Lessons Learned from Net Zero Energy Assessments and Renewable Energy Projects at Military Installations

Michael Callahan, Kate Anderson, Sam Booth, Jessica Katz, and Tim Tetreault

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Technical Report
NREL/TP-7A40-51598
Revised September 2011

Contract No. DE-AC36-08GO28308

NATIONAL RENEWABLE ENERGY LABORATORY

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Prepared under Task No. FE10.3310

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National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401
303-275-3000 • www.nrel.gov

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Contract No. DE-AC36-08GO28308

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Acknowledgments

The authors wish to thank the following people for the help they provided for this report: Jeff Allen, John Barnett, Steve Dumont, William Fussinger, Vince Guthrie, Charles Howell, George Hoffman, Ken Johnston, Alicen Kandt, Gary Meredith, Sid Mohseni, Gary Morrissett, Dave Peterson, Kevin Taylor, Jermaine Woodall, and Lea Yancey.

A Note on the Revisions

This report, as originally published, contained editorial errors that have been corrected in this revision. Also, reference to material no longer available has been deleted. No changes changed the authors' intent.

Acronyms and Abbreviations

AFV	alternative fuel vehicle
ARRA	American Recovery and Reinvestment Act
Btu	British thermal unit
CBECS	Commercial Building Energy Consumption Survey
CHP	combined heat and power
CNCI	Climate Neutral Communities Initiative
CNG	compressed natural gas
CO_2	carbon dioxide
CSP	concentrating solar power
CSU	Colorado Springs Utility
DG	distributed generation
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DoN	U.S. Department of the Navy
ECIP	Energy Conservation Investment Program
ECM	energy conservation measure
EE	energy efficiency
EJV	energy joint venture
E.O.	Executive Order
EPA	U.S. Environmental Protection Agency
ESPC	energy savings performance contract
EUI	energy use index
EUL	enhanced use lease
FEMP	Federal Energy Management Program
FFV	flexible fuel vehicle
FY	fiscal year
GHG	greenhouse gas
GSHP	ground source heat pump
HELCO	Hawaiian Electric Light Company
HEV	hybrid electric vehicle
HQ	headquarters building
hr	hour
HVAC	heating, ventilating, air conditioning
JCTD	Joint Capability Technology Demonstration
kBtu	kilo (1,000) British thermal units
KCF	kilo (1,000) cubic feet
kW	kilowatt
LCOE	levelized cost of energy
LED	light-emitting diode
LEED	Leadership in Energy and Environmental Design
MAC	multiple-award contract
MAGTFTC	Marine Air Ground Task Force Training Command
MARFORRES	U.S. Marine Forces Reserve
MCAS	U.S. Marine Corps air station

MCLB	U.S. Marine Corps logistics base
MILCON	military construction
MT	metric tons
MT CO_2e	metric tons of carbon dioxide equivalent
MW	megawatts
NAVFAC	Naval Facilities Engineering Command
NEPA	National Environmental Policy Act
NPV	net present value
NREL	National Renewable Energy Laboratory
NZEI	net zero energy installation
O&M	operations and maintenance
OSD	Office of the Secretary of Defense
PPA	power purchase agreement
PTA	Pohakuloa Training Area
PV	photovoltaic
RE	renewable energy
REC	renewable energy certificate
RFI	request for information
RFP	request for proposal
RPS	renewable portfolio standard
RTU	rooftop cooling units
SECNAV	Secretary of the Navy
SNI	San Nicholas Island
SPIDERS	Smart Power Infrastructure Demonstration for Energy Reliability and Security
USACE	United States Army Corps of Engineers
UESC	utility energy services contract
UP	utility privatization
USAF	United States Air Force
USAFA	United States Air Force Academy
USNORTHCOM	United States Northern Command
WTE	waste to energy

Executive Summary

The net zero energy installation (NZEI) assessment process is a methodology that can be used to improve an installation's energy self-sufficiency by minimizing energy consumption and developing local renewable energy resources. This report summarizes lessons learned from past NZEI assessments across the military services and highlights six NZEI case studies. This report also reviews the NZEI assessment process and identifies the limitations of isolated NZEI assessments. A portfolio assessment approach involving multiple sites is introduced as a way for a service or agency to develop a comprehensive energy strategy. To further contribute to DoD energy efficiency and renewable energy project deployment, this report also summarizes lessons learned from implementing large-scale renewable energy projects at selected DoD installations.

The DoD accounts for nearly 80% of the U.S. government's energy consumption,[1] and in recognition of the relationship between energy and national security, the DoD has established very ambitious energy efficiency and renewable energy goals. United States Defense Secretary Robert Gates identified energy as one of the department's top-25 transformational priorities.[2] Likewise, Secretary of the Navy (SECNAV), Ray Mabus, said, "Energy reform will make us better fighters. In the end, it is a matter of energy independence and it is a matter of national security."[(2)] SECNAV Mabus also announced several impressive energy goals, such as the goal that 50% of the U.S. Department of the Navy's (DoN) installations will be net zero by 2020.

"Net zero" can describe both a methodology and a goal. A net zero energy goal for an installation is to produce as much energy on-site from renewable energy generation, or through the on-site use of renewable fuels, as it consumes in its buildings, facilities, and fleet vehicles.[3] An NZEI assessment should be viewed as a process to help determine an optimal energy strategy for an installation. Reaching the net zero energy goal at a given installation may not be feasible. Likewise, there can be benefits to developing an energy strategy for multiple installations together, such as for a region or a branch of the DoD.

While the NZEI analyses show that in some cases completing the energy efficiency (EE) and renewable energy (RE) projects can save the DoD money, one primary conclusion is that achieving the DoD's stated energy goals requires a multiple-order-of-magnitude increase in EE and RE investments and project implementation. The results of the Fort Carson NZEI assessment prepared by the National Renewable Energy Laboratory (NREL) indicate that completing the EE and RE projects to approach the net zero energy goal for this one installation requires an estimated capital investment of $842 million. Fortunately, completing these EE and RE projects yields a positive return on investment of $96 million net present value after 40 years, but the required capital investment at this one installation would likely require more than double the $387 million that has been invested in the DoD's Energy Conservation and Investment Program

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[1] Bartis, J. T., Van Bibber, L. "Alternative Fuels for Military Applications." http://www.rand.org/content/dam/rand/pubs/monographs/2011/RAND_MG969.pdf. Accessed May 16, 2011.
[2] PR Newswire. "Pew Study: Department of Defense Embracing Clean Energy." http://www.prnewswire.com/news-releases/pew-study-department-of-defense-embracing-clean-energy-91607604.html. Accessed May 15, 2011.
[3] Booth, S.; Barnett, J.; Burman, K.; Hambrick, J.; Westby, R. "Net Zero Energy Military Installations: A Guide to Assessment and Planning." NREL/TP-7A2-48876. Golden, Colorado: National Renewable Energy Laboratory, August 2010. http://www.nrel.gov/docs/fy10osti/ 48876.pdf. Accessed May 17, 2011.

(ECIP) program over the last 8 years[4]. The total investment required to approach the net zero energy goal will vary considerably for each installation. NREL's estimated cost to approach the net zero energy goal at Marine Corps Air Station (MCAS) Miramar was approximately $60 million, for example, and for the Army's Pohakuloa Test Area it was approximately $3 million. The DoD, however, has not yet significantly increased resources to the levels required to meet its challenging energy goals, nor has the private sector made sufficient investments in DoD energy projects to achieve these ambitious goals.

Additionally, the years required to implement large-scale EE and RE projects demonstrate that many of the U.S. Navy's installations should be accelerating the implementation of NZEI assessments and projects now to meet this single 2020 goal. The 14-MW photovoltaic (PV) array at Nellis Air Force Base, for example, took nearly four years from concept to completion, and the Nellis PV array was a less challenging project than making an installation such as Fort Carson a net zero energy facility. The lengthy timelines required to complete large capital EE & RE projects indicate the enormous increase in resources, speed, and scale that is required to achieve the DoD energy efficiency and renewable energy goals.

Fortunately, the DoD has the potential to reach many of their energy goals by using currently available technology, building on their experience completing projects, and re-allocating resources. The DoD continues to successfully complete large-scale energy projects and reap the benefits as highlighted in this report. Investments in EE and RE projects can improve energy security and can result in a positive economic return on investment. In addition to DoD investments, private-sector financing through third-party contracts could provide some of the capital needed to fund projects and accomplish these goals. Furthermore, the required investment capital to reach many of these EE & RE goals is not insurmountable when compared to other DoD expenditures.

The following introductory section summarizes the many additional lessons learned from NZEI assessments and large-scale renewable energy projects completed at DoD installations. In general the results of this report may be useful for all of the following:

- Energy and facility managers at DoD installations
- Commanders at DoD installations
- DoD budget and policy decision makers
- DoD installation support services (e.g., Army Corps of Engineers, Navy Facilities
- Engineering Command, Defense Logistics Agency, Air Force Civil Engineer Support Agency)
- Public- and private-sector organizations involved with energy efficiency or renewable energy projects at military installations.

[4] Office of the Under Secretary of Defense, Installation and Environments. "Energy Conservation Investment Program (ECIP)." http://www.acq.osd.mil/ie/energy/ecip/ecip.shtml. Accessed May 15, 2011.

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1 Introduction

The U.S. Department of Defense long has recognized the strategic importance of energy in all components of its operations. It is working to reduce energy consumption as well as to enhance energy self-sufficiency by drawing on renewable energy sources. In 2008, the DoD and the U.S. Department of Energy (DOE) defined a joint initiative to address military energy use by identifying specific actions to reduce energy demand and increase use of renewable energy on DoD installations. Early attention was given to the possibility of net zero energy military installations—which are defined as military installations that produce as much energy on-site from renewable energy generation or through the on-site use of renewable fuels as is consumed in the site's buildings, facilities, and fleet vehicles.

Several organizations are currently working on different names and definitions for Net Zero Energy Installation (NZEI). Because the principal audience for this report is the DoD, NREL has adopted the terminology used within the DoD. Also, for this report NREL uses the Net Zero energy definition employed in the activities of the DoD/DoE joint initiative.

The National Renewable Energy Lab was asked to perform an NZEI assessment for multiple military installations and to create a template that explains the methodology for performing the assessment. NREL has completed—or is in the process of completing—net zero energy assessments for installations 1 through 6 listed below, and performing a climate neutral analyses (which is a very similar assessment to net zero energy) for installation 7.

1. United States Air Force Academy, Colorado Springs, Colorado
2. United States Army Base, Fort Carson, Colorado Springs, Colorado
3. Marine Corps Air Station Miramar, San Diego, California
4. San Nicolas Island, Naval Base, Ventura County, California
5. Pohakuloa Army Training Area, Hawaii
6. Naval Support Activity South Potomac, Indian Head, Maryland and Dahlgren, VA
7. Marine Forces Reserve (MARFORRES) Center, New Orleans, Louisiana

In an effort to learn from the previous analyses and continue to improve the NZEI assessment methodology, the DOE Federal Energy Management Program (FEMP) commissioned NREL to summarize the lessons learned from these analyses. NREL documented the details of each assessment and categorized the lessons learned in a simple format so that others considering performing such an assessment can quickly learn from the past experience. Furthermore, this document highlights the timing of when the DoD might wish to consider a portfolio assessment methodology for energy planning. The NZEI assessments and this report focus on non-tactical installation energy use, not addressing alternative fuel use in tactical weapons systems. NREL also summarized the lessons learned from military installations which have successfully completed large-scale (more than $1 million) renewable energy projects. Lessons learned from large-scale energy efficiency projects, which typically are most cost effective, are not included in the scope of this report.

To gather the lessons learned from completed RE projects on military installations, NREL selected from various branches of the DoD larger projects that were implemented through various financial mechanisms, such as power purchase agreements (PPA), energy savings performance contracts (ESPC), utility energy service contracts (UESC), and the military Energy Conservation Investment Program. Lessons learned from the following projects are included in this report; this is not a complete list of all the successful and completed RE projects at military installations. These installations also might have completed additional RE projects at their sites.

- Camp Pendleton, California: 4,371-Mbtu/year solar thermal and 63,200-kWh/year PV
- Fort Carson, Colorado: 2-MW PV array
- Fort Knox, Kentucky: 5-million ft^2 served by geothermal heating and cooling
- Twentynine Palms, California: 1.2-MW PV array
- Barstow, California, Marine Corps Logistics Base: 1.5-MW wind farm
- Nellis Air Force Base, Nevada: 14-MW PV array
- Warren Air Force Base, Wyoming: 3.1-MW wind farm

The National Renewable Energy Laboratory reviewed the existing literature on these projects and then conducted brief interviews with some of the key people involved. The lessons learned are summarized and categorized in a simple format so that others considering implementing larger-scale renewable energy projects at military installations quickly can learn from these past projects. Many of these projects have presentations or case studies already documented, therefore NREL did not recreate case studies for these projects; however, this report includes references to these case studies.

In an effort to help the DoD achieve its energy goals, this document highlights the incongruities between current DoD energy use, current rate of EE and RE project implementation, and long-term DoD energy goals. To succeed in reaching all the DoD energy goals, the rate of financial and human-resource investment and the speed and scale of project deployment must be greatly increased.

Net zero can be used to describe both a methodology and a goal. An NZEI assessment should be viewed as a methodology to help determine an energy strategy for an installation. In some cases, however, reaching the net zero energy goal at an installation might not be economically feasible. Likewise, there could be some benefit in developing an energy strategy for multiple installations together, such as for a region or a branch of the DoD, rather than for each individual installation. If an NZEI assessment is performed at each installation independently, then the NZEI assessment methodology could create artificial design constraints that in some cases could limit the most cost-effective and timely implementation of EE and RE projects worldwide.

A cost-effective approach to renewable energy development often takes advantage of the economies of scale provided by large-scale renewable energy projects. Rather than installing small PV arrays on numerous DoD facilities across the country, for example, the DoD could support a utility-scale renewable energy project near multiple installations in an area with good economic incentives for renewable energy. This might be a more cost-effective solution to meet some goals, such as achieving 50% alternative energy across the U.S. Navy; however it might not meet some electrical islanding goals. In some cases, considering energy efficiency and renewable energy potential for all installations—rather than taking an isolated design approach to EE and RE—could be more effective to achieving DoD goals. In this report this is called a "portfolio approach." Based on NREL's experience in completing NZEI assessments and a climate-neutral analysis, the authors have gathered and documented the key lessons learned; these are highlighted in the points discussed below.

1.1 Summary of Lessons Learned from Net Zero Energy Assessments at DoD Installations

Goals, Mandates, and Incentives

The realization of DoD energy efficiency and renewable energy goals and mandates requires incentives, enforcement, and consequences for not achieving the goals. Achieving many of the DoD EE and RE goals requires a multiple-order-of-magnitude increase in funding from the DoD, utilities, and the private sector. To better comprehend the enormity of the DoD energy goals, it could helpful to translate the goals that are listed as percentages into total energy consumption in megawatt-hours, renewable energy production and procurement in megawatt-hours, investments dollars required, and total number of staff members needed.

Leadership, Chain of Command, Training, and Culture

Support from top leadership at the installation and headquarters will greatly influence whether the assessment and projects will be implemented successfully. To increase the speed of implementation, however, management of the project details should be delegated to staff members. An effective educational and communication campaign that demonstrates the links between national security, energy efficiency, and renewable energy could help create the cultural and behavioral changes needed to reach the DoD's ambitious goals.

Design Criteria

Installations might need to define more stringent and specific energy-efficiency building design criteria for designing new buildings or retrofitting old buildings. In some cases, the Leadership in Energy and Environmental Design (LEED) criteria is insufficient to meet DoD energy goals. LEED provides specifications for overall environmental sustainability that might not match DoD energy goals exactly.

Technology Selection

Selecting the appropriate renewable-energy technology for a site requires balancing an array of technical and non-technical requirements (e.g., land availability) dictated by the installation and headquarters. Architectural, aesthetic, and other site-specific regulations can limit the EE and RE technologies available for use.

Islanding and Microgrids

There often is disagreement about the need to electrically island an installation. The cost and benefits of islanding often are not fully understood by all involved parties.

Ownership of Facilities and Control of Land Resources

Installations have limited ability to implement EE and RE projects in leased buildings and facilities.

Operations and Maintenance Contracts

Operations and maintenance (O&M) service contracts can help ensure that EE and RE systems continue to operate properly. The O&M contracts should incorporate DoD energy goals.

Data Collection

Difficulties in collecting accurate data have both increased the duration and reduced the quality of the NZEI assessments.

Portfolio Approach

An alternative approach to a site-specific NZEI assessment is to consider an optimal energy strategy for an installation and to incorporate other considerations, such as multiple DoD energy goals and the DoD's portfolio of installations. Some installations will be able to exceed net zero energy status to become net energy producers; others won't be able to approach it reasonably. In fact, a net zero energy goal that is too strictly applied to an installation can lead to solutions that do not make sense from economic or other perspectives. The boundary for a net zero energy assessment could be defined as a specific building, an installation, a region, or a branch of the armed services. An analysis using a national or regional boundary versus an installation boundary could produce different results for the same installation.

Implementation

Currently, an NZEI assessment is a planning exercise used to determine an energy strategy for an installation. It would be helpful if the NZEI assessment were expanded to include a detailed action plan and follow-up support. A strategy alone is insufficient to quickly achieve the desired impact. The detailed action plan could include the schedule, budget, investment required, investment plan, staff plan, and responsibility assignments. Providing implementation support after the assessment should be a mandatory part of the assessment process.

1.2 Summary of Lessons Learned from Renewable Energy Projects at DoD Installations

Because the NZEI assessment is a relatively new strategic energy planning process, many of the installations that have had NZEI assessments or have undertaken similar strategic energy planning exercises—such as Fort Bliss—have not yet installed large-scale energy projects. Many military installations will be implementing large-scale renewable energy projects as a result of the net zero energy analyses, net zero energy template, and the DoD goals. This guide summarizes the lessons learned from military installations that have successfully completed large-scale (> $1 million) renewable energy projects. These "lessons learned" are intended to provide information for installations that soon will be implementing projects, so that these installations can implement projects faster and more cost effectively. (Lessons learned from large-scale energy efficiency projects—which typically are more cost effective—are not included in the scope of this DOE-commissioned study.)

NREL gathered information on the projects by reviewing existing case studies and interviewing key people involved in the projects. The following sections summarize some of the key lessons learned from implementing large-scale renewable energy projects at U.S. military installations.

Market
There are financial advantages to completing renewable energy projects at military installations located in top renewable energy marketplaces. Top renewable market places are the locations where conditions are favorable for completing renewable energy projects. These conditions can include financial incentives, a skilled workforce, adequate transmission, and an abundant renewable resource.

Project Team
It is important to involve the appropriate members from the local utility early in the RE project-development process. Top-level support for RE project implementation is helpful for securing the financial and human resources needed for project implementation. A successful core RE project team has the appropriate skills and resources to manage all components of the project. Identifying and involving all project stakeholders (e.g., property, contracting, legal, environmental, engineering, security) early in the project-development process can help to streamline the implementation and can increase support for the project.

Training
The DoD-related renewable energy conferences (such as GovEnergy) and the exchange of information through site visits have served as useful forums to exchange ideas and project information within the DoD.

Market Timing and Project Schedule
Bases with "shovel-ready" RE projects can better manage changes in the RE marketplace. The corollary also is true. A project team that completes the applicable permits and the regulatory process outside of the RE project-critical path will be better prepared to take advantage of favorable market conditions.

Site Considerations
Clearly defining the level of priority for RE project development and creating master site and energy plans can help resolve any land-use conflicts existing at potential installations. Improved knowledge, specifications, and dissemination of information on the real versus perceived impacts of some RE technologies on DoD air operations could increase the speed of RE project development. Former landfills can be good sites for solar energy projects, but likely will require coordination with environmental agencies to ensure success. If wind projects are to be implemented near public airports, then the project team should work with the Federal Aviation Administration early in the project-development process to determine whether the flight approach rules must be rewritten or if the project design must be changed. The DoD has established an Energy Siting Clearinghouse to assist with site issues.[5]

Policy, Funding, and Incentives
Uniform guidance and agreement on renewable energy credit (REC) purchases across the DoD will incentivize all installations to work toward the same standards and goals, such as solar RECs, wind RECs, or developing projects on site. Starting early in the design process, it is

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[5] Belote, D. Energy Siting Clearinghouse, Office of the Secretary of Defense. "The 2011 NDAA and DoD's Energy Siting Clearinghouse." http://www.usafnevadaforum.com/process_meeting_nov2010/proceedings/Belote_OSD%20ESC_Nevada%20Process%20NDAA%20Brief%20010711%20v3%20-%20final.pdf. Accessed May 15, 2011.

important to clearly understand all the criteria for RE incentives and design the project to fit the incentives.

Guidelines that define when and where microgrids are required might help accelerate RE projects; forcing the coupling of microgrid and renewable energy projects can impede quick project deployment. Deploying renewable energy technology products that have a proven performance record and which have warranties reduces potential downtime and maintenance costs. Resolving network security concerns enables personnel to easily access data from advanced meters and improves the monitoring and performance of renewable energy projects.

Installations can be more successful in securing funding for renewable energy projects if they are familiar with the application processes associated with different funding programs. Bases with "shovel-ready" RE projects have financially benefited from unexpected funding opportunities. Also, installations that have successfully completed RE projects and achieved a cost savings might be more likely to receive additional funds for RE project development. Typically, installations that are able to retain a portion of the RE project cost savings at the installation are more motivated to implement RE projects. Installations have used the cost savings from energy efficiency projects to fund renewable energy projects. In cases where funding is not available through DoD funding programs such as Energy Conservation Investment Program and Military Construction funds, third-party financing is a viable option to fund renewable energy projects.

Contracts

Contracts that require the contractor to provide the system maintenance at a reasonable cost and in a timely manner for the life of the renewable energy project can improve overall performance. Standardized and widely disseminated DoD renewable energy contracting processes and documents will help to streamline project implementation. Creating a DoD prequalified list of renewable energy developers also could streamline the request for proposal (RFP) process, and can ensure that the DoD is contracting with high-quality developers. The DoD could realize significant financial and other project benefits by bundling the RE project development for multiple bases and competitively selecting one or more contractors to complete the RE projects. Installations also might benefit by not specifying the exact size for the RE project in the RFP.

Before beginning the contracting process for a renewable energy project, installations should consult local utilities. There might be financial advantages for an installation to issue its own RFP for renewable energy projects rather than procuring renewable energy through the local utility. The "low bid technically acceptable" evaluation process can be a successful method to select a project developer. Installations should evaluate the proposals based on the life-cycle cost of the energy delivered and not just the price per kilowatt-hour of electricity.

