industry, less than 3 percent came from renewable energy sources (U.S. Energy Information Administration, 2012). This strongly suggests the need for an increase in renewable energy use among the commercial building sector.

Although there is a clearly defined need, there remains a significant lack of its embrace by the building construction industry. This stems from the idea among the building construction industry that sustainable design concepts are more likely to be costly additions to new building construction projects as opposed to effective options to the building program requirements. Building construction procurement teams are conceiving of sustainable designs as a totally separate feature (Langdon, Matthiessen, & Morris, 2007).

There have been several case studies that depict the benefits of incorporating sustainable design into commercial buildings. These in addition to an increasing amount of LEED certification requests amongst building owners surely creates a path for specialty contractors to excel in sustainable design and construction. Until however, more procurement teams are completely convinced that sustainable design incorporations such as on-site renewable energy are beneficial program options as opposed to costly additions, the building construction industry will likely continue to fall short of its capabilities to incorporate such sustainable design features.

1.2 Background on Procurement Techniques

In projects that have relatively simple overall scopes of work, the public sector recommends that the evaluation process for bids submitted by contractors be based on price alone. The Florida Department of Transportation (FDOT) has used this type of low bid approach for evaluating project bids in times past known as the low bid design/build. In this type of evaluation, it was procedure to award the project to the lowest responsive bidder (Palaneeswaran & Kumaraswamy, 2000). In most cases, this approach for low bidding was used on projects where there is a clearly defined scope of work. The bidders of this type of work would not be expected to seek innovations or alternatives.

In contrast to the low bid approach for evaluating contractor bids, the approach for evaluating best value design build projects is recommended for projects in which the scope is not so clear. This method involves a technical component or proposal in addition to a price proposal. These two proposals are often submitted at the same time by contractors and are evaluated separately by the client or owner of the project. In the evaluation process for a best value design build procurement, the price proposal would be evaluated and scored accordingly the same as the as it would be in the low bid approach for the most part. The technical proposal however, would be evaluated based on a predetermined set of evaluation criteria. In the public sector, an effort is made to judge each technical proposal based on the evaluation criteria, not the other bids being evaluated. Once scores or evaluations have been made for both the technical and pricing proposals, the scores are weighted based on a predetermined scale. These scores can be weighted differently and often vary from project to project. In any case, the technical score and the pricing score are combined to represent the total score for a particular bid.

In best value design build projects that have a goal of LEED certification or any other requirement which would require the incorporation of sustainable features, it may be beneficial for a bidding contractor to highlight some of the past work they have done in the area by including it in the technical component of the bid. The ultimate goal of this type of procurement method is to optimize design, schedule and quality. Thus the case, in addition to highlighting any experience in the area, it would also be beneficial for the contractor to detail how they may have successfully saved time or money by innovative ways of incorporating the sustainable feature into the original design of a past project.

1.3 Research Objectives

This thesis will provide a method of identifying and quantifying the benefits gained from including a sustainable feature such as a photovoltaic module system with the original procurement effort for a new building project. The information gained from identifying and quantifying these benefits could be used in the technical component of future best value design build bids for a contractor.

According to the Global Status Report, the global capacity for energy generated by photovoltaics increased by 42 percent from 2005 to 2010, and by over 80 percent from 2010 to 2011 (Renewable Energy Policy Network for the 21st Century, 2011). Even though this is the case, the construction industry is still reluctant to incorporate these types of sustainable features into new construction projects. A study by Davis Langdon in 2006 that studied the incorporation of sustainable features into new construction projects concluded that project teams often viewed sustainable design as separate features to a project, rather than viable options to the building program. There is a flawed view that these features have negative effects on the construction schedule and costs of a project that outweigh its benefits. Thus the case, more often than not, they are thought of as features only to be added if the owner requests them. This undermines the notion that if effectively incorporated into the design from the beginning, a contractor may be able to mitigate some of these negative factors. One of the objectives of this study is to illustrate this point by detailing previous research in the area of sustainable construction.

In order to incorporate sustainable features such as photovoltaic module systems into a project, studies suggest that it is first necessary to obtain the proper procurement system. In doing so, the procurement team should establish team goals from the start, include those goals in the building program, align the budget with the program and stay on track throughout the design and construction phase. Furthermore, the procurement system should be based on factors including but not limited to speed, price, quality and risks associated with the project.

The U.S General Services Administration defines the concept of life cycle analysis as one that is used in the comparison of alternatives that impact both pending and future costs. Building on this concept, this study will focus on identifying and quantifying the benefits that are gained by first establishing the proper procurement technique that would incorporate a sustainable feature into a project. Studies by Dhillon (1989) and Singletary (2006) suggest that both alternative procurement techniques, the one that does consider the sustainable feature and the one that does not, be considered by obtaining and evaluating involved cost estimates. Similar to the concepts of the proper procurement techniques, the individual goals and objectives be established prior to performing any type of analysis (Singletary, 2006).

By utilizing procurement techniques for both design build and design bid build projects as well as life cycle costing principles, this study will derive a methodology that will identify and quantify the cost and schedule benefits of incorporating a renewable energy source into an original procurement effort. This methodology will then be applied to real data from a new building project procurement effort, to assess the benefits it may have gained by incorporating photovoltaic module on site renewable energy source into its original design and cost estimate. Information gained from this type of application could be used by a contractor in technical components of future design build project bids.

1.3.1 List of Research Objectives

To summarize, the objectives of this research are as follows:

1) Identify previous areas of research
    a) Identify and summarize previous areas of research related to renewable energy sources in new building construction projects, specifically Photovoltaic Modules
    b) Identify and summarize previous areas of research related to project procurement techniques for and life cycle costing analyses concepts

2) Derive a methodology for assessing the benefits of incorporating renewable energy sources, such as Photovoltaic Modules into original building procurement efforts
   a) Utilize procurement techniques for commercial building construction projects and life cycle costing concepts to derive the research methodology

3) Used data from a completed building construction procurement effort to apply the research methodology and assess the effects of incorporating a Photovoltaic Module energy source into the original procurement effort
   a) Assess what effects the incorporation had on the estimated project costs and durations
   b) Assess weather or not the incorporation provided the contractor with any competitive advantages in the bidding process

1.4 Thesis Outline

This thesis is divided into 6 chapters. The first chapter gives a brief explanation of renewable energy sources and their presence in the construction industry. Chapter one also lists and explains the objectives of this research. The second chapter details the background information and literature review of Photovoltaic Module Systems and other renewable energy sources. Chapter three details the background information and literature review on procurement methods and sustainable construction, as well as life cycle costing concepts relevant to the research methodology of this thesis. Chapter four contains a detailed description of the research methodology of assessing the benefits of considering a renewable energy source with original procurement efforts as opposed to additions to original procurement efforts. The fifth chapter details the application of the research methodology explained in chapter three, on data from a new building construction procurement effort. Chapter six presents the conclusions and recommendations of this research and thesis.

CHAPTER TWO

BACKGROUND INFORMATION AND LITERATURE REVIEW OF RENEWABLE ENERGY SOURCES

2.1 Renewable Energy Sources

Renewable Energy is energy which comes from natural sources. These natural sources include sunlight, wind, tides, rain, waves and geothermal heat. The energy derived from these natural sources is replenished constantly. Before coal was developed in the middle of the 19th century, all energy came from natural sources. However, by the end of the 19th century there were growing concerns about the exhaustion of coal resources. This concern was the catalyst to experiments with using renewable energy sources. Throughout the late 19th century and early 20th century, the U.S. public sector has lead the push for renewable energy use for the most part. Legislation such as the Energy Policy Act of 2005 and the American Recovery and Reinvestment Act of 2009 have had a tremendous effect on various energy-related activities in the U.S. (Connecticut's Energy Efficiency Programs, 2009). These and other policies create commercial and industrial tax benefits for on-site renewable energy production. They also provide an avenue to achieve tax credits for facilities that manufacture advanced energy components and systems.

Although there has been a significant push from the federal government to incorporate renewable energy use in the US, there is substantial room for an increase in renewable energy dependency. According to the Energy Information Agency however, of the three major economic sectors (Commercial, Industrial, Transportation & Residential), the commercial sector accounted for roughly 50 percent of the total energy used in 2011. Of the 18,020 trillion Btu of energy consumed by the commercial industry, less than 3 percent came from renewable energy sources (U.S. Energy Information Administration, 2012). This strongly suggests the need for an increase in renewable energy use among the commercial building sector.

2.1.1 Geothermal Energy

Geothermal energy is created from thermal or heat energy that is generated by and stored in the earth. Heat energy from the earth comes from the original formation of the planet and the radioactive decay of minerals within the earth. The heat used to harvest Geothermal energy is often collected from areas deep within the core of the earth. As it is common practice for most power plants to use steam to generate energy, Geothermal power plants use steam produced from hot water that is often sourced miles beneath the surface of the earth. The steam is used to rotate a turbine that, in turn, activates a generator.

Dry steam and flash steam are the most common steam processes used in geothermal power plants. Dry steam is piped directly from wells underground into the power plant and directed into a turbine/generator unit. Flash steam is generated from reservoirs deep beneath the surface of the earth. Water from these reservoirs is piped up to the surface of the earth through its own pressure. As the water flows up to the surface of the earth, the decrease in pressure causes some of the water to boil and create steam. This steam is directed into the turbine/generator units. Any water or condensed steam left over is injected back into the reservoir. Flash steam is the most common process used in geothermal power plants.

2.1.2 Biomass & Biofuel

Plants are the main source of biomass energy creation. Through the process of photosynthesis, plants capture the suns energy. When these plants are burned, they then release the energy they have stored from the sun. There are two main approaches to using plants for energy production. The first is growing plants specifically for the purpose of burning them to create energy. This is known as first and third generation biomass. The second approach, known as second generation biomass, comes from the use of residue from plants and other biological matter. There are plants in various parts of the world that collect and separate garbage for biological matter to be burned for energy production.

Similarly, energy produced from Biofuels is so done through the burning of fuels derived from biological matter. There are a wide range of known biofuels. Bioethanol, bio alcohols and biodiesel are liquid forms of biofuels. Ethanol is commonly used as a gasoline additive to improve vehicle emissions and increase octane. Landfill gas, synthetic gas and biogas are gaseous forms of biofuels that are burned to produce energy.

2.1.3 Hydropower

Energy harnessed from flowing water is used to generate what is known as Hydropower. Similar to the way steam is used to rotate turbines to activate generators, flowing water is directed to turbines to create rotation and ultimately activate generators to produce electricity. The most common practice used to harness the energy of flowing water is a dam. Dams are used to create a height difference between the water on either side of the dam. This height difference is known as the head. As the water falls from the high side of the dam to the low side of the dam, it is directed over turbines to make them turn and ultimately activate generators to produce electricity. The greater the head of a dam, the more potential energy there is for the falling water to transfer to the turning turbines thus resulting in more energy created. Energy produced by large scale dams is usually referred to as Hydroelectricity. Currently, Hydroelectricity is the largest renewable energy source, with and estimated global capacity of 970GW according to the Global Status Report (Renewable Energy Policy Network for the 21st Century, 2011).

2.1.4 Wind Power

As is the case with steam and water, wind can also be used to generate electricity by turning turbines that ultimately activate generators. Wind mills have long been used as a source of energy. In modern applications, wind turbines are manufactured to operate in a wide variety of horizontal and vertical axis types. As it is calculated, the power generated from wind is a function of the cube of the speed of the wind. This suggests that as wind speeds increase, the power produced by a wind turbine increases dramatically up to the maximum output for the turbine. Large scale wind turbines are often referred to as wind farms. The largest source of commercial wind power comes from large scale grid-connected wind farms.

2.2 Photovoltaic Energy Systems

It should be noted that as the research methodology of this thesis was applied to the incorporation of a Photovoltaic Module Renewable energy system into an original procurement effort, background information on Photovoltaic Module systems will be discussed in detail in the sections below.

2.2.1 The Photovoltaic Effect and Solar Modules

The photovoltaic effect, the charter principle beneath solar panels and their operation, is the conversion of solar radiation to voltage or electric current. The photovoltaic effect is scientifically defined as the electric voltage that results from shining a light into a system of two electrodes that are attached to a separate solid or liquid system of some sort.

In photovoltaic energy systems, this photovoltaic effect occurs in the smaller photovoltaic cells that make up the system. The most significant component of these smaller photovoltaic solar cells is the semiconductor wafers in its core. These semiconductor wafers are made from material that can be chemically altered to vary its electrical conductivity. As it will be discussed in more detail below, the material that is most widely used to form these wafers required in photovoltaic solar cells is silicon. In any case however, the semiconductor wafer, once formed, are treated with chemicals and heat to slightly alter their composition and create either an excess of positive (p-type) or negative (n-type) electrical charges in the molecular structure of the wafer material (BP, 2007).

The positive to negative (pn) junction is then formed by layering the two oppositely charged materials on top of each other thus forming the nucleus of the solar cell. Once the positive and negative semiconductors have been created and positioned to create the junction between the two of them, metallic contacts are then placed on each side of the semiconductors, thus completing the solar cell. Individual solar cells are then typically encapsulated between either a glass layer or plastic polymer of some sort to serve as protection from weather effects.

Depending on the application and manufacturing process, individual photovoltaic solar cells can generally range from about .25 inches to roughly 4 inches across in size. One individual cell can produce, at most, up to 3 watts of power (Swanson, 2009). As this is not enough to power most practical applications, the individual cells are electrically connected into a packaged weather-tight group of cells. This group of cells is most commonly referred to as the photovoltaic module. The modules then can be further connected to form an array or generating plant. The generating plant can be made up few or many photovoltaic modules. The exact number of photovoltaic modules in an array depends on the amount of power need for the application of the system.

Photovoltaic Module systems are typically secured to either a tracker or fixed rack system. The tracker can increase the amount of energy produced by tilting back and forth to follow or track the sun through the sky. The fixed rack system holds the panels in a stationary position, which is often times tilted at an angle that will maximize the daily direct exposure of the modules to the sun. The modules and rack system are usually mounted to either a roof or similar structure, or to a ground supported system.

In a ground supported system, there are various ways for supporting the rack. The most common methods include pole mounts that are embedded in concrete or embedded directly into the ground, and foundation mounts such as concrete slabs or poured footings. Figure 2.2 above shows an example of the ground mounting system used in the application of the research methodology detailed later in chapter five.

2.2.2 History of Solar Cells

The photovoltaic effect was first observed by a French experimental physicist named Edmund Becquerel in 1839. When he was only 19, Becquerel discovered that he could produce a weak electrical current by exposing certain materials to direct sunlight. He named this phenomenon the Photovoltaic Effect.

Utilizing the basic photovoltaic effect described above to convert sunlight into electricity, the first solar cell was developed in one of the national Bell Laboratories in 1954 by Chapin et al. The first cell created had an efficiency of 6%. This was quickly increased to 10%. For many years, the main application was in space vehicle power supplies (Goetzberger, Luther, & Willeke, Solar Cells: Past, Present, Future, 2002). The high standard of silicon technology that was originally developed for transistors and later for integrated circuits greatly benefited early solar cell technology. In the early developments only Czochralski grown single crystals were used for solar cells. This material still plays an important role in crystals used in modern solar cell applications.

2.2.3 Types of Photovoltaic Semiconductors

The most essential component of a photovoltaic solar cell is its semiconductor used in the photovoltaic process described above, to absorb photons from the incoming light source. This semiconductor is the largest factor affecting both the efficiency and the cost of a solar cell. The semiconductor material used in most practical photovoltaic module applications is silicon. The efficiency at which silicon can absorb the photons coming into the cell and produce electricity is only, at best, 25% (Goetzberger, Luther, & Willeke, Solar Cells: Past, Present, Future, 2002). Although this is the case, among those known, silicon is the most ideal material for solar cells. The silicon present in most practical photovoltaic modules comes from either bulk crystalline silicon or what is commonly known as thin-film silicon.

2.2.3.1 Crystalline Silicon

Crystalline silicon created in bulk, is generally separated into two categories according to the crystallinity and size of the silicon formation. The two main categories of crystalline silicon are monocrystalline silicon, polycrystalline silicon. Most monocrystalline silicon is made through a process named after the Polish scientist that discovered it, Jan Czochralski (U.S. Energy Information Administration, 2012). Through this process the silicon is grown as one single cylindrical piece known as an ingot, and then sliced into wafers to be used in the photovoltaic cells. The crystal lattice of the silicon ingots produced by this technique is continuous and unbroken, with no boundaries between the crystal grains all the way through to the edges of the solid. These single crystal wafers, in comparison to other methods of silicon wafer production, are generally more expensive. One of the most significant reasons for this is in the difference in the circular shape of the silicon ingots that are grown, and the square shape of the end product silicon wafers that are used in the photovoltaic modules. The circular slices of the cylindrical ingots have to be cut into squares, thus resulting in a substantial amount of waste of refined silicon. Thus the case, most monocrystalline silicon photovoltaic panels have uncovered gaps at the four corners of the individual cells to help reduce the amount of silicon that would have to be cut and wasted from the circular slices.

As stated above, the crystal lattice of monocrystalline silicon wafers is continuous and unbroken with no boundaries between the crystal grains of the individual wafers. This lack of boundaries between the crystal grains is the single reason why monocrystalline silicon wafers are the most efficient source of silicon used in photovoltaic modules. For this reason, a crystalline photovoltaic module energy system was used to apply the research methodology of this thesis.

