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COMPARATIVE COST-BENEFIT ANALYSIS OF RENEWABLE ENERGY RESOURCE TRADE OFFS FOR MILITARY INSTALLATIONS

by

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The purpose of this research is to analyze the framework the Department of Defense (DoD) is undertaking with renewable energy and energy efficiency initiatives across military installations to determine the potential savings the United States Marine Corps (USMC) and DoD could realize by managing investments in renewable energy in all installations as a portfolio of opportunities, maximizing benefits and sustainability. In addition, this study evaluates renewable energy resource technologies that have long-term the best economic stability and least challenges for future growth on military installations. It also describes how the challenges of human behavior, budget cuts, financing approaches and regulations may play a big part in harnessing the optimal benefit from renewable energy resources.

This study analyzes how comprehensive knowledge management in combination with renewable energy efforts across installations can capitalize DoD cost savings for long-term stability. This research recommends DoD take a comprehensive strategy approach through risk management analysis, information sharing, and better business practices.

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TABLE OF CONTENTS

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LIST OF FIGURES

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LIST OF TABLES

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LIST OF ACRONYMS AND ABBREVIATIONS

ARRA	American Recovery Reinvestment Act
BCA	Budget Control Act
BOS	Balance of Systems
C4ISR	Command, Control, Communication, Computers, Intelligence, Surveillance, and Reconnaissance
DOE	Department of Energy
DSIRE	Database of State Incentives for Renewable and Efficiency
ECIP	Energy Conservation Investment
EIA	Energy Information Administration
EO	Executive Order
ESPC	Energy Savings Performance Contract
GAO	Government Accountability Office
KM	Knowledge Management
LCC	Life Cycle Costs
NREL	National Renewable Energy Laboratory
NZEI	Net Zero Energy Initiative
PPA	Power Purchasing Agreement
PV	Photovoltaic
UESC	Utility Energy Service Contract
WEC	Wave Energy Converter

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I. INTRODUCTION

A. PURPOSE

The purpose of this study is to analyze the framework the Department of Defense (DoD) is undertaking with renewable energy and energy efficiency programs to determine an optimal sustainability with the best return on investment (ROI). This report assesses two military installations: the Marine Corps Air Station in Miramar, California, and the Marine Corps base in Kaneohe Bay, Hawaii. The data for these Marine Corps installations is readily available through reports from the National Renewable Energy Laboratory (NREL) of the U.S. Department of Energy (DOE). These installations are chosen to show a variety of environmental effects in different areas. The objective is to assess the short-term and long-term issues associated with the energy industry that may impact renewable energy future decisions. Assessing the renewable energy industry will assist in focusing on the right sustainable renewable energy resources for Marine Corps installations. Sustainability should be the key, but the policies and regulations have different outcomes in each of the states. The study analyzes the Net-Zero Energy Installation (NZEI) assessments that DoD and DOE jointly address to determine the optimal ROI based on its particular climate and environment utilizing a portfolio analysis approach.

DoD is setting the precedent with energy efficiency initiatives. Military forces have been dependent on fossil fuels for energy consumption for far too long. Energy security is a defense-wide concern that requires a new strategy. The strategy should drive the budget not the budget driving the strategy; however, DoD has a limited budget and renewable energy can be costly depending on what federal, state or local regulations (or policies) are binding.

Energy efficiency and renewable energy through the net-zero concept is a DoD strategy shift towards creating energy security. This paradigm shift will require a comprehensive strategy, risk management, better business practices and time to accomplish the long-term sustainability that the military requires.

Renewable energy is not something new, but it has become more attractive due to the recent spike in oil prices and the unrest in many of the oil producing regions of the world. The three specific renewable energy sources discussed in this study are geothermal, wind, and solar power. The objective is to analyze the resources in a holistic approach to reap long-term benefits and sustainability. The supply and demand for these resources determines how attractive they are now—and how attractive they will become in the near future.

B. RESEARCH OBJECTIVES

This study assesses past historical economic challenges that may pose a threat in today's industry. Our objectives are to:

1. Provide an overview of the challenge that DoD faces with energy security and dependence on fossil fuel for energy.
2. Provide an overview of the DoD net-zero initiative for installations.
3. Provide an overview of the Energy Efficiency/Renewable Energy Directives mandating federal agencies to act.
4. Provide an overview of the financing approaches available and which approaches each military service utilizes for its energy efficiency projects.
5. Provide an overview of three renewable resources that have potential energy savings with long-term stability located in specific regions to benefit surrounding DoD installations.
6. Analyze the state of the DoD budget and its effects on the renewable energy initiatives with the upcoming Budget Control Act (BCA) sequestration.
7. Analyze the ROI for a renewable energy portfolio.
8. Provide recommendations for better business practices in approaching renewable energy resources for long-term stability and economic growth.

C. RESEARCH QUESTIONS

- Are there cost savings in building a renewable energy portfolio? This question addresses objectives 1, 2, 3, and 4.
- Can such a concept as renewable energy sustainability be achieved, and can DoD reach sustainable long-term energy efficiency? This question addresses objectives 1, 2, 7, and 8.
- Is the renewable energy industry on a sustainable economic development or is the industry only expecting to thrive for the short run? This question addresses objective 5.
- Can DoD sustain the current energy efficiency initiatives with the upcoming BCA sequestration? This question addresses objectives 6 and 8.

D. SCOPE

This study looks at the main policies governing the DoD renewable energy and energy efficiency mandates. It also looks at the different financing approaches used by each military service. In addition, the study analyzes the industry for wind, solar, water, geothermal, biomass and hydroelectric renewable energy resources and their optimal strategic location. An optimal strategic location is an area where a renewable energy resource can perform at capacity. This study examines the upcoming BCA sequestration and the effects it may have on the renewable energy and energy efficiency effort. Furthermore, it looks at cost-benefit analysis models to determine an optimal portfolio. Lastly, the study provides recommendations for the way DoD is implementing its renewable energy initiatives.

E. STUDY BENEFITS

DoD is taking action on energy initiatives across all services; however, the installation-by-installation approach can be capitalized by comprehensive information sharing, and combining renewable energy efforts for an optimal cost benefit across each service. This study shows how a comprehensive effort—as opposed to the current ongoing renewable energy resource efforts—can provide DoD cost savings for long-term sustainability on a larger scale.

F. METHODOLOGY

This study can be broken down into four phases. The first phase addresses the overall background and understanding of all subjects involved. The data for the first phase is gathered from DoD energy initiatives from 2009, NREL NZEI assessments, and current DoD budget and financing challenges. Then, the second phase outlines a number of renewable energy resources that benefit military installations, by industry outlook. It also builds on challenges in human behavior and business practices that shape the future of renewable energy at military installations. The third phase deals with the analysis of data in a GAO report from 2009 collected from different military installations that implemented renewable energy projects on a small scale. This data is also compared to a life cycle cost model for the right renewable energy resources in the same areas, by researching the climate changes in each area to determine the optimal location for each renewable resource on a larger scale. The last phase recommends changes for an optimal portfolio approach in each area considering human behavior factors and a better business practices.

G. ORGANIZATION

This study is presented in five chapters. The first chapter introduces the focus of the study. It presents the questions and areas of interests that are covered in the study. The second chapter addresses the problem and briefly goes through the background of the areas involved or affected by the process. The third chapter provides a literature review of renewable energy resources, human behavior and better business practices. The fourth chapter discusses the analysis of the data and the findings. Finally, the last chapter sums up the study with a conclusion and further recommendations for future research.

II. PROBLEM AND BACKGROUND

A. RENEWABLE ENERGY AND ENERGY EFFICIENCY

To understand the concepts undertaken in this research, renewable energy and energy efficiency are defined. Renewable energy comes from natural sources, those that are naturally replenished by the planet, such as rain, sunlight, wind, geothermal heat and tides. Energy efficiency can be defined as obtaining more with limited resources. In a system, it is the ratio of energy input compared to the output. A system can be analyzed at different levels. For example, someone can think of the world system in the macro sense for the environment as a whole, or in the micro aspect of a building's air conditioning unit. The Energy Information Administration (EIA) adds an additional layer to this concept and defines energy efficiency as energy intensity which "…is the ratio of energy consumption to some measure of demand for energy services—what we call a demand indicator" (EIA, n.d.). This is the consumption of a certain kind of energy to the total demand for all kinds of energy.

B. ENERGY SUPPLY AND DEMAND OVERVIEW

Researchers across the globe have tried to lessen the demand in energy consumption by coming up with innovative ways of offsetting dependency. In the 1970s when the first energy crisis hit the economy, the United States realized it needed to offset its dependence on foreign energy. Energy is still in great demand, but what is the best way to get it without imposing great risks to the environment and the people who live in it? According to Allcott and Greenstone (2012), there is an energy efficiency gap created by investment inefficiencies in our economy. It is described as a wedge: one end is the level of minimizing cost, and the other end is the actual level achieved. An issue is the current methodologies used through engineering analysis to calculate the energy cost savings. They do not show the unobserved costs or the benefits that energy efficiency investments have (Allcott and Greenstone, 2012). Like Allcott and Greenstone (2012), Arimura, Li, Newell, and Palmer (2011) describe similar missing aspects in the analysis that evaluate the cost effectiveness of utility demand side management programs.

The U.S. is the biggest consumer and importer of oil. In 2010, 22 percent of U.S. consumption was supplied by net imports. Figure 1 shows the steady incline of U.S. energy consumption and the offset of production and imports required to sustain the country's energy use.

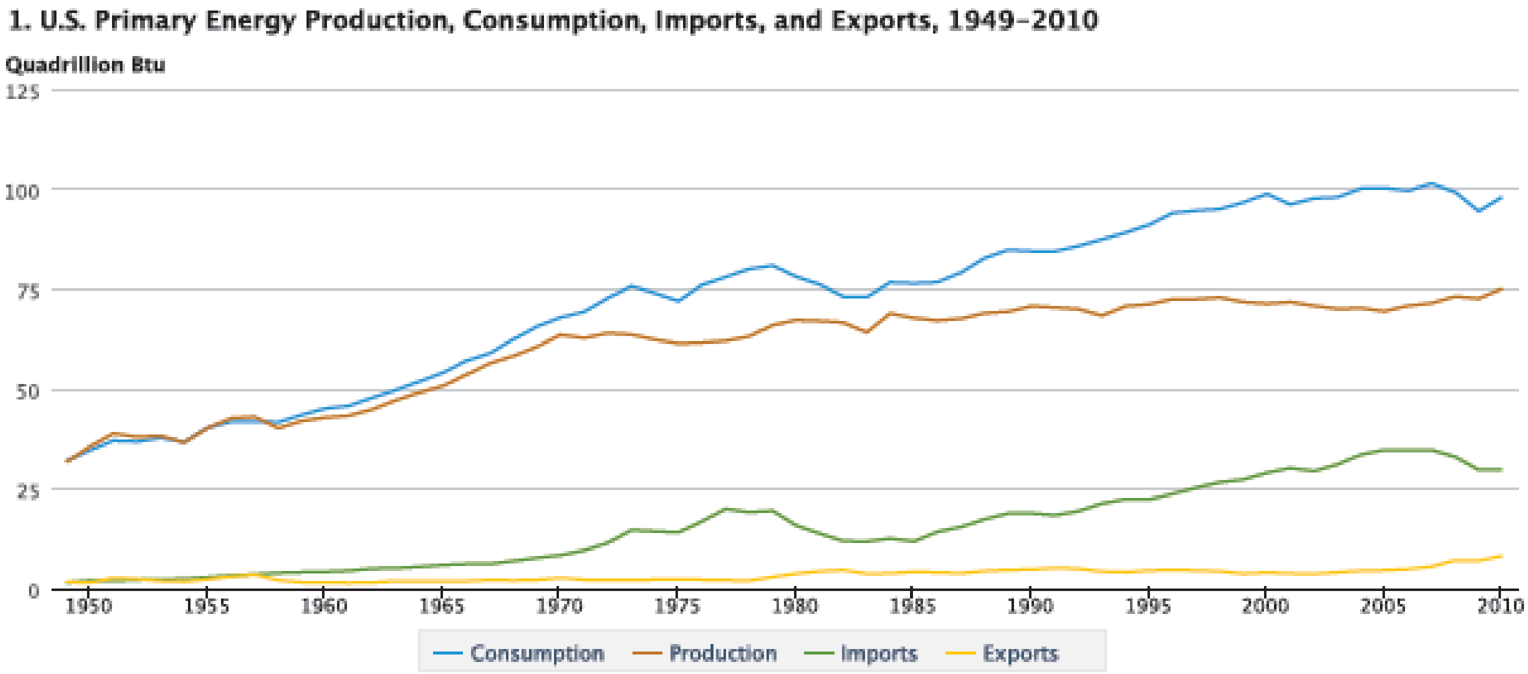

Figure 1. U.S. Primary Energy Production, Consumption, Imports and Exports 1949–2010 (From EIA, 2010)

C. CURRENT MEASUREMENTS USED IN DETERMINING COST-EFFECTIVE SAVINGS

There are many quantitative formulas that take certain variables into consideration when estimating the cost effectiveness of energy efficiency. The basic approach to calculating the best rate of return or the net present value of an investment is by discounting a cash flow (in this case, the cost of the energy resource) by the inflation rate and adding any capital up-front costs. However, this method does not take into account any risk factors contributed from the type of financial funding utilized, economic industrial factors, risks specific to the type of resource, and (for the military) the installation commander's energy cost priorities. Additional quantitative methods are used to determine the savings and ROI for renewable energy and energy efficiency programs.

D. DEPARTMENT OF DEFENSE ELECTRIC GRID CHALLENGES

The DoD installations with mission critical infrastructure—such as Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) —rely heavily on commercial utility grids for power. In case of a power outage, each installation has backup generators to provide a limited power capacity for the short term. However, the backup power supply will not provide the sustainability required for the long term. This becomes a matter of national security if the military forces are unable to communicate high-value information at a moment's notice. DoD declared that prior assumptions about using commercial power grids to support military installation are no longer acceptable for ongoing critical missions. In the event of a natural disaster, brown-out or terrorist attack, military installations will be an integral part of the Homeland Defense mission—at the very least through command and control in rescue/recovery missions, aide and resources. "DoD must take a more rigorous risk-based approach to assuring adequate power to its critical missions" (More Fight, 2008, p. 53).

1. The Grid

An electricity network is also known as an electric grid. Three main factors take place in a grid: electricity generation, electric power transmission and electricity distribution. It starts with electricity generation from a main power plant. The electric power transmission takes place traveling through transmission lines (typically 34 to 500Kv). Local utilities then take the transmission voltage down to a distribution voltage (under 34Kv) and deliver it to residential, commercial or industrial customers. At the customer location, the voltage is transformed to its final voltage (120/240v for home use and 240/440v for commercial use) by the local utilities.

Conventional power grids are now getting changed over to smart grids. Smart power grids have a three-system focus: infrastructure system, management system and protection system. The smart grid is on digital metering system that raises many privacy violation concerns. Essentially, it will track personal habits that may be considered a privacy violation by some.

Micro-grid networks would prevent total loss of power from occurring even with a national grid failure. The whole concept is a network of enhancements. It works when energy efficient facilities are generating their own power and are linked to other smaller networks (or islands of power) to enhance the entire network. It makes the facilities less vulnerable to blackouts.

E. DEPARTMENT OF DEFENSE NET-ZERO INITIATIVE

“Military installations are almost completely dependent on a fragile and vulnerable commercial power grid, placing critical military and homeland defense missions at unacceptable risks of extended outage” (More Fight, 2008, p. 3). The Department of Energy (DOE) teamed with National Renewable Energy Laboratory (NREL) to assess different military service installations and provide technical expertise on base-wide net-zero energy goals, in an effort to transform them to Net-Zero Energy Installations (NZEI). Net-zero installations produce as much energy as they consume across the installation (Optimize Deployment, n.d.). Each service developed their own pilot programs to meet the net-zero initiative.

After NREL completed their net assessments and renewable energy projects at some military installations, they concluded that net-zero installations may not be as effective as initially expected. Net-zero may be an effective way to island the grid of a specific installation (as a micro grid) to ensure that any outages will not be critical to the mission. NREL reports that “for DoD an NZEI assessment might not make the best sense economically as compared to using a portfolio approach to implementing agency-wide energy efficiency and renewable energy projects” (Lessons Learned, 2011, p. 23). NREL concluded that a portfolio approach can be exercised to achieve better outcomes.

1. Regulation, Policy Directives and Incentives Overview

Since the energy crisis in the 1970s, the U.S. has enacted many regulations and policies to promote the importance of energy efficiency. In reference to the Database of State Incentives for Renewable and Efficiency (DSIRE), across all states there are currently a total of 385 rules, regulations and policies for renewable energy (“Rules, Regulations and,” 2012). The U.S. also provides incentives, rebates, grants, tax cuts and more to encourage energy efficiency. The DSIRE database reports a total of 1,120 incentives across all the states combined (“Financial Incentives for,” 2012). States differ in the types of incentives available for use.

The Energy Act of 2005, Executive Order (EO) 13423, and the American Recovery and Reinvestment Act (ARRA)—to name a few—are some legislative enactments for energy efficiency and renewable energy that drive the energy goals for energy security in DoD. According to the Energy Act of 2005, “all federal agencies [are] to consume 3 percent of renewable energy from 2007 through 2009 with an incremental increase thereafter to 7.5 percent by fiscal year 2013” (Energy Policy Act, 2005). The EO 13423 required each agency to report information on energy use, costs and efficiencies to the President (*Department of Defense*, 2009). The ARRA provided operations and maintenance funds for defense facilities sustainment applied toward energy efficiency projects (*Department of Defense*, 2009).

F. FINANCING CHALLENGES FACING DEPARTMENT OF DEFENSE

In a recent Government Accountability Office (GAO) report (Renewable Energy, 2012), DoD acknowledges the challenges it faces with financing renewable energy. DoD launched numerous pilot projects in concert with the Department of Energy (DOE) across all services to determine the best cost-benefit investment for each site where the study was conducted. Renewable energy incentives were established; however, there were differences in the financing approaches that each service utilized, and each approach had a different effect on maximizing benefits at local installations (Renewable Energy, 2012). The question then becomes: is each local installation getting the best rate of return on each renewable energy investment using decentralized efforts across all services?

1. Financing Approaches

There were 454 projects listed on renewable energy initiatives across DoD installations throughout all services, and they ranged in cost. Out of those projects, 189 initiatives were under one million dollars, and 138 initiatives were one million dollars or more (Reich et al., 2010). There are 127 initiatives where the DoD installations did not provide cost information. Each of the services utilized their own financing approaches. There is a concern that up-front annual appropriations are not the right funds for larger initiatives such as wind power.

a. Military and Construction Appropriations

These appropriations include the Energy Conservation Investment Program (ECIP). This funding is mainly used for annual military construction in temporary or permanent facilities. Real property can also be financed through these appropriations.

b. Operations and Maintenance Appropriations

Construction projects within the threshold amount of $750,000 or less are authorized. Facility renovations can be financed through these appropriations, which may include energy efficiency repairs.

c. Other Appropriations

Congress has other direct appropriations that DoD uses for energy renewable projects, such as the American Recovery and Reinvestment Act of 2009 and the Environmental Security Technology Certification Program.

d. Energy Savings Performance Contract (ESPC)

One form of alternative financing is a contract between two entities: the federal agency and the energy company. Audits are performed by the service company to provide an assessment of the best savings for an installation.

e. Utility Energy Service Contract (UESC)

Another form of alternative financing is when the cost of capital is financed by the utility and repayment of the finance comes over the life of the contract. The difference from the ESPC is that the contractor is not required to guarantee savings to repay all capital costs.

f. Power Purchase Agreement (PPA)

This is an agreement between installation and private-sector provider to purchase renewable energy. DoD refers to these types of contracts as Energy Services Contracts.

g. Enhanced-Use Lease

This approach "allows the military services to out-lease available non-excess real property to the private sector in return for cash or in-kind consideration" (Renewable Energy, 2012, p. 47).

h. Other Alternative Financing

There are three other alternative approaches worth noting: in the first, the secretary of a military department conveys utility systems (that are owned by DoD) to a utility company; in the second, the electricity generated on installation is sold to the utility; and in the third, there is an agreement for lease-to-own facilities with the private sector at the contractors expense. Other alternative approaches outlined are:

(1) Convey Utility System to Utility Company. A form of compensation for this type of financing is savings from reduced rates.

(2) Sell Electricity to a Utility. The proceeds would go into an appropriations fund to recycle for other military departments to utilize on energy related projects.

(3) Lease-to-own Energy Production Facilities. Once the lease is complete it belongs to the Federal Government.

2. Financing Approaches to Renewable Energy

In fiscal year 2011, the main DoD financing approach for renewable energy was appropriations—at 85 percent across installations. Only 15 percent of installations used alternative-financing approaches (as shown in Table 1). Is DoD underutilizing alternative means to financing? There are many financial approaches that can be utilized; however, they have to be suitable for that specific installation, taking into consideration factors such as land availability for an enhanced-use lease (Renewable Energy, 2012). The financing approach is also off the decision table if it is not available to the installation.

With a comprehensive policy and information sharing across all the services, installations can be equipped to make better cost-benefit analysis decisions for projects. The Return on Investment (ROI) would be much greater if DoD centralized its renewable energy efforts across all services with a comprehensive policy—in a centralized effort versus a decentralized one.

Table 1. Financing Approaches Used for Renewable Energy on Military Installations in Fiscal Year 2011 (From Renewable Energy, 2012)

Financing approach	Army	Navy	Marine Corps	Air Force	Total
Up-front appropriations	158	160	71	120	**509**
Annual military construction appropriations	42	19	7	19	**87**
Energy Conservation Investment Program	29	38	26	21	**114**
Operation and Maintenance appropriations	41	57	32	64	**194**
American Recovery and Reinvestment Act of 2009	27	34	4	8	**73**
Other up-front appropriations	20	12	2	9	**43**
Alternative financing	26	23	20	19	**88**
Energy Savings Performance Contract	15	10	5	8	**38**
Utility Energy Service Contract	8	10	13	3	**34**
Power purchase agreement	2	1	1	7	**11**
Enhanced-use lease	1	0	0	1	**2**
Other alternative-financing approaches	0	2	1	0	**3**
Total (all projects)	184	183	91	139	597

3. Benefits Versus Drawbacks/Risks

DoD surveyed different installations to gather the information provided in Table 2 and Table 3. There are both benefits and risks (or drawbacks) to purchasing renewable energy across all installations, depending on which approach is utilized. There are federal, state, and local regulations that impede some financing approaches. A concerted effort to incorporate information flow and policy will circumvent any differences between services if a cost analysis can demonstrate that two different services in close proximity can benefit from the same renewable source.

