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MASSACHUSETTS MILITARY BASES

Clean Energy Assessment and Strategic Plan for Massachusetts Military Installations

MA Department of Energy Resources / MassDevelopment

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Table of contents

List of Exhibits

1 EXECUTIVE SUMMARY

1.1 Project Overview

The Massachusetts Military Clean Energy Assessment and Strategic Plan is part of a long-term initiative to support the Commonwealth's military installations to both collaborate with them and to explore opportunities to support existing and new missions. This report provides the results of the evaluation of clean energy opportunities across the six military bases in support of Department of Defense (DoD) renewable energy, environmental sustainability, and energy security goals. The bases that were included in this assessment were:

- Barnes Air National Guard Base (Westfield, MA)
- Fort Devens (Devens / Ayer, MA)
- Hanscom Air Force Base (Bedford, Concord, Lexington and Lincoln ,MA)
- Joint Base Cape Cod (Cape Cod, MA)
- Natick Soldier Systems Center (Natick, MA)
- Westover Air Reserve Base (Chicopee, MA)

The Massachusetts Military Clean Energy Assessment and Strategic Plan is supported by the Commonwealth's Military Asset and Security Strategy Task Force (Military Task Force) and managed by the Massachusetts Department of Energy Resources (DOER) and MassDevelopment, the state's finance and development authority. Other key state-level stakeholders who were kept informed of project activities and provided input throughout the process included the Massachusetts Department of Environmental Protection, the Massachusetts Clean Energy Center, and Massachusetts Institute of Technology Lincoln Laboratory.

The consulting team (Clean Energy Team), led by DNV GL and sub-consultants MCFA Global, Vanderweil Engineers, JK Muir, and Nobis Engineering was hired to complete all phases of the assessment and provide recommendations for clean energy project opportunities across all of the military bases.

1.2 Key Findings and Opportunities

This study uncovered numerous opportunities to support each base in their efforts to improve infrastructure, increase cost savings and energy efficiency, increase the use of clean renewable energy and foster new partnerships with the local community. As a result of the assessment, the Clean Energy Team identified a total of 189 potential projects across all of the bases.

The costs and benefits of each of these projects were weighed using a common approach to prioritize projects based on a set of criteria developed by the Clean Energy Team and project stakeholders. This framework for assessing and prioritizing projects facilitated a comparison of potential projects across all bases to determine which projects were most compelling in terms of:

- Energy efficiency and clean energy development
- Enhanced energy security and improved resilience
- Overall societal and environmental impacts

Many of the projects that top the list are individual building-level energy conservation measures; however several large projects were also found to be worth pursuing.

Projects that align with DOER clean energy policies, programs, and pilot initiatives will be selected for further development by the Clean Energy Team. For this effort, emphasis will be placed on projects that represent renewable and emerging technologies that could benefit from state or federal-level assistance, and where base leadership had expressed clear interest in the projects. Eight small projects and three more complex projects will be selected for this initiative in the next phase of work.

The Commonwealth's Military Task Force also selected a number of high impact projects that could be funded under the state's capital plan which allocated $5 million to military bases for energy projects. The projects selected under this initiative best fit with Commonwealth, DoD, and individual base goals. Table 1-1 provides a summary of the projects selected to receive capital funding from the Commonwealth.

Table 1-1 Select Projects for Capital Funding

Base	Description	Total Measure Score	Total Annual kWh Savings	Total Est. Upfront Cost	Cost Savings	Payback
Barnes	Replace existing gas furnace with high efficient gas furnace in Bldg 69	44.94	0	$ 1,085	$ 468	2.3
Barnes	Replace existing boilers with natural gas for Bldgs 29, 31, 64, 65	25.16	0	$ 76,778	$ 8,110	9.4
Barnes	Energy Reduction Measure (Partial). Measures include lighting, lighting control upgrades, installation of infrared heat pipes, on-demand hot water heaters, and envelope improvements.	22.83	0	$ 797,262	$ 93,181	8.5
Barnes	Upgrades at building level to be controlled by existing EMCS. Install DDC controls at Bldgs 17, 27, 28, 33, 52, 401 (401 has DDC, but needs to be connected to network)	18.75	3,685	$ 84,875	$ 7,516	11.2
Ft. Devens	Bldg 672 - Boiler Replacement	30.70	0	$ 23,318	$ 4,290	5.0
Ft. Devens	Bldg 673 - DHW Replacement	29.64	0	$ 25,261	$ 10,032	2.3
Ft. Devens	Bldgs 675 & 676 installation of full building, gas-fired generator.	19.75	0	$ 61,421	$ -	N/A
Hanscom	Replace air furnace with new high efficiency furnace: Bldg 1851	30.60	0	$ 1,120	$ 265	4.0
Hanscom	Replacement of existing Bell & Gossett 40 hp steam and chiller pump motor with premium efficiency unit.	36.9	41,785	$ 16,000	$ 6,769	2.2
Hanscom	Replace existing gas fired boiler with new high efficiency gas fired boiler: Bldgs 1065 and 1812	25.68	0	$ 14,905	$ 2,124	6.7
Hanscom	Replacement of existing 75 hp blower with high efficiency unit to operate with a variable frequency drive.	25.63	149,519	$ 104,230	$ 24,222	4.5
Hanscom	Pump rebuild of Well 1 (10 hp) and Well 2 (20 hp).	24.72	37,805	$ 16,156	$ 6,124	2.5

Base	Description	Total Measure Score	Total Annual kWh Savings	Total Est. Upfront Cost	Cost Savings	Payback
Hanscom	Rebuild of Upper and Lower Sewer Lift Station Pumps (3-38.7 hp, 1-125 hp, and 2-50 hp units).	22.64	89,910	$ 78,589	$ 14,565	5.2
JBCC - Camp Edwards	Boiler Replacement: Bldgs 5515, 5502, 5501	29.77	0	$ 61,720	$ 10,478	5.5
JBCC - Camp Edwards	DHW Replacement; Bldgs: 5515, 5510, 5505, 5501	23.79	0	$ 3,280	$ 509	6.0
JBCC PAVE PAWS	Installation of second VAV box w/ electric reheat	26.89	0	$ 42,000	$ 6,555	6.1
JBCC-Otis	Renewables Integration Plan	N/A	N/A	$ 101,412	N/A	N/A
JBCC-Otis	Replace Boiler: Bldgs 104, 120, 122, 149, 155, 156, 158, 159, 162, 167, 197, 322, 330, 430, 754, 971, 5236, 5238, 124.	34.43	0	$ 356,183	$ 91,591	3.8
JBCC-Otis	102nd Building Management System control upgrades	23.31	44,447	$ 742,405	$ 93,484	7.8
JBCC-USCG	Replace steam boiler at Hangar 3170 with infrared heaters	34.4	0	$ 110,000	$ -	
JBCC-USCG	Establish submeters to report base electrical consumption data	24.20	5,040	$ 13,000	$ 5,040	2.3
Westover	Bldgs - 5101, 5103, 5102, 5104 and 5105 - Base dorms - New Burner and Hot Water Reset Controls	35.98	0	$ 31,726	$ 17,901	1.7
Westover	Bldgs - 2200, 2201, B5101, 5102, 5103, 5104 and 5105 - Room Control Upgrade	29.33	327,778	$ 116,278	$ 47,556	2.4
Westover	EMCS Jace upgrade - Improvements to the EMCS are highly desirable for increased functionality, controls, and energy trending	26.76	104,199	$ 457,951	$118,298	3.8
Westover	Upgrade of utility meters to smart meters and connection to EMCS	19.72	36,399	$ 324,045	$ 51,292	6.2
Westover	Additional for Solar Field at Chicopee/Westover - Funding to be used to clear city property in advance of solar construction	N/A	N/A	$1,000,000	N/A	N/A
All Bases	One Full Electric Charging Stations with 2 charging units per base @ $14K per station. Includes all bases at JBCC.	N/A	N/A	$ 126,000	N/A	N/A

2 INTRODUCTION

In 2012, the lieutenant governor signed an Executive Order creating a Military Asset and Security Strategy Task Force (Military Task Force). Subsequently, the Task Force called for a long term initiative to support all military installations in Massachusetts, to enhance them, and explore opportunities to attract new missions. The initiative included supporting initiatives in pursuit of clean energy, energy security, and reduced energy costs.

The DOER and MassDevelopment led the initiative to assess clean energy opportunities at each of the six military bases in Massachusetts. Both the Commonwealth of Massachusetts and the US Department of Defense (DoD) share common goals to reduce energy consumption, increase clean energy generation and support energy security. The goal of this Clean Energy Assessment project was to identify energy efficiency, renewable energy and technology piloting possibilities at the bases that could reduce base operating costs and increase energy security.

The DOER and MassDevelopment assembled a team of state-level experts to provide input and guidance in for this project. This team consisted of representatives from the Military Task Force, Massachusetts Department of Environmental Protection (MassDEP), Massachusetts Clean Energy Center (MassCEC) and MIT Lincoln Laboratory. The Clean Energy Team has routinely consulted with this group and incorporated their feedback into our recommendations.

This report provides a summary of the most compelling clean energy and energy efficiency projects found by our team. The results of this study will be used to support future funding decisions and technical assistance for the implementation of recommended projects.

2.1 Study Approach

The DOER, MassDevelopment, and the Clean Energy Team worked closely with the six military bases in Massachusetts to identify and prioritize clean energy projects at each base. Developing a relationship with personnel at each of the bases was key to the success of this project. The military bases that participated in this project were:

- Barnes Air National Guard Base (Westfield, MA)
- Fort Devens (Devens / Ayer, MA)
- Hanscom Air Force Base (Bedford, Concord, Lexington and Lincoln, MA)
- Joint Base Cape Cod (Cape Cod, MA)
- Natick Soldier Systems Center (Natick, MA)
- Westover Air Reserve Base (Chicopee, MA)

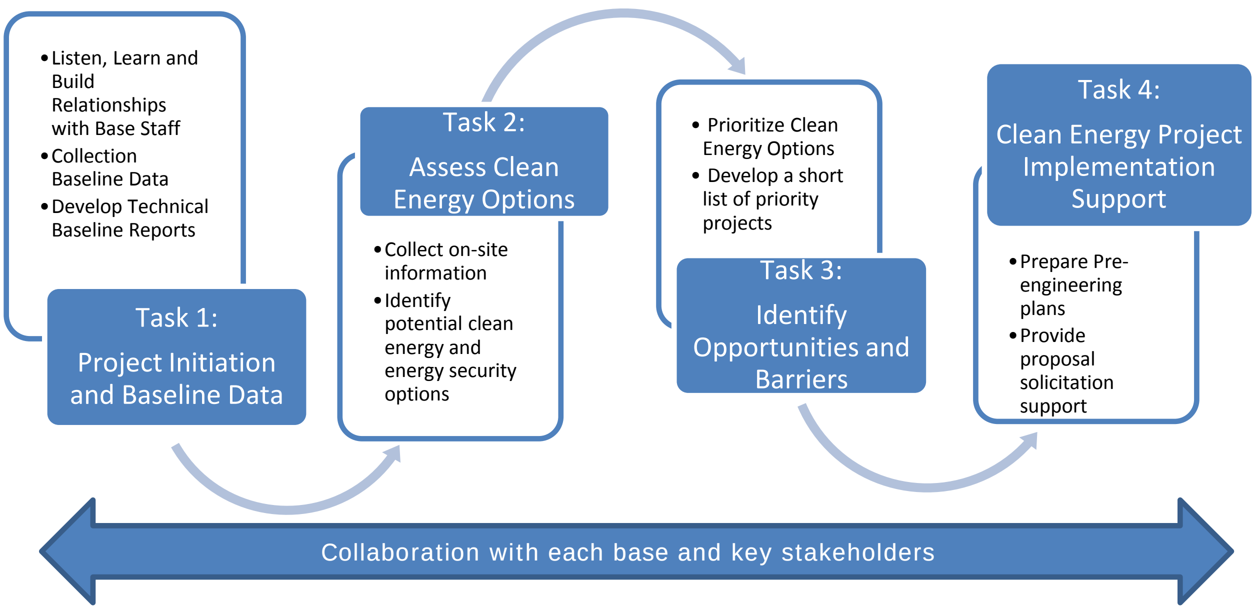
These diverse military bases encompass a range of active, reserve, National Guard and Coast Guard components with different chains of command and unique challenges and opportunities.

The military bases have experienced varied success in implementing clean energy and energy efficiency projects. Like private sector entities, funding constraints are a significant barrier. Moreover, the bases have traditionally been challenging for the Massachusetts Energy Efficiency Programs to influence through established financial rebate programs. The state’s current effort presented a significant opportunity to support local military installations, assess strategic clean energy opportunities, engage base personnel, and leverage regionally appropriate financial and technical resources.

The Clean Energy Team's process was to engage and work closely with base personnel, understand baseline conditions at each base, identify potential projects, analyze potential projects, and then prepare documentation for near-term implementation of selected projects.

Figure 2-1 provides an overview of the project approach and four primary tasks: Project initiation and gathering baseline data, assessing clean energy options, identifying opportunities and barriers, and providing project implementation support.

Figure 2-1 Overview of Project Approach



A fundamental part of each task was collaborating with base personnel and key stakeholders to gain a common understanding of desired outcomes, address issues or concerns and work together to identify new clean energy opportunities.

To initiate the project, Task 1 included discussion of existing conditions and clean energy technologies of interest to each base and key stakeholders. The project initiation task included background research and kick-off meetings with each base to identify existing initiatives, future plans, energy procurement strategies, operational patterns, and facility conditions. The Clean Energy Team also identified remediation projects, and any potential mission conflicts or site environmental impacts to be considered in assessing clean energy opportunities.

As part of Task 2, the Clean Energy Team then collected baseline data including utility billing data, relevant plans, reports (e.g. facility energy audits) and other documents on base facilities, infrastructure and equipment. The team also met with MIT Lincoln Laboratory and engaged with the utility providers (NSTAR, National Grid, Westfield Gas and Electric, Chicopee Electric, and Columbia Gas) to collect their feedback on the bases and on any recent energy projects at the bases.

The approach for assessing clean energy project opportunities was to cast a wide net and look at a range of clean energy technologies for each base. Each step of the project helped to narrow down the list of potential projects. Following the discussions and the baseline data collection effort, the Clean Energy Team developed a series of technical baseline reports to summarize information gathered at each installation and present a preliminary list of clean energy project opportunities for further analysis. The reports contained:

- An overall assessment of the recent energy usage at each base including electricity, steam, and fuel consumption for building conditioning, and fleet vehicles
- An assessment of base progress towards goals for federal building energy use intensity, renewable energy, and greenhouse gas (GHG) reductions
- A summary and assessment of operational clean and strategic energy projects underway or under development, particularly in relation to funding opportunities and priorities of the DoD and the services relevant to each base
- An inventory of key opportunities including planned new construction or retrofits to buildings, planned utility upgrades, and opportunities for renewable energy projects
- Information on the electric, gas, and water utilities that serve each installation including contact information for account executives
- An inventory of the energy use and opportunities relevant to any civilian operations on or near each installation.

After reviewing the technical baseline reports and preliminary lists of clean energy projects with each base, the Clean Energy Team developed site visit plans summarizing how each clean energy project opportunity would be evaluated in further detail. Where necessary, the Clean Energy Team conducted site visits to each base to confirm facility and site conditions, and gather additional data necessary for identifying potential projects. The Clean Energy Team identified 189 potential clean energy projects across the six military bases.

In the effort to provide meaningful guidance to the Military Task Force on this list of projects, the Clean Energy Team developed an approach for prioritizing the projects based on costs and benefits. The scoring approach allowed for the valuation of other co-benefits to be considered in the prioritization such as energy reliability, environmental impacts, community benefits, reduced air pollution, and ease of implementation. The projects identified will all provide value to the installations and communities. Many of these projects are eligible for state funding, federal funding, third party financing, or other options.

This report represents findings and recommendations associated with the clean energy projects identified for each base. These recommendations need to be carefully reviewed by key stakeholders. In some cases, there may be valid reasons for prioritizing other projects that were not captured by the prioritization approach. Following review of the results, a number of projects will be selected for further development, including solicitation and procurement documents that enable the bases to move forward with specific projects.

2.2 Organization of Clean Energy Focus Areas

The approach for assessing clean energy project opportunities was designed to systematically evaluate a potential projects according to defined list of clean energy focus areas for each of the six bases. Table 2-1 provides an overview of the clean energy focus areas and options that were included in this project.

Table 2-1 Summary of Clean Energy Focus Areas and Project Options

Clean Energy Focus Area	Potential Project Options
Buildings	Energy Management Control Systems
	Metering and Procurement
	Energy Conservation Measures
Central Plants	Combined Heat and Power
	Central Plant Energy Efficiency
Renewables	Solar
	Wind
	Anaerobic Digestion
	Biomass
Transportation	Alternative Fueled Vehicles / Electric Vehicles
Infrastructure	Microgrids
	Energy Storage
Environmental	Green Remediation
	Water / Wastewater

The clean energy focus areas span project options ranging from energy efficiency/conservation to on-site distributed generation (e.g., renewables) to infrastructure improvement projects (e.g., meters and control systems) to transportation. Emerging technologies were also included in the analysis across all focus areas.

The Clean Energy Team conducted a thorough assessment of the clean energy and energy efficiency opportunities at the base. Not all technologies or clean energy options were appropriate for each base. For example, many bases did not have central plants. Key findings from our review are summarized below for each base for the clean energy options that were applicable.

3 CLEAN ENERGY ASSESSMENT RESULTS

The Clean Energy Team found that significant opportunities for clean energy and energy efficiency enhancements exist at each of the bases in Massachusetts. Our recommendations focus on those improvements that have immediate impact on energy costs and enhance energy security. The results of the assessments are provided below along with a description of the activities at each of the bases for background purposes. Key projects are identified and summarized along with any notable barriers to project implementation. The bases are presented in alphabetical order.

3.1 Barnes Air National Guard Base

Barnes Air National Guard (ANG) Base is located in Westfield, MA and is home to the 104th Fighter Wing. The base consists of 185 acres including the airfield which is owned by the City of Westfield. The base maintains all operational aspects of their systems and airport infrastructure including snow plowing, maintenance, and security.

The overall mission of the104th Fighter Wing is to guard national airspace in wartime and peacetime, and maintain highly trained and well-equipped military forces. They provide combat-ready F-15 aircraft and all support elements. The base has several rapid response capabilities beyond their direct mission including: security, explosive ordinance disposal, fire, and civil engineering support. These services are also provided to the local community on an as-needed basis.

Barnes ANG currently employs roughly 700 traditional guardsmen and over 300 AGR/military technicians. This accounts for an annual payroll in excess of $36 million. In fiscal year 2012, the total operating budget for the base was $53.5 million.

Electricity and natural gas are provided by Westfield Gas & Electric. In 2013, Barnes ANG used approximately 4,984 MWh of electricity, at a cost of approximately $655,000. They also spent approximately $241,000 on natural gas. Both electrical and natural gas distribution lines are owned by the installation.

Most of the base has been a product of recent construction or renovation. Approximately 60% of the building stock has been constructed, significantly upgraded or remodeled in the past 10 years. Nevertheless, a significant amount of energy efficiency is already planned or underway at the base, and Barnes is the first base in Massachusetts to have installed smart meters for all facilities for electricity, natural gas, and water, with full trending capabilities. Within the last year, base personnel developed a $2.8 million package for efficiency measures comprising LED lights, on-demand hot water heaters, and replacement of fuel oil boilers with natural gas boilers.

The following recommendations are focused on augmenting and supporting the desired projects that were identified with help from base personnel in addition to projects identified via independent investigation.

3.1.1 Buildings

Barnes ANG Base features approximately 124 structures, 58 of which are buildings and facilities. The total square footage of space allocated to buildings is 471,063. The average age of the buildings is 22 years, with nearly 28% of the total square feet being constructed in the last 10 years. Additionally, many facilities have been recently renovated according to staff at the base. The total cost basis value listed on the Real Property Inventory is currently $78 million.

The Clean Energy Team discussed with base personnel and investigated potential opportunities for energy efficiency improvements. For buildings, the team focused on potential improvements to the building energy management control systems, metering infrastructure, and energy conservation measures.

Energy Management Control Systems

Most facilities on the installation have some form of direct digital control (DDC) within the facility, with varying levels of controls available depending on the equipment located within that facility. Our review of these systems found that there are several buildings which could directly benefit from improvements to the EMCS equipment including:

- Buildings 17, 27, 28, 53: No DDC controls currently in the facility. Therefore, install new DDC controls to improve equipment monitoring and operations.
- Building 33: The building needs DDC controls on roof-top unit 1 to improve monitoring and control of equipment.
- Building 401: There is no network connection to the building for DDC controls. Therefore, connect the DDC system to the base's EMCS network.