Polycrystalline silicon is made from square ingots, as opposed to the cylindrical shaped monocrystalline silicon ingots. Polycrystalline silicon is not grown from the formation of a single crystal, but rather from the formation of multiple small silicon crystals. It is the individual crystals of polycrystalline silicon ingots that are used to grow monocrystalline silicon ingots. As opposed to allowing the silicon ingots to grow from a single grain, in the production of the most common polycrystalline silicon source used in photovoltaic cells, the ingots are produced from molten silicon that is made up of multiple small silicon crystals. The grains that are formed from the boundaries between these multiple small crystals is what makes polycrystalline silicon, and the photovoltaic modules made from them, easily recognizable. Once the silicon is in a molten and malleable state, it is then carefully cooled and solidified into block shaped ingots. From these block shaped ingots, square wafers are sliced and used as the semiconductors in polycrystalline photovoltaic cells.

Another popular technique for producing polycrystalline silicon used in solar cells is the technique of producing ribbon silicon. Ribbon silicon is formed There are various methods to forming polycrystalline silicon, including a ribbon silicon technique. In this technique, wires with high temperature resistant properties are pulled through molten silicon. This results in the formation of a multi-crystalline ribbon of silicon crystals.

The visible grains, as can be seen in the figure above, of polycrystalline silicon panels are the reason why polycrystalline photovoltaic cells are generally less efficient than monocrystalline cells. This along with the waste produced from the process of making monocrystalline wafers, result in polycrystalline photovoltaic cells and modules being generally less expensive than monocrystalline cells modules.

2.2.3.2 Thin Film Silicon

Among the various forms of silicon available, thin film silicon photovoltaic cells most commonly utilize amorphous silicon to convert light energy to electricity. In crystalline silicon, as described above, the actual crystal lattice of this type of silicon requires more space than that of amorphous silicon which is not made up of well-ordered crystal lattices. In amorphous silicon rather, the atoms tend to form in a continuous random network. For this reason, amorphous silicon can be produced much thinner than crystalline silicon. Amorphous silicon can also be formed at temperatures as low as 75 degrees Celsius, much lower than that of crystalline silicon (Goetzberger, Hebling, & Schock, Photovoltaic Materials, History, Status and Outlook, 2003).

Due to how thin the amorphous silicon is when it is produced, a substrate material of some sort is needed to underlay the element in thin film silicon applications. Since amorphous silicon can be formed at relatively low temperatures, its underling substrate can be either low quality silicon of some sort or a foreign material such as glass, ceramics, graphite or even plastic. The layer of the active silicon that goes on this substrate is typically 5-50 nanometers in thickness (Goetzberger, Luther, & Willeke, Solar Cells: Past, Present, Future, 2002).

In comparison to crystalline silicon modules, thin-film modules are generally less expensive. This decrease in cost comes, however at the cost of reduced effenciey when compared to crystalline photovoltaic cells. Lower efficiencies generally cause higher installation costs due to the need for additional panels, and thus ends up negating its benefit of being less expensive in many applications.

2.2.4 Costs of Photovoltaic Module Renewable Energy

The largest contributor to costs associated with photovoltaic solar cells is the cost of the silicon used in the cell. Roughly 50 percent of the cost of a module is due to the cost of the processed silicon that makes up the wafers of the cells (Goetzberger, Luther, & Willeke, Solar Cells: Past, Present, Future, 2002). Although the costs are relatively high and the manufacturing process is rather complex, crystalline silicon has dominated the photovoltaic market for the most part. The greatest reason for this is that there is an abundant supply of silicon as a raw material along with the feasibility to accomplish higher efficiencies with crystalline silicon. In one of his many studies on photovoltaics, Goetzberger also points out that silicon, in its crystalline form, also has practically no degradation. This would make it ideal for lengthy applications.

According to the Energy Information Agency, the price of solar panels fell steadily for roughly 40 years until 2004. In 2004, the demand for purified silicon was greatly increased by high subsidies in Germany. Following the laws of simple economics, the price of purified silicon subsequently increased as the demand increased. This was the case until around the time of the recession of 2008. Around this time, there was also an onset of Chinese Manufacturing that caused prices of purified silicon to resume its previously paused decline.

Overall, due to steady advances in technology and increases in the manufacturing of purified silicon for solar cell use, the cost of photovoltaic modules has declined at a relatively steady rate since they were first manufactured. In a publication by Science Magazine, Richard M. Swanson concluded that in the year 2000, in order to generate 1 Watt of power, roughly 15 grams of highly refined and expensive silicon was used (Swanson, 2009). By 2009, the quantity of silicon used to produce 1 Watt of power in a comparable module was down to 5.6 grams (Swanson, 2009). In additions to declining amounts of purified silicon required to produce power using photovoltaic cells, manufacturing processes of purified silicon are expected to become much more efficient over the years. Both of these factors suggest that the unit cost of energy produced by photovoltaic modules will continue to decrease in the years to come.

The global capacity for energy produced from photovoltaic modules is increasing at a very high rate. This can be directly related to the decrease in costs associated with producing energy through the use of photovoltaic module systems. As technologies continue to advance and manufacturing process for silicon refining continue to progress, this capacity is expected to continue to increase.

2.2.5 Photovoltaic Renewable Energy Sources In Comparison to Other Energy Sources

From an environmental standpoint, photovoltaic modules are an easily accessible renewable energy source. What is likely more important however, is that due to declining unit cost per power output, photovoltaic modules are viable utility options for both building owners that would use energy, and utility companies that would sell energy. In comparison to both renewable energy sources and conventional energy sources, Figure 2.6 below shows the levelized cost of energy for photovoltaic modules for new generation constructed in the 2009 to 2012 time frame. The prices include a 30% U.S, federal investment tax credit for renewables.

According to Richard M. Swanson, when utility companies consider adding photovoltaic energy sources to their grids, in addition to considering the cost effectiveness of photovoltaics illustrated in the figure above, the lack of fuel price risk, lack of potential carbon emission costs, lack of water use and minimal sitting limitations are also taken into consideration as well. In addition to this, construction times are also significantly shorter for photovoltaic energy sources when compared to conventional energy sources. In Spain for example, more than 2 GW of photovoltaic power plants were constructed in 2008. To construct the same 2 GW of power through conventional generation, it would take roughly 10 to 15 years to complete (Swanson, 2009).

When compared to wind power, geothermal power, hydropower, solar hot water and heating, ethanol production and biofuel production, the capicity of energy generated through photovoltaics (both grid and non-grid onnected) is increasing at a rate significantly higher than that of the other forms of renewable energy. Furthermore, that rate is increasing at a higer rate each year.

Applying the same benefits mentioned above of cost effectiveness (including federal tax incentives), lack of fuel price risk, lack of potential carbon emission costs, lack of water use, and short construction times when compared to other energy sources, photovoltaic modules are clearly a viable source of renewable energy. Furthermore, this would suggest the need for them to be considered as viable options to building program options from original procurement efforts of new building construction projects, as opposed to possible additions to the ends of a project.

CHAPTER THREE

BACKGROUND AND RELEVANT RESEARCH ON CONSTRUCTION PROCUREMENT METHODS AND LIFE CYCLE COST ANALYST

3.1 Overview

In order to derive a methodology for assessing the benefits of considering a renewable energy source with original building construction procurement efforts as options as opposed to additions later in a project, it was first necessary to research the applicable building construction procurement techniques and life cycle costing concepts necessary to build this methodology. In this chapter the background information and research related building construction procurement techniques will be discussed along with the different building construction procurement methods. Sustainable construction techniques and their incorporation in building construction procurement will also be discussed. Background information and research on life cycle cost analysis concepts will also be as well. Lastly, information on how to use the life cycle concepts to incorporate the sustainable techniques discussed into building construction procurement efforts will be summarized.

3.2 Background on Building Construction Procurement

The term procurement refers to the acquisition of goods or services. Generally speaking, the procurement of goods and services is done with great consideration given to all aspects of the goods or services being procured. If good data is available, it is good practice to do an economic analysis of some sort before a purchase is made. In terms of building construction procurement, the same idea are viewed and applied to the acquisition of a new building project in whole, rather than particular goods and services alone. Building construction procurement determines the overall framework and structure of both the responsibilities and the authorities for the participants within the building process. In the procurement of a new building project, the selection of the most suitable procurement method is critical for both the clients and participants the same (Love, Skitmore, & Earl, 2010). As this is the case, the procurement process is not only necessary but critical to successfully delivering the new building product that satisfies the needs of the owner.

In new construction, specifically building construction, the procurement process refers to the actions performed by a client of any source, to obtain a building. The building would typically have a set of minimum requirements that must be including in the building project to be considered complete. There are many different techniques and applicable methods of building construction procurement. Though these procurement systems have become increasingly flexible for new building construction projects, most new building project procurement systems tend to originate from one of two typical procurement methods. The first of these methods is the Design-Bid-Build method, which is commonly referred to as the Traditional procurement method. The other method is the Design and Build or Design-Build procurement method.

Historically, the Federal Acquisition Regulations made it difficult for public sector projects to utilize anything other than the traditional design-bid-build method of procurement for new construction projects. Thus the case, the private sector lead the way for the newer design-build procurement systems up through the end of the 20th century. This however changed in February of 1996, when the U.S. Congress passed the Clinger-Cohen Act. This act allowed for the use of the design-build delivery method for new public sector building projects (Hale, Shrestha, Gibson, & Migliaccio, 2009). The Clinger- Cohen Act established guidelines to determine whether design build is appropriate for public projects. In comparison of design-build and design-bid-build project methods by Darren R. Hale, P.E. (2009) it is pointed out that the Naval Facilities Engineering Command (NAVFAC) has been a strong contributor to the trending increase of the design-build project delivery method.

3.2.1 Design-Bid-Build Procurement Method

The Design-Bid-Build procurement method is well established and recognized in the building construction industry and thus often referred to as the Traditional procurement method. In this particular procurement method, as the name may imply, the design of the building project is separate from the construction of the project. The traditional building procurement system is a separated and cooperative approach (Love, Skitmore, & Earl, 2010). As this method would have it, the building owner would designate and subsequently go into contract with an architect or engineer to design the building. The architect or engineer would work with the owner to identify the needs of the owner, as well as develop a written program that documents those needs. It is the responsibility of the architect or engineer to design the works of the building, prepare the specifications and produce the construction drawings for the building. It is typical for the engineer and owner to establish, based on the mutually agreed upon design, an expected range for which the project should fall in terms of costs and durations.

Once the design is complete, the procurement process enters the bidding or tender phase. Although there are various methods for awarding a project through this method, it is common for general contractors to be allowed to bid or submit a proposal to construct the building project. Depending on the owner the bidding process can either be open to any general contractor that is qualified to perform the work, or closed to only a select number of pre-qualified general contractors. In any case, the bidding general contractors would then obtain a copy of the bidding documents and, in most building construction efforts, solicit them to multiple subcontractors for bids on sub-items. A general contractor may elect to subcontract these and other portions of the project such as concrete, structural or even landscaping either because the general contractor does not have the capabilities to perform the work, or if the items or activities that can be performed at a lower price by a specialized subcontractor. After prices are obtained for all individual scopes of the building project, the bidding general contractors each compile a complete 'bid' price for submission by the pre-determined deadline. The bid price would include any fees, supervision costs and any other costs associated with the building project.

Once the bids are submitted to the owner, the architect or engineer responsible for the design of the building reviews the bids and checks them against the requirements of the owner. The architect or engineer may seek any clarifications required of the bidders at this time. If the bids fall in the pre-determined range for the project, the owner evaluates the submitted bids and ultimately awards the project to the lowest bidding general contractor. At this point the owner would then enter into a contract with the general contractor for the construction of the building. This contract would be completely separate from that between the owner and the engineer or architect. Therefore, these two separate contracts that are administered to two separate entities are utilized by the building owner to complete one construction project (Hale, Shrestha, Gibson, & Migliaccio, 2009).

3.2.2 Design-Build Procurement Method

The Design-Build procurement method, often referred to as the Turn-Key procurement method, is becoming increasingly more popular among both public and private building owners. In the Design-Build procurement method the owner first produces a list of requirements for a project. This list would include the overall view of the project. Although the list would generally steer away from too many specifics that would deter creativity among general contractors, it would indeed serve to establish the overall goals of the project.

Once the list of minimum requirements and project goals are established by the owner, the owner can either select a Design Build contractor to work with, or solicit bids for qualified Design-Build contractors. If the owner decides to solicit bids for the project, as is the case with most public owner building projects, the list of minimum requirements are then solicited to Design-Build contractors to present a proposal for the project. Similar to the bidding step of the traditional process discussed above, the owner may solicit for any qualified Design-Build contractor to submit a proposal or only a pre-qualified selection of Design-Build contractors. In any case, the contractors are to present ideas about how to accomplish the goals and minimum requirements of the project imposed by the owner. In addition to submitting a proposal of ideas to meeting the goals and building program requirements of the owner, the Design-Build contractors may also be required to provide a conceptual design supplemented with cost and schedule estimates for their proposed building program. It should be noted that regardless of how much or little is required for a proposal that is submitted for evaluation by the owner, a proposal submitted under this procurement method should assume the complete responsibility of both the design and construction of the proposed building project.

In design build projects, in addition to a cost proposal and possible conceptual design, a technical component is often required to be submitted with a qualifying project bid. In a technical proposal a contractor could be required to include information on its financial managerial and organizational capabilities (Palaneeswaran & Kumaraswamy, 2000). In addition, they may also be requested to provide information on any technical capabilities and relevant innovations from past projects. This is where it would benefit a contractor to be able to highlight any past innovations that may have saved the owner time and or money. Regardless of the criteria and requirements of the proposal, the technical component is then weighted in comparison to the pricing proposal. In some cases, as it will be seen in the case study application in later chapters of this thesis, it could be considered as much as fifty percent of the procurement evaluation.

After the proposals are prepared to include all necessary components and submitted, the owner evaluates each of them against the initial goals and requirements of the building. The owner, at their own discretion, will then select the Design-Build proposal that best fits the minimum requirements and goals of the project. At that time, the owner will then enter into contract with the winning Design-Build contractor. In contrast to the traditional Design-Bid-Build procurement method the Design-Build procurement, regardless of how the owner goes about selecting the a contractor, ends with only one contract being administered from the owner to one entity for both the design and construction of the project.

For the purposes of this thesis, the Design-Build procurement method would also include methods of construction management contracting as well. These would include but not be limited to fixed fee contracts, modified and negotiated construction management contracts. These types of contracts, as is the case described above for design-build contracts, end with only one contractor that manages all activities, regardless of how the fee structure is set up.

3.3 Studies on Sustainable Construction and Procurement Methods

There has long been a concern about the effects that construction industry has on the environment. Thus the case there are numerous studies and articles that illustrate both the long term and short term benefits of incorporating sustainability into the practices and procedures of the construction industry. In addition to studying the effects of sustainable construction practices, there has also been significant research and studies that have assessed the new building project procurement process and what effect it may have on the incorporation of sustainable concepts into the construction industry.

3.3.1 Procurement Systems and Sustainable Construction

One of many studies researched in the preparation of this thesis is one that describes the effects that the procurement process of a new building project can have on sustainability in construction was conducted by P. D. Rwelamila. Rwelamila was an Associate Professor at the University of Cape Town, South Africa when he conducted a study on project procurement systems in the attainment of sustainable construction. By focusing on the construction sustainability in the Southern African Development Community public building sector, Rwelamila was able to show that an improper procurement system can result in insignificant focus on construction sustainability.

The principle argument of Rwelamila's study rested on the fundamental aspect of the building process that requires early and particular attention if construction sustainability is to be achieved on a particular project. In the study, the term Construction Procurement System was defined to be the amalgam of activities undertaken by a client to obtain a building (Rwelamila, Talukhaba, & Ngowi, 2000). Construction Sustainability is then defined to include managing the serviceability of a building not only through its lifetime, but also through its inevitable deconstruction and recycling of materials and resources in an effort to reduce the waste that is typically associated with the demolition of a building (Rwelamila, Talukhaba, & Ngowi, 2000). Rwelamila then offers two equations based on similar arguments to integrate the terms Construction Procurement System and Construction Sustainability:

1) CPS →MSF on (SS, ES, BS and TS)
2) MSF on (SS, ES, BS, & TS) + EA + EMS = + CS

The first equation states that the selection of an appropriate Construction Procurement System (CPS) leads to a Multistage Framework (MSF) based on Social Sustainability (SS), Economic Sustainability (ES), Biophysical Sustainability (BS), and Technical Sustainability (TS). The second equation then states that a Multistage Frame work based on the factors from the first equation, plus an Environmental Assessment (ES) and an Environmental Management System (EMS) will result in a project that successfully achieves Construction Sustainability (+CS).

The first equation is based on the argument that once a client is satisfied about the real need and feasibility of the building project within over-all budgetary constraints the next step would be for the owner to begin assessing the risk toward devising an appropriate CPS. The second equation goes further to show that in order to achieve construction sustainability (+CS) it is necessary to consider an environmental assessment (EA) and an environmental management system (EMS) in addition to a multistage frame work on social, economic and biophysical sustainability.

Rwelamila describes that achieving construction sustainability (+CS) depends on how the project managers and subordinates applies the necessary aspects of construction sustainability, such as the environmental assessment and the environmental management system to implement the principles of sustainable construction (Rwelamila, Talukhaba, & Ngowi, 2000). In addition to this, based on the equations above, the proper construction procurement system (CPS) must be selected first in order to make construction sustainability possible (+CS). From Rwelamila 's formulas the argument can then be made that the proper construction procurement system for construction sustainability would include not only an environmental assessment and environmental management system, but also any other aspects that would contribute to construction sustainability as well. Thus the case, they would need to be considered with the original procurement efforts in order to contribute to construction sustainability.

To illustrate the theory defined by the two equations described above, Rwelamila conducted an empirical survey of construction firm executives, site managers, trade managers and skilled operatives. Those surveyed were questioned on how close the traditional construction procurement systems they used on the projects they were involved with operated to the way they were intended to. The results of the study showed that since the appropriate management systems were not in place to incorporate the features needed for the projects achieve construction sustainability, said construction sustainability was a constant challenge to achieve.