Table 2. Benefits of Financing Approaches (From Renewal Energy, 2012)

	Up-front appropriations			Alternative financing approaches			
	Annual military construction appropriations	Energy Conservation Investment Program	Operation and maintenance appropriations	Energy Savings Performance Contract	Utility Energy Service Contract	Power purchase agreement	Enhanced-use lease
Benefits							
Contractor may be eligible for certain incentives that can help make a project more cost-effective				**X**		**X**	
Limited or no agency up-front capital is required, can finance project over time while getting benefit of the project immediately				**X**	**X**	**X**	**X**
Developer operates and maintains equipment or operations and maintenance can be added to contract				**X**	**X**	**X**	**X**
Known long-term electricity price allows service to better budget for energy costs						**X**	
Contractor guarantees energy savings				**X**			
No additional private sector financing charges makes project cheaper for the government in the long term	**X**	**X**	**X**				
Installation or military service receives full savings from implementing the project immediately rather than after financing is repaid	**X**	**X**	**X**				
Funding is specifically for energy projects, so less competition than for other sources		**X**					
Limited paperwork requirements to request funding		**X**	**X**				
Generally the contract is for purchasing energy, so the government does not have to pay the contractor if the project does not produce energy, depending on the terms of the contract						**X**	**X**
Contract is with the local utility, with which the installation already has an established relationship					X		

Table 3. Drawbacks or Risks of Financing Approaches (From Renewal Energy, 2012)

	Up-front appropriations			Alternative financing approaches			
	Annual military construction appropriations	Energy Conservation Investment Program	Operation and maintenance appropriations	Energy Savings Performance Contract	Utility Energy Service Contract	Power purchase agreement	Enhanced-use lease
Drawbacks or Risks							
Projects are generally more costly to the government due to private financing				**X**	**X**	**X**	**X**
Limited federal sector experience in implementing the approach; installation officials may not be familiar with approach						**X**	**X**
Approach may not be available for all facilities or installations				**X**	**X**		**X**
Cannot ordinarily leverage state tax incentives because project is owned by the federal government	**X**	**X**	**X**		**X**		
Some key incentives that make projects financially viable are ending soon or public funding for such incentives is limited				**X**		**X**	**X**
Installation is responsible for operation and maintenance of equipment, but personnel may not have needed expertise	**X**	**X**	**X**				
Lengthy process to receive project approval and funding	**X**	**X**	**X**				
Contracts are often complex, challenging, or time consuming to develop and implement				**X**		**X**	**X**
Concerns with, or difficulties in, using approach specifically for renewable energy				**X**	**X**	**X**	**X**
Projects require extensive or time-consuming analysis to develop		**X**				**X**	**X**
Limited funding available and project must compete for funding	**X**	**X**	**X**				
Limits on total cost of project established in law, so approach can only be used to fund small projects that do not generate much renewable energy			**X**				
Installation or military service does not receive full amount of savings from the project until the contractor is repaid				**X**	**X**		
Termination of contract may require payment to contractor				X	X	X	X

G. DOD BUDGET CONSTRAINTS OVERVIEW

DoD has already implemented a reduction in all spending areas and policy makers believe that this reduction diminishes capability and puts U.S. defense at risk. Another round of budget cuts will be forced on DoD if the BCA sequestration takes place. Policy makers report, “The inability of the Joint Select Committee on Deficit Reduction to find $1,200,000,000,000 in savings will trigger automatic funding reductions known as ‘sequestration’ to the Department of Defense of $492,000,000,000 between 2013 and

2021 under section 251A of the Balanced Budget and Emergency Deficit Control Act of 1985 (2 USC 901a)" (S. Res. 3254., 2012).

If the joint committee is unable to produce a deficit reduction plan, then there will be automatic budget cuts (as shown in Figure 2) for DoD across the board. First, the interest savings on the budget will come from an 18 percent discount factor, and once discounted, it is divided by the amount of years the sequester is set for (in this case it is nine years). Overall, sequestration will decrease the DoD budget by 1,029 billion over the next 10 years ("The Budget Control," 2012).

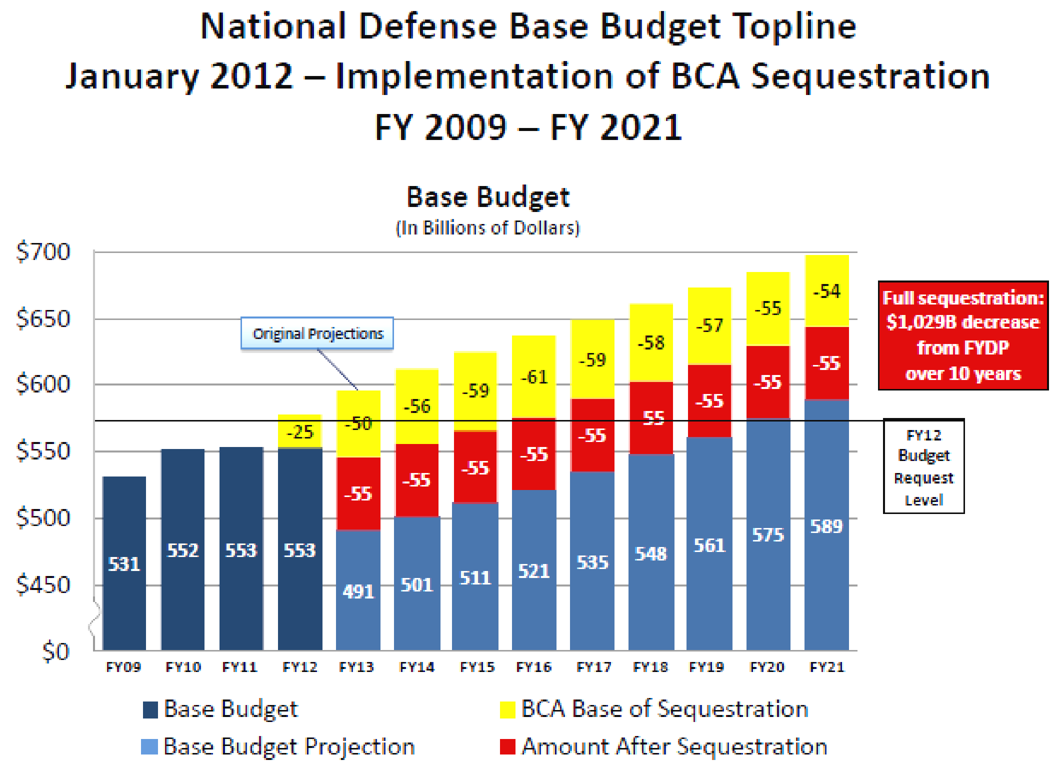

Figure 2. Budget Control Act Sequestration Outlook (From Sequestration Budgetary, 2012).

No one can ignore the fact that there are always political agendas when it comes to policies or the budget formulation. These political agendas are another aspect that plays a big part in the process of renewable energy or energy efficiency efforts. It will depend on the views of the political party in office if it is worth spending the money, time and effort needed to become an energy-efficient nation.

H. STRATEGY CHALLENGES AND RECOMMENDATIONS

Implementing the right strategy for energy efficiency and renewable energy is a challenging task. There are many parts to the process that can greatly affect an optimal ROI for military installations, as previously discussed. The military has a certain culture, and within each military service there is an additional subculture. Broken down further, each rank level has different patterns or behavioral levels. Aside from just being ordered to do something by high-ranking officials, it is challenging to get different entities to join together and find the common ground needed for a joint effort.

Information sharing is another challenge that can be improved on a wide scale. Each installation conducts its own energy efficiency or renewable energy audit (using contractors), and the installations go through a cost-learning curve that can benefit other services. However, due to the lack of transparency from installation to installation, savings are not harnessed to their potential. Imagine the savings from information sharing. Every installation could be at the same cost-learning curve instead of trying to figure things out independently. Overall, the military culture and lack of information sharing can pose a negative outcome to the energy efficiency effort.

The first step installation commanders and base energy experts should take in the effort to gain energy independence is to make installation structures energy efficient. The American Institute of Architects notes that existing structures can be remodeled to reduce energy requirements by 50 percent, while new buildings can be constructed to save up to 80 percent in energy requirements.

Energy savings initiatives can include a wide range of techniques:

- Solar hot water systems.
- Energy-efficient appliances, heat pumps, lights.
- Proper building placement to take advantage of sunlight and ventilation.
- Daylighting.

- Use of vegetation to reduce excessive sunlight and wind.
- Sunshades and overhangs to regulate the amount of sunlight.

Although many energy saving techniques are inexpensive, energy-efficient buildings typically do require higher capital expenses than traditional buildings. However, energy-efficient buildings can provide additional benefits. “It is especially significant that the payback period for capital expenditures for energy efficient buildings might range from 10 to 15 years. This is half the usual time required to recoup investments in traditional large scale utility systems” (Rose, p.20).

While planning for energy efficiency with an eye on security, consideration should be given to constructing individual buildings that are capable of producing net-zero capacity. In other words, designing and constructing buildings that are each capable of generating the energy it requires. The benefit to producing self-sufficient facilities is that it will eliminate the need for a large installation-wide energy-generation capability which could still be targeted by adversaries or vulnerable to natural phenomenon. The reduction of installation-wide energy-generation sources would also reduce the large capital and O&M costs associated with geothermal plants, wind turbines, and solar arrays. Without these initial capital expenditures, the payback period for the capital costs of the energy-efficient building construction is further reduced. These savings could be significant.

Installation self-sufficiency does not necessarily mean a complete disconnect from the national grid. It may be important to remain connected for convenience—and as a backup system in case installation systems fail or become disabled for whatever reason. Installations connected to the grid would also have the ability to support energy requirements on the grid with any extra energy capacity that the installation creates but cannot use. However, there are issues that need to be addressed if installations remain connected to the grid. As energy expert and former employee of Pacific Power and Light, Bob McFaul, explains:

> Back in the 80's, lumber companies began delving into co-generation by burning their previously discarded wood waste and generating electricity. This was primarily because we were going through a huge inflationary

cycle and rates were going up 10%-20% per year. The companies wanted to generate their own power to offset at least a part of their purchased power requirement. They did not, however want us to remove our facilities in case their system went down or they needed additional resources. This created a real dilemma for the utilities in that you have to site and develop your generation and transmission system based on projected load. Too much generation is expensive on a unit cost basis. Too little generation and you can't serve your load which you are mandated to do by law. Some of the lumber facilities were very large (10 to 20Mw) loads so were a substantial part of our regional load factor. Because the loads were not necessarily going away and we were going to continue to pay both capital and O&M expenses as well as taxes on facilities not in use, a new rate formula was developed.

The two that I am most familiar with were:

1. Partial Requirements Rate where the utility agreed to keep some facilities in place and would provide power for part of the existing load but not all of it. If the customers system went down they had to curtail part of their load. The part we did supply was at a substantially higher unit cost than when we had supplied their entire load so it was up to them to determine their point of diminishing returns.

2. Stand-By Rate. This is where we leave all our facilities in place and are prepared to supply all or part of the customers load at any time. This was a very expensive option that I never saw implemented. Basically, the customer paid about half their historical charges all the time and if they needed to rely on our system they paid about double the going rate.

In addition, the U.S. is broken up into specific grids. These are Transmission based (typically 34,000 to 500,000 volts). The local utilities then take the transmission voltage down to a distribution voltage (under 34Kv) and deliver it to the residential, commercial or industrial customer who uses it to power everything from a television to a lumber plainer. At the customers location the voltage is transformed to its final used voltage (120/240 for a house, 240/440 for some commercial usages, etc.) by the local utility.

My point is that NORMALLY the local utilities own and operate the system (the poles and wires). Who owns and operates the poles and wires on the base? If it's the local utility then you may have difficulty using their facilities to move your green power. Bottom line, back in the day most lumber mills found it to be cheaper and much more reliable to remain on our system and sell us whatever power they produced via the co-generation they developed (B. McFaul, personal communication, June 2, 2012).

I. SUMMARY

Renewable energy challenges can be mitigated through prior planning and proper assessment of renewable energy industry outlooks, including overall costs involved. When military installations invest in renewable energy projects, cradle-to-grave Life Cycle Cost (LCC) assessments determine if such renewable energy projects are feasible. The capital costs define how some decision makers determine the feasibility of an energy project. The long-term sustainable cost of a renewable project is not projected in upfront costs. As mentioned under the budget section of this chapter, funding across DoD will continue to decrease and politics will play a big part on regulations. Leaders in the position to make decisions on energy projects can benefit from LCC assessments. Renewable energy is popular and DoD is mandated to be more energy efficient; the decisions made today have a profound impact on the future, and may have ramifications for the next 20–25 years.

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III. RENEWABLE ENERGY OPTIONS AND FACTORS FOR ANALYSIS

A. RENEWABLE ENERGY RESOURCES

Items to consider for analysis:

- What are the renewable energy resources that can most benefit the Marine Corps?
- How does the renewable energy resource industry look for future sustainment?
- What challenges do renewable energy resources face that may interfere with future sustainment?
- What mitigating actions are being conducted to deter challenges from negatively impacting renewable energy resources?

1. Wind Energy and How It Works

The wind is a valuable natural resource, since wind power can generate electricity. As the wind hits the windmill, rotating its turbines, it captures the kinetic energy and transfers it from one form to another, creating electricity through the rotor into the generator (Layton, 2006, "Wind Power," para. 2). This is a natural resource that is vast and abundant across the country. However, to leverage it for mass energy efficiency, only certain areas with high winds may capture the benefit. So because wind varies in speed, strategic placement of a wind farm is the key to obtaining the best cost-benefit analysis.

a. Wind Variation Study

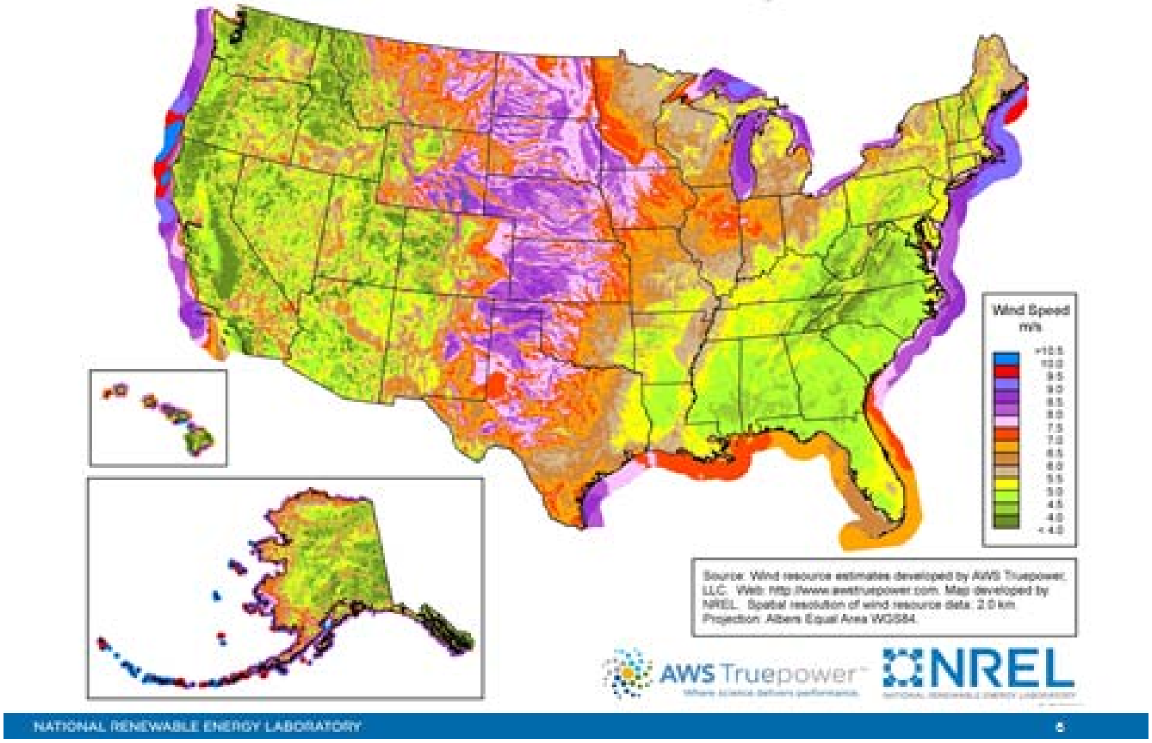
In general, the data collected in other research assumes a constant wind speed, when the reality is that wind speeds constantly change. The study, "Projected Future Wind Speed and Wind Power Density Trends Over the Western U.S. High Plains" (Greene, Chatelain, Morrissey, and Stadler, 2012), challenges the reliability of estimates of wind power cost and benefits without factoring the changing wind speed patterns during different seasons of the year. Greene, Chatelain, Morrissey, and Stadler (2012) claim that wind energy is susceptible to variations in wind speed. It proves that wind speeds are not constant year around, as some researchers assume when they look at the cost-benefit analysis of wind power. “Wind speeds will experience change in the future due to near surface wind speeds being linked to the location of temperature gradients, which will change as the planet warms” (Greene, Chatelain, Morrissey, & Stadler, 2012, p. 32). Greene et al. (2012) offer that any change in near-surface wind speed will cause an even greater change in wind-power potential as the energy created by a turbine is proportional to the cube of the wind speed.

The evidence includes data captured by the Climate Change Assessment Program, which compare past and future data in predicting the climate with a focus on the Central High Plains. This information sets this research apart by resolving uncertainties that other models did not. Greene et al. (2012) uses several different equations to evaluate a wind measure resource at a given site, which in turn—along with other equations—provides the percent change in median wind speed across the focus regions during different seasons. Greene et al. (2012) display the evidence with tables and figures to methodically document variations in future median wind speed with a 5 percent decrease across the region and decreases throughout different temperature gradients.

In addition, the evidence is the trend in the amount of output power in conjunction with the hub height, which is calculated by the power law index equation (Greene et al., 2012). There are some limiting conditions. It acknowledges that a certain change in wind speed does not necessarily predict a specific quantity change in wind power, but turning trends into values that will have meaning is important to utility companies and policy makers to analyze future costs and benefits (Greene et al., 2012). Another acknowledgement is that “this is an estimate, and there have been observed values that are height than the power law. With this in mind, the height extrapolation may be under estimated for the study, but will still give a good idea of the trends across the area” (Greene et al., 2012). Currently, wind provides the U.S. with 23 percent of its renewable-generated electricity.

b. Industry Overview

Pernick, Wilder and Winnie report, “Wind power (new installation capital costs) is projected to expand from $71.5 billion in 2011, up from $60.5 billion the prior year, to $116.3 billion in 2021. Last year’s global wind power installation equaled 41.6 gigawatts, the largest year for global installations on record” (Pernick, Wilder, & Winnie, 2012, p. 3). Though there may be some growing pains due to China’s low prices, the wind power industry is rapidly growing. According to Pernick et al. (2012) the United States falls third in the world for wind power installation. Figure 5 shows the areas where wind energy is harnessed.

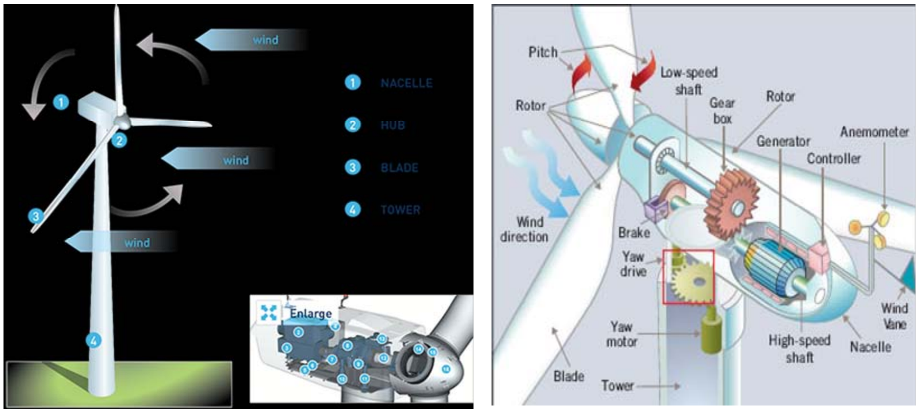


Source: Wind resource estimates developed by AWS Truepower, LLC. Web: http://www.awstruepower.com. Map developed by NREL. Spatial resolution of wind resource data: 2.0 km. Projection: Albers Equal Area WGS84.

Figure 3. NREL U.S. Wind Resource Map (From “National Renewable Energy,” 2012)

c. Challenges and Workable Solutions

Component transportation for wind turbine projects is currently a big challenge, and continues to increase Life Cycle Cost (LCC) assessments. Wind turbines have very large components that rely heavily on intermodal transportation to get to their final destination. Heavy items are easier and less expensive if transported by barge or ship, but wind turbines consist of components that cannot be exposed to the open deck of a tug and barge due to their high value and sea water exposure. Figure 3 shows the major component break down of a wind turbine. The tower is normally broken down into three segments for transport. The blades and the hub are too big to transport while attached, so they are normally transported separately. The nacelle is where the internal high dollar valuable components are housed. A more detailed picture of the internal nacelle is displayed in Figure 3.



Major Components

Internal Components

Figure 4. Major and Internal Components of a Wind Turbine

Wind turbines require multiple modes of transportation, such as ship, rail and truck (as seen in Figure 4). This all depends on where the components are coming from. For example, if a component comes from overseas, it will travel by ship and then get transferred to its final destination by intermodal rail or truck. A great number of wind turbines are transported by truck to their final destination.