An enhanced use lease (EUL) is a more-effective contract for utility-scale renewable energy projects than for small projects. Signing indefinite-term renewable energy contracts with developers can reduce the project risk to the DoD; however, this generally increases the risk to the developer and likely will increase the contract cost to the host site.

Installations have reported varying results and preferences with utility energy service contracts and energy savings performance contracts. Some installations have developed a strong relationship with the utility and prefer to use UESCs. Conversely, other installations prefer the guarantee that the ESPC offers. In most cases, installations agree that the contractor-provided operations and maintenance services typical in a UESC or ESPC help to ensure that the system remains in proper working condition.

2 U.S. Department of Defense Energy Consumption and Goals

2.1 U.S. Department of Defense Energy Consumption

The DoD accounts for nearly 80% of the U.S. government's energy consumption,[6] and its annual energy use is equivalent to the combined energy consumption of an additional 16,397,380 cars on the road every year.[7] Of the DoD's energy use, 75% is tactical "liquid fuels that power aircraft, ships, combat vehicles, and forward-deployed generators."[(7)] Tactical fuel use was not included in the initial NZEI assessment projects, but it is recommended that tactical fuel use be examined and included in the NZEI baseline, to provide a complete picture of the energy footprint at an installation.

In fiscal year (FY) 2008 the DoD consumed 889 trillion site-delivered Btu (more than used by entire nations, such as Denmark and Israel) and spent on the order of $20 billion on energy.[8] Moreover, this $20-billion figure does not include the "fully burdened cost of fuel—the cost of the people and operations required to deliver the fuels that are used to fly the jets, power the tanks, and run the expeditionary bases."[(8)] For example, fully burdened energy cost calculations could account for the logistical costs and casualties resulting from transporting fuel to forward operating bases. Some estimates indicate a gallon of fuel delivered to a forward conflict area can cost as much as $400 per gallon.[9] This $20 billion expenditure also does not include the cost of the externalities associated with using fossil fuels—such as the health costs of increased air pollution and the resulting illnesses. In summary, energy cost estimates vary greatly depending on what fully burdened cost factors are included.

A 2010 Pew Charitable trust report entitled "*Reenergizing America's Defense*" summarized the DoD energy use by branch as listed in the following bullets.[10]

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[6] Bartis, J. T., Van Bibber, L. "Alternative Fuels for Military Applications." http://www.rand.org/content/dam/rand/pubs/monographs/2011/RAND_MG969.pdf. Accessed May 16, 2011.

[7] The PEW Project on National Security, Energy and Climate. "Reenergizing America's Defense; How the Armed Forces Are Stepping Forward to Combat Climate Change and Improve the U.S. Energy Posture." http://pewclimatesec-cdn-remembers.s3.amazonaws.com/ 172e73107e0952fd86378269bdeb62f6.pdf. Accessed May 16, 2011.

[8] Subcommittee on Federal Financial Management, Government Information, Federal Services, and International Security. "Cutting the Federal Government's Energy Bill: An Examination of the Sustainable Federal Government Executive Order." Testimony of Dr. D. Robyn. http://hsgac.senate.gov/public/ index.cfm?FuseAction=Hearings.Hearing&Hearing_ID=c7cb1779-8aa1-4250-8dfe-18e06b579af1. Accessed May 16, 2011.

[9] "Remarks by the Honorable Ray Mabus Secretary of the Navy." Naval Energy Forum. Hilton McLean Tysons Corner, McLean, Virginia. Wednesday, October 14, 2009. www.navy.mil/navydata/people/secnav/Mabus/Speech/SECNAV%20Energy%20Forum%2014%20Oct%2009%20 Rel1.pdf. Accessed May 16, 2011.

[10] The PEW Project on National Security, Energy and Climate. "Reenergizing America's Defense; How the Armed Forces Are Stepping Forward to Combat Climate Change and Improve the U.S. Energy Posture." http://pewclimatesec-cdn-remembers.s3.amazonaws.com/ 172e73107e0952fd86378269bdeb62f6.pdf. Accessed May 16, 2011.

U.S. Army

- Consumed 880 million gallons of fuel and 9.1 million MWh (9.1 million MWh per year is roughly equivalent to the electrical use in 1.5 million U.S. homes in one year, assuming the average U.S. home used 6 MWh per year).
- Permanent bases are the U.S. Army's greatest source of energy consumption (contrary to the other branches, for which the source of greatest energy consumption is transportation fuels).
- Consumed 36% of the total DoD facility energy use.

U.S. Navy

- Sea operations comprise 75% of the U.S. Navy's total energy use.
- Consumes 25% of the DoD's total use of petroleum.

U.S. Air Force

- U.S. Department of Defense's largest energy user.
- Spent $9 billion on energy in 2008.
- Consumes 84 % for aviation fuels.
- Uses 12% for facilities.
- Spends $10 million per day on energy.
- Consumes 2.5 billion gallons of aviation fuel per year.
- Reduced energy consumption at the facility and mobility level by nearly 20%, but the energy cost has increased by approximately 300% due to increased fuel prices.
- On average, every $10 increase in the per-barrel price of oil equals more than $1.3 billion in additional DoD energy costs.[11] (Renewable energy often is an ideal option to hedge against rising energy prices.)

[11] Center for Naval Analyses (CAN). "Powering America's Defense: Energy and the Risks to National Security, May 2009." www.cna.org/nationalsecurity/energy. Accessed May 16, 2011.

2.2 Department of Defense Renewable Energy Procurement

In 2009, 3.6% of DoD's electrical consumption came from renewable electricity. It is important to note that this figure only includes electrical consumption, and it excludes the more than 75% of DoD energy that powers aircraft, ships, combat vehicles, and forward-deployed generators as well as the natural gas and liquid fuels used for heating and powering vehicles at DoD facilities.

The FY 2009 DoD energy management report indicates the renewable energy electricity consumption rates for each branch of the DoD as listed below[12]. (These figures include self-generated renewable energy and purchasing renewable energy credits.)

- U.S. Army, 2.1%
- U.S. Navy, 0.6 %
- U.S. Air Force, 5.8%

Some organizations in the DoD permit purchasing of renewable energy credits in place of actually developing renewable energy projects on the sites of its installations (RECs were not considered an option in the NZEI assessment). The DoD goals do not have uniform guidance related to REC purchases, therefore it is likely that the various branches of the armed forces—and even installations within the same branch—count RECs differently. One installation in Nevada, for example, could implement a large PV array on its own site and purchase the RECs for \$180/MWh, a different installation might choose to purchase RECs from a wind farm at \$1/MWh, and another installation could purchase \$250/MWh solar REC from New Jersey. Because not all RECs are equal and are not traded on one uniform, controlled market, it is likely that installations will apply different standards for their REC purchases. As a result, the installations will be working toward different standards and goals. Uniform guidance and agreement on REC purchases across the DoD will incentivize all installations to work toward the same goal—whether that is solar RECs, wind RECs, or developing on-site projects. The United States Air Force (USAF) has begun working toward this standardization goal by not allowing individual installations to purchase RECs, and instead making REC purchases at the agency level.

2.3 Department of Defense Energy Goals

"National security experts have been clear in their warnings—America's dependence on foreign sources of energy constitutes a threat—militarily, diplomatically and economically. United States Defense Secretary Robert Gates has identified energy as one of the department's top-25 transformational priorities in the armed forces."[13] Such energy efficiency and renewable energy production is a high-priority mission for the DoD, and has led the DoD to establish more ambitious goals than the federal goals established by Energy Policy Act of 2005.

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[12] Department of Defense. Office of the Deputy Under Secretary of Defense (Installations and Environment). "Annual Energy Management Report; Fiscal Year 2009." http://www.acq.osd.mil/ie/energy/library/aemr_fy_09_may_2010.pdf. Accessed May 16, 2011.

[13] PR Newswire. "Pew Study: Department of Defense Embracing Clean Energy." http://www.prnewswire.com/news-releases/pew-study-department-of-defense-embracing-clean-energy-91607604.html. Accessed May 15, 2011.

The FY 2010 Department of Defense Strategic Sustainability Performance Plan summarizes the DoD's energy-related goals as follows.[14]

- Reduce Scope 1 and Scope 2 greenhouse gas (GHG) emissions from facilities by 34% from FY 2008 to FY 2020.
- Reduce Scope 3 GHG emissions by the end of FY 2020 by 13.5%, relative to a FY 2008 baseline.
- Reduce facility energy intensity by 3% each year from FY 2006 through 2015, and by 1.5% per year from FY 2016 through 2020.
- Produce or procure 18.3% of all energy consumed within its facilities during FY 2020 from renewable energy sources (thermal as well as electrical energy).
- Reduce the use of petroleum products by non-tactical vehicle fleets by 2% annually, relative to FY 2005, for a total 30% reduction by FY 2020.
- Open and operate 10 landfill-gas capture facilities by FY 2020, for the production, capture, and use of methane coming from landfills (owned both by DoD and by other parties).

In addition to these DoD goals, leaders of each branch of the DoD have created even more ambitious and specific energy goals.

U.S. Army[15]

- By 2020, 5 installations will be net zero.
- By 2030, 25 installations will be net zero.
- By 2058, all U.S. Army installations will be net zero.

U.S. Air Force[16]

- By 2025, 25% of base energy needs will be met with renewable energy sources.
- By 2016, 50% of aviation fuels will come from biofuel blends.

U.S. Navy[17]

- By 2015, petroleum use in the 50,000-unit commercial fleet will be reduced by 50%.

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[14] Department of Defense. "Department of Defense Strategic Sustainability Performance Plan" http://www.acq.osd.mil/ie/download/green_energy/dod_sustainability/DoD%20SSPP-PUBLIC-26Aug10.pdf. Accessed June 22, 2011.

[15] Department of Defense. Office of the Deputy Under Secretary of Defense (Installations and Environment). "Annual Energy Management Report; Fiscal Year 2009." http://www.acq.osd.mil/ie/energy/library/aemr_fy_09_may_2010.pdf. Accessed May 16, 2011.

[16] PR Newswire. "Pew Study: Department of Defense Embracing Clean Energy." http://www.prnewswire.com/news-releases/pew-study-department-of-defense-embracing-clean-energy-91607604.html. Accessed May 15, 2011.

[17] "Remarks by the Honorable Ray Mabus Secretary of the Navy." Naval Energy Forum. Hilton McLean Tysons Corner, McLean, Virginia. Wednesday, October 14, 2009. www.navy.mil/navydata/people/secnav/Mabus/Speech/SECNAV%20Energy%20Forum%2014%20Oct%2009%20Rel1.pdf. Accessed May 16, 2011.

- By 2020, 50% of all shore-based energy requirements will be met using alternative sources.
- By 2020, 50% of all bases will be net zero in energy consumption.
- By 2020, 50% of the total energy consumed by the U.S. Navy, ashore and afloat, will come from alternative energy.

U.S. Marine Corps[18]

- By 2015, reduce energy intensity 30%, relative to a 2003 baseline.
- By 2025, increase renewable electric energy use to 25%.

2.4 Greater Speed, Scale, and Resources Required to Reach Department of Defense Energy Goals

There seems to be an incongruity between the current 3.7% *electrical* renewable energy procured in the DoD in FY 2009 and the DoD's goal to produce or procure 18.3% of *all* energy consumed within its facilities from renewable energy sources by 2020. Similarly, some of the other goals seem even more difficult to reach, such as the U.S. Navy going from 0.6% renewable energy in 2009 to making 50% of all U.S. Navy bases net zero by 2020. Defining these goals in percentages could be misleading. Asking an average U.S. homeowner to pay 20% more for electricity per year versus asking that same homeowner to pay $120 more per year, for example, provides a different understanding when, in fact, the goal is the same.

To better comprehend the enormity of the DoD energy goals, it might helpful to translate these percentage goals to total energy consumption in megawatt-hours, renewable energy production and procurement in megawatt-hours, investments dollars required, and total number of staff members needed. Although a detailed and precise translation is beyond the scope of this report, it is important to touch upon this subject to better explain the challenge presented.

A review of the current DoD energy use, renewable production, and the Energy Conservation Investment Program combined with the results of the NZEI assessment indicate that, to achieve the DoD energy goals, *a drastic increase in the speed and scale of EE and RE project investment and implementation is required*. Currently, the DoD "emphasizes the use of ECIP in reducing energy consumption and greenhouse gas emissions, and increasing the use of renewable energy."[19] Military installations submit energy efficiency and renewable energy projects to the Office of the Deputy Under Secretary of Defense for consideration. From 2001 to 2009, the DoD invested a total of $387 million in the ECIP program (or an average of $48 million per year). This $48 million average annual budget is a very small fraction of the DoD $670.9 billion FY12 budget request."[20]

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[18] The PEW Project on National Security, Energy and Climate. "Reenergizing America's Defense; How the Armed Forces Are Stepping Forward to Combat Climate Change and Improve the U.S. Energy Posture." http://pewclimatesec-cdn-remembers.s3.amazonaws.com/ 172e73107e0952fd86378269bdeb62f6.pdf. Accessed May 16, 2011.

[19] Office of the Under Secretary of Defense, Installation and Environments. "Energy Conservation Investment Program (ECIP)." http://www.acq.osd.mil/ie/energy/ecip/ecip.shtml. Accessed May 15, 2011.

[20] Office of the Under Secretary of Defense, "United States Department of Defense Fiscal Year 2012 Budget Request." http://comptroller.defense.gov/defbudget/fy2012/FY2012_Budget_Request_Overview_Book.pdf Accessed July 20, 2011.

NREL's results for the Fort Carson NZEI assessment indicate that achieving the net zero energy goal for this one installation requires an estimated capital investment of $842 million and will return $96 million positive net present value after 40 years. (The Fort Carson NZEI will be published in 2011). This single net zero energy installation requires more than double the $387 million that has been invested in the entire Energy Conservation and Investment Program over eight years.(17) Granted, the total cost to make a base net zero energy or to complete renewable energy projects varies considerably (the estimated cost to approach the net zero energy goal was $60 million at MCAS Miramar and $3 million at Pohakuloa). Achieving energy efficiency and renewable energy goals still will require significant financial investment. If the DoD is going to achieve the U.S. Navy's goal of 50% net zero installations by 2020, the estimated investment needed is a multiple-level-of magnitude greater than what has been invested in the past.

Fort Carson uses approximately 160,000,000 kWh of electricity per year (or 1,600,000 MBtu source energy). This does not include the source 1,000,000 MBtu of natural gas consumed at the installation or any of the energy used for tactical operations. In addition to energy efficiency projects, the recommended renewable energy projects to help achieve net zero energy at Fort Carson include wind turbines, photovoltaics, concentrating solar power, biomass, solar vent preheat, solar hot water, and ground-source heat pump. Examining just one of these RE technologies—72 MW of photovoltaic panels—can provide insight into the project scale and schedule. Building 72 MW of PV arrays would require recreating one of largest PV arrays installed at a U.S. military base to date. Such an array would be more than five times larger than the 14-MW Nellis AFB array—a size which has never been built in the United States. (The Nellis AFB array is composed of 72,000 solar panels and sits on 140 acres).[21] By multiplying the $100-million Nellis PV array project by five, one can begin to comprehend the investment that is required to help a single base move towards net zero energy installation. (The Nellis PV array was financed by a third party and saves Nellis AFB approximately $1 million per year).

Furthermore, to achieve the DoN 50% net zero goal by 2020 requires an enormous acceleration in project implementation. A NZEI assessment typically takes one year. Additional project development steps, such as environmental assessments, engineering design, procurement, construction, and closeout can take several more years. The $100-million Nellis Air Force Base 14-MW PV array, for example, took nearly four years from project idea to project completion. Moreover, the Nellis AFB PV project is much less complicated than an attempt to implement many comprehensive NZEI projects for a base. The years required to implement these projects indicate that many of the U.S. Navy's installations should be in the process of implementing a NZEI assessment and EE and RE projects now to meet the DoN 2020 goal.

This review of just one of the DoN's goals is by no means an exact example of the total time and investment required to achieve the DoN 50% net zero goal or all of the DoD goals. This review, however, does demonstrate the exponential increase of investment and resources required to meet the DoD goals. Fortunately, this simple comparison demonstrates that assigning the resources to EE and RE in the DoD likely still would be a very small percentage of the overall DoD budget. Moreover, third-party financing could play a significant role in providing the necessary investment capital. (In third-party financing, if a nongovernmental intermediary has

[21] United States Air Force. "Nellis Activates Nations Largest PV Array." http://www.nellis.af.mil/news/story.asp?id=123079933. Accessed May 17, 2011.

reasonable assurances that it will be repaid, then it raises money through private capital markets to provide funding for the activity.)

3 Net Zero Energy Installation Assessment

3.1 Department of Defense and Department of Energy Net Zero Energy Initiative

In 2008, the DoD and DOE defined a joint initiative to address military energy use by identifying specific actions to reduce energy demand and increase use of renewable energy on DoD installations. The initiative established a task force composed of representatives from the Office of the Secretary of Defense (OSD), the four military services, the DOE Federal Energy Management Program (FEMP), and the National Renewable Energy Laboratory. In light of DoD priorities, early attention was given to the possibility of net zero energy military installations; that is, installations that would meet their energy needs with local renewable resources. The Marine Corps Air Station Miramar was selected by the task force to be the prototype installation for net zero energy assessment and planning. The choice was based on Miramar's strong history of energy advocacy and extensive track record of successful energy projects.

NREL's role was to perform a comprehensive, first-of-its-kind assessment of Miramar's potential to achieve net zero energy status—including energy project recommendations—and then to develop a template based on this work that could be employed at other military installations. The "Net Zero Energy Military Installations: A Guide to Assessment and Planning"[22] template was developed and published.

3.2 Net Zero Energy Installation Concept

Net zero energy is a concept of energy self-sufficiency based on minimized demand and use of local renewable energy resources. Although net zero energy status might not be a high priority for DoD installations, is some cases it could be a useful design point well suited to a disciplined analysis of how energy is provided and used. Net zero energy first was developed in the context of individual houses, where the challenge is to provide all required energy using on-site renewable resources. The concept, however, in recent years has been extended to communities, campuses, and military installations. In principle, a net zero energy installation should reduce its load through conservation (use what is needed) and energy efficiency (typically the most cost-effective measure that will allow the greatest returns per dollar spent), then meet the remaining load through on-site renewable energy. Defining a net zero energy military installation is complicated by the need to consider—in addition to individual buildings, public facilities, and infrastructure—the questions of how to treat energy used for various forms of transportation, and how to address mission-specific energy requirements such as tactical fuel demands.

The original definition of a net zero energy installation adopted by the DoD-DOE task force was, an installation that produces as much energy on or near the installation as it consumes in its buildings and facilities. The definition was expanded to include a focus on renewable energy, on-site generation, and fleet fuel use. The definition employed in this guide is, "A net zero energy military installation produces as much energy on-site from renewable energy generation or through the on-site use of renewable fuels, as it consumes in its buildings, facilities, and fleet vehicles."(19)

[22] Booth, S.; Barnett, J.; Burman, K.; Hambrick, J.; Westby, R. "Net Zero Energy Military Installations: A Guide to Assessment and Planning." NREL/TP-7A2-48876. Golden, Colorado: National Renewable Energy Laboratory, August 2010. http://www.nrel.gov/docs/fy10osti/ 48876.pdf. Accessed May 17, 2011.

A more detailed explanation of this elaboration and the net zero energy definition is given below.

- “Net Zero Energy” means that the energy produced on-site over the period of a given year is equal to the installation’s energy demand. This implies a connection to a local power grid which, in a sense, “banks” the energy. Thus, on-site renewable resources, such as solar energy systems, might produce energy greater than that used by the installation during the day, with any excess energy fed into the local grid. At night, when the solar system is not producing energy, the installation can pull the previously “banked” energy from the grid to net out the total consumption.
- Energy consumption could be in the form of electricity, steam or hot water, or the direct use of fuel.
- A military installation can be a contiguous area or can comprise separate areas. When assessing the energy of the installation, all activities within the defined boundaries are included—regardless of whether the energy is managed by the base energy manager or paid for by different agencies.
- A facility is any structure on a military installation that is not a building or fleet vehicle. Examples of facilities include swimming pools and area lighting.
- The task force’s willingness to include energy production “on or near the installation” was left open to interpretation. The assessment team focuses primarily on the possibilities of on-site energy production, accepting energy generated on-site from renewable sources and renewable fuel used on-site. The set of on-site renewable energy sources follows standard DOE practice: commercially available solar (photovoltaic, concentrating solar power, water heating), wind and hydropower systems, and electricity or heat generated from natural gas produced in on-site landfills or by burning the installation’s solid waste (waste-to-energy).
    - Renewable fuels include various forms of biomass (wood waste, agricultural byproducts); natural gas produced, for example, from external landfills or as a byproduct of sewage processing; and various renewable transportation fuels (ethanol-E85, biodiesel).
    - As employed here, the net zero energy concept does not include non-primary energy imported from offsite (e.g., electricity from a local off-site renewable source), or purchases of renewable energy certificates—that is, getting credit for renewable energy generation somewhere else in the world. This is in keeping with the net zero energy installation concepts’ emphasis on meeting energy needs with local resources.

The task force definition does not explicitly discuss minimizing the installation’s load—an essential first step toward net zero energy status. Load minimization can be accomplished through personnel actions to conserve energy or reduce energy waste, or by identifying approaches to conserve energy without impacting the installation’s mission. This also includes the implementation of standard facility energy-efficiency technologies to the extent that is economically feasible. These could include heating, ventilating, and air conditioning (HVAC) and lighting upgrades (efficient chillers and boilers, solar ventilation preheat, fluorescent or light-emitting diode [LED] lighting); environmental control systems; plug load reductions;

systems generating both electricity and heat (cogeneration systems) where both forms of energy are needed; and building envelope upgrades or design features such as insulation, high-performance windows, and daylighting.

Installation energy consumption can be measured in several ways. Possible measurement approaches include the following (adapted from Torcellini et al.[23]).

- Net Zero Site Energy: Energy used by the installation is accounted for at the site, for example, as indicated by building electricity and gas meters. This approach generally is straightforward but omits transmission losses to bring energy to the site.
- Net Zero Source Energy: Source energy refers to the primary energy used to generate and deliver the energy to the site, for example by a local utility generation site and transmission system. For transportation fuel, source energy would include a multiplier to account for the energy required to transport the fuel to the fueling station.
- Net Zero Energy Costs: In this approach, the amount of money the utility pays the installation for renewable energy generated on-site and exported to the grid is compared with the amount the owner pays the utility for energy used over a year.
- Net Zero Energy Emissions: In this approach, the installation aims to produce on-site at least as much renewable energy as it currently uses from off-site nonrenewable energy sources, on an annual basis, thus offsetting the off-site emissions.

Net Zero Source Energy was selected as the basis for energy accounting for a NZEI assessment because it is the most representative measure of primary energy consumption.