Metering and Procurement

Barnes ANG was found to have recently completed a metering project in which all facilities were retrofitted with smart meters for electricity, natural gas and water. These meters have full trending capability and the base will soon have access to a full year's worth of trended data. Because this project was recently completed and appear to be operating well, no additional project recommendations are provided for this clean energy focus area.

Energy Conservation Measures

To assess the potential for further energy efficiency in the buildings themselves, the Clean Energy Team reviewed a set of construction documents previously developed under a project known as the Energy Reduction Measure Project. The package of measures primarily addressed lighting, lighting control upgrades, installation of infrared heat pipes in larger hangar spaces, and building level controls enhancements to the EMCS (such as DDC controllers). Construction documents were completed for all projects in this package. These projects are ready to permit, bid and build.

Our team assessed this package of projects as well as a few additional opportunities. Additional opportunities for building level savings were identified by the Clean Energy Team. They include:

- **Building 29:** Replace existing dual fuel boiler and domestic hot water heater**.** The boilers and water heater were found to be operating beyond their life expectancy.
- **Building 31, 64, and 65:** Replace oil fired boilers with new high efficient gas boilers. The boilers were found to be operating beyond life expectancy. In addition to increased efficiency and reduced emissions, the update will eliminate oil deliveries and reduce base truck traffic.
- **Building 69:** Replace existing oil fired furnace with new high efficient gas furnace. This equipment was also found to be old and operating beyond life expectancy.
- **Munitions Area Exterior Lighting:** The area exterior from the perimeter security fence surrounding the Munitions Complex is illuminated by twin beam, 150 Watt high pressure sodium (HPS) flood light fixtures. Replacing all high-intensity discharge lighting with LED fixtures presents an opportunity for savings.

3.1.1 Renewables

The Barnes ANG Base has suitable area for potential photovoltaic (PV) systems. The City of Westfield had considered installing up to 4 MW solar PV on their property north of the main runway. The feasibility study for this project was not provided but interviews with base personnel indicated that the economics of entering into a power purchase agreement for a proposed array were not found to be cost-effective.

The team also considered wind turbines at the base, but these types of systems were found to only be worth consideration if the market conditions (i.e., technology performance, costs and electricity price) significantly improve or if the economic viability is not the primary driver for decision making.

Solar

The Clean Energy Team reviewed suitable sites for solar PV installations and identified opportunities for three types of systems: ground, carport and roof-mounted systems. The proposed locations for PV systems are based on our team's understanding of base operations, and expansion plans.

The largest, most suitable ground mount areas are located at the Munitions parcel. Barnes ANG has recently built five (5) hangars which have been identified as being prospects for rooftop solar. Additional rooftops have also been identified in case the hangar rooftops cannot support a solar PV system. The map in Figure 3-1 shows locations of the prospective sites identified by the Clean Energy Team.

Figure 3-1 Solar PV Sites Studied at Barnes ANG Base

Table 3-1 through Table 3-3 describe in more detail the solar PV project opportunities for ground-mount, rooftop, and carport sites. Access to the rooftops was not possible during the site visit. Therefore, the recommendations are based on aerial images. Preliminary input from base staff indicated preference for carport solar PV systems. Further evaluation of the building rooftop sites would require on-site verification of roof conditions as well as usable roof space for a solar system.

Table 3-1 Summary of Ground-mount Prospective Solar Sites

Ground-mount	Notes
GM3	The topography undulates and there appears to be a few natural drainage courses that cross from West towards the wooded area to the East, which makes this site less desirable.
GM2	The area is currently used as a baseball field and appears to be relatively flat lawn.
GM1	This area consists of two sites separated by the access road that to the Munitions area. Both sites appear to be suitable areas to support solar PV systems • GM1 North is a flat grass lawn. There appears to be vegetative swales along the West, South and East perimeter that will not be included as viable usable area. • GM1 South is a flat grass lawn. There appears to be vegetative swales along the Western and Northern perimeter that would not be included as viable usable area.

Table 3-2 Summary of Rooftop Prospective Solar Sites

Buildings	Notes
45, 46, 47, 13 and 19	These buildings appear to have: roofs that are pitched North and South midway, good orientation and no roof top obstructions (HVAC, conduit, screens, fans, etc.), with enough usable area on the Southern pitched roofs for small systems.
54, 29 and 26	These buildings appear to have flat roofs, good orientation and moderate roof top obstructions (HVAC, conduit, screens, and fans).

Table 3-3 Summary of Carport Prospective Solar Sites

Carport Sites	Notes
P1, P2 and P3	These sites are large, flat, open parking lots adjacent to buildings 29 and 20. The only potential challenges identified at this time are the light fixtures which are dispersed across the entire area.

3.1.2 Infrastructure

The base owns all of the infrastructure on the base property. The electrical supply is fed via a single primary meter through two feeders into a single substation. There is a single point of feed for the primary natural gas to the base, through a single utility owned meter. The water and wastewater distribution systems on base are also owned by the base.

The Clean Energy Team assessed opportunities for infrastructure modernization, increased efficiency, and improved resiliency. Since infrastructure systems appear to be in good condition, no significant opportunities exist for improvements to base infrastructure.

3.2 Fort Devens

Fort Devens is a US Army Reserve base located approximately 40 miles west of Boston, just outside of the towns of Ayer and Shirley, MA. The base is the major Army Reserve presence in New England, with history spanning back to 1917 when it was used as an activation and training center for soldiers during World War I. Many of the original buildings at the base were constructed at the onset of World War II, when the base was a designated reception center for all men in New England who would serve as draftees.

Today, the mission of Fort Devens is to provide operational, training, and logistic resources to tenants, other units, and area customers. More specifically, the base provides services and facilities to soldiers, family members, retirees, and civilian employees, and also serves as an active training site for Reserve and National Guard forces. Fort Devens is a subordinate installation of Fort Dix.

The base consists of the South Post Training Area, the Main Post, and a smaller parcel known as the 3400 block. The South Post Training Area supports over 130,000 service members and other personnel annually. Additionally, the South Post has 25 firing ranges, 24 training facilities, and 26 company-sized training areas. The Main Post contains lodging for soldiers (approximately 1,500 beds across 11 buildings), classrooms and conference facilities.

Fort Devens is eager to embrace renewable energy technology but have focused on their immediate need to renovate barracks and office buildings (including replacing mechanical and lighting systems). Projects include Buildings 674 and 3413, and those under design are 673 and 637. As funds have become available, base personnel have been able to convert flat-roofed barracks buildings to sloped, roofed, weatherized buildings that save energy and enhance comfort of visiting reservists and trainees. The base has sought and received studies on energy efficiency savings and renewables opportunities from several national labs, providing a roadmap of for efficiency projects and locations for potential solar PV installations.

The following sections describe clean energy opportunities that the Clean Energy Team identified with help from base personnel and through independent investigation.

3.2.1 Buildings

Due to the age and design of Ft. Devens' buildings, the greatest opportunities for improvements are related to building-level energy efficiency. Counting buildings of 800 square feet or more, Ft. Devens has 80 buildings totaling just over 1.3 million square feet. Building types include: barracks, dining halls, office buildings, a data center, instructional buildings, storage areas, vehicle maintenance shops, a chapel, theater, and a training center. The largest building is the North East Army Reserve Intelligence System Center, Building #3413, comprising 118,592 square feet.

The Clean Energy Team reviewed options for improving building EMCS and metering systems; however, the team found that there is no existing central communications network at Fort Devens that could connect an EMCS system while simultaneously meeting the DoD's "Networthiness" security requirements.

Metering and Procurement

While many of the buildings are individually metered by the local utility, the meters are not considered advanced meters and they cannot be read digitally. The primary barrier to an advanced metering system is the lack of a communications network to link the meters to a central location. However, data can be collected manually from each building, and data is reported monthly on electric and gas utility bills.

Since Fort Devens is on the Army Corps of Engineers Smart Metering Program list and due to the physical constraints of the communications infrastructure, the team did not assess any further metering projects for the base.

Energy Conservation Measures

A comprehensive energy and water audit project was completed for Fort Devens in early 2014 covering approximately 80% of the facilities on the installation. Based on a review of the previous study and energy efficiency retrofit projects underway, the Clean Energy Team identified a number of additional potential projects for further consideration. These include:

- **Building 3416. Replace existing Garage Bay Metal Halide (MH) 400 W fixture with LED fixtures.** The existing Garage Maintenance Bays was found to have 27 MH 400W lamp/fixtures. These lights are on for two shifts, 7 days a week. The Clean Energy Team recommends replacing these lights with LED fixtures.
- **Building 3415. Replace existing Warehouse MH (250W) Fixture with LED fixtures.** The existing warehouse has 68 MH 250W lamp/fixtures. The space is in use for 1 shift, 7 day per week. We recommend replacing these lights with LED fixtures. In addition, the existing occupancy sensors require calibration.
- **Buildings 637, 673, and 674. Upgrade fluorescent tube lights specified for near-term renovations to LED area light fixtures.**
- **Buildings 675 and 676. Install natural gas full building back-up generator.** Buildings 675 and 676 are currently used as computer classrooms and contingency command centers during regional/national disaster and other emergency events. The buildings currently have no back-up power source during a power outage. We recommend the installation of a single gas-fired full building generator, the installation if two automatic transfer switches, and other required electrical modifications.
- **Add roof and wall insulation to buildings 571, 601, 603, 617, 637, 638, 641, 642, 644, 646, 653, 656, 658, 665, 666, 667, 668, 669, 670, 672, 673, 674, 675, 678, 679, 680, 683, 689, 693, 694, 695, 696, 3911, 3912, and 3913.** Many buildings at the base lack adequate wall and roof insulation. Buildings have flat roofs with minimal roof insulation. Exterior walls are block, maybe in-fill insulation at the open cells. The base has developed a prototype roof/wall design and specification (which includes substantial insulation); the prototype has been used to install sloped roofs onto a handful of flat-roofed buildings.
- **Building 3413. Install a ground source heat pump**. The Clean Energy Team understands that Building 3413 is an office and computer center. During the site visit, access to the building was not obtained, but we understand that the HVAC is a water cooled system that includes electric chillers and open cell water cooling towers. The team recommends installing two pairs of pumps, two

plate/frame heat exchangers and ground source heat pump system. The feasibility of a geothermal field would need to be assessed by another entity.

- **Building 672. Replace existing gas fired boiler with a new high efficient gas boiler.** The existing boiler is in good condition but new higher efficiency gas boilers are available.
- **Building 673. Replace existing gas fired domestic hot storage tank with new high efficiency domestic water heater.** The existing boiler was found to be approaching the useful life expectancy. No data were available on the domestic hot water storage tank.
- **Building 672. Replace air handling unit and replace building pneumatic controls with direct digital controls (DDC).** The existing building pneumatic controls require replacement with DDC controls. Also the existing air handling unit is old and beyond its life expectancy. During the field visit, the Clean Energy Team found that the air conditioning unit has no direct return, per building operators. The controls are pneumatic and do not work. The air conditioning unit is past its expected useful life. Entire building and systems need to be over-hauled.

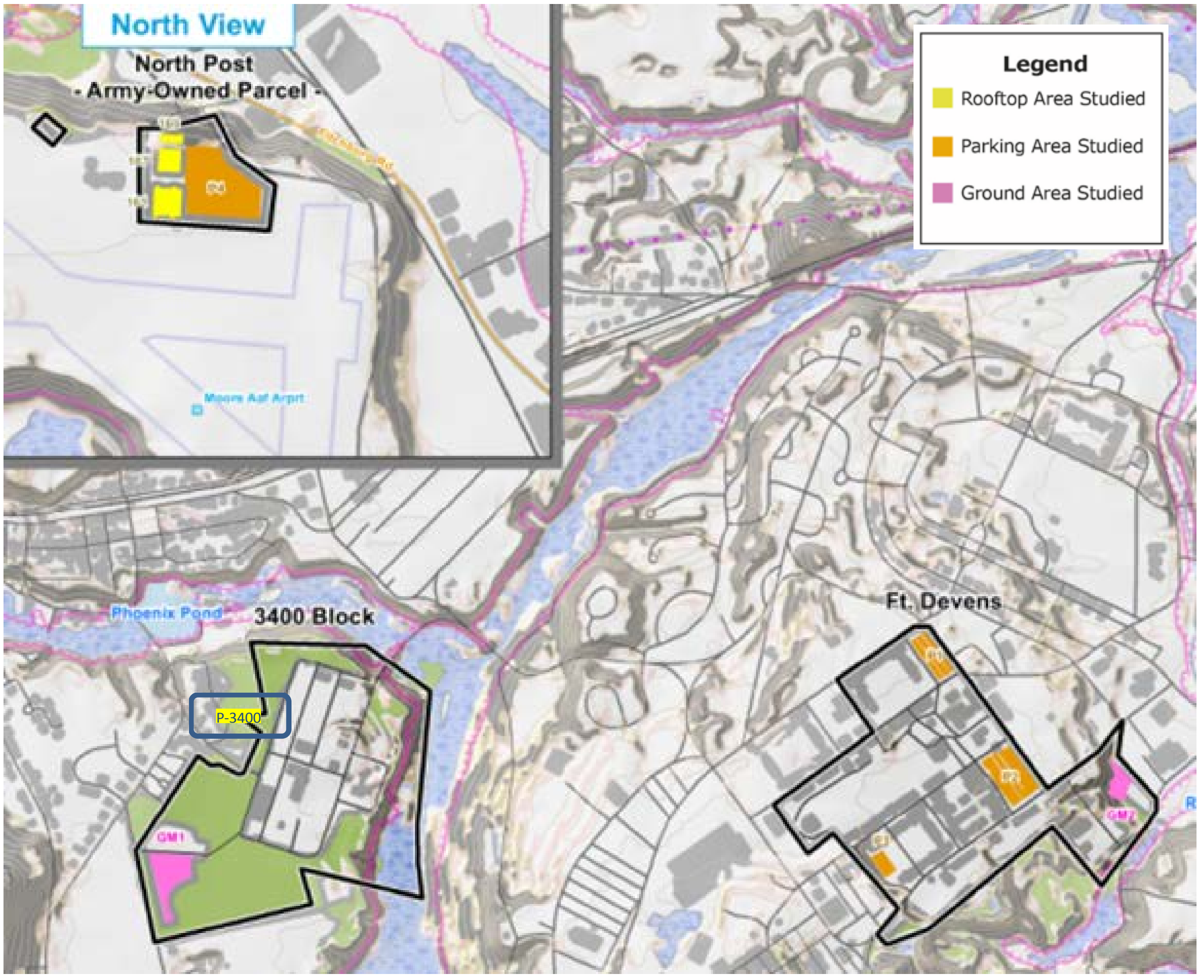
3.2.2 Central Plant

At one point, the base operated four steam plants that provided heating for base buildings, but all steam plants are now decommissioned, and all buildings have their own separate heating and cooling systems. Thus, no clean energy opportunities were identified related to a central plant or combined heat and power.

3.2.3 Renewables

An assessment of renewable energy project opportunities was conducted for Fort Devens spanning solar, wind, anaerobic digestion and biomass resources. Of these, solar PV systems were identified as a feasible clean energy opportunity. Fort Devens does offer some suitable areas to support solar PV systems. Figure 3-2 provides an overview of the sites assessed by the Clean Energy Team.

Figure 3-2 Solar PV Sites Studied at Fort Devens



The tables below identify the key opportunities for ground-mount solar sites and carport sites respectively. The team did not identify rooftops that had adequate southern orientation or roof space. For each type of project, the sites are listed in order of viability.

Table 3-4 Summary of Ground-mount Prospective Solar Sites

Ground-mount	Notes
GM2	The area consists of less than optimal easterly rolling topology and a lawn area that is adjacent to nearby buildings and accessible by adjacent roads or parking lots. A northern fence line is the assumed project boundary.
GM1	The area consists of relatively flat topology, a southern lawn area, and an east-west dirt road and baseball fields to the north.

Table 3-5 Summary of Carport Prospective Solar Sites

Carport	Notes
P1, P2 and P3	These areas are relatively large, flat, open parking lots adjacent to buildings, suitable to support parking canopy PV systems. These areas have overhead utilities, lighting, and some trees that will need to be avoided or relocated.

Based on a recommendation from the Fort Devens personnel, the parking lots in the 3400 block location were also evaluated for PV during the site visit. The existing area consists of multiple parking lots that vary in use designation from personal vehicles to construction equipment and military hauling equipment. It was noted the parking carports would need to accommodate a minimum 13'-6" height requirement and standard highway vehicle width. The systems here were found to have a payback period of over 28 years and therefore were not recommended.

3.2.4 Transportation

The mandates on military fleet vehicle management fall into two categories: vehicle procurement and petroleum and greenhouse gas savings goals. The Energy Policy Act of 1992, Executive Order 13423, and Executive Order 13514 have all taken steps to speed the adoption of Alternative Fuel Vehicles (AFVs) and reduce petroleum consumption and associated GHG emissions. Ground vehicle fleets at bases are typically composed of a mixture of vehicles owned by the base and vehicles leased from the General Services Administration (GSA). Base-owned vehicles and GSA-leased vehicles must follow replacement rules based on minimum accrued mileage, years of service, or pre-established maintenance budgets. As a result, vehicle turnover at bases is low and vehicles typically remain in service for extended periods of time.

Taking all of these factors into consideration, the Clean Energy Team evaluated opportunities for vehicle fleet replacements and fuel switching at Fort Devens. For each base's fleet, three strategies for reducing GHG emissions were considered:

1) Replacing existing vehicles with electric vehicles (EVs)
2) Replacing existing vehicles with hybrid electric vehicles (HEVs) and
3) Switching from fueling with pure gasoline to fueling with ethanol fuel blend of 85% denatured ethanol fuel and 15% gasoline (E85) for existing flexible-fuel vehicles.

Based on the fleet characteristics for Fort Devens, all three scenarios were analyzed. Table 3-6 provides for calculations of fuel reduction and CO_2 reductions.

Table 3-6 Potential Fuel and Emissions Impact of Fleet Change Strategies

Strategy	Number of Eligible Vehicles	Annual Reduction in Fuel Consumption (gallons)	Annual Reduction in GHG Emissions (CO2 in pounds)
EV Replacement	14	2,137	40, 493
HEV Replacement	4	8,230	155,959
Switch to E85 Fueling	24	9,232	212,537

It is important to note that some vehicles in the fleet could potentially be impacted by more than one strategy (i.e. vehicle X could be replaced by an EV or be replaced by an HEV). Thus, the annual reductions in fuel consumption and GHG emissions in Table 3-6 are not additive. All three strategies represent different paths towards reducing fleet GHG emission at Fort Devens. At Fort Devens, switching flexible-fuel vehicles from regular gasoline to E85 has the largest potential for reducing GHG emissions (212,537 lbs. annually), followed by replacing eligible vehicles with HEVs (155,959 lbs. annually). The up-front capital and fuel costs associated with these strategies are summarized in Table 3-7.

Table 3-7 Costs and Fuel Savings of Fleet Change Strategies

Strategy	Up-Front Infrastructure Cost	Purchasing Premium Per Vehicle	Percent Savings in Fuel Cost Per Vehicle
EV Replacement	\$6,000 - \$9,200[1]	\$19,200	83%
HEV Replacement	\$0	\$12,500	30%
Switch to E85 Fueling	\$20,000 - \$70,000[2]	N/A	-37%

[1] Cost of EV level II charging stations varies based on desired built-in features (e.g. ability to process and track credit card payments).

[2] Cost of E85 fueling station is on lower end of this range if an existing fuel tank can be converted to an E85 tank and on the higher end of this range if a new tank must be installed.

There are significant up-front infrastructure costs associated with replacing current vehicles, such as charging stations for EVs and fueling stations needed to switch from current flexible-fuel vehicles to E85. The per-vehicle premium for purchasing EVs (\$19,200) and HEVs (\$12,500) is also a significant cost to consider. Finally, while there are substantial per-vehicle fuel cost savings for EV replacements (83%) and HEV replacements (30%), the savings are negative 37% when running flexible-fuel vehicles on E85 instead of regular gasoline. This is due to the fact that a gallon of ethanol has less energy in it than a gallon of gasoline. Therefore, the team does not suggest pursuing these opportunities without subsidies.