Figure 5. Modes of Wind Turbine Transportation

It takes about seven years to plan for and build wind farms, but even then it seems like the logistics aspect is left as an afterthought to the whole project. Currently, the 1.5 megawatt (MW) wind turbine is the largest wind capacity used, but with recent innovation and technology improvements wind turbines are getting up to 2.5 and 3 MW units. There is already a shortage in personnel for the truck-driving industry—coupled with the increasing size of wind turbine components, this plays a part in transportation challenges on our roads for the final leg of transportation. The trucking industry adheres to many state regulations while en-route to transport wind turbine components. For example, “one truck-route from Fargo, N.D., to a Wyoming wind farm site. The company identified a workable route 894 miles in length, but the route ultimately permitted by states along the way totaled 1,221 miles, or 36% longer” (Gray, 2010, “Unwieldy Regs and Road Routes,” para. 3). There are specified roads per state that must be traveled when carrying large loads. Tacking on more mileage, and the requirement of escort vehicles, slows a process that would normally be utilized as a quick efficient mode of transportation and increases transportation costs. Reliability of a component is important because it involves transportation costs as well. The more reliable a component is, the fewer number of times it will have to get transported for maintenance.

Wind Turbine companies are now incorporating the transportation planning at the onset of a possible wind farm location. The planning must start from the beginning to validate if the transportation of components to a specified location is feasible. Transportation costs will decrease for the overall wind farm project due to proper pre-planning of transportation feasibility to find the lowest possible multiple modes of travel between ship, rail and truck. For the ease of transportation, manufacturing companies are also working on ways to break down the components into smaller sizes with a quick connection upon arrival at their final destination.

2. Solar Photovoltaic (PV) Energy and How It Works

The word photo means light, and the word voltaic means electricity, which means that photovoltaic panels utilize the sun's direct energy source, sunlight. The photovoltaic panels are made up of silicon, which is a semiconductor. When the sunlight hits the solar panels, the heat (sun's energy) is absorbed within the silicon (semiconductor), creating a transfer of energy from one source to another. The energy harnessed in the silicon then allows electrons to flow freely by the energy force. The power is defined by the built-in electric fields on the solar panel and, coupled with the current of elections, creates the power that is produced (Toothman and Aldous, 2000, "Photovoltaic Cells," para 2).

a. Industry Overview

The solar PV industry is on a steady rise; however, the industry is hesitant to put their money in future investments due to the historical lesson of the oil crisis back in the 1970s. When the oil prices tremendously increased, the solar PV industry expanded its promising investments. But as the oil prices decreased in the 1980s, there was a decrease in demand for solar PV, which caused the industry to decline with a loss in the public's interest. The rebates expired and were not renewed, which made the interest in new investments too costly without the rebate offsets. Today the industry is leveraging economies of scale with their costs dropping by more than half. This is one of the most cost-competitive markets out there on the renewable energy scale. According to *Clean Energy Trends 2012*, "Solar photovoltaics (including modules, system components, and installation) increased from $71.2 billion in 2010 to a record $91.6 billion in 2011.

[They] project the market to continue to expand to 130.5 billion by 2021" (Pernick et al., 2012, p. 4). Currently, solar provides the U.S. with less than 1 percent of its renewable-generated electricity. Figure 6 shows the areas where solar energy is harnessed.

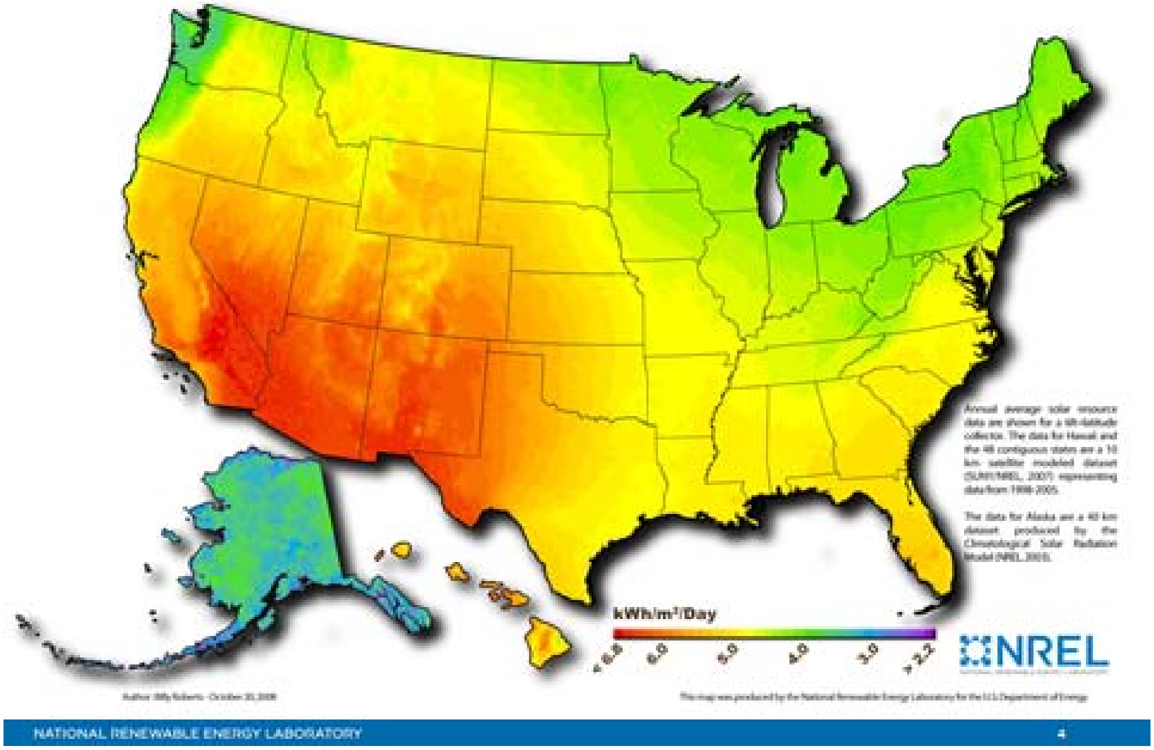


Figure 6. NREL U.S. Photovoltaic Solar Resource Map (From "National Renewable Energy," 2012)

b. Challenges and Workable Solutions

Some challenges that overshadow solar energy are cost effectiveness, space requirements, and environmental effects of manufacturing and disposing. One photovoltaic panel only utilizes about 40 percent of its capacity; therefore additional panels are required to obtain the cost effectiveness and efficiency of solar power. In other words, a large amount of space is required to gain an optimal benefit in solar energy to offset the costs. Many military installations take advantage of the space already available to them by installing solar panels on top of preexisting carports and buildings.

A good indication of the possible impact of renewable energy environmental is to look to areas of the globe that are ahead of the United States in renewable energy production, such as Asia. What kind of issues do we see in Asia that may outweigh the beneficial purpose (if not taken into consideration) when producing solar panels? The solar panels themselves are not harmful, but the manufacturing process and the improper disposal can cause extremely negative effects on the environment. The toxic chemicals used in manufacturing solar panels (such as mercury and chromium, and including the conduit installation with PVC adhesives) are harmful to the environment. The disposal of solar panels, like the computer industry in 2005, may end up in our landfills polluting our environment (Underwood, 2009, para. 2). Various sources indicate that the life cycle of photovoltaic panels is about 25 years, which gives the solar industry time to come up with innovative ways to prevent similar negative environmental outcomes taking place in Asia from happening here in the United States.

3. Wave and Tidal Energy and How It Works

Energy is harnessed from different types of water power, but more specifically, the focus for this study is wave power. Waves hold a great amount of energy from the rush of wind along the ocean water surface. The rush of wind causes friction, and ripples that continue to form into larger ripples, eventually forming a wave (McGrath, 2008, “How Wave Energy,” para. 3). Wave energy is then harnessed through Wave Energy Converters (WECs) and turned into electricity.

a. Industry Overview

There is an overabundance of water on our planet to harness the positive energy net benefit from wave power. “Some estimates say today’s wave energy technology could possibly fuel 10 percent of the planet’s energy consumption” (How Wave Energy, n.d.). This type of renewable energy is continuously advancing with technology and in the future may be cheaper renewable resource. Currently the costs outweigh the research and development funding to make leaps and bounds in advancements; however, as advancements are forthcoming, the challenge is getting wave energy as cheap—or close to the level of—fossil fuels costs to be competitive in the industry.

b. Challenges and Workable Solutions

The challenges associated with producing wave and tidal energy stem largely from its immaturity as a technology. Engineering an energy-producing system in the dynamic environment of the ocean is a monumental task that requires far more research and experimentation. Currents, tides, and shifting seafloor all contribute to the engineering challenges. Wave motion is another challenge. Wave motion is erratic and unpredictable, which makes generating electricity erratic and unpredictable. Finally, converting wave motion into efficient electricity generation is a difficult task. Combine these with possible environmental impacts that a large, efficient system may produce and the challenges are great.

The attraction of wave and tidal energy is that it is a clean and inexhaustible form of energy. If properly harnessed, wave and tidal energy can provide an enormous amount of energy to coastal areas. Transmission of power far from coastal areas would be inefficient. However, big storm waves carry a lot of power. Currently, wave and tidal energy technology is still immature. Collaboration and experimentation with existing energy technologies and oceanographic industries should be able to develop an efficient, effective, and profitable source of energy generation.

4. Geothermal Energy and How It Works

Geothermal energy is harnessed from heat within the Earth. The Earth's heat is generated from three primary sources. The first and most common source is the decay of naturally-occurring radioactive elements. The second source is from the compression of the Earth, which increases closer to the center because of the increasing weight of the material above. The third and least common source is produced from the Earth's electromagnetic field (Thomas, 2012). A geothermal energy plant produces energy by extracting hot water from a variety of heat sources within the Earth. The basic concept is to use steam from the hot water to turn a turbine which creates mechanical energy. There are several different geothermal energy plant designs used to produce energy. The different designs require different ranges of hot water temperatures from different sources. The most recent design is binary cycle power, which uses much cooler water to generate steam than the other designs. Currently, geothermal heat pumps for home heating are the fastest-growing use of geothermal energy.

a. Industry Overview

Geothermal energy produced from heat is one of the most abundant sources of renewable energy on Earth and is an efficient, cost effective, sustainable, reliable and environmentally safe way to extract renewable energy by natural processes. However, geothermal plants have traditionally been limited to regions near tectonic plate boundaries that allow easier access to the heat sources within the Earth. According to the *U.S. Energy Information Administration,* the contribution of geothermal energy as a source of renewable energy in the U.S. as of 2011 is only three percent. Although growing, geothermal energy does have some cons. First, geothermal fields close to the Earth’s surface are only found in a few places; although, geothermal heat is available everywhere if one drills deep enough. Second, the start-up costs are expensive, due mostly to the costs of drilling. Finally, there is evidence that wells could eventually be depleted. According to the International Geothermal Association (IGA), the U.S. currently generates just over 3,000 MW of power from geothermal sites, most of which are in the western U.S. It is estimated that the U.S. has approximately two million km^2 of geothermal areas that are capable of generating nine GW of energy (Bertani, 2010). Geothermal energy resources are theoretically capable of supplying the majority of energy needs, but accessible sources are relatively limited. Drilling and exploration for deeper geothermal sources is extremely expensive, making up the majority of the start-up costs. Currently, geothermal energy costs between 8–10 cents per kwh, with geothermal providing the U.S. with three percent of the country’s renewable-generated electricity. Figure 7 shows the locations of identified geothermal sites.

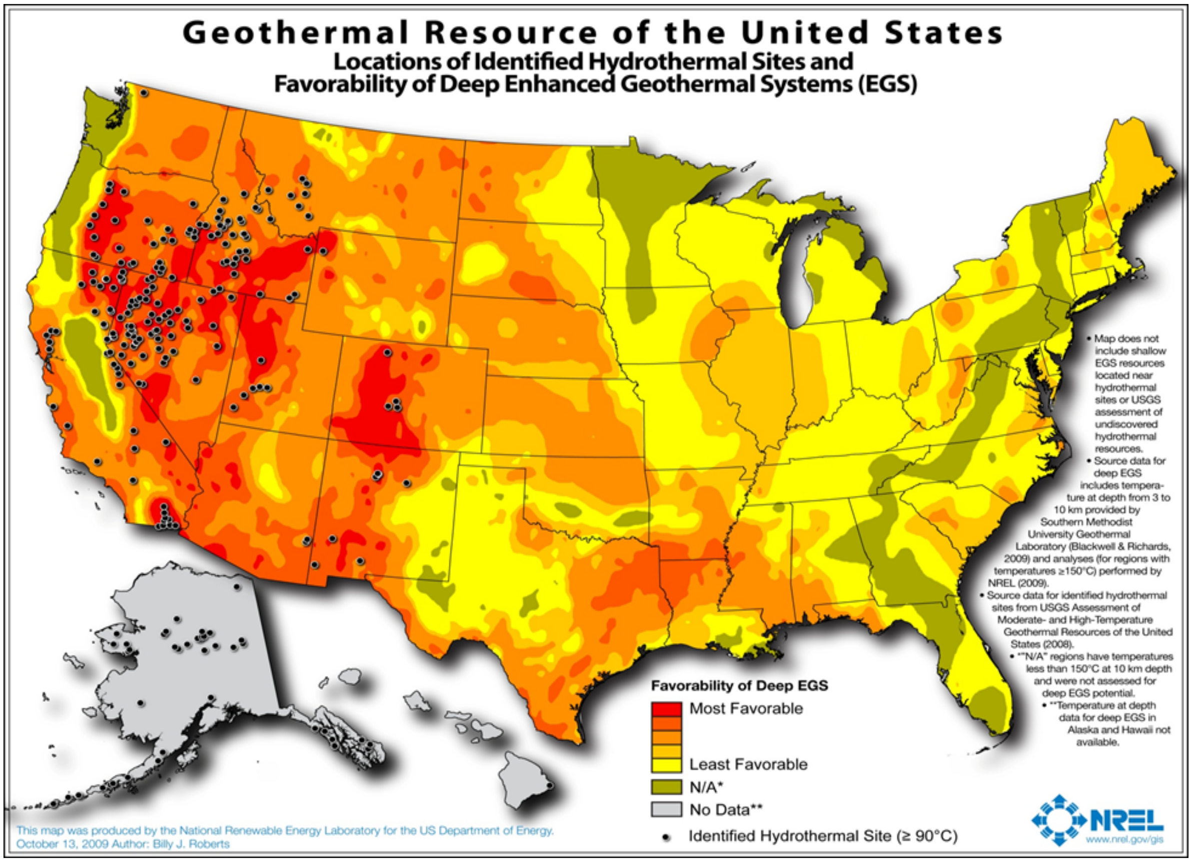


Figure 7. NREL U.S. Geothermal Resource Map (From "National Renewable Energy," 2012)

b. Challenges and Workable Solutions

The production of geothermal energy has some environmental effects due to harmful gases damaging the environment if released. The toxic gases that form (mercury, arsenic, boron and antimony) are captured in the process of chemical precipitation when the water cools, allowing the chemicals to be released into the atmosphere. The land placement and construction of a geothermal plant may cause instability, and its systems can also give rise to earthquakes in the area.

5. Bio Energy and How It Works

Bioenergy is the renewable energy released from organic material known as biomass. "One of the advantages of biomass fuel is that it is often a byproduct, residue or waste-product of other processes, such as farming, animal husbandry and forestry"

(Urban et al., 2011). Under processes such as heating, biomass releases stored chemical energy from the sun. Energy is harnessed from biomass types (using one of several conversion technologies) into a number of useable forms. The conversion technologies include thermal conversion, chemical conversion, and biochemical conversion.

a. Industry Overview

The United States has an abundance of types of biomass available to convert into bioenergy including wood (and wood wastes) in the vast forests, agricultural waste in the large agricultural areas, and manure and other animal by-products. According to the Energy Information Administration:

> Biomass energy is derived from three distinct energy sources: wood, waste, and alcohol fuels. Wood energy is derived both from direct use of harvested wood as a fuel and from wood waste streams. The largest source of energy from wood is pulping liquor or “black liquor,” a waste product from processes of the pulp, paper and paperboard industry. Waste energy is the second-largest source of biomass energy. The main contributors of waste energy are municipal solid waste (MSW), manufacturing waste, and landfill gas. Biomass alcohol fuel, or ethanol, is derived almost exclusively from corn. Its principal use is as an oxygenate in gasoline. (Energy Information Administration, 2008)

Biomass fuels provided about four percent of the renewable energy used in the United States. Of this, about 45 percent was from wood and wood-derived biomass, 44 percent from biofuels (mainly ethanol), and about 11 percent from municipal waste (Energy Information Administration, in 2011). Figure 8 shows the regional areas where biomass resources are harnessed.

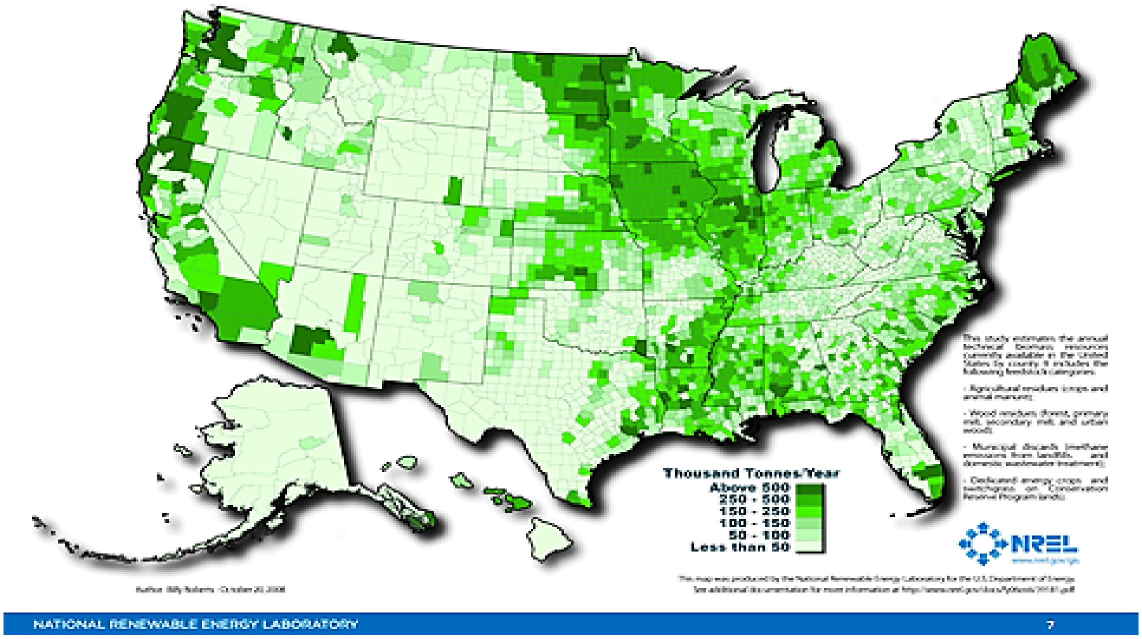


Figure 8. NREL U.S. Biomass Resource Map
(From "National Renewable Energy," 2012)

b. Challenges and Workable Solutions

The challenges of bioenergy mainly concern its emissions of pollution. The process of producing bioenergy does emit some gas and liquid waste. It also increases emissions of nitrogen oxides. In addition, some fossil fuels are used in the conversion process. Despite the challenges, there is an abundant supply, and it is a versatile energy that can be converted for use in diesel engines. Environmental Protection Agency (EPA) regulations and pollution filters are effective methods of managing the pollution challenges.

6. Hydroelectric Energy and How It Works

Energy is generated from the gravitational force of falling or flowing water. Hydroelectric power is the most abundant source of renewable energy, providing approximately 63 percent of the renewable energy in the U.S. It is also the most efficient, at 80 percent. The start-up costs are the greatest expenditure, as operating costs are negligible. The environmental impact is also great where conventional dams are used.

a. Industry Overview

Hydroelectric power is the most abundant, widely used, and reliable form of renewable energy, with a low cost of producing electricity (3–5 cents per kilowatt hour for plants larger than 10 megawatts). Hydroelectric power is also very flexible, since it is possible to regulate the amount of energy being produced as demand increases or decreases by regulating the amount of water released to turn the generators (Worldwatch Institute, 2012). The capital costs of hydroelectric power plants are extremely large, but once completed, they are very economical with low labor costs for operation due to plant automation that requires relatively little human capacity. It also produces less greenhouse gases than any other source of renewable energy. Hydroelectric power has a long economic lifespan, with each plant producing 50 to 100 years of electrical service. Figure 9 shows the regions where hydroelectric energy is best harnessed.