Transportation fuel use is included with the following limitations. All transportation fuel consumption data is gathered for the purpose of establishing an installation's total footprint, data permitting. This can include government ground-fleet vehicle fuel use, fuel associated with commercial air travel for official business, fuel used in personnel commuting, and tactical fuel use. Only the government fleet use is further addressed in the NZEI assessment, however. Potential reduction measures include converting to electric vehicles, using electricity generated on-site from renewable sources, or the use of renewable fuels in fleet vehicles.

The DoD's capability to significantly affect energy used in commercial air travel and by commuters includes minimizing trips, encouraging public transportation, carpooling, telecommuting, or providing electric-vehicle charging stations as an incentive for employees to consider electric vehicles when these become widely available commercially; however, these categories are have not been a component of the net zero energy assessment to date.

Tactical fuel requirements are not addressed in the assessment because renewable fuel alternatives are not yet commercially available. The DoD can (and does) examine training requirements and opportunities to use simulators instead of real tanks, personnel carriers, aircraft, ships, and submarines, and explores logistical variations in theater that can further

[23] Torcellini, P.; Pless, S.; Deru, M. "Zero Energy Buildings: A Critical Look at the Definition (Preprint)." NREL/CP-550-39833. Golden, Colorado: National Renewable Energy Laboratory, June 2006. http://www.nrel.gov/docs/fy06osti/39833.pdf. Accessed May 17, 2011.

reduce fuel use. These options, however, have not been a component of the net zero energy assessment to date.

In summary, in some cases the net zero energy installation concept might be a useful framework to analyze reducing energy use through human action and energy-efficiency technology, and meeting the remaining energy needs with local renewable energy resources. Some installations will be able to exceed net zero energy status to become net energy producers, and others won't be able to reasonably approach it. In fact, a net zero energy goal too strictly applied can lead to solutions that make poor sense from economic or other perspectives. Conversely, an assessment of a site's net zero energy potential, combined with consideration of the site-specific constraints is one approach for identifying an energy strategy tailored to the requirements of each site.

3.3 Net Zero Energy Assessment and Planning Approach

The net zero energy assessment and planning approach that has been used in the past is briefly summarized below.

- Initiate the project: Secure leadership support, establish a team representing key stakeholders, define project boundaries, and set a timeline.
- Establish energy and greenhouse gas baselines: Identify the installation mission, geographic boundaries, relevant energy-related mandates, and any special energy requirements (e.g., reliability, performance in emergency situations); summarize annual (source) energy used by all identified sources supporting the mission, its type, and its means of distribution. Become familiar with energy projects already planned on site. A greenhouse gas baseline assessment is included for later comparison with the emissions projected for the recommended future energy system (DoD has not yet released its official GHG-emissions reduction goal; however, a preliminary goal has been set internally and a final goal is expected to be released in the near future).
- Reduce energy use through human action: Identify approaches to minimizing wasted energy and maintain or improve the quality of mission execution by engaging the will, energy, and creativity of installation personnel.
- Perform an energy efficiency assessment: Identify specific on-site energy efficiency projects and their effect on installation energy consumption.
- Perform a renewable energy and load reduction assessment: Identify projects exploiting on-site renewable energy for electricity and/or heat production, or employing renewable fuels on-site for electricity and/or heat production.
- Perform a transportation assessment: Identify projects to reduce and replace fossil-fuel use in fleet vehicles.
- Perform an electrical systems assessment: Identify the impacts of recommended on-site renewable energy projects on the installation's electrical systems. As required by the installation, outline the characteristics of a smart microgrid to support emergency operations in the event of a public grid outage.
- Make energy project recommendations: Summarize the findings from the preceding efforts to evaluate energy projects and examine implementation options. Then, with

reference to broader installation and mission constraints, recommend a set of energy projects. Calculate the extent to which the installation can approach net zero energy status. Demonstrate how the recommended projects—in concert with projects already planned by the installation—can be implemented to produce energy savings, with attention to project timelines, life-cycle economics, and contractual and financing options.

A summary of the NZEI assessment concept can be seen in Figure 1. This figure illustrates how installation considerations can be used to develop an optimal energy strategy that leads to project implementation and toward net zero energy status.

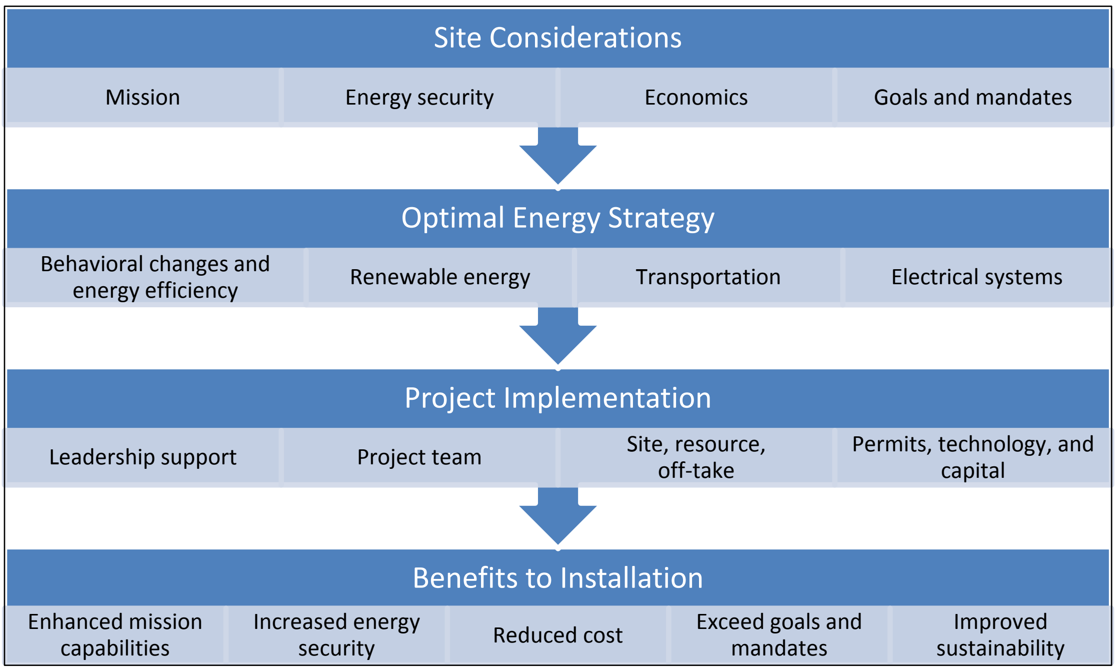

Figure 1. Flow diagram of net zero energy assessment and implementation

The NZEI assessment for military installations is a relatively new process, therefore in future assessments it could be changed to improve the procedures and outcomes.

3.4 Energy Strategies for Department of Defense Installations: Key Considerations

An NZEI assessment is one framework for a military installation to develop an energy strategy. An installation's energy strategy should reflect a number of constraints and considerations, including the following.

3.4.1 Mission Compatibility

Even if attractive by other measures, energy efficiency and renewable energy measures that are incompatible with the installations stated mission are not likely to be implemented.

3.4.2 Security

Energy security, surety, and reliability, as well as overall physical security of the site, must be maintained or enhanced by the installation's energy system. For example, a biomass-fueled power system might be unsuited to some sites due to off-site truck traffic required to bring in fuel. Conversely, the ability to meet an installation's critical load using on-site renewable sources (e.g., landfill gas, geothermal power, solar energy) in an islanding mode could greatly enhance energy security. This is underscored not only by the threat of malicious activities (e.g., physical attack, cyber attack), but also by the possibility of major blackouts such as those which have occurred in the United States many times in recent decades. More are anticipated due to aging electric-grid infrastructure, decreased maintenance investment, increasing loads, and the lack of situational awareness on the part of grid operators.[24] A recent Defense Science Board report stated that critical military missions are at a high risk of failure in the event of an electric grid failure.[25] The development of on-site energy supplies and smart microgrids, which are part of a net zero energy solution, can reduce this risk, and could become an increasingly important strategic concern.

3.4.3 Economics

Life-cycle, system-based economic assessment of alternatives should reflect such factors as technological maturity; fuel availability and cost; energy-storage requirements; distribution and interconnection arrangements; financing options; federal, state, and local incentives; environmental impacts; and costs for operations, maintenance, repair, and parts replacement.

3.4.4 Agency Goals and Federal Mandates

The DoD has a strategic energy plan to reduce consumption, leverage new technologies, drive personnel awareness, and increase energy supply; a primary goal is to achieve 18.3% renewable electrical energy use by 2025. Further, in October 2009 the Secretary of the Navy stated a new goal: By 2020, 50% of the energy consumed by ships, aircrafts, tanks, shore vehicles, and installations is to come from alternative sources.[26] Federal mandates presently focus on energy efficiency and renewable energy goals; these are planned to be expanded to include carbon-emission targets in the near future.

3.4.5 Site Resources

Energy system siting opportunities (buildings, disturbed or undisturbed land, accessibility) vary among installations, as do local climate, renewable energy resources, and electrical system interconnection opportunities. These factors all impact energy-system design.

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[24] U.S. Department of Energy. "The Smart Grid, An Introduction." No. DE-AC26-04NT41817, Subtask 560.01.04. http://www.oe.energy.gov/DocumentsandMedia/ DOE_SG_Book_Single_Pages.pdf. Accessed May 17, 2011.

[25] Office of the Under Secretary of Defense, for Acquisition, Technology, and Logistics. Report of the Defense Science Board Task Force on DoD Strategy. "More Fight—Less Fuel." February 2008. http://www.acq.osd.mil/dsb/reports/ADA477619.pdf. Accessed May 17, 2011.

[26] Mabus, R. "Remarks by the Honorable Ray Mabus, Secretary of the Navy." Naval Energy Forum. October 14, 2009. http://osiris.usnwc.edu/pipermail/nwc_onlinediscussion/attachments/ 20091119/9d999c42/attachment.obj. Accessed May 17, 2011.

3.4.6 Doctrine, Organization, Training, Material, Leadership and Education, Personnel and Facilities

Over time, holistic change to DoD energy systems, technologies, and practices will involve new doctrine, adjustments to organizations and training, new acquisition methodologies, leadership by example, and updates to education systems.

4 Portfolio Approach for Energy Optimization Assessments

The DoD has an enormous portfolio of facilities where EE and RE projects could be implemented. If an NZEI assessment is performed at each installation independently, the NZEI assessment process and goals could create artificial constraints that, in some cases, can limit the most cost-effective and timely implementation of EE and RE projects worldwide. For the DoD, taking a larger systems approach (discussed herein as the "portfolio approach") might be more effective than an independent installation approach. In a portfolio approach, the DoD could determine and prioritize specific energy goals for the entire DoD system and apply these goals at the installations.

The NZEI goal and process have limitations. Net zero energy is not always the appropriate end goal for a given military installation and was not the final recommended solution determined in some of NREL's NZEI assessments. An NZEI assessment provides a framework to improve energy efficiency, increase renewable energy production, reduce energy demand, minimize energy costs, provide energy security, and reduce greenhouse-gas emissions at military installations. When an installation achieves a net zero energy goal, (as defined in Section 3) the installation still could require significant amount of offsite fuel for its tactical operations. In some cases, a net zero energy designation might be inaccurate, representing a suboptimal goal for an installation.

The most appropriate energy assessment for a military installation depends on many factors such as site constraints, EE and RE goals, and DoD orders. An example in which a net zero energy goal is not optimal is the geothermal development at the U.S. Naval Air Weapons Station, in China Lake, California. At its peak this project produced 273 MW of electricity,[27] but the China Lake installation does not use all this energy. If the China Lake geothermal plant was sized to just meet a mandated net zero energy goal, the electricity generation would be much less and this renewable geothermal resource would not be optimally developed. This example demonstrates a circumstance where the constraints of the NZEI assessment could actually limit the positive benefits of a larger-scale renewable energy development at a military installation. This is only one unique example, but it can be inferred that, in other cases, the net zero energy goal on a base-by-base approach can create artificial design constraints and limit the DoD's great advantages of having facilities all over the world.

The U.S. Navy, for example, has stated a goal of producing at least 50% of shore-based installations' energy requirements from alternative sources by 2020.[28] Rather than attempting to

[27] Monastero, F. C. "Model for Success: An Overview of Industry-Military Cooperation in the Development of Power Operations at the Coso Geothermal Field in Southern California." *GRC Bulletin*. Sept./Oct. 2002. http://www.geothermal.org/articles/coso.pdf. Accessed May 17, 2011.

[28] United States Navy. "USDA, Navy Sign Agreement to Encourage the Development, Use of Renewable Energy." January 21, 2010. http://www.navy.mil/search/display.asp?story_id=50710. Accessed May 17, 2011.

implement 50% renewables at every facility, it might be more efficient, effective, and timely to identify the most cost-effective facilities for renewable energy projects and produce more than 50% of the total renewable energy at these facilities. There also could be significant financial benefits to this approach by reaching greater economies of scale for renewable energy deployment.

The U.S. Army has commissioned a report to prioritize RE energy projects at its facilities throughout the United States. As a result of this prioritization study, the U.S. Army will be able to efficiently assign its resources to develop the most viable RE projects nationwide. Likewise, the Pacific Northwest National Laboratory is performing a RE prioritization study for the U.S. Air Force.

This same portfolio approach also could be applied to energy efficiency project implementation. Because there are energy efficiency measures that can be implemented at all installations, one effective approach might be to perform energy assessments for all bases, define the installation energy baseline, identify the efficiency measures, determine the investment required and the return on investment, and use any other pertinent metrics. Using this information, the DoD could begin to prioritize resources required for implementing the energy efficiency projects. Prioritizing EE and RE project deployment based on financial metrics (e.g., state incentives, utility costs, net present value), environmental metrics (e.g., proximity to wetlands, endangered species impacts), and political metrics could result in focusing scarce resources on the most viable EE and RE projects.

In some ways, the DoD's Energy Conservation Investment Program is a portfolio approach to prioritize EE and RE projects using financial metrics. This system still is somewhat reactive rather than proactive. The projects submitted by the individual bases might not include the most optimal projects. Additionally, the ECIP program does not account for projects that could be implemented with third-party financing. Regardless, defining the appropriate EE and RE metrics and goals and identifying and selecting the projects that best meet these metrics could be an appropriate approach to implementing energy efficiency and renewable energy projects with greater speed and scale.

Conversely, analyzing an installation for net zero energy potential is a disciplined approach to identify a specific energy strategy for one military installation. In some cases, the DoD can determine that it is critical to island the installation from the utility's electrical grid. To achieve this goal an NZEI is likely the most appropriate approach. In fact, the U.S. Navy has indicated that 50% of all shore installations will be net zero energy consumers.[29] Consequently, an NZEI assessment will be an important part of the process to achieve the stated goal. Furthermore, many of the steps in an NZEI assessment—such as energy efficiency audits—are appropriate for any type of energy optimization study. The NZEI assessment incorporates many of the standard EE and RE analysis tools and applies them towards one goal. The NZEI assessment can be a beneficial process for analyzing site-specific considerations and creating a plan for an installation to produce as much energy from on-site renewable energy generation, or through the on-site use

[29] United States Navy. "USDA, Navy Sign Agreement to Encourage the Development, Use of Renewable Energy." January 21, 2010. http://www.navy.mil/search/display.asp?story_id=50710. Accessed May 17, 2011.

of renewable fuels, as it consumes in its buildings, facilities, and fleet vehicles. The key is to ensure that the net zero energy goal fits the goals of the installations and the DoD.

It might be helpful to understand a portfolio approach to net zero energy by categorizing the net zero energy assessment by different boundaries. For example, the boundaries for a net zero energy assessment could be a building footprint, an installation fence line, a regional boundary across several states, or a branch of the armed services. The results of the analysis and level of detail provided would depend on the defined boundary. In a portfolio approach the net zero energy assessment could be defined as all U.S. Navy installations, for example. In this case, some installations (e.g., China Lake) would produce much more renewable energy than could be used by the installation; other installations in areas less favorable for renewable energy generation might not become net zero energy. This example demonstrates that there are various approaches to optimizing energy use, and a net zero energy assessment is a methodology that is not required to be limited to one installation.

In summary, for the 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. The bottom-line recommendation therefore is to use a design method that promotes an optimal energy strategy, considering such real-world considerations as renewable resources, economics, energy surety and security, financial and human resources, other installations, and other DoD EE and RE goals. In some cases, a portfolio approach to reaching net zero energy could be the preferred course of action.

5 Summary of Lessons Learned from Net Zero Energy Assessments

The National Renewable Energy Laboratory has completed six net zero energy installation assessments for military installations. The following sections summarize the common lessons learned in the NZEI assessment process. The specific details and results for each of the NZEI assessments are provided in the Appendix.

5.1 Goals, Mandates, and Incentives

The realization of DoD energy efficiency and renewable energy goals and mandates requires incentives and enforcement. Penalties for not achieving goals also could be helpful. Some installation personnel are attempting to meet EE and RE goals, mandates, and executive orders. Conversely, a few personnel share the sentiments of one sergeant who exclaimed, “Executive orders are made to be broken!” Without properly designed incentives and enforcement, installations might not prioritize achieving all of the DoD EE and RE goals.

A net zero energy assessment often is requested by a higher-level organization or agency (i.e., DoD Headquarters) rather than by the staff of the specific site. Without any local investment in the assessment or any incentives and penalties encouraging participation, site personnel do not always place high value on achieving the goal. In some cases, installation personnel could have other priorities (e.g., energy projects, building upgrades), might have only limited interest in a NZEI assessment, and could have limited time available. As a result, the energy team might not function as effectively as is possible. Participation and buy-in can be improved by involving installation personnel in the NZEI assessment site-selection process, and requiring the selected sites to invest a portion of its own resources in the assessment. Implementing incentives and penalties for achieving the NZEI assessment goals also would encourage participation and could improve the schedule, quality, and—ultimately—the implementation of the assessment.

In some cases the true cost of fossil fuel is not borne by the installation, so it has less incentive to switch to energy efficiency and renewable energy options. When the Defense Energy Supply Center (DESC) covers the cost of transporting fuel to an installation, for example, the fuel bill for the installation doesn’t capture the cost of transportation, supply interruptions, or supply and demand fluctuations. This makes the costs and benefits of fossil fuels versus renewable energy more difficult to evaluate, because the true cost of the baseline fossil-fuel energy is unknown.

5.2 Leadership, Chain of Command, Training, and Culture

The DoD uses a top-down chain of command. The installations that are going to successfully and quickly conduct the assessment and implement the projects therefore are those which have leaders that make energy efficiency and renewable energy a priority. At the same time, micromanagement by leaders in distant offices also can slow down a project.

Achieving immediate and substantial reductions in energy use is possible via occupant awareness and behavioral changes. Behavioral changes to increase conservation and energy efficiency can be a low-cost measure that saves energy. Emphasizing that the attaining energy efficiency and using renewable energy is DoD top-25 mission could improve the commitment of installations.[30] An effective educational campaign to demonstrate the links between national security, energy efficiency, and renewable energy can help create the culture and behavioral changes needed to reach the DoD's ambitious goals.

Each installation has its own history and culture, which can include ingrained policies, perceptions, and habits. It could be beneficial to candidly discuss the community culture within the context of successfully achieving goals for net zero energy. If these issues are addressed up front, then the installation is more likely to successfully incorporate sustainability values in its policies, programs, incentives, education and training, decision process, and follow-on evaluation metrics.

Sometimes there exists a lack of knowledge, understanding, and confidence in renewable energy technologies. In one case, for example, base personnel were reluctant to deploy wind turbines due to the perceived challenges of managing distribution of wind resources. It might be helpful to provide training and to facilitate site visits so that personnel can see the different projects and become more comfortable with implementing EE and RE projects at their own installations.

5.3 Data Collection

Difficulties collecting accurate data can increase the duration and reduce the quality of an NZEI assessment.

Data can be very difficult to obtain. Data regarding energy consumption, electrical systems, transportation fuel consumption, and other information related to NZEI assessment resides often with many different organizations in many different places. It can be difficult to obtain data/information from organizations with limited project interest and support, and with different chains of command. Data may not always be available and may not always overlap precisely in terms of the detail, time frame, and level of data available. The project lead must be flexible and make judgment calls relative to aggregation of data into a single energy baseline for an installation.

Data regarding energy uses not directly included in net zero energy installation definition and not often tracked such as air miles traveled and commuter fuel use can be particularly difficult to obtain.

Data availability affects the level of analysis. Lack of data requires the assessment team to make assumptions that may reduce the accuracy of the assessment. The project lead needs to adapt the analysis to the level of data that is available, documenting assumptions as necessary.

The NZEI Energy Assessment team should investigate, gather, and review all information that the installation has already completed related to EE and RE. For example most military installations will already have had energy assessments or screened for renewable energy projects. These previous studies can be used as part of the NZEI assessment.

[30] PR Newswire. "Pew Study: Department of Defense Embracing Clean Energy." http://www.prnewswire.com/news-releases/pew-study-department-of-defense-embracing-clean-energy-91607604.html. Accessed May 15, 2011.

5.4 Assessment Schedule, Investment, and Benefits

In some cases it might be beneficial to omit or phase parts of the NZEI assessment to meet the site conditions, goals, resources, and schedule. Performing a complete NZEI assessment requires expending significant resources and time. Occasionally, the time and resources required for a full NZEI assessment might not meet all the goals and schedules of the installation or DoD HQ. Because an NZEI assessment is a significant commitment, it is critical that the installation determine whether a full assessment is required rather than a more specific assessment or only parts of the NZEI assessment. Some bases, for example, have declined to perform all parts of a full assessment—such as an islanding and microgrid study or greenhouse gas baseline—because these studies did not match other goals and the funding available.

5.5 Technology Selection

Renewable energy technology selection requires balancing an array of technical and non-technical requirements dictated by the specific installation conditions To have a reasonable chance at implementation, renewable energy projects must balance installation priorities such as mission, goals and mandates, energy security, cost, and environmental concerns. Many installations have expressed interest in energy technologies that are not yet available commercially, such as ocean energy, algae to fuels, and small nuclear reactors. Typically, an NZEI assessment focuses on commercially available technologies that can help achieve the net zero energy goal. By evaluating all potential technologies, however (e.g., fuel cells, microturbines, solar pool heaters), and not just common renewables (e.g., photovoltaics, wind), the NZEI team can better match the technology that best fits with the installation's requirements.

5.6 Islanding and Microgrids

There often is disagreement about the need to electrically island an installation, and the cost and benefits of islanding often are not fully understood. Further, the energy security benefits for islanding an installation are difficult to financially evaluate and the DoD has not established quantifiable islanding requirements. The expense to electrically island an entire installation might not be justified for every installation, therefore using microgrids carrying only mission-critical loads and installing backup generators in many cases might be better alternative.