3.2.5 Infrastructure

Electricity and natural gas are provided by the local utility operated by MassDevelopment. All electric distribution at Fort Devens is owned by MassDevelopment except at the South Range where the base owns the electric distribution system. The electric grid at the South Range of Fort Devens is mostly underground with 4,870 linear feet of buried electrical lines and only 25 linear feet above ground. The range has four transformers built in 2009. National Grid provides gas distribution services for the South Range. Each building has its own natural gas meter.

Potable water at Fort Devens is also supplied by MassDevelopment from a series of wells. For wastewater, there are four septic systems used for wastewater treatment at the South Post area otherwise wastewater flows are directed to local wastewater treatment plant.

The Clean Energy Team assessed opportunities for infrastructure modernization, increased efficiency, and improved resiliency. Given the good condition of the infrastructure systems, no significant opportunities were found for further improvements.

3.2.6 Environmental

The Clean Energy Team performed a desktop investigation of the types of remedial systems utilized at site with ongoing remedial actions at Fort Devens. Much of this information is publically available information on the MassDEP website. The desktop study indicated there are currently two active remediation systems in operation at Fort Devens with US Environmental Protection Agency (EPA) identification numbers.

- EPA Operable Unit 1 – Shepley's Hill Landfill (SHL), Areas of Concern (AOC) 4, 5, and 18: encompasses approximately 84 acres in the northeast corner of the Main Post of Fort Devens.
- EPA Operable Unit 8 - Moore Army Airfield, AOC 50: Operable Unit 8 consists of less than 2 acres of land and surrounds Buildings 3803, 3840, 3824, and 3801.

Further assessment found that both Shepley's Landfill and Moore Army Airfield are not part of Fort Devens current base operations. Therefore, the team did not conduct any further evaluation of these systems.

All other ongoing remedial actions at Fort Devens (as part of base operations) were found to be passive in nature (i.e., institutional controls, no action, or monitoring only), and therefore do not offer opportunities for the consideration of green remediation or remedial process optimization.

3.3 Hanscom Air Force Base

Hanscom Air Force Base, the only active duty Air Force base in New England, is an 846-acre base located in Bedford, Lexington and Lincoln, and bordering Concord. At the base, a mix of active-duty military, civilian and contractor employees develop and acquire sophisticated radar, cyber and information technology-based systems that provide critical battlefield situational awareness to US warfighters. Hanscom is also the home to the Massachusetts Army and Air National Guard's Joint Forces Headquarters.

Hanscom's host unit is the 66th Air Base Group whose mission is to provide worldwide support for the Air Force Life Cycle Management Center. The base supports more than 3,600 direct and 14,500 indirect jobs for a total of over 18,000 jobs, with a 2011 economic impact of $8.4 billion for the Commonwealth's economy. Additionally, the base provides services to more than 125,000 retired military personnel, annuitants and spouses living in the six-state New England area and New York.

Hanscom is also home to two major Air Force Program Executive Offices (PEOs): The PEO for Command, Control, Communications, Intelligence and Networks; and PEO Battle Management. One of Hanscom's newest tenants is the Joint Forces Headquarters, which is the combined headquarters of the Massachusetts Air and Army National Guards. In addition to the Joint Force Headquarters, Hanscom supports tenants, such as MIT Lincoln Laboratory, and other organizations outside of the base including the MITRE Corporation, and various DoD-related companies and groups.

There are many clean energy opportunities identified as applicable to Hanscom, including energy management control systems, energy efficiency/energy conservation measures, central plant combined heat and power, and several renewable energy options.

It is worth nothing that the Base Civil Engineer's office rigorously explores energy savings opportunities for the base and its facilities. The base has formed an Energy Management Steering Group that tracks progress toward total facility energy consumption, greenhouse gas reductions, fleet fuel reductions, and water consumption reductions. In addition to preparing to participate in demand response programs, the base is also preparing for an energy savings performance contract, which is a third party financed contract used to reduce energy and water consumption. Given the capacity and extent of distribution of its central steam plant, the base is considering the considerable energy and cost savings of supplanting some of its steam generation capacity with a natural gas co-generation plant. Civil Engineering personnel have also continued to develop economic scenarios and early feasibility studies for solar PV arrays and an anaerobic digestion plant. The implementation of any one of these projects would be a significant step toward achieving federal efficiency and renewables goals.

The following sections describe clean energy opportunities that the Clean Energy Team has identified with help from base personnel and through independent investigation.

3.3.1 Buildings

The base comprises a mixture of offices, military support facilities, research labs, testing facilities, and two public schools. The building stock represents over 4 million square feet of non-residential building space, many of which were originally constructed in the 1950's and 60's. The base also contains extensive residential housing totaling 732 single and multi-family units.

Energy Management Control Systems

The Clean Energy Team found that Hanscom is taking a phased approach to replace their N2 and other outdated controllers, and nearly all of them have been upgraded and migrated to the new Extended Architecture Metasys server. The only facilities that have not had the controllers upgraded are a few unoccupied facilities in the 1100 block that are located within the potential footprint of a newly proposed Massachusetts Institute of Technology's Lincoln Laboratory (MIT LL) facility, which is the largest tenant of Hanscom Air Force Base. These controls will be upgraded as part of the renovation process should these facilities become occupied again.

Most of the HVAC equipment on the installation is controlled or visible via the Metasys interface. While the system is in good repair, recomissioning the EMCS in order to ensure that occupied and unoccupied set points are up-to-date could save energy and money with a relatively small investment of labor.

Metering and Procurement

The steam meters at the central plant need to be replaced as they no longer provide accurate measurements of plant production. In addition, the steam meters throughout the system should be replaced or re-commissioned in order to ensure that steam usage throughout the base is accurately measured and recorded. This is important, as steam is a major component of the energy consumption at Hanscom.

Energy Conservation Measures

The base has a number of ongoing initiatives to reduce energy consumption on base, including raising set points, cycling heating, ventilation and cooling (HVAC) units, and turning off non-essential lighting. Energy conservation measures (ECMs) identified for Hanscom focused on replacement of heating and cooling systems for buildings that are not on the central steam plant. They include:

- Replacing existing oil fired boiler serving the buildings (as listed below) with new high efficiency gas fired boiler or an alternative fueled systems: 1065, 1101, 1103, 1118, 1603, 1608, 1712, 1810, 1811, 1812, 1814, 1823, and 1827
- Installing ground-source heat pumps for buildings 1436, 1603, 1605, and 1721
- Installing a new furnace for building 1851. The hot air furnace was found to be in fair/poor condition. The Clean Energy Team recommends replacing the existing furnace with a new furnace and associated controls.

3.3.1 Central Plant

Hanscom's central steam plant and year-round steam load provide an opportunity for a combined heat and power (CHP) plant or a combined heat, power, and cooling (CHPC) plant. The recent agreement to tap the Kinder-Morgan natural gas pipeline that runs through the site should result in an advantageous fuel price that enhances the viability of a CHP or CHPC plant at Hanscom.

Based on the energy analysis performed, the Clean Energy Team sized the plant at 9.2 Megawatts (MW) with two turbine-based engines operating at 4.6 MW each. Due to the nature of the electrical distribution system at Hanscom, with a distinct Air-Force electrical system and a separate MIT LL system, this analysis is based on one engine serving each electrical distribution system independently, unless the systems are reconnected again at a later date. The basis of the energy and cost models developed is the Solar Mercury 50 Turbine system, which is a recuperated gas-turbine generator set.

A heat recovery steam generator (HRSG) is utilized to extract heat from the exhaust stream of the turbine generator set. There are also many potential configurations of HRSG's, including the addition of a supplemental gas burner in order to increase the steam output. This analysis assumes that two HRSGs would be required, one for each generator; however, it might be possible to use only one, reducing operating expense and perhaps improving thermal efficiency. The existing boiler plant will remain in place in order to provide redundancy and also meet the demand that is not met by the HRSG system.

Although it was originally thought that the addition of an absorption chilling system would be beneficial, the team has analyzed a system without it. The cogeneration system included in this analysis has a heat output that can be used in its entirety for most of the year, and therefore an absorption cooling system to add thermal demand in the summer is not necessary. As the analysis is refined and optimized during a detailed engineering study, it might again be considered, depending on engine configuration options.

In addition to combined heat and power, energy efficiency opportunities at the existing central steam plant were also assessed. The Clean Energy Team recommends that either the variable frequency drive (VFD) is removed from the Bell & Gossett pump or the motor is replaced with a VFD compatible motor. The Bell &

Gossett pump is not VFD compatible and operating as currently installed could potentially wear down the bearings.

3.3.2 Renewables

A number of renewable energy opportunities were assessed for Hanscom Air Force Base, with possibilities related to solar, wind and anaerobic digestion.

Solar

Hanscom is pursuing solar PV installations to increase renewable energy sources and reduce costs. To complement this effort the Clean Energy Team reviewed suitable sites for solar PV installations to identify opportunities for ground-mount solar sites, rooftop, and carport sites. Figure 3-3 shows locations of the prospective sites assessed by the Clean Energy Team.

Figure 3-3 Solar PV Sites Studied at Hanscom

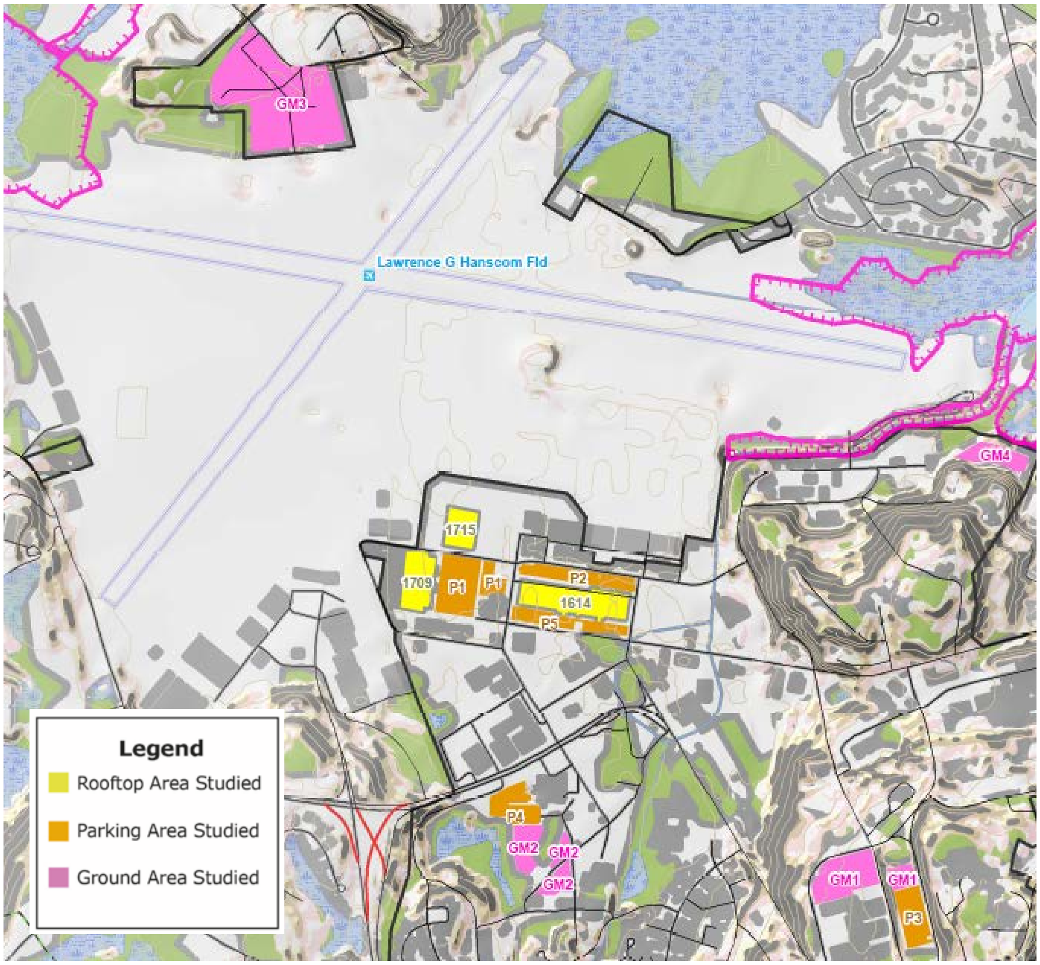


Table 3-8 through Table 3-10 identify remaining solar PV project opportunities for ground-mount solar sites, rooftop sites, and carport sites. For each type of project, the sites are listed in order of what the team considers the most viable.

Table 3-8 Summary of Ground-mount Prospective Solar Sites

Ground-mount	Notes
GM3	The location appears to be both an open field and an abandoned parking area that could be restored as a large PV system. No photos were taken here as the team field technicians were told this is not a part of the base.
Naval Weapons Industrial Reserve Plant area	This appears to be a suitable area to support a solar PV system. Areas 1, 2 and 3 are flat abandoned parking lots. Should this area be acquired and the land dedicated to installing solar PV for the benefit of the base, a site visit and direction from the base on usable land area is recommended.
GM4	The area is a capped landfill, appears to be relatively flat, and consists of mixed field vegetation. The site is fenced off and CEC members were not permitted access within, thus the landfill slopes were not ascertained.
GM1	This site consists of two sides, a larger area to the west side of the road (referred to as GM1 West) and a smaller area to the east (GM1 East). Both sites appear to be suitable areas to support a solar PV system.
GM2	The area consists of a three flat, lawn areas, divided by paved paths, adjacent to nearby buildings and accessible by adjacent roads or parking lots.

Table 3-9 Summary of Roof-top Prospective Solar Sites

Buildings	Notes
1709 and 1715	The roofs were relatively new, flat, in good condition and have a minimal amount of roof top obstructions (e.g. HVAC, conduit, screens, and fans). Solar access appeared to be good with no significant shading concerns.
1614	Though the team was not allowed access to the roof top to take photographs, aerial images depict a moderate to high amount of roof top obstructions. Heightened security for this building also means it is a poor candidate for solar PV.

Table 3-10 Summary of Carport Prospective Solar Sites

Carport Sites	Notes
P1	This area is a large, flat, open parking lot adjacent to buildings 1709 and 1715. The only potential challenges to this site are the recently upgraded light fixtures which are dispersed across the entire area.
P3	It is flat and relatively open, with trees bordering the east and south sides. The recently upgraded light fixtures are located around the perimeter.

P5	As with P1, it is flat and open, but has recently upgraded light fixtures distributed through the entire area.
P2	This area is bordered by building 1614 to the south. It is very similar to P5 in size and shape, but has a center island running lengthwise through the lot, with trees and light fixtures distributed the whole length of the island.
P4	Parking area P4 is bordered by building 1900 to the East. There are a few trees and light fixtures distributed throughout the parking area. The carport site appear to be suitable for supporting a PV system

Wind

The Clean Energy Team reviewed a wind potential study[1] for Hanscom's Fourth Cliff site, which is a 56 acre recreational area in Scituate, MA. The site is located along oceanfront and includes 25 cottages and a small recreation center. The estimated annual wind speed averages at the Fourth Cliff site range from 4.7 meters per second (m/s) at 30 meters (m) above ground level to 6.2 m/s at 100 m above ground level. The team estimated the levelized cost of wind electricity (without incentives) for medium-scale wind to be generally well above utility prices for the base. However, state incentives can make a medium-scale wind project at the Fourth Cliff economically viable. For large-scale wind, the levelized cost is estimated at $150/MWh compared with $200/MWh for utility electricity. Therefore, large-scale wind turbines appear viable and may warrant further investigation. The recommended follow-up action is to perform a preliminary fatal flaw analysis covering topics such as National Environmental Policy Act (NEPA) and environmental issues, site suitability, and social acceptance including noise and shadow flicker.

Anaerobic Digestion

Civil Engineering staff has been investigating anaerobic digester technology for the processing of food waste at the facility and for the generation of electricity.

The Clean Energy Team found that a large-scale anaerobic digestion system does have potential at the base. Key issues to consider would be food waste resource availability and logistics, as well as overall strategic planning of the most appropriate on-site generation (i.e. natural gas or electricity) that will meet the base's energy needs.

Civil Engineering has also noted that a 9 MW max CHP system at the central plant and a PV project are of interest. If the anaerobic digestion system is chosen as a priority project by DOER and the base to pursue further, the Clean Energy Team will recommend evaluating the use of methane created by the facility to partially offset the natural gas purchased by the base.

3.3.3 Transportation

The mandates on military fleet vehicle management fall into two categories: vehicle procurement and petroleum and greenhouse gas savings goals. The Energy Policy Act of 1992, Executive Order 13423, and Executive Order 13514 have all taken steps to speed the adoption of alternatively fueled vehicles (AFVs) and

[1] National Renewable Energy Laboratory. Federal Energy Management Program Renewable Energy Technical Assistance for the "Assisting Federal Facilities with Energy Conservation Technologies" (AFFECT) Grant , Air Force – Fourth Cliff Site – Wind. November 2013.

reduce petroleum consumption and associated GHG emissions. Ground vehicle fleets at bases are typically composed of a mixture of vehicles owned by the base and vehicles leased from the GSA. Base-owned vehicles and GSA-leased vehicles must follow replacement rules based on minimum accrued mileage, years of service, or pre-established maintenance budgets. As a result, vehicle turnover at bases is low and vehicles typically remain in service for extended periods of time.

Taking all of these factors into consideration, the team evaluated opportunities for vehicle fleet replacements and fuel switching at Hanscom. For each bases fleet, three strategies for reducing GHG emissions were considered: 1) replacing existing vehicles with EVs, 2) replacing existing vehicles with HEVs, and 3) switching from fueling with pure gasoline to fueling with E85 for existing flexible-fuel vehicles. Based on the fleet characteristics for Hanscom Air Force Base, all three scenarios were analyzed, and the results are provided in Table 3-11.

Table 3-11 Potential Fuel and Emissions Impact of Hanscom Fleet Change Strategies

Strategy	Number of Eligible Vehicles	Annual Reduction in Fuel Consumption (gallons)	Annual Reduction in GHG Emissions (CO2 in pounds)
EV Replacement	14	7,250	137,468
HEV Replacement	41	3,124	59,200
Switch to E85 Fueling	62	13,715	315,745

It is important to note that some vehicles in the fleet could potentially be impacted by more than one strategy (i.e. vehicle X could be replaced by an EV or be replaced by a HEV). Thus, the annual reductions in fuel consumption and GHG emissions in Table 3-11 are not additive. All three strategies represent different paths towards reducing fleet GHG emissions but at Hanscom Air Force Base, switching flexible-fuel vehicles from regular gasoline to E85 has the largest potential for reducing GHG emissions (315,745 lbs. annually). There are varying up-front capital and fuel costs associated with each strategy. Table 3-12 summarizes these costs.

Table 3-12 Costs and Fuel Savings of Hanscom Fleet Change Strategies

Strategy	Up-Front Infrastructure Cost	Purchasing Premium Per Vehicle	Percent Savings in Fuel Cost Per Vehicle
EV Replacement	$6,000 - $9,200[1]	$19,200	83%
HEV Replacement	$0	$12,500	30%
Switch to E85 Fueling	$20,000 - $70,000[2]	N/A	-37%

[1] Cost of EV level II charging stations varies based on desired built-in features (e.g. ability to process and track credit card payments).

[2] Cost of E85 fueling station is on lower end of this range if an existing fuel tank can be converted to an E85 tank and on the higher end of this range if a new tank must be installed.

As noted previously, are significant up-front infrastructure costs associated with replacing current vehicles with EVs and E85 fuel. The per-vehicle premium for purchasing EVs ($19,200) and HEVs ($12,500) is also a significant cost to consider. Finally, while there are substantial per-vehicle fuel cost savings for EV replacements (83%) and HEV replacements (30%), the savings are negative when running flexible-fuel vehicles on E85 instead of regular gasoline (negative 37%) because a gallon of ethanol contains less energy than a gallon of gasoline. Therefore, vehicles running on E85 consume more gallons per mile but produce fewer greenhouse gases overall.

If HEV and EV purchases and infrastructure upgrades, such as electric charging stations, are subsidized, then there are real fuel and emissions savings to be achieved. The case for E85 is less attractive in that fueling stations have to be altered and the fuel itself costs more per mile travelled. The benefits are reduced CO2 emissions and vehicles that are E85 ready (i.e., without modification).

3.3.4 Infrastructure

The existing electrical system on the base is owned and operated by Hanscom. There is one substation on the base. NStar's local distribution system has three feeds coming into the main substation. The substation is located next to the central steam plant on the base. The capacity of the electrical system appears to be sufficient to support additional on-site generation. Since 1998, Circuits 1, 2, 2A and 4 were placed underground.