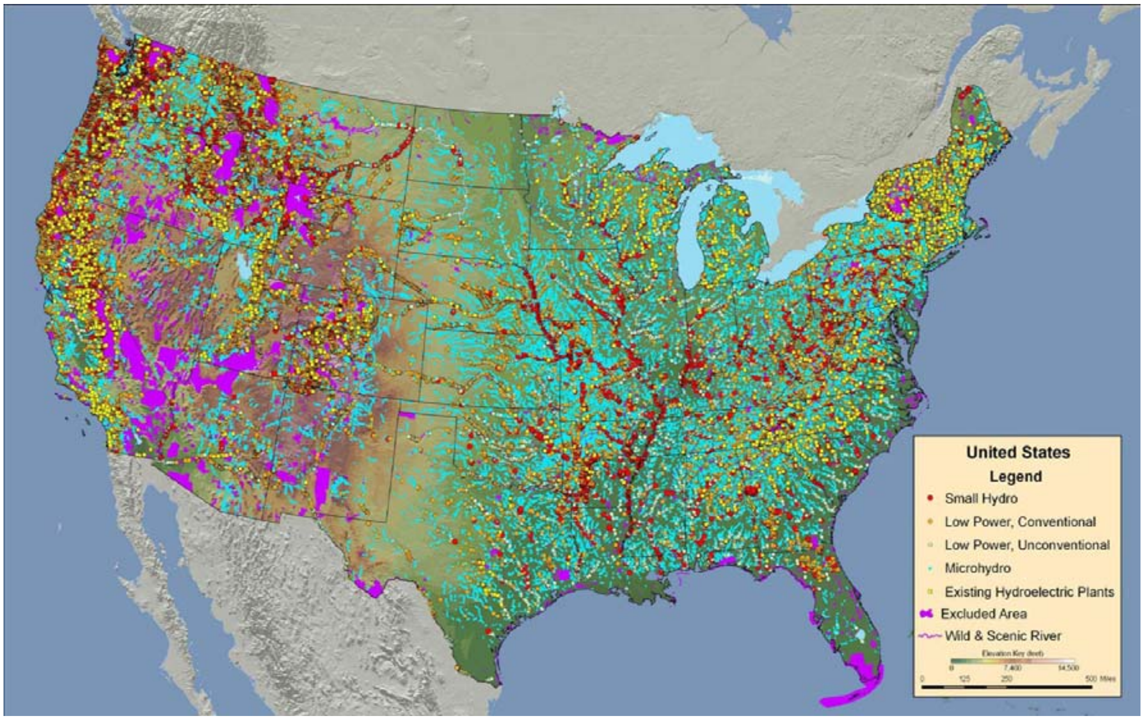


Figure 9. NREL U.S. Hydroelectric Resource Map (From “National Renewable Energy,” 2012)

b. Challenges and Workable Solutions

The challenges of hydroelectricity can be monumental. Of immediate concern is the damage to the ecosystem and the submersion of extensive areas of land. Destruction of aquatic ecosystems—both up and down stream—can have devastating effects on species like salmon, because the dams block access to spanning areas. Dams also change the river environment downstream by changing the temperature of the water. Upstream, the rising water covers biologically rich river valleys and marshlands. Siltation is another concern with hydroelectric plants. The slowing of river currents (that typically carry particles down river and keep the flow clear) now cause sediments to build up in the reservoirs. This build up can cause a reduction in power generation. It can also reduce the capability of reservoirs to control flooding. The extremely high capital costs to build a hydroelectric plant are one of the most severe challenges.

Hydroelectricity is a mature technology and many challenges can be managed responsibility. Fish ladders allow salmon to transverse dams to get to spanning grounds. Reservoirs also provide important sources of water for agriculture, especially in arid climates, turning land with little use into large expanses of farmland. Despite these efforts, many challenges remain. Habitat destruction is unavoidable with the reservoirs required to operate the large power stations. While hydroelectric power provides one of the cleanest sources of electricity at low rates, the initial capital cost are unavoidable. The sheer size and structural challenges prohibit cheaper methods and materials.

B. ENERGY BUSINESS PRACTICES

Energy security is a capability requirement for military installations. A collaborative process among the DoD energy communication network is critical to expound on the renewable energy resource learning curve. Budget constraints are inevitable, so cradle-to-grave cost assessments of renewable energy resources are beneficial to capture realistic long-term costs and benefits.

The Marine Corps initiated 78 energy projects, and 87 percent of those energy projects used upfront appropriations as their financing approach. This study utilizes only the 52 energy projects that were operational at the time of the GAO report. The 78 projects are provided in detail in Appendix A for visibility. Table 4 summarizes each Marine Corps installation's fully operational energy projects with total energy produced on each installation and total capital project cost per installation.

Table 4. Fully Operational Marine Corps Renewable Energy Initiatives Including Energy Produced and Total Capital Costs (After Reich, H., Bennett, S., Reid, S., Rygg, R., Turner, C., & Willems, M., 2010).

Installation / Location	**State**	**If Operational: Year Placed In Service**	**Number of Energy Projects**	**Type of Renewable Resource**	**Energy Produced as of FY 2009 (MMBtu)**	**Projects Total Capital Cost (Thou. $)**
MCAGCC 29 Palms	CA	Yr 04 = 1 project; Yr 09 = 12 projects	13	Solar Photovoltaic	10,105	$18,077.00
MCAS Beaufort	SC	Yr 09 = 2 projects	2	Solar Photovoltaic, Solar Thermal	176	$58.00
MCAS Cherry Point	NC	Yr 09 = 3 projects	3	Solar Photovoltaic	777	$1,569.00
MCAS Miramar	CA	Yr 09 = 1 project; Yr 10 = 3 projects	4	Solar Photovoltaic	2,313	$3,868.00
MCB Camp Pendleton	CA	Yr 04 = 1 project; Yr 05 = 3 projects; Yr 07 = 2 projects; Yr 08 = 4 projects; Yr 09 = 4 projects; Yr 10 = 2 projects; Various = 1 project	17	Solar Photovoltaic, Geothermal, Day lighting	8,446	$10,228.00
MCAS Yuma	AZ	Yr 09 = 3 projects; Yr 10 = 2 projects	5	Solar Photovoltaic	737	$1,744.00
MCB Hawaii	HI	Yr 08 = 2 projects; Yr 09 = 3 projects	5	Solar Photovoltaic, Solar Thermal, Day lighting	1,726	$2,157.00
MCB Quantico	VA	Yr 09 = 1 project	1	Solar Photovoltaic	120	$248.00
MCLB Barstow	CA	Yr 09 = 1 project	1	Wind	15,696	$4,598.00
MCRD San Diego	CA	Yr 09 = 1 project	1	Solar Photovoltaic	1,317	$1,640.00
TOTALS:			**52**		**41,413**	**$44,187.00**

The Marine Corps takes a top-down approach in setting its energy efficiency goals, and a bottom-up approach (by installation) in the implementation of its renewable energy initiatives. Every installation is implementing its own energy projects to reach the mandated goal in energy savings, which means each installation is generating its own learning curve with all energy project assessments. According to research, it is unknown how detailed the installations were in conducting energy audits to gain insight into the most beneficial renewable energy resource prior to procurement. The cost associated with each installation is assumed to be the cost of capital or the purchase of only renewable energy resource materials (i.e., equipment). To avoid confusion, the data captured in the GAO report will remain in the same energy production units of one million British thermal units (MMBtu), which are not converted into kilowatt hours as normally seen with electricity.

In Figure 10, the MCLB Barstow installation stands out with the most energy produced and the MCAGCC 29 Palms installation with the highest project total capital costs. The ratio of project total capital cost to energy produced is highly positive for MCLB Barstow and highly negative for MCAGCC 29 Palms. MCLB Barstow utilized wind energy as its primary renewable resource to harness long-term benefits while MCAGCC 29 Palms used primarily solar projects. In addition, MCLB Barstow financed its energy project with an alternative method, UESC. As discussed in Chapter II, UESC financing is where the cost of capital is paid over a period of the contract, whereas, MCAGCC 29 Palms primarily utilized upfront financing appropriations. Logically, the government is paying less in the long run when the capital costs are spread over a period of time in comparison to financing all costs upfront at one time.

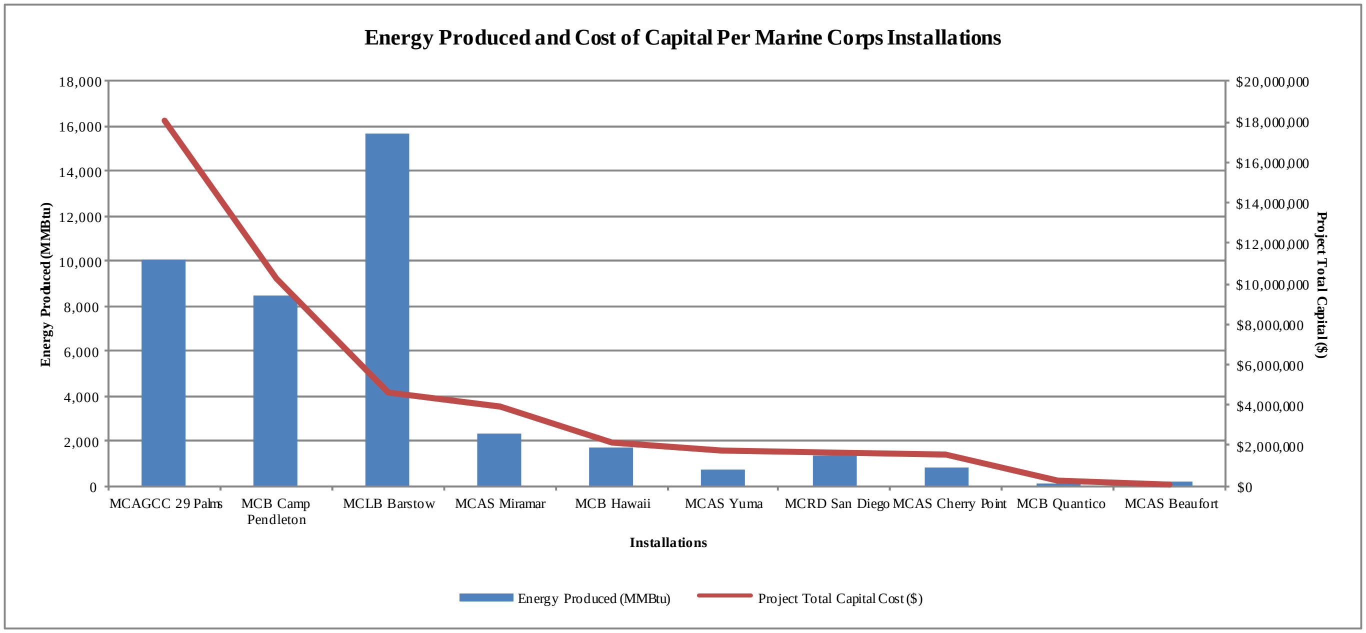


Figure 10. Marine Corps Installation Project’s Renewable Energy Production per Total Cost of Capital

C. BEHAVIOR

1. Breaking through the Cultural Barriers

Energy programs, especially large energy programs, come up against a lot of barriers in order to reach fruition. The difficulties facing large energy projects include: “requirements creep, funding instability, poor cost estimating, immature technology, and the lack of flexibility to solve problems. These issues are compounded by the fact that many individuals with little or no accountability can profoundly impact funding, schedule, personnel assignments, and administrative demands” (BENS, 2009, p. 6).

Ensuring that energy projects are acquired and delivered to organizations that need them in a timely and economically efficient manner can be a difficult and daunting assignment. Still, the war-fighter deserves the best efforts. Unfortunately, these efforts are often policy driven, increasing the complexity of the acquisition process. Attempts to streamline or simplify the acquisition process usually lead to (or are viewed as) organizational changes—and a strong organizational culture is difficult to change.

2. Changing Leadership Thinking

Leadership is vital to the successful implementation of strategy. Cynthia Montgomery, Professor of Business Administration, and head of the Strategy Unit at Harvard Business School, suggested in her article Putting Leadership Back into Strategy that managers today apply strategy to organizations as a static plan instead of a dynamic process that guides the continuous development of an organization throughout its life (Montgomery, 2008). Prof Montgomery also states, “the CEO’s unique role as arbiter and steward of strategy has been eclipsed; and the exaggerated emphasis on sustainable competitive advantage has drawn attention away from the fact that strategy must be a dynamic tool for guiding the development of a company over time” (Montgomery, 2008).

An inspirational leader can get people to do, or believe in something when they do not necessarily want to. Strategic managers know what to say and when to say it. They have a vision and can present a clear strategy to each and every stakeholder, in the way each stakeholder can understand, giving them a sense of purpose and commitment to the organization’s vision. The strategic manager must also be passionate. Passion will inspire and draw people to the organization’s cause, and can become infectious.

IV. DATA ANALYSIS

A. INTRODUCTION

Harnessing an optimal indigenous renewable energy resource solution is an important goal. Installations can reach this goal by improving lateral communication and information sharing, and by taking into account costs, benefits and risks in comparison with previous installation analysis data, along with regional geographic conditions, weather patterns and human factors. The installations can ultimately provide a system of informational analysis that will allow the installation commander to best apply his limited resources in accomplishing mandated energy savings, installation security, and an overall increase in efficiency and decrease in costs to obtain self-sufficiency from the grid in order to provide U.S. security under environmental threat and security conditions. This goal requires installation commanders to look carefully at their options in order to provide increased energy efficiency at the most economical cost, rather than engaging in blanket investments that may or not meet ultimate mission standards set by the DoD mandate for energy self-reliance.

The research conducted in Chapter III depicts three renewable energy resources for further analysis: geothermal, wind, and solar. These three indigenous renewable resources were chosen for a comparative analysis because of their technological maturity, energy efficiency, and regional availability. Each is capable of off-setting USMC installation energy consumptions using a net-zero philosophy. Although these resources are commercially available in a range of scopes and sizes, the standard used to provide a comparable energy output in kWh for each of them in this analysis are: one (5-30MW) medium geothermal facility, one (1.5MW) wind turbine, and one (150W) square meter solar panel.

B. REGIONAL CLIMATE PATTERN ANALYSIS

According to the assessment of renewable energy resources completed in Chapter III, the most mature and economically feasible renewable resources are geothermal, wind, and solar energy. Figures 11, 12, and 13 show the Marine Corps installation locations in relation to annual average wind speed, photovoltaic resources, and geothermal resources, respectively. Marine Corps Air Station Miramar in California and Marine Corps Base Kaneohe Bay, Hawaii were chosen as the standard example for analysis due to recent NREL reports that provided the most abundant and accurate information.

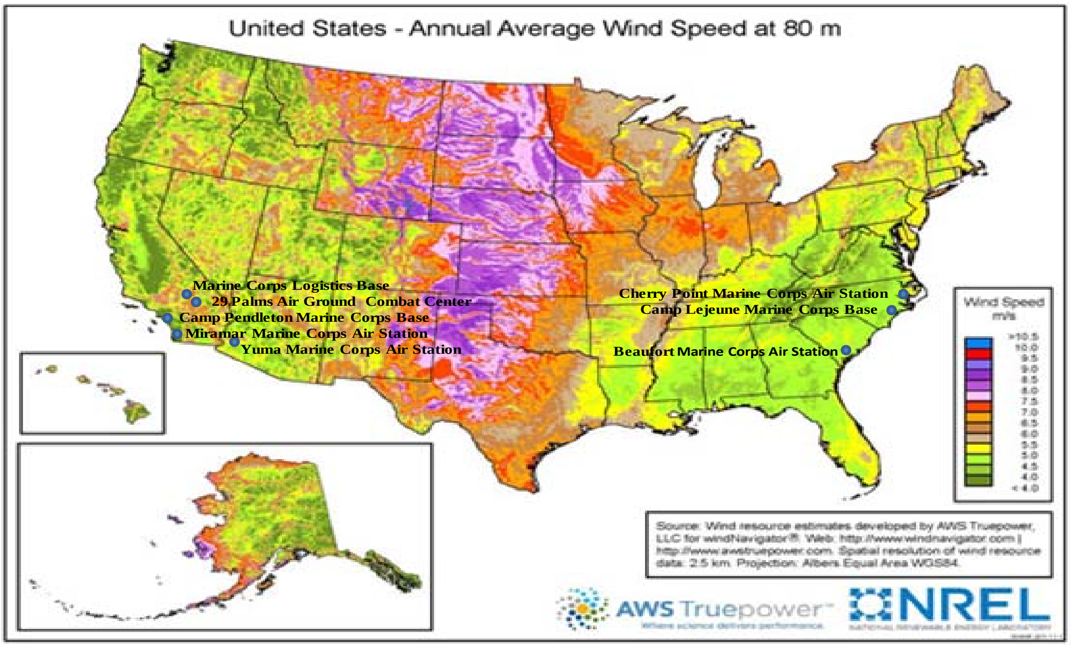


Figure 11. U.S. Annual Average Wind Speed (After "National Renewable Energy," 2012)

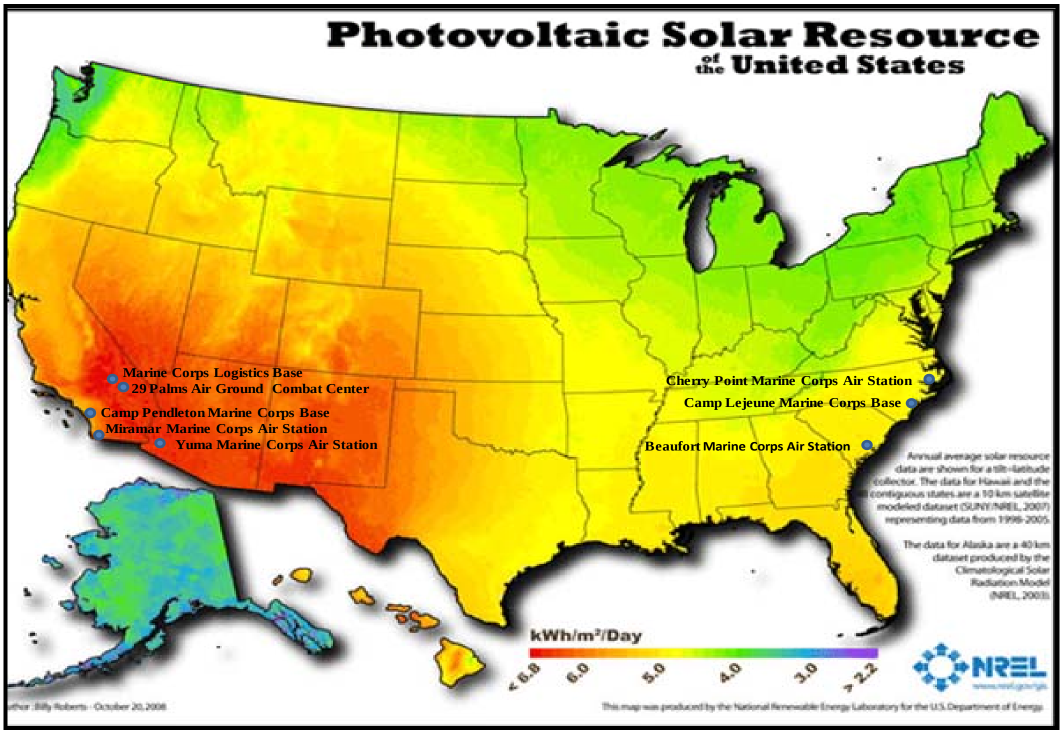


Figure 12. U.S. Photovoltaic Solar Resource (After "National Renewable Energy," 2012)

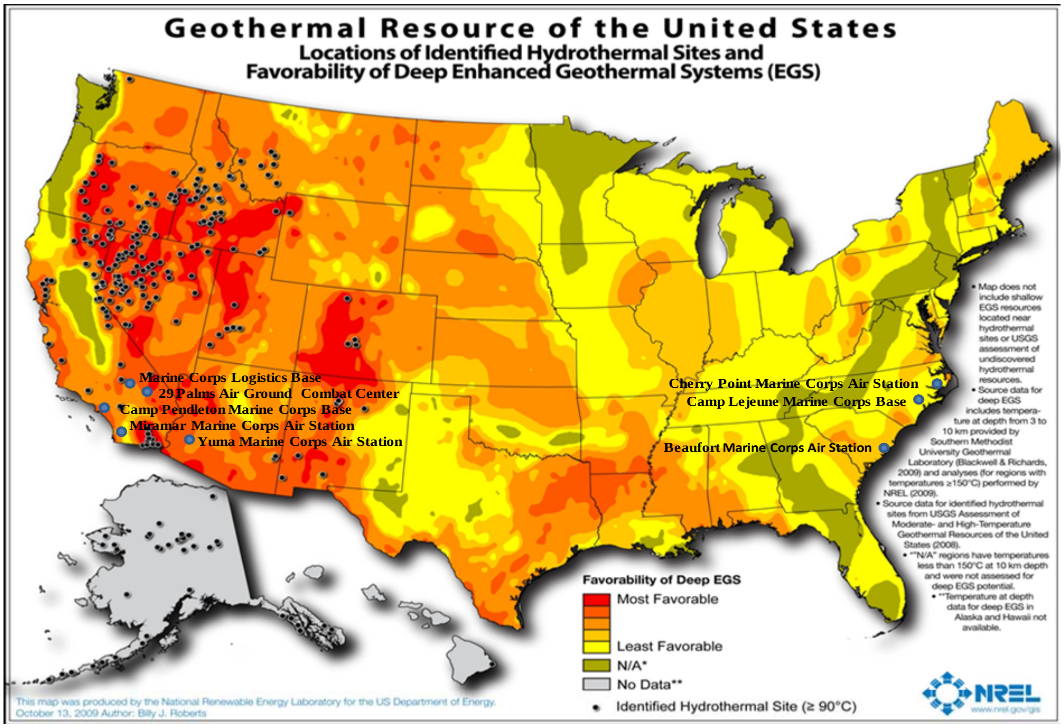


Figure 13. U.S. Geothermal Resources (After "National Renewable Energy," 2012)

C. ECONOMIC INVESTMENT ANALYSIS

DoD requires the implementation of measures to capture the costs and benefits of investments. Economic analysis for investments is presented in terms of Net Present Value (NPV), and the time frame of a project payback period.

A higher NPV for a project determines a more favorable investment. Accepting investments with a positive NPV is like receiving that NPV in cash today. A dollar today is worth more than a dollar tomorrow because a dollar today can be invested to gain interest. The time value of money makes the difference in today's value versus its future value. The difference between the present value of benefits and the present value of costs is defined as the sum of all outflows and inflows of cash. This measure is more widely used for long-term projects, and incorporates its opportunity costs and capital costs (Return on Investment, n.d., para. 3). The discount rate is another factor in the NPV measure that makes it sensitive to analysis. A project with the same cash flow at different interest rates is worth less today—and the longer the timeframe the less it is worth because it is a continual discount overtime. This measure is best utilized with long-term projects. Projects are costly, so a limitation to NPV is the attractive upfront costs associated with a project. All else equal, the projects with the least initial risk are most attractive, but it does not necessarily mean that they are the best investment.