Many renewable energy technologies (e.g., PV, wind) generate power intermittently. Such generation is more difficult to incorporate into a microgrid than is dispatchable generation such as biomass and concentrating solar power (CSP). If long-term islanding with renewables is a high priority, then a dispatchable technology could be required. In some cases this might cost more than other renewable technologies.

A high penetration of renewable energy on an installation likely will require coordination, special contracts, or negotiations with the local electric utility to insure the ability to interconnect systems. Coordination with the utility also could improve financial viability, as it is a key partner in securing rebates, tax credits, net metering capability, REC purchases, and other potential incentives.

5.7 Design Criteria

Designers of DoD facilities and installation personnel should follow clearly defined, quantitative energy-efficiency design criteria for designing new buildings or retrofitting old buildings. Incorporating energy efficiency into initial building design is the most cost-effective way to reduce energy use; it therefore is critical to select the correct design criteria for new buildings. Retrofits performed on new buildings to improve energy efficiency are not as cost effective as incorporating these efficiency characteristics into the building design.

In some cases new buildings use more energy per square foot than is used by the old buildings. Modern military building requirements result in more energy use for building conditioning, including modern HVAC systems and greater lighting power densities. Installations should use energy-efficiency design criteria tailored to DoD energy goals to ensure that new buildings and retrofit buildings use less energy as compared to older buildings. Criteria might be required to be more stringent than the LEED Silver standard.

5.8 Installation Influence on Energy Efficiency and Renewable Energy Projects

New buildings could be designed at a central DoD office, and the individual installation might not have any control over the building-design criteria that will have a huge impact on the installation's future energy consumption and expenses. It is important that installations have the ability to influence energy efficiency design measures.

It might be helpful if the installation has increased ability to authorize greater energy expenditures to invest in renewable energy projects. In some cases the initial payments for renewable energy can be greater than for fossil-fuel energy but, in the long run, the renewable energy use could cost the installation less. Similarly, if the installation has the authority to allocate land to renewable projects, then it might be able to use local resources most efficiently.

5.9 Ownership of Facilities and Control of Land Resources

Installations have limited ability to implement energy efficiency and renewable energy projects in leased buildings and facilities. The ownership and operational control of facilities influences the site's options for reaching net zero energy status. In some cases, a military installation might not own the building it occupies and is limited in making improvements (for legal or financial reasons). Ideally, installations can choose buildings that meet minimum efficiency standards or can work with leasing agencies that will allow energy savings performance contracts to implement retrofits.

As installations privatize the aging utility infrastructure (as directed by DoD), it will be important to balance control of installation energy assets versus the costs of investing in the infrastructure. To avoid the cost of upgrading and maintaining its aging utility grid, for example, one installation is undergoing a utility privatization (UP) effort. As a result, it will give up control of the infrastructure that ultimately will be required to manage the proposed network of distributed energy generation and storage assets on the site. In the case of a utility outage, it might be more difficult for the installation to wheel power from its distributed sources to its critical loads and thus maintain operations. Conversely, the privatized and upgraded utility infrastructure will not require a significant investment from the installation and, on a day-to-day basis, the local grid could function more effectively and efficiently if it was privatized. The key is to negotiate UP agreements that still allow the installation to control the interconnection of distributed generation (DG) sources. Additionally, utility privatization is a mechanism that—when designed correctly and when requirements for electrical islanding are built into the agreement—can strengthen the microgrid at an installation.

5.10 Operations and Maintenance Contracts

Operations and maintenance service contracts that include the proper incentives can help to ensure that energy efficiency and renewable energy systems continue to operate properly and contribute to DoD energy goals. Some installations have hired third-party contractors to perform O&M for building facilities. Typically the contractor's main responsibility is to ensure that building mechanical systems are running. The contractors usually can respond to requests to increase the heat or to provide increased air conditioning to keep building occupants comfortable, but contractors typically are not incentivized to improve energy efficiency and are not responsible for paying the utility bills. To ensure that the building mechanical and electrical equipment is running optimally and efficiently, service contracts should include energy-savings incentives.

In one case, an installation purchased a PV and battery system and also was responsible for the system's operations and maintenance. The installation did not maintain the system. As a result, the battery system stopped functioning and the still-functioning PV system was not used for many years. If the PV system and battery system were owned and operated by third party under a power purchase agreement, then the contractor would be both required and motivated to ensure that the system performs optimally.

5.11 Regulations

Various regulations can reduce an installation's options for implementing energy efficiency and renewable energy projects. Existing rules and regulations for interconnection of renewables and net metering might not initially permit the installation to interconnect a large project to achieve net zero energy status. Thus, cost-effective RE implementation strategies for the base might require a modification or waiver of these rules for the projects to be possible. Legislation and policy changes might be required to enable interconnection and net metering for some projects.

Architectural or aesthetic requirements also can limit EE and RE projects. For example, large installations require significant amounts of personnel, energy, water, and other resources just to maintain its landscape. In many cases installations could save money and reduce resource use by changing the landscape design; however, aesthetic preferences and cultural norms have prevented some installations from changing resource-intensive landscapes to those more suitable to the local climate. Some military installation buildings are designated as historic landmarks, for example, and there are restrictions regarding how the buildings can be renovated. Such restrictions can limit the energy efficiency and renewable energy opportunities or can make the renovations too costly. Likewise, when new buildings are designed for a base, the architecture of the new building might have to conform to the architectural theme of the older buildings. This can make it more difficult or costly for the new buildings to incorporate more modern energy efficiency and renewable energy components.

5.12 Financial Estimates

Financials for an NZEI assessment depend on many factors that are time sensitive, unknown, and require estimation. Overall, NZEI assessment financials should be viewed as rough estimates that are useful for planning purposes, but are not sufficient for project investment. Reporting the financial results in standard terms such as investment required, net present value, and dollars per kilowatt-hour, and providing other time-sensitive financial metrics could be helpful to evaluate and plan for implementation.

The financing mechanism chosen for implementing the projects recommended in an NZEI assessment could have a great impact on the financial viability of projects. Government-owned projects funded through appropriations reduce contractor financing and markup fees, but they also require up-front capital investment and cannot receive federal tax incentives. Such projects also place the O&M burden on the installation. Privately owned projects allow the installation to implement renewables without any up-front capital investment and with reduced O&M responsibility. They also enable the installation to take advantage of federal tax credits and other incentive programs, although the money gained from these programs could be offset by contractor financing and markup fees.

5.13 Resource Commitment

An NZEI assessment will likely be most successful when long-term commitments from team members and funders are established. Providing implementation support after the assessment should be part of the up-front project planning and budgeting. The end goal of the NZEI assessment is not a report, but rather reductions in energy use and an increase in renewable energy use at the installation. The completion of the final NZEI assessment report is just the beginning of the process.

Even if third-party financing is used to implement many of the recommendations in the net zero energy assessments, the base will require additional personnel and financial resources to manage the implementation of the projects. The project implementation is above and beyond the typical activities of the installation personnel and likely will require more staff and funding.

5.14 Implementation

Typically an NZEI assessment is a preliminary assessment of EE and RE options, optimization, and recommendations. It typically does not establish a specific action plan—prioritizing options, setting deadlines for next steps, or assigning responsibilities for implementation and evaluation of performance. It would be helpful if the NZEI assessment were expanded to include a detailed action plan. A strategy alone is insufficient to quickly achieve the desired impact.

The detailed action plan could include such information such as the schedule, budget, investment required, investment plan, and staff plan and could assign responsibilities. Any entities functioning in a consulting role should both provide recommendations from analyses and give specific guidance on how to implement the recommendations. Even if it is difficult to assign responsibilities and funding because people and funding aren't yet available, a consultant still can estimate the human and financial resources required to implement the recommendations. If staff and funding aren't immediately available to begin the work, the DoD leadership still can gain an understanding of the resources and schedule required to achieve the goals. If the DoD leadership has a clear roadmap indicating the required funding and staff, then it can work to obtain and assign sufficient resources. It is critical that a framework be developed, and it should include the goals, define a proponent with decision authority, set a timeline, and define steps and roles.

Most of the NZEI reports have not yet been completed, therefore it is difficult to measure how quickly and efficiently the recommendations have been implemented. It would be helpful to evaluate the NZEI effectiveness within one year of each completed NZEI assessment.

6 Renewable Energy Projects Lessons Learned

The following sections summarize lessons learned from large-scale (>$1 million) renewable energy projects. Because the DoD will be increasing the speed and scale of renewable energy project implementation, this summary could help military personnel learn from past experience and then use this knowledge to facilitate future projects.

To gather some lessons learned from completed RE projects on military installations, NREL selected larger projects from various branches of the DoD that were implemented through various financial mechanisms, such as power purchase agreements (PPA), energy savings performance contracts, utility energy service contracts, and the military energy conservation investment program (projects implemented through the Energy Joint Venture or MILCON funds were not included). Lessons learned from the following projects are included in this report. This list, however, is not a complete list of all the completed RE projects or lessons learned at military installations. In some cases, additional renewable energy projects were completed at these installations.

The six military installations selected for review include:

- Camp Pendleton, California, 4,371-Mbtu/year solar thermal and 63,200-kWh/year PV;
- Fort Carson, Colorado, 2-MW PV array;
- Twentynine Palms, California, 1.2-MW PV array;
- Marine Corps Logistics Base (MCLB) Miramar, Barstow, California, 1.5-MW wind farm;
- Nellis Air Force Base (AFB), Nevada, 14-MW PV array; and
- Warren Air Force Base, Wyoming, 3.1-MW wind turbines.

NREL reviewed the existing literature about these projects and then conducted brief interviews with some of the key people involved. The lessons learned are summarized and categorized in a simple format so that others who are considering implementing large-scale renewable energy projects at military installations can quickly learn from these past projects. Many of these projects have presentations or case studies already documented. This guide does not include additional case studies for these projects; however, it does include references to these case studies in the Appendix.

6.1 Renewable Energy Markets

There are financial advantages to completing renewable energy projects at military installations located in top renewable-energy marketplaces. For example, financial incentives for RE projects have helped make Nevada one of the top five states in the United States with completed solar projects. Nevada's renewable portfolio standard (RPS) requiring that 15% of all electricity be generated from renewable sources by 2013 facilitated the 14.2-MW photovoltaic PPA at Nellis Air Force Base. The RPS created a strong market for renewable energy credits (RECs) and generated interest from developers. In fact, the Nellis AFB PV project was initiated when a developer made unsolicited contact with the base. The base benefited from high renewable energy credit prices and, as a result, saves an estimated $1 million dollars per year.[31] Similarly, Colorado has a RPS, and personnel at Fort Carson were approached by a private developer before it initiated its PPA for a 2-MW PV system. When a state has a market favorable to developing renewable energy projects, developers are likely to seek partnerships with the DoD because the installations often have land, large power requirements, aggressive energy goals, and energy expertise.

Conversely, when a local market does not exist for RECs, project financials are less attractive. One challenge that Fort Carson has faced in implementing energy efficiency and renewable energy projects, for instance, is that electric and natural gas prices in the Colorado Springs, Colorado, area are low as compared to those in other parts of the country. Thus the net present value for projects is less than for similar project in markets with greater electrical rates.

6.2 Project Team

It is important to involve the appropriate members from the local utility early in the RE project-development process**.** The utility company can be a key partner for many steps in the project design and implementation process, such as providing information on incentives and on the process for connecting the renewable energy source to the utility's grid. If the utility is not involved then there could be significant delays or constraints on the RE project. The 1.5-MW wind turbine at the MCLB in Barstow, California, for example, was completed under a utility services energy contract. Even though some members of the local utility were involved early in the process, members of the interconnection department were not involved and, as a result, there were delays in connecting the wind turbine output to the grid.

Top-level support for RE project implementation is helpful for securing financial and human resources. Support from the Marine Corps headquarters was critical to the successful deployment of a 1.2-MW PV array and a 7.2-MW dual-fuel combined heat and power (CHP) system at Twentynine Palms Marine Air Ground Task Force Training Command (MAGTFTC). This support not only resulted in funding for projects at Twentynine Palms, it also facilitated the development of a capable project team. This team consisted of personnel with a wide range of skills, including mechanical engineering, contracting, and budgeting. Likewise, Nellis AFB also emphasized the importance of obtaining project support at the office of the Secretary of the Air Force. High-level support has helped motivate entities throughout the organization to prioritize renewable energy projects.

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[31] United States Air Force. "Nellis Activates Nations Largest PV Array." http://www.nellis.af.mil/news/story.asp?id=123079933. Accessed May 17, 2011.

A successful core RE project team will have the appropriate skills and resources to manage all components of the project. The primary project team at Nellis AFB consisted of individuals at multiple levels throughout the organization. Among others, this team included a base-level "champion," U.S. Air Force middle management, and an USAF utilities lawyer from the Air Force Civil Engineer Support Agency (AFCESA). This team had contracting, technical, legal, and economic expertise. The diverse skill set of the core team members facilitated successful project completion.

Identifying and involving all project stakeholders—such as property management, contracting, legal, environmental, engineering, and security—early in the project-development process can help to streamline the implementation and increase early support for the project. Additionally, establishing both primary and alternative representatives for all stakeholders can ensure the continuity of the project, because primary contacts might not always be available or could leave their positions over the course of RE project.

6.3 Training

The DoD-related renewable energy conferences, such as GovEnergy, and site visits have served as useful forums to exchange ideas and project information within the DoD. A project team considering implementing an RE project at its base, for example, can gain useful information by visiting another base where a similar RE has already been implemented.

6.4 Market Timing and Project Schedule

Bases with "shovel-ready" renewable energy projects can better manage changes in the RE marketplace. For example, the bid process for the Nellis PV array coincided with a time when REC prices were high in Nevada. If the project had been bid six months later, then the financial benefits for the base would have been much less because of the rapidly declining REC prices.

Installations that were not prepared or could not act quickly enough to implement RE projects missed project development opportunities. In 2009, for example, Fort Carson had an opportunity to construct a large solar array, but the lengthy land lease approval process required by the Office of the Assistant Secretary of the Army, Installations, Energy and Environment, caused delays. Ultimately, the project developer moved the project to another location.

A project team that completes the applicable permits and the regulatory process outside of the RE project critical path will be better prepared to take advantage of favorable market conditions. Environmental assessments, land appraisals, and legal surveys can take a significant amount of time. The base can avoid project delays by completing these activities out of the critical path for the project. At one 600-acre USAF site where the market is currently not favorable for renewable energy deployment, for instance, the USAF currently is developing an environmental assessment so that the project can proceed quickly when the market becomes more favorable.

6.5 Site Considerations

Clearly defining the priority level of renewable energy project development, and creating master site and energy plans, will help resolve any land-use conflicts arising at installations. Land-use conflicts often arise between the installation's tactical mission and its energy-related goals. Personnel managing installations with artillery ranges or flight lines, for example, might not believe that the installation can be converted for use with renewable energy systems. If RE development is designated a high priority or is incorporated into the mission of an installation, then energy managers and site planners have more authority to manage the land at the base, acquire new land, or purchase clean energy beyond the installation's footprint.

Former landfills can provide good sites for solar energy projects, but likely will require coordination with environmental agencies to ensure success. Some DoD bases, such as Fort Carson and Nellis AFB, have deployed large solar PV projects on former landfills. Capped landfills can provide excellent sites for solar projects because of the restrictions on using the land for other purposes. For its 2-MW PV array, the project team at Fort Carson evaluated siting a PV-array project atop a landfill that was beginning the closure process. During the process, Fort Carson worked closely with the U.S. Environmental Protection Agency (EPA) to incorporate solar projects as a certified purpose for the closed landfill. Through this collaboration, the EPA and Fort Carson were able to simultaneously complete the landfill closure and solar certification, accelerating the permitting process.

Improved knowledge, specifications, and dissemination of information on the real versus perceived impacts of some renewable energy technologies on DoD air operations could increase the speed of RE project development. Early concerns of interference between wind turbines and radar, for example, delayed wind turbine deployment for years. Studies and specifications have enabled turbine deployment to proceed, but there still is a lack of information or specific design specifications for developing these projects near DoD air operations. The DoD recently created the Energy Siting Clearinghouse to help overcome challenges such as these.

Those involved with wind projects to be sited near public airports should work with the Federal Aviation Administration early in the project-development process to determine whether flight approach rules must be rewritten or the project design be changed. Warren AFB, for example, worked with the local airport authority, which had to rewrite approach rules. This was one of the biggest hurdles to deploying the wind turbines at Warren AFB, and a result of the process was the reducing of the height and size of the turbines.

6.6 Funding and Incentives

Bases with "shovel-ready" RE projects have benefited financially from unexpected funding opportunities. In 2002, for example, Camp Pendleton began work on the project development for a 1.5-MW PV array at the closed Box Canyon landfill. When the American Recovery and Reinvestment Act was passed in 2009, Camp Pendleton was able to secure sufficient funding to start the project. Similarly, Twentynine Palms MAGTFTC was awarded funding at the end of the fiscal year because it already had developed a prioritized list of RE projects, including associated costs, life-cycle assessments, and other documentation. Representatives from various installations also noted the importance of obtaining funding and personnel to complete the project planning and prepare project budgets and funding requests.

Installations can be more successful in securing funding for RE projects if they are familiar with the application processes associated with different funding programs. For instance, projects submitted under the Energy Conservation Investment Program are sent directly to a headquarters office for approval. Military Construction (MILCON) funds (which now fund some energy projects), have a different funding application process. Base personnel who know and follow the requirements associated with each funding program improve their chances of receiving funding.

Installations that have successfully completed RE projects and achieved a cost savings could be more likely to receive additional funds for renewable energy project development. Typically, RE projects bring positive public relations attention to installations, which results in more goodwill. Installations that are able to retain a portion of the RE project cost savings at the installation usually are more motivated to implement RE projects. In some cases, installations have found it helpful to use the project savings to fund additional staff members dedicated to RE projects.

For cases in which funding is not available through DoD funding programs such as ECIP and MILCON, third-party financing is a viable option. Twentynine Palms could not obtain ECIP or MILCON funding for several proposed energy projects, for example, so it instead used an ESPC to complete RE projects. Installations have used the cost savings from energy efficiency projects to fund RE projects. Twentynine Palms MAGTFTC funded its $16.2 million, 7.2-MW combined heat and power plant under an ESPC administered by the United States Army Corps of Engineers (USACE) and Naval Facilities Engineering Command (NAVFAC). The payback period for the CHP was determined to be 3.5 years, so Twentynine Palms MAGTFTC was able to fund many other energy projects in the ESPC using the savings from the CHP project. These additional projects included a 1.2-MW PV system, daylighting projects, smart-grid controls, and adsorption chillers (to utilize the CHP's waste heat to cool the facilities). Combined, these measures have a simple payback period of approximately 20 years and they reduce the need to purchase brown electricity.

Early in the design process it is important to clearly understand all the criteria for RE incentives and design the project to fit the incentives. In one case, an installation implemented a 1.5 MW renewable energy project, but the incentives capped the output at 1 MW. As a result, the project output was curtailed at 1MW. Unfortunately, the capital investment has been made for 1.5-MW system, but the power output is 33% less than what the system is capable of producing.

6.7 Technology

Guidelines defining the conditions in which microgrids are required might help accelerate RE projects, because forcing the coupling of microgrid and renewable energy projects can impede quick project deployment. Some organizations mandate the microgrid functionality in renewable energy deployment projects. On occasion, however, base or contractor renewable energy technical experts lack expertise in microgrid and storage applications—and this lack can halt projects that are required to incorporate a microgrid. Rather than requiring microgrid functionality for renewable energy projects, simply mandating that projects be "microgrid ready" could increase the potential for projects to be deployed. A base can add microgrid capability once it determines that is a priority and acquires the necessary expertise and systems to support this functionality.

Deploying renewable energy technology products that have a proven performance record and have warranties can reduce potential downtime and maintenance costs. Using certified project designers (when available) and technologies backed by warranties or operations and maintenance contracts helps ensure both proper design and project success. Fort Knox indicated that the certified geo-designers properly designed the geothermal heating and cooling system.

Resolving network security concerns enables personnel to easily access data from advanced meters and improves the monitoring and performance of renewable energy projects. In some cases energy managers at installations are unable to download the data from advanced meters because the network security prevents the transmission of the data wirelessly or prevents incorporating the data into the existing IT networks. The data from advanced meters and building automations systems are not readily available, therefore the personnel are unable to effectively monitor the energy systems.

Energy planners should consider all potential technologies for an installation, such as fuel cells, microturbines, waste to energy, and ground source heat pump rather than just solar or wind. Fort Knox is included here to highlight the potential to implement large-scale renewable energy projects using commercial available technologies beyond solar and wind. An UESC was completed at Fort Knox to implement a geothermal heating and cooling system serving more than 5 million ft^2. One phase of the project included 800,000 ft^2 and 38 facilities. The resulting savings came to $900,000 per year and 106,600 MBtu.[32]

6.8 Contracts

Contracts that require the contractor to provide the system maintenance at a reasonable cost and in a timely manner for the life of the renewable energy project can improve the overall performance. Moreover, third-party contracts that only reward the contractor for the electrical output also incentivize the contractor to properly maintain the system. Currently, the personnel at one installation that purchased wind turbines are finding it difficult to find contractors to perform the necessary turbine maintenance. As a result, the wind turbines are inoperable for weeks at a time. The installation has had difficulty getting a maintenance schedule from the manufacturer and the installation is forced to hire third-party service contractors on an ad hoc basis and at great cost. In this installation's experience, single-turbine systems seem to be a lower maintenance priority for manufactures and contractors than are larger wind farms. This situation could be improved if the contract was structured differently.

Enhanced use leases are more effective for utility-scale renewable energy projects than they are for small projects. For leases of large land areas developers can build sizeable systems, from which only a fraction of the output is required to meet the DoD base needs. An EUL provides a relatively effective mechanism for enabling the DoD to lease land and the developer to provide "in kind" power to a base from its large system. For smaller projects, however, from which a base might consume all of the power produced, the EUL adds unnecessary layers of complication. A conventional lease or an easement could streamline the contracting process for projects that purely are intended to supply power to a DoD base.

Standardized and widely disseminated DoD RE contracting processes and documents will help to streamline project implementation. Personnel from multiple installations in different branches of the armed forces noted the need for branch- or department-level contract support and tools for RE projects. These contracts could codify steps for obtaining approvals and releasing requests for proposal, thereby streamlining the contracting process. Additionally, training contracting officers and creating a contracting support network within the DoD for implementing energy projects would facilitate efficient and effective deployment. The U.S. Army Corps of Engineers (Huntsville) might be able to help develop contracting support tools. Huntsville develops

[32] U.S. Department of Energy, Energy Efficiency & Renewable Energy, Federal Energy Management Program. "Federal Applications of Renewable Energy; U.S. Army Fort Knox: Using the Earth for Space Heating and Cooling."April 2010. http://www1.eere.energy.gov/femp/ pdfs/46349.pdf. Accessed May 17, 2011.

generic, performance-based specifications that simplify and reduce the costs of contracting. A similar system could be useful in writing renewable energy development contracts.