The natural gas infrastructure is under a mixed ownership. Part of the system is owned and operated by National Grid. The other part is owned by the base. The total capacity of the natural gas distribution system is 884 million cubic feet (MCF)[2]. The most recent annual consumption numbers indicate that consumption is about 650 MCF (650,117 MMBtu). In addition, Kinder Morgan owns a natural gas transmission pipeline that runs through the base. This 24-inch steel line enters the base fence-line north of Hartwell Avenue and runs northeast to southwest across the base towards the residential area and next to Heritage Road.

Hanscom's central heating plant provides steam heat to approximately 70% of the base facilities, excluding housing, through 39,000 feet of steam lines, which are mostly underground. The base has spent about $6-$8 million annually on energy projects in the last five years. The Civil Engineering staff at Hanscom has dedicated a good portion of these funds, including the DoD's Energy Conservation Investment Program funds, on maintaining the steam system by fixing leaks and updating controls.

Microgrids

In addition to evaluating the potential for CHP assets at Hanscom, the Clean Energy Team also analyzed whether a microgrid would be technically and economically feasible at the base. The analysis focused on five microgrid configurations of varying sizes and technologies. Generation and storage assets comprising combined heat and power gas turbine generators, ground-mounted solar PV units and a utility-scale lithium ion electric battery. The capital investment for the configurations varied between $21- $40 million, although all of the configurations were financially viable. The discounted, 15-year return on investment was in the range of 23% - 40%. Under outage conditions, the microgrid would significantly increase the electricity reliability supply to critical loads. Additionally, the microgrid configurations analyzed would increase the overall efficiency of CHP to supply thermal and electric loads compared with purchasing electric energy from the utility grid and the use of inefficient boilers.

[2] Ibid

The following key factors contribute to a compelling case for microgrid installation at Hanscom:

- The viability of a large centralized CHP plant to replace the existing steam plant.
- Availability of real estate conducive to the installation of MW-scale ground-mounted solar PV plants.
- Base ownership of the distribution system and suitability of the system for microgrid infrastructure upgrades.

The existing electric distribution system at Hanscom is suitable for accommodating microgrid infrastructure but with modifications. A capital investment of about $1.5 million is required to enable islanded operation with automated transfer, load shedding and network re-configuration.

The Clean Energy Team recommends that any investment in distributed generation include a diverse portfolio of complementary generation and storage technologies that would be managed through centralized microgrid controls. This would enable Hanscom to realize the full potential of its energy assets and achieve DoD goals for energy security at its bases.

Energy Storage

A stand-alone electric storage installation at Hanscom is not financially viable at present. The team has modeled in detail a 600 kW, 4-hour lithium–ion electric storage device installed in the vicinity of building 1505. The associated capital expenditure is $1.9 million and the 15-year discounted net present value is -$806,000, which equates to a Return on Investment of -40.5%. The annual average energy bill savings with the device is $129,000, with the entirety of the savings derived from reduction in peak demand charges.

Although the financial return is poor for a stand-alone device, our analysis shows that storage installation coupled with solar PV is viable from a financial and technical perspective. It is also relevant to keep in mind that the reliability benefits of storage have not been monetized in this analysis, and no federal or state incentives for stand-alone storage have been considered.

Fuel Cell for Hanscom Collaboration and Innovation Center

As part of enhancing resiliency and incorporating cleaner energy sources at the base, the Clean Energy Team considered the installation of a fuel cell to address the full building electrical load of the Hanscom Collaboration and Innovation Center. The measure looks at the economics of installing a molten carbon stack fuel cell with a capacity of 800 kW at 75% utilization, which would offer N+2 backup. When the fuel cell electricity production exceeds the building's load, it would energize the local distribution system at the base. Initial estimates achieve a positive net present value for a molten carbon fuel cell operating over a 15-year life cycle. The estimate account for two stack replacements over the life cycle.

Water/Wastewater

The Town of Lexington provides most of the potable water supply for Hanscom. The water distribution system at Hanscom dates back to the 1940s. Some of the piping is cast iron, but the majority is asbestos and needs to be replaced to address concerns of quality and infrastructure integrity.

Hanscom discharges sanitary sewage into the Massachusetts Water Resources Authority system. There are two sanitary sewer pumping stations at the base: the lower station at Building 1539 and the upper station at Building 1306. The base does not operate a wastewater treatment facility.

The Clean Energy Team assessed the pumps at Hanscom's Upper and Lower Sewer Lift Stations in an effort to determine the hydraulic efficiency of each pump. Energy and cost savings could be achieved by rebuilding the existing pumps and restoring them to their original operating efficiency. A pump rebuild would include pump disassembly, blast and cleaning, replacement of bearings and packings as required, replacement of the mechanical seal, new painting and coatings, and reassembly and re-installation.

3.3.5 Environmental

The ongoing environmental issues at Hanscom Air Force Base and neighboring Massport's Hanscom Field include environmental remediation of contaminated areas. The investigation of contaminated areas at Hanscom Air Force Base and Massport's Hanscom Field dates back to the 1980s; in 1994, Hanscom Air Force Base and Hanscom Field were placed on the EPA National Priorities List and are considered a Superfund site. There were 22 individual sites with known or suspected contamination; six of these sites have on-going remedial actions. These six sites include:

- Fire training area II
- Paint waste disposal area
- Jet fuel residue/tank sludge disposal area
- Sanitary landfill
- Landfill / former filter beds
- Unit 1 petroleum release site

Cleanup remedies have been implemented at all sites and have been found to be protective of human health and the environment. The federal government has started an initiative known as Green Remediation. The concept of Green Remediation is to ensure that remediated sites, including Superfund sites, are remediated using methods that are energy efficiency and incorporate renewable energy and other technologies to reduce energy and water consumption during the remedial process.

Energy and cost savings could be achieved by rebuilding the existing pumps or retrofitting with new pumps at Well 1 and 2. A pump rebuild would include pump disassembly, blast and cleaning, replacement of bearings and packings as required, replacement of the mechanical seal, new painting and coatings, and reassembly and re-installation. By rebuilding the pump, the operating efficiencies would be restored to like-new conditions.

The remediation treatment system also includes two centrifugal blowers, one of which operates continuously. It may be feasible to replace the blowers with high efficiency units that operate on variable frequency drives and to install a control system to automatically regulate the speed of the blower.

3.4 Joint Base Cape Cod

Joint Base Cape Cod (JBCC) is a 22,000 acre base located on the western end of Cape Cod. Modern military presence at JBCC dates back to the late 1930's and early 1940's when the state legislature approved the acquisition of the properties forming Camp Edwards.

The base is primarily bounded by Massachusetts Route 28 to the west, south and east and US Route 6 to the north and is surrounded by the Towns of Bourne, Sandwich, Mashpee, and Falmouth. The four primary military commands located at JBCC are:

- **Otis Air National Guard (ANG) Base –102nd Intelligence Wing (102IW).** The 102IW supports both the Commonwealth of Massachusetts and the U.S. Government in line with national security objectives as dictated by either peacetime or wartime needs or requirements, and assists state authorities during national disasters, civil disturbance, and other emergencies at the call of the governor.
- **Camp Edwards – Army National Guard (ARNG).** Camp Edwards serves to command, operate, manage and administer the Maneuver Training Center-Light to accomplish all assigned missions. The base provides year-round service through administrative, engineering, logistical, training and operational support to the assigned, attached, transient, or tenant units and joint forces activities for multiple battalions.
- **Cape Cod Air Force Station – 6th Space Warning Squadron.** The mission of the Air Force PAVE/PAWS (radar station) and specifically the 6th Space Warning Squadron is to survey air and space to detect, track, and report missile launches and high-interest satellite passes. The 140 active duty U.S. and Canadian military, and BAE Systems contractors conduct surveillance and continuously track events.
- **Coast Guard Base Cape Cod – U.S. Coast Guard.** Base Cape Cod hosts the only Coast Guard aviation facility in the northeast and is responsible for the waters from New Jersey to the Canadian border. In addition, Base Cape Cod provides personnel services, comptroller, electronics, and facilities maintenance support to all local Coast Guard units. The base provides medical and community service support to all USCG personnel and local DoD agencies. Shore infrastructure consists of 217 housing units, over 1.4 million square yards of runway and taxiway, and nearly 100 buildings (operational and non-operational). Approximately 500 USCG personnel work at Base Cape Cod.

In recognition of the shared energy savings opportunities and benefits of knowledge sharing, member agencies at JBCC have formed an energy team. The collaboration of this team has resulted in the installation of over 7.5 MW of wind power on base property since 2009. The electricity generated offsets all of the consumption of remediation pump and treat systems and approximately 50% of the operations at Cape Cod Air Force Station.

Individual bases have tackled their facilities and operations and continue find projects to convert to additional savings. The 102IW at Otis ANG was ranked second, up from eighth the year before, on the Air National Guard's Top Ten List for energy intensity reduction for FY2013. The 102d Intelligence Wing has recently completed a comprehensive interior lighting retrofit by utilizing services and funding through Cape Light Compact (CLC) and Camp Edwards has done the same with CLC and improved lighting, heating and water utilities at their 5500 Area Housing. The Cape Cod Air Force Station replaced their two, 450-ton chillers with new high efficiency units (an anticipated $100K savings) and replaced lights and motors, installed variable frequency drives for an additional anticipated savings of over $100K. In its newest construction, the Coast Guard achieved a LEED Silver building featuring a geothermal heat pump and rain water harvesting systems. The hangar was projected to achieve a 52% energy savings and a 35% energy cost saving over conventionally designed building.

The following sections describe clean energy opportunities that the Clean Energy Team has identified with help from base personnel and through independent investigation.

3.4.1 Buildings

There are approximately 1,000 buildings at JBCC, with varying ownership and tenancy arrangements across each military command. Given the age of the buildings, many energy efficiency and energy conservation measures were identified across the base.

At the 102IW there are 155 facilities reported as Air National Guard controlled, but a majority of these buildings are leased to other military and non-military entities. Of the 155 buildings listed, 57 buildings are used by the 102IW, totaling more than 600,000 square feet of floor area. The 102IW has gone through a process of demolishing some older facilities in recent years. In 2011 alone, the 102IW reduced its facility square footage by nearly 100,000 square feet, including the demolition of 19 buildings, and the entire Petroleum, Oils, Lubricants facility that had over 1 million gallons of fuel capacity.

According to Army National Guard officials, Camp Edwards has completed a 5-year capital plan investing $40 million in improvements to the base and is now implementing a 3-year plan for which $46.5 million of funds is allocated. Camp Edwards lists 606 separate facilities in its inventory alone. Of these assets, 214 represent buildings totaling 1,057,006 square feet. The average age of these facilities is 38 years, with 56 showing a date of service of 1942 and 109 being built before 1980. The largest single building, totaling over 77,000 square feet is the Army Aviation Support Facility #1.

At Air Force PAVE/PAWS, there are 72 assets listed in the Automated Civil Engineering System including 17 buildings totaling 119,772 square feet. The average age of all buildings is 28 years. At over 65,000 square feet, the Scanner Building is five times larger than the next largest, the Electric Power S Building at 12,936 square feet. All the remaining 15 buildings cover fewer than 10,000 square feet combined.

Finally, the Coast Guard maintains 43 operational buildings covering 408,674 square feet as well as 217 family housing units totaling over 1.1 million square feet. Of the Coast Guard non-residential buildings, nearly 166,000 square feet or 40% of the total are hangars. The other large buildings on the base include the barracks and housing which total another 80,000 square feet or 20% of building square footage. The ages of buildings range from under 5 years to 55 years.

Energy Management Control Systems

The EMCSs at the individual bases at JBCC range from updated and in good repair to non-centralized, local systems. At Otis ANG, the 102IW is working with several systems from various vendors and eras. Personnel believe there could be substantial savings by leveraging a single, unified building automation system across the installation. An energy audit performed by Booz Allen Hamilton in 2011 supports the expansion and retuning of the EMCS, which they estimated to result in over $55,000 in annual savings. They cite a lack of controls capabilities for the existing system, as well a lack of night/unoccupied setback programming.

Camp Edwards has recently renovated its gym and has an advanced energy controls package that is local to the facility. Many other facilities occupied by the Army National Guard also have controls in the form of local thermostats linked to the heating for the facility; however, few buildings have built-up air conditioning. In fact, many facilities are using window AC units to meet cooling needs. Discussions with Camp Edwards base personnel indicate that often many of the facilities are unmanned, or are only used for 2-3 days every 2-3 weeks. Without significant loads to control, an EMCS would be very costly and yield little to no savings.

At Air Force PAVE/PAWS, a Johnson Controls system upgrade was recently installed. All of the large energy loads at the base are connected to the EMCS, and setpoints are monitored and controlled through the system. Since the system is performing as expected, no additional EMCS projects were identified for this base.

The Coast Guard does not have a basewide EMCS, and most of the facilities are controlled via thermostats linked directly to the specific equipment. The base is requesting guidance from the Coast Guard on how they should implement a centralized EMCS. As the Coast Guard is working on an approach for EMCS, we do not recommend investing in anything other than local equipment controls until a standard and methodology for networking these controls can be established.

At this time, the Coast Guard has a wireless advanced metering system installed to track electrical consumption in operational buildings. The system is active but is not sending data to the manufacturer's server for monitoring and management. The Coast Guard indicates that, if corrected, the advanced metering system could be a primary energy management system tool for them.

Energy Conservation Measures

Many energy efficiency and energy conservation measures were identified across the four military commands at JBCC. The main opportunities appear to be related to boiler replacements and lighting.

102IW

The 102IW has identified a number of ECM's but the most pressing is replacement of twenty boilers that were installed after the central heat plant was demolished in 1992. The boilers provide hot water (180°F) for heating and domestic hot water, along with high temperature hot water (140°F) and steam for dining facility needs. The boilers associated with 19 buildings[3] have now outlasted their useful lives and are proving costly to repair.

Other potential building energy efficiency projects at the 102IW include:

- **Demand Control of Ventilation at Building 104 Communications Facility:** The facility is served by a mixture of heating and cooling systems. The Air Handling Unit (AHU) provides ventilation for the building. Some of the spaces served by the AHU are of variable occupancy and the system is designed for maximum occupancy. This measure proposes to implement demand ventilation control of the variable occupancy spaces served by the AHU. With this control, space mounted CO2 sensors would monitor the occupancy levels of the space to control the VAV box minimum position. This control would allow the heating and cooling delivered to these spaces to be minimized during times of low to no occupancy while still allowing the system to serve the design occupied loads of the space.

[3] Buildings 120, 122, 149, 155, 156, 158, 159, 162, 167, 186, 189, 197, 322, 330, 430, 754, 971, 5236, 5238

- **Variable Speed Drive Control of Hot Water pumps at Building 162:** The hot water pumps serving this building are 5 hp each and are currently constant volume to serve the HVAC systems in the building. This measure proposes to install variable speed drives to control the hot water flow. In addition, the cooling for the facility is provided by a 65-ton air-cooled chiller mounted outside the building on grade. Potential improvements here include the implementation of variable speed control of the condenser fans which will provide fan energy savings as well as make the chiller more efficient with better set point control.
- **Office Exhaust Fan at Building 971 Civil Engineering:** A previous study conducted in 2011 suggested a measure to remove a constantly operating exhaust fan in operation in one of the offices. This fan could not be located during the field survey of the building. Since this fan would be serving an enclosed private office, it would be better to implement occupancy control of the fan rather than removing it. If this fan is still in operation, it should be put under the control of a space mounted occupancy sensor that would allow the fan to operate only when the space is occupied. This would result in fan energy savings with less demolition and impact to the comfort of the occupant.
- **Programmable Thermostats/Night Setback at Building 971 Civil Engineering:** The administrative spaces for the facility are served by a mixture of split cooling units and a penthouse AHU that provides heating, cooling and ventilation to the facility. Many of the spaces are controlled to a constant occupied set point regardless of whether the spaces are scheduled to be occupied. This measure proposes to replace the thermostats, as needed, such that an occupancy schedule can be implemented with unoccupied setback of the space setpoints.

Camp Edwards

A number of energy efficiency measures were identified through our assessment of Camp Edwards facilities. Opportunities exist to replace all of lighting fixtures which have not been upgraded recently. Adding new occupancy sensors in all areas as well as replacement of all exterior building lighting with energy efficient LED cut-off type fixtures with photo cell and astronomic time clock control are other potential opportunities.

The specific lighting and lighting controls projects recommended include the following buildings:

- **Building 2807 Roads and Grounds**: Replace selected lighting fixtures, add new occupancy sensors, and add new exterior lighting fixtures and photocell/time clock control. The building has been upgraded, by RISE Engineering, with new lighting fixtures in most areas. However, some areas of the building were not upgraded with occupancy sensors and the exterior lighting is not scheduled to be upgraded.
- **Building 2808 Facility Engineering:** Replace selected lighting fixtures, add new occupancy sensors, and add new exterior lighting fixtures and photocell/time clock control. Some areas of the building were not upgraded and the exterior lighting is not scheduled to be upgraded.
- **Building 2814 Echo Company:** Replace all lighting fixtures, add new occupancy sensors and add new exterior lighting fixtures and photocell/time clock control. The building is primarily illuminated with 40 W T12 lamps with magnetic ballasts.
- **Building 2816 Support Facilities:** Replace selected lighting fixtures, add new occupancy sensors, and add new exterior lighting fixtures and photocell/time clock control. The building has been

partially upgraded with fixtures replaced in the office and corridor areas. Support areas and stairways are primarily illuminated with strip fixtures with 40 W T12 lamps with magnetic ballasts.

- **Building 2822 AV Readiness Center:** Replace all lighting fixtures, add new occupancy sensors, and add new exterior lighting fixtures & photocell/time clock control. The building has is primarily illuminated with 40 watt T12 lamps with magnetic ballasts.

While the greatest opportunities identified are primarily related to lighting upgrades and improvement, other potential opportunities were identified as well. These include:

- **Replace existing boilers with new high efficiency boiler.** Boilers are beyond useful life in buildings 5515, 5505, 5510, and 5501. New boilers are available with much higher efficiencies.
- **Replace water heaters for buildings 5515, 5510 5505, and 5501.** The domestic water heater could be replaced with an instantaneous type for greater efficiency.
- **Replace water heaters for building 5510.** The Pool Heaters (i.e., boilers) are beyond useful life. Much higher efficiency boilers available. The domestic water heater is in good condition and when it fails should be replaced with instantaneous type.

US Air Force PAVE/PAWS

The team found that the existing Scanner Building has approximately 17 variable air valve (VAV) boxes with hot water reheat coils. The building has a correctly designed VAV system with hot water reheat; however, the building's functionality has changed and the critical zone control that the hot water reheat system was designed for changed. Most zones do not require hot water reheat at this point.

Currently, the boiler plant has two oil fired boilers. One of the boilers provides hot water in the summer, and one hot water circulation pump maintains the loop. An opportunity may exist for installing a second VAV box with electric reheat at the critical space allowing the hot water boilers and pumps to be turned off during the summer months. In the critical space (an office), the VAV box with hot water reheat would be off in the summer and low in the winter. The VAV box with electric reheat would only operate in the summer resulting in saving in summer reheat fuel plus pumping energy.

Coast Guard Base Cape Cod

At the U.S. Coast Guard, a large number of lighting and lighting controls projects were identified. These include projects at the following buildings:

- **Building 3456/3457 ESD Shop and Garage:** Replace exterior lighting fixtures with LED fixtures with bi-level, photocell, & time clock control. The exterior lighting is provided by high pressure sodium and incandescent fixtures that have compact fluorescent replacement lamps.
- **Building 3424/3425/3426 Recycling/Warehouse/PSU 301:** Add occupancy control and re-circuit fixtures. Replace exterior lighting fixtures with LED fixtures that have photocell and time clock control. The interior fluorescent lighting fixtures, which appeared to have been recently replaced, are controlled by switch only. The exterior lighting is controlled with photocell controls only.
- **Building 3170 Maintenance Hangar:** Replace T8 Lighting Fixtures with LED Fixtures and add new occupancy sensors. The building office and shop areas are illuminated with T8 type fluorescent

lamps in various types of fixtures. Also, all areas of the building, except three or four rooms, do not have occupancy sensor control of lighting fixtures.