The payback period is the time it takes for a project to reach the breakeven point where benefits equal costs. Is a short payback period a beneficial economic analysis for projects? The nominal timeframe for a project payback period is about three to five years and may be longer. Innovation continues to play a big part in energy investments. We live in an environment where more reliable and improved products are being introduced to the market at a fast pace. A decision maker is more inclined to accept a shorter payback period for a project because it determines better potential for investment, especially if budget constraints are involved; however, it depends on the life span of the project. The payback period can be utilized as a risk factor when determining whether or not to move forward with long-term energy projects. Once this point is determined, it shows the potential in an investment, but those are the payback period measure limits. Used independently, the payback period measure provides the initial step in analysis to further consider a project or not. For simplicity, it gives a notional go or no-go for a project without any further analysis after the breakeven point.

Which economic analysis is more beneficial for an energy project? As previously discussed, technology is continuously changing and all projects vary in scope and size. As DoD continues to undergo budget cuts, the economic analysis for energy projects continues to get scrutinized. It is the scope and size of the project that will determine the best measure for the output analysis, but each measure should not be used independently to capture economic analysis. The approach analyzed for energy projects in this thesis to help distinguish the marginal projects from the obvious no-go projects is the payback period. This measure takes into account the initial risk of an investment, and NPV is then utilized the show the broader picture as a supplemental measure for long-term projects.

D. METHODOLOGY

1. Power to Energy Conversion

A specific standard output is utilized for each renewable resource. The assessment analyzes a 5 to 30MW geothermal plant, a 1.5MW wind turbine, and a 150W solar panel (approximately one square meter). Each renewable energy resource is converted from power produced to energy consumed in kilowatt hours, in order to associate current commercial energy costs with each renewable energy resource to determine the benefits achieved. Based on available information and data, the following equations and variables are used:

$$P(\mathrm{kW}) = \frac{E(\mathrm{kWh})}{t(\mathrm{hr})} \tag{1.1}$$

$$E(\mathrm{kWh}) = P(\mathrm{kW}) * t(\mathrm{hr}) \tag{1.2}$$

a. Variables

P = power

E = energy

t = time

b. Units

W = watt

kW = kilowatt

kWh = kilowatt hour

hr = hour

yr = year

c. Standard Metric Conversions

1MW = 1,000kW

1W = 0.001kW

1yr = 8,760hrs

d. Renewable Energy Generated with Geothermal Power in a Medium-Sized Plant (5 to 30MW)

$$\begin{aligned} &30MW * 1{,}000 = 30{,}000kW \\ &E_{(Geo)} = 30{,}000kW * 8{,}760hr \\ &E_{(Geo)} = 262{,}800{,}000kWh / yr \end{aligned} \tag{1.3}$$

e. Renewable Energy Generated with Wind Power in a Standard Wind Turbine (1.5 MW) @ 30% Capacity

$$
\begin{aligned}
&1.5MW * 1{,}000 = 1{,}500kW \\
&\mathrm{E}\left(_{Wind}\right) = 1{,}5000kW * 8{,}760hr \\
&\mathrm{E}\left(_{Wind}\right) = 13{,}140{,}000kWh/yr * 0.30 \text{ capacity} \\
&\mathrm{E}\left(_{Wind}\right) = 3{,}942{,}000kWh/yr
\end{aligned}
\tag{1.4}
$$

f. Renewable Energy Generated with Solar Power in a 1 Square Meter Solar Panel (150W) @ 18% Capacity

$$
\begin{aligned}
&0.001kW * 150W = 1kW \\
&\mathrm{E}\left(_{Solar}\right) = 0.15kW * 8{,}760hr
\end{aligned}
\tag{1.5}
$$

$$
\begin{aligned}
&\mathrm{E}\left(_{Solar}\right) = 1{,}314 \text{ kWh/yr * 0.18 capacity} \\
&\mathrm{E}\left(_{Solar}\right) = 237kWh/yr
\end{aligned}
\tag{1.6}
$$

g. Renewable Energy kWh Output

$\mathrm{E}(_{\mathrm{Geo}})$ = Geothermal Energy
$\mathrm{E}(_{\mathrm{Wind}})$ = Wind Energy
$\mathrm{E}(_{\mathrm{Solar}})$ = Solar Energy

$\mathrm{E}(_{\mathrm{Geo}}) = 262{,}800{,}000kWh/yr$
$\mathrm{E}(_{\mathrm{Wind}}) = 3{,}942{,}000kWh/yr$
$\mathrm{E}(_{\mathrm{Solar}}) = 237kWh/yr$

2. Renewable Energy Total Costs

The renewable energy resource costs are cited from resources as indicated. The costs are separated into two main categories: capital costs and O&M costs. Each main category is broken down further into sub-categories of costs, which are different for each renewable energy resource and filtered into the main category.

a. Geothermal Energy Costs

Geothermal total capital costs are calculated by summing up the sub-category level costs: exploration, steam field and power plant. Total capital costs are captured in dollars per kW and each geothermal plant generates energy per MW; therefore, each MW of energy generated is converted into kWs. Once the MWs are converted into kWs then the total kWs are multiplied by the total capital costs. Table 5 captures all geothermal energy costs. The geothermal costs are captured by equations 1.7 and 1.8.

$$\text{Capital Costs} * \text{kW per plant size} = \text{Total Capital Costs} \tag{1.7}$$

$$\text{O\&M Costs} * E_{GEO} = \text{Total O\&M Costs} \tag{1.8}$$

For example, 1MW equals 1,000kWs, therefore, a medium geothermal plant that generates 5MWs of power is converted into 5,000kWs. The capital costs captured in Table 5 and the converted power of 5,000kWs are imputed into Equation 1.7 to calculate total capital costs. The total capital costs for this specific example equals $10,250,000, which is a onetime cost for the 30 year life span of a geothermal plant.

Geothermal total O&M costs are calculated by summing up the sub-category level costs: steam field and power plant. Total O&M costs are recurring costs and are captured in cents per kWh; therefore, each MW of energy generated by a geothermal plant is converted into kWh by using Equation 1.3. Equation 1.3 calculates kWh for a 30MW geothermal plant, but any geothermal plant size can use the same equation by converting the MWs into the kW in order to capture the kWh per year.

A medium 5MW geothermal plant converted into 5,000kWs is inputted into Equation 1.3 and calculates 43,800,000kWh per year. The 43,800,000kWh per year inputted into Equation 1.8 with its O&M costs totals to $3,066,000. The total O&M cost is a recurring annual cost so it is multiplied by the 30 year life cycle of the geothermal plant and added to the capital costs to capture the undiscounted life cycle costs.

Table 5. Geothermal Total Cost (After "REPP-CREST," 2010)

Plant size	Cost Component	Capital Costs ($/KW)	O&M ($cents/kWh)
Small Plants (<5 MW)	Exploration	$700	
	Steam field	$450	$0.05
	Power Plant	$1,250	$0.06
	Total	**$2,400**	**$0.11**
Medium Plants (5--30 MW)	Exploration	$425	
	Steam field	$550	$0.03
	Power Plant	$1,075	$0.04
	Total	**$2,050**	**$0.07**

b. Wind Energy

The costs associated in Table 6 are per wind turbine. Costs are captured by adding the O&M costs to capital costs and then multiplying the total cost by the number of wind turbines. The cost per turbine is multiplied by the maximum life cycle of a wind turbine (20 years). Equation 1.9 goes step by step in calculating the total wind costs. Table 6 shows the total costs for wind turbines captured in an NREL report (NREL/TP-500-40566) minus the utilities and insurance costs, which are assumed costs for our cost assessment.

O&M Cost + Capital Cost = Total Costs
Total Cost * number of 1.5MW Wind Turbines = Total Costs per Wind Turbine
Total Cost per Wind Turbine * Life Cycle per Wind Turbine (20 years) = Total Life Cycle Costs (1.9)

Table 6. Wind Total Costs (After Fingersh, Hand, & Laxson, 2006)

1.5MW Wind Turbine	**Costs Component**	**Total Costs ($/yr)**
O&M Costs	Replacement Costs	$16,000
	Land Lease	$5,000
	Maintenance	$30,000
	Utilities	$5,000
	Insurance	$47,000
	Total	**$103,000**
Capital Costs	BOS Costs	$367,000
	Turbine Capital Cost	$1,036,000
	Total	**$1,403,000**

c. Solar Energy

The solar costs are displayed in Table 7. Solar costs are calculated by multiplying the solar energy generated in Equation 1.6 (237kWh) by the Balance of Systems (BoS) cost. The BoS costs include; business processes, structural installation, racking, site prep, attachments, and electrical. The module costs are multiplied by the kWh generated without the capacity factor (1,314 kWh) as seen in Equation 1.5. The sum of the total BoS and module cost become the total capital costs.

The maintenance cost are all calculated with the 18 percent capacity factor and summed up to show the total O&M costs. Then the total O&M costs are multiplied by the system life span (20 years) and capital costs are added for the total life cycle costs. Equation 1.10 goes step by step in calculating the costs in more detail.

$$\begin{aligned}
&\text{BoS costs} * E_{\text{Solar}} = \text{BoS total costs} \\
&\text{Module costs} * E_{\text{Solar}} \text{without the capacity factor} = \text{Module total costs} \\
&\text{BoS costs} + \text{Module total costs} = \text{Total Capital Costs} \\
&\text{Maintenance costs} * E_{\text{Solar}} = \text{Total O\&M costs} \\
&\text{Total Capital Costs} + \left(\text{Total O\&M Costs} * 25\ \text{years}\right) = \text{Total Life Cycle Costs}
\end{aligned} \tag{1.10}$$

Table 7. Solar Total Costs (After Bony, Doig, Hart, Maurer & Newman, 2010)

One Square Meter Photovoltaic Panel	Total Costs	$/kWh
O&M Costs	Sytem O&M	0.02
	Inverter Maint	0.01
Capital Costs	BoS Cost	0.09
	Module Cost	0.10
	Total	0.22

3. Monetary Benefits

The benefits captured represent the savings in monetary value that are achieved with each renewable energy resource. The monetary benefit of each renewable energy resource is captured by using the output of Equation 1.2 (E=P*t) and the current energy price, which is 0.1023 cents per kWh (Energy Information Administration, 2012). The current energy price is captured from a 2012 EIA report.

a. Geothermal Energy

For example, a 30MW medium plant generates 262,800,000kWh per year as calculated in Section D, therefore the kWh per year are multiplied by the current energy price of 0.1023 cents per kWh and equals $26,884,440 annually. The annual monetary benefits are multiplied by its life cycle (30 years) and equals $806,533,200 is the total life cycle benefits for geothermal. Equation 1.11 shows the steps required to capture total life cycle benefits for geothermal energy.

$$(E_{Geo} * \text{Current Energy Price}) * 30 \text{ years} = \text{Total Life Cycle Benefits} \qquad (1.11)$$

b. Wind Energy

A 1.5MW wind turbine generates 3,942,000 kWh per year as calculated in Section D. Then the 3,942,000 kWhs generated are multiplied by the current energy price of 0.1023 cents per kWh and equals $403,267 annually. The annual monetary benefits are multiplied by the renewable energy resource life span (20 years) and equals $8,065,332 is the total life cycle benefits for wind. Equation 1.12 shows the steps required to capture total life cycle benefits for wind energy.

$$(E_{Wind} * \text{ Current Energy Price})*20 \text{ years} = \text{Total Life Cycle Benefits} \tag{1.12}$$

c. Solar Energy

A one Square meter solar panel generates 237kWh per year as calculated in Section D. The 237kWh per year is multiplied by the current energy price of 0.1023 cents per kWh and equals $24.20 annually. The annual monetary benefits are multiplied by the renewable energy life span (25 years) equals $606.12 is the total life cycle benefits for solar. Equation 1.13 shows the steps required to capture total life cycle benefits for wind energy.

$$(E_{Solar} * \text{ Current Energy Price})*25 \text{ years} = \text{Total Life Cycle Benefits} \tag{1.13}$$

4. Payback Period

As previously discussed, the payback period can be utilized as a risk management factor when determining long-term energy projects. The payback period is the time it takes for a project to reach the breakeven point where benefits equal costs. Once this point is determined, it shows the potential of the energy project.

$$\text{Payback Period (years)} = \frac{\text{Initial Investment (Capital Costs)}}{\text{Annual Savings (Cash Flow Benefits)}} \tag{1.14}$$

5. Net Present Value (NPV) and Discount Rate

A higher NPV for a project determines a more favorable investment. The difference between the present value of benefits and the present value of costs is defined as the sum of all outflows and inflows of cash. The discount rates used for geothermal, wind, and solar analysis are 2, 1.7, and 1.85 percent respectively (as extracted from the 2012 OMB circular).

$$\sum_{t=1}^{N} \frac{C_t}{(1+i)^t} \tag{1.15}$$

a. Values

C*t* = Net cash flow at time *t*

i = discount rate

t = time of cash flow

6. Expected Value (EV)

EV captures risk exposure, which is the probability of the occurrence of a risk multiplied by the impact of that risk. EV is calculated to show that installation commanders have the option to capture additional risks. Table 8 was built as an example capturing Miramar's EV of each renewable energy resource. The commander can identify specific risks associated with each type of renewable resource as depicted in Table 8. There is a probability assigned to each risk and if the probability occurs there is an assumed impact stated in a dollar amount. The monetary assumed impact multiplied by the probability calculates the EV per risk. The sum of the EVs of the individual risks equal the total risk exposure.

The EV is used to develop an average risk range assessment of the best case to worst case cost values. The best case cost value is depicted by the total costs with no risk factors occurring. The worst case cost value is depicted by the total costs with all risk factors occurring. The best case cost value plus the sum of the individual risks EV cost equals the EV for the renewable energy resource. The EV depicts a more realistic risk assessment that the commander can utilize for decision making.

E. NPV ANALYSIS OF PRIOR MARINE CORPS ENERGY PROJECTS

The past data collected by GAO report (GAO-10-681R) shows each installation at a negative NPV for the renewable resource projects implemented. Each installation authorized renewable energy projects based on convenience and availability. The predominant financing approach utilized was upfront appropriations, which limited the span of analysis. Data collection and information sharing are the corner stones of building an optimal solution with renewable energy resources. Marine Corps installations are underutilizing alternative means of financing. The overall analysis shows that installations proceeded with energy projects regardless of a negative NPV.

In addition, installations were not harnessing an optimal renewable energy resource solution, possibly due to limited economic research, limited financing approaches, and limited lateral communication with other installations. For example, MCAS Miramar utilized upfront appropriations to procure each energy project, which captured a negative NPV due to the high capital cost in comparison to the benefits achieved. Figure 14 was built to show the summary of capital costs, benefits, and NPVs of all fully operational Marine Corps projects. The y-axis includes the NPV, capital costs, and benefits for the total renewable energy projects completed at each Marine Corps installation shown on the x-axis. The sum of the total capital costs of each installation shows the total amount invested. The sum of the total benefits of each installation shows the total monetary benefit calculated by multiplying the price per MMBtu ($34.04) by the amount of energy generated for each energy project at each installation. The price per

MMBtu of $34.04 was extracted from the Rapier (2010) resource. Each installation captured low benefits and high costs for the projected life cycles of each renewable energy resource project. Appendix B shows each project per installation in more detail. The figures to build this chart are taken from Table 4 in Chapter III. The NPV is calculated by using Equation 1.4 where the cash flows are the monetary benefits captured with a discount rate of 2.8 percent over a span of 20 years for simplicity. The NPV in this analysis is used to capture the attractiveness of the energy projects during the year it was placed in service. All installations reflect a negative NPV for their investments in energy projects. A negative NPV is not an attractive investment; however, it may be seen as a required investment due to national security purposes.

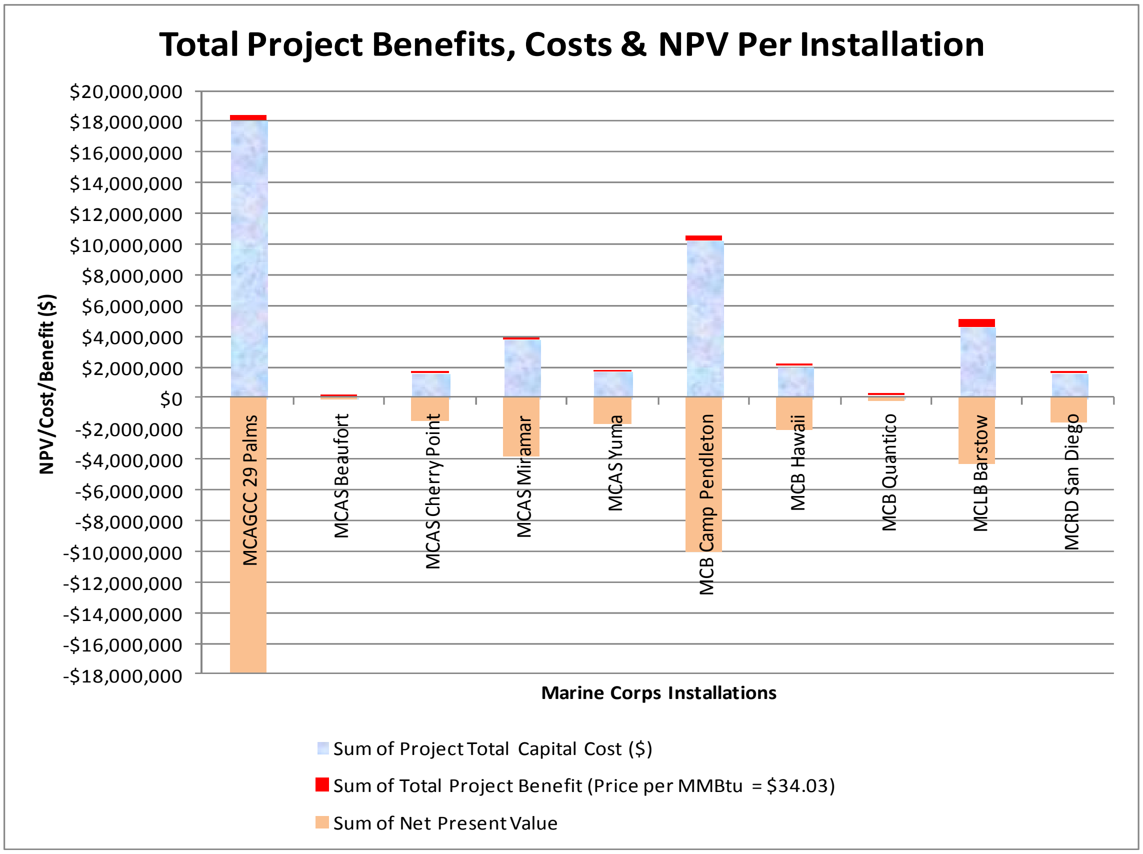


Figure 14. Total Project Benefits, Costs and NPV per Installation

F. RISK ANALYSIS

Considering uncertainties in the planning process helps mitigate—but not eliminate—risks. Some risks regarding geothermal, wind, and solar projects are identified and defined. The EVs of all three renewable energy resources are calculated in Table 8 to show how the risks and probabilities can impact renewable energy resource project costs.

The different types of risks selected for the risk analysis in Table 8 are considered important to renewable energy resource projects. The research conducted in previous chapters assisted with the selection of the risks defined in the following section. The probability and impact values are assumed because installation commanders plan for risks associated to their specific installation. As discussed in the previous section, the EV provides a risk exposure which equals the probability of an occurrence multiplied by the impact. Risks are not a one size fits all; therefore, the risk assessment conducted in Table 8 is only to provide an example of a risk analysis process of EVs within a risk range. The EVs calculated will not be utilized in further analysis.

In Table 8, the first column lists the different types of risks that each investment could face. The probability column indicates how likely each of these risks might occur. The assumed impact column estimates how much the project's monetary value is affected by that specific risk. The expected value is the probability of the occurrence of a risk multiplied by the impact of that risk.

Table 8. Utilizing Expected Value to Show Miramar’s Risk Analysis For Geothermal, Wind and Solar Renewable Energy Resources

Geothermal Risks				Geothermal Risk Range		
Risks	Probability	Assumed Impact	Expected Value of Risk	No Risks	Expected Value of Project	All Risks
Regulatory Risks	20%	$127,000,000	$25,400,000	$163,568,000	$427,868,000	$989,568,000
Human Behavior	30%	$191,000,000	$57,300,000			
Learning Curve	10%	$63,000,000	$6,300,000			
Environmental laws	5%	$31,000,000	$1,550,000			
Supplier Failures	50%	$319,000,000	$159,500,000			
Maintenance	15%	$95,000,000	$14,250,000			
Weather effects/delays	0%	$0	$0			
Total Cost		**$826,000,000**	**$264,300,000**			

Wind Risks				Wind Risk Range		
Risks	Probability	Assumed Impact	Expected Value of Risk	No Risks	Expected Value of Project	All Risks
Regulatory Risks	35%	$13,000,000	$4,550,000	$43,831,000	$73,481,000	$126,831,000
Human Behavior	50%	$19,000,000	$9,500,000			
Learning Curve	30%	$11,000,000	$3,300,000			
Environmental laws	25%	$9,000,000	$2,250,000			
Supplier Failures	15%	$5,000,000	$750,000			
Maintenance	30%	$11,000,000	$3,300,000			
Weather effects/delays	40%	$15,000,000	$6,000,000			
Total Cost		**$83,000,000**	**$29,650,000**			

Solar Risks				Solar Risk Range		
Risks	Probability	Assumed Impact	Expected Value of Risk	No Risks	Expected Value of Project	All Risks
Regulatory Risks	40%	$36,000,000	$14,400,000	$92,421,504	$157,321,504	$282,421,504
Human Behavior	50%	$46,000,000	$23,000,000			
Learning Curve	20%	$18,000,000	$3,600,000			
Environmental laws	30%	$27,000,000	$8,100,000			
Supplier Failures	15%	$13,000,000	$1,950,000			
Maintenance	25%	$23,000,000	$5,750,000			
Weather effects/delays	30%	$27,000,000	$8,100,000			
Total Cost		**$190,000,000**	**$64,900,000**			

Installation commanders must plan to consider risks and apply probabilities to those risks. This risk analysis provides a risk range that varies with different views (optimistic or pessimistic); however, it defines the concerns that a commanders may have, which is a step closer to mitigating those risks. Table 8 is just a snap shot to show Miramar’s EV if it pursued one specific renewable energy resource alone to reach a net-zero return. The best case cost values are pulled from Table 9 in this specific example. In the following section, each of those risks is explained.

