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Downstream benefits of energy management systems

Vermeychuk, Theodore J.

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MBA PROFESSIONAL REPORT

DOWNSTREAM BENEFITS OF ENERGY MANAGEMENT SYSTEMS

December 2015

By: Theodore J. Vermeychuk

Advisors: Nick Dew
Eva Regnier

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DOWNSTREAM BENEFITS OF ENERGY MANAGEMENT SYSTEMS

Theodore J. Vermeychuk, Lieutenant Commander, United States Navy

Submitted in partial fulfillment of the requirements for the degree of

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Approved by: Nick Dew

Eva Regnier

Don Summers
Academic Associate
Graduate School of Business and Public Policy

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DOWNSTREAM BENEFITS OF ENERGY MANAGEMENT SYSTEMS

ABSTRACT

This report examines the downstream benefits of energy management systems (EMS) at Department of Defense (DOD) installations. The DOD has mandated thorough energy metering at shore installations, but EMSs are not widespread within the DOD. Four DOD installations with EMSs serve as individual case studies in a multiple-case study analysis. This report identifies three categories of downstream benefits associated with EMSs: addressing errors that cause energy waste, identifying wasteful buildings on an installation, and identifying valuable follow-on investments. Much of the value associated with EMSs is in analyzing the data provided, and future improvements in EMS data analysis will likely yield additional benefits.

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LIST OF ACRONYMS AND ABBREVIATIONS

ALC	Automated Logic Corporation
AMS	Advanced Metering System
Auto-Cx	Automatic Commissioning
DDC	Direct Digital Controls
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
EMCS	Energy Management Control System
EMS	Energy Management System
eROI	Energy Return on Investment
ESPC	Energy Savings Performance Contract
ESPM	Energy Star Portfolio Manager
FNMOC	Fleet Numerical Meteorology and Oceanography Center
HVAC	Heating, Ventilation, and Air-Conditioning
kVa	Kilovolt-Amperes
MCAGCC	Marine Corps Air Ground Combat Center
MCAS	Marine Corps Air Station
NPS	Naval Postgraduate School
NSAM	Naval Support Activity Monterey
OAT	Outside Air Temperature
POM	Presidio of Monterey
RCx	Retro-Commissioning
Solar PV	Solar Photovoltaic
VSG	Virtual Smart Grid

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I. INTRODUCTION

A. ENERGY MANAGEMENT SYSTEMS

An energy management system (EMS) is, at a minimum, a network of sensors that record and aggregate data on direct energy usage and associated data at an individual-building scale or finer resolution (e.g., operating status of heating, ventilating, and air-conditioning [HVAC] equipment, outside air temperature, electrical load for specific equipment), at intervals of one hour or less. More capable EMS include real-time monitoring and/or some degree of centralized control functionality (often referred to as an energy management control system, or EMCS), allowing an operator to monitor several buildings and make adjustments to optimize HVAC systems, lighting, and other energy consumption. Throughout this report, the term *EMS* is used to refer to any of these systems.

The most basic sensor to be included in an EMS is an energy meter, which is used to measure consumption of electricity, fuel, or other energy source. The term *smart meter* is generally used to indicate an energy meter that provides data to the user at some regular interval. For EMS purposes, a network of smart meters can be set up to collect data for each building on an installation (or each floor of a building, etc.). This meter data can then be transmitted to a central user terminal, allowing a facility energy manager to monitor the facility's energy use.

An EMS may also include a variety of sensors and controllers for energy-intensive equipment. Generally, buildings' biggest energy loads are for lighting and HVAC. Additionally, large numbers of computers or data centers require significant energy. An EMS can include sensors monitoring operating status of lighting and HVAC equipment. An EMS may also include direct digital controls (DDC) for automated control of lighting and/or HVAC equipment.

B. PURPOSE OF THIS STUDY

The purpose of this research is to identify benefits of installing and operating EMSs at DOD facilities in order to help DOD managers evaluate the potential benefits of

EMS investments and attribute cost savings and other benefits to the capabilities provided by EMSs. Specifically, this thesis aims to catalog *downstream benefits*—those benefits that may not be immediately apparent when making the decision to invest in an EMS. These would include unanticipated benefits (i.e., unexpected reductions in energy use), further investment options that would not have been feasible or apparent without the output data from the EMS, and any procedural or behavioral changes that become feasible as a result of operating the EMS. These latter changes are contingent on the initial EMS investment (they only create value—improve facility performance or lower facility costs—in *combination* with the EMS investment).

Installing an EMS in itself may not directly result in an immediate reduction in energy demand at a facility. However, an EMS does facilitate optimization of energy systems that may indirectly reduce energy demand. A relatively simple EMS may only provide aggregated energy-use data with no control functionality. But, even with no control features, there is value in the data provided by an EMS because analysis of the EMS's output data will likely yield opportunities to improve facility energy use, identify potential waste, and thereby reduce total energy consumption.

It remains to be determined what the likely energy savings are for a given type of EMS, depending on the level of resolution and functionality. Some cost savings associated with operating an EMS are likely to accrue incrementally over time (e.g., incremental reductions in energy used per year, adding up to significant savings whose net present value exceeds net present costs) They are also detected over time—for example, as more sophisticated equipment becomes available that interacts with the EMS to allow for more efficient or effective operation. Proper financial analysis of installation energy projects requires considering life-cycle costs that includes those later benefits. Thorough analysis must also incorporate likely tenant behavioral changes, as these may be significant (Harrington & Carmichael, 2009). Additionally, future energy costs are unpredictable, and that can affect the economic value of any energy savings. Lastly, including energy upgrades with planned equipment improvements or retrofit efforts can reduce the incremental cost of energy projects (Harrington & Carmichael, 2009).

For the DOD, installing EMSs may also generate downstream benefits related to security, resilience, cost savings, and identifying investment options. Given the broad scope of potential downstream benefits associated with EMSs, it is important to consider those benefits in determining whether