- **Building 5200 Marine Fisheries:** Replace Boat House fixture lamps with LEDs and add occupancy sensors. The exterior lighting is provided by inefficient HPS and incandescent fixtures and should be replaced with more efficient technologies such as LED or fluorescent fixtures.
- **Building 5201 Medical Clinic:** Add new occupancy sensors. Most areas of the building do not have occupancy sensor control of lighting fixtures. The exterior lighting is provided by inefficient metal halide and mercury vapor fixtures.
- **Building 5203 Coast Guard Exchange:** Add new occupancy sensors, replace lighting fixtures with bi-level, photocell, and time clock control. Most areas of the building do not have occupancy sensor control of lighting fixtures.
- **Building 5211 FED Building:** Add new occupancy sensors and replace lighting fixtures with LED fixtures. The building has very few occupancy sensors for control of lighting fixtures. Also, incandescent lighting and HPS fixtures are not energy efficient.
- **Building 5214 Chief's Mess:** Replace lighting fixtures with LED fixtures, re-lamp some fixtures with LED lamps, and add new occupancy sensors. The building has some areas with no occupancy sensors for control of lighting fixtures. Also, most of the building is illuminated with incandescent lighting.
- **Building 5215 Engineering (Garage/Shop Area):** Replace T8 fluorescent & metal halide lighting fixtures with LED fixtures and add new occupancy sensors. The building garage and shop areas are illuminated with T8 type fluorescent lamps in industrial type of fixtures & metal halide fixtures.
- **Building 5204 Wing's Inn (Hotel):** Add new occupancy sensors to control two-thirds of the corridor and common area lighting. Also, replace the combination fan/light fixture units with LED ceiling mounted fixtures. Corridor fixtures are reported to be illuminated virtually 24/7 unless switched off by security during their rounds. When the corridor lights are switched off, there is no night light circuit in the corridor for guests.
- **Building 5205 Child Development Center:** Add new occupancy sensors, and replace exterior lighting fixtures with photocell and time clock control. The building is generally illuminated with fluorescent lighting fixtures with 32 W, T8 lamps with Sylvania QTP type ballasts. It appears none of the lighting fixtures in the building is being controlled by occupancy sensors.

While the greatest opportunities identified are primarily related to lighting upgrades and improvement, other potential opportunities were identified as well. These include projects at the following facilities:

- **Building 3170 Maintenance Hangar:** A measure identified in the assessment process is replacement of the steam boiler at Hangar 3170 with an infrared gas-fired heat pipe system, which is more appropriate for heating high bay spaces like hangars. The measure would include boiler replacement with a ceiling mounted natural gas furnace and installation of ceiling-mounted heat pipes.

- **Building 3172 Readiness Hangar: Setback Control of HVAC.** The administrative spaces in the Readiness Hangar are served by a mixture of a ground source heat pump system and small PTAC units. This measure proposes to initiate setback control of the spaces.
- **Building 5203 Coast Guard Exchange: VSD Control of 15-ton AC Unit.** This unit and the others serving this facility should be replaced with newer high efficiency VAV units. Cooling and heating energy savings will result from the higher efficiency of the units with fan energy savings resulting from the variable operation of the fans. The controls for these units should be installed with setback control of the space temperatures based on the scheduled occupancy of the spaces served.
- **Building 5203 Coast Guard Exchange: Reach in Refrigerator Curtains**. The reach in refrigerator case in the Coast Guard Exchange provides convenience for shoppers to access the produce, meat, and dairy products inside. With 36 feet of open access with no coverings, there is a considerable amount of loss of conditioned refrigerated air to the ambient space.
- **Building 5204 Wings Inn: Occupancy Control of HVAC.** The Wings Inn is a 25,500 square foot hotel located on base. Opportunities exist to install occupancy-based controls for the packaged terminal air conditioner (PTAC) units that will automatically reset the space set point control depending on occupancy of a space.
- **Building 5211 FED Building: Destratification Fans.** The shops areas in the FED building are heated and ventilated only by a gas-fired rooftop unit. These spaces have high peaked ceilings making them harder to heat as the air has a tendency to rise to the highest point in the room causing stratification. Opportunities exist to install destratification fans to even out the air temperatures in the space. The fans will allow the higher temperature air to mix better with the lower level air, resulting in more even air temperature distribution and greater comfort levels in the space.

3.4.2 Central Plant

A significant, centralized CHP opportunity does not exist at JBCC. With the decentralization of heating equipment, the thermal loads dispersed across the base vastly increase the infrastructure that would be necessary to combine these loads for a large CHP.

Potential for a distributed CHP was investigated at Coast Guard Base Cape Cod at the barracks and galley facility, Building 3159, and the maintenance hangar, Building 3170. Each building is served by separate boilers that provide steam and hot water to the facilities. Hangar 3170 was the former fuel cell test site, which has been decommissioned. No further information about the fuel cell project was available.

For Buildings 3170 and 3159, the Clean Energy Team identified a dramatic drop in natural gas consumption during the summer months. Therefore, additional interval data would be needed to determine whether sufficient thermal loads exist during the summer. There are no existing absorption chillers on the base. Coupled with the non-uniformity and inconsistency of monthly thermal energy usage, distributed CHP at any other building location would not be feasible.

3.4.3 Renewables

In regard to further development of renewable energy systems, each command was found to be interested in developing additional renewable energy systems at the base. The systems under consideration range from small rooftop solar installations to large multi-MW renewable energy systems. The greatest challenge the base will have in seeing these projects come to fruition is managing and overcoming capacity, power quality, and regulatory net metering issues. The joint base needs to develop a plan to optimally integrate expanded renewable energy generation assets on the electric distribution system.

Furthermore, all bases at JBCC (and across the state) need regulatory clarification of net metering caps. The Massachusetts Department of Public Utilities (DPU) has interpreted existing legislation to mean that all DoD facilities in MA have a 10 MW net metering cap in total as one combined entity. With each command planning to develop additional multi-megawatt solar PV and wind projects there may be a need to connect directly to the local utility's electric distribution grid which will risk exceeding the 10 MW net metering cap.

All Air Force and Army sites in MA are individual entities with few if any connections to each other, and especially not in the energy efficiency area. But, while behind-the-meter projects will forestall hitting the 10 MW limits for now, the limits could delay future renewable energy projects at Hanscom, Westover ARB, and Otis ANG Base due to the collective net metering limit.

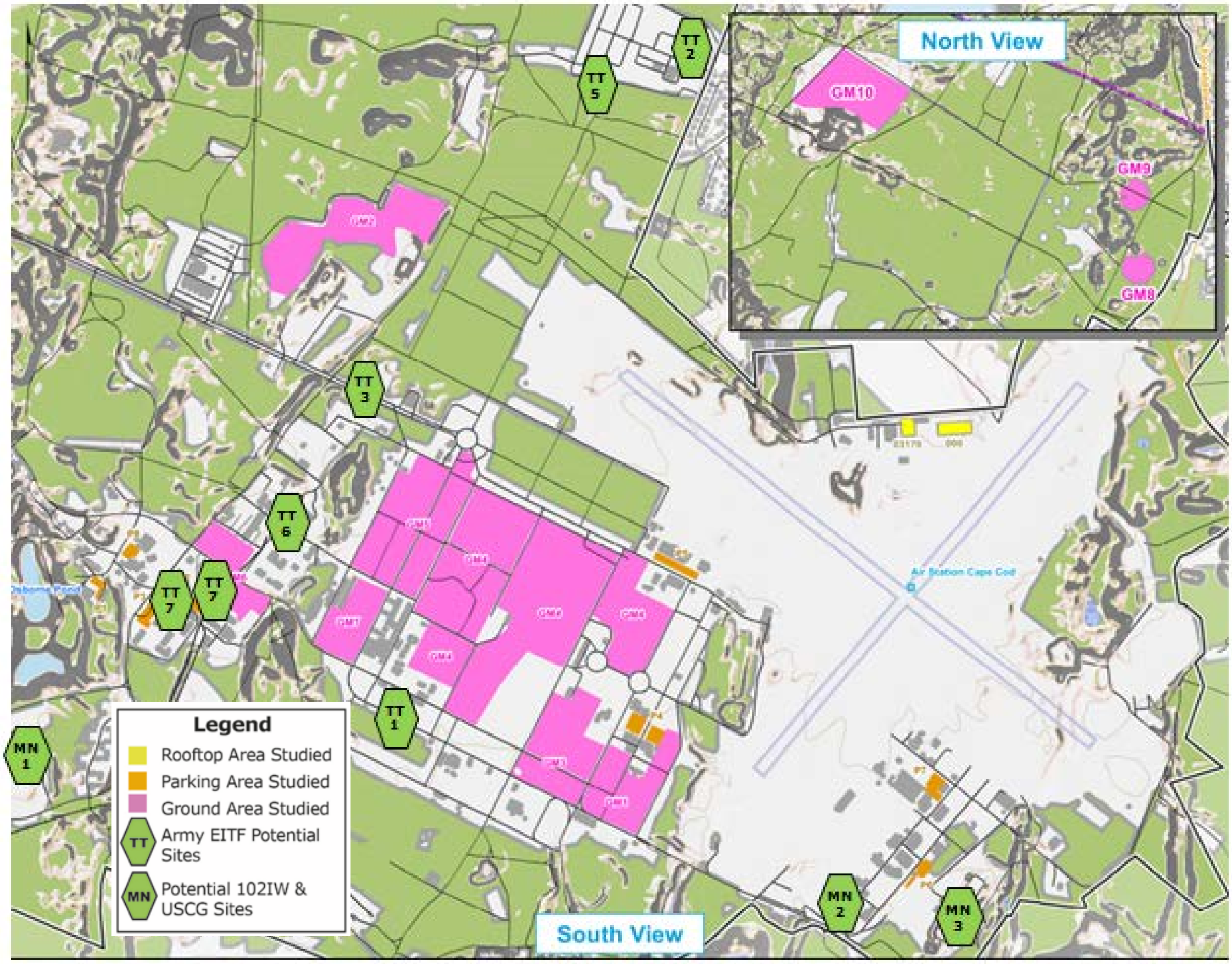
Other military entities have also recently increased their interest in renewables, e.g. the Army's Energy Initiative Task Force, and could run into net metering problems for their preferred multi-megawatt sized projects. The Clean Energy Team recommends that DPU examine this barrier faced by the Massachusetts military bases and consider sensible expansions of their caps[4].

Solar

JBCC has a number of suitable areas to support solar photovoltaic (PV) systems. The most significant opportunities being related to ground mounted systems, but opportunities in parking lots and on roof tops also exist. The Clean Energy Team completed a GIS analysis to identify optimal ground-mount, parking area, and roof-mount photovoltaic installation locations at the base. However, after the initial assessment, many of the sites were deemed to be unsuitable for PV systems due to multiple species habitat restrictions as well as conflicts with training exercises, and land use identified through master planning efforts. The map below provides an overview the prospective sites assessed by the Clean Energy Team.

[4] One way to expand net metering caps would be to treat each individual base as a separate public entity, with each base being able to apply for its own public entity identification number from the DPU. Each base would then be allowed to develop up to 10MWdc apiece.

Figure 3-4 Solar PV Sites Studied at JBCC



Assessments of the locations for ground mounted solar systems were ultimately conducted on twelve areas across the base. They entailed:

1. Taking photos of the potential Ground Mounted System Locations and the surrounding areas.
2. Noting topography, layout, potential obstructions, landscaping, and other physical site attributes.
3. Analyzing shade and solar access at the sites.

Based on our assessments, the team's results are summarized in TablesTable 3-13 through Table 3-15.

Table 3-13 Summary of Ground-mount Prospective Solar Sites

Ground-mount	Notes
GM2	GM2 appears to be a suitable area to support a ground mount solar PV system. JBCC has already performed a renewable energy assessment which resulted in issuing a request for proposal to solar PV developers for a chosen location on the

	retired dump owned by the state being leased to the Air National Guard. The RFP is well developed and allows specification of up to a 10MWac system.
GM1, GM3-GM10	GM1 and GM3 through GM10 are not suitable areas to support a ground mount solar PV systems given existing restrictions on the land and that these sites are primary habitat for a state listed endangered species (which would require significant mitigation) and that they also conflict with training and other mission uses.
TT1-TT7	The TT1-TT7 sites were selected by the Army Energy Initiative Task Force as the result of a considerable scoping and analysis effort with Camp Edwards. The sites are considered to be lower quality habitat and therefore require less costly mitigation. All seven sites are relatively flat, small areas that could support smaller ground mount PV systems, although some areas are wooded which are not recommended for development.
MN2 and MN3	The areas around the munitions site (MN2 and MN3) were also found to be suitable for ground mounted solar arrays.
MN1	The U.S. Coast Guard submitted a proposal to construct a 6 MW solar PV system in the vicinity of site MN1. The proposed site for this PV array is on a parcel of land that has assigned land use controls under CERCLA enabling the PV array to be separate from the base electrical grid and therefore would provide energy directly to the NSTAR electrical grid.

Table 3-14 Summary of Roof-top Prospective Solar Sites

Buildings	Notes
Coast Guard Buildings 3170 and 3181	The buildings have good orientation and minimal roof top obstructions, with enough usable area for a moderate sized PV system.

Table 3-15 Summary of Carport Prospective Solar Sites for Hanscom

Carport Sites	Notes
P1, P3, P7 and P8	Parking areas P1, P3, P7 and P8 are suitable to support parking canopy PV systems. These are relatively large, flat, open parking lots adjacent to buildings.
P2, P4, P5 and P6	Parking areas P2, P4, P5 and P6 are also suitable to support parking canopy PV systems. These are also relatively large, flat, open parking lots adjacent to buildings, but have overhead utilities or lighting that will need to be avoided or relocated.

As a part assessing which sites presented the greatest opportunities, the Clean Energy Team conducted energy estimates for the selected viable sites. This included site-specific weather and snow soiling characteristics assessments along with reasonable design assumptions related to technology (i.e., module, inverter and racking), orientation, spacing and common losses like shading and ohmic wire losses. All of this information was entered into PV simulation software to generate preliminary first year energy estimates for each project.

Wind

The Clean Energy Team found that there are opportunities for additional wind systems. What makes additional wind turbines more favorable at JBCC are the abundant wind resources at the base plus the relatively high electricity rates. However, there are several environmental barriers to wind development, including the presence of a bat species that may be placed under protection of the Endangered Species Act. Other barriers are related to the availability of land, interference with existing systems and training programs, and the interest in large scale ground-mounted photovoltaic systems at the base. Due to the environmental issues and operational concerns, the Clean Energy Team did not pursue further wind development at the base.

3.4.4 Transportation

The mandates on military fleet vehicle management fall into two categories: vehicle procurement and petroleum and greenhouse gas savings goals. The Energy Policy Act of 1992, Executive Order 13423, and Executive Order 13514 have all taken steps to speed the adoption of AFVs and reduce petroleum consumption and associated GHG emissions. Ground vehicle fleets at the bases are typically composed of a mixture of vehicles owned by the base and vehicles leased from the federal General Services Administration (GSA). Base-owned vehicles and GSA-leased vehicles must follow replacement rules based on minimum accrued mileage, years of service, or pre-established maintenance budgets. As a result, vehicle turnover at bases is low and vehicles typically remain in service for extended periods of time.

The Clean Energy Team collected information on vehicle fleet composition, fuel consumption, and annual mileage for sedans, pick-up trucks, and other passenger vehicles but excluded service vehicles such as snow plows, aircraft refueling trucks, backhoes, and fire trucks. Understanding that vehicle replacement is, at this time, infrequent, the recommendations below provide a sense of what fuel and GHG savings could be achieved if opportunities for vehicle procurement and fuel switching arise. The team focused on opportunities[5] for electric vehicles (EVs), hybrid electric vehicles (HEVs), and fuel switching to ethanol (E85) fuel.

102IW

The Clean Energy Team evaluated opportunities for vehicle fleet replacements and fuel switching at Otis 102IW. Similar to the other bases, three strategies for reducing GHG emissions were considered: replacing existing vehicles with EVs, replacing existing vehicles with HEVs, and switching from pure gasoline to E85 for existing flexible-fuel vehicles.

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[5] Biodiesel was excluded from the analysis due to feedback from some bases that had already tried biodiesel. In colder climates, biodiesel can gel especially for infrequently used vehicles and vehicles that are not garaged. As a result, the vehicles have to be repaired if the fuel gels and clogs up the fuel delivery system.

Based on the fleet characteristics for Otis 102IW, all three scenarios were analyzed, the results of which are provided in Table 3-16.

Table 3-16 Potential Fuel and Emissions Impact of Fleet Change Strategies

Strategy	Number of Eligible Vehicles	Annual Reduction in Fuel Consumption (gallons)	Annual Reduction in GHG Emissions (CO2 in pounds)
EV Replacement	32	5,438	103,312
HEV Replacement	5	2,807	55,210
Switch to E85 Fueling	12	1,057	24,334

It is important to note that some vehicles in the fleet could potentially be impacted by more than one strategy, so the annual reductions in fuel consumption and GHG emissions in Table 3-16 are not additive. All three strategies represent different paths towards reducing fleet GHG emission at Otis 102IW. Replacing existing vehicles with EV has the largest potential for reducing GHG emissions (103,312 lbs. annually), followed by replacing vehicles with HEVs (55,210 lbs. annually) and switching flexible-fuel vehicles from regular gasoline to E85 (24,334 lbs. annually). There are varying up-front capital and fuel costs associated with each strategy. Table 3-17 summarizes these costs.

Table 3-17 Costs and Fuel Savings of Fleet Change Strategies

Strategy	Up-Front Infrastructure Cost	Purchasing Premium Per Vehicle	Percent Savings in Fuel Cost Per Vehicle
EV Replacement	\$6,000 - \$9,200[1]	\$19,200	83%
HEV Replacement	\$0	\$12,500	30%
Switch to E85 Fueling	\$20,000 - \$70,000[2]	N/A	-37%

[1] Cost of EV level II charging stations varies based on desired built-in features (e.g. ability to process and track credit card payments).

[2] Cost of E85 fueling station is on lower end of this range if an existing fuel tank can be converted to an E85 tank and on the higher end of this range if a new tank must be installed.

There are significant up-front infrastructure costs associated with replacing current vehicles with EVs (EV charging stations) and switching current flexible-fuel vehicles to E85 (E85 fueling stations). The per-vehicle premium for purchasing EVs (\$19,200) and HEVs (\$12,500) is also a significant cost to consider. Finally, while there are substantial per-vehicle fuel cost savings for EV replacements (83%) and HEV replacements (30%), the savings are negative when running flexible-fuel vehicles on E85 instead of regular gasoline (-37%) because a gallon of ethanol has less energy in it than a gallon of gasoline.

Camp Edwards

The Clean Energy Team evaluated opportunities for vehicle fleet replacements and fuel switching at Camp Edwards. Three strategies for reducing GHG emissions were considered: replacing existing vehicles with EVs, replacing existing vehicles with HEVs, and switching from pure gasoline to E85 for existing flexible-fuel vehicles. Based on the fleet characteristics for Camp Edwards, only the HEV replacement strategy and EV replacement strategy were analyzed due to a lack of vehicles suitable for E85 fuel switching. The results are provided in Table 3-18.

Table 3-18 Potential Fuel and Emissions Impact of Fleet Change Strategies

Strategy	Number of Eligible Vehicles	Annual Reduction in Fuel Consumption (gallons)	Annual Reduction in GHG Emissions (CO2 in pounds)
EV Replacement	10	6,495	123,080
HEV Replacement	2	239	4,536

It is important to note that some vehicles in the fleet could potentially be impacted by more than one strategy, so the annual reductions in fuel consumption and GHG emissions in Table 3-17 are not additive. The two strategies represent different paths towards reducing fleet GHG emission at Camp Edwards. Replacing eligible vehicles with EVs has the largest potential for reducing GHG emissions (123,080 lbs. annually), followed by replacing eligible vehicles with HEVs (4,536 lbs. annually). There are varying up-front capital and fuel costs associated with each strategy. Table 3-19 summarizes these costs.

Table 3-19 Costs and Fuel Savings of Fleet Change Strategies

Strategy	Up-Front Infrastructure Cost	Purchasing Premium Per Vehicle	Percent Savings in Fuel Cost Per Vehicle
EV Replacement	$6,000 - $9,200[1]	$19,200	83%
HEV Replacement	$0	$12,500	30%

[1] Cost of EV level II charging stations varies based on desired built-in features (e.g. ability to process and track credit card payments).