Creating a DoD prequalified list for renewable energy developers also might streamline the RFP process and ensure that the DoD is contracting with high-quality developers. Currently, a GSA schedule includes eight solar contractors who have been prequalified to work with federal agencies. Agencies that wish to develop a solar project have the option to solicit bids from the prequalified list of contractors; as a result, the agency benefits from a competitive process and quality assurance. This system could be expanded to areas within the DoD.

The DoD could realize significant financial and other project benefits by bundling RE project development at multiple bases and competitively selecting one or more contractors to complete RE projects. By reaching greater economies of scale the contractors can lower their costs and prices. The U.S. Navy Facilities Engineering Command southwest is using this contracting method through its solar multiple-award contract (MAC). The NAVFAC Southwest "awarded a $200 million contract on Feb. 24 to construct up to 40 megawatts (MW) of solar photovoltaic power plants at Navy and Marine Corps installations throughout the southwestern United States."[33]

Before beginning the contracting process for a renewable energy project, installations should consult with the local utilities. Under 40 USC 591, a department, agency, or instrumentality of the federal government cannot purchase electricity, "in a manner inconsistent with state law governing the provision of electric utility service." In the case of the Nellis PPA, the utility preferred that Nellis issue a competitive RFP for the PV array. There could be financial advantages for an installation to issue its own RFP for renewable energy projects rather than procuring renewable energy through the utility. In the case of Nellis AFB, a sole-source renewable energy contract issued with the utility likely would have resulted in an electricity price approximately equal to the existing electrical rate. By issuing the RFP itself, it received an electrical rate that was significantly less than the existing electrical rates.

Installations could benefit by not specifying the exact size of the RE project in the RFP. A component of the USAF's successful competitive solicitation process at Davis Monthan Air Force Base was its allowing developers to propose the PV system size. By offering a large amount of land to lease and setting only a minimum system size (i.e., 1 MW), the USAF enabled developers to size the proposed systems to optimize the life-cycle economics.

The "low bid technically acceptable" evaluation process can be a successful method for selecting a project developer. The project team at Nellis AFB used this strategy to select its PV developer. Under this approach, a technical team not privy to the price of each bid evaluates each proposal for technical acceptability. Once the technical team had eliminated any unacceptable proposals from the competitive range, the winning proposal is chosen based on the lowest bid. This approach reduces the risk of selecting a poor-quality contractor and attaining the best price. Ultimately, the $100 million PV system at Nellis AFB required less than $100,000 to acquire.

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[33] United States Navy. "NAVFAC Southwest Solar Energy Contract Will Generate 40 Megawatts." March 2, 2010. http://www.navy.mil/search/display.asp?story_id=51636. Accessed May 17, 2011.

Nellis staff noted that clearly ranking proposals in order and documenting nonconforming proposals also provided support in the event of a protest.

Installations also should evaluate the proposals based on the life-cycle cost of the energy delivered and not just the price per kilowatt-hour of electricity. The cost-calculation method should be clearly defined in the RFP, and this calculation should reflect a base's utility bill as closely as possible by accounting for factors such as standby charges, tariffs, escalation rates, and demand reduction.

Signing indefinite-term renewable energy contracts with developers can reduce the project risk to the DoD. Nellis AFB, for example, has an indefinite-term contract with the project developer. This arrangement allows Nellis to cancel its power purchase from the developer with one-year notice. This contracting mechanism reduces the risk to the USAF. When coupled with a long land lease, the indefinite-term contract is not necessarily unacceptable for developers. Nellis AFB's 20-year land lease provides stability to developers because the developer can continue to operate the PV system and find other customers for the power even if the USAF cancels its contract. Because the financial incentives for the developer at Nellis AFB were significant, it might have enabled the developer to accept the indefinite-term contract. Other sites might not be able to find developers willing to agree to an indefinite term. This arrangement could be more an exception and not a rule.

Installations have reported varying results and preferences with utility energy service contracts and energy savings performance contracts. Some installations have developed a strong relationship with a utility and prefer to use a USEC. Other installations prefer the guarantee that an ESPC contract offers. In most cases, installations agree that the contractor-provided operations and maintenance services typical in a UESC or an ESPC help to ensure that the system will remain in proper working condition. When installations are required to maintain the system, in some cases the staff does not receive adequate training or funding to maintain the equipment properly. Likewise, high personnel turnover from site to site makes it difficult to perform proper routine maintenance.

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Appendix: Net Zero Energy Installation Case Studies

A.1. United States Air Force Academy

- Location: Colorado Springs, CO
- Size: 18,500 acres
- Population: 8,200
- Installation Details: Approximately 370 facilities (not including privatized housing), 6.8 million f^2 (dormitory = 28%, warehouses = 15%, hangars =2%, office = 11%, classroom = 28%, retail = 4% other = 11%)
- Average Energy Use Index (EUI): 169 kBtu/ft^2
- General Purpose of Installation: Cadet education, research, and flight training
- Baseline: The energy boundary baseline for the U.S. Air Force Academy (USAFA) is assumed to include all onsite buildings and fleet vehicles with the exception of the privatized housing, the preparatory school, and associated buildings.

Energy

Table A1. United States Air Force Academy 2009 Energy Use Baseline

	Site Energy (Variable Units)	Site Energy (MBtu)	Source Energy (MBtu)
Buildings and Facilities			
Electricity	99,900,717 kWh	340,861	986,452
Natural Gas	635,226 KCF	523,077	571,200
Propane	93,000 therms	8,882	9,699
Total Building Energy Use	—	872,820	1,567,351
Fleet Fuel			
Gasoline	71,460 gallons	8,146	9,670
Diesel	70,312 gallons	8,016	9,282
E85	16 gallons	2	2
Total Fleet Fuel Use	—	16,164	18,954
Total USAFA Energy Use	—	888,984	1,586,305

Greenhouse Gas

Based on the U.S. Air Force Academy's baseline electricity and fuel consumption, NREL developed an installation-wide greenhouse gas emissions baseline. This baseline includes select Scope 1, Scope 2, and Scope 3 GHG emission sources. The USAFA's baseline energy consumption results in 130,286 metric tons of carbon dioxide equivalent (MT CO_2e). Table A2 shows, the installation's emissions according to scope and emissions source. The majority (65%) of the Academy's GHG emissions arise from electricity consumption. The emissions from tactical jet fuel and aviation gas as well as on-site motor gas, diesel, and DSS-fuel consumption are included in the GHG baseline for informational purposes, and are shown in Table A2. These emissions, however, are not included in the net zero energy analysis. This “other” fuel consumption accounts for only 3% of the USAFA’s total GHG emissions.

Table A2. United States Air Force Academy 2009 Baseline Greenhouse Gas Emissions

Scope 1 Emissions	**(MT CO_2e)**
Stationary combustion (propane, natural gas)	37,597
Fleet fuel combustion	1,284
Other fuel combustion (JP8, aviation gas, DSS, non-fleet motor gas, diesel)*	2,736–4,085
Scope 2 Emissions	
Purchased electricity consumption	85,756
Scope 3 Emissions	
Transmission and distribution losses from purchased electricity	5,649
Total GHG emissions (not including fuel use)	130,286
Total GHG emissions (including all known sources)	133,022–134,371
* Please note that a range is given for the GHG emissions resulting from “other” fuel consumption due to uncertainty regarding the extent to which this fuel consumption includes fleet gasoline and diesel use.	

Project Overview

The U.S. Air Force Academy was selected by the DoD/DOE Net Zero Energy Assessment Task Force as the initial prototype USAF installation for a net zero energy assessment. The USAFA was selected based on its history of taking initiative on energy-management issues and because of the unique opportunity to educate the next generation of U.S. Air Force leadership on energy efficiency and renewable energy.

Although the Air Force Academy has the benefit of a good renewable energy resources and land available for RE projects, it also has very low utility-provided energy rates. The relatively low-cost energy plus a lack of sufficient financial incentives, make it challenging for RE projects to be life-cycle cost effective. Due to this challenging economic environment for RE technology, NREL approached this NZEI analysis from a technical rather than economic feasibility perspective. Additionally, NREL performed an analysis of non-renewable energy technologies that would result in reduced overall source energy use and GHG emissions for the Air Force Academy. The results provide the recommended combination of RE technologies that could technically achieve a net zero energy status at the lowest life-cycle cost, but which are not economically viable compared to current and project energy rates. The results also list a set of recommended economically viable energy projects that result in reduced source energy use and reduced GHG emissions.

Energy Efficiency Assessment

Buildings are responsible for the majority of the natural gas and electricity consumption at the USAFA. Additionally, several buildings in the Cadet Area are designated as National Historic Landmarks, which limits the scope of renovations that can be performed for energy-efficiency improvements. Over the course of the past few decades, the Academy has made dramatic improvements in its energy use index but—to meet the current mandate of a 30% reduction from the 2005 baseline by 2015—more aggressive measures are required.

Figure A1. Cadet Chapel—National Historic Landmark NREL/Pix 03824

Through discussion with base personnel, analysis of previous energy audits, and a comparative analysis using the Commercial Building Energy Consumption Survey (CBECS), NREL estimated the energy-efficiency savings potential of the base. Table A3 summarizes the potential energy savings at the USAFA, which totals a 25.2% electrical load reduction, a 17.1% natural gas load reduction, and a 19.1% overall energy reduction. The CBECS database was used to estimate end-use energy distribution for the most common building types at the USAFA. The estimated electrical and thermal energy savings were derived by comparing the current energy use index, in British thermal units, per square foot of USAFA building inventory to that of the average energy use index intensity for similar buildings in the same climate zone (using data from the CBECS database). Researchers carefully ensured that savings already identified in the two energy audit reports was not duplicated in this assessment.

Table A3. Energy Efficiency Savings Potential

Measure	Unit	Savings	% Fuel	MBtu Equivalent Savings	% Total Site Savings
2008 Commissary Audit	MWh	378	0.4%	2,637	0.3%
	MBtu	1,348	0.2%		
2009 Energy Assessment 1	MWh	10,027	10.1%	74,252	7.0%
	MBtu	40,030	5.7%		
CBECS Reduction	**Unit**	**Savings**	**% Fuel**	**MBtu Equivalent Savings**	**% Total Site Savings**
CBECS Reduction Potential 2	MWh	12,765	12.8%	123,102	11.8%
	MBtu	79,534	11.3%		
Totals	**Unit**	**Savings**	**% Fuel**	**MBtu Equivalent Savings**	**% Total Site Savings**
Total Site Potential	MWh	25,227	25.2%	199,991	19.1%
	MBtu	120,912	17.1%		

Renewable Energy Assessment

NREL evaluated the technical and economic performance of all of the commercially available RE technologies that were deemed compatible with the USAFA mission. The technologies evaluated included photovoltaics, wind, landfill gas, biomass, and combined heat and power opportunities (such as fuel cells plus microturbines, daylighting, solar thermal or concentrating solar power, solar hot water, solar pool heaters, solar vent preheating, and anaerobic digesters). The results of this evaluation were used as inputs for a financial spreadsheet used to determine the life-cycle cost of each technology and to calculate the economic figures of merit.

The projects already planned by the base are listed below and will continue to position the USAFA as an energy leader. These projects also will help the base meet its federal government and DoD energy mandates.

- Existing: 6 MW of ground-mounted PV
- Existing: 0.5 MW of rooftop-mounted PV
- Existing: 0.03-MW microturbine powered by methane from anaerobic digester
- Existing: 6 buildings using ground source heat pumps
- Planned: 0.1 MW of biomass combined heat and power

The results of the RE evaluation recommend the following additional technologies for the Air Force Academy to use to achieve net zero energy status at the lowest life-cycle cost.

- Photovoltaics: 2 MW roof mounted
- Ground Source Heat Pump: 3,359 tons
- Solar Water Heating collector area: 6,220 ft^2
- Solar Vent Preheat: 47,939 ft^2
- Biomass CHP: 8 MW (electric), 140 MBtu/hr (thermal)
- Small Wind Turbine: 0.2 MW

For the U.S. Air Force Academy to achieve a near net zero energy operating condition, the combination of recommended projects requires a capital investment of approximately $120 million. The net present value after 25 years, without federal tax rebates, is negative $151 million. The results from this analysis illustrate that if fossil energy prices rise as predicted, then the near net zero energy project recommendations would cost $150 million more than the cost of purchasing utility-provided electricity and natural gas.

Recommendations for Economically Feasible Energy Projects

NREL found that energy efficiency and natural gas–fired internal combustion CHP systems both are economically viable. To perform the technical and economic evaluation of the CHP system, a 5-MW system size was selected. Assuming a 19% energy savings from energy efficiency analysis and a 5-MW CHP system, it is projected that the USAFA would reduce site energy use from 2009 levels by 11%, its source energy use by 29%, and its GHG emissions by 36%. The system also would provide a source of dispatchable power to the microgrid and improve the energy surety of the mission-essential loads. Using a 25-year analysis period, an investment in these two projects would result in a net present value of $30 million.

Electrical Systems and Microgrid Assessment

NREL analyzed the high-level potential for the interconnection of renewable energy generation projects into the distribution system at the Academy. The proposed placement and interconnection of the recommended renewable energy systems was analyzed for conductor and protection device capacity. The Air Force Academy is served by the Colorado Springs Utility (CSU) and is interconnected to the CSU distribution system through two substations, the West Substation and the South Substation. The worst-case impact for the proposed distributed generation typically will result when maximum generation occurs while the load on the feeder is at its minimum load, resulting in export of generation. The minimum existing load on the substations is 5,903 kW and 4,189 kW. Therefore, to eliminate the possibility of exporting power to the CSU substations and to minimize impact on voltage regulation, the practical limits of distributed generation on the complete USAFA system would be slightly more than 10 MW. According to CSU, a split of up to 16 MW between systems is possible before more-detailed studies are required.

Transportation Assessment

The analysis evaluated options for reducing transportation energy use at the U.S. Air Force Academy. The resulting recommendations include right-sizing the fleet, switching to alternative-fuel vehicles, using hybrids and electric vehicles, and improving operating efficiencies.

Implementation Plan

The USAFA has many potential avenues available to implement energy projects. These include energy savings performance contracts, utility energy services contracts, power purchase agreements, energy joint ventures, and appropriated funds. There are many issues that must be considered when selecting an implementation option. Such issues include the National Environmental Policy Act (NEPA) review process, utility interconnection requirements, and the incentives available for renewable energy.

The USAFA showed great leadership and initiative by orchestrating a unique three-party arrangement with the local utility and an independent third-party developer to leverage $18.3 million of American Recovery and Reinvestment Act (ARRA) funding in the development of an on-site PV array. Through this agreement with the Colorado Springs Utility and a third-party developer-owner, the Academy was able to extend the buying power of the ARRA funds to purchase the electricity from a 6-MW PV array that is approximately three times the size of the array if it was purchased outright. If funds are available, this type of agreement is ideal for the development of additional PV arrays.

It is recommended that both of the projects deemed economically feasible—energy efficiency and a CHP system—be implemented through an ESPC. Although the CHP system is a good candidate for a private-ownership structure, it still could be implemented through an ESPC as an energy services agreement. This would allow the CHP system, with its shorter payback, to help the overall economics of the ESPC to cover the implementation and financing costs within the 25-year limit.

The NREL Super ESPC Financial Analysis Tool was used to provide an estimate of the payment schedule for an ESPC to include both recommended projects. Using this tool, a payment schedule was developed reflecting 23 years of payments to the ESCO. The total estimated cost savings were $84.6 million, the guaranteed cost savings were $80.4 million, and the total contractor payments were $79.1 million. The annual contractor payment varies from year to year, however the average payment over the 23-year contract lifetime was $3.44 million. The payments during the performance period include principle, interest, and performance-period expenses such as measurement and verification and operations and maintenance At the end of the ESPC term, the estimated utility cost savings are estimated to be $4.2 million per year.

Next Steps

The NZEI assessment for the USAFA represents a high-level analysis of the opportunity for the base to work toward becoming a net zero energy installation. Based on this assessment, it is hoped that the Academy will move forward with energy projects, and NREL will provide ongoing implementation support as funding is available. Additionally, NREL will be working to support the planning and design of a microgrid on base.

Lessons Learned

Electric Grid Ownership

The U.S. Air Force Academy is undergoing a utility privatization effort to free itself from the burden of upgrading and maintaining its aging utility grid. As a result, the Academy will give up control of the infrastructure that ultimately will be required to manage the proposed network of distributed energy generation and storage assets on the site. In the case of a utility outage, this will make it more difficult for the academy to wheel power from these distributed sources to the critical loads and thus maintain operations. Conversely, it can be an argued that the improved utility network, as a result of the UP effort, will provide more energy security than the existing antiquated network. In this particular case the local utility has expressed interest in exploring smart grid and microgrid options, which could provide the USAFA with the unique benefit of maintaining some control of the distribution system but releasing ownership and responsibility to the utility. As other military bases pursue the privatization of their aging utility infrastructures, it will be important to address the issue of controlling energy assets within the boundaries of their operations.

Building Renovation Restrictions

The designation of several buildings on the USAFA campus as National Historic Landmarks limits how these buildings can be renovated. Typically, the most cost-effective energy projects involve building energy-efficiency upgrades. Restrictions on modifying buildings, however, limit the energy efficiency and renewable energy opportunities, and oftentimes make them too costly to implement. Although the architecture in the Cadet Area is striking, it was not designed with energy efficiency in mind. As a result, the Academy suffers from relatively high energy use intensities. Additionally, updated design and construction techniques are two important factors impacting building energy use, but the Academy's historical significance mandates that all new buildings developed in the Cadet Area be designed in a manner consistent with the existing—inefficient—buildings. This makes it more difficult for the new buildings at the academy to achieve the performance of today's most energy-efficient buildings. It is important to understand the impacts of restrictions on building renovations and to pay special attention to life-cycle cost of buildings at the early stages of the design.

Energy Use Data

The USAFA does not have submeters at its buildings and, as a result, the energy use for most buildings was estimated by USAFA's Energy Manager based on aggregated site data. This makes it very difficult to identify and quantify energy-efficiency opportunities with enough confidence to warrant investment.

A.2. Fort Carson

- Location: Colorado Springs, CO
- Size: 137,403 acres
- Population: 69,000
- Installation Details: Approximately 800 facilities, 14.63 million ft^2 (privatized housing = 30%; barracks = 29%; office and HQ = 23.7%, hospital = 4.6%; retail and commissary = 2.7%; other = 10%),
- General Purpose of Installation: Train, mobilize, deploy, and sustain combat- ready forces.
- Financial Summary: The simple payback for this project is 35 years. The project requires a capital investment of $842 million. The net present value after 40 years, without federal tax rebates, is $99 million.
- Baseline: NREL determined an energy boundary for Fort Carson's baseline that includes all buildings, facilities, and fleet vehicles on the main base (cantonment, training, and range). The Turkey Creek Recreation Area and Pinon Canyon Maneuver Site are not included.

Energy

The total baseline energy usage at Fort Carson is 2.6 million source MBtu, shown in Table A4 (60% electricity, 39% natural gas, 1% fleet).

Table A4. Fort Carson Energy Baseline

Energy Source	2009 Energy Use		
	Site Energy (Variable Units)	**Site Energy (MBtu)**	**Source Energy (MBtu)**
Buildings and Facilities			
Electricity	164,406,919 kWh	560,956	1,569,556
Natural Gas	1,137,540 KCF	927,095	1,012,388
Total Building Energy Use	—	1,488,052	2,581,944
Fleet Fuel			
Gasoline	77,799 gallons	8,558	10,158
Diesel	53,051 gallons	7,321	8,478
E85	126,152 gallons	11,089	13,163
Compressed Natural Gas	19,497 gallons	2,435	2,659
Total Fleet Fuel Use	—	29,403	34,458
Totals			
Total Energy Use	—	1,517,455	2,616,402

Greenhouse Gas

A greenhouse gas inventory was not included in the budget for the net zero energy assessment at Fort Carson.

Project Overview

The DoD's U.S. Northern Command (USNORTHCOM) partnered with NREL to assess opportunities for increasing energy security through renewable energy and energy efficiency at Front Range installations. Fort Carson was selected by USNORTHCOM to be the prototype installation for net zero energy assessment and planning. Fort Carson was selected based on its history of energy advocacy and track record of successful energy projects.

The assessment conducted by NREL shows that Fort Carson has the potential to make significant progress toward becoming a net zero energy installation. If the recommended energy projects and savings measures are implemented, then a 92% site Btu reduction and a 95% source Btu reduction will be achieved by the base. By achieving this status, the base will set an example for other military installations, provide environmental benefits, reduce costs, increase energy security, and exceed its goals and mandates.

Energy Efficiency Assessment

Through discussion with base personnel, assessment of a previous energy audits, and modeling of typical buildings, NREL estimated energy efficiency savings potential. Table A5 summarizes the potential energy savings at Fort Carson totaling 26.7% electrical load reduction, 17.2% natural gas load reduction, and 20.3% overall energy reduction.

Table A5. Energy Efficiency Savings Potential

Measure	Units	Savings (Percent of Fuel Type)		MBtu Equivalent Savings	Percent Total Site Savings
DHW Boiler Replacement	MWh	—	—	—	—
	MBtu	10,704	0.9%	10,704	0.6%
2009 Energy Assessment Measures	MWh	3,378	2.1%	11,529	0.7%
	MBtu	39,743	3.5%	39,743	2.3%
Privatized Housing	MWh	5,020	3.1%	17,133	1.0%
	MBtu	102,115	9.0%	102,115	6.0%
Central Heating Plants	MWh	—	—	—	—
	MBtu	43,225	3.8%	43,225	2.5%
Specific Main Base Facilities					
Retail (28% reduction)	MWh	371	0.2%	1,266	0.1%
Barracks (16% reduction)	MWh	5,955	3.6%	20,324	1.2%
Hospital (38% reduction)	MWh	6,420	3.9%	21,911	1.3%
Commissary (31% reduction)	MWh	1,439	0.9%	4,911	0.3%
Headquarters (35% reduction)	MWh	1,710	1.0%	5,836	0.3%
Office (35% reduction)	MWh	1,311	0.8%	4,474	0.3%
Other (29% reduction)	MWh	3,671	2.2%	1,529	0.7%

Base-Wide Energy Conservation Measures					
Retro-Commissioning	MWh	8,220	5.0%	28,055	1.7%
Vending Machine Miser	MWh	147	0.1%	501	0.0%
Delamp Vending Machines	MWh	46	0.0%	157	0.0%
Computer Energy Mgmt	MWh	3,957	2.4%	13,505	0.8%
Occupancy Sensors	MWh	2,173	1.3%	7,416	0.4%
Total					
Electricity	MWh	43,818	26.7%	149,550	8.8%
Natural Gas	MBtu	195,787	17.2%	195,787	11.5%
Total MBtu				345,337	20.3%

Renewable Energy Assessment

After assessing energy-use reduction opportunities, NREL evaluated the potential for renewable energy generation to meet the remaining energy needs at Fort Carson. Table A6 summarizes the renewable energy technologies analyzed, including size, potential energy savings, and simple payback period.