Rwelamila concluded that there was a significant gap between the appropriate construction procurement system necessary for construction sustainability, and the default system that was being used in this particular area of South Africa. Although the objective of Rwelamila's study was to determine the issues slowing the advancement of sustainable construction in South Africa, he was able to shine light on the notion that in order to achieve construction sustainability, it is necessary to include all necessary components with the original construction procurement system.

A similar study conducted by P.E.D. Love (1997) on selecting a suitable procurement method for a building project described procurement techniques that were comparable to those discussed by Rwelamila. Love (1997) utilized a postal questionnaire survey of 41 clients and 35 consultants to obtain information on the attitudes towards a variety of procurement methods and the criteria used for its selection. The findings of the study concluded that a simple set of the criteria generally is adequate and sufficient for procurement path selection. Furthermore, the study pointed out that contrary to expectations, similar clients in most cases have differing procurement needs (Love, Skitmore, & Earl, 2010).

Love (1997) offers criteria that can be used to examine a particular client's requirements and preferences for the performance of the designated procurement method. This criteria listed below, was summarized by Love (1997) and first employed by NEDO (1985), Skitmore and Marsden (1988) and Singh (1990) (Love, Skitmore, & Earl, 2010).

1) Speed (during both design and construction)

2) Certainty (price and the stipulated time and knowledge of how much the client has to pay at each period during the construction phase)
3) Flexibility in accommodation design changes
4) Quality (Contractors' reputation, aesthetics and confidence in design)
5) Complexity (Client may specify particular subcontractor, or constructability analysis)
6) Risk allocation/avoidance
7) Responsibility (Completion of program, price, product quality, design and construction)
8) Price competition (covering such issues as value for money, maintenance costs and competitive bidding)
9) Disputes and arbitration.

3.3.2 Factors Slowing the Incorporation of Sustainable Construction

In addition to studies that pointed out the significance of the proper procurement criteria and systems to achieve construction sustainability, research was also done to assess the degree to which sustainable design and construction concepts are being incorporated into new building projects. In addition, a focus was placed on identifying any sources that might possibly serve to deter the incorporations of sustainability into construction practices and procedures.

A study done by Chris Langdon (2006) sought out to re-examine the cost of incorporating sustainable design features into projects provided insight on the status of LEED projects in the US. This study was a follow up to a study conducted a few years prior, also by Chris Langdon (2004), that examined the cost of green from three perspectives; the cost of incorporating individual sustainable elements; the cost of green buildings compared to a population of buildings with a similar program; and the cost of green building compared to their original budget (Langdon, Matthiessen, & Morris, 2007). Both studies used the US Green Building Code's LEED rating system as a parameter to determine the level of sustainable design.

In the most recent study, Langdon compared the costs of buildings where LEED certification was a primary goal of the building program, to similar buildings where LEED was not considered during the original design. The building types were academic buildings, laboratories, libraries, community centers and ambulatory care facilities. Langdon concluded that many of the projects were achieving LEED within their budgets, and in the same cost range as non-LEED projects. As the time of the study, it was also observed that although construction costs had risen significantly, projects were sill indeed achieving LEED.

The most significant finding of Langdon's study was that there was still the flawed idea within the building construction industry, that green concepts and principles are added features to construction projects. Langdon concluded that project teams often viewed sustainable design as separate features to a project, rather than viable options to the building program. Langdon went on to point out that this flawed view leads to the untrue notion that green design then, since it is a separate addition to the project, must add cost. Until design and procurement teams understand that green design does not always have to be additive, it will be difficult to overcome the flawed notion that green principles will always add cost.

Lagdon builds on the findings of the study by also concluding that when establishing a budget for a LEED building, it is very important to consider sustainability concepts and features as an option to meet the building program requirements, rather than additional requirements. The feasibility of sustainable concepts and features must be considered as early as possible in a project. This feasibility has to also be considered at every step of the design and construction. The most important view that is necessary is that sustainability is not a below-the-line item (Langdon, Matthiessen, & Morris, 2007). Langdon suggests the following procedure to insuring the consideration of sustainable concepts:

a) Establish team goals, expectations and expertise
b) Including specific goals in the program
c) Aligning budget with program
d) Staying on track through design and construction

By assessing the studies conducted by Langdon and his colleagues, the argument can be made from their findings that there is a lack of evidence in the building construction industry that shows that sustainable construction and green building principles do not have to necessarily add to the overall costs of a construction project. There is a significant need to show that for projects that have a goal to incorporate sustainable features, it would be more advantageous to consider these features from the start of a project design and procurement effort as opposed to a costly addition at the request of the owner later in the procurement effort.

3.4 Life Cycle Cost Costing

As concepts of Life Cycle Costing were used in the research methodology derived to support this thesis, it is necessary to provide the following background information and research utilized to incorporate these concepts.

3.4.1 Background information on Life Cycle Costing

The term life cycle costing first received a great amount of attention when the Logistics Management Institute, Washington, D.C. conducted a study for the Assistant Secretary of Defense for Installations and Logistics. The report was entitled "Life Cycle Costing in Equipment Procurement" (Dhillon, 1989). According to B.S. Dhillon, this report resulted in a series of three guidelines for life cycle costing procurement being published by the United States Department of Defense. These guidelines were entitled Life Cycle Costing Procurement Guide, Life Cycle Costing in Equipment Procurement-Casebook, and Life Cycle Costing Guide for System Acquisitions (Dhillon, 1989).

In its simplest form, the term Life Cycle Cost Analysis or Life Cycle Costing is best defined by the U.S. General Services Administration as an analysis used in the selection of alternatives that impact both pending and future costs. Depending on the industry and the individual application, Life Cycle Costing can be based on different concepts and have different procedures. There is no set procedure for performing this type of analysis. There is however a seemingly underlying principle that is present in all application of Life Cycle Analysis applications. That principle is that the analysis should be all inclusive and it should consider all viable options.

From an owner standpoint, many states of the United States have made life cycle cost analysis a requirement of both procurement and construction of its new buildings. According to B.S.Dhillon, since 1974 states like New Mexico, Alaska, Maryland, North Carolina and Texas have all incorporated this requirement into the procurement and construction of their new building programs.

3.4.2 Relevant Research on Life Cycle Costing

In a thesis assessment of the financial feasibility of implementing wireless technologies for construction management, Matthew Singletary (2006) effectively described both the need and purpose if Life Cycle Costing. Life Cycle Costing according to Singletary (2006), attempts to solve the problem of considering only the initial or immediate cost of a decision. Life Cycle Costing is a tool that can be used to quantify the costs of several investment alternatives to insure that the most favorable investment alternative is chosen (Singletary, 2006). Singletary goes on to point out the evolution of Life Cycle Costing into a concept applied for cost accounting for business management. Traditional cost accounting systems that accounted for only partial income costs became outdated and subsequently served as a catalyst for the evolution of the concept (Singletary, 2006). This would suggest a signifigance in the importance of reasonable overhead costs when considering and comparing alternatives.

According to Dhillon (1989) Life Cycle Costing analyses are important in establishing, reducing, and controlling costs of a project (Dhillon, 1989). Dhillon compiled a list of applications of the Life Cycle Costing technique. That list included the following:

1) Choosing the most beneficial procurement strategy
2) Determining cost drivers
3) Making strategic decisions and decision trade-offs
4) Selecting among options
5) Assessing a new technology application
6) Formulating contractor incentives
7) Forecasting future budgets

In the same thesis by Singletary (2006), Life cycle costing is described as an economic tool that can be utilized to make smart investment decisions among a group of viable alternatives. As this is the case, Life cycle costing is based on economic and financial principles of investment. These principles are mutually exclusive alternative investments, time value of money, economic methods of comparing alternatives, income tax and depreciation and lastly, sensitivity analysis.

Singletary (2006) summarizes a variety of methods that can be used to conduct a Life Cycle Cost Analysis. As it was previously explained in this thesis, there is no set procedure for performing a Life Cycle Cost Analysis. In most cases the application to which the analysis will be applied would likely be the greatest determinant of the best procedure to follow. The research methodology of this thesis that will be described in a later chapter, utilizes some of the steps and subsequent arguments present in a procedure originally presented by Dhillon (1989) and later summarized by Singletary (2006) for conducting a Life Cycle Cost Analysis. The steps of the procedure are as follows:

1) Determine the useful operational life of the item or product
2) Obtain estimate for involved costs including costs of operation and maintenance
3) Determine the item or products terminal value
4) Take away the terminal value from the ownership cost of the item or product
5) Discount the final amount of step (4) to the present value
6) Add the procurement cost to the amount estimated in step (5) to obtain life cycle cost of the item or product
7) Repeat the above steps for every item or product under consideration for the procurement
8) Make comparisons of life cycle costs of items or products being considered for purchase
9) Purchase the item or product with the least life cycle cost.

Singletary (2006) also notes that the individual goals, objectives, constraints and alternatives for the study should all be clearly established before performing the Life Cycle Costing assessment through the steps defined above. As it will be discussed in later chapters, aspects of this argument were used in the research methodology of this thesis.

CHAPTER FOUR

RESEARCH METHODOLOGY

4.1 Methodology Overview

The first step in the development of this thesis was to investigate the incorporations of on-site renewable energy generation and use into the original procurement efforts of new construction projects. This investigation was done through an extensive literature review. Through the course of this investigation, the lack and subsequent need for incorporations of renewable energy sources into the original procurement efforts of new construction projects was identified. In addition to identifying this need, Life Cycle Costing concepts and procurement strategies of new building construction were also investigated in an effort to identify factors hindering the incorporations of on-site renewable energy considerations into new construction procurement efforts.

Following an extensive literature review, a methodology was derived to assess the benefits of incorporating renewable energy sources into building construction projects as options form the beginning, as opposed to additions either later or at the end of a project. The research methodology derived will identify project cost, schedule and competitive advantage benefits resulting from the consideration of a renewable energy source from the original estimate of a particular building construction procurement effort. Through the use of Life Cycle Cost Analysis concepts similar to those used by Singletary (2006) and Rwelamila (2000), and the strategies of building construction project procurements, the research methodology was applied to data from an actual procurement effort to assess the benefits it gained from considering a Photovoltaic Module system into its building program project from the beginning. In this and other applications of this methodology, the results could be used in for present and future proposals to display a contractors ability to incorporate innovative solutions to building programs.

4.2 Assessing the Benefits of Incorporating a Renewable Energy Source With Original Procurement Design & Estimates

4.2.1 Identify the Need

As it was previously discussed in this thesis, Life Cycle Costing concepts suggest that the first step in analyzing the feasibility or the benefits of a particular investment is to identify the need of said investment. As it pertains to the consideration of a renewable energy source in an initial procurement effort, the need for this consideration must first be established before an effective assessment can be done to identify the benefits of the consideration.

The general need for the consideration of sustainable construction and design principles, such as renewable energy sources, were described in detail above. Research suggests that there is an underlying consensus among the building construction industry that sustainable construction and design features will add costs that exceed its benefits. Thus the case, they are often conceded to be included as additions to building construction projects at the request and additional payment of the owner. The argument can be made, that the consideration of a renewable energy source is a need of every new procurement effort. However on a project specific level, the specific requests of the project owner as well as the details of a particular project must be analyzed to determine weather or not serious consideration of renewable energy sources would be beneficial in a particular project. Factors that could affect this consideration include project duration requirements, budget goals, LEED Certification goals, incentives available to public and private owners, as well as the procurement evaluation criteria. As the need for the renewable energy source within a particular project is identified, the subsequent need to identify benefits of considering this renewable energy source from the original procurement effort as opposed to an addition to the project becomes present as well.

4.2.2 Determine the Objectives

The second step in assessing the benefits of considering a renewable energy source as an option from the original procurement effort as opposed to an addition at the end of a project is to determine what the intended objectives are of considering the renewable energy source as an option from the original procurement effort. In this step, the intended benefits should be identified and described in detail. These benefits would include cost, schedule and competitive advantage benefits. After detailing these intended benefits, each proceeding step of the assessment should then be conducted with respect to the intended objectives. In the event that any of the objectives are shown to be unattainable, it should be detailed throughout the assessment.

4.2.3 Identify the Alternatives

As it was previously discussed, in assessing the benefits of one solution over another, Life Cycle Analysis concepts suggest that the alternatives of a particular solution must be analyzed in order to gain a fair assessment of one alternative over another. In the assessment of the benefits of renewable energy source consideration in new building construction procurement efforts, the two alternatives to be analyzed in this research methodology are:

1) Alternative #1 - The consideration of a Renewable Energy Source with the original procurement effort of a new building construction project

2) Alternative #2 - The consideration of a Renewable Energy Source as an addition to the original procurement effort of a new building construction project

It goes without saying that, each new building construction project is different than the next. Thus the case, considering a renewable energy source will result in different outcomes for different projects. In assessing the consideration of a Renewable Energy Source with the original procurement effort of a new building construction project, it is necessary to analyze the procurement techniques used to consider the renewable energy source as well as the results of this consideration. By considering a renewable energy source from the beginning, a project may be able to take advantage of incorporating the design of the renewable energy source into the original design of the building. Similarly, the construction schedule of the renewable energy source could be potentially phased into the original project schedule without adding any additional duration to the project. Ultimately the differences between the means and methods that result from the consideration of a renewable energy source with original procurement efforts and those that result from not considering the renewable energy source from the beginning will be compared for the benefits one may provide over another later in the research methodology.

To analyze the effects of the first alterative, the first step would be to define the scope of work associated with the renewable energy source. This would entail detailing the means and methods intended to be used to incorporate and construct the renewable energy source. Any special design considerations for the incorporation of the renewable energy source into the original procurement effort should be explained in the definition of the scope of work. Considering the renewable energy source with the original project planning and procurement steps would likely result in the opportunity to use other aspects of the project design to supplement the design or incorporation of the renewable energy source. In this case, these aspects should be clearly defined in establishing the scope of work for both the renewable energy source and the project as a whole. For the renewable energy source, the scope of work should be clearly defined to detail what exactly is to be included in terms of materials and labor, with the construction of the renewable energy source.

To analyze the effects of the second alternative of not including the renewable energy source with the original construction effort, similar to identifying what aspects of the projects design and or sequence could have been utilized by incorporating the source from the beginning, it is necessary to identify what aspects of the design that are not available if the renewable energy source is not considered from the beginning. In doing so it is necessary to detail what, if any, work this may add to the entire project. This may include work that falls outside the means of the specialty contractors responsible for the renewable energy source such as additional site work or structural support systems because those in the original project plan were not designed to accommodate for the renewable energy source. If indeed this is the case, following the process mentioned above for defining scopes of work, these additional scopes of work must be clearly defined to detail what they consist of and what exactly is to be included in terms of materials and labor. In any case, the means and method of the renewable energy source installation that result from it not being considered with the original procurement effort should be clearly defined and supported.

In both alternatives, once the scope of work is defined for the renewable energy source, the pricing data acquired for the scope of work is analyzed. The pricing data will likely consist of quotes from contractors that specialize in constructing the specified renewable energy source. These quotes should be analyzed individually first, to assure that they include the desired scope of work and nothing extra. Once they are compared individually, they can be compared side by side to determine the most accurate price for the defined scope of work.

In the case of the second alternative, when not considering the renewable energy source as a part of the original procurement effort results in additional work outside the scope of the renewable energy source such as additional site work, additional structural support systems, etc. this work should be priced separate from the renewable energy source. This work should be priced using pricing data that would accurately represent the cost of the specified scope of work. The price of the renewable energy source and any additional work that may be required should be separate as they are separate scopes of work.

4.2.4 Identify and Quantify Benefits of Alternatives

Once the scopes of work are defined and priced for the means and methods that result from both alternatives one and two, they can then be compared to identify and quantify the benefits of one over the other. As stated above, for the purposes of this thesis, the most beneficial alternative would have possible advantages over the other in terms of cost, schedule and competitive advantages.

In terms of cost benefits of one alternative over the other, the most obvious benefit would be quantified by the net difference in cost of one alternative when compared to the other. The means and methods that result from considering the renewable energy source from the beginning and those that result from not considering the renewable energy source from the beginning may have some overlap. There may be some activities and/or materials that would be included regardless of whether or not the renewable energy source is considered from the beginning or not. If this were the case, assuming the costs of these items are the same for both alternatives, they would then essentially cancel each other out when the costs of the alternatives are compared. Once these cost overlaps of the alternatives are accounted for and canceled out, the net difference in cost between the alternatives that results would contribute to the total cost benefit of one alternative over the other.

4.2.4.1 Cost Trending

In addition to the net cost differences between the two alternatives, the first alternative of considering a renewable energy source as a part of the original procurement effort could result in an additional cost benefit. This benefit would be the result of a cost trending technique that becomes available in effective procurement and planning efforts. In a well-planned procurement effort, by utilizing this cost trending technique, the general contractor can analyze the price associated with constructing a renewable energy source and procure the scope of work for the best (or lowest) possible cost.

The first step in trending costs would be to identify a clearly defined scope of work for the activity to be analyzed. As it pertains to a renewable energy source, a clearly defined scope would include all materials and labor to be included with the price of installing the renewable energy source. In most cases, the scope is defined after the conceptual design for the renewable energy source is complete. In some cases, the final design may even be complete. For a general contractor looking to trend the cost of a specialized scope of work such as a renewable energy source, once the scope is defined the next step is to identify the specialty contractors in the area that can perform the specified scope of work. After a list of specialty contractors is identified, they are then solicited by the general contractor to provide a price for the specified scope of work. Once prices from the first solicitation of the pre-defined scope of work are obtained for the renewable energy source, the general contractor would then compare the price quotes to determine the best price for the scope of work. The best price would then serve as the cost to be carried for the construction of the renewable energy source in the original estimate of the project.