There are significant up-front infrastructure costs associated with replacing current vehicles with EVs (EV charging stations). The per-vehicle premium for purchasing EVs ($19,200) and HEVs ($12,500) is also a significant cost to consider. However, there are also substantial per-vehicle fuel cost savings for EV replacements (83%) and HEV replacements (30%). Despite relatively high infrastructure costs and per-vehicle premiums, replacing eligible vehicles with EVs represents Camp Edwards best opportunity to significantly reduce transportation emissions.

Air Force PAVE/PAWS

Taking all of these factors into consideration, the team evaluated opportunities for vehicle fleet replacements and fuel switching at Air Force PAVE/PAWS. Based on the fleet characteristics for Air Force PAVE/PAWS, only the HEV replacement strategy was analyzed due to a lack of vehicles suitable for EV replacement or E85 fuel switching.

Table 3-20 Potential Fuel and Emissions Impact of Fleet Change Strategy

Strategy	Number of Eligible Vehicles	Annual Reduction in Fuel Consumption (gallons)	Annual Reduction in GHG Emissions (lbs. CO2)
HEV Replacement	3	472	8,944

At Air Force PAVE/PAWS replacing eligible existing vehicles with HEVs would reduce GHG emissions 8,944 lbs. annually. There are up-front capital and fuel costs associated with replacing vehicles with HEVs. Table 3-21 summarizes these costs.

Table 3-21 Costs and Fuel Savings of Fleet Change Strategy

Strategy	Up-Front Infrastructure Cost	Purchasing Premium Per Vehicle	Percent Savings in Fuel Cost Per Vehicle
HEV Replacement	$0	$12,500	30%

The per-vehicle premium for purchasing HEVs ($12,500) is a significant cost to consider. However, HEVs have significant fuel savings (30%) compared to equivalent non-HEV vehicles and as more HEV models enter the market, price premiums are expected to decrease.

Coast Guard Base Cape Cod

The Clean Energy Team evaluated opportunities for vehicle fleet replacements and fuel switching at Coast Guard Base Cape Cod. Similar to the other bases, three strategies for reducing GHG emissions were considered: replacing existing vehicles with EVs, replacing existing vehicles with HEVs, and switching from pure gasoline to E85 for existing flexible-fuel vehicles.

Based on the fleet characteristics for Coast Guard Base Cape Cod, all three scenarios were analyzed, the results of which are provided in Table 3-22.

Table 3-22 Potential Fuel and Emissions Impact of Fleet Change Strategies

Strategy	Number of Eligible Vehicles	Annual Reduction in Fuel Consumption (gallons)	Annual Reduction in GHG Emissions (CO2 in pounds)
EV Replacement	8	4,625	87,653

HEV Replacement	5	593	11,229
Switch to E85 Fueling	20	5,733	131,988

It is important to note that some vehicles in the fleet could potentially be impacted by more than one strategy, so the annual reductions in fuel consumption and GHG emissions in Table 3-22 are not additive. All three strategies represent different paths towards reducing fleet GHG emission at Coast Guard Base Cape Cod. At Coast Guard Base Cape Cod, switching flexible-fuel vehicles from regular gasoline to E85 has the largest potential for reducing GHG emissions (131,988 lbs. annually), followed by replacing eligible vehicles with EVs (87,653 lbs. annually). There are varying up-front capital and fuel costs associated with each strategy. Table 3-23 summarizes these costs.

Table 3-23 Costs and Fuel Savings of Fleet Change Strategies

Strategy	Up-Front Infrastructure Cost	Purchasing Premium Per Vehicle	Percent Savings in Fuel Cost Per Vehicle
EV Replacement	\$6,000 - \$9,200[1]	\$19,200	83%
HEV Replacement	\$0	\$12,500	30%
Switch to E85 Fueling	\$20,000 - \$70,000[2]	N/A	-37%

[1] Cost of EV level II charging stations varies based on desired built-in features (e.g. ability to process and track credit card payments).

[2] Cost of E85 fueling station is on lower end of this range if an existing fuel tank can be converted to an E85 tank and on the higher end of this range if a new tank must be installed.

There are significant up-front infrastructure costs associated with replacing current vehicles with EVs (EV charging stations) and switching current flexible-fuel vehicles to E85 (E85 fueling stations). The per-vehicle premium for purchasing EVs (\$19,200) and HEVs (\$12,500) is also a significant cost to consider. Finally, while there are substantial per-vehicle fuel cost savings for EV replacements (83%) and HEV replacements (30%), the savings are negative when running flexible-fuel vehicles on E85 instead of regular gasoline (-37%) because a gallon of ethanol has less energy in it than a gallon of gasoline.

3.4.5 Infrastructure

The 102nd Intelligence Wing owns and operates a significant portion of the utilities at JBCC, including all the electric, water and wastewater utilities at the Otis ANG Base. The Clean Energy Team assessed opportunities for infrastructure modernization, increased efficiency, and improved resiliency.

Microgrids

The Clean Energy Team reviewed the potential for two different microgrid systems at the 102IW focusing on buildings of critical importance to the base. The review is based on site surveys for CHP potential, solar PV potential, distribution system infrastructure, utility scale battery storage, and detailed software modeling of two microgrid configurations for financial viability and reliability impact.

The hypothetical microgrid configurations incorporate existing back-up generation on critical buildings with installations of parking lot canopy solar PV and a lithium-ion electric battery sized as follows: a) 1.02 MW PV, a 300 kW, 4-hour storage and b) 602 kW solar PV, 150 kW, 4-hour storage. The cost of infrastructure upgrades to enable automated islanding and operation of a microgrid supporting the critical buildings was estimated to be in the range of $940,000 - $1.05 million. The total cost of implementation of the microgrids including PV and storage was $4.8 million for the smaller system (b) and $7.8 million for the larger system (a). The 15 year discounted Net Present Value of the investments are -$755,000 and -$970,000. This equates to a Return on Investment of -15.7% and -12.5%. The net reduction in carbon dioxide emissions is in the range of 3.1% - 5.5% over the 15-year life cycle.

Under outage conditions, the microgrid would significantly increase in the electricity reliability supply to critical loads. This is a substantial improvement for the following reasons: under the existing back-up system, large generators are dedicated to a few of the critical buildings while some of critical buildings have generation sufficiency only for critical circuits and not the entire electric load. The microgrid configurations allow full service to all critical buildings under every outage scenario examined.

The following factors are advantageous to the development of a microgrid at the 102IW:

- Ownership of the distribution system by the base and suitability of the system for microgrid infrastructure upgrades.
- Scope of improvement in the reliability of electric supply to critical loads through efficient and centralized re-allocation of existing supply.

The following key factors contribute to the low economic viability for microgrids:

- Limited potential for large controllable centralized generation. Centralized CHP is not viable because of the existing, relatively new decentralized heating system
- Limited potential for medium scale ground mount PV systems within the 102IW. The financial case for the canopy PV systems examined is not compelling because of relatively high costs of such systems at military installations.

The team concludes that a microgrid installation at the102IW would be technically feasible, but marginally economically feasible. A microgrid would improve the energy security of the base by improving reliability and reducing energy costs.

Energy Storage

The102IW is exploring the use of liquid metal batteries with the new battery manufacturer, Ambri, in an upcoming pilot project. Furthermore, the base has expressed interest in exploring utility-scale battery systems to support existing back-up power capabilities. The Clean Energy Team found that a stand-alone utility-scale battery system would not be financially viable. However, a storage system coupled with solar PV would have a positive financial return, particularly as the penetration of solar PV approaches 25 % of campus load.

Water / Wastewater

Water at the base is partly provided by a well on the base - J-Well. There is a 150 hp pump operating on a VFD for approximately 3 hours per day. The Clean Energy Team sought to assess the operational efficiencies of this pumping system to determine of a potential energy efficiency opportunity might exist, but found that the calculated $/MG is low compared to systems that operate under similar conditions making potential improvements likely unfavorable.

The wastewater system consists of several lift stations and a treatment plant. The treatment plant at the base is designed to treat 360,000 gallons a day, but it currently operates at half of its capacity. The flow to the wastewater treatment plant is also limited to 100 gallons per minute (gpm) to maintain the desired process control. Because many of the mechanical process equipment are oversized for the existing flow, we found that downsizing the equipment may present an opportunity. Replacing the existing systems with more adequately sized equipment, would allow the facility would operate more efficiently. Smaller systems would also reduce the kW demand associated with the operation of the larger sized equipment. The installation of smaller units, however, would result in an overall reduction of the plant's treatment capacity. This would limit the facility if an increase in wastewater occurs in the future.

The lift stations are controlled to avoid pumping more than 100 gpm of wastewater to the treatment plant. The pumps at the stations operate at constant speed and cycle on and off depending on the wet well level and the flow restriction at the plant. Given the flow limitations, it may be feasible to downsize the pump stations and to install lower capacity pumping systems to accommodate the minimum flow requirement at the plant[6].

Rather than replacing the pumps with smaller units, VFDs could also be installed at the pump stations. The VFDs would allow the pumps to discharge lower flows and would operate for longer periods. However, the pumps at the lift stations are designed to discharge 250 to 680 gpm, much higher than the 100 gpm flow restriction at the WWTP. While the VFDs would allow the existing pumps to operate at lower flows, the pumps would still discharge more than 100 gpm given the minimum pump flow per the manufacturer's specifications. The VFDs would therefore not provide significant energy savings under these conditions.

3.4.6 Environmental

The responsibility for groundwater remediation on JBCC is divided between several different military branches, the two largest of which are the Air Force Civil Engineering Center (AFCEC), which is responsible for the remediation of groundwater contaminant plumes in the south portion of JBCC, and the Department of the Army, which is responsible for the remediation of groundwater within the Army Impact Area Ground Water Study Program (IAGWSP) area in the north portion of JBCC.

The Clean Energy Team recommended evaluating alternative remedial approaches and less energy-intensive remediation options. We found that the AFCEC portion of JBCC has undergone a number of Remedial Process Optimization assessments since 2000 in order to decrease energy requirements at the base and offset emissions generated by the treatment plants. For example, AFCEC has offset the energy used by groundwater treatment systems through the use of electricity generated by the wind turbines at the base.

6 Reducing the size of the pumps to manage flow to 100 GPM does not take into account future growth at JBCC or whether the plant will be used in the future to support the four surrounding towns and their needs for sewage treatment.

According to discussions with personnel from the Army, each plume and treatment system associated with the IAGWSP area is evaluated at least annually. Proposed changes or optimization measures are regularly recommended and eventually implemented once approved by regulators. Contracts are in place to operate each system, with incentives provided for the reduction in energy consumption and accelerated site closure. As such, the Clean Energy Team has no specific recommendations on additional green remediation practices at the IAGWSP portion of JBCC.

3.5 Natick Soldier Systems Center

The Soldier Systems Center at Natick is a DoD installation tasked to protect and sustain America's military forces. Natick Soldier Systems Center (NSSC) is located roughly 20 miles west of Boston. The NSSC mission: conduct research, development, acquisition and sustainment to maximize combat effectiveness and survivability of military personnel.

NSSC supports civilians and military personnel from every branch of service: Army, Marine Corps, Navy, Air Force, and Coast Guard. Ranging from food to clothing to shelter to soldier support items, the base researches and develops everything service members require for mission accomplishment in combat. Research at the base also helps to manage and develop energy efficient shelters and airdrop systems used in battle.

We found that key opportunities remain relative to measuring and improving building efficiencies as well as the integration of renewable energy or clean energy systems on the base. Within the last 18 months, the base has engaged in an energy savings performance contract (ESPC) with Pepco Inc. and is addressing many energy conservation measures. The Clean Energy Team looked at opportunities that were not ultimately included in the ESPC contract.

Within the last 18 months, the team managing facility maintenance and energy projects was able to procure an $8 million, 23-year Energy Savings Performance Contract (ESPC) with Pepco Energy Services. The scope of this ESPC includes up to 33 buildings and addresses some longer payback measures such as envelope and window improvements that will greatly increase occupant comfort. Additional measures include lighting upgrades, water conservation, EMCS upgrades, and installation of a micro co-generation plant serving two buildings. In its entirety, the ESPC is expected to result in an annual savings of $500,000 and reduce energy consumption at the installation by a significant 42%.

The following sections describe clean energy opportunities that the Clean Energy Team has identified with help from base personnel and through independent investigation.

3.5.1 Buildings

Overall, NSSC has responsibility for 124 buildings located in the town of Natick as well as residential properties in three neighboring communities. The 78 acre main campus lines Lake Cochituate and shares a 50 yard border with the Cochituate State Park. NSSC facilities include administration, laboratories, maintenance, and storage, along with the four housing areas. A self-contained installation, the NSSC main campus has a shopette, cafeteria, barbershop, credit union, recreation center, and a travel office.

Energy Management Control Systems

Natick Soldier System Center has recently awarded a large ESPC to Pepco Energy Services. Included in the Pepco ESPC in this project is approximately $1.25 million in controls work and over 3,600 hardware points. This upgrade includes providing a new Tridium front end and upgrading the existing Carrier controls at the equipment level, as well as expanding the existing controls and updating the graphical user interface. Due to this EMCS upgrade, the team did not have any further recommendations for improvements.

Metering and Procurement

We found that most of the buildings at Natick have smart meters for electricity, but they are not currently networked. There are still a few areas where there is one electric meter for a group of buildings however, this is likely to remain as is and does not represent significant opportunities for savings even if buildings are individually metered.

Natural gas, water, and waste water are all still master-metered at the base. Opportunities for improvements appear to be limited outside of connecting the advanced meters to a local network. Improvements to the EMCS may address this. The Clean Energy Team believes that networking of smart meters should be a top priority as it will yield invaluable information for assessing ECMs once the data collection is properly functioning.

Energy Conservation Measures

Data was collected on the ECMs that were excluded from the final scope of the Pepco ESPC in an effort to capture potential projects that could be reviewed under this contract. The Doriot Chambers houses significant energy systems and represents a large energy load for the base. This facility was a particular focus for the Clean Energy Team.

The energy conservation measures that we assessed and recommend for further analysis include:

- Air compressor system upgrades in Buildings 3, 4, 5, 36 and 45
- HVAC and Boiler Upgrades for Building 32
- Kitchen Hood Variable Speed Fans and VFDs for two fans and two pumps in Building 36
- HVAC Air/Water Testing and Balancing and Commissioning in Building 4
- Power Factor Correction for Buildings 5 and 36
- Doriot Chambers Chiller Replacement and Controls Upgrades at Building 2

3.5.2 Central Plant

The base decommissioned its steam plant in 2010 due to the level of disrepair of the steam lines. With American Recovery and Reinvestment Act funds, NSSC decentralized heating to a per-building level. The oldest boilers at the facility are about 10 years old.

NSSC is considering a revamp of the old steam plant into a tri-gen plant, but would need to convert the plant to natural gas-fired boilers and install a new hot water distribution system; upgrades to the natural gas lines feeding the plant would likely be needed as well. Because Natick buildings have mostly been converted over to hot water distribution, they would require minimal enhancements to connect to the tri-gen plant.

The Clean Energy Team assessed two other buildings that appeared to have favorable conditions for a CHP type system. Building 1 (Carney Hall), the headquarters building, and Building 36 (Bainbridge Building) were assessed. Our analysis found that integrating a CHP system with these buildings resulted in a negative net present value and was not worth pursuing further.

3.5.3 Renewables

There is currently no renewable generation on base but there is significant interest in integrating these types of systems. NSSC staff has assessed PV arrays at the base in the past; most likely any solar PV arrays would have to go onto buildings, over parking areas or parking structures. The Clean Energy Team also assessed the potential from wind turbines at the base but only large-scale wind turbines were found to be potentially viable but raise concerns regarding proper siting setbacks.

Solar

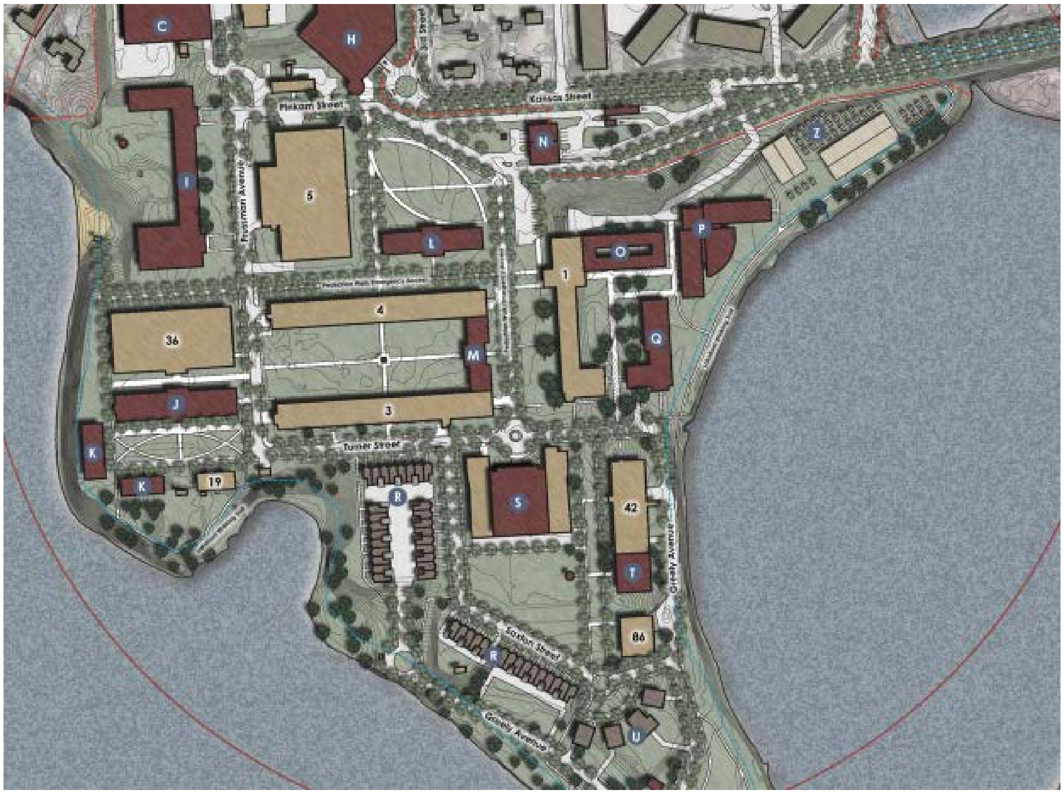
Regarding prospective PV sites, small rooftop systems were considered the only viable options. Ground-mounted and carport systems were found to potentially conflict with future building plans.

Potential rooftop PV site consisted of seven roof tops. The roofs were found to have varying amounts of roof top obstructions that will complicate the amount of PV sited and the ease of installation.

The Clean Energy Team developed cost estimates for solar PV for building-mounted PV at NSSC. In doing so, the team reviewed turnkey industry projections and a recent estimate prepared by Pepco Inc., as part of an energy savings performance contract with NSSC.

Using roofs that are listed in the Master Plan as “existing” (i.e., tan colored roofs 3, 4, 5 and 36 in Figure 3-5) yields 392 kW of potential solar PV estimated capacity, with an estimated turnkey cost of $1,577,472. Considering all the roofs that are potential solar PV sites (both tan and maroon highlighted roofs) yields 664 kW of total potential solar PV estimated capacity, with an estimated turnkey cost of $2,670,293. The average payback on these systems was about 14 years.

Figure 3-5 Solar PV Sites Studied at NSSC



Wind

Medium-scale wind turbines are not economically viable under current assumptions, but large-scale wind turbines appear to be marginally viable and could warrant further investigation except there is not enough land to site large-scale wind turbines according to best practice setbacks. Base personnel agreed that the siting of any type of large scale wind turbines at the base would be undesirable given space constraints and proximity of residential neighborhoods.

3.5.4 Infrastructure

The NSSC electric distribution system has two separate utility feeds, each of which appears to be able handle the approximately 3 MW of normal base load. The system was privatized in 2009 when it was partially undergrounded. The team found that the system appears to have adequate capacity for the base load, and outside of a few recent severe weather events, has been sufficiently reliable. The base maintains multiple portable generators for use in emergency conditions.

The natural gas distribution system is under mixed ownership. Some lines are owned by the base, others are owned by NSTAR. NSSC owns the on-base water and sewage distribution systems.

The Clean Energy Team assessed opportunities for infrastructure modernization, increased efficiency, and improved resiliency but found that no significant opportunities exist for improvements to base infrastructure.

Microgrids

In addition to evaluating micro-CHP and renewable potential at the base, the Clean Energy Team evaluated the feasibility of creating a microgrid at NSSC. We examined a hypothetical microgrid incorporating existing back-up generation on critical buildings, hypothetical roof-top solar PV installations, and a lithium ion electric battery.