Table A6. Renewable Energy Technologies: Potential Energy Savings and Payback Period

Technology	Evaluated Size	Potential Site Energy Savings (MBtu)	Potential Source Energy Savings (MBtu)	Simple Payback Period (Years)
Solar Ventilation Preheating	88,050 ft^2	26,353	28,777	15
Wind	10.5 MW	61,304	171,528	16
Photovoltaics	42.43 MW	216,178	604,865	26–46**
Biomass Heat Only	30 MBtu/hr	160,000	174,720	29
Solar Water Heating	43,441 ft^2	20,887	22,809	30
Concentrating Solar Power	10 MW	81,888	229,123	42
Fuel Cell	1400 kW	-8,000	45,856	43
Ground Source Heat Pump	18,150 tons	378,391	178,463	57
Daylighting	770,000 ft^2	35,053	38,278	147
Biomass Combined Heat & Power	5 MW thermal, 7 MW electrical	283,771	452,792	Negative*
Microturbine	60 kW	-1,428	389	Negative*
Waste-to-Energy	670 kW	15,333	42,902	Negative*
Landfill Gas	0	0	0	N/A
Anaerobic Digestion	0	0	0	N/A
Hydro Power	0	0	0	N/A

* The cost of the fuel for the biomass combined heat and power plant and microturbines, plus the high O&M cost of the waste to energy, exceed the value of the energy savings.
** The payback on photovoltaics assumes an outright purchase. Fort Carson previously implemented a PV PPA that was roughly equivalent to current electric rates because of favorable REC prices.

This assessment shows that renewables currently have long payback periods at Fort Carson due to the low cost of fossil-fuel energy. Solar ventilation preheating, biomass, and solar water heating are the most cost-effective heating technologies. Wind and photovoltaics are the most cost-effective electric technologies. Projected increases in energy prices could improve the economics of renewable projects.

Microgrid Assessment

In this assessment, NREL optimized the size of each technology to find the most cost-effective solution to meet critical loads of 3 MW to 4 MW in an islanded microgrid scenario (that is, having no grid connection). This scenario looked at traditional diesel generation and battery storage in addition to PV, wind, and biomass. An analysis found the optimal solution to be a combination of 3.1 MW of biomass, 1 MW of diesel generation, and 500 kW of PV (see Table A7). The COE for this solution is $0.17/kWh, compared to a diesel-only COE of $0.250/kWh. Diesel fuel use decreases 93% from the diesel-only solution.

Table A7. Energy Mix Recommended to Meet the Critical Load for a Microgrid System

Component	Size (MW)	Production (kWh/yr)	Production
Biomass	3.1	23,349,642	91%
Diesel Generator	1.0	1,552,869	6%
PV Array	0.5	778,655	3%
Total	—	25,681,166	100%

In a microgrid, the load and generation must match exactly at all times, so consistent base load sources of power such has biomass, concentrating solar power, or diesel are preferred over more variable generation sources like photovoltaics and wind. The Fort Carson microgrid modeled here relies mainly on biomass as the least-expensive source of base-load power, and would require a large supply of off-site biomass. To reduce reliance on outside fuel sources, such as biomass and diesel, concentrating solar power with thermal energy storage also could provide consistent base-load power at a cost of $0.21/kWh. Forty acres of land near the microgrid area are required for this system.

Transportation Assessment

The opportunity for transportation fuel savings was evaluated for Fort Carson. Fort Carson has done an excellent job of incorporating alternative fuel vehicles (AFV); approximately 50% of the fleet now is composed of AFVs. There is, however, opportunity for additional transportation energy savings. Of the Fort Carson fleet, 50% is fueled by traditional gasoline or diesel and consumes an estimated 130,000 gallons of petroleum annually. If half of the gasoline vehicles were replaced by E85 flexible fuel vehicles (FFV) and are fueled consistently with E85, then nearly 40,000 gallons of gasoline consumption could be eliminated. If biodiesel was used consistently in the diesel vehicle fleet, another 10,000 gallons of petroleum could be displaced.

Additionally, it is recommended that Fort Carson institute a system to track fleet fuel use, reduce the total number of vehicles in the fleet, use only E85 in FFVs, consider a biodiesel program for diesel vehicles, and consider hybrid and electric vehicles when other AFV technologies are not available to meet the mission. Also recommend is examining fuel-savings opportunities for tactical and commuter fuel use. Tactical and commuter fuel comprise 97% of the transportation energy used at Fort Carson—dwarfing federal fleet fuel use. If commuter fuel use was reduced by 5%, the resultant 350,000 gallons of petroleum displaced would more than exceed the fuel used by the fleet.

Recommendations and Financial Analysis

NREL proposed energy projects to help Fort Carson approach net zero energy. Figure A2 shows the mix of renewables recommended to reach near net zero energy by 2015. Implementation of these projects would provide 100% of electrical energy, 88% of thermal energy, and 57% of transportation energy from renewable sources.

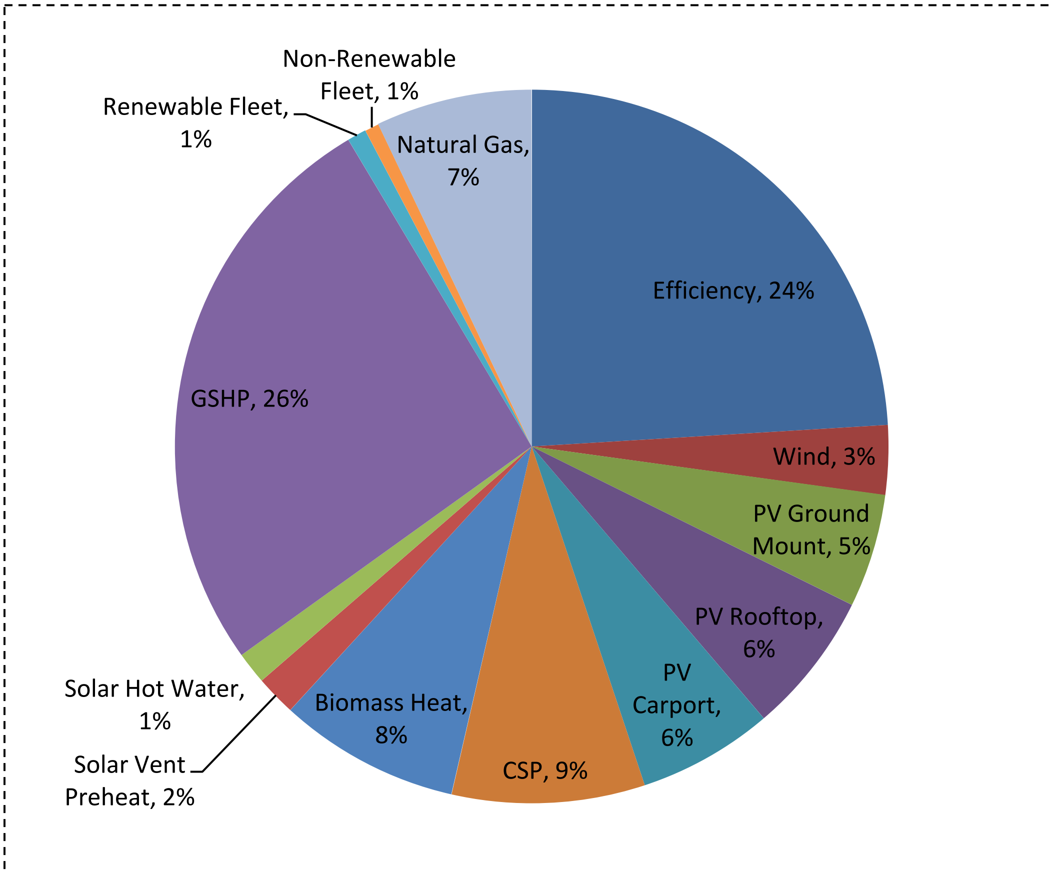


Figure A2. Energy sources to meet 2015 energy needs

The simple payback for this project is 35 years. The project requires a capital investment of $842 million. The net present value after 40 years, without federal tax rebates, is $96 million. The results from this assessment illustrate that if fossil-fuel energy prices rise as predicted, then the near net zero energy project recommendations likely are viable over a 40-year project lifetime and would provide reduced energy costs to the base. This assessment is greatly dependent on future fossil-fuel energy prices, however. If energy prices increase at a lesser rate than predicted, net present value could become negative. (For the Fort Carson financial assessment, NREL used the utility's predicted rates for the next 5 years, and then the National Institute of Standards and Technology's standard escalation rates for the remaining 15 years of the 20-year analysis period.)

Implementation

Fort Carson has several implementation options for energy projects, including energy savings performance contracts, utility energy services contracts, power purchase agreements, energy joint ventures, and appropriated funds. Government-owned projects funded through appropriations reduce contractor financing and markup fees, but require up-front capital and prevent Fort Carson from receiving federal tax incentives. Such projects also place the O&M burden on Fort Carson. Privately owned projects allow Fort Carson to implement renewables without investing any up-front capital and with reduced O&M responsibility. This also allows Fort Carson to take advantage of federal tax credits, although the money gained in tax credits could go toward contractor financing and markup fees.

Next Steps

The NREL NZEI assessment for Fort Carson represents a high-level analysis of the opportunity for the base to work toward becoming a net zero energy installation. Based on this assessment Fort Carson is moving forward with energy projects and NREL is providing ongoing implementation support.

- Fort Carson and NREL are studying the integration of electric vehicles into Fort Carson's distribution system. They are comparing building energy requirements to energy-generation potential from solar parking canopies and evaluating how electric vehicles can provide storage to smooth variable PV generation. This study will result in an RFP to build the system modeled.
- The U.S. Army Corps of Engineers is working to integrate green building design strategies into its new buildings and using construction cost savings for rooftop PV systems.
- The DoD is planning to demonstrate a microgrid at Fort Carson in FY2012, through the Smart Power Infrastructure Demonstration for Energy Reliability and Security (SPIDERS) Joint Capability Technology Demonstration (JCTD). The microgrid will incorporate large-scale renewables, electric vehicles, and smart microgrid controls.
- The U.S. Army selected Fort Carson to be a Net Zero Energy Installation pilot site for net zero energy, water, and waste by 2020.

Lessons Learned

Data Availability

The data available affects the level of analysis that NREL can perform. Lack of individual building data and electrical one-line diagrams for Fort Carson prevented a detailed electrical analysis of renewable interconnection points and their effects on the distribution system. Lack of transportation fuel-use data and hourly energy-use data required NREL to make assumptions that could reduce the accuracy of the assessment. The project lead must adapt the analysis to the level of data that is available, documenting any assumptions made as is necessary.

Future Energy Prices:

Future utility energy prices have a huge affect on the economics of renewable projects. At current energy prices, few renewable projects are cost-effective for Fort Carson. At predicted increased future prices, however, a near net zero energy solution was cost-effective. The project lead needs to consider potential energy price increases in the financial assessment.

Site Interests and Goals

Often a net zero energy assessment is requested by a higher organization (i.e., DoD) rather than the individual site. The assessment, however, requires significant time on the part of site personnel to gather data, provide input on current and potential energy efficiency and renewable projects, host site visits, and review reports. It is important to understand the interests of the site and try to incorporate these into the net zero energy assessment as is possible. If the site has particular interest in a certain renewable technology, for example, then the consultant might do a more detailed assessment of that technology as part of the overall assessment.

New Building Design

Fort Carson's population is growing by 36% over the next 5 years, and many new buildings are under construction to accommodate the additional personnel. Although new buildings must meet LEED Silver standards, Fort Carson energy managers find that these new buildings are equally energy intensive as older buildings because of added air conditioning and plug loads. As a result, designers should consider using a more stringent energy design criteria beyond the more general LEED system. Incorporating energy efficiency into initial building design is the most cost-effective means to reduce energy use at Fort Carson, and increased energy savings should be a priority for new buildings.

Identifying Decision Makers

At Fort Carson, new buildings are designed at the central U.S. Army Corps of Engineers office in Omaha, Nebraska. Fort Carson has little control over the building design—which will have a huge impact on future energy use. Understanding who has decision authority to implement energy requirements, authorize payment of higher rates for renewable energy, or allocate land to renewable projects can help NREL target the people with the ability to implement the recommendations.

A.3. Marine Corps Air Station Miramar

The complete report, entitled "Targeting Net Zero Energy at Marine Corps Air Station Miramar: Assessment and Recommendations," is available online at http://www.nrel.gov/docs/fy11osti/47991.pdf (accessed May 18, 2011).

- Location: 15 miles north of San Diego, CA
- Size: 23,000 acres
- Population: 15,000
- Installation Details: 800 facilities, 6.1 million ft^2 (housing = 19%, warehouses = 18%, hangars =12%, office = 9%, other = 42%)
- Average EUI: 55 $kBtu/ft^2$
- General Purpose of Installation: Flight operations and training
- Financial Assessment: Estimated $26 million savings over a 20-year lifetime and a net present value of $6.7 million.

- Baseline: NREL determined an energy boundary for Miramar's baseline that includes all onsite buildings plus facilities (Main Base, Brig, Privatized Housing, Commissary), and fleet vehicles.

Energy

The total baseline energy usage at Miramar is approximately 870 billion source Btu (80.7% electricity, 16.5% natural gas, 2.8% fleet) (*see* Table A8).

Table A8. Baseline Annual Energy Usage Information

Electricity (kWh)	66,543,615
Natural Gas (MBtu)	131,615
Fuel (gallons)	
Gasoline	89,500
Diesel	10,000
Biodiesel	31,000
Compressed Natural Gas	45,000

Greenhouse Gas

A greenhouse gas inventory was calculated for Miramar for Scope 1 and Scope 2 emissions. All of the energy uses included in the baseline was put into the GHG calculations. Miramar's GHG emissions baseline was approximately 30,183 tons of carbon dioxide (CO_2) per year.

Project Overview

The Miramar site was selected by the DoD/DOE Net Zero Energy Analysis Task Force as the initial prototype installation in the net zero energy analysis of all the services. Miramar was selected based on its history of energy advocacy and its track record of successful energy projects. The analysis conducted by NREL indicates that Miramar has the potential to make significant progress toward becoming a net zero energy installation for its facilities and buildings. If the recommended energy projects and savings measures are implemented, then a 90% source Btu reduction will be achieved by Miramar. Net zero energy status is within reach if Miramar implements the recommended measures, replaces all remaining natural gas with biogas, and completely switches the government transport fleet to renewable fuels or to electric vehicles as these become more widely available. By achieving net zero energy status, the base will set an example for other military installations, increase mission capabilities, provide environmental benefits, reduce costs, increase energy security, and exceed its goals and the DoD mandates.

Energy Efficiency Assessment

Buildings are responsible for the majority of the natural gas and electrical energy consumption at Miramar. Building energy efficiency was assessed for Miramar facilities to determine the potential for additional energy efficiency investment. The energy use index for Miramar was calculated as 55 kBtu/ft^2 This EUI value is quite low as compared to other buildings, and indicates that the base already is managing energy use quite well. The base already has undertaken numerous energy-efficiency projects. Miramar has daylighting (see figure A3) and lighting controls installed in some of the warehouses and hangars, it has executed an energy savings performance contract, and it has enacted significant water-conservation measures.

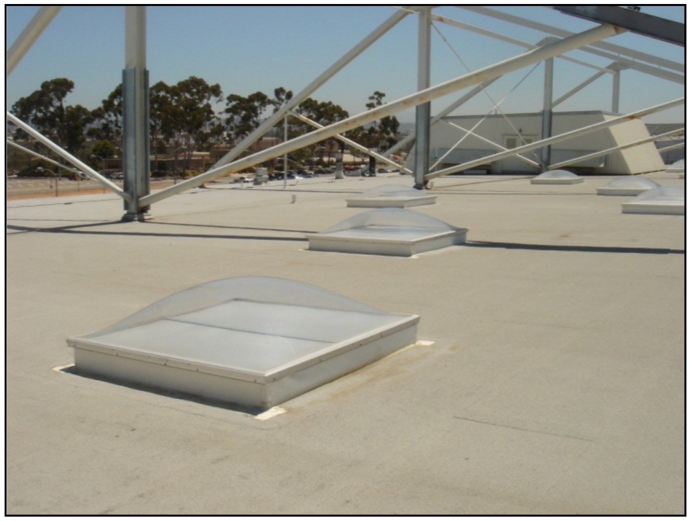


Figure A3. Daylighting on a hangar at Miramar

Despite the base's already low EUI and past energy-efficiency investments, NREL determined that there still was potential for the buildings at Miramar to become even more energy efficient in a cost-effective manner. It was beyond the scope of the project, however, to conduct detailed energy audits of the approximately 800 facilities at Miramar. Through discussion with base personnel, analysis of a previous ESPC proposal, and walkthroughs of several facilities, however, the savings potential for energy efficiency improvements at Miramar were estimated for numerous energy conservation measures, such as lighting retrofits, building commissioning, and boiler replacement. NREL analyzed the projects planned by the base as well as the potential for additional projects.

- Total electrical reduction = 10,676 MWh or 16.0% load reduction
- Total natural gas reduction = 14,104 site MBtu or 10.7% load reduction
- Total Btu reduction = 13.3% reduction

Renewable Energy Assessment

The NREL team conducted an initial assessment of the renewable energy opportunities for Miramar based on high-level energy, building, and resource data using NREL's Renewable Energy Optimization software tool. The initial screening evaluated technologies including: photovoltaics, wind, landfill gas, biomass, combined heat and power opportunities (such as fuel cells and microturbines), daylighting, solar thermal or concentrating solar power, solar hot water, solar pool heaters, solar vent preheating, and anaerobic digesters. NREL analyzed the projects already planned by the base as well as the base's potential for additional projects.

The projects already planned by the base are listed below and will continue to position Miramar as an energy leader. These projects also will help the base meet its federal government and DoD energy mandates.

- Purchase 3 MW of electricity from landfill gas-generation project
- Install solar hot water systems on several buildings
- Install 2.3 MW of PV on building rooftops and carports across the base
- Install 100-kW CSP system consisting of four 25-kW sterling dishes
- Install approximately 600 solar-powered street lights across the base

NREL proposed additional projects that will help Miramar progress toward NZEI status cost effectively, and which will continue providing environmental benefits and increased energy security.

- Install solar hot water systems on additional buildings
- Install solar pool heating systems
- Install 2.2 MW of PV on additional buildings and carports
- Implement a PPA to allow for the installation of two 1.4-MW CHP fuel cells
- Install daylighting systems on additional buildings
- Install microturbines to provide CHP in several buildings

Electrical Systems and Microgrid Assessment

NREL analyzed the high-level potential for the interconnection of renewable energy generation projects into the Miramar distribution system. The proposed placement and interconnection of the recommended renewable energy systems was analyzed for conductor and protection device capacity. The relatively robust primary electrical distributions system at Miramar would allow the proposed projects to be tied into the distribution system anywhere on the primary feeders without requiring significant upgrades to the base distribution system. NREL simulated various configurations for distributed-energy resources. Simulations covered hour-by-hour performance of the planned and proposed renewable energy generation systems and the coincidence between renewable energy generation and the hourly load profile at Miramar. The worst case scenario was reviewed for the minimum load and the maximum distributed generation on a given feeder. All feeders proved to be capable of handling the excess DG, including both main feeders from the utility. Additionally, the net zero energy assessment included analysis of a microgrid with DG sources able to continue critical base operations despite any disruption to the electrical grid. Implementing a microgrid with renewable energy, storage, and generators ensures the base's ability to continue critical operations during an extended emergency.

Transportation Assessment

The opportunity for transportation fuel savings was evaluated at Miramar. Miramar currently uses compressed natural gas (CNG) and biodiesel as alternative fuels for fleet vehicles onsite. Soon E85 (a fuel blend that is 85% ethanol and 15% gasoline) will be available near the base. Miramar can utilize E85 fuel in its numerous E85-compatible fleet vehicles to reduce gasoline consumption. Additionally, Miramar should explore the potential to adopt and use more neighborhood electric vehicles and use vehicle pooling to reduce the total fleet size.

Implementation Plan

Miramar has many potential avenues available for the implementation of energy projects. These include energy savings performance contracts, utility energy service contracts, renewable power purchase agreements, energy joint ventures, and appropriated funds. There are many issues that must be considered when selecting an implementation option, including the National Environmental Policy Act review process, utility interconnection requirements, and the incentives available for renewable energy. The projects currently planned by Miramar are exclusively appropriations funded with the exception of the landfill gas project, which is a PPA for electrical energy. The total NZEI source Btu reduction for the planned Miramar projects is 36%.

NREL proposed using private financing for the projects that aren't currently planned. Third-party private financing will not require up-front capital from Miramar. The fuel-cell project would be structured as a PPA that includes purchased electrical energy and no-cost thermal energy. Electrical and natural gas energy efficiency, solar hot water, daylighting, solar pool heaters, and microturbines all would be built into a single ESPC contract. Implementation of these additional energy projects along with the Miramar proposed projects would result in a 90% NZEI source Btu reduction. A breakdown of the final Btu energy mix is provided in Figure A4.