Once the project contract is awarded, the winning bidder or general contractor would then decide whether to acquire the scope of work from the specialty contractor that provided the best price from the first round of solicitation, or to conduct an additional round of price solicitation for the renewable energy source. Since there is typically a significant delay between the time project estimates are compiled and when the project is actually awarded to the best bidder, it is typical for the general contractor to re-solicit pricing to get an updated price for the scope of work. The general contractor would then decide if the scope of work should be acquired based on the pricing from the updated solicitation, or if it should delay the purchase after an additional round of solicitation. The general contractor may elect to delay for an additional round of pricing for the following reasons:

a) The price from the second solicitation is <u>lower</u> than that of the first

b) Details that would affect the price may still be pending (Specific to design-build contracts)

c) Additional specialty contractors may have become available since initial solicitation

In contrast to delaying the purchase of a scope of work until after an additional pricing solicitation, it may not always be beneficial to re-solicit the scope of work. Factors that would hinder a an additional solicitation of the scope of work include:

a) The price from the second solicitation is <u>higher</u> than that of the first

b) Other project decisions cannot be made until this scope of work is finalized

c) Time constraints require that the scope of work be finalized to assure there is enough time for specialty contractor to prepare for construction

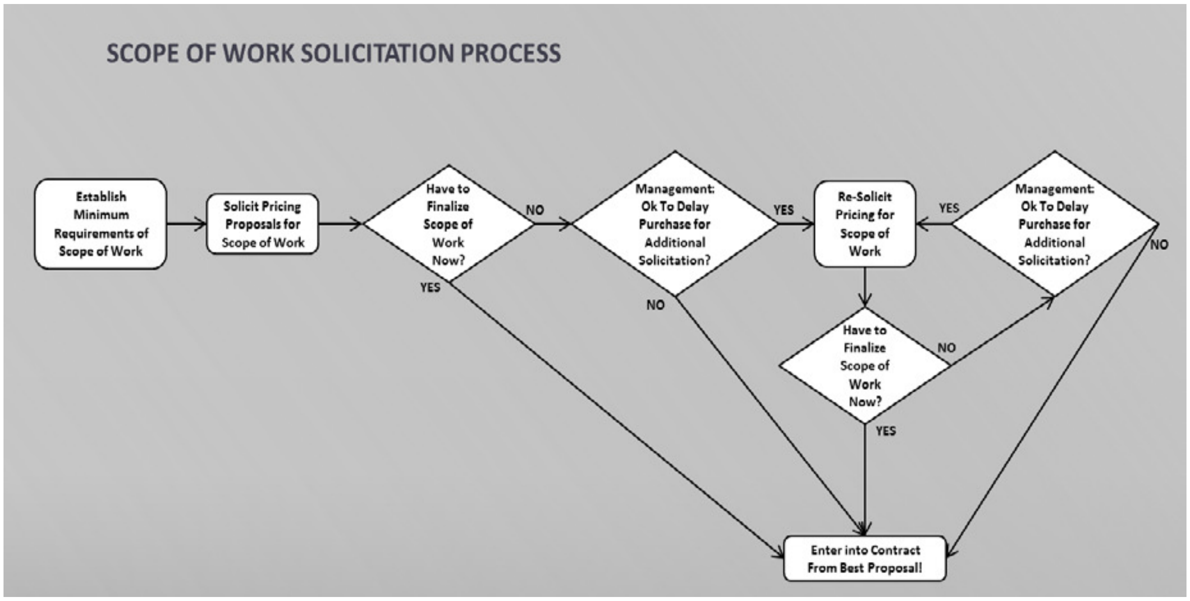


Figure 4.1: Scope of Work Solicitation Process

Once management performs the desired amount of pricing solicitations, the general contractor subsequently decides on the best price for the scope of work and purchases it at this price. This technique of price trending can present a significant advantage for considering a renewable energy source with the original procurement effort. Figure 4.1 above illustrates the process of price trending as described above.

4.2.4.2 Schedule Benefits

When assessing the benefits in terms of schedule that could be attained by incorporating renewable energy source with the original designs and costs estimates with new building projects, it is necessary to establish to what extent the renewable energy source would be able to be incorporated after the building were to be designed without it. As previously stated, this research methodology would assess two alternatives. The first would incorporate the renewable energy source and the second would not. In the second alternative that does not include the renewable energy source with the original design, a determination needs to be made based on the project sequence or schedule, if the feature could be incorporated into the schedule or not. If it could be, then the schedule impacts may not be that great.

If however, by adding the renewable energy source after the original schedule and phasing are complete it would cause discrepancies with the schedule or conflict with resource (ie crane, crews, etc) allocation, then it may be in the best interests of the project to add the activities associated with the renewable energy source to the end of the project. In this case, the schedule would be significantly affected by not considering the renewable energy source with the original design and schedule estimates.

In either case, following the principles previously discussed for life cycle costing, the estimates for both alternatives should be thoroughly assessed. The alternative that results in the longest overall durations should be clearly identified. The proposed savings could then be used in the proposals for the current project or for projects in the future as well.

4.2.4.3 Competitive Advantage Benefits

In addition to cost and schedule benefits, there is also the possibility of gaining competitive advantages by incorporating an on-site renewable energy source into a particular project. These benefits can vary significantly depending on the type of contract that will govern a particular project.

Due to the technical component typically included in its evaluation process, Design-Build Contract procurement efforts would serve to gain the most from assessing the benefits of incorporating a renewable energy source. According to the Arizona Department of Transportation (Arizona Department of Transportation Intermodal Transportation Division, 2007), and as is the case with most government agencies, the purpose of a technical proposal is to address the technical components of the design and construction of the project. The selection process will consider the bidder's proposed response to key issues in the areas of design and quality management, design features, schedule, public relations, and aesthetics. In addition innovation and construction resources may also be evaluated (Arizona Department of Transportation Intermodal Transportation Division, 2007).

Another benefit that could be available for the inclusion of certain sustainable features is a tax credit for projects with private owners. Legislation such as the American Reinvestment and Recovery Act of 2009 makes it possible to earn tax credits for the inclusion of the onsite renewable energy source. Up to 30 percent of the total cost of the system is tax deductible (Connecticut's Energy Efficiency Programs, 2009). This in addition to the savings that would be generated by not having to purchase power from the grid would significantly reduce the payback period for the system. These details would offer a significant advantage in the technical proposal for both the present and future projects with private owners that pay Federal Taxes. For projects that have public owners, though the owner may not be eligible, the designer may be eligible for tax credits based on the amount of energy that is saved by the renewable energy source.

In any case, publicly or privately owned projects, a Design-Build bidder could earn a competitive advantage through a well-presented technical proposal detailing the benefits gained from the incorporation of a renewable energy source. The cost and schedule benefits identified for this project can also be used in the technical proposal for future design build projects as well.

Assessing the benefits of incorporating a renewable energy source such as solar from the procurement stage would include analyzing the system for the contribution it may make toward a LEED Certification effort of any kind. LEED stands for the 'Leadership in Energy and Environmental Design'. It is a nationally accredited rating system created by the U.S. Green Building Council (USGBC) in 2000. The LEED rating system was created to serve as an independent, third-party verification that a building, home or community was designed and built using strategies that are aimed at achieving high performance in key areas of human and environmental health including sustainable site development, water savings, energy efficiency, materials selection and indoor environmental quality. Offices, retail and service establishments, institutional buildings (e.g., libraries, museums, schools and religious institutions), hotels and residential buildings of four or more habitable stories are examples of the building types that are eligible for certification (Community Center Energy, 2011). By meeting certain guidelines and minimum requirements a building may acquire points in the areas of sustainable site development, water savings, energy efficiency, materials selection and indoor environmental quality.

These points ultimately add up to a LEED score or rating or certification. There are a total of 100 possible points in which 21 come from the Sustainable Sites criteria, 11 from Water Efficiency criteria, 37 from Energy & Atmosphere criteria, 14 from Materials & Resources criteria, & 17 from Indoor Environmental Quality criteria. Bonus points are also achievable and outlined by the Innovation and Design criteria & Regional Priority criteria in the amounts of 6 points and 4 points, respectively. A building, home or community may register itself as LEED Certified by achieving at least 40 points, LEED Silver by achieving at least 50 points, LEED Gold by achieving at least 60 points and LEED Platinum by achieving 80 or more points (U.S. Green Building Council, Inc., 2009).

The points attainable for solar energy generation and use through a Photovoltaic

Module system would be defined in the Credit #2 criteria of the Energy and Atmosphere section as On-Site Renewable Energy. This credit has a total of 7 possible points. According to the US Green Building Council, the intent of this credit is to encourage and recognize the increasing levels of on-site renewable energy self-supply. It also serves to reduce the environmental and economic impacts associated with the use of energy generated by fossil fuels (U.S. Green Building Council, Inc., 2009). The requirement of the credit is that the energy of a renewable system offset a percentage of the building's annual energy costs. The minimum renewable energy percentage for each point threshold is as follows:

Table 4.1: LEED On-Site Renewable Energy Percentages and Point Thresholds

Percentage Renewable Energy	Points
1%	1
3%	2
5%	3
7%	4
9%	5
11%	6
13%	7

(U.S. Green Building Council, Inc., 2009)

Through the use of a computer simulation model, the engineer of record can verify the energy outputs from the proposed Photovoltaic Module system. These calculated energy outputs would then be characterized as a percentage of building program's total calculated annual energy cost in order to determine what LEED points are achievable for a particular Certification effort.

If LEED certification is a requirement of a particular project, the consideration of an on-site renewable energy source may be necessary to accumulate the number of credits required for the certification. If not however, it can still serve as a competitive bidding advantage in a carefully and effectively prepared technical proposal. The information gained from this application may also be able to be used in the technical proposal for future projects as well.

In any case, any competitive advantages gained can be combined with cost and schedule advantages gained to illustrate the total benefit of either including a renewable energy source with the original procurement effort or alternatively considering it as an addition to the original procurement efforts.

CHAPTER FIVE

CASE STUDY APPLICATION – THE BASIC SCHOOL PROJECT PROCUREMENT

5.1 Project Description

For the assessment of the research methodology, procurement data was used for the procurement of The Basic School (TBS) project in Quantico, Virginia. TBS is a project solicited by the Naval Facilities Engineering Command Washington for the design and construction of the new Student Quarters to house newly commissioned officers undergoing initial training. The contract is intended to be a fixed price contract to include both the design and construction of the new Student Quarters. This project procurement method follows the design build structure previously outlined in this thesis. The project will consist of four building facilities referred to as phases, numbered five through eight. Phase 5 is building P566, Phase 6 is building P567, Phase 7 is building P562 and Phase 8 is building P563. Phase five will be the base contract and phases six through eight are options to be added to the base contract. The government's intent is to award one contract, which would include the options for the additional phases, for all phases.

In notice of solicitation released by the Naval Facilities Engineering Command Washington, the project is to include a base year for phase 5 with a construction period of 24 months for the phase. The additional options, phases 6, 7 & 8, are to be approximately 24 months each as well. Option 1 may overlap the construction period of the base year, and options 2 and 3 may overlap the construction period of a previously awarded phase. The total projected construction costs may exceed $130 million for all 4 facilities, with each ranging from $30 million to $50 million each.

Each of the 4 phases will include both the design and construction of a new multi-story facility that is not to exceed approximately 92,268 SF. Most facilities will support billeting for 250 or fewer Marine Officers undergoing initial training at the Basic School. The facility shall be handicap accessible and provide rooms with semi private bathrooms and walk in closets. The building facilities are to include modular gear storage rack systems, weapons lockers, and wash racks. Fully operational Electrical, mechanical, telecommunications, and fire protection systems are required. Each building must be compliant with DOD Antiterrorism and Force Protection criteria. The project is to acquire a minimum of LEED Silver certification from the USGBC.

Facilities shall also comply at minimum with EPACT 2005 including 30% or greater energy reduction below ASHRAE 90.1 Guidelines.

The exterior supporting facilities work includes site and building utilities and connections, covered parking, sidewalks, roadway access. Wetlands mitigation and environmental mitigation will both be performed as a part of site development. The project will also include the selective demolition of some of the existing buildings on site. Before approval and final acceptance, the design will undergo stringent local, State and Federal preservation reviews as part of the design build process.

For all design build proposals that are submitted for award of The Basic School project, Technical Factors and Price are considered equal in importance to each other. The government reserves the right to reject any or all proposals at any time prior to award, to negotiate with any or all entities submitting a proposal. Furthermore, the government reserves the right to award the entity submitting the proposal determined by the Government to be the most advantageous based on the consideration of both Technical Factors and Price evenly; thus making the solicitation of The Basic School a best value design-build procurement and construction project.

5.2 Establish the Need

As previously discussed, the Naval Facilities Engineering Command Washington required that the project be LEED Silver certified by the USGBC. The project owner also requested that the project comply with EPACT 2005 including 30% or greater energy reduction below ASHRAE 90.1 Guidelines. To adhere to the requirements of the project owner, the contractor decided to utilize a Photovoltaic Module renewable energy source help acquire LEED certification and serve as one of the major components to help achieve compliance with the EPACT 2005. Past the point of achieving the requirements of the Naval Facilities Engineering Command Washington, the contractor had no immediate need to assess the total benefits of including a Photovoltaic Module renewable source of energy into its original procurement effort for this particular project.

There is however, an immanent need to assess the benefits of including this renewable energy source into the original procurement effort for the insight it will provide on the overall view of sustainable features on commercial buildings. It should be noted that the intent of this thesis is not to show the benefits of considering a renewable energy source over not considering a renewable energy source. The intent of this thesis is rather to show the possible benefits of considering a renewable energy source with the original procurement efforts as opposed to considering it later in the procurement effort as an addition to the project. This will serve to help disprove this inaccurate yet prevalent notion that sustainable construction and design techniques in commercial building construction projects have costs that exceed its benefits and thus leaving it, in many cases, to be considered as an addition as opposed to a program option.

5.3 Determine the Objectives

The intended objective is to assess the overall benefits of considering a renewable energy source such as a Photovoltaic Module system into the original procurement effort as opposed to an addition. As mentioned above the contractor conceived on including the Photovoltaic Module Renewable energy source to achieve the required LEED Certification and EPACT 2005 compliance for 30 percent energy reduction. The consideration of a renewable energy source would make the project eligible for LEED points that would otherwise be unattainable.

In addition to illustrating the benefits to LEED certification and EPACT 2005 compliance, a successful assessment will exemplify the cost and schedule benefits of including a renewable energy source in an original procurement effort. Ideally, the inclusion of the Photovoltaic Modules into the TBS original estimate will decrease costs by allowing the procurement team to take advantage of trending costs of Photovoltaic Module systems as well as show its cost advantages over its alternative of including the renewable energy source as an addition to the end of the project. A successful assessment will also show the competitive bidding advantages a contractor can gain by including a renewable energy source into its original procurement efforts.

5.4 Determine the Alternatives

5.4.1 Alternative One – Considering a Renewable Energy Source With Original Procurement Effort

In assessing the total benefits of a solution according to the research methodology explained in Chapter 4, it is necessary to first identify all reasonable options or alternatives of the solution. For the TBS project procurement effort that was researched, the first of those alternatives considered was the “do nothing” alternative. The assessment of the “do-nothing” alternative would consist of analyzing the original

TBS project procurement effort as is. Since it included the Photovoltaic Module renewable energy source, no changes would have to be made to it.

As a part of the original procurement strategy for Phase 5, in an effort to earn points towards the LEED Silver Certification and EPAct requirements of the project, the procurement team decided to propose a Net Zero building program of some sort. A Net Zero facility is one that, when operating under normal loads and conditions, requires no additional power from any outside power grid to operate. To adhere to the proposed Net Zero strategy, the procurement team planned to utilize a Mono-crystalline Photovoltaic Module renewable energy source.

One of the biggest challenges of incorporating a Photovoltaic Module system into a commercial building project is the amount of area required to accommodate the system. Since Photovoltaic Module systems are made up of individual module units that each have to receive direct sunlight to produce electricity, the modules have to be oriented in a series such that there is no shading that would result from overlap between any of the modules.

As stated above, the original contract was to include covered parking to service the building facilities. The procurement team was able to derive an effective solution that would fulfill this covered parking requirement while simultaneously providing the area needed to accommodate a Photovoltaic Module system large enough to make the proposed building a Net Zero facility. This solution was essentially a steel canopy that would be installed over the two designated surface lots. The canopy would be structurally designed to withstand the required wind and snow/rain loads and installed as the cover required for the parking spaces. In addition, the canopy would also be designed to support the Photovoltaic Module system atop of it as well. Had the steel canopy not been designed to accommodate the load of the Photovoltaic Module System, according to a manufacturer of these types of systems, the price of the steel canopy for the covered parking would have been the same price due to weather seals and additional pieces installed to the top of the canopy to break up snow build up and bird nesting.