1. Regulatory Risk (Financing, Expiration of Tax Breaks, Subsidies, and Political)

Regulatory risks are those related to the type of financing approach used, the expiration of subsidies and tax breaks which could increase total costs, and political agendas brought by political parties that could affect installation priorities. The most mature and reliable of the three indigenous renewable energy resources, geothermal, is clean. However, capital expenses are high and it is visually non-intrusive. Wind is a clean energy source; however, it is visually intrusive as utility-scale wind turbines can reach over 300 feet high with a rotor diameter of 150 feet. Wind energy also has high capital costs and reliability is dependent on the contractor. Solar energy is relatively cheap and has a variety of subsidies and financing opportunities. Solar is relatively unobtrusive but can have a large footprint. Overall, solar is a very clean energy source, but has varying degrees of efficiency and capital costs. Geothermal energy is safe, clean, and reliable. The other resources are safe and clean, but are also heavily dependent on environmental conditions.

2. Human Behavior

Human behavior presents challenges at all levels related to furthering the implementation of energy projects. Personal agendas, adversity to change, contentment with the status quo, and so forth, are widespread issues. Geothermal and wind energy are renewable energy technologies that require high capital costs. All three resources can project a nonconformist attitude toward energy, but wind resources receive the predominate share of negative attention because of their visual obtrusiveness. Solar is less obtrusive, but widely known to be much less efficient in its energy production.

3. Learning Curve and Knowledge Management

A learning curve represents the changing rate of learning over time—and typically, the longer one does something the more easily they learn (practice makes cheaper). Lateral information sharing is the result of good “Knowledge Management” or KM. Coupled together, these two have the potential to provide applicable data on lessons learned that can be distributed to other installations to communicate and share laterally. How much learning and KM are required to create a mature technology at a low cost? Is there going to be a learning curve? Geothermal energy has been around a long time and can be considered a mature, established technology; however, there is an additional element that goes into finding productive geothermal pockets. Wind resources are getting more efficient but still have room for improvement. Solar is a simple technology that does not require extensive construction, but the technology is very inefficient in energy production (only 18 percent efficiency).

4. Environmental

Energy production with renewable resources affects the environment, including plant and animal species. Geothermal and solar are very clean and supported by environmental laws. They are also visually non-obtrusive. Wind is clean, but is believed to affect bird habitat. Wind turbines can also adversely affect animal wintering grounds and migration routes.

5. Supplier Failures

Materials and systems for geothermal production are mature and abundant, so it is less subject to supplier failures. Wind turbine parts are large compared to the equipment needed for other resources, with fewer suppliers making them. Transportation of the large parts of wind turbines also leads to increases in costs. Solar technology is widespread with competitive suppliers providing different models and sizes of arrays that utilize economies of scale.

6. Maintenance

The maintenance impact of geothermal systems is relatively low with production systems requiring little maintenance, but constant monitoring. Repair can be relatively intensive due to the size of some systems and parts. The maintenance impact of wind systems is predominant in the initial construction phase, but thereafter requiring only periodic scheduled and unscheduled maintenance. Solar requires little maintenance, but is the most fragile of the three resources.

7. Weather Effects

Geothermal energy production is not affected by weather conditions. Wind depends heavily on weather patterns and geographical locations to produce energy. Solar is less dependent on weather as it can still produce some energy on cloudy days, however, solar is most effective in very sunny regions.

G. COST-BENEFIT ANALYSIS OVERVIEW

Cost-benefit analysis is utilized to capture the energy capacity per renewable resource for the Miramar and Hawaii installations. Capital costs, Operating and Maintenance (O&M) costs, and NPV are the variables used to determine the cost-benefit analysis. The cost-benefit analysis is based on scenarios that include combinations of renewable resources that equal the average annual energy output for Miramar and Hawaii installations (net-zero capacity). The purpose is to identify the trade-offs between using a single renewable resource to accomplish net-zero capacity and a scenario-based analysis with combinations of renewable resources to accomplish net-zero capacity. The assumption is that using a single-source renewable energy resource to accomplish net-zero capacity for an installation is inefficient and cost ineffective. In addition, the analysis shows that a combination of renewable resources should be taken into account. This is dependent upon the region and installation to identify the most cost-effective and energy-efficient portfolio of renewable resources.

1. Maximum Capacity Scenario per Renewable Resource Analysis

Table 9 and 10 show the size and cost of using a single renewable resource to accomplish an annual net-zero capacity for Miramar and Kaneohe Bay respectively. Table 11, makes comparisons using combinations of renewable resources at Miramar to show the effectiveness of combining the best types to reach net-zero energy requirements based on installation needs and regional capabilities. Scenario 1, Table 9 , one 8 MW geothermal plant producing approximately 70,000,000 kWh per year would be required to supply Miramar’s average annual energy requirement of 66,543,615 kWh per year. Scenario 2, Table 9 illustrates how many 1.5 MW wind turbines would be required to meet Miramar’s energy output. In this table, we see that seventeen 1.5 MW wind turbines—producing approximately 67,000,000 kWh per year—would be required to provide the energy requirement for Miramar. Scenario 3, Table 9 illustrates the requirement for 280,000 one square meter solar panels to produce approximately

66,000,000 kWh per year to meet MCAS Miramar’s net-zero requirements. Associated with the three scenarios are the capital cost, net benefits, and NPV for each single-source application.

In this section, these three scenarios are compared against additional scenarios using multiple combinations of renewable resources to meet net-zero requirements. This is done to show the possible cost savings that can be obtained by mixing a portfolio of renewable energy resources rather than relying on one resource to produce the entire installation’s energy. The purpose of this is not to present a particular scenario as the “correct solution,” but to show the installation commander that there are multiple choices to maximize energy production. This is dependent on determining the most effective resources available for a particular region while minimizing the costs of procuring and utilizing renewable resources.

Table 9. Miramar Capacity per Renewable Resource

MCAS MIRAMAR							
Scenario	**Geo Plant Size (MW)**	**Wind Turbines (#)**	**Solar Panels (#)**	**Output (kWh, thou)**	**Cost ($M)**	**Benefits ($M)**	**NPV ($M)**
1	8.0	0	0	70.0	**163.6**	**215.1**	**34.3**
2	0	17.0	0	67.0	**43.8**	**137.1**	**74.7**
3	0	0	280,000	66.2	92.4	169.4	52.4

Best	**Worst**

Scenario 1 of Table 10 illustrates the size of the plant that would be required to meet MCB Kaneohe Bay Hawaii’s annual energy output using only geothermal energy (assuming that geothermal resources were available). In this example, one 12 MW geothermal plant producing approximately 105,000,000 kWh per year would be required to supply Kaneohe Bay’s average annual energy output of 107,088,800 kWh per year. Scenario 2, Table 10 illustrates how many 1.5 MW wind turbines would be required to meet Kaneohe Bay’s energy output. In Table 10, we see that twenty-seven 1.5 MW wind turbines, producing approximately 106,000,000 kWh per year would need to be built. Scenario 3, Table 10 illustrates the requirement for 460,000 one square meter solar panels that produce approximately 108,000,000 kWh per year to meet MCB Kaneohe Bay's net-zero requirements. Associated with the three scenarios are the capital cost, net benefits, and NPV for each single-source application.

Table 10. Hawaii Capacity per Renewable Resource

MCB KANOEHE BAY, HAWAII

Scenario	Geo Plant Size (MW)	Wind Turbines (#)	Solar Panels (#)	Output (kWh, thou)	Cost ($M)	Benefits ($M)	NPV ($M)
1	12.0	0	0	105.1	**245.4**	**322.6**	**51.4**
2	0	27.0	0	106.4	**69.1**	**217.8**	**119.2**
3	0	0	460,000	108.8	151.8	278.3	86.1

Best **Worst**

2. Resource Combination Scenario Analysis

Tables 11 and 12 illustrate ten and eight different scenarios for Miramar and Hawaii, respectively. These are examples of the cost-benefit analysis that can be applied by installation commanders using a variety of combinations of renewable energy resources to obtain net-zero energy production goals. In this particular example, combinations of geothermal, wind, and solar energy resources are displayed to show the cost-benefit analysis of obtaining net-zero energy production. Highlighted are the best and worst capital costs, net benefits and NPVs for each scenario. This information can be used by the installation commanders to determine the best combination of resources that can be applied to their renewable energy portfolio, taking into consideration the total costs, benefits, and reliability of the renewable resource for that particular region. Not all renewable resources are available—or most efficient—for each installation. For example, it is not feasible to use geothermal energy where geothermal resources do not exist. Chapter III provides a highlight of renewable energy resources—including several NREL energy resource maps—that can provide an optimal solution per installation when used in combination with the cost-benefit analysis for each energy portfolio.

Tables 11 and 12 are a summary of the detailed data found in Appendix C for Miramar and Hawaii. The analysis of this data concludes that geothermal has the highest capital and O&M costs, and greater monetary benefits (kWh per year times the price of commercial electricity in 2011); however, it provides the lowest NPV of the three renewable energy resources. On the other hand, wind has the lowest capital and O&M costs with a decent amount of monetary benefits, but it provides the highest NPV. Solar energy lies between geothermal and wind energy values.

Small geothermal plants produce negative ROI and should be excluded from energy portfolios. The combination of wind and solar typically produce optimal results. Wind produces the most efficient ROI; however, due to wind's limited regional efficiencies the combination of wind and solar seems to produce the most complementary results.

Table 11. Miramar Combination Scenarios

MCAS MIRAMAR							
Scenario	**Geo Plant Size (MW)**	**Wind Turbines (#)**	**Solar Panels (#)**	**Output (kWh, thou)**	**Cost ($M)**	**Benefits ($M)**	**NPV ($M)**
1	5	5	0	63.5	115.8	174.7	43.7
2	0	9	133,333	67.0	67.7	153.2	64.1
3	0	12	80,000	66.2	**57.6**	**145.2**	**67.5**
4	0	2	246,667	66.2	87.5	165.3	54.2
5	5	0	96,666	66.7	134.1	192.9	39.5
6	3	0	170,000	66.5	150.8	183.5	19.5
7	2	12	0	64.8	94.4	150.6	44.3
8	4	3	83,334	66.6	**162.3**	182.1	**11.7**
9	6	1	43,320	66.7	140.4	**195.6**	37.5
10	5	3	46,667	66.7	126.1	186.8	42.7

Best	**Worst**

Table 12. Hawaii Combination Scenarios

MCB KANOEHE BAY, HAWAII

Scenario	Geo Plant Size (MW)	Wind Turbines (#)	Solar Panels (#)	Output (kWh, thou)	Cost ($M)	Benefits ($M)	NPV ($M)
1	9	7	0	106.4	202.6	298.4	68.9
2	0	13	233,000	106.4	110.7	245.8	100.1
3	0	20	116,667	106.4	90.0	231.9	110
4	0	3	400,000	106.4	140.5	266.2	87.4
5	10	0	80,000	106.5	230.9	317.2	57.8
6	5	0	266,667	106.8	190.3	295.7	71.3
7	5	16	0	106.8	143.5	263.5	91.7
8	5	10	99,510	106.8	161.2	275.3	83.7

Best **Worst**

H. SUMMARY

The analysis shows that combining a variety of indigenous renewable resources for an installation based upon its regional location and energy output requirements is more efficient than blanket purchases and installation of the most available renewable resource technology. Increased comparative analysis should be utilized to determine the most efficient and effective combination of resources that provides the installation commander the best “bang for his buck.” Installations can reach this goal by improving lateral communication and information sharing, taking into account costs, benefits, and risks in comparison with previous installation data analysis, along with regional geographic conditions, weather patterns and human factors.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The focus of this thesis is to illustrate how the United States Marine Corps should implement the renewable energy programs mandated by the Department of Defense. Achieving this mandate can be accomplished with more efficiency and cost effectiveness, and budgetary constraints and national security concerns also drive the necessity for DoD installations to become self-reliant from the national electrical grid system.

National security requirements in today's world rest heavily upon the militaries' ability to respond immediately to any threat (this is especially true for the Marine Corps). However, the current reliance on the national electrical grid to supply power to USMC installations is the greatest security concern that America faces today. There are a wide range of circumstances that might result in widespread power outages that could last for weeks or months: terrorist attacks aimed at disrupting America's energy production; natural disasters that wreak havoc on key energy generation facilities and systems; and surges in the grid system resulting in regional "brown-outs" (best case scenario) or "black-outs" (worst case). The USMC is as vulnerable as the rest of the country when it comes to losing its infrastructure and capability to handle basic, mission essential tasks. In a situation like this—without power—it is necessary for the military to react immediately to maintain order, help the needy, and defend the country. Without power, the USMC loses the capability to do any of this.

This thesis uses three primary renewable energy technologies at two specific USMC installations to analyze the data collected with a net-zero energy generation mentality. This is done to provide "best practice" guidance to installation commanders and their installation energy experts for initiating future energy projects using a portfolio approach. The portfolio approach is based on selecting the optimal renewable energy technology by leveraging more than the most readily available data. The portfolio approach encourages energy leaders to select technology based on regional conditions and resources, technological maturity, cost-benefit analysis, and risk assessments. This approach will ensure that installations can move toward energy independence in an economical and efficient manner—and one which will allow the USMC to operate in the best interest of the United States under any condition.

B. RECOMMENDATIONS

1. NPV and Risk Analysis

Installation commanders should include NPV and risk analysis to choose the most optimal portfolio. NPV includes the present value of benefits and the present value of costs which is more widely used for long-term projects because it incorporates opportunity costs, capital costs, and discount rates. Risk considers uncertainties in the planning process and helps to mitigate risks that are inevitable.

2. Energy Portfolios

As discussed in the data analysis section, certain areas and regions of the country are more favorable for a particular type of renewable energy; it is wise for the installation commander to refrain from relying on only one renewable energy technology. Instead, combining the most efficient renewable energy approach for the area with additional productive technologies can maximize the potential energy generation capabilities of an installation. For example, solar energy cannot be generated at night, but wind energy can (if it strong enough). The same is true if it is sunny but calm. Solar can generate when the air is still. The old adage, “Don’t put all your eggs in one basket” is important when planning an installation energy portfolio.

3. Technological Maturity

The data analyzed in this thesis concentrated on geothermal, wind, and solar energy technologies because of their maturity—even though they vary in efficiency. The more mature the technology, the more cost effective and reliable it will be. As additional renewable energy generation technologies become available, energy portfolios will have the ability to be even more diversified. Technologies like wave and tidal energy generation systems could one day provide unlimited energy to installations along coastal areas. Waste energy generation systems have the potential for unlimited energy production with the added benefit of reducing waste storage and cleanup. Currently, too many issues remain to be solved for these technologies to be used as viable options in energy portfolios.

4. Knowledge Management

Our analysis included information sharing/knowledge management as essential elements to improving the understanding of how to best implement renewable energy capabilities and integrate solutions that maximize efficiencies while reducing costs. Information sharing encourages deliberate and well-planned processes that accelerate material requirements and installation technology infrastructure improvements. To accomplish effective information sharing, an energy implementation working group needs to be developed to work with installation commanders. The working group is a multifunctional organization made up of civilian energy experts, military acquisition specialists, and policy personnel that can validate requirements and new technology solutions, and document streamlined acquisition methodologies. An energy implementation working group can assist commanders in implementing renewable energy solutions, and help processes and share information to improve overall technology management across all USMC installation energy programs. Figure 15 is a flow diagram to show that KM is the central idea in the renewable energy resource selection process aimed at minimizing costs and maximizing benefits. Every step contributes to the central idea of sharing information. As each installation internally communicates and documents its process and findings at each stage, they are also collaborating with other installations laterally.

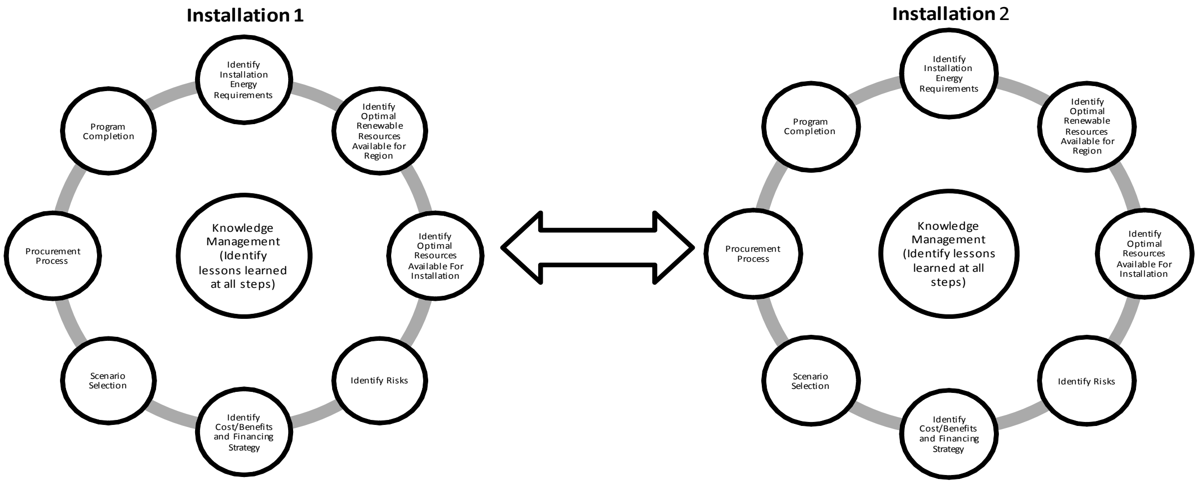


Figure 15. Knowledge Management Chart

5. Further Research

Further Research into the best combination of renewable energy portfolios that can be utilized to provide installation commanders net-zero options to meet energy requirements needs to be conducted. Additional research also needs to be conducted in the best business practices to acquire and manage energy portfolios that maximize the limited budgets that the DoD will face in the coming decade. Energy best practices are dynamic and require constant analysis, manipulation, and research to stay on the cutting edge of implementation and utilization.

C. SUMMARY

The large national debt that is forcing DoD budget cuts has encouraged the USMC to find cost savings wherever possible. The ability of the military to generate enough energy to power their own installations could result in cost savings of hundreds of millions of dollars over the next decade. The use of mature indigenous renewable energy, especially in the form of geothermal, wind, and solar technology, could “reduce or eliminate the nation’s dependence on imported energy, thereby reducing trade deficits” (REPP-CREST, p.4). The DoD is the largest consumer of energy in the United States and the relief that would result from removing DoD’s energy requirements from the aging and over-burdened grid system would enhance the energy capacity of the United States and lesson budgetary requirements.

The purpose of this thesis is to get installation commanders and their energy experts to institute holistic approaches of implementing renewable energy policies in order to diminish their dependence on the American energy grid. The ability to gain energy self-reliance helps reduce or eliminate the nation’s dependence on imported energy, thereby reducing trade deficits. Separation from the grid also strengthens security, and ensures that the Marine Corps can operate to assist Americans during times of crisis and defend the Country under any circumstances. These energy policies should include a careful and thorough consideration of the value of each energy source in a particular region—with an analysis of the costs, benefits, and risks involved. Information sharing efforts can ensure consistent and efficient evaluation and implementation of indigenous renewable energy sources and best budgeting and management practices. Failure to effect these changes presents one of the greatest threats to America’s security and the United States Marine Corp's mission to protect and defend the United States of America and its citizens.

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APPENDIX A. MARINE CORPS RENEWABLE ENERGY INITIATIVES BY INSTALLATION

The data was obtained from a 2010 GAO report that conducted a review of DoD renewable energy projects. The data was extracted from the GAO report to show the Marine Corps installations with energy initiatives. Each table is broken down by Marine Corps installation.