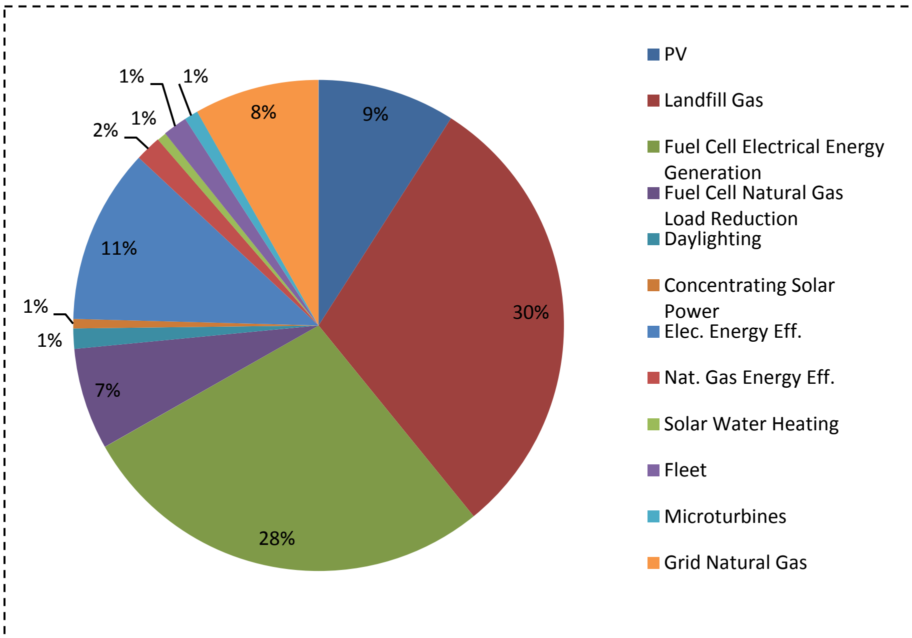


Figure A4. Final source Btu generation/reduction mix by energy-system type

Financial Assessment

A basic financial analysis of the recommended solution to approach net zero energy was conducted, and NREL projected the future energy costs for Miramar. These estimated future costs for the base-case scenario were compared to the costs of implementing the planned and recommended projects. The results from this analysis illustrate that this set of energy-project recommendations is likely viable under a 20-year project lifetime and would provide reduced energy costs to the base. Over the 20-year lifetime that was analyzed, the savings are $26 million and the net present value is $6.7 million. This analysis is sensitive to many estimated factors, such as inflation rate, energy price escalation rates, and natural gas prices. These factors can substantially affect the estimated cost savings, as well as the net present value (NPV), both positively and negatively. This financial analysis, however, shows that under a variety of scenarios the recommended energy projects enable the base to move closer to NZEI status and will reduce its energy costs.

Next Steps

NREL's NZEI assessment for Miramar represents a high-level analysis of the opportunity for the base to work toward becoming a net zero energy installation. Based on this assessment, the base is moving forward with energy projects and NREL is providing ongoing implementation support. Several of the ongoing efforts are listed below.

- The base is conducting a study with its utility provider (NAVFAC) to further determine the electrical requirements, opportunities, and issues with the installation of large-scale renewable energy projects on the base.
- NREL will support the planning and design of a microgrid on base.
- The base is finalizing negotiations for a PPA agreement to purchase power from the energy-generation project installed at the base landfill.

Lessons Learned

Data Can Be Very Difficult to Obtain

Data regarding energy consumption, electrical systems, transportation fuel consumption, and other information related to NZEI assessment often resides with many different organizations and in many different places. It can be difficult to obtain information from organizations with limited project interest and support, and from those that have different chains of command. Data might not always be available and might not always overlap precisely in terms of the detail, time frame, and level of data available. The project lead must be flexible and make judgment calls relative to aggregation of data into a single energy baseline for an installation.

Be Open to All Technologies

It is important to consider all potential technologies for an installation—such as fuel cells, microturbines, and solar pool heaters—and not just more common renewables, such as photovoltaics and wind. For Miramar, common renewable energy projects like biomass, CSP, and wind were not possible. Initially the only possible large-scale energy project seemed to be photovoltaics, which was cost prohibitive and unlikely to have been implemented. By looking to fuel cells as an energy project option, NREL was able to recommend a project that was both renewable and financially viable.

Net Zero Energy Is Not Always the Goal, It Is an Approach

The ability for a military installation to become a net zero energy installation depends on many factors, and might not be practically achievable. An NZEI assessment should focus on developing an optimal energy strategy that incorporates competing interests such as costs, mandates, and energy security. For the present project, the optimal energy strategy was not to recommend that the base become entirely a net zero energy installation. This largely is because it was cost-prohibitive to remove natural gas–fueled building systems that were relatively new and functioning properly and replace them with electrical systems powered by renewable energy.

The Goal of the Assessment Is to Inform and Encourage Implementation

The ultimate goal of any energy project assessment is to provide information essential to the successful implementation of energy savings and renewable energy projects. Assessments should focus on realistic projects that have a high probability of implementation. Recommending 20 MW of PV projects, for example, would have made Miramar a net zero energy installation. The chance of successful implementation of such a great amount of photovoltaics, however, was remote. It therefore was better to recommend other projects that would have a higher probability of implementation.

A.4. Marine Forces Reserve Center

- Location: New Orleans, LA
- Size: 29 acres
- Population: 3,375 (anticipated)
- Installation Details: 5 buildings, 620,000 sq. ft., (97% mixed-use office space, classrooms, and barracks; 1% data center; 1% warehouse; and 1% residential)
- Average EUI: 67.5 MBtu/ft^2/yr
- General Purpose of Installation: Headquarters for all Marine reserve units located throughout the United States
- Baseline: The baseline includes energy consumption and GHG emissions from five buildings:
    - The Marine Forces Reserve (MARFORRES) Headquarters (HQ) building (400,000 ft^2 office space, classrooms, and data center);
    - H-100 (208,000 ft^2 office space and barracks);
    - H-101 (5,000 ft^2 warehouse);
    - H-102 (central plant supplying chilled water, steam, and hot water to H-100); and
    - Quarters A (6,500 ft^2 historic residence).

Energy

The total baseline energy usage is shown in Table A9.

Table A9. Baseline Annual Energy Usage Information

Electricity (kWh)	9,627,621
Natural Gas (MBtu)	8,871
Fuel (gallons)	Unknown
Gasoline	Unknown
Diesel	Unknown
Biodiesel	Unknown
Compressed Natural Gas	Unknown

Greenhouse Gas Emissions

A Scope 1 and Scope 2 greenhouse gas baseline was calculated for the MARFORRES Center. The greenhouse gas baseline for this site is approximately 5,032 MT CO_2e and includes the energy uses described above.

Project Overview

In 2009, the U.S. Department of Energy's Federal Energy Management Program (FEMP) launched its Climate Neutral Communities Initiative (CNCI); its purpose is to assist federal agencies in determining cost-effective greenhouse-gas emissions abatement options. The CNCI is intended to provide case studies and methodologies aimed at helping federal agencies meet the E.O. 13514 GHG-reduction targets and ultimately to achieve carbon neutrality. The analysis of the MARFORRES Center in New Orleans, Louisiana, represents one of two pilot case studies completed for FEMP's CNCI (the other location is Pacific Northwest National Laboratory). The National Renewable Energy Laboratory conducted this study using funds from the American Recovery and Reinvestment Act.

Located at the Naval Support Facility in New Orleans, Louisiana, the MARFORRES Center is a 29-acre secure compound composed of four buildings (the Herbert buildings: H-100, H-101, and H-102) and one new headquarters building. The headquarters building was under construction at the time of the assessment, but is now open.(*see* Figure A5). The State of Louisiana is funding the construction of the HQ building to incentivize MARFORRES' continued presence in New Orleans after the Base Closure and Realignment Commission closes the existing MARFORRES facility on the east bank of the Mississippi River. After construction is complete, the U.S. Marines will take ownership of the new facility and move to the 29-acre secure compound. Upon this transition, MARFORRES also will become the first tenants of Federal City New Orleans, a development project that seeks to create a new national model for small to mid-sized DoD and other federal installations. Federal City New Orleans is envisioned to provide a campus-type environment for federal, private sector, and residential tenants and to incorporate green design and sustainable development.

Figure A5. The 400,000 ft^2 MARFORRES HQ building (photo taken April 12, 2010)

The MARFORRES Center climate neutrality study includes all four buildings within the 29-acre secure compound, as well as a nearby historic plantation home (Quarters A, which houses the commanding officer). The three existing buildings in the secure compound as well as Quarters A currently are under U.S. Navy operation and ownership; however, MARFORRES anticipates possibly taking control of these buildings in the future. Once construction is complete, MARFORRES will take ownership of the HQ building. The state of Louisiana is funding the construction of the HQ facility, therefore no alterations to the building design can be made prior to MARFORRES' occupancy of the building. This climate neutrality assessment therefore provides recommendations for upgrades and improvements to be implemented after the U.S. Marines have taken ownership of the building.

In general, the climate neutrality study of the MARFORRES Center uses the net zero energy installation (NZEI) approach to determining baseline energy consumption and options for energy savings. Additionally, this study applies the principles of GHG accounting and reporting to determine the emissions baseline and potential reductions. Because the HQ building was under construction at the time of the assessment and MARFORRES does not yet occupy the secure compound, limited data was available to develop an energy and GHG emissions baseline. No fleet data was available at the time of this study, nor were the utility bills for the HQ and existing buildings. Thus, design documents were used to develop energy models of the HQ and three existing buildings. These energy models provided baseline energy consumption from these facilities. Utility bills were available to develop the baseline for Quarters A. Based on these baselines, recommendations for energy conservation measures, renewable energy deployment, and associated greenhouse gas emissions were developed for all buildings on the site. Additionally, a net zero energy and climate neutrality assessment of the HQ building critical loads and backup power systems was performed. The assessment helps all involved parties to understand the impact of the proposed energy projects on enabling a microgrid in the event of an interruption of the utility grid. The results of these studies are summarized below.

Energy Efficiency Assessment

A total of 34 energy conservation measures (ECMs) were identified for all buildings at the site. These ECMs ranged from installing occupancy controls for lighting and ventilation to replacing the nine packaged rooftop cooling units on the HQ building with water-cooled condensers that draw cool water from the Mississippi River. If MARFORRES implements all possible ECMs, then a site-wide energy reduction of 17% and GHG emissions reduction of 19% could be realized (*see* Table A10). The payback period for these retrofits ranges between 6 and 38 years, depending on the building.

Table A10. Impact of Energy Conservation Measures on Greenhouse Gas Emissions

Building	Baseline Energy Consumption (MBtu)	Energy Consumption After Energy Conservation Measures Implementation (MBtu)	Percent Energy Reduction	Percent GHG Reduction	Payback Period (years)
Headquarters	21,560	19,459	10%	10%	35.5
H-100 and H-102	19,011	14,129	26%	33%	38
H-101	247	246	0.4%	42%	25
Quarters A	172	116	33%	12%	6
MARFORRES Site Total	40,990	33,950	17 %	19%	—

Renewable Energy Assessment

After all of the potential energy efficiencies had been identified, an analysis of the renewable energy options at the site was performed. The objective of the analysis was to make the HQ building a net zero energy building. The HQ building was the focus of this analysis because it is the site's largest energy consumer, and it is the only on-site building that the U.S. Marines currently control.

The assessment indicated that the MARFORRES New Orleans HQ building can be a net zero–energy building by using a combination of solar PV and fuel cell technology. Wind, biomass, and concentrated solar power also were considered but were not recommended, due to the limited resource availability in New Orleans. Solar PV and fuel cells could supply 23% and 67%, respectively, of the HQ building's energy demand, resulting in its requiring only 10% grid-purchased electricity. Enough excess energy could be produced on-site and sold back to the utility annually to make the HQ building a net zero energy building. In this scenario, the levelized cost of energy (LCOE) increases by 80% from \$0.09/kWh to \$0.162/kWh. The energy produced using the solar PV system is considered climate neutral. For the entire building to reach climate neutrality and net zero energy status, however, renewably produced biogas is required to power the fuel cell. Additionally, waste heat from the fuel cells can be used to meet the heat load of the building and drive an absorption or adsorption chiller system to help meet the cooling load.

Microgrid Assessment

Lastly, an analysis was performed to determine whether—in the event of a utility grid failure—the runtime of the critical load backup power could be extended using renewable sources. For the MARFORRES Center, the critical load includes only the electricity required to support the 24/7 operation of a command center located in the top two floors of the HQ building. The U.S. Marines have purchased two 1,250-kW diesel generators, capable of supplying a critical load for four days. The microgrid analysis indicates that, in the event of a failure of the main electric grid, the site can use an augmented zero-energy solution to provide electric power to the critical load. The identified microgrid system can run for as long as there is enough fuel to run the fuel cells. Solar PV contributes 34% of the load and fuel cells contribute 66% of the load. In this scenario, the LCOE is \$0.518/kWh. As a comparison, the microgrid analysis was performed with diesel generators, and a combination of solar PV and diesel. The LCOE for these scenarios was $0.825/kWh and $0.892/kWh, respectively. The difference between the fuel cell and the diesel generator scenarios in terms of the LCOE largely is due to the greater efficiency of the fuel cells.

Transportation Assessment

A fleet vehicle assessment was not included in this analysis due to lack of data. However, NREL did analyze the fuel consumption and greenhouse gas emissions associated with potential "commuter" bus options for transporting troops from a barracks located in Belle Chasse, Louisiana (approximately 15 miles from the MARFORRES Center), to the MARFORRES Center and back. A high-level analysis indicates that using biodiesel-fueled (B20) buses to transport troops reduces annual GHG emissions by 13.5% compared to the use of diesel-fueled buses.

Financial Assessment

The majority of the ECMs recommended in this study are cost effective. Of the 34 ECMs recommended for the five buildings included in this assessment, 22 have a simple payback period of less than 20 years, the assumed lifetime of these energy projects. The proposed solar PV and fuel cell projects are not cost effective within their lifetimes. The simple payback period on the solar PV system alone is approximately 66 years, and the levelized cost of energy for the combined PV/fuel cell system is 80% more than the utility price of electricity. These unfavorable economics largely are due to the lack of renewable incentives in the city of New Orleans or the State of Louisiana (the state currently has no renewable portfolio standard). If MARFORRES could work with private developers, however, to design, install, and maintain their renewable energy system, the private developers could take advantage of federal incentive programs (such as the Renewable Energy Investment Tax Credit) and the cost of electricity would decrease. Although the solar PV and fuel cell projects might not show a positive return within a 20-year project lifetime, they do provide the energy-security benefits of potentially longer run times, reduced costs, and on-site generation with a reduced need for fuel imports during grid outages.

Next Steps

NREL's climate neutrality case study for the MARFORRES Center represents a high-level evaluation of the possibilities for net zero energy and climate neutrality at the MARFORRES Center in New Orleans. Based on the study, NREL recommended the following actions as "next steps" for the base.

- Focus any future studies on the HQ building (rather than the entire secure compound) because this facility will be the only building over which the U.S. Marines have control. The other buildings can be addressed when they become the responsibility of the U.S. Marines.
- In implementing any of the recommended ECMs, renewable energy, or microgrid options provided in this analysis, give first priority to any measures that can be adopted before the building is completely constructed, followed by the implementing the most cost-effective energy efficiency measures, and then renewable energy measures.
- Conduct a follow-up study once construction on the new HQ building is complete and the U.S. Marines have moved to the site. Because the MARFORRES Center still is under construction and many staffing and transportation plans have yet to be

finalized, several areas of assessment have been left incomplete. Additionally, collecting a year's worth of energy-use data from the HQ building could help to determine actual building performance as compared to model estimates.

- Explore the possibility of hydrokinetic generation. The MARFORRES Center is located on the Mississippi River which could become another source of renewable energy. The Federal Energy Regulatory Commission has issued 86 preliminary permits for hydrokinetic assessment along the Mississippi River. Because the technology still is relatively new, however, it was not included in the renewable energy analysis. MARFORRES is currently exploring this option further and will be meeting with hydrokinetic energy companies in the near future.

Lessons Learned

Lessons learned from completing the MARFORRES climate neutrality study center on data availability, leasing and operational control, and implementing energy projects in the design rather than the retrofit stage.

Data Availability

The ability to develop a robust net zero energy and climate neutrality analysis at a site depends on the availability of meaningful data to construct a baseline. For the MARFORRES Center, comprehensive data to develop a baseline was not always available. In some cases, the data simply did not exist (for instance, no utility data exists for the HQ facility because this building was not yet operational at the time of the assessment). In others, data was inaccessible or had not previously been collected through MARFORRES's reporting systems. In this study, developing alternative methods for developing a baseline became very important. Architectural and engineering drawings for the HQ and existing buildings informed the development of building energy models, which were used to estimate baseline energy consumption and to develop reduction scenarios. Metered building electricity and natural gas consumption clearly would provide a much more accurate baseline energy use. Building models, however, provided a reasonable proxy for actual energy consumption. This approach can inform development of energy projects during the design phases of a facility rather than after construction.

Building Ownership

In the MARFORRES case study, the ownership and operational control of facilities strongly influenced the site's options for reaching net zero energy and climate neutral status. The MARFORRES HQ building occupies land that is being leased from the U.S. Navy. The other existing buildings within the secure compound are under the control of the U.S. Navy, and the provisions of the lease do not allow the MARFORRES HQ building to make use of infrastructure that is currently owned by the U.S. Navy but still is within the secure compound. This leasing arrangement has two effects on climate neutrality and net zero energy use at the HQ building.

- The design of the HQ building must incorporate electric rooftop cooling units (RTUs) to the cool the building and the data center. These RTUs are more expensive and more energy intensive than the site's existing chilled water plant. Because MARFORRES's lease prevents it from using chilled water from this existing plant in the HQ facility, use of the RTUs adds a significant cost in terms of capital, energy, and climate neutrality.

- In the event of a utility-grid disruption the RTUs will require more energy from the backup power systems than would a cooling system using the chilled water plant. This increases the energy for cooling and decreases the amount of time the backup system can operate in the event of a grid failure.

The primary lesson learned from this project in terms of operational control is that leases should be designed to be flexible enough to accommodate the energy needs of an entire site.

Building Design

Retrofits to new buildings to improve energy efficiency are not as cost effective as incorporating these efficiency characteristics into the design in the first place. Because the State of Louisiana is funding the construction of MARFORRES' HQ building, MARFORRES might not directly influence the design of this facility. Therefore, all of the ECMs identified in this climate neutrality study must be treated as retrofits to a new building. In most cases, the cost of implementing these measures as retrofits is significantly greater than it would have been if the ECMs were incorporated into the original building design. According to the NREL analysis, if all identified ECMs were implemented on the HQ building as retrofits, then the simple payback period for these ECMs is approximately 35.5 years. In contrast, if these same ECMs had been incorporated into the design and construction of the facility, then the simple payback period is reduced to 10.5 years. The best route to net zero energy status and climate neutrality lies in planning for it from the start.

A.5. San Nicolas Island, Naval Base, Ventura County

- Location: 60 miles west of Los Angeles, California; most remote island of the Channel Islands
- Size: 14,500-acres
- Installation Details: 145 buildings totaling approximately 400,000 ft^2
- Average EUI: 91 $kBtu/ft^2$
- Population: 150–200
- General Purpose of Installation: U.S. Navy–owned and operated weapons testing and training facility
- Baseline: The baseline includes energy consumption and GHG emissions from the buildings on the island. Transportation fuel baseline was calculated, but no transportation analysis was performed.

Energy

The total baseline energy usage is shown in Table A11.

Table A11. Baseline Annual Energy Usage Information

Electricity (kWh)	5,644,774
JP-5 (MBtu)	17,319.6
Fuel (gallons)	
Gasoline	Unknown
Diesel	Unknown
Biodiesel	Unknown
Compressed Natural Gas	Unknown

Greenhouse Gas Emissions

A Scope 1 and Scope 2 greenhouse gas baseline estimate was calculated for San Nicolas Island. The greenhouse gas baseline for this site is approximately 3,227 MT CO_2e, and includes the building energy uses described above.

Project Overview

In 2008, the Department of Defense, U.S. Navy, funded NREL to provide: a current energy, water, and waste baseline of SNI; and a plan outline for transitioning U.S. Navy Outlying Landing Field San Nicholas Island (SNI) into a renewable community. The renewable energy community conceptually is a community in which integrated, renewable energy technologies play the primary role in meeting energy supply and demand. It has near zero or zero-energy buildings, uses integrated transportation with advanced vehicles, and incorporates sustainable operating practices.

San Nicolas is an island, therefore the community boundary is clearly defined. The U.S. Navy has complete jurisdiction, control for change, and decision-making authority. Used as a weapons testing and training facility, SNI is minimally inhabited and has a runway, air terminal, housing, power plant, wastewater treatment facility, fuel housing, and basic support facilities. Sectors relevant to this site include residential, commercial, industrial, and transportation. At any given time the island hosts approximately 150 to 200 people. This number fluctuates based on operations being performed, and increases to a maximum of about 250 people. All people are transported to the island via military planes which operate several flights per day.

An island is uniquely suited to benefit from sustaining as a renewable community. All food and fuel for energy and transportation are shipped to the island via barge, resulting in costs that are substantially more than on the mainland. Water is produced from seawater on the island but also is barged in to make up any shortfalls. Wastewater is treated on the island and solid waste is transported off of the island. Most islands, including SNI, also play host to unique and fragile ecosystems.

The NREL analysis to-date focused on the amount of renewable energy needed to replace the use of JP-5 fuel for stationary energy use (both heating and electric) on the island. The JP-5 jet fuel is used in 5 diesel generators for main island power. There are 32 back-up diesel generators. The 85 vehicles and the heavy equipment inventory (33 items) on the island operate on JP-5 or gasoline. NREL also assessed the areas of transportation (ground and air), waste, water, food, and supplies. The energy use and emissions associated with these and the renewable energy alternatives, sizing, and optimization, however, were not part of this analysis.

Energy Efficiency Assessment
Recommendations for conservation and energy efficiency include education and improvements in occupancy awareness and behavior, O&M operation practices, and capital improvements. Further analysis is required to quantify the benefits of such actions.

Renewable Energy Assessment
An optimization analysis was performed to determine the combination of renewable energy technologies that could replace the use of JP-5 fuel to heat and power the stationary loads at San Nicolas Island, first with batteries and then without batteries (*see* Figure A6). The technologies evaluated include photovoltaics, wind power, solar ventilation air preheating, solar water heating, solar thermal steam and solar thermal electric, biomass thermal steam and biomass electric, and daylighting. Results indicate that solar water heating, solar ventilation air preheating, and daylighting can be integrated directly into buildings to reduce both electric and heating use. The remaining electrical requirements can be reduced by wind power connected to the central plant. Remaining heat uses at some buildings would continue to be supplied by oil because there is no renewable energy technology considered that can serve those loads. This remaining load, however, easily could be served by biodiesel purchased and be delivered in the same way that JP-5 fuel currently is delivered. These oil-fired loads also could be converted to electricity, which could be provided by renewables, although this would not reduce life-cycle cost under current conditions.