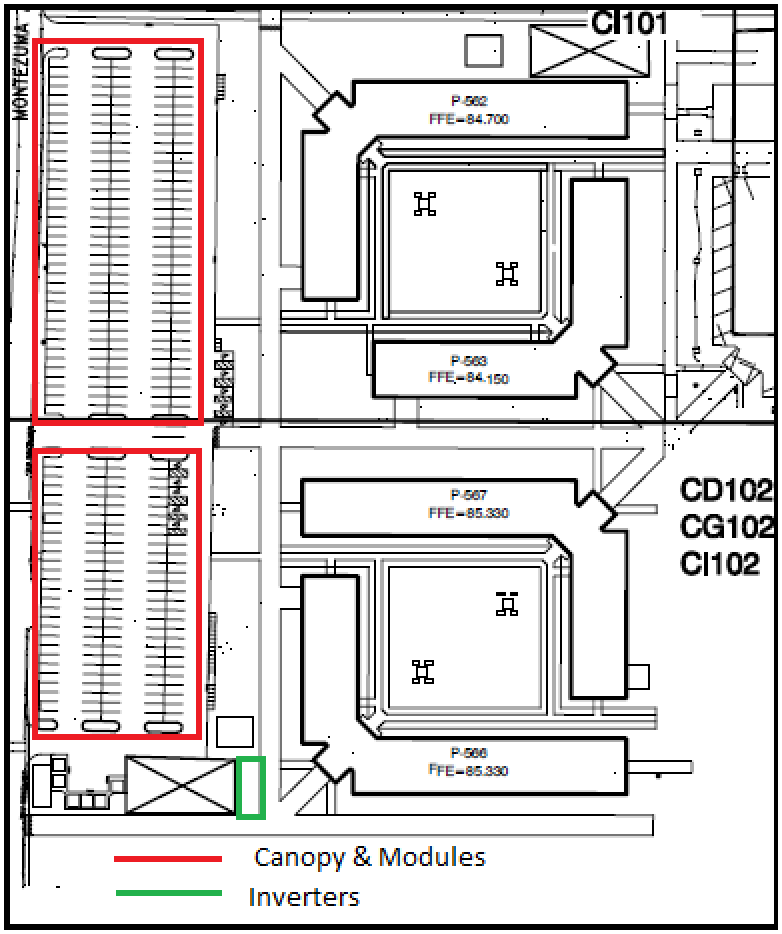


Figure 5.1: Proposed Layout of Canopy and PV System

The early conceptual designs for the building program estimated that the facility would consume 900,000kWh annually; however that estimate rose to 970,000kWh as the design progressed and became more detailed. The Photovoltaic Modules were to be installed over two separate surface parking lots using a single incline canopy structure. The parking canopy was to be designed to provide a tilt of 10 degrees and a clearance of 14’ at the lowest edge of the module array.

With the requirements of both the Photovoltaic Module system and its supporting canopy established, the general contractors could then implement the design build procurement method to acquire a fair market price for the complete scope of work. Coinciding with the structure of the design build procurement method previously discussed in this thesis, the general contractor used the requirements of the system and canopy to solicit prices from contractors specialized in this type of work. In this, the first alternative of considering the renewable energy source with the original procurement effort, the estimated durations for installing the system and the canopy were to be phased into the overall building schedule. This was done to ensure that there would be no additional durations added to the total project duration for the Photovoltaic Module system alone.

After the bidding contractors for the TBS project submitted their original estimates for the project bid, the owner of the project delayed the evaluation by requesting best and final offers from all bidding contractors. In doing so, it allowed the contractors additional time to adjust their estimates if necessary. As this was the case, by including the consideration of a Photovoltaic Module renewable energy source with the original procurement effort, the procurement team was able to solicit additional rounds of pricing and utilize the technique of price trending previously discussed in this thesis. In doing so, the procurement team then began its solicitation of the Photovoltaic Module contracting community to acquire fair market values for the proposed Module system. Table 5.1 below summarizes the proposed system components and pricing received in the first round of solicitation that was used in the original estimate. Although multiple vendors were solicited, the two proposals summarized in the tables below provided the most complete system proposals based on the system requirements.

Table 5.1: First Round of Photovoltaic System Solicitation

Vendor #1		***Vendor #2***	
Module Size (Watts)	305	Module Size (Watts)	327
System Size (kWp) DC	728.04	System Size (kWp) DC	800.00
Number of Modules	2,387	Number of Modules	2,446
Estimated Canopy Area (sf)	41,773	Estimated Canopy Area (sf)	42,813.46
Price	$ 3,160,788	Price	$ 4,100,000
5% Tax (Material Only)	$ 71,118	5% Tax (Material Only)	$ 92,250
Effective $/Watt (w/o Tax)	$ 4.34	Effective $/Watt (w/o Tax)	$ 5.13
Est. First Year Production (kWhrs)	910,044	Est. First Year Production (kWhrs)	969,464

The values in green in Table 5.1 above denote values that were estimated values not included in the quotes received for the Photovoltaic Module system. The area value for vendor #1 was calculated based on the average size of 17 square feet per panel that was observed amongst the quotes. Since they were not included in the quotes received from the vendors, the tax values were estimated based on the 5 percent tax for the county in which the project is located. Since tax is only applied to material, not labor, after speaking with estimators and manufacturers a 45 percent of the total cost of the system was estimated to be materials. 5 percent of the material cost was then calculated as the tax to be included with the system cost. This procedure was also used to calculate the values for taxes for the second and third rounds of solicitation as well.

Similarly, the first year production of the panel systems were calculated based on the first year production values of other quotes. Although Vendor #1 and Vendor #2 both verified that their respective systems would create the minimum 900,000 kilowatt-hours required of the system, they did not explicitly provide the exact output values. Thus the case, they were calculated based on an observation made among other system quotes that the system size was roughly 80 percent of the first year production in kilowatt-hours. Dividing the system sizes by .80 gave the values used for the estimated first year productions. The estimated first year production for Vendor#1's system in the second round of solicitation was estimated using this same procedure.

Vendor #1 proposed the system with the lowest total price of $3,160,788. The system consisted of 2,387 modules, rated at 305 watts each resulting in a total system size of 728.04kWh (DC). The estimated first year production of the system was 910,044 kWh which exceeds the required 900,000 kWh. The effective cost of the system was $4.34 per watt, before taxes.

The system components and pricing received in the second and third rounds of solicitation, that resulted from the owner delaying the evaluation of the project estimates, are summarized in tables 5.2 below. It should be noted that the first and second rounds were both based on the early conceptual estimates of 900,000kWh annual consumption, the third round of solicitation was based on the more detailed estimate of 970,000kWh annual consumption.

Table 5.2: Second Round of Photovoltaic System Solicitation

Vendor #1		***Vendor #2***	
Module Size (Watts)	305	Module Size (Watts)	327
System Size (kWp) DC	728.04	System Size (kWp) DC	1,462
Number of Modules	2,387	Number of Modules	4,472
Estimated Canopy Area (sf)	40,579	Estimated Canopy Area (sf)	83,179
Price	$ 2,724,817	Price	$ 6,101,435

Table 5.2 - Continued: Second Round of Photovoltaic System Solicitation

Vendor #1		Vendor #2	
5% Tax (Material Only)	$ 61,308	5% Tax (Material Only)	$ 137,282
Effective $/Watt (w/o Tax)	$ 3.74	Effective $/Watt (w/o Tax)	$ 4.17
Est. First Year Production (kWhrs)	910,044	Est. First Year Production (kWhrs)	1,927,000

Table 5.3: Third Round of Photovoltaic System Solicitation

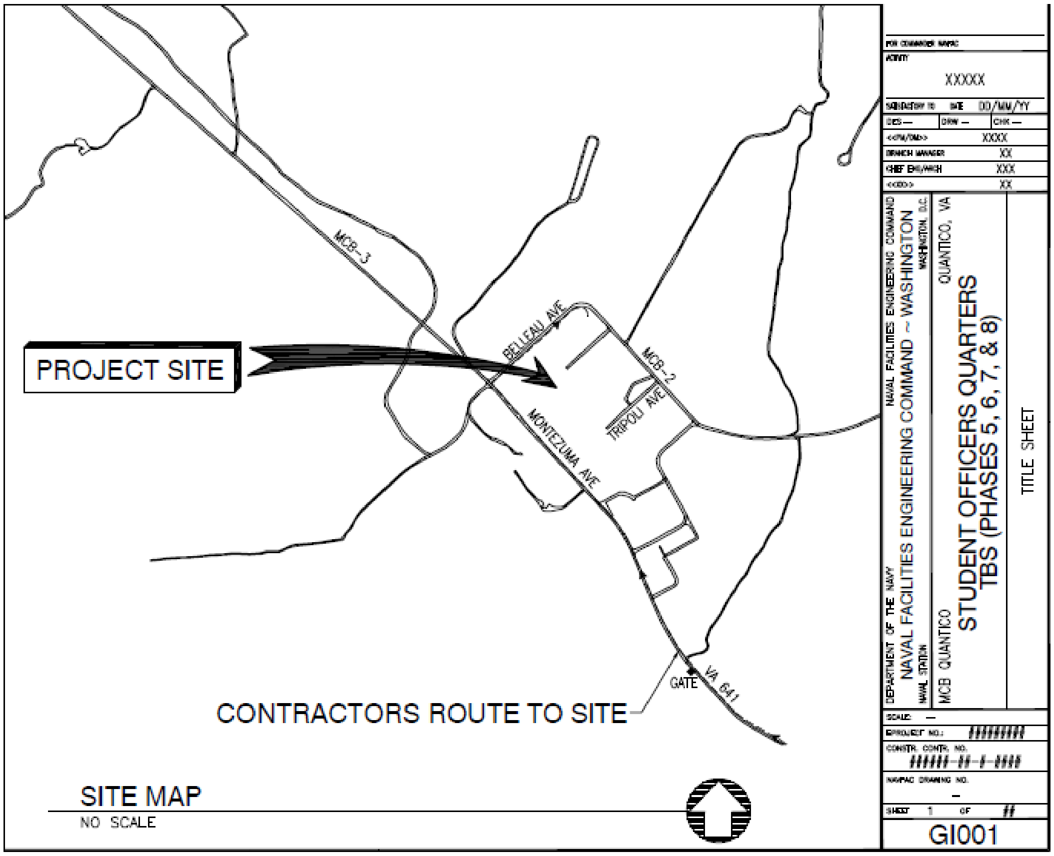
Vendor #1		Vendor #2	
Module Size (Watts)	240	Module Size (Watts)	327
System Size (kWp) DC	777.60	System Size (kWp) DC	1,462
Number of Modules	3,240	Number of Modules	4,472
Estimated Canopy Area (sf)	55,080	Estimated Canopy Area (sf)	83,179
Price	$ 2,545,000	Price	$ 5,308,248
5% Tax (Material Only)	$ 57,263	5% Tax (Material Only)	$ 119,436
Effective $/Watt (w/o Tax)	$ 3.27	Effective $/Watt (w/o Tax)	$ 3.63
Est. First Year Production (kWhrs)	970,000	Est. First Year Production (kWhrs)	1,927,000

Referring to Table 5.3, the lowest total price of the system was $2,545,000 from the third round of solicitation. The effective price per watt decreased to $3.27 per watt by the third round of solicitation. Although the system requirements rose from 900,000kWh to 970kWh from the first round to the third, the effective price per watt decreased by 32%.

5.4.2 Alternative Two – Not Considering Renewable Energy Source With Original Procurement

In the alternative of not considering the Photovoltaic Module system in the original procurement effort of phase 5 but rather as an addition to be incorporated either with the additional building phases or at the end of the project, the canopy system used for the covered parking would not have been designed to withhold the additional loads of the Module system. This would mean that a separate location and a separate mounting system would have to be considered as a result of not considering the Photovoltaic Module system with the original procurement effort.

In considering this alternate location and mounting system for the Photovoltaic Module System, the assumption was made that the same system size and area designed to be used in the original procurement to produce the required output, would also be used in the consideration of the alternate location and mounting system. Thus the case, 59,000 SF would be needed to fulfill the space requirements of the system.



5.2: Proposed Location for Alternative #2

As shown in Figure 5.2 above, the intended area of buildings P566, P567, P562 and P563 cover the useable space bordered by Montezuma Ave, MCB-2 and Belleau Ave. On the opposite side of Belleau Ave is the proposed location for the parking lots for the building facilities. Without altering the original design, the closest acceptable space large enough to accommodate the 59,000SF needed for the Photovoltaic Module System is the area on the outside corner of Belleau Ave and MCB-2. In order to account for the total 59,000 SF needed for the Module system and while simultaneously fitting into the area allowed, a 30,000SF area and a 29,000SF are were selected to be right next to one another.

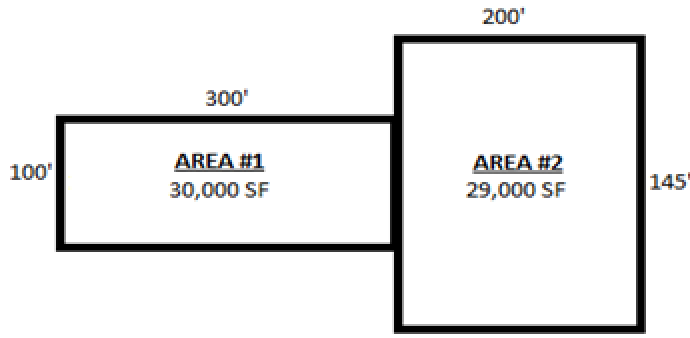


Figure 5.3: Proposed Area Layout for Alternative #2

Though this location is available in the sense that it is not occupied by any existing buildings nor is it considered by the Marine Corps to be restricted space, there is site work that would have to be done to the area in order to make compatible to hold the 59,000 SF needed for the Photovoltaic Modules. The area is covered by trees that would have to be cleared. In addition to clearing the trees the site would need to have fill material brought in, and compacted to account for the decreasing slope that exists in the area. Actual grades of the alternative area were not available at the time of this study; however based on the conditions of the surrounding areas that were provided it was assumed that the alternate area had a negative slope of .25% toward West.

5.4.2.1 Alternative Two – Direct Costs

Using the conditions defined above for the new location of the Photovoltaic Module System, the same techniques used in the original procurement effort to estimate subcontracted scopes of work were utilized to obtain an accurate cost estimate for the site work needed to make the area compatible for the Photovoltaic Module System. The first step then was developing a list of activities that needed to be done to the site. Following the same sequence used to complete the site work for the parking lots, the list of activities and respective units of measure shown in Table 5.4 was developed.

Table 5.4: Site Work Activities for Alternative #2

#	Activity	Unit of Measure
1	Survey / Layout	Ea
2	Silt Fence and Temporary Fencing	LF
3	Inlet Protection	Ea

Table 5.4 - Continued: Site Work Activities for Alternative #2

#	Activity	Unit of Measure
4	Clear and Grub Trees	SF
5	Import Fill Material	CY
6	Spread and Compact Fill Material	CY

The next step was to determine the quantities associated with each activity listed:

1) *Survey / Layout:* It was assumed that official survey layout would only be needed ***once***, and offset control points would be used to layout any additional layout that may be needed.
2) *Silt Fence and Temporary Fencing:* Following the same procedures used in the site work estimated for the original procurement effort, it was assumed that silt fence and temporary fencing would be placed along the outside of the two areas that will be used for to place the Photovoltaic Module System. Using simple geometry calculations, the linear footage (LF) of silt fencing and temporary fencing was calculated to be the following:

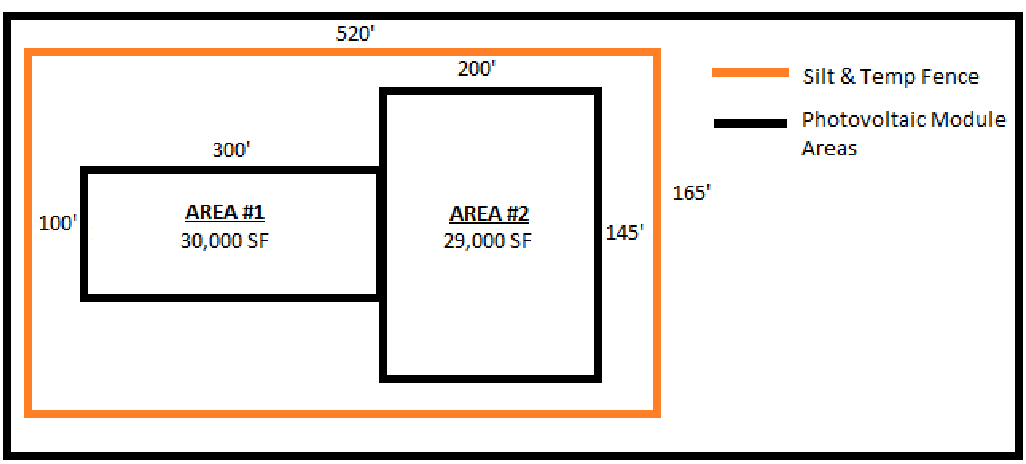


Figure 5.4: Silt and Temporary Fencing

Linear Footage = Total Perimeter

Linear Footage = 2(165’) + 2(520’)

Linear Footage = 1370 LF

3) *Inlet Protection:* Following the same procedures used in the site work estimate for the original procurement effort, it was assumed that the *four* inlets on Beleau Avenue would have to be protected from construction runoff.
4) *Clear and Grub Trees:* It was assumed that only the 30,000SF and 29,000SF, 59,000SF total, areas designated for the Photovoltaic Modules were included in the quantity to be cleared. It should be noted that this is a conservative estimation of the quantity, as it would likely be necessary to clear additional area to ensure there is enough space for all construction activities and equipment.
5) *Import Fill Material:* The .25% slope and the area dimensions previously assumed were used along with simple geometric equations to estimate the amount, in cubic yards (CY), of fill material that needed to be imported to create a consistent grade for the Photovoltaic Modules. To calculate the volumes, the cross sectional areas of the sub areas were calculated and multiplied by the distances. The total volume was calculated by adding the 3333 CY and the 2148 CY to get a total of 5481 CY.