The cost of infrastructure upgrades to enable automated islanding and operation of a microgrid for critical buildings was estimated to be approximately $1.4 million. The total cost of implementation of the microgrid including solar PV and storage was $3.8 million. The discounted fifteen year net present value was -$932,000 with a return on investment of -25%.

Under outage conditions, the microgrid demonstrated an increase in the reliability of supply to critical loads by 9% over the existing system of back-up. Additionally there would have been a net reduction in carbon dioxide emissions of 2.5% over the 15-year life cycle.

Given the level of investment needed, we concluded that a microgrid installation at Natick would not be economically feasible at this time.

Energy Storage

A stand-alone electric storage installation at Natick Soldier Systems Center (Natick) was also assessed but was found not to be financially viable. We modeled in detail a 160 KW, 4 hour lithium–ion electric storage device installed in Parking Lot A. The associated capital expenditure was $530,000 and the 15 year discounted net present value was -$ 40,000, which equates to a return on investment of -7.5%. The annual average energy bill savings with the device was $ 49,000, with the entirety of the savings derived from reduction in peak demand charges.

Although the financial return was poor for a stand-alone device, our analysis showed that storage installation coupled with solar PV is more viable from a financial and technical perspective. It is also relevant to keep in mind that the reliability benefits of storage were not monetized in this analysis, and no federal or state incentives for stand-alone storage have been considered.

Water / Wastewater

The NSSC has multiple submersible wastewater pumping stations that are located at the north end of the base, by the baseball field, and in the larger buildings throughout the base. The wastewater from these stations is discharged to the Town of Natick’s sewer collection system. In assessing these systems the Clean Energy Team concluded that there were no wastewater pumps at the NSSC that could show significant energy savings due to small equipment size.

3.5.5 Environmental

NSSC has one groundwater extraction and treatment system in place to address volatile organic compound (VOC)-contaminated groundwater in the T-25 Area of the NSSC. The Clean Energy Team interviewed the contractor responsible for operating the treatment system. Our findings for potential improvements to this system were based on discussions with base personnel and the contractor, as well as a review of the equipment in place.

Green Remediation Systems

Based on our assessment of the remediation systems on site, the Clean Energy Team recommends that a detailed review of operating extraction wells be completed to determine whether all the extraction wells currently in use are necessary to maintain the capture zone, or to determine whether wells with low VOC (i.e., PCE/TCE)[7] concentrations could be shut down.

The wells with low PCE/TCE concentrations are effectively diluting the influent concentrations into the treatment plant, making the treatment process less efficient and using more energy than is necessary. In 2013, the influent concentration was below the EPA Maximum Contaminant Level (MCL), i.e. drinking water standards, for both TCE and PCE in 11 of 12 months (only PCE exceeded the MCL of 5 µg/L in May 2013 with a concentration of 5.5 µg/L). All of these influent concentrations are very low, and the need for continued extraction throughout the entire well network should be re-evaluated.

The Clean Energy Team also suggests that alternate, less energy-intensive methods are considered to remediate the remaining contamination at the Natick site. As stated above, the influent concentrations entering the groundwater treatment plant are very low and the site-wide TCE/PCE groundwater concentrations are also significantly lower than the pre-remediation concentrations. Alternate remedial technologies, such as in situ treatment using bioremediation or chemical oxidation, may be able to remediate the groundwater to meet remedial action objectives faster while using less energy than the current extraction and treatment method.

A third suggestion for potential improvement to the remediation system includes the use of non-virgin Granulated Activated Carbon (GAC) in the treatment plant and that spent GAC materials be sent for regeneration. The GAC currently used in the treatment system is not regenerated.

Pump Rebuild

The Clean Energy Team also assessed the efficiency of a 10-hp remediation pump. Readings were taken under the current operating conditions. Due to the low efficiency of the pump, we found that it is likely that the unit is operating well below the original design conditions. We recommend a pump rebuild to restore the operating efficiency of the unit.

3.6 Westover Air Reserve Base

Westover ARB is a United States Air Reserve base located in Chicopee, Massachusetts. The base employs approximately 3,902 Air Force personnel including 2,826 military members, 766 civilian employees, and 310 other civilians (contractors or non-appropriated fund employees). An additional 2,160 people are employed through the multiple Army and Marine Corps Reserve units on base.

Westover ARB is the nation’s largest Air Force Reserve base, and is home to the Air Force’s largest cargo aircraft, the C-5 Galaxy. More than 2,700 military and civilian workers are assigned to Westover’s 439th Airlift Wing (439 AW), which operates and maintains the C-5 Galaxy cargo planes.

The day-to-day mission also includes recruiting, training and supervision of personnel to assure mission readiness. The wing is responsible for the management of aircraft maintenance and all assigned Air Force combat support real property, equipment, and supplies.

[7] Perchloroethylene and trichloroethylene are chlorinated solvents commercially used as industrial degreasers.

Westover has formed an Energy Management Steering Group to guide its energy program and to promote energy conservation opportunities. It has actively initiated projects, such as an investment grade audit in 2011, which has guided recent upgrades. Overall, Westover has accomplished the following actions in recent years:

- Decentralizing central heat plant and specifying individual boilers for each building. Installation of new boilers at quarters for visiting airmen in Buildings 5101, 5102, 5103, 5104, and 5105.
- Power factor correction up to 97% (from 93% or so) by working with Chicopee Electric.
- Interior lighting upgrades
- Retrocommissioning HVAC controls and completing HVAC modifications that have a quick payback.

The following sections describe clean energy opportunities that the Clean Energy Team has identified with help from base personnel and through independent investigation.

3.6.1 Buildings

Westover hosts about 125 buildings, totalling 1,656,329 square feet of building space. The average age of the buildings is 44 years and the buildings were found to be in fair to excellent condition.

Energy Management Control Systems

Several deficiencies exist in the current EMCS system that creates urgency in the need to upgrade the existing system by middle of 2015. Therefore, we recommend the following projects:

- Upgrade existing R2 controllers with new controllers
- Replace existing EMCS server/frontend with new server
- Upgrade to newest version of EMCS server package
    - Include new dashboard capabilities for review of base status
    - Include new metering and trending capabilities
    - Retune all alarm setpoints
    - Institute summer/winter operations modes for alarms
    - Reprogram occupancy schedules
- Purchase laptops with VPN capability for off-base access to EMCS
- Restructure EMCS so that Air Force civilians have control of temperature setpoints and overrides
- Issue Exception Requests for Java for machines used to access the EMCS server

These recommendations should be considered as part of a package that includes upgrades to the metering system.

Metering and Procurement

According to the metering information provided by Westover ARB, a number of buildings on the base are individually metered for gas and electricity consumption. Most utilize advanced meters in accordance with Air Force guidelines. Although few of them have been set up for proper connection to EMCS, none is properly archiving appropriate data. Westover ARB does have plans to install advanced metering equipment on additional buildings where economically feasible.

Meters are read by physical inspection for the purposes of reporting. The metering at Westover exists in several states.

1. No metering at the facility.
2. A ‘non-advanced’ meter exists at the facility.
3. An advanced meter exists at the facility, but is not connected to the EMCS.
4. An advanced meter exists at the facility and is connected to the EMCS, but the values appear errant.
5. An advanced meter exists at the facility and is reporting properly.

Most of the metering at Westover falls into categories 2-4 of this list. Site inspections demonstrated that while there were some advanced meters on the installation, they often were simply not connected to a communication line. Other meters that existed were primarily not advanced meters. Furthermore, some of the meters that were connected to the EMCS seemed to read values that were not possible (One meter red negative values.).

It is likely that these meters simply need factors to be adjusted in the EMCS itself. Of the over 100 facilities on the installation, approximately only 13 of these currently have advanced meters that are connected to the EMCS. Estimates for a full update of building meters and their connection to the active on-base network will be included as part of the EMCS update cost estimate.

Energy Conservation Measures

Westover maintains over one million square feet of buildings for visiting reservists, on site full-time staff, and aircraft support (hangars) for the operation and maintenance of C-5 Galaxy transport aircraft. The variety of the building stock, some of which is aging, offers opportunities for a number of building-level efficiency projects as follows:

- **Buildings 2200 and 2201**. At the Visiting Officers Quarters buildings 2200 and 2201, the Clean Energy Team found opportunities for boiler, domestic water heater, and controls upgrades. The energy efficiency opportunities include:
  - Replacing existing gas fired boiler and domestic hot water equipment with new high efficiency gas fired boiler and domestic hot water tank
  - Installing occupancy controls for temperature and lighting control of individual suites. These controls would place the room from unoccupied mode to occupied mode. There are 40 rooms per VOQ that would benefit from these controls.

- **Building 2235**. The Reserve Component Medical Training building hosts a 50-ton Trane chiller which was examined. It was found to be in fair condition with two evaporator circuits; each with a 15-ton and 10-ton screw compressor. There is an energy saving opportunity to upgrade the existing chiller with a higher efficiency chiller and air cooled condensing unit.
- **Buildings 5101, 5102, 5103, 5104 and 5105**. These buildings are dormitories for visiting reservists, which are heated by a central boiler plant. The Clean Energy Team examined the plant and found that the two Cleaver Brooks Boilers are in good condition, but have low efficiency firing rates (approximately 80%) and no hot water reset controls. The boilers also provide hot water during the summer, due to the lack of a separate domestic water heating system. However, there is a domestic hot water storage tank with a 600 gallon capacity at each building. There are opportunities to improve the performance of the boilers and avoid summer usage. Retrofitting with new burners and a hot water reset control (based on outside air temperature), along with

rebalancing and commissioning the water heating and hot water distribution system would results in savings. We also recommend installing a new summer domestic hot water heater and storage tank with associated piping, pumps and controls.

Lighting and Lighting Controls:

The Clean energy Team also examined lighting systems. High pressure sodium lights were found in all six hangars. We recommend upgrading to LED lighting technology in these spaces to maximize energy efficiency. Table 3-24 provides a more detailed description of the baseline lighting technologies and further recommendations for upgrades.

Table 3-24 Summary of Hangar Lighting Technologies Found

Buildings	Baseline Lighting Equipment	Recommended Upgrade
Hangars 1, 2, 5 and 9	Each has 72 high bay high pressure sodium lights (estimated at 400 W) with high operating hours	Replace with new LED lights and lighting controls
Hangar 7000	105 high pressure sodium lights	Replace with new LED lights and lighting controls
Hangar 7040	80 high pressure sodium lights	Replace with new LED lights and lighting controls

3.6.2 Central Plant

The Clean Energy Team conducted an assessment of the following facilities for potential combined heat and power opportunities: Central plant at Building 5100 serving “dormitory” buildings 5101 – 5105, base hangars, and aircraft wash facility.

The results of the field visit found that a significant, centralized CHP opportunity does not exist. With the decentralization of heating equipment, thermal load opportunities dispersed across the base vastly increases the infrastructure that would be necessary to combine these loads for a large CHP.

We also assessed the following areas for the opportunity for distributed CHP but found that coupled with the non-uniformity and inconsistency of monthly thermal energy usage, distributed CHP was concluded to be not feasible either:

- Building 5100. Potential for a distributed CHP was investigated to provide hot water to the soldier barracks buildings 5101 through 5105. While hot water usage is utilized year-round, the occupancy of the buildings is too sporadic for the feasible installation of a CHP system.
- Flight Simulators located in the Base Hangar. The electronics in simulators generate significant heat such that the potential for a year-round thermal (cooling) load could exist. However, simulator use and scheduling varies widely and the cooling requirements are not consistent.
- Aircraft Wash Facility. Location was investigated for potential thermal loading that would support a distributed CHP. Similar to the simulators, the washing of aircraft does not present the consistent and uniform thermal requirement necessary to support CHP.

3.6.3 Renewables

Westover currently has no existing renewable energy technologies onsite. A fuel cell was previously located at the installation, but it has since been moved off-base. There is a solar farm near the fence line installed by the US Department of Labor Job Corps but it does not provide electricity to the base.

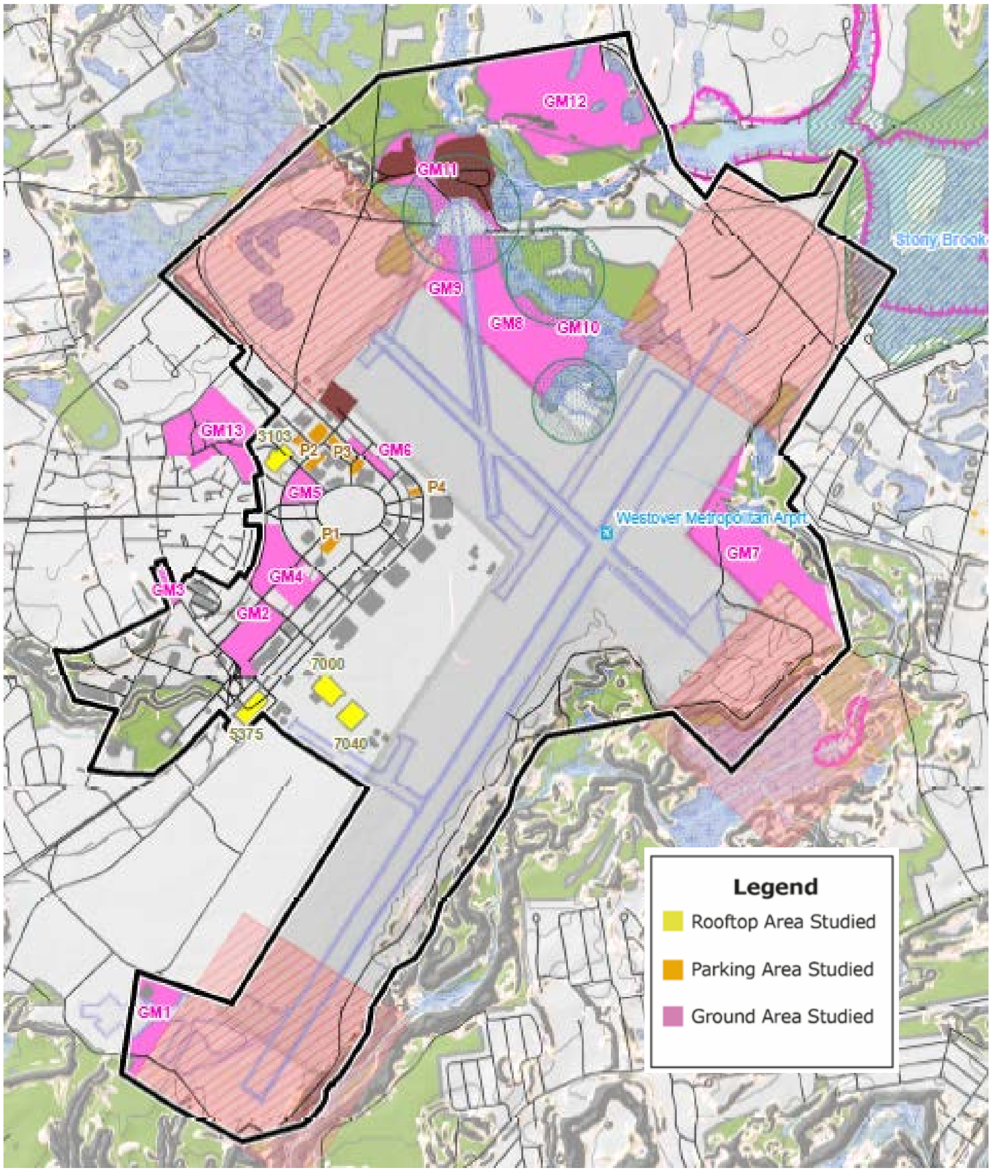
A number of recent studies have been conducted to assess the potential for installing renewable energy systems at Westover, but it was uncertain whether the electrical infrastructure of the base is adequate for transporting the additional supply across or from the base.

Chicopee Electric Light Department (CELD) has worked closely with the base for the last five years under a contract to update the base's electrical distribution system. CELD claims that the current electrical distribution system would have to be upgraded to a larger size conductor (as opposed to current size of the newly installed distribution lines) to provide enough capacity for larger electricity generation systems such as photovoltaic arrays or combined heat and power units. Any recommended clean energy projects will need to take into account the capacity of the distribution system to accept the power and may be connected directly into individual buildings' electrical panels where possible to avoid impacting the distribution system.

Solar

The Clean Energy Team found the Westover ARB to have considerable suitable area to support solar photovoltaic (PV) systems. As shown in Figure 3-6, the Clean Energy Team completed a GIS analysis to identify optimal ground-mount, parking area, and roof-mount photovoltaic installation locations at the base.

Figure 3-6 Solar PV Sites Studied at Westover



Based on further site investigations, all prospective parking areas were found to not be viable for solar PV systems due to additional costs and resources (primarily snow plowing and potential risk of falling snow and ice). The tables below identify remaining solar PV project opportunities for ground-mount solar sites and rooftop sites only. For each type of project, the sites are listed in order of viability.

Table 3-25 Summary of Ground-mount Prospective Solar Sites

Ground-mount	Notes
GM12	The topography appears to undulate and consists of brush and mowed areas as well as a materials stock yard.

GM7	The topography appears to be relatively flat with some undulations and natural drainage patterns heading toward the wooded area to the East.
GM8, GM9, GM 10 and GM11	The topography appears to be relatively flat. Base personnel described these areas as non-active runways not used 100% of the time for training and surplus areas generally used for parking planes and storing snow.
GM13	GM13 contains former Naval housing that has been deeded to the City of Chicopee. Housing will be razed and plans are underway to develop the approximately 25 acres into a series of ground-mount arrays.

Table 3-26 Summary of Rooftop Prospective Solar Sites

Buildings	Notes
5375	This building has a flat roof, southwest orientation and a low number of roof top obstructions (e.g., HVAC, conduit, screens, and fans,).
7000	This is a relatively flat, white membrane roof reconstructed less than 7 years ago; less than optimal SW orientation and moderate roof top obstructions along the centerline .
7040	This roof appears to be a slightly pitched, corrugated metal roof reconstructed over 10 years ago, less than optimal SW orientation and little to no roof top obstructions.
3103	This is a relatively flat roof, raised at multiple elevations, a membrane roof reconstructed within the last 3-5 years, less than optimal SW orientation and moderate roof top obstructions .

Wind

The Clean Energy Team conducted an independent assessment of the feasibility of wind power at Westover ARB given the existing wind resource and state of wind turbine technology. The analysis estimated annual wind speed averages at Westover ARB to range from 4.3 meters/second (m/s) at 30 meters above ground level to 5.7 m/s at 100 meters above ground level. The associated levelized cost of wind electricity estimated at $180/MWh would be well above utility prices. Therefore, wind energy does not appear to be economically viable at this time.

Anaerobic Digestion

A study completed in 2010 by Pacific Northwest National Laboratory identified that potential use of landfill gas from the South Hadley Landfill for electricity generation at the base. There was interest from the Westover ARB in developing a cooperative agreement with the town of South Hadley for the purchase of the landfill gas, but based on a discussion with representatives from the Town of Hadley and the base, the landfill has recently entered into a contractual agreement for the sale of the landfill gas with the Town of Granby. These findings indicate that the development of a landfill gas electrical generation system at Westover ARB would not be a feasible option at this time.

3.6.4 Transportation

Similar to the other bases, ground vehicle fleets at bases are typically composed of a mixture of vehicles owned by the base and vehicles leased from the GSA. Base-owned vehicles and GSA-leased vehicles must follow replacement rules based on minimum accrued mileage, years of service, or pre-established maintenance budgets. As a result, vehicle turnover at bases is low and vehicles typically remain in service for extended periods of time.

Taking all of these factors into consideration, the Clean Energy Team evaluated opportunities for vehicle fleet replacements and fuel switching at Westover Air Reserve Base. Three strategies previously mentioned to assess the potential for reducing GHG emissions from fleet vehicles were considered: replacing existing vehicles with EVs, replacing existing vehicles with HEVs, and switching from fueling with pure gasoline to fueling with E85 for existing flexible-fuel vehicles.

Based on the fleet characteristics for Westover Air Reserve Base, only the EV replacement strategy was analyzed due to a lack of vehicles suitable for HEV replacement or E85 fuel switching. See Table 3-27 below.