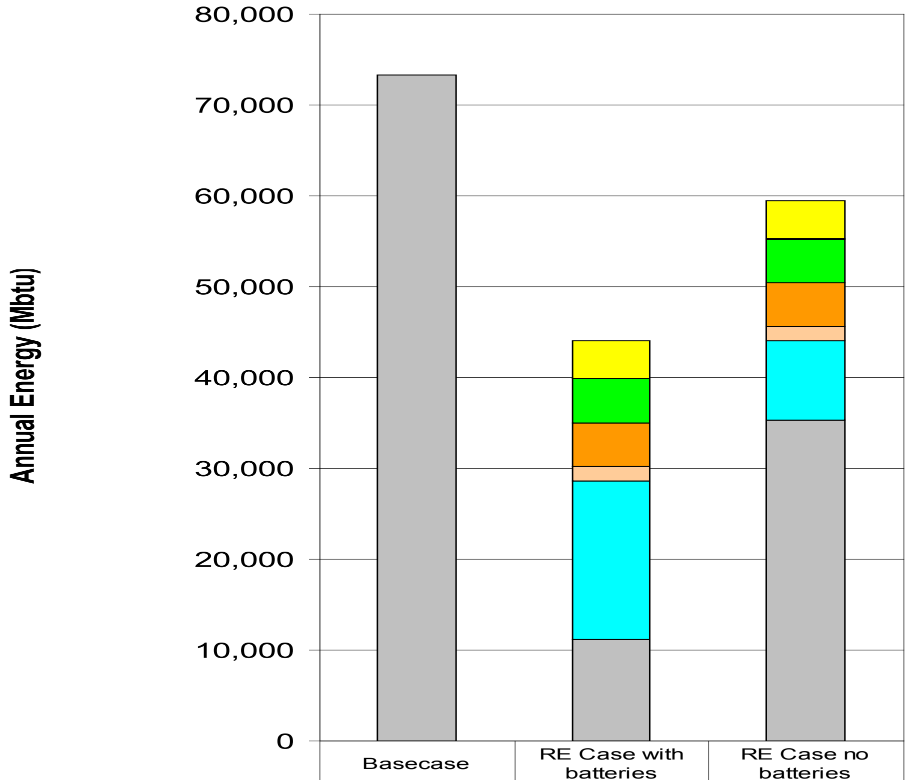
The annual energy supplied by JP-5 fuel in the base case is 73,261 million Btu per year. If a large battery plant is considered then, by using wind power, biomass power, and measures on several buildings (daylighting, solar water heating, solar ventilation air preheating), this is reduced to 11,233 million Btu/year. A large battery plant involves high capital cost, high maintenance, high replacement costs, and use of potentially hazardous materials. If batteries are not considered, then the wind plant is much smaller, but the use of JP-5 is reduced to 35,514 million Btu/year by the renewable energy technologies. These results simply displace the baseline fuel use and do not include the benefits of efficiency measures and occupancy awareness and behavior that would further reduce fuel use and also reduce the size of the renewable energy systems required to serve the smaller load. The difference in total energy use is due to avoided inefficiency (waste heat) at the power plant.

Overall, the analysis shows that JP-5 fuel use can be reduced (by more than 50%) but cannot eliminated completely. Some of the renewable energy will continue to operate without power from the central plant but could require electricity to operate equipment such as pumps. The renewable energy options therefore do not provide complete energy independence from imported fossil fuels and from associated supply and cost fluctuations.

Microgrid Assessment
A microgrid assessment was not included in the scope of this analysis.

Transportation Assessment
A high-level assessment was included for reducing fuel consumption from transportation to, from, and within SNI. Recommendations include the following.

- Implementing a program in which efficient sedans, including hybrid and plug-in hybrid vehicles, are used in less-rugged areas, and large clearance vehicles (including hybrid-electric vehicles) are evaluated for rugged-terrain use. The vehicle fleet on the island currently is oversized, and every vehicle is a large truck or van.
- Transitioning all vehicles and equipment to diesel power (versus gasoline) equipment would avoid the $1.50/gallon transportation costs for gasoline. The transportation costs associated with the gas are not included in the $2.23 per gallon cost of the gas paid to Defense Energy Supply Center; the transportation costs associated with the JP-5 fuel transportation are included in the $2.33 per gallon costs paid to DESC. Ridding the island of a need for gasoline not only would eliminate the barge trips and associated costs necessary to transport the fuel to SNI, but also would eliminate the need to maintain two fuel infrastructures (gas and JP-5 fuel) on the island. The use of biodiesel in diesel vehicles and equipment is another opportunity for sustainable operations.
- Consolidating airplane and barge trips to ensure that only full planes and barges—both going to and coming from SNI—are in transport. The JP-5 fuel barge returns from SNI empty. This presents an opportunity to capitalize on empty barge space and use it to transport items such as trash back to the mainland. Additionally, encouraging workers to stay on the island rather than fly back to the mainland for a night could result in savings.



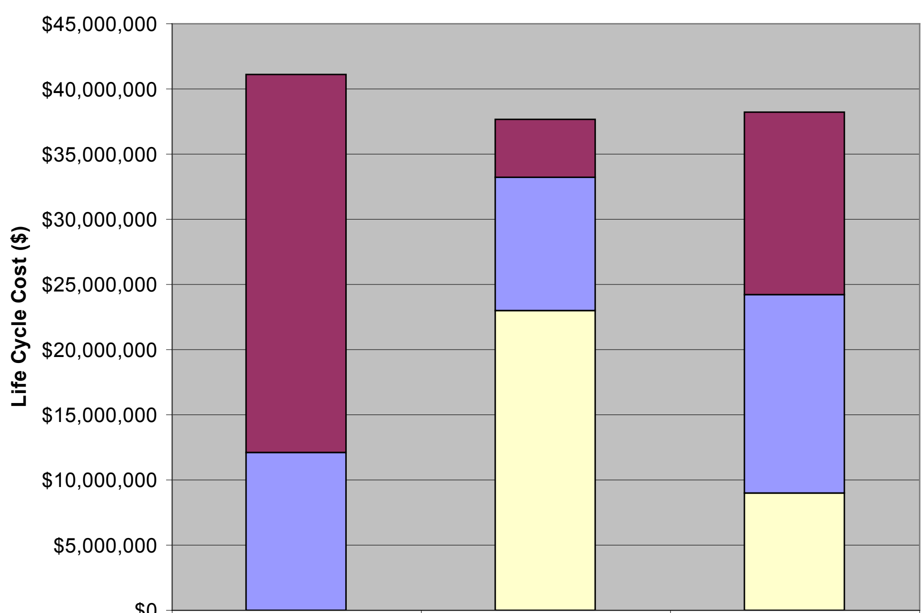
	Basecase	RE Case with batteries	RE Case no batteries
Daylighting (Mbtu)		4,186	4,186
Anaerobic Digester (Mbtu)		43	43
Biomass Gasifier (Mbtu)		4,851	4,851
Biomass Combustion (Mbtu)		0	0
Solar Themal (Mbtu)		0	0
Solar Water Heating		4,814	4,814
Solar Vent Preheat (Mbtu)		1,546	1,546
Wind (Mbtu)		17,430	8,727
Photovoltaics (Mbtu)		0	
JP5 Fuel (Mbtu)	73,261	11,223	35,314

Figure A6. Annual energy delivery (million Btu per year) for base case and renewable energy case with and without batteries

Financial Assessment

The life-cycle cost of the base case (i.e., continuing to burn JP-5 in the power plant and for building end uses) is estimated at $41.1 million. Continuing to purchase and ship JP-5 to SNI has zero initial cost but has high annual cost and high life-cycle cost (*see* Figure A7). Conversely, the renewable energy cases have high initial costs but low annual cost and a reduced life-cycle cost. Optimization of on-site renewable energy use with batteries could reduce the life-cycle cost to $37.7 million. Without batteries, the life-cycle cost is estimated at $38.1 million. Figure A7 shows the breakdown of life-cycle cost in terms of fuel, O&M, and capital expenditure. Although the total life-cycle cost of the three alternatives is similar, the breakdown is quite different. The batteries involve a large capital investment but they reduce overall fuel use and O&M costs by allowing the generators to be turned off for long periods. Without battery use there is a greater capital expense for the renewable energy technologies. The O&M costs increase because it includes O&M for both of the generators and the renewable energy systems, but the fuel cost is decreased considerably over that of the base case.

Over a 25-year analysis period, the life-cycle costs of the renewable energy cases are less than for the base case—and it is important to acknowledge other benefits. The life-cycle cost analysis does not include a dollar value for emissions (e.g., NOx, SOx, CO_2), security, educational value, or other benefits associated with SNI's renewable energy goal. The on-site renewable energy provides a hedge against future fuel-price increases. In this analysis, renewables do not obviate the need to import at least some fuel to the island, but they decrease the dependence on fuel and allow some loads to continue operating without fuel. Daylighting is a good example. When the power goes out, occupants of a daylit building still can see and perhaps even can continue working. Many of these reliability benefits, however, only are realized in the case considering batteries. Without batteries, many of the renewable energy technologies would cease to operate without using power from the generator plant. Solar water heating, for example, depends on electric-powered pumps to operate.



	Basecase Life Cycle Cost ($)	RE Case with Batteries	RE Case without Batteries
Fuel Cost	$28,972,405	$4,438,462	$13,965,490
O&M Cost	$12,157,078	$10,264,001	$15,254,556
Initial Cost	$0	$22,966,941	$9,021,320

Figure A7. Life-cycle cost ($2008) of the base case, the renewable energy case including batteries, and the renewable energy case without including batteries

Lessons Learned

Lessons learned from completing the SNI study center on data availability, education, fuel cost, cultural sensitivity, and implementation issues.

Data Availability

The data to establish baseline energy use was successfully collected and documented. Establishing a baseline energy and emission inventory can be challenging. In the case of SNI, the island provides a natural boundary for defining the flows of energy and resources in and out of the community. One of the challenges in establishing a baseline inventory is reliance on another organization's motivation to provide data, and ensuring the accuracy and completeness of the data. Site visits are critical to see layout, equipment, and facilities firsthand and to be able to talk with the on-site facility personnel. The SNI facility personnel pay the bills and document fuel shipments received. SNI has many generators therefore quantifying the fuel consumption is challenging. In contrast, for other sites grid-connected to a municipal utility, viewing utility bills to capture energy use can be easier.

Importance of Education

Immediate and substantial reductions in energy use are possible through occupant awareness and behavior. Education of facility operators, residents, and visitors on the island is critical to reducing energy use. At SNI, for example, there is a misconception that good behavior involves leaving lights and equipment on to keep the generators' load high. Although this could help the efficiency of the generators it wastes fuel. It is anticipated that fuel savings of 10% to 20% is possible by putting less load on the generators, by turning off lights and equipment when not in use, as well as consolidating dispersed building occupants to fewer buildings. Similar savings are possible with behavior changes to increase conservation and energy efficiency. Prior to completion of this study, education and outreach efforts about water conservation have been hugely successful on SNI.

There also is a lack of knowledge, understanding, and confidence with wind power. The SNI central plant workers expressed concern and hesitation regarding deploying wind turbines, due to intermittency of the wind and concerning energy storage. It might be helpful to first deploy wind turbines in a pilot project to gain firsthand knowledge and train local workers on the suitability of wind to meet the community's needs.

True Cost of Fuel

The Defense Energy Supply Center covers the cost to transport JP-5 fuel to the island. The fuel cost is established annually and costs the same worldwide. This therefore is not the real cost of fuel. The fuel cost doesn't capture the true cost, based on where or how the fuel is produced, how far it is transported, supply interruptions, or supply and demand fluctuations. This has an impact on the comparison of costs between different energy scenarios for a given site. The attractiveness or disincentive to implement renewable energy therefore is difficult to evaluate, because the true cost of the baseline energy with JP-5 fuel is unknown. Moreover, by moving some DoD installations to renewable energy, the true cost of JP-5 fuel could be reduced. Using a straight fixed-fuel cost, however, these benefits are not realized.

Cultural Sensitivity
Communities have a history and culture with ingrained policies, perceptions, and habits. It could be beneficial to have candid conversations about the community culture within the context of successfully achieving goals for net zero energy and carbon neutral communities. By addressing these up front, there might be greater likelihood of success in incorporating sustainability values in the culture, its objectives, policies, programs, incentives, education and training, decision process, and follow-on evaluation metrics.

Implementation issues
The undertaking to identify how SNI could be a renewable energy community, preliminary analysis of energy efficiency and renewable energy options and optimization, and recommendations for steps forward have been completed successfully. Moving forward with an action plan, prioritizing options, setting a timeline for next steps, implementation, and evaluation of performance, however, have not been pursued by the Navy/SNI. It is critical that the vision to achieve a renewable energy community is shared by all involved, including leadership from the top down. If and when this project (or others) goes forward, it would be worth sharing responsibility for the execution and cost for the subsequent efforts. The investment in time and money ensures that all parties are committed both to completing all the steps and to successful implementation. Furthermore, entities functioning in a consulting role, such as NREL, should provide both recommendations from analyses and guidance on how to implement the recommendations. Otherwise there is risk of the lack of implementation to achieve the community's goals.

Development of a framework that includes the goals, a proponent with decision authority, time line, steps, and roles is critical. Development of a financial plan to complete each phase also is essential.

A.6. Pohakuloa Training Area

- Location: The Island of Hawaii on the saddle road in between Mona Loa and Mona Kea
- Size: 133,000 acres
- Population: About 80 permanent staff and 1,000 soldiers at any given time; however, population is greatly dependent on training requirements and needs
- Installation Details: 188 facilities, 308,386 ft^2 (barracks = 39%, maintenance = 11%, office/admin = 9%, storage =7%, other = 34%)
- Average EUI: 21 kBtu/ft^2
- General Purpose of Installation: Army training
- Baseline: NREL determined an energy boundary for Pohakuloa Training Area's (PTA) baseline that includes all onsite buildings, facilities, and fleet vehicles.

Energy

The total baseline energy usage at the PTA (*see* Table A12) is 6,827 site MBtu, and 23,027 source MBtu (96% electricity, 4% propane, fleet consumption is unknown).

Table A12. Baseline Energy Use

Electricity (kilowatt-hours)	1,718,400
Propane (gallons)	10,479
Fleet Fuel Use	unknown
Total JP-8 (gallons)	401,530
Total Gasoline (gallons)	42,082
Total Diesel (gallons)	47,248
Aviation Fuel (gallons)	unknown

Greenhouse Gas

A greenhouse gas inventory was calculated for the PTA for Scope 1, Scope 2, and select Scope 3 emissions. The Pohakuloa Training Area's baseline was 1,245 MT CO_2e for the net zero energy project (electrical and propane) and 8,156 MT CO_2e, when fuel use on base and commuter fuel use are considered.

Project Overview

Pohakuloa Army Training Area partnered with NREL to assess opportunities for increasing energy security through renewable energy and energy efficiency at the PTA's installations. Pohakuloa was selected by the U.S. Army to be a prototype installation for net zero energy assessment and planning. NREL performed an assessment of the PTA's potential to achieve net zero energy status. The analysis shows that the PTA has the potential to make significant progress toward becoming a net zero energy installation. If the recommended energy projects and savings measures are implemented, then a 93% site Btu reduction and a 98% source Btu reduction will be achieved by the base. By achieving this status, the base will set an example for other military installations, provide environmental benefits, reduce costs, increase energy security, and exceed its goals and mandates.

Energy Efficiency Assessment

The Pohakuloa Training Area's main cantonment area is an 80-acre site. The cantonment area supports up to 2,300 troops at a time and primarily houses them in the existing Quonset huts. There is a dining facility, a medical clinic, a fire department, and the Bradshaw Army Airfield. Figure A8 shows a typical Quonset hut.

Figure A8. Quonset hut at the Pohakuloa Training Area

At the PTA, 86% of the facility-related energy usage is from electricity and 14% is from propane. An end-use breakdown of electrical energy was not available for the PTA. Propane use at the Pohakuloa Training Area was broken down into 40% for shower facilities and 60% for cooking facilities (cooking facility usage comprises hot water for dish washing as well as direct use for cooking food). The Pohakuloa Training Area's EUI was calculated at 21. This is a very low number and indicates that, relative to other buildings, those of the PTA do not use much energy. The EUI probably is so low because the PTA has a large amount of space with minimal heating and cooling loads.

Through discussion with base personnel, building walkthroughs, and basic analysis, NREL estimated energy efficiency savings potential. Table A13 summarizes the potential energy savings at the PTA, totaling 22% electrical load reduction, 24% propane reduction, and 22% overall energy reduction.

Table A13. Energy Efficiency Savings Potential

Specific Main Base Facilities			
Building Type	**kWh (Electricity)**	**Gallons (Water)**	**Gallons (Propane)**
Barracks	41,015	270,571	—
Vehicle Maintenance Shops	40,019	—	—
Operations	28,886	23,916	—
Health Clinic	10,444	—	—
Administrative	61,732	9,965	—
Shower Facilities	4,325	1,587,900	1,799
Dining Facilities	5,686	—	912
Exchange	25,579	—	—
HQ	40	—	—
ENG/Housing MNT	37,823	13,951	—
Other	23,444	93,656	—
Base-Wide ECMs			
Retro-Commissioning	82,245	—	—
All Base Total	361,238	1,999,959	2,711
Percent Reduction	22%	33%	24%

Renewable Energy Assessment

An NREL team conducted an initial assessment of the renewable energy opportunities for the Pohakuloa Training Area based on high-level energy, building, and resource data. The initial screening evaluated the following technologies: photovoltaics, wind, biomass, combined heat and power opportunities such as fuel cells and microturbines, daylighting, solar thermal or concentrating solar power, solar hot water, solar vent preheating, and waste to energy. NREL analyzed the projects already planned by the base as well as the potential for additional projects.

The most promising technologies for implementation include solar hot water, solar photovoltaics, and wind**.** Implementation of these projects would provide 100% of electrical energy and 50% of thermal energy from renewable sources at the PTA. The PV at Bradshaw already exists; it simply must be reconnected to the grid. The PTA has received ARRA funding for PV at the headquarters buildings and the fire station. The wind turbines in this scenario are oversized to account for projected future growth at the base. A summary of the technologies and their savings is provided in Table A14.

Table A14. Energy Project Recommendations

Project Name	Size	Savings	Source Btu Savings MBtu	Percent of Total Btu
PV at Bradshaw	15 kW	25,000 kWh	334	1.5%
PV at HQ and Fire Station	60 kW	115,000 kWh	1538	6.7%
Wind Turbines	550 kW	1,918,429 kWh	25,659	111.5%
Solar Hot Water	1,052 ft^2	4,611 gal propane	488	2.1%
Totals			28,020	121.7%

Electrical Systems and Microgrid Assessment

NREL analyzed the high-level potential for the interconnection of renewable energy generation projects into the distribution system at the PTA. The proposed placement and interconnection of the recommended renewable energy systems was analyzed for voltage drop as well as conductor and protection-device capacity. The electrical distributions system at the PTA would enable the proposed projects to be tied into the distribution system anywhere on the primary feeders without requiring significant upgrades to the base distribution system.

For microgrid analysis, NREL simulated various configurations for distributed-energy resources and energy storage (fuel cells and batteries). Simulations covered hour-by-hour performance of the proposed renewable energy generation systems and the coincidence between renewable energy generation and the hourly load profile at the PTA. Implementing a microgrid with renewable energy, storage, and generators ensures the ability to continue critical operations during an extended emergency should the need arise.

Transportation Assessment

NREL was able obtain some information about the PTA's fleet composition, commuting patterns of staff, and total fuel consumption. It was not possible to complete a detailed non-tactical fleet assessment, however, because the fleet manager was unable to provide requisite additional transportation data. Basic recommendations include vehicle pooling, fleet transformation, and alternative fuel use.

Implementation Plan

The PTA has several implementation options for energy projects including energy savings performance contracts, utility energy services contracts, power purchase agreements, enhanced use leases, energy joint ventures, and appropriated funds. Government-owned projects funded through appropriations reduce contractor financing and markup fees, but require up-front capital and prevent the PTA from receiving federal tax incentives. They also place the O&M burden on the PTA. Privately owned projects allow the PTA to implement renewables without requiring any up-front capital and with reduced O&M responsibility. Such projects also allow the PTA to take advantage of federal tax credits, although the money gained in tax credits might go toward contractor financing and markup fees.

Several possible options for the PTA to implement projects to get the base to net zero energy were examined. These included expanded net metering with the Hawaiian Electric Light Company (HELCO), implementing energy storage, negotiating an UESC with HELCO, developing an EUL project, and working through Hawaii's feed-in tariff program. Implementation of these recommended energy projects along with the planed solar project would result in a 98% NZEI source Btu reduction for facility energy at the base.

Financial Assessment

A basic financial analysis of the solution to approach net zero energy was conducted. NREL analyzed the costs of a business-as-usual energy scenario at the base, and the costs associated with various scenarios of energy project implementation. All of the scenarios analyzed would provide a significant energy cost savings for the PTA; the feasible implementation option with the least net present cost should be chosen. The analysis, however, is sensitive to many as-yet undetermined factors, such as inflation rate, energy price escalation rates, and propane gas prices. These factors can impact the estimated cost savings and the net present value substantially—both positively and negatively. This financial analysis, however, shows that under a variety of scenarios the recommended energy projects enable the base to move closer to NZEI status and will reduce its energy costs.

Next Steps

The NZEI assessment for the PTA represents a high-level analysis of the opportunity for the base to work towards becoming a net zero energy installation. The base is moving forward with the installation of its ARRA-funded PV project and currently is examining other options for using renewable energy technologies.

Lessons Learned

Utility Regulations Can Be Major Barriers

The PTA has the renewable energy resources and high energy costs to make achievement of net zero energy status technically and financially viable. The current rules and regulations of the base's utility (the Hawaiian Electric Light Company) regarding interconnection of renewables and net metering, however, do not allow the base to interconnect a large project to achieve net zero energy status. Thus, most of the cost-effective implementation strategies for the base require a modification or waiver of these rules for the projects to be possible.

The Level of Engagement and Interest from Installation Personnel Varies

Although most data from the PTA was very easily and readily obtained from helpful personnel on base, NREL was unable to acquire the necessary fleet-transportation data from the base. An analysis was conducted using the data provided but, because the fleet-transportation data was missing, a complete picture of energy consumption at the base could not be obtained.

Base Modernization Presents a Challenge and an Opportunity

Most of the buildings at the PTA are Quonset huts built in the 1950s, and the base is planning a facility modernization. The old buildings have low energy usage because they largely are unconditioned and have low lighting power densities. The newer buildings on base actually use more energy than the older ones do because they have modern HVAC systems and higher lighting power densities to conform to modern buildings codes. This is a unique challenge that prevents significant investment in older buildings if they are slated to be replaced soon, but provides the opportunity to design very efficient new buildings with renewable energy systems.

Operations and Maintenance of Systems is Key for Long-Term Success

The PTA had a grid-independent PV and battery system installed in 2003 to provide power for the Bradshaw Army Airfield. The batteries were not maintained, however, and the system stopped functioning a few years after it was installed. Rather than fix or reconfigure the system it was simply shut off and the airfield was reconnected to the electrical grid and powered with purchased energy. Thus, not only was the system not properly maintained but, after the battery failed, instead of reconnecting the PV system to the grid to produce valuable energy, the system was allowed to sit idle.