Installation / Location	State / Country	Project Title	Type of Renewable Energy	Project Status	If Operational: Date Placed In Service	Project Designed to Supply DoD Independent of Grid?	Fiscal Year	Energy Produced (MMBtu)	Project Total Capital Cost (Thou. $)	Project DoD Capital Cost (Thou. $)	Funding Mechanism
MCAGCC 29 Palms	CA	ESPC / 1.2 MW Solar Array	Solar Photovoltaic	Fully Operational	Sep-04	No	2009	6,576	$10,493	$10,493	ESPC
MCAGCC 29 Palms	CA	Range 500	Solar Photovoltaic	Fully Operational	Sep-98	Yes	2009	90			Appropriated
MCAGCC 29 Palms	CA	Remote repeater stations	Solar Photovoltaic	Fully Operational	Sep-02	No	2009	975			Appropriated
MCAGCC 29 Palms	CA	Walkway lighting Areas 1100 1200 and 1300	Solar Photovoltaic	Fully Operational	Jun-09	No	2009	9	$1,280	$1,280	Appropriated
MCAGCC 29 Palms	CA	Buildings 2056, 2057 & 2058 (Vehicle Holding Sheds)	Solar Photovoltaic	Under Const - Non Op	Jun-10	No	2009	694	$1,159	$1,159	Appropriated
MCAGCC 29 Palms	CA	Vehicle holding Sheds (Buildings 2067, 2068, 1201, 1202, and 2008)	Solar Photovoltaic	Under Const - Non Op	NA	No	2009	2,894	$3,728	$3,728	Appropriated
MCAGCC 29 Palms	CA	B2009 (Vehicle Holding Shed)	Solar Photovoltaic	Budgeted	NA	No	2009	694	$1,618	$1,618	Appropriated
MCAGCC 29 Palms	CA	BEQs 1462–1463	Solar Photovoltaic	Budgeted	NA	No	2009	460	$1,458	$1,458	Appropriated
MCAGCC 29 Palms	CA	Building 2050	Solar Photovoltaic	Fully Operational	Jun-09	No	2009	299	$672	$672	Appropriated
MCAGCC 29 Palms	CA	Building 1231 & 1233	Solar Photovoltaic	Fully Operational	Jun-09	No	2009	299	$559	$559	Appropriated
MCAGCC 29 Palms	CA	Building 1229 & 1230	Solar Photovoltaic	Fully Operational	Jun-09	No	2009	299	$485	$485	Appropriated
MCAGCC 29 Palms	CA	B2048	Solar Photovoltaic	Fully Operational	Oct-09	No	2009	442	$311	$311	Appropriated

Installation / Location	State / Country	Project Title	Type of Renewable Energy	Project Status	If Operational: Date Placed In Service	Project Designed to Supply DoD Independent of Grid?	Fiscal Year	Energy Produced (MMBtu)	Project Total Capital Cost (Thou. $)	Project DoD Capital Cost (Thou. $)	Funding Mechanism
MCAGCC 29 Palms	CA	B2049	Solar Photovoltaic	Fully Operational	Oct-09	No	2009	442	$738	$738	Appropriated
MCAGCC 29 Palms	CA	B2051	Solar Photovoltaic	Fully Operational	Oct-09	No	2009	442	$740	$740	Appropriated
MCAGCC 29 Palms	CA	B1203	Solar Photovoltaic	Fully Operational	Oct-09	No	2009	287	$540	$540	Appropriated
MCAGCC 29 Palms	CA	B1204	Solar Photovoltaic	Fully Operational	Oct-09	No	2009	287	$639	$639	Appropriated
MCAGCC 29 Palms	CA	B1205	Solar Photovoltaic	Fully Operational	Oct-09	No	2009	287	$543	$543	Appropriated
MCAGCC 29 Palms	CA	B1222	Solar Photovoltaic	Fully Operational	Dec-09	No	2009	257	$550	$550	Appropriated
MCAGCC 29 Palms	CA	B1251	Solar Photovoltaic	Fully Operational	Dec-09	No	2009	179	$527	$527	Appropriated
MCAGCC 29 Palms	CA	B1801	Solar Photovoltaic	Under Const - Non Op	NA	No	2009	203	$462	$462	Appropriated
MCAGCC 29 Palms	CA	B1802	Solar Photovoltaic	Funded	NA	No	2009	203	$450	$450	Appropriated
MCAGCC 29 Palms	CA	B1803	Solar Photovoltaic	Funded	NA	No	2009	203	$446	$446	Appropriated
MCAGCC 29 Palms	CA	B1804	Solar Photovoltaic	Funded	NA	No	2009	203	$439	$439	Appropriated
MCAGCC 29 Palms	CA	B1805	Solar Photovoltaic	Funded	NA	No	2009	203	$639	639	Appropriated
MCAGCC 29 Palms	CA	GTF Tracked Sunshades	Solar Photovoltaic	Budgeted	NA	No	2009	5,980	$2,700	$2,700	Appropriated
							Total:	**22,907**	**$31,176**	**$31,176**	

Installation / Location	State / Country	Project Title	Type of Renewable Energy	Project Status	If Operational: Date Placed In Service	Project Designed to Supply DoD Independent of Grid?	Fiscal Year	Energy Produced (MMBtu)	Project Total Capital Cost (Thou. $)	Project DoD Capital Cost (Thou. $)	Funding Mechanism
MCAS Beaufort	SC	Install 60 Government Provided Solar Power Security Lights	Solar Photovoltaic	Fully Operational	Oct-09	No		16	$8	$8	Appropriated
MCAS Beaufort	SC	Solar Domestic Hot Water at O-Club (ECM in Beaufort ESPC III)	Solar Thermal	Fully Operational	Oct-09	No	2010	160	$50	$50	ESPC
							Total:	**176**	**$58**	**$58**	

Installation / Location	State / Country	Project Title	Type of Renewable Energy	Project Status	If Operational: Date Placed In Service	Project Designed to Supply DoD Independent of Grid?	Fiscal Year	Energy Produced (MMBtu)	Project Total Capital Cost (Thou. $)	Project DoD Capital Cost (Thou. $)	Funding Mechanism
MCAS Cherry Point	NC	50KW PV system - Warehouse (Building 1016)	Solar Photovoltaic	Fully Operational	Mar-09	No	2009	299	$594	$594	Appropriated
MCAS Cherry Point	NC	50 KW PV system - General Warehouse (Building 159)	Solar Photovoltaic	Fully Operational	Oct-09	No	2009	299	$587	$587	Appropriated
MCAS Cherry Point	NC	30 KW PV system - Theater (Building 194)	Solar Photovoltaic	Fully Operational	Oct-09	No	2009	179	$388	$388	Appropriated
							Total:	**777**	**$1,569**	**$1,569**	

Installation / Location	State / Country	Project Title	Type of Renewable Energy	Project Status	If Operational: Date Placed In Service	Project Designed to Supply DoD Independent of Grid?	Fiscal Year	Energy Produced (MMBtu)	Project Total Capital Cost (Thou. $)	Project DoD Capital Cost (Thou. $)	Funding Mechanism
MCAS Miramar	CA	30 KW Solar Roof mounted & Thermal applications	Solar Photovoltaic	Fully Operational	Nov-09	No	2009	1,007	$683	$683	Appropriated
MCAS Miramar	CA	260 KW Solar Carport	Solar Photovoltaic	Fully Operational	Apr-10	No	2009	1,184	$1,749	$1,749	Appropriated
MCAS Miramar	CA	300 KW Solar roof and Carport	Solar Photovoltaic	Budgeted	NA	No	2010	1,481	$2,377	$2,377	Appropriated
MCAS Miramar	CA	Replacing Parking lot lights with Solar Units in Area 5	Solar Photovoltaic	Budgeted	NA	No	2010	287	$2,659	$2,659	Appropriated
MCAS Miramar	CA	216 KW Solar Carport	Solar Photovoltaic	Budgeted	NA	No	2010	1,287	$2,349	$2,349	Appropriated
MCAS Miramar	CA	Replaced Parking lot lights with Solar Units near Hangars 5 & 6	Solar Photovoltaic	Fully Operational	Feb-10	No	2009	61	$722	$722	Appropriated
MCAS Miramar	CA	Replaced Parking lot lights with Solar Units near Buildings 6003 & 6004	Solar Photovoltaic	Fully Operational	Feb-10	No	2009	61	$714	$714	Appropriated
							Total:	**5,368**	**$11,253**	**$11,253**	

Installation / Location	State / Country	Project Title	Type of Renewable Energy	Project Status	If Operational: Date Placed In Service	Project Designed to Supply DoD Independent of Grid?	Fiscal Year	Energy Produced (MMBtu)	Project Total Capital Cost (Thou. $)	Project DoD Capital Cost (Thou. $)	Funding Mechanism
MCAS Pendleton	CA	134kW Solar PV Array - Roof Mounted (Bldgs 23208/23210)	Solar Photovoltaic	Under Const - Part Op	NA	No	2009	801	$1,333	$1,333	Appropriated
MCAS Pendleton	CA	53kW Solar PV Array - Roof Mounted (Bldg 23209)	Solar Photovoltaic	Fully Operational	Mar-10	No	2009	317	$772	$772	Appropriated

Installation / Location	State / Country	Project Title	Type of Renewable Energy	Project Status	If Operational: Date Placed In Service	Project Designed to Supply DoD Independent of Grid?	Fiscal Year	Energy Produced (MMBtu)	Project Total Capital Cost (Thou. $)	Project DoD Capital Cost (Thou. $)	Funding Mechanism
MCB Camp Pendleton	CA	46KW PV Array Roof Mounted Bldg 31917	Solar Photovoltaic	Fully Operational	Aug-04	No	2009	281	$595	$595	Appropriated
MCB Camp Pendleton	CA	32KW PV Array Roof Mounted Bldgs 22111 and 22112	Solar Photovoltaic	Fully Operational	Apr-05	No	2009	191	$360	$360	Appropriated
MCB Camp Pendleton	CA	43KW PV Array Roof Mounted on Bldgs 2246 and 2253	Solar Photovoltaic	Fully Operational	May-05	No	2009	225	$360	$360	Appropriated
MCB Camp Pendleton	CA	14KW PV Array and Solar Thermal Ground Mounted 14 Area Pool	Solar Photovoltaic	Fully Operational	Jun-07	No	2009	86	$1,046	$1,046	Appropriated
MCB Camp Pendleton	CA	32KW PV Array and Solar Thermal Ground Mounted 62 and 53 Area Pools	Solar Photovoltaic	Fully Operational	Jun-07	No	2009	173	$1,046	$1,046	Appropriated
MCB Camp Pendleton	CA	30KW PV Array Roof Mounted Bldg 22113	Solar Photovoltaic	Fully Operational	Jun-08	No	2009	179	$350	$350	Appropriated
MCB Camp Pendleton	CA	75KW PV Array Roof Mounted Bldg 2251	Solar Photovoltaic	Fully Operational	Jun-08	No	2009	448	$637	$637	UESC
MCB Camp Pendleton	CA	50KW PV Array Roof Mounted Bldg 22114 & Electrical Service Upgrade	Solar Photovoltaic	Fully Operational	Jun-09	No	2009	299	$732	$732	Appropriated
MCB Camp Pendleton	CA	50KW PV Array Roof Mounted Bldg 2252	Solar Photovoltaic	Fully Operational	Nov-09	No	2009	299	$450	$450	UESC
MCB Camp Pendleton	CA	50KW PV Array Carport Mounted Bldg 430715	Solar Photovoltaic	Fully Operational	Dec-09	No	2009	299	$450	$450	Appropriated
MCB Camp Pendleton	CA	10 KW PV Array Carport Mounted Bldg 2291 & 22 motor pool	Solar Photovoltaic	Fully Operational	Dec-05	No	2009	60	$100	$100	Appropriated
MCB Camp Pendleton	CA	288 (240 w) streetlights	Solar Photovoltaic	Fully Operational	Various	No	2009	356	$960	$960	UESC
MCB Camp Pendleton	CA	5KW PV Array Roof Mounted 33 Area Fitness Center	Solar Photovoltaic	Fully Operational	Dec-09	No	2009	30	$50	$50	Appropriated
MCB Camp Pendleton	CA	50KW PV Array Roof Mounted Building 41404	Solar Photovoltaic	Fully Operational	Apr-10	No	2009	299	$500	$500	Appropriated
MCB Camp Pendleton	CA	66 KW PV on Buildings 41408 and 41409	Solar Photovoltaic	Under Const - Non Op	On line July 2010	No	2009	395	$480	$480	UESC
MCB Camp Pendleton	CA	252 KW Recycling Center and 43 Area Artillery Shed.	Solar Photovoltaic	Under Const - Non Op	On line June 2010	No	2009	1,507	$3,114	$3,114	Appropriated
MCB Camp Pendleton	CA	1.445 MW Box Canyon landfill	Solar Photovoltaic	Funded	NA	No	2009	8,640	$10,946	$10,946	Appropriated
MCB Camp Pendleton	CA	1.0 - 1.5 MW Box Canyon landfill	Solar Photovoltaic	Budgeted	NA	No	2009	7,175	$10,000	$10,000	Appropriated
MCB Camp Pendleton	CA	Day lighting Harvesting Systems (300)	Daylighting	Fully Operational	Dec-08	No	2009	761	$420	$420	UESC
MCB Camp Pendleton	CA	Ground Source Heat Pump (100 Tons)	Geothermal Heat Pump	Fully Operational	Dec-08	No	2009	4,143	$1,400	$1,400	UESC

Installation / Location	State / Country	Project Title	Type of Renewable Energy	Project Status	If Operational: Date Placed In Service	Project Designed to Supply DoD Independent of Grid?	Fiscal Year	Energy Produced (MMBtu)	Project Total Capital Cost (Thou. $)	Project DoD Capital Cost (Thou. $)	Funding Mechanism
							Total:	**26,964**	**$36,101**	**$36,101**	

Installation / Location	State / Country	Project Title	Type of Renewable Energy	Project Status	If Operational: Date Placed In Service	Project Designed to Supply DoD Independent of Grid?	Fiscal Year	Energy Produced (MMBtu)	Project Total Capital Cost (Thou. $)	Project DoD Capital Cost (Thou. $)	Funding Mechanism
MCAS Yuma	AZ	Solar PV Sunshade (structure 233)	Solar Photovoltaic	Fully Operational	Jan-10	No	2009	190	$407	$407	Appropriated
MCAS Yuma	AZ	Solar PV Metal Sunshades (Bldg 1239 & Bldg 1235)	Solar Photovoltaic	Fully Operational	Sep-09	No	2009	191	$508	$508	Appropriated
MCAS Yuma	AZ	Solar PV (Bldg 1958) Clearwell	Solar Photovoltaic	Fully Operational	May-10	No	2010	194	$448	$448	Appropriated
MCAS Yuma	AZ	Solar Electric Vehicle Charging Station (Bldg 603)	Solar Photovoltaic	Fully Operational	May-09	No	2009	42	$125	$125	Appropriated
MCAS Yuma	AZ	Environmental BIPV Roof (Bldg 228)	Solar Photovoltaic	Fully Operational	Aug-09	No	2009	120	$256	$256	Appropriated
							Total:	**737**	**$1,744**	**$1,744**	

Installation / Location	State / Country	Project Title	Type of Renewable Energy	Project Status	If Operational: Date Placed In Service	Project Designed to Supply DoD Independent of Grid?	Fiscal Year	Energy Produced (MMBtu)	Project Total Capital Cost (Thou. $)	Project DoD Capital Cost (Thou. $)	Funding Mechanism
MCB Camp Lejeune	NC	B1316 - completion expected 6/21/2010	Solar Photovoltaic	Funded	NA	No	2009	419	$718	$718	Appropriated
MCB Camp Lejeune	NC	B1317 - completion expected 6/21/2010	Solar Photovoltaic	Funded	NA	No	2009	419	$718	$718	Appropriated
MCB Camp Lejeune	NC	Roofs 1116, 1211, and 1212 - 288 kW per roof - Completion expected 12/21/2010	Solar Photovoltaic	Funded	NA	No	2009	5,166	$7,309	$7,309	Appropriated
MCB Camp Lejeune	NC	TBD - facilities and possibly open areas where a PV array would be feasible	Solar Photovoltaic	Budgeted	NA	No	2009	11,361	$10,000	$10,000	Appropriated
							Total:	**17365**	**$18,745**	**$18,745**	

Installation / Location	State / Country	Project Title	Type of Renewable Energy	Project Status	If Operational: Date Placed In Service	Project Designed to Supply DoD Independent of Grid?	Fiscal Year	Energy Produced (MMBtu)	Project Total Capital Cost (Thou. $)	Project DoD Capital Cost (Thou. $)	Funding Mechanism
MCB Hawaii	HI	32 KW Building Integrated Photovoltaic Roofing, Bldg 1027	Solar Photovoltaic	Fully Operational	Sep-08	No	2009	173	$521	$521	Appropriated

Installation / Location	State / Country	Project Title	Type of Renewable Energy	Project Status	If Operational: Date Placed In Service	Project Designed to Supply DoD Independent of Grid?	Fiscal Year	Energy Produced (MMBtu)	Project Total Capital Cost (Thou. $)	Project DoD Capital Cost (Thou. $)	Funding Mechanism
MCB Hawaii	HI	32 KW Building Integrated Photovoltaic Roofing, Bldg 1045	Solar Photovoltaic	Fully Operational	Sep-08	No	2009	170	$521	$521	Appropriated
MCB Hawaii	HI	Solar Hot Water System, Bldg 503	Solar Thermal	Fully Operational	Apr-09	No	2009	1,062	$370	$370	Appropriated
MCB Hawaii	HI	Skylights and Lighting Upgrades, Bldg 6469	Day lighting	Fully Operational	Nov-08	No	2009	66	$189	$189	Appropriated
MCB Hawaii	HI	Solar Hot Water System, Bldg 386 and Lighting Upgrades, Bldg 375	Solar Thermal	Fully Operational	Jul-09	No	2009	255	$556	$556	Appropriated
							Total:	**1726**	**$2,157**	**$2,157**	

Installation / Location	State / Country	Project Title	Type of Renewable Energy	Project Status	If Operational: Date Placed In Service	Project Designed to Supply DoD Independent of Grid?	Fiscal Year	Energy Produced (MMBtu)	Project Total Capital Cost (Thou. $)	Project DoD Capital Cost (Thou. $)	Funding Mechanism
MCB Quantico	VA	Marathon Building (B3399)	Solar Photovoltaic	Fully Operational	Sep-09	No	2009	120	$248	$248	Appropriated
							Total:	**120**	**$ 248**	**$ 248**	

Installation / Location	State / Country	Project Title	Type of Renewable Energy	Project Status	If Operational: Date Placed In Service	Project Designed to Supply DoD Independent of Grid?	Fiscal Year	Energy Produced (MMBtu)	Project Total Capital Cost (Thou. $)	Project DoD Capital Cost (Thou. $)	Funding Mechanism
MCLB Barstow	CA	1.5 MW wind turbine	Wind	Fully Operational	Apr-09	No	2009	15,696	$4,598	$4,598	UESC
							Total:	**15,696**	**$4,598**	**$4,598**	

Installation / Location	State / Country	Project Title	Type of Renewable Energy	Project Status	If Operational: Date Placed In Service	Project Designed to Supply DoD Independent of Grid?	Fiscal Year	Energy Produced (MMBtu)	Project Total Capital Cost (Thou. $)	Project DoD Capital Cost (Thou. $)	Funding Mechanism
MCRD San Diego	CA	6 adjacent warehouse rooftops	Solar Photovoltaic	Fully Operational	Jan-09	No	2009	1,317	$1,640	$1,640	UESC
MCRD San Diego	CA	* 250 KW PV system on the roof of buildings 218, 219, 223, 233, 234, 238. * 250 KW PV system on the roof of buildings 225, 226, 227, 228, 231, 232	Solar Photovoltaic	Under Const - Non Op	NA	No	2009	2,928	$3,184	$3,184	Appropriated
MCRD San Diego	CA	*1.5MW ground mounted PV system	Solar Photovoltaic	Budgeted	NA	No	2009	8,785	$10,000	$10,000	Appropriated
							Total:	**13,030**	**$14,824**	**$14,824**	

Installation / Location	State / Country	Project Title	Type of Renewable Energy	Project Status	If Operational: Date Placed In Service	Project Designed to Supply DoD Independent of Grid?	Fiscal Year	Energy Produced (MMBtu)	Project Total Capital Cost (Thou. $)	Project DoD Capital Cost (Thou. $)	Funding Mechanism
							Grand Total:	**104,866**	**$122,473**	**$122,473**	

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APPENDIX B. MARINE CORPS FULLY OPERATIONAL ENERGY PROJECTS PER INSTALLATION