Table 3-27 Potential Fuel and Emissions Impact of Fleet Change Strategy

Strategy	Number of Eligible Vehicles	Annual Reduction in Fuel Consumption (gallons)	Annual Reduction in GHG Emissions (CO_2 in pounds)
EV Replacement	63	29,877	570,386

Pick-up trucks represent the largest vehicle category at Westover and largest opportunity for petroleum and GHG emissions reductions. While there is not a hybrid or electric pick-up truck currently available on the market, the Clean Energy Team used the specifications from commercially available electric SUVs to estimate the potential impact of replacing gas and diesel pick-up trucks at Westover with EVs. Replacing eligible vehicles with EVs would reduce GHG emissions by 570,386 lbs. annually. The up-front capital and fuel costs associated with this strategy are summarized in Table 3-28.

Table 3-28 Costs and Fuel Savings of Westover Fleet Change Strategies

Strategy	Up-Front Infrastructure Cost	Purchasing Premium Per Vehicle	Percent Savings in Fuel Cost Per Vehicle
EV Replacement	\$6,000 - \$9,200[1]	\$19,200	83%

[1] Cost of EV level II charging stations varies based on desired built-in features (e.g. ability to process and track credit card payments).

There are significant up-front infrastructure costs associated with replacing current vehicles with EVs. The per-vehicle premium for purchasing EVs (\$19,200) is also a significant cost to consider. However, the per-vehicle cost of fueling would be reduced by 83% if these EV replacements were made. If EV purchases and infrastructure upgrades, such as electric charging stations, are subsidized, then there are real fuel and emissions savings to be achieved.

3.6.5 Infrastructure

Chicopee Electric Light is the local municipal utility which supplies electricity to Westover and has a 50-year contract for maintenance of Westover's distribution system. Chicopee Electric Light just oversaw a major refurbishment of the distribution system upgrading lines from 4.8 kV to 13.8kV, completed in 2013. Municipal utility staff indicate they have a close working relationship with the base.

Westover receives all of its natural gas supplies from Columbia Gas of Massachusetts. The gas distribution system was replaced in FY1991 and provides reliable gas supplies to all the facilities on the base. The base owns and operates the potable water system on-site, but the City of Chicopee also owns the sanitary sewer lines on base.

The Clean Energy Team assessed opportunities for infrastructure modernization, increased efficiency, and improved resiliency but found that no significant opportunities exist for improvements to base infrastructure.

Water / Wastewater

The potable water system is an important topic for the base. The City of Chicopee provides potable water to Westover ARB through a connection on Moody Street in Ludlow, MA. The water supply system accommodates both supply demand and storage reserves to meet consumption requirements (both domestic and industrial) and fire protection purposes.

The water delivery system is sized for the original size and population of the base. Until recently, the water needed to be blown-off to keep water moving through the pipes to maintain water quality standards. A chlorination station was recently installed on the base to reduce the need for blow-offs and maintain quality.

A 500,000-gallon elevated storage tank is used to maintain pressure and flow in the event of fire-fighting activities. The fire pumps associated with this system are used infrequently.

We found that Hangar Building 7040 has one small wastewater pump station. The system consists of four submersible pumps (two 3-hp and two 1-hp units) that operate when airplanes are being cleaned in the building. Since no equipment related to the water and wastewater systems was found to be greater than 5-hp in size, we did not investigate energy saving opportunities for these systems.

3.6.6 Environmental

The Clean Energy Team performed a desktop investigation of the types of remedial systems utilized at site with ongoing remedial actions at Westover ARB. There is one active remediation system currently in operation at the former Building 1601. Gasoline-contaminated soils were excavated in 2013 from the former building 1601 site and in situ chemical oxidation using magnesium sulphate is underway to treat the residual contamination in soil and groundwater. This method is considered an active soil and groundwater treatment method that requires very low energy demands.

The only other ongoing remedial activity identified at Westover during the desktop study was Sanitary Landfill A, which has an activity and use limitation in place.

Based on a search of the Massachusetts Department of Environmental Protection website, no other remediation systems are active at the Westover ARB. Since no treatment systems are in place for groundwater contamination, no other clean energy projects are recommended for further analysis related to green remediation.

4 KEY FINDINGS AND RECOMMENDED OPPORTUNITIES

As a result of the clean energy assessments at each of the bases, the Clean Energy Team identified 189 potential projects. The costs and benefits of each of these projects were evaluated using a common prioritization framework and a scoring approach. A weighting was applied for each rating criteria based on input from project stakeholders, and a total weighted score for each project was computed.

This computation allowed the Clean Energy Team to compare projects across all of the bases and determine which projects were the most attractive in terms of energy efficiency and clean energy development, enhanced energy security and improved resilience, and overall societal and environmental impacts. The projects that were found to be the most compelling opportunities at each base are described below. Many of the projects that top the list are individual building-level energy conservation measures.

In the next phase of work, the DOER will select a separate set of projects that are likely to require longer design and development phases. They will comprise eight small projects and three complex projects across the bases. Once the second set of projects is selected, then the Clean Energy Team will provide technical assistance in the form of specifications and schematic design, which is intended to accelerate the projects from ideas to fully developed RFP's through the appropriate military agencies.

The following projects listed below are intended to be funded from the state's Military Bond bill allocation. The state will encourage swift implementation of these projects.

Barnes ANG

- **Building 69.** Replace existing oil fired furnace with new high efficient gas furnace. This equipment was also found to be old and operating beyond life expectancy.
- **Building 29, 31, 64, and 65.** Replace oil fired boilers with new high efficient gas boilers. The boilers were found to be operating beyond life expectancy. In addition to increased efficiency and reduced emissions, the update will eliminate oil deliveries and reduce base truck traffic.
- **Energy Reduction Measures.** This group of measures originally packaged into bid documents by the base is partially represented here (some measures have been recommended in other bulleted items), and addresses lighting, lighting control upgrades, installation of infrared heat pipes in larger hangar spaces, and installation of instantaneous water heaters. Construction documents were completed for all projects, and they are ready to permit, bid and build.
- **Buildings 17, 27, 28, 33, 53, and 401.** Install DDC controls and connect DDC controls to base EMCS network. This will allow central control of all HVAC equipment and the reporting of utility consumption at all occupied base buildings.

Fort Devens

- **Building 672. Replace existing gas fired boiler with new high efficient gas boiler.** The existing boiler is in good condition but new higher efficiency gas boilers are available. The existing domestic water heater manufacturer, model and capacity were recorded as part of the site visit.
- **Building 673. Replace existing gas fired domestic hot storage tank with new high efficiency domestic water heater.** The existing boiler was found to be approaching the useful life expectancy. No data was available on the domestic hot water storage tank.

- **Buildings 675 and 676.** Install natural gas full building back-up generator. Buildings 675 and 676 are currently used as computer classrooms and contingency command centers during regional/national disaster and other emergency events. The buildings currently have no back-up power source during a power outage. We recommend the installation of a single gas-fired full building generator, the installation of two automatic transfer switches, and other required electrical modifications.

Hanscom AFB

- **Replacement of 40 Hp Bell & Gossett Pump.** The existing pump is not variable frequency drive (VFD) compatible. Due to the size of the pump and hours of operation, replacement with a more efficient pump that is VFD compatible will yield attractive savings.
- **Installation of a new furnace for building 1851.** The hot air furnace was found to be in fair/poor condition. The Clean Energy Team recommends replacing the existing furnace with a new furnace and associated controls.
- **Replace existing gas fired boilers in Buildings 1065 and 1812.** Replace existing gas fired boiler serving the buildings with new high efficiency gas fired boiler or an alternative fueled systems.
- **Replacement of existing 75 hp blower with high efficiency unit to operate with a variable frequency drive.** The remediation treatment system includes two centrifugal blowers, one of which operates continuously. It may be feasible to replace the blower motors with high efficiency units which operate on variable frequency drives that automatically regulate the speed of the blower.
- **Pump rebuild of Well 1 (10 hp) and Well 2 (20 hp).** Energy and cost savings could be achieved by rebuilding the existing pumps or retrofitting with new pumps at Well 1 and 2 as part of pump-and-treat remediation efforts. By rebuilding the pump, the operating efficiencies would be restored to like-new conditions.
- **Rebuild of Upper and Lower Sewer Lift Station Pumps - three 38.7 hp, one 125 hp, and two 50 hp units**. Energy and cost savings could be achieved by rebuilding these six existing large pumps and restoring them to their original operating efficiency. A pump rebuild would include pump disassembly, blast and cleaning, replacement of bearings and packings as required, replacement of the mechanical seal, new painting and coatings, and reassembly and re-installation.

Joint Base Cape Cod

- **Camp Edwards, Boiler and Domestic Hot Water Heater Replacements.** Boilers are beyond useful life in buildings 5515, 5505, 5510, and 5501. DHW equipment needs to be replaced in buildings 5515, 5510, 5505, 5501. New boilers and water heaters are available with much higher efficiencies.
- **PAVE/PAWS, VAV box improvements.** The building has a correctly designed VAV system with hot water reheat; however, the building's functionality has changed and the critical zone control that the hot water reheat system was designed for has changed. Most zones do not require hot water reheat at this point.
- **102IW, Boiler Replacements and Upgrades to Energy Management & Control System.** A central heat plant serviced facilities at Otis ANGB until 1992. When the heat plant was demolished

natural gas boilers were installed in the facilities. The boilers have now outlasted their useful lives and are proving costly to repair. The base is working with EMCS systems from various vendors and eras, which lack control capabilities for the existing systems including night/unoccupied setback programming. Personnel believe there could be substantial savings by leveraging a single, unified building automation system across the installation, estimated to be over $55,000 in annual savings.

- **Coast Guard Base Cape Cod, Establish submeters to report base electric utility data and upgrade steam boiler at Hangar 3170 to Infrared Heat Pipes.** The Coast Guard has a wireless advanced metering system installed to track electrical consumption in operational buildings. The system is active but is not sending data to the manufacturer's server for monitoring and management. This metering system needs to be established as a primary energy management system on base. The steam boiler in Hangar 3170 could be replaced with a much more efficient infrared heat pipe system that would provide radiative rather than convective heat, which is far more effective for high bay spaces.
- **Joint Base Cape Cod Renewables Integration Plan.** Each command was found to be interested in developing additional renewable energy systems at the base. The systems being considered range from small rooftop solar installations to large multi-MW renewable energy systems. The greatest challenge the base will have to seeing these projects come to fruition is managing and overcoming demand and capacity issues on the electric distribution system.

Natick SSC

The Clean Energy Team identified a number of viable clean energy projects for the Army base as listed below. Due to current state funding commitments to Natick SSC for research and an upgrade to key laboratory space, no additional projects are recommended for funding this year. However, the following list of measures should be considered for future investment.

- Air compressor system upgrades in Buildings 3, 4, 5, 36 and 45
- HVAC and Boiler Upgrades for Building 32
- Kitchen Hood Variable Speed Fans and VFDs for two fans and two pumps in Building 36
- HVAC Air/Water Testing and Balancing and Commissioning in Building 4
- Power Factor Correction for Buildings 5 and 36
- Doriot Chambers Chiller Replacement and Controls Upgrades at Building 2
- Roof-Mounted solar PV for Buildings 2, 3, 4 & 5

Westover ARB

- **Buildings 5101, 5102, 5103, 5104 and 5105 New Burner and Hot Water Reset Controls -** These buildings are dormitories for visiting reservists, which are heated by a central boiler plant. The Clean Energy Team examined the plant and found that the two Cleaver Brooks Boilers are in good condition, but have low efficiency firing rates (approximately 80%) and no heating hot water reset controls. The boilers also provide hot water during the summer, due to the lack of a separate domestic water heating system. However, there is a domestic hot water storage tank with a 600 gallon capacity at each building. There are opportunities to improve the performance of the boilers and avoid summer usage. Retrofitting with new burners and a hot water reset control (based on outside air temperature), along with rebalancing and commissioning the water heating and hot water distribution system would results in savings. We also recommend installing a new summer domestic hot water heater and storage tank with assorted piping, pumps and controls.

- **Buildings 2200, 2201, 5101, 5102, 5103, 5104 , and 5105 Room Control Upgrades.** Installing occupancy controls for temperature and lighting control of individual suites. These controls would place the room from occupied mode to unoccupied mode when visitors leave. They are similar to controls now found in energy efficiency minded hotels.
- **EMCS System Improvements -** Several significant deficiencies exist in the current EMCS system that creates urgency in the need to upgrade the existing system by middle of 2015. These include the server not meeting military network security requirements and R2 field controllers not being supported by the manufacturer after the end of 2015. Therefore, we recommend the following projects:
  - Upgrade existing R2 controllers with new controllers
  - Replace existing EMCS server/frontend with new server
  - Upgrade to newest version of EMCS server package
    - Include new dashboard capabilities for review of base status
    - Include new metering and trending capabilities
    - Retune all alarm setpoints
    - Institute summer/winter operations modes for alarms
    - Reprogram occupancy schedules
  - Purchase laptops with VPN capability for off-base access to EMCS
  - Restructure EMCS so that Air Force civilians have control of temperature setpoints and overrides
  - Issue Exception Requests for Java for machines used to access the EMCS server

  These recommendations should be considered as part of a package that includes upgrades to smart meters and meter network connections for each occupied building.
- **Preparation for Ground-Mount Solar Field –** The City of Chicopee and Westover ARB are jointly interested in converting former naval property near the base into a solar PV field. Funding for this project would go toward clearing the land and making site improvements that would facilitate siting PV systems. The actual development of the solar PV field is most likely to be requested by RFP for a third party developer.

All Bases

- **Installation of Electric Vehicle Charging Stations –** In support of the Commonwealth's efforts to decrease transportation-related greenhouse gas emissions, electric vehicle charging stations are considered important infrastructure to encourage purchase of electric vehicles by the military bases and their staff. A Level II charging station (240V) with two ports will be deployed at or around each base at the location deemed most practical by the bases or the surrounding community if on-base is not possible. Level II charging stations take approximately 4 hours to recharge regular passenger vehicles.

Projects that align with DOER clean energy policies, programs, and pilot initiatives will be selected for further development by the Clean Energy Team. For this effort, emphasis will be placed on projects that represent renewable and emerging technologies that could benefit from state-level assistance, and have support from base leadership. Eight small projects and three more complex projects will be selected for this initiative in the next phase of work.

The Military Task Force also selected a number of these high impact projects that to be funded under the state's capital plan. The projects selected under this initiative best fit with Commonwealth, DoD, and individual base goals. Table 4-1 provides a summary of the projects selected military bond funding.

Table 4-1 Select Projects for Capital Funding

Base	Description	Total Measure Score	Total Annual kWh Savings	Total Est. Upfront Cost	Cost Savings	Payback
Barnes	Replace existing gas furnace with high efficient gas furnace in Bldg 69	44.94	0	$ 1,085	$ 468	2.3
Barnes	Replace existing boilers with natural gas for Bldgs 29, 31, 64, 65	25.16	0	$ 76,778	$ 8,110	9.4
Barnes	Energy Reduction Measure (Partial). Measures include lighting, lighting control upgrades, installation of infrared heat pipes, on-demand hot water heaters, and envelope improvements.	22.83	0	$ 797,262	$ 93,181	8.5
Barnes	Upgrades at building level to be controlled by existing EMCS. Install DDC controls at Bldgs 17, 27, 28, 33, 52, 401 (401 has DDC, but needs to be connected to network)	18.75	3,685	$ 84,875	$ 7,516	11.2
Ft. Devens	Bldg 672 - Boiler Replacement	30.70	0	$ 23,318	$ 4,290	5.0
Ft. Devens	Bldg 673 - DHW Replacement	29.64	0	$ 25,261	$ 10,032	2.3
Ft. Devens	Bldgs 675 & 676 installation of full building, gas-fired generator.	19.75	0	$ 61,421	$ -	N/A
Hanscom	Replacement of existing Bell & Gossett 40 hp steam and chiller pump motor with premium efficiency unit.	36.9	41,785	$ 16,000	$ 6,769	2.2
Hanscom	Replace air furnace with new high efficiency furnace: Bldg 1851	30.60	0	$ 1,120	$ 265	4.0
Hanscom	Replace existing gas fired boiler with new high efficiency gas fired boiler: Bldgs 1065 and 1812	25.68	0	$ 14,905	$ 2,124	6.7
Hanscom	Replacement of existing 75 hp blower with high efficiency unit to operate with a variable frequency drive.	25.63	149,519	$ 104,230	$ 24,222	4.5

Base	Description	Total Measure Score	Total Annual kWh Savings	Total Est. Upfront Cost	Cost Savings	Payback
Hanscom	Pump rebuild of Well 1 (10 hp) and Well 2 (20 hp).	24.72	37,805	$ 16,156	$ 6,124	2.5
Hanscom	Rebuild of Upper and Lower Sewer Lift Station Pumps (3-38.7 hp, 1-125 hp, and 2-50 hp units).	22.64	89,910	$ 78,589	$ 14,565	5.2
JBCC - Camp Edwards	Boiler Replacement: Bldgs 5515, 5502, 5501	29.77	0	$ 61,720	$ 10,478	5.5
JBCC - Camp Edwards	DHW Replacement; Bldgs: 5515, 5510, 5505, 5501	23.79	0	$ 3,280	$ 509	6.0
JBCC PAVE PAWS	Installation of second VAV box w/ electric reheat	26.89	0	$ 42,000	$ 6,555	6.1
JBCC-OTIS	Renewables Integration Plan	N/A	N/A	$ 101,412	N/A	N/A
JBCC-OTIS	Replace Boiler: Bldgs 104, 120, 122, 149, 155, 156, 158, 159, 162, 167, 197, 322, 330, 430, 754, 971, 5236, 5238, 124.	34.43	0	$ 356,183	$ 91,591	3.8
JBCC-OTIS	102nd Building Management System control upgrades	23.31	44,447	$ 742,405	$ 93,484	7.8
JBCC-USCG	Replace steam boiler at Hangar 3170 with infrared heaters	34.4	0	$ 110,000	$ -	
JBCC-USCG	Establish submeters to report base electrical consumption data	24.20	5,040	$ 13,000	$ 5,040	2.3
Westover	Bldgs- 5101, 5103, 5102, 5104 and 5105 - Base dorms - New Burner and Hot Water Reset Controls	35.98	0	$ 31,726	$ 17,901	1.7
Westover	Bldgs- 2200, 2201, B5101, 5102, 5103, 5104 and 5105 - Room Control Upgrade	29.33	327,778	$ 116,278	$ 47,556	2.4
Westover	EMCS Jace upgrade -Improvements to the EMCS are highly desirable for increased functionality, controls, and energy trending	26.76	104,199	$ 457,951	$118,298	3.8
Westover	Upgrade of utility meters to smart meters and connection to EMCS	19.72	36,399	$ 324,045	$ 51,292	6.2
Westover	Additional for Solar Field at Chicopee/Westover - Funding to be used to clear city property in advance of solar construction	N/A	N/A	$1,000,000	N/A	N/A
All Bases	One Full Electric Charging Stations with 2 charging units per base @ $14K PER STATION. Includes all bases at JBCC.	N/A	N/A	$ 126,000	N/A	N/A

Microgrids – Barnes, Westover, and Fort Devens

While opportunities to develop microgrid capabilities were assessed as part of this project, a detailed analysis was not performed for Barnes ANG, Westover ARB or Fort Devens. Elements that are critical to owning and operating a microgrid, such as central energy plants, established plans to develop clean energy generation, back-up generation assets, staffing needed to operate an islanded microgrid, and interest of base personnel in pursuing microgrid options were all considered by the Clean Energy Team. Based on these factors, we determined that current conditions were not present to develop successful microgrid installations.

5 CONCLUSION

The Massachusetts Military Clean Energy Assessment and Strategic Plan is part of a long-term initiative launched by the Commonwealth of Massachusetts to support and enhance military installations. It is intended to assist the bases in developing, coordinating, and implementing actions related to infrastructure improvements, environmental and utility savings, increasing energy efficiency and fostering new missions and partnerships that support economic development. As part of this assessment, the Clean Energy Team uncovered many opportunities to further support each base in their efforts to meet Department of Defense goals for energy, environmental sustainability and energy security.

The state has used the results of this study to identify projects to financially support with capital funding, which are listed in Table 4-1. Additionally, the results will be used to develop technical specifications and schematic designs for eight small and three large projects as directed by DOER. The technical assistance is intended to help facilitate and accelerate the implementation of selected high impact projects at each of the bases.

Finally, study results will be also used to support future partnerships between the state and the bases to implement clean energy and infrastructure improvement projects at the bases. The list of projects identified in this report can be used as a basis for these decisions, but this study should be considered a living document. We have found that the military bases are constantly working to improve their energy infrastructure and reduce their energy intensity. The Massachusetts bases are generating new energy projects and ideas every year.

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