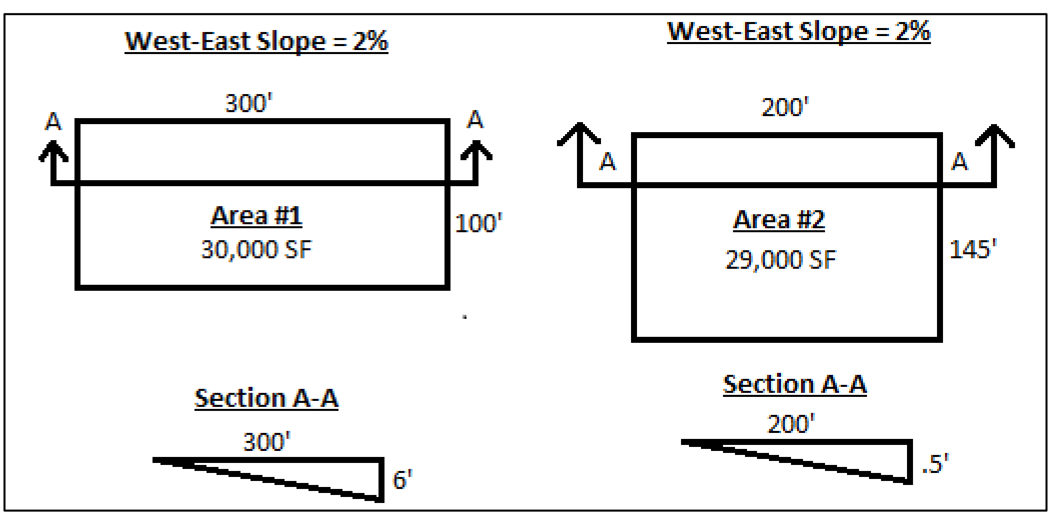


Figure 5.5: Alternate Areas

Volume of Area #1 = (Area of Section A-A)(Length of Section)

Volume of Area #1 = [(.5)(300)(6)] x (100′) x (1Yard/3′)^3

Volume of Area #1 = 3333 CY

Volume of Area #2 = (Area of Section A-A)(Length of Section)

Volume of Area #2 = [(.5)(200)(4)] x (145′) x (1Yard/3′)^3

Volume of Area #2 = 2148 CY

6) *Spread and Compact Fill Material:* The quantity used for the spreading and compaction of the fill material was the same quantity used as imported fill material, 5481 CY

Once the quantities for the site work activities were determined, the next step was to determine the most accurate unit price for each activity. In the original procurement effort the unit prices were solicited from site work contractors for specified activities. These unit prices were compared side by side and the lowest reasonable unit price was used as the estimated unit price of the specified activity. The unit prices, unless specified otherwise, included materials equipment and labor. Table 5.5 shows the unit prices pulled from the solicitation data as well as the unit prices used to estimate the cost of the site work activities required to make the alternate space compatible for the Photovoltaic Module System.

Table 5.5: Unit Price Comparison for Site Work Activities

#	Item / Activity	Quantity	Unit of Measure	Unit Price Used	Vendor #1 Unit Price	Vendor # 2 Unit Price	Vendor # 3 Unit Price
1	Survey / Layout	1	EA	$ 15,000	$ 15,000	$ 15,500	$ 1,600
2	Super silt fence	1370	L.F.	$ 8	$ 8	$ 8.25	$ 8.10
3	Inlet protection	4	EA	$ 300	$ 325	$ 315	$ 320
4	Clear and Grub Trees	59000	CY	$ 0.25	$ 0.3	$ 0.25	$ 0.3

Table 5.5 - Continued: Unit Price Comparison for Site Work Activities

#	Item / Activity	Quantity	Unit of Measure	Unit Price Used	Vendor #1 Unit Price	Vendor # 2 Unit Price	Vendor # 3 Unit Price
5	Fill Material - Material Only	5481	CY	$ 15	*No Price Provided*	*No Price Provided*	*No Price Provided*
6	Fill Materal Spread - by Dozer	5481	L.C.Y.	$ 2.15	$ 2.15	$ 2.2	$ 2.25
7	Compaction	59000	E.C.Y.	$ 0.33	$ 0.35	$ 0.4	$ 0.33

After the unit prices for the site work were determined, the next step was to determine what alternate mounting system would be used to support the Photovoltaic Modules, and the costs associated with this alternative. The two most conventional options would be a bracket system that sits on a base that is either driven into the ground or poured into a concrete footer. Due to soil conditions that would likely increase the required depths of piles driven into the ground surface, manufactures of these types of brackets in the area recommend the bracket be poured into a concrete footer. A review of similar systems also showed that the bracket system driven into the ground surface may not be the best for this particular application as it would introduce problems such as erosion to the bracket itself, and settling of the system as a whole in the long term. Therefore, the alternative mounting system was chosen to be a bracket socketed into a concrete base.

The next step in assessing the mounting system was to determine the orientation of the Photovoltaic Modules in the system that is to be placed in an alternate location. As previously stated, the assumption was made that this system would be the same as the original system in terms of its size and system output. Thus the case, the same quantity of 3,240 individual Photovoltaic Modules would need to be used.

The Sharp 240 Watt Photovoltaic Module used in the system has dimensions of 5.38’ x 3.26’. In order to determine which orientation of these dimensions would fit the required 3,240 modules into the selected areas the best, the modules had to be projected onto the areas as a check. This was done by making two test projections. The first projection was done with the modules placed with their longer dimension in the North-South direction and resulted in 3242 modules. The second projection was done with the modules placed with their longer dimension in the East-West direction and resulted in 3278 modules.

Since the system only requires 3,240 modules, Projection # 1 is the best orientation of the modules. This would make room for 1650 modules in area #1 and 1628 modules in area #2. It should be noted that the exact dimensions of the Modules were used in the orientation projections, while the system is designed for the modules to have a 10 degree tilt. This tilt would actually decrease the dimensions projected onto the ground surface. This would result in a greater area than that which is considered by using the exact dimensions to project on the ground surface. This was done as a conservative measure, to ensure that enough space was included in the area calculations.

Once the orientation of the system was established, the next step was to evaluate the mounting brackets for the Modules and the concrete base that would support the mounting brackets brackets and ultimately the Modules themselves. Following methods illustrated in the literature review, it was assumed that the concrete base supporting the Module brackets would be 2' wide x 1' high. Most bracket systems are fabricated to be project specific. Though this is the case, after consulting two separate steel bracket manufactures as well as an original patent for a Photovoltaic Module bracket, all sources suggest that each bracket section can hold roughly 8 modules (McMaster, 1989).

Following the same procedure used to determine the unit prices for the additional site work items, the unit prices for the modules and the mounting system components then need to be determined. The first step would then be to list the activities associated with the mounting system components and the module installation.

Table 5.6: Mounting System and Module Installation Activities for Alternative #2

#	Activity	Unit of Measure
1	Concrete Base	CY
2	Mounting Brackets	Ea
3	Photovoltaic Modules' Installation	Ea
4	Inverter Installation and Wiring of Modules	Ea
5	Re-Seed and Site Clean-up	SF

The next step was to determine the quantities associated with each activity listed:

1) *Concrete Base:* The brackets supporting the Photovoltaic Modules are poured into the concrete bases. The quantities for the concrete base were estimated based on the total quantity of the brackets (bracket quantities below). The concrete bases were estimated to be 2′ wide x 1′ high x 3′ long. The 3′ length dimension was used as a conservative estimate to account for uncertainties. The total linear footage (LF) of concrete base was calculated to be:

LF of Concrete Base = (# of Brackets) x (3 LF of Concrete Base per Bracket)

LF of Concrete Base = 405 x 3′

LF of Concrete Base = 1215 LF

2) *Mounting Brackets:* Based on conversations with bracket manufacturers, each bracket section was considered to hold 8 modules. Using this and the total number of modules, 3240 (described below), the total number of brackets was calculated to be:

Total # of Brackets = (Total # of Modules) / (8 Modules per Bracket)

Total # of Brackets = 3240 / 8

Total # of Brackets = 405

3) *Photovoltaic Modules:* Since the total output for the alternate system is the same as the system used in the original procurement effort, the total number of panels for the alternate system will also be 3240.

4) *Inverter and Wiring of Modules:* For the purposes of estimating the system that would have resulted in not considering the Photovoltaic Module System from the beginning, the inverter installation and wiring of modules is considered to be a lump sum item, with a quantity of one.

5) *Re-Seed and Site Clean up:* Once the concrete bases and the brackets are set, and the Modules of the alternate system are also set in place, the site has

to be cleaned and re-seeded for erosion control purposes. The quantity for this activity was calculated to be the total area of the alternate site, less the area of the concrete bases. The quantities for Re-Seed and Site Clean-Up were calculated to be:

Re-Seed and Site Clean Up (SF) = (Total Site Area) – (Area of Concrete Bases)

Re-Seed and Site Clean Up (SF) = 59,000SF – (1218LF of Concrete Base x 2LF of Concrete per Base)

Re-Seed and Site Clean Up = 56,564 SF

Once the quantities for each activity of the Photovoltaic Module System mounting and installation are listed and quantified, techniques similar to those used to acquire unit prices for site work activities were used to determine the unit price for each of the system mounting and installation activities. Data from unit price quotes were compared side by side to determine the fair market value for each scope of work. Table 5.7 below shows the unit price data for the items specified.

Table 5.7: Unit Price Comparision for Concrete, Re-Seed & Clean-Up, & Module Brackets

Item / Activity	Quantity	Unit of Measure	Unit Price Used	Vendor #1 Unit Price	Vendor # 2 Unit Price	Vendor # 3 Unit Price
Concrete	1218	LF	$ 50.00	65	55	50
Re-Seed, Sod & Clean-up	59000	SF	$ 0.35	37	0.35	40
Brackets - 8 Panels/Bracket	405	EA	$ 600.00	600	650	500

The concrete unit price is one acquired for linear footage (LF) of 2′ x 1′ concrete footer, formed poured and stripped. The prices were solicited for a portion of work included in the site work of the origional procurement effort. The Re-seed and Clean-up price was taken from a unit price solicited for re-seeding and sodding the site, based on the square footage (SF). Alothough no sod was used in this application, the price savings earned from not using sod was assumed to be negated by the inclusion of clean-up in this application. Price data for the Module brackets came from manufactures, as rough unit price estimates based on the size and components of the system.

To estimate the unit price of the Photovoltaic Modules separate from the canopy system included in the origional estimate, suggestions were taken from the Module contractors as well as procurement estimators. Based on these suggestions, the unit cost of the Modules are derivied in Table 5.8 below.

Table 5.8: Photovoltaic Module Material & Installation Cost Breakdown

Unit Price ($/Panel)	$ 785.49
Material - %45 of Total Price	$ 353.47
Total Installation - %50 of Total Price	$ 392.75
Module Installation - %30 of Total Installation	$ 117.82
Modules Material - %80 of Material Price	$ 282.78
Module Material + Installation $/Panel	$ 400.60

Once the unit price and quantities for all items estimated, simple unit price calculations previously discussed can be utilized to calculate the direct costs for each item of the alternate system's mounting system and installation.

Total Item Cost ($) = (Item Quantity) x (Item Unit Price)

Table 5.9 below shows the calculation of each item's cost, based on its corresponding unit cost and total quantity. The table also tabulates the total direct costs associated with the alternative of not considering the renewable energy source with the original procurement efforts.

Table 5.9: Alterative #2 - Direct Cost Breakdown By Activity

#	Item / Activity	QUANTITY	UNIT	$/UNIT	TOTAL
1	Survey / Layout	1	EA	$ 15,000.00	$ 15,000.00
2	Silt Fence and Temp Fence	1370	LF	$ 8.00	$ 10,960.00
3	Inlet Protection	4	EA	$ 300.00	$ 1,200.00

Table 5.9 - Continued: Alterative #2 - Direct Cost Breakdown By Activity

#	Item / Activity	QUANTITY	UNIT	$/UNIT	TOTAL
4	Clearing and Grubbing	59000	SF	$ 0.25	$ 14,750.00
5	Import Fill Material - *MATERIAL ONLY*	5481	CY	$ 15.00	$ 82,215.00
6	Spread Imported Material By Dozer	5481	CY	$ 2.15	$ 11,784.15
7	Compact Dumped Material	59000	CY	$ 0.33	$ 19,470.00
8	Concrete Base	1215	LF	$ 50.00	$ 60,750.00
9	Brackets - *MATERIAL ONLY*	405	EA	$ 600.00	$ 243,000.00
10	Modules - Unit Price Includes Inverters and Wiring Material	3240	EA	$ 400.60	$ 1,297,950.00
11	Inverters and Wiring Installation	*DURATION ONLY - MATERIAL W/ MODULES*			
12	Re-Seed/Sod, and Clean up	56570	SF	$ 0.35	$ 19,799.50
					$ 1,776,878.65

5.4.2.2 Alternative Two – Indirect Costs

In addition to the direct costs associated with the alternative of not considering the Photovoltaic Modules with the original procurment efforts, there are also indirect costs associated with this alternative. As previously discussed in this thesis, indirect costs are calculated in direct realtion to the estimated project schedule. As this is the case, in order to estimate any additionl indirect costs associated with the alternaive of not considering the Photovoltaic Module energy source from the original procurement effort, the durations of installing the system that results from this alternative must first be determined.

In the original procurement effort, since the Photovoltaic Module system was considered an option from the begning, the construction of the system was phased into the construction of the facility so as to not add any additional duration to the total schedule estimate for just the system alone. For the purposes of this thesis however, it is assumed that the alternative of not considering the Photovoltaic Module System in the original schedule estimate resulted in the construcion durations for the system being added to the end of the schedule as additions to the originally estimated project duration. Subesequently, these additions to the schedule durations ultimately result in additions to indirect costs. Based on information gained from Photovoltaic Module system contractors, Module bracket manufacturers and the original procurement team, the estimated durations for the construction of the alternate system were compiled into a schedule for Alternative #2. Utilizing the information gained from manufacurers and installers of these types of Photovoltaic Module Systems and a sequence proposed by the original project estimators, the schedule used to estimate the indirect costs associated with Alternative #2 is illusteated in Figure 5.7 below.

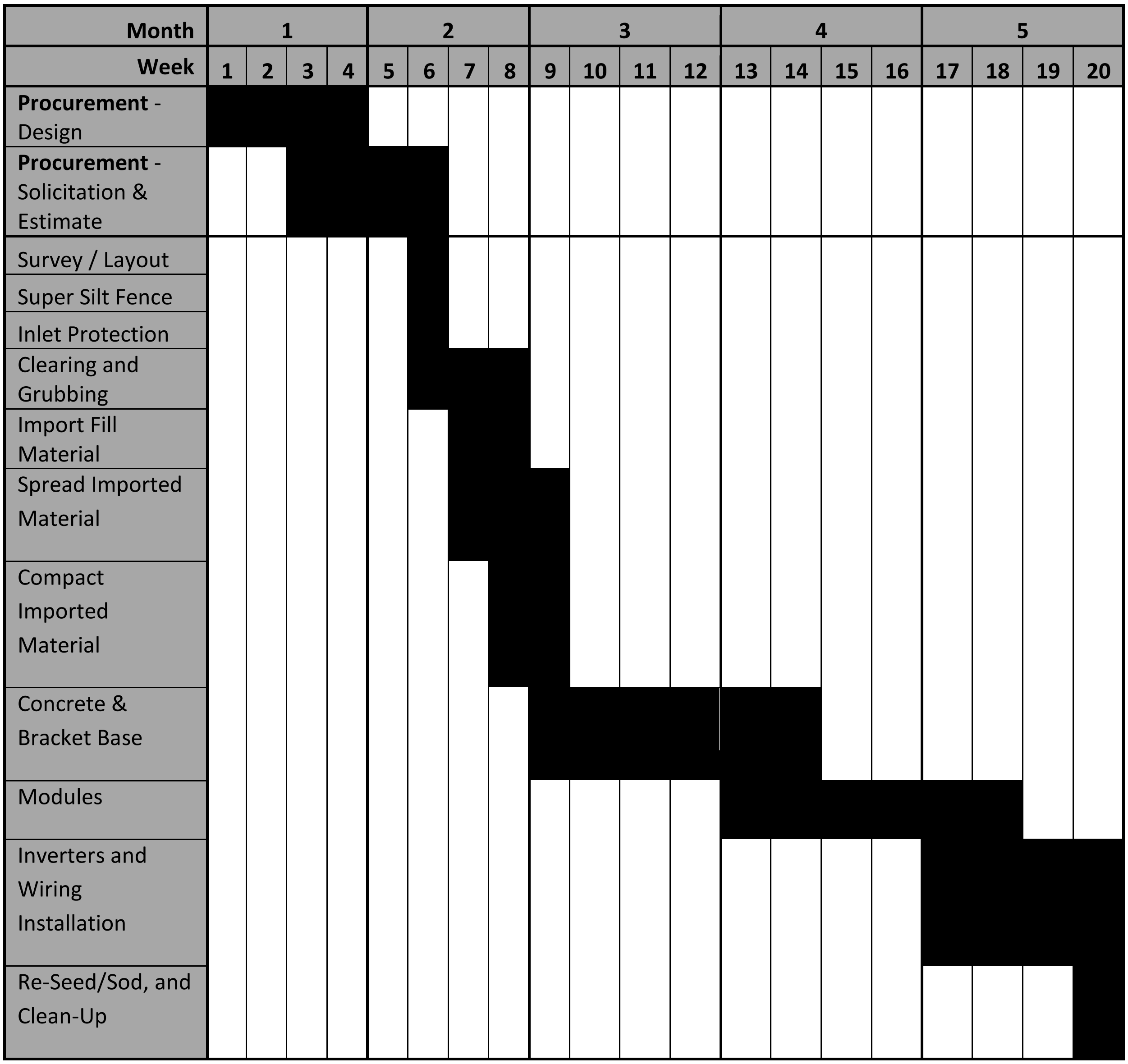


Figure 5.6: Proposed Activity Schedule For Alternative #2

By utilizing techniques similar to those previously used to acquire unit pricing for items contributing to direct costs, unit prices for items contributing to indirect costs were also derived. This was done by acquiring data used in the original procurement effort to determine unit prices for indirect costs incurred by the schedule additions caused by not including the the renewable energy source as a part of the original estimate. Table 5.10 below shows the the unit prices used to calculate these indirect costs.