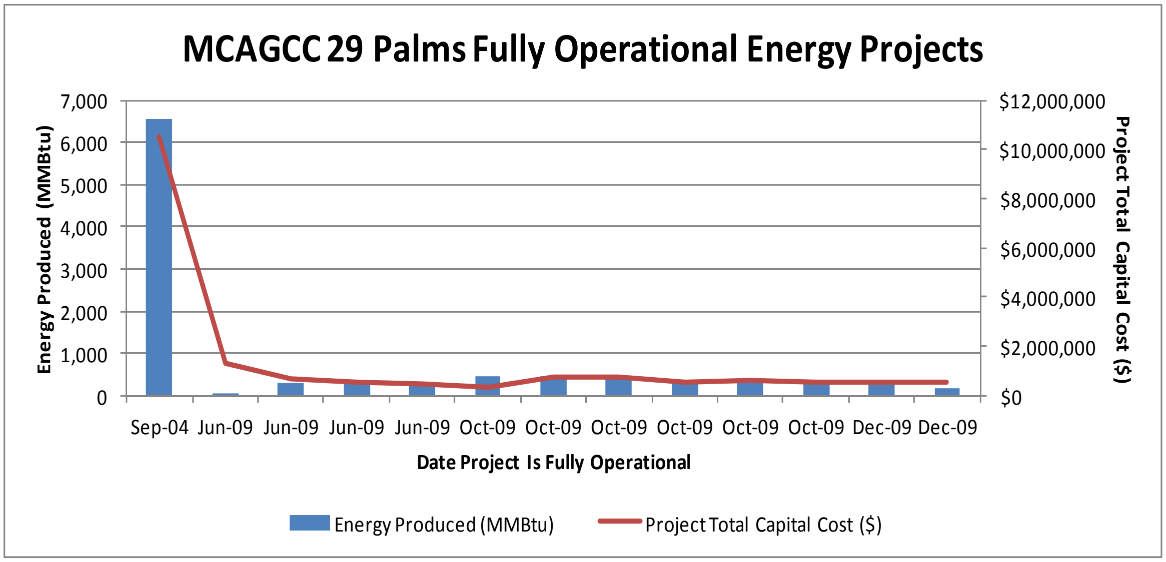

Figure 16. MCAGCC 29 Palms Fully Operational Energy Projects

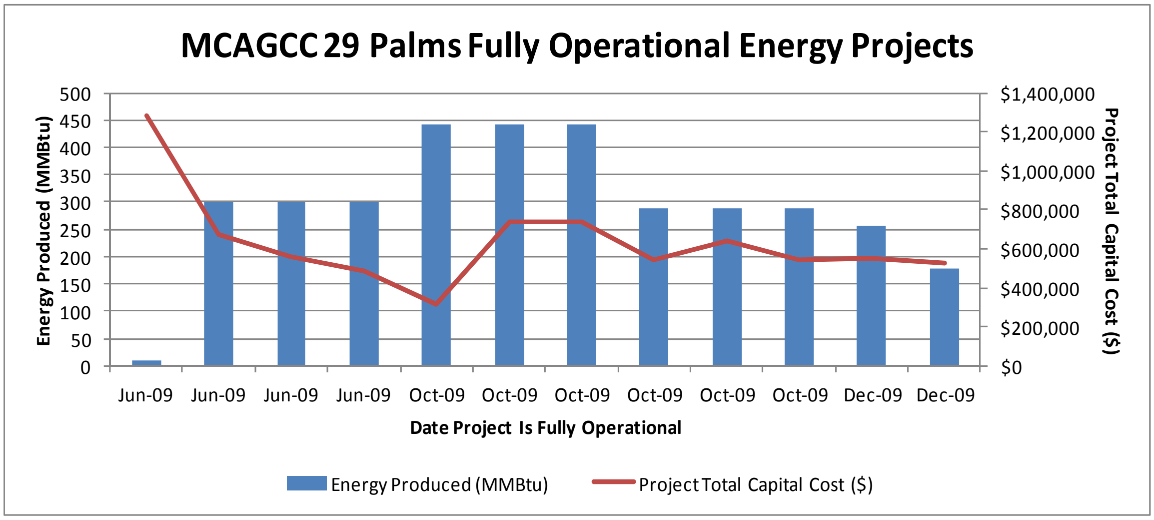

Figure 17. MCAGCC 29 Palms Fully Operational Energy Products Minus Outlier

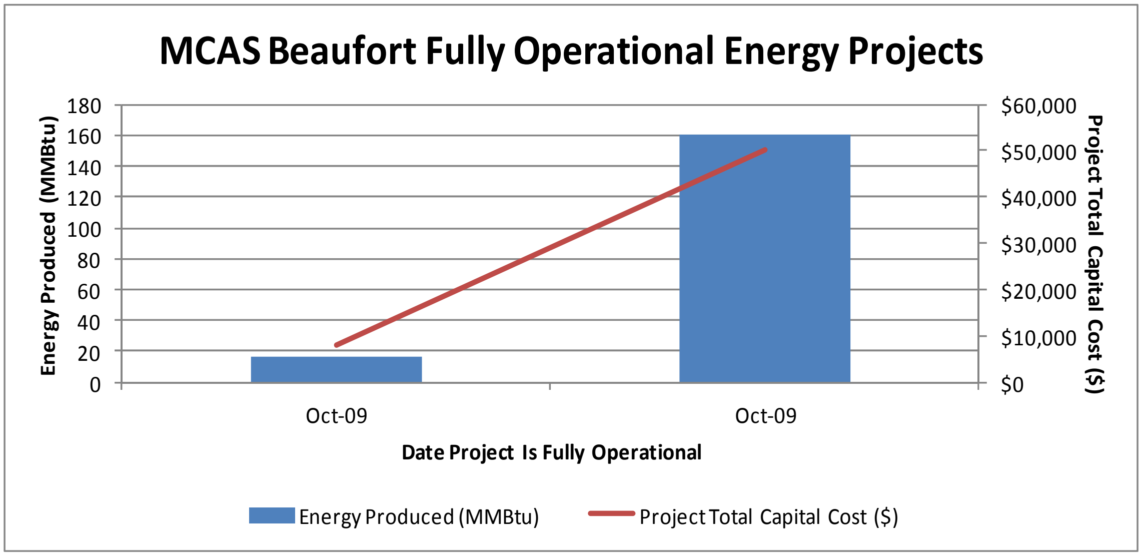

Figure 18. MCAS Beaufort Fully Operational Energy Projects

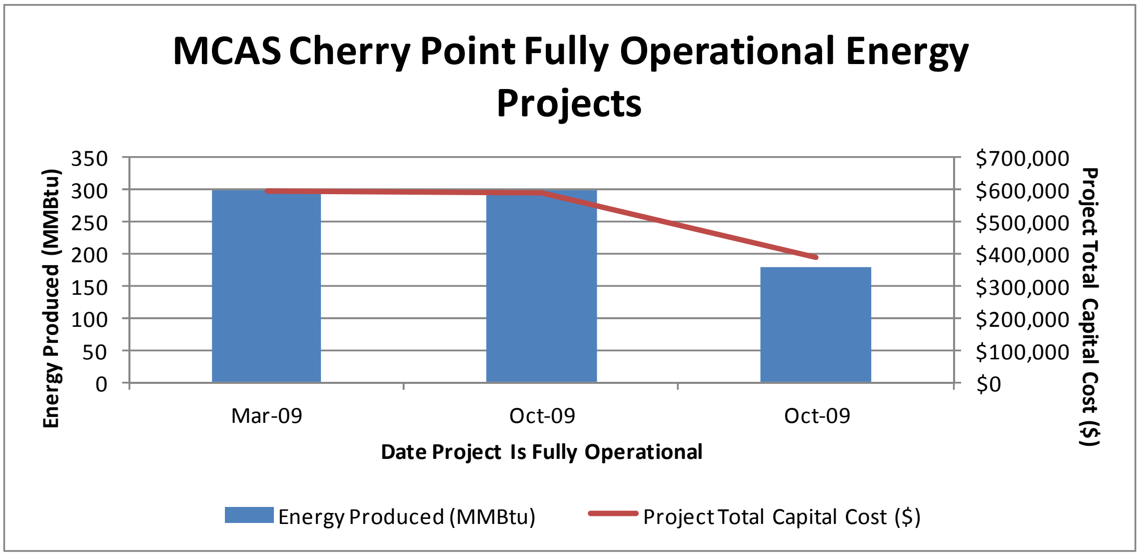

Figure 19. MCAS Cherry Point Fully Operational Energy Projects

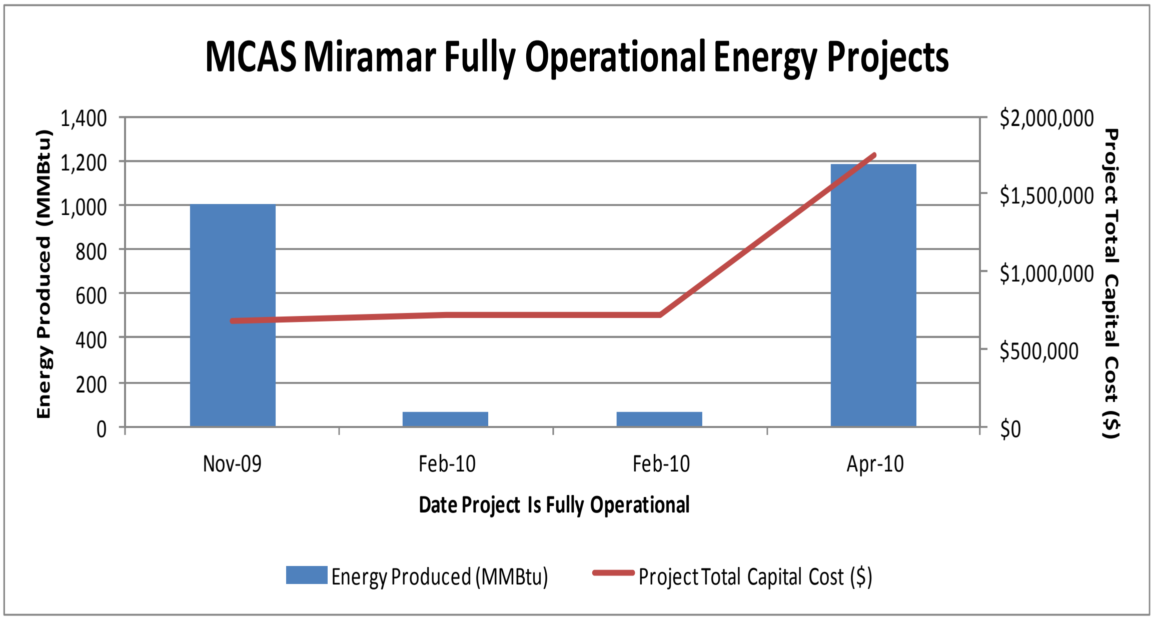

Figure 20. MCAS Miramar Fully Operational Energy Projects

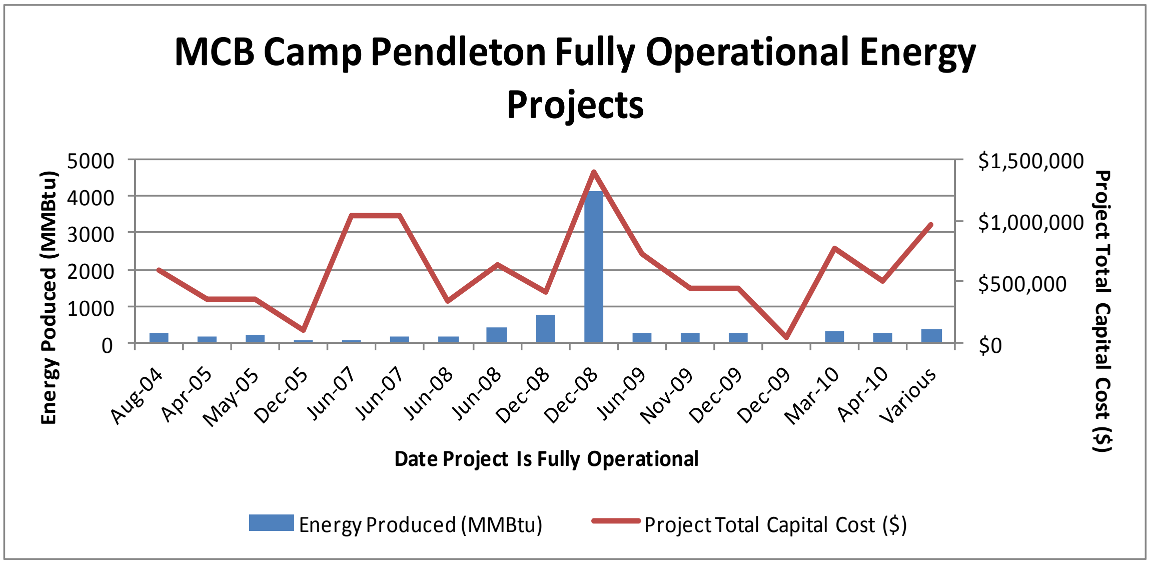

Figure 21. MCB Camp Pendleton Fully Operational Energy Projects

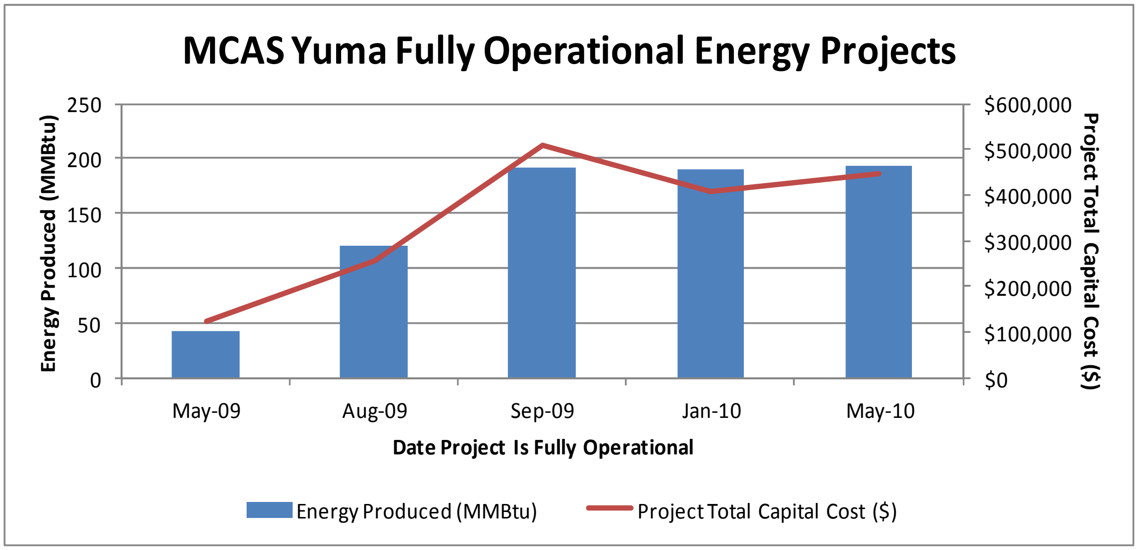

Figure 22. MCAS Yuma Fully Operational Energy Projects

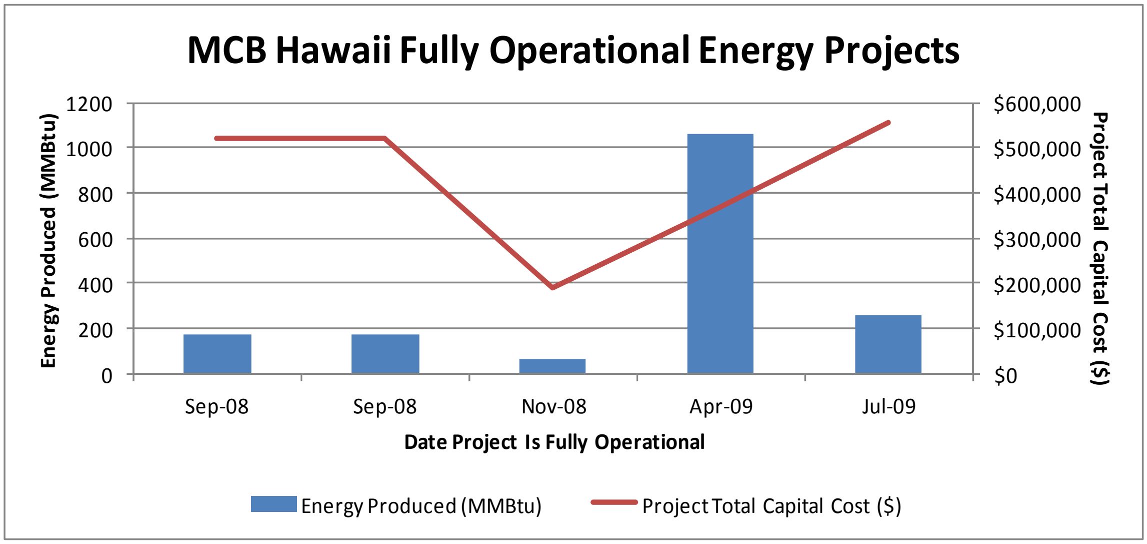

Figure 23. MCB Hawaii Fully Operational Energy Projects

APPENDIX C. SCENARIO ANALYSIS

Table 13. Miramar Scenario Analysis

Miramar	**Scenario 1**			**Scenario 2**			**Scenario 3**		
	Geothermal	Wind	Solar	Geothermal	Wind	Solar	Geothermal	Wind	Solar
Size	Medium	5	0	0	9	133,333	0	12	80,000
Power Output (MW, W)	5	8	0	0	14	19,999,950	0	18	12,000,000
Energy produced (kWh)	43,800,000	19,710,000	0	0	35,478,000	31,535,921	0	47,304,000	18,921,600
Capital and O&M Costs ($/life cycle)	$102,230,000	$13,555,000	$0	$0	$23,647,000	$44,010,130	$0	$31,216,000	$26,406,144
Benefits ($/life cycle)	$134,422,200	$40,326,660	$0	$0	$72,587,988	$80,653,118	$0	$96,783,984	$48,391,992
NPV ($/life cycle)	$21,435,162	$21,424,700	$0	$0	$39,197,450	$24,950,139	$0	$52,527,013	$14,970,121
IRR (%)	13.49%	24%	0%	0.00%	24%	10%	0.00%	24%	10%
Payback period (yrs)	7.25	4.15	0.00	0.00	4.10	8.93	0.00	4.09	8.93
Discount rate (%)	2%	1.70%	0.00%	0%	1.70%	1.85%	0%	1.70%	1.85%
Life Cycle (yrs)	30	20	0	0	20	25	0	20	25

	Scenario 4			**Scenario 5**			**Scenario 6**		
	Geothermal	Wind	Solar	Geothermal	Wind	Solar	Geothermal	Wind	Solar
Size	0	2	246,667	Medium	0	96,666	Medium	0	170,000
Power Output (MW, W)	0	3	37,000,050	5	0	14,499,900	3	0	25,500,000
Energy produced (kWh)	0	7,884,000	58,341,679	43,800,000	0	22,863,442	26,280,000	0	40,208,400
Capital and O&M Costs ($/life cycle)	$0	$5,986,000	$81,419,054	$102,230,000	$0	$31,907,204	$94,712,400	$0	$56,113,056
Benefits ($/life cycle)	$0	$16,130,664	$149,208,844	$134,422,200	$0	$58,473,254	$80,653,320	$0	$102,832,983
NPV ($/life cycle)	$0	$8,095,137	$46,157,934	$21,435,162	$0	$18,088,771	-$12,320,636	$0	$31,811,506
IRR (%)	0.00%	23%	10%	13.49%	0%	10%	0.00%	0%	10%
Payback period (yrs)	0.00	4.33	8.93	7.25	0.00	8.93	-31.49	0.00	8.93
Discount rate (%)	0%	1.70%	1.85%	2%	0.00%	1.85%	2%	0.00%	1.85%
Life Cycle (yrs)	0	20	25	30	0	25	30	0	25

	Scenario 7			**Scenario 8**			**Scenario 9**		
	Geothermal	Wind	Solar	Geothermal	Wind	Solar	Geothermal	Wind	Solar
Size	Small	12	0	Small	3	83,334	Medium	1	43,320
Power Output (MW, W)	2	18	0	4	5	12,500,100	6	2	6,498,000
Energy produced (kWh)	17,520,000	47,304,000	0	35,040,000	11,826,000	19,710,158	52,560,000	3,942,000	10,246,046
Capital and O&M Costs ($/life cycle)	$63,141,600	$31,216,000	$0	$126,283,200	$8,509,000	$27,506,620	$122,676,000	$3,463,000	$14,298,927
Benefits ($/life cycle)	$53,768,880	$96,783,984	$0	$107,537,760	$24,195,996	$50,408,728	$161,306,640	$8,065,332	$26,204,264
NPV ($/life cycle)	-$8,213,757	$52,527,013	$0	-$16,427,515	$12,538,324	$15,594,000	$25,722,194	$3,651,949	$8,106,320
IRR (%)	0.00%	24%	0%	0.00%	23%	10%	13.49%	21%	10%
Payback period (yrs)	-31.49	4.09	0.00	-31.49	4.23	8.93	7.25	4.67	8.93
Discount rate (%)	2%	1.70%	0.00%	2%	1.70%	1.85%	2%	1.70%	1.85%
Life Cycle (yrs)	30	20	0	30	20	25	30	20	25

	Scenario 10		
	Geothermal	Wind	Solar
Size	Medium	3	46,667
Power Output (MW, W)	5	5	7,000,050
Energy produced (kWh)	43,800,000	11,826,000	11,037,679
Capital and O&M Costs ($/life cycle)	$102,230,000	$8,509,000	$15,403,694
Benefits ($/life cycle)	$134,422,200	$24,195,996	$28,228,864
NPV ($/life cycle)	$21,435,162	$12,538,324	$8,732,633
IRR (%)	13.49%	23%	10%
Payback period (yrs)	7.25	4.23	8.93
Discount rate (%)	2%	1.70%	1.85%
Life Cycle (yrs)	30	20	25

Table 14. Hawaii Scenario Analysis

Hawaii	**Scenario 1**			**Scenario 2**			**Scenario 3**		
	Geothermal	Wind	Solar	Geothermal	Wind	Solar	Geothermal	Wind	Solar
Size	Medium	7	0	0	13	233,000	0	20	116,667
Power Output (MW, W)	9	11	0	0	20	34,950,000	0	30	17,500,050
Energy produced (kWh)	78,840,000	27,594,000	0	0	51,246,000	55,109,160	0	78,840,000	27,594,079
Capital and O&M Costs ($/life cycle)	$184,014,000	$18,601,000	$0	$0	$33,739,000	$76,907,894	$0	$51,400,000	$38,509,070
Benefits ($)	$241,959,960	$56,457,324	$0	$0	$104,849,316	$140,941,677	$0	$161,306,640	$70,571,857
NPV ($/life cycle)	$38,583,291	$30,311,075	$0	$0	$56,970,201	$43,600,476	$0	$88,072,515	$21,831,488
IRR (%)	13.49%	24%	0%	0.00%	24%	10%	0.00%	24%	10%
Payback period (yrs)	7.25	4.12	0.00	0.00	4.08	8.93	0.00	4.07	8.93
Discount rate (%)	2%	1.70%	0.00%	0%	1.70%	1.85%	0%	1.70%	1.85%
Life Cycle (yrs)	30	20	0	0	20	25	0	20	25

	Scenario 4			**Scenario 5**			**Scenario 6**		
	Geothermal	Wind	Solar	Geothermal	Wind	Solar	Geothermal	Wind	Solar
Size	Medium	3	400,000	Medium	0	80,000	Medium	0	266,667
Power Output (MW, W)	0	5	60,000,000	10	0	12,000,000	5	0	40,000,050
Energy produced (kWh)	0	11,826,000	94,608,000	87,600,000	0	18,921,600	43,800,000	0	63,072,079
Capital and O&M Costs ($/life cycle)	$0	$8,509,000	$132,030,720	$204,460,000	$0	$26,406,144	$102,230,000	$0	$88,020,590
Benefits ($)	$0	$24,195,996	$241,959,960	$268,844,400	$0	$48,391,992	$134,422,200	$0	$161,306,842
NPV ($/life cycle)	$0	$12,538,324	$74,850,603	$42,870,323	$0	$14,970,121	$21,435,162	$0	$49,900,464
IRR (%)	0.00%	23%	10%	13.49%	0%	10%	13.49%	0%	10%
Payback period (yrs)	0.00	4.23	8.93	7.25	0.00	8.93	7.25	0.00	8.93
Discount rate (%)	0%	1.70%	1.85%	2%	0.00%	1.85%	2%	0.00%	1.85%
Life Cycle (yrs)	0	20	25	30	0	25	30	0	25

	Scenario 7			**Scenario 8**		
	Geothermal	Wind	Solar	Geothermal	Wind	Solar
Size	Medium	16	0	Medium	10	99,510
Power Output (MW, W)	5	24	0	5	15	14,926,500
Energy produced (kWh)	43,800,000	63,072,000	0	43,800,000	39,420,000	23,536,105
Capital and O&M Costs ($/life cycle)	$102,230,000	$41,308,000	$0	$102,230,000	$26,170,000	$32,845,942
Benefits ($)	$134,422,200	$129,045,312	$0	$134,422,200	$80,653,320	$60,193,589
NPV ($/life cycle)	$21,435,162	$70,299,764	$0	$21,435,162	$43,640,638	$18,620,959
IRR (%)	13.49%	24%	0%	13.49%	24%	10%
Payback period (yrs)	7.25	4.07	0.00	7.25	4.10	8.93
Discount rate (%)	2%	1.70%	0.00%	2%	1.70%	1.85%
Life Cycle (yrs)	30	20	0	30	20	25

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