Table 5.10: Alternative #2 – Direct Cost Breakdown

			$/Month					
Indirect Item	Unit of Measure	Qty	Labor	Material	Equip.	Sub.	Unit Cost	Total
Lead Estimator	Months	0.75	$ 7,775				$ 7,775	$ 5,831
Estimator	Months	1.5	$ 6,479				$ 6,479	$ 9,718
Project Manager	Months	2.5	$ 8,293	$ 500	$ 575		$ 9,368	$ 23,420
Project Engineer	Months	5	$ 6,220				$ 6,220	$ 31,100
Field Engineer	Months	3	$ 5,183				$ 5,183	$ 15,549
Utility Locating Services	Lump Sum	1				$ 5,000	$ 5,000	$ 5,000
Office Trailer	Months	4.5				$ 3,000	$ 3,000	$ 13,500
Temporary Toilets	Months	4.5		$ 100		$ 175	$275	$ 1238
Office Supplies & Equipment	Months	3		$ 1,500				
Personal Computers	Months	3			$ 75		$ 75	$ 225
Q.C. System	Lump Sum	1	$ 1,000				$ 1,000	$1,000
Forklift & Operator	Months	1.5	$ 3,200				$ 3,200	$ 4,800
Small Tools & Accessories	Lump Sum	1	$ 5,000				$ 5,000	$ 5,000
								$ 105,332

Also shown in Table 5.10 above are the durations of each item, quantified in months or lump sums, based on the schedule shown in Figure 5.7. The quantity of each item was estimated based on insight obtained from the estimators from the original procurement effort. The Lead Estimator qantity was calculated to be the duration of the design process, .75 Months. The Estimator quantity was calculated to be the total duration of the procurement process, 1.5 Months. The rational behind this is that a single Estimator would need to be present throughout the entire procurement process, however a Lead Engineer would typically only need to be present through the design process for a project of this size. Using a similar rational provided by the procurement team for the typical construction management personell for this type of project, the Project Manager quantity was calculated to be half of the total duration, 2.5; the Project Engineer quantity was calculated to be the total duration of the project and the Field Engineer quantity was assumed to be 2.25 months. The Office Trailer and Temporary Toilets were calculated to be the duration of the construction activities, 4.5 moths. A coservative estimate of 3 months was used for the durations of the Office Supplies & Equipment and Personal Computers. The Forklift and Operator was assumed to be needed for the duration of the modules installation. A single Lump Sum was used for the Utility Locating Services, Quality Control System, and Small Tools & Accessories items.

Using simple unit price calculations previously discussed, the total cost for each indirect line item is also calculated in table 5.10 above. As the table also illustrates, the alternative of not considering the renewable energy source with the original procurement effort resulted in an additional $94,038 in indirect costs.

With the direct and indirect costs both calculated, the total cost associated with the alternative can be calculated as:

Total Cost of Alternative #2 = (Direct Costs) + (Indirect Costs)

Total Cost of Alternative #2 = $ 1,776,878.65 + $ 105,332.15

Total Cost of Alternative #2 = $ 1,882,210.15

5.5 – Identify and Quantify Benefits

5.5.1 Cost Benefits

Once the cost effects of both alternatives were identifited, they were then compared to quantify the benefits of one alternative over the other. This is a step discussed earlier in this thesis, that was presented by Dhillon (1989) as one necessary to select among the viable options of an alternative. Ultimately, the alternative of not including the Photovoltaic Module renewable energy cost with the original procurement effort for The Basic School project in Quantico, Virginia lead to an additions in both direct costs indirect costs. In order to fairly account for the actual increase in costs of the second alternative when compared to the first, the cost of the Photovoltaic Module materials must be deducted from this additional cost value. As prevously discussed as a possible scenerio in the methodology portion above, this is because both alternatives incur the cost of the Module materials. Therefore since the total cost increase of the alternative includes the cost of Module materials that would have to be purchased in both alternatives, it has to be deducted from the value of increased cost. Since the price of the Photovoltaic Module Systems as they were quoted did not break out the price of the modules from the price of the steel canopy, suggestions from a manufacturer of similar systems on how to break down the costs based on percentages of the total system cost were used to estimate the cost of the modules. Those percentages and costs were shown in table 5.7 above.

Table 5.11 below sums the additional costs of the alternative of not considering the renewable energy source from the begning, and deducts the cost of the Module materials to show the net price increase of the alternative solution.

Table 5.11: Net Additional Cost of Alternative #2

Direct Costs	$ 1,776,878.65
Indirect Costs	$ 105,331.50
Indirect + Direct Costs	$ 1,882,210.15
Module Credit	$ 1,297,950.00
Net Gain of Alternative #2	$ 584,260.15

As it was discussed above, delays by the project owner in the evaluation process resulted in additional solicitaion rounds for the project. Thus the case, the alternative of considering the renewable energy source with the original procurement effort provided the added benefit of re soliciting the price of the renewable energy source scope of work utilize the cost trending method previously described in the research methodology. This trending process of the Photovoltaic Module system showed a decrease in the price of the system's scope of work. The procurement team was able to then utilize the lowest responsible price as the cost of incorporaing a renewable energy source into the original procurement effort. Figure 5.8 below illustrates the cost trend of the renewable energy source scope of work when considered with the original procurement efforts of the TBS project. Similarly, Table 5.12 summarizes the cost decreases. As can be seen in the table, the total savings from trending the costs of the Photovoltaic Module System is $632,788.

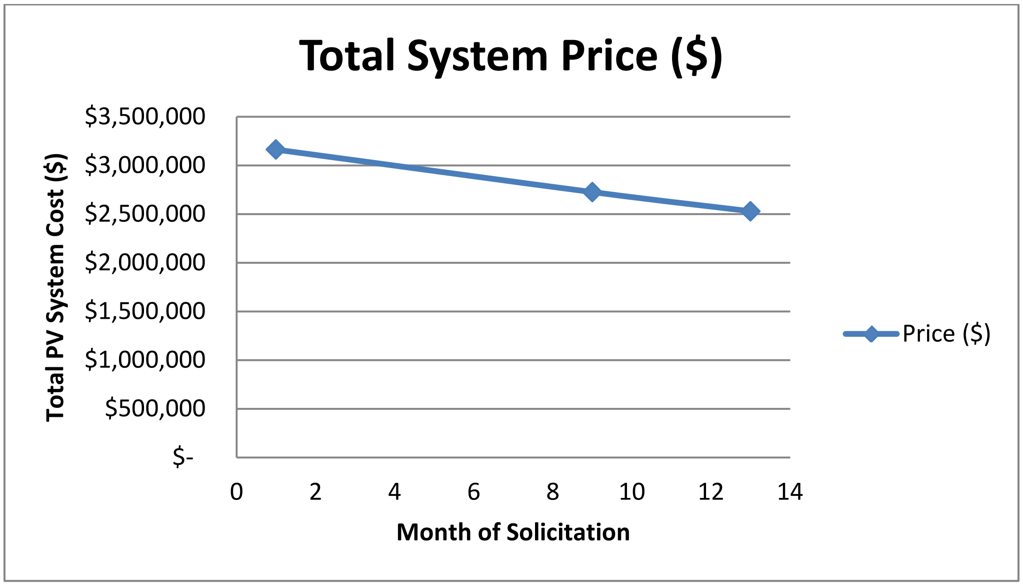


Figure 5.7: Graph of Trending Total Cost of Photovoltaic Module System

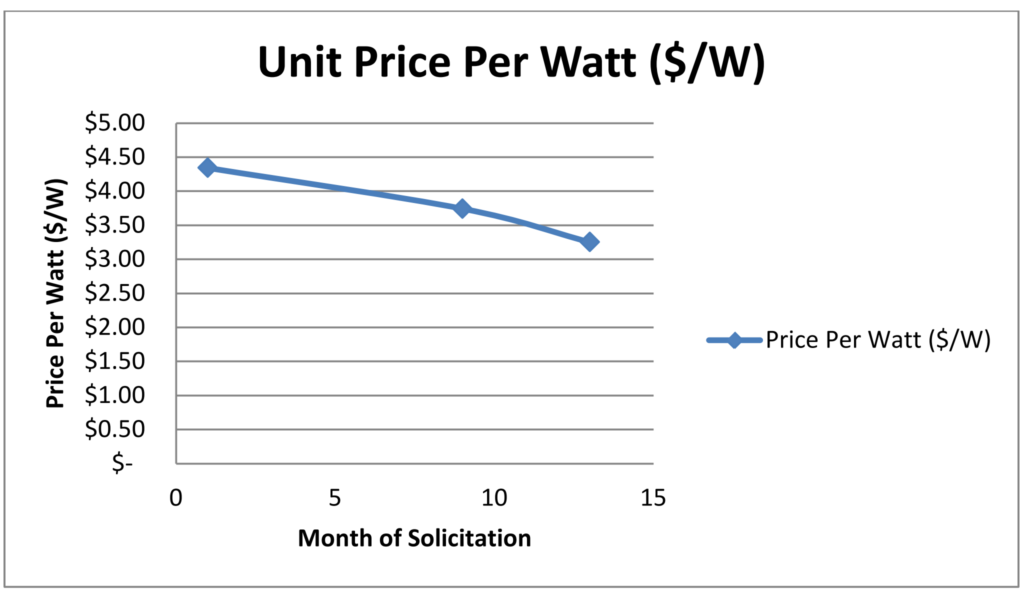


Figure 5.8: Graph of Trending Unit Cost of Photovoltaic Module System

Table 5.12: Change in System Cost

Month	Total Price ($)	System Size (kWh)	1st Year Production (kWh)	$/Watt	%Increase / Decrease
1	$ 3,160,788	728.04	910,043.75	$ 4.34	0%
9	$ 2,724,817	728.04	910,043.75	$ 3.74	-14%
13	$ 2,528,000	777.60	970,000.00	$ 3.25	-25%

Although the first alternative did save a total of $632,788 by trending the cost of the system and purchasing it at the lowest price, it cannot not be easily included as a cost saving over the second alternative. This is because since the price is trending downward, the argument can be made that if the prices would have continued to stay at the lowest quoted price, the second alternative would have been able to purchase the system at the lowest price as well. Therefore, for the purpose of this research study, the total cost benefits are quantified to be the additional cost associated with the alternate mounting system and indirect cost associated with alternative #2, only. The total cost benefit then, of alternative #1 is $584,260.

5.5.2 Schedule Benefits

In regards to schedule benefits, in assessing the alternative of not considering the renewable energy source in the original procurement effort, it was asssumed that the Photovoltaic Module System would have been added to the end of the schedule. Re allocating the schedule phases and resources to phase the construction of the energy source would not have been in the best interests of the project as a whole. According to the procurement team, it would have added significant cost and delays to multiple trades to incorporate the module system into an already planned schedule for the project. This can also be viewd as a worst case impact of considering a sustainable feature as an addition as opposed to an option from the begning. In the application then of The Basic School project, total estimated construction duration of 5 months for the alternate Photovoltatic Module system would be equal to the total delay.

5.5.3 Competitive Advantage Benifits

The inclusion of renewable energy sources into a building program from the procurement stage would create a competitive advantage for bids on privately owned projects. This advantage manifests itself in the form of tax incentives for the owner. The Federal Government offers Tax incentives that differ from state to state, for the incorporation of renewable energy sources into commercial building projects.

The American Recovery and Reinvestment Act of 2009 introduced tax credits for what it refers to as On-Site Renewable Energy Production. It should be noted that a tax credit lowers tax responsibility dollar for dollar, making it more advantageous than a tax deduction which only lowers taxable income. Businesses are eligible for said tax credits for qualified solar water heating and photovoltaic module systems, and for certain solar lighting systems. These tax credits would be in the amount of 30 percent of the total cost of the system. Furthermore, according to the Act, systems installed after 2009 are not subject to a cap imposed on systems installed before 2009. Using the lowest proposed price for the Photovoltaic Module System proposed for The Basic School project of $2,545,000 to calculate the 30 percent credit would have resulted in a tax credit of $763,500 for the project.

This would be very significant and would lower the overall payback period if the owner of The Basic School project would have been one from the private sector. However this was not the case, as the TBS project owner was the Naval Facilities Engineering Command Washington and subsequently the competitive advantage of making the owner eligible for tax incentives was not available. There are however similar advantages, in the form of contributions to goals set by the Federal Government for renewable energy use.

The Energy Act of 2005) requires that the President seek to ensure that of the total energy consumed by the Federal Government, a minimum of 5 percent be renewable energy (109th Congress of The United States of America, 2005). This minimum rises to 13 percent by the year 2013 (109th Congress of The United States of America, 2005). According to the Act, the intent of this and other goals for renewable energy use is to encourage the Federal Government to use techniques of life-cycle costing and innovative procurement methods. The incorporation of a renewable energy source into the proposed building program from the original procurement effort serves to achieve that exact purpose. For the first phase of the contract, the estimate incorporated a Photovoltaic Module system that would generate over 900,000kWh of on-site renewable energy in its first year of operation. This should be viewed highly favorable by the US Marine Corps as a significant contribution to the innovative procurement goals set by and for the Federal Government.

As pointed out earlier in this chapter, the main catylist behind the consideraion this Photovoltaic Module renewable energy source with the original procurement of the TBS project was for the credits it could contribute to the LEED Silver Certification requirement. By utilizing the Photovoltaic Module System as a source of on-site renewable energy, the project became eligible for all 7 of the on-site renewable energy credits according to the USGBC guidelines. Furthermore, the Photovoltaic Module System was designed to make the building a Net-Zero facility. A Net-Zero facility is one that requires no additional energy from any outside power source to facilitae the building under normal operating conditions.

One of the most important aspects to consider in the design build evaluation criteria for The Basic School project in Quantico, Virginia is the technical proposal component. As it was discussed at the beginning of this chapter, the technical component of the proposal is equal to the price component of the proposal. The government reserves the right to award the entity submitting the proposal determined by the Government to be the most advantageous based on the consideration of both Technical Factors and Price evenly; thus making the solicitation of The Basic School a best value design-build procurement. Thus the case, by employing the research methodology of this thesis to identify and quantify the benefits of considering a renewable energy source as a part of the original procurement, specifically in terms of schedule cost and LEED contributions, a well prepared technical proposal can also be utilized in this case to emphasize the aforementioned benefits of considering this renewable energy source as a part of the original procurement effort. This advantage would not be available without fully assessing and understanding the benefits gained by incorporating this renewable energy source from the start.

CHAPTER SIX

CONCLUSIONS AND RECCOMMENDATIONS

6.1 Conclusions

This thesis is based on the principle argument that for projects considering sustainable construction and green building techniques such as an on-site renewable energy source, the benefits of considering that renewable energy source could be greater if the energy source is considered as an option from the start of the procurement effort as opposed to being considered as an addition later in the procurement effort. In establishing this thesis it was necessary to perform an extensive amount of research in the areas of renewable energy sources and their presence in construction, new building construction procurement and its associated methods, as well as life cycle costing concepts that could be used to derive a methodology to assess the benefits of early consideration versus late consideration of a renewable energy source in a procurement effort. The findings of this research were also outlined as objectives in the presentation of this thesis.

As the first step in both establishing and supporting this thesis, the research of renewable energy sources spawned significant insight and information on photovoltaic module systems. By analyzing both previous studies on photovoltaics and data obtained to apply the research methodology, a trending decline in photovoltaic energy costs was observed. It was actually this trending decline in costs associated with photovoltaic energy generation that produced the most beneficial evidence supporting this thesis.

After gaining insight on renewable energy sources, research on procurement methods for new building construction projects was done with the intent of assessing how, and to what extent renewable energy sources may have been incorporated into building construction in the past. This research confirmed that although virtually every building construction procurement effort can different from the next, all procurement methods generally originate from either the traditional design-bid-build procurement method or the design-build procurement method. The term sustainable construction was introduced and used to categorize renewable energy sources. Studies showed that establishing the proper procurement system is a necessary prerequisite for incorporating sustainable construction aspects such as renewable energy sources into building construction projects. It was also observed that there is a flawed notion that seems to be prevalent within the building construction community, that sustainable construction aspects and green building practices will always add to overall project costs. Subsequently, sustainable construction techniques and green principles are then more often considered as costly additions to projects rather than initial options to meeting the program requirements. Building on these findings with the intent to disprove this untrue notion, a methodology was then derived to assess the overall benefits of considering sustainable construction and green building principles such as on-site renewable energy systems with original building project procurement efforts as opposed to additions. In order to maximize the benefits that can be obtained by incorporating sustainable features and green principles into new construction projects, these features would need to be incorporated into the planning and procurement phases from the beginning. Previous research suggests that the successful methodology for this study would include establishing the most beneficial procurement strategy, determining the cost drivers and selecting among the options.

Utilizing significant aspects of life cycle costing concepts in combination with principles of the procurement methods researched and summarized, the research methodology that would be used to support this thesis was established. This methodology consisted of four steps; establishing the need; determine the intended objectives; identify the alternatives; identify and quantify the benefits. This methodology was then applied to data from the project procurement effort of a new building project to assess the benefits it may have gained by considering a renewable energy source with its original procurement effort.

By applying the first step of the research methodology, the need for the assessment was first identified. With the project in which this research methodology was applied requiring a LEED Silver Certification, an on-site Photovoltaic Module renewable energy source was considered to help achieve this certification. Since an this on-site renewable energy source was considered in the project, there is a need to assess the benefits that may have been gained by considering this source with the original procurement as opposed to an addition.

After outlining the need for assessment within the project, the intended objectives of the assessment were established. Those intended objectives included identifying cost, schedule and competitive advantages associated with considering a renewable energy source with the original procurement effort of the first phase of the project. Ideally, considering a Photovoltaic Module energy source with the original procurement efforts of the project would save money, time and provide competitive bidding advantages for the general contractor.

Once the need and the objectives are established, the alternatives of when the Photovoltaic Module energy source could have been considered within the procurement process were then established. The first alternative was to consider the Photovoltaic Module System with the original procurement estimate as it had been done in the actual procurement of the first phase of the project. This consideration allowed the procurement team the opportunity to design a steel canopy that would serve as the covered parking required for the project, as well as a supporting base for the photovoltaic module system. In addition to this, the argument can be made that the most significant benefit of the first alternative was the opportunity to trend the costs of the system and acquire the lowest cost for the scope of work.

The second alternative would have been to consider the Photovoltaic Module System at any point after the original procurement effort and design was complete. For this alternative, the reasonable assumption was made that if the Photovoltaic Module System was not considered with the original procurement effort, its construction durations would not be able to be phased into the original schedule. The second alternative of not considering the renewable energy source with the original procurement effort ultimately resulted in additional costs associated with preparing the additional land needed for the system, the separate mounting system, and the additional indirect costs resulting from additional durations to the project.

In terms of competitive advantages gained by considering the renewable energy source from the beginning of the procurement effort, the most significant advantage outside of the LEED contribution and energy reduction would have manifested itself in the form of tax incentives for the owner. Had the owner instead been one from the private sector, tax credits could have been made available for the use of an on-site renewable energy source. The long term savings gained from these tax credits could have been calculated and presented in a well prepared technical proposal to be submitted as a part of the design build bid for the project. However since the owner of the project is the Naval Facilities Engineering Command Washington, a public sector entity that does not pay taxes, these advantages are not present in this case.

All things considered, the research and methodology application presented in this thesis show that there are indeed benefits to be gained for considering sustainable construction and green building principles in the original procurement efforts of new building projects rather than additions later or at the end of procurement efforts. In the application detailed in this thesis, it proved to be more costly to consider a Photovoltaic Module renewable energy system as an addition to the project rather than consider it with the original procurement efforts of the project. The consideration of the renewable energy source after the original procurement effort also took away the ability to phase its construction durations in with the original project construction duration, thus adding to the overall duration of the project. Notwithstanding the lack of more substantial competitive advantages due to the public sector owner of the project assessed in this thesis, considering a renewable energy source with the original procurement effort of a project showed to be more beneficial overall, than considering it as an addition.

6.2 Recommendations

Sustainable features such as renewable energy systems should be considered as an option from the beginning of every project procurement effort, regardless of whether they are a minimum requirement of the owner or not. The negative factors typically associated with these types of sustainable features in new building projects can often times be mitigated by considering them from the beginning of a project with the original design, cost and schedule estimates. Until the construction industry as a whole embraces the thought of sustainable features as options rather than additions, it will continue to fall short of its potential to incorporate these features into its projects.

The methodology and application introduced and applied in chapters four and five of this study, should be used by contractors and future studies to identify and quantify the benefits that were gained on other projects by including a sustainable feature from the beginning as opposed an addition to the project after the original design is complete. In addition to Photovoltaic Module Systems, other sustainable features should be assessed as well. Future studies should also be done on projects that have private owners that would be eligible for more benefits like tax credits for their incorporations of sustainable features.

In the future, by successfully applying the research methodology introduced in this study by contractors on past and present projects, the results of the application could greatly benefit the contractor in future project procurement efforts. It will allow a contractor to illustrate a firm example of past innovations that saved previous clients time and money by incorporating sustainable features into a project from the start. Ultimately however, as it was the case in the application in this study, future studies will produce more evidence encouraging the consideration of sustainable features as options from the start of project procurement and design effort, even if they are not requested by the project owner.

APPENDIX A

THE BASIC SCHOOL PROJECT SOLICITAION

NOTICE OF INTENT TO ADVERTISE
DESIGN & CONSTRUCTION OF THE BASIC SCHOOL
STUDENT QUARTERS PHASE 5, 6, 7 AND 8
MARINE CORPS BASE
QUANTICO, VIRGINIA
SOLICITATION N40080-11-R-0004

This notice does NOT constitute a request for proposal. The Naval Facilities Engineering Command Washington intends to issue a Request for Proposal (RFP) to award a firm-fixed price contract for design and construction of new Student Quarters to house newly commissioned officers undergoing initial training at The Basic School (TBS), Marine Corps Base, Quantico, Virginia.

The project will consist of 4 new Student Quarters of similar scope, as follows:

BASE YEAR: P566 TBS Student Quarters, Phase 5, Quantico, VA
OPTION 1: P567 TBS Student Quarters, Phase 6, Quantico, VA
OPTION 2: P562 TBS Student Quarters, Phase 7, Quantico, VA
OPTION 3: P563 TBS Student Quarters, Phase 8, Quantico, VA

The Government's intent is to award one contract (including Options) for all these facilities. The project includes a base year (FY 2011) for P566 with a construction period of 24 months with 3 project option periods as stated above. The total projected construction costs may exceed $130M, with the 4 facilities in the range of $30M - $50M. The option periods (approximately 24 months each) are expected to be awarded as a phase in process over Fiscal Years 2012 through 2014. Option 1 may overlap the construction period of the base year, and Options 2 & 3 may overlap the construction period of a previously awarded phase.

All facilities will include the following: design and construction of a new multi-story facility not to exceed approximately 92,268 SF. Most facilities will support billeting for 250 or fewer Marine Officers undergoing initial training at The Basic School. Each facility shall be handicap accessible and provide rooms in either a modified 2+0 configuration or 1+1E configuration (250 rooms maximum / 125 modules maximum), with semi private bathrooms and walk in closets. Built in equipment includes modular gear storage rack systems, weapons lockers, and wash racks. Community and service core areas consist of laundry, lounges, admin offices, housekeeping areas and restrooms. Electrical, mechanical, telecommunications, and fire protection systems are required. Compliance with DOD Antiterrorism / Force Protection criteria are included. Facilities will be minimum LEED Silver rating certified from the USGBC. Facilities shall comply at minimum with EPACT 2005- including 30% or greater energy reduction below ASHRAE 90.1 Guidelines".

Exterior supporting facilities work includes site and building utilities and connections, parking, sidewalks, roadway access. As part of site development, wetlands mitigation and environmental mitigation will be performed. Project also includes selective demolition of some existing buildings. The design will undergo stringent local, State, and Federal preservation reviews as part of the design/build process.

Technical Factors and Price are considered equal in importance to each other. The Government reserves the right to reject any or all proposals at any time prior to award, to negotiate with any or all Offerors, and to award to the Offeror submitting the proposal determined by the Government to be the most advantageous. OFFERORS ARE ADVISED THAT AN AWARD MAY BE MADE WITHOUT DISCUSSIONS. Therefore, proposals should be submitted initially on the most favorable terms. Offerors should not assume that they will be contacted or afforded an opportunity to qualify, discuss or revise their proposals prior to award.

The forthcoming solicitation is expected to be unrestricted, best value, and two-step. The Government is expected to begin formal solicitation on or about late November/early December 2010, via the NECO website. Offerors can view and/or download the solicitation, and any attachments, at https://www.neco.navy.mil when it becomes available.

The Government does not wish to receive any questions or responses regarding this “Notice of Intent”, and the Government does not intend to respond to any correspondence that might be submitted. Further instructions and other information will be provided with the forthcoming “formal solicitation”.

REFERENCES

109th Congress of The United States of America. (2005, January 4). Energy Policy Act 2005. Washington, D.C., USA.

Alibaba. (2012). *Solar Ground Mounting Bracket*. Retrieved September 2012, from Alibaba.com: http://www.alibaba.com/product-gs/507264240/Solar_Ground_Mounting_Bracket.html

Arizona Department of Transportation Intermodal Transportation Division. (2007). *Design-Build Procurement and Administration Guide.* Phoenix, AZ: ADOT Construction Group.

Bakker, M., Zondag, H., Elswjik, M., Strootman, K., & Jong, M. (2003). Performance and Costs of a Roof-Sized PV/Thermal Array Combined with A Group Coupled Heat Pump. *Solar Energy*, 331-339.

Bodie, Z., Treussard, J., & Willen, P. (2007). *The Theory of Life-Cycle Saving and Investing.* Boston, MA.: Federal Reserve Bank of Boston.

BP. (2007). Gaining on The Grid. *Frontiers*, pp. 1-6.

Bureau of Labor Statistics U.S. Department of Labor. (2012). *Average Energy Prices in Miami-Fort Lauderdale.* Atlanta, Ga: Department of Labor.

Community Center Energy. (2011). *Solar Energy*. Retrieved October 2012, from http://www.communityenergyinc.com/education/renewable-energy101/

Connecticut's Energy Efficiency Programs. (2009). Energy-Efficiency and Renewable-Energy Tax Incentives. Connecticut.

Dashony. (2011). *Polycrystalline Solar Panels.* Retrieved July 2012, from http://www.dashony.com/Polycrystalline%20Solar%20Panels.php

Dhillon, B. (1989). *Life Cycle Costing.* New York, NY: Gordon and Breach Science Publishers.

Ding, G. (2008). Sustainable Construction - The role of Environmental Assessment Tools. *Journal of Environmental Management*, 451-464.

European Photovoltaic Indistury Association. (2012). *Global Market Outlook for Phovoltaics Until 2016.* Brussels, Belgium: Renewable Energy House.

Gluch, P., & Baumann, H. (2004, May). The Life Cycle Costing (LCC) Approach: A Conceptual Discussion of Its Usefullness for Environmental Decision-Making. *Building and Environment*, pp. 571-580.

Goetzberger, A., Hebling, C., & Schock, H.-W. (2003). Photovoltaic Materials, History, Status and Outlook. *Materials Science and Engineering* , 1-46.

Goetzberger, A., Luther, J., & Willeke, G. (2002, October). Solar Cells: Past, Present, Future. *Solar Energy Materials and Solar Cells*, pp. 1-11.

Hale, D., Shrestha, P., Gibson, G., & Migliaccio, G. (2009). Emperical Comparison of Design/Build and Design/Bid/Build Project Delivery Methods. *Journal of Construction Engineering Management*, 579-587.

Hazardous Waste and Toxics Reduction Program. (2002, October). *Cost Analysis for Pollution Prevention.* Retrieved July 2012, from http://www.greenbiz.com/sites/default/files/document/CustomO16C45F7762.pdf

Hrayshat, E. (2009). Viability of Solar Photovoltaics as an Electricity Generation Source for Jordan. *Renewable Energy*, 2133-2140.

Kellog, W., Nehrir, M., Venkataramanan, G., & Gerez, V. (1998). Generation Unit Sizing and Cost Analysis for Stand-Alone Wind, Photovoltaic and Hybrid Wind/PV Systemd. *IEEE Transactions on Energy Conversion EC*, 70-75.

Kim, D., Gabor, A., Yelundur, V., Upadhyaya, A., Meemongkolkiat, V., & Rohatgi, A. (2003). String Ribbon Silicon Solar Cells With 17.8% Efficiency. *Photovoltaic Energy Conversion* (pp. 1293-1296). Atlanta, Ga.: University Center for Excellence in Photovoltaic Res. & Educ.

Langdon, D., Matthiessen, L., & Morris, P. (2007). *The Cost of Green Revisited: Reexamining the Feasibility and Cost Impact of Sustainable Design in the Light of Increased Market Adoption.*

Lopes, L., & Lienhardt, A.-M. (2003). A Simplified Nonlinear Power Source for Simulating PV Panels. *Power Electronics Specialist Conference* (pp. 1729-1734). Montreal, Canada: Department of Electrical & Computer Engineering, Concordia University.

Love, P., Skitmore, M., & Earl, G. (2010, October 21). Selecting a Suitable Procurement Method for a Building Project. *Construction Management and Economics*, pp. 221-233.

McMaster, H. (1989). *Patent No. 4,872,925.* Woodville, Ohio.

Molenaar, K., Songer, A., & Barash, M. (1999). Public-Sector Design/Build Evolution and Performance. *Journal of Engineering Management*, 54-62.

Mounting Systems. (2012). *Omega Open Terrain.* Retrieved August 2012, from http://www.mounting-systems.us/omega-open-terrain-mounting-system.html

Nieuwlaar, E., & Alsema, E. (1997). Environmental Aspects of PV Power Systems. *Netherlands Organization for Energy and the Environment*, (pp. 1-45). CH Utrecht, The Netherlands.

Oliver, M., & Jackson, T. (2000, November). The Evolution of Economic and Environmental Cost for Crystalline Silicon Photovoltaics. *Energy Policy*, pp. 1011-1021.

Palaneeswaran, E., & Kumaraswamy, M. (2000). Contractor Selection for Design/Build Projects. *Journal of Construction Engineering Management*, 331-339.

Perlin, J. (2004). *The Silicon Solar Cell Turns 50.* Washington, D.C.: National Renewable Energy Laboratory.

Plug Into The Sun. (2012). *Solar Power.* Retrieved September 2012, from http://www.plugintothesun.co.uk/images/howitworks_diag.jpg

Rehman, S., Bader, M., & Al-Moallem, S. (2007). Cost of Solar Energy Generated Using PV Panels. *Renewable and Sustainable Energy Reviews*, 1843-1857.

Renewable Energy Policy Network for the 21st Century. (2011). *Renewables 2011 Global Status Report.* Paris, France: Ren21 Secretariat.

Renewable Energy World. (2012). *News*. Retrieved August 2012, from Geothermal Energy Production: http://www.renewableenergyworld.com/rea/tech/geoelectricity

Rwelamila, P., Talukhaba, A., & Ngowi, A. (2000). Project Procurement Systems in the Attainment of Sustainable Construction. *Sustainable Development*, 39-50.

Safer Wholesale. (2012). *230 Watt Solar Panel 24 Volt PV Module*. Retrieved October 2012, from Saferwholesale.com: http://www.saferwholesale.com/230-Watt-Solar-Panel-24-Volt-PV-Module-p/aim-pv230poly.htm?utm_source=google+product&utm_medium=versafeed&utm_term=aim+pv230poly&utm_content=230+watt&utm_campaign=home+garden+household+supplies+pest+control+fly+swatters&v_

Shah, A., Torres, P., Tscharner, R., Wyrsch, N., & Keppner, H. (1999, July 30). Photovoltaic Technology: The Case for Thin-Film Solar Cells. *Science*, pp. 692-698.

Sharp. (2010). *Solar Electric Supply.* Retrieved 2012 August, from http://www.solarelectricsupply.com/Solar_Panels/Sharp/NU-U240F1.html

Singletary, M. (2006). *Assessing the Financial Feasibility of Implementing Wireless Technologies for Construction Management.* Tallahassee, FL: Florida State University.

Solar, O.-l. (2012). *Online Solar*. Retrieved October 2012, from http://www.mrsolar.com/content/photovoltaic_effect.php#.UHmOSPv-3Tc

Swanson, R. (2009, May 15). Photovoltaics Power Up. *Science*, pp. 891-892.

The National Renewable Energy Laboratory. (2004, January). PV FAQs. Washington, D.C., USA.

The Tax Incentives Project. (2011). *Businesses*. Retrieved October 2012, from On-Site Renewables Tax Incentives: energytaxincentives.org/business/renewables.php#solar

Trigon General Contractors & Construction Managers. (n.d.). Points of Value of the Construction Management Method. Tulsa, OK, USA.

Turner, J. (1999). A Relizable Renewable Energy Future. *Science*, 687-689.

U.S. Department of Energy. (2011, August 12). *Energy Basics*. Retrieved September 2012, from Energy Efficiency & Renewable Energy: http://www.eere.energy.gov/basics/renewable_energy/types_silicon.html

U.S. Energy Information Administration. (2010). *Electric Power Annual, 2010.* Washinton, D.C.: U.S. Energy Information Administration.

U.S. Energy Information Administration. (2012). *Electric Power Monthly.* Washington, D.C.: U.S. Department of Energy.

U.S. Energy Information Administration. (2012). *October 2012 Monthly Energy Review.* Washington, D.C.: U.S. Energy Information Administration.

U.S. Energy Information Administration. (2012, April 19). *Solar Explained, Photovoltaics and Energy*. Retrieved August 2012, from http://www.eia.gov/energyexplained/index.cfm?page=solar_photovoltaics

U.S. Energy Information Administration. (2012). *Solar Photovoltaic Cell/Module Shipments Report.* Washington, D.C.: U.S. Department of Energy.

U.S. Green Building Council, Inc. (2009). LEED 2009 for New Construction and Major Renovations. Washington, D.C., USA.

Walker, G. (2004). Cascaded DC-DC Converter Connection of Photovoltaic Modules. *IEEE Transactions on Power Electronics*, 1130-1139.

Wenham, S., Green, M., Watt, M., & Corkish, R. (2007). *Applied Photovoltaics.* Sterling, VA: Earthscan.

Zhejiang Trunsun Solar Co., Ltd. (2011). *90w Monocrystalline Solar Panel.* Retrieved July 2012, from http://www.tradevv.com/chinasuppliers/trunsun_p_865f0/china-90w-Monocrystalline-Solar-Panel.html

BIOGRAPHICAL SKETCH

The author graduated from Florida State University with his Bachelor of Science in Civil Engineering in 2009. While earning his undergraduate degree, he worked in an earthquake engineering lab in Tallahassee, Florida performing research on blast loads on vertical structures under the guidance of John Walsh, PhD. The author also worked as a Field Engineer with PCL Construction Company in Orlando, Florida as an undergraduate student. As a Field Engineer, he coordinated field activities and aided in construction scheduling. After earning his bachelor's degree, the author then worked as an Engineer with Kiewit in Atlanta, Georgia for two years. As an Engineer he was responsible for all field operations for sub and above grade intake structures. In the spring of 20011, the author resigned in good standing with Kiewit to pursue his Masters of Science in Civil Engineering from Florida State University. While earning his graduate degree, the author worked as an Estimator with Hensel Phelps Construction Company in Washington, D.C. As an estimator, the author compiled estimates for over 5 million dollars' worth of new construction work. He built estimates for design build and fully designed competitive bid contract proposals that included both self-performed and subcontracted scopes of work. He will graduate with his Masters in Civil Engineering in December of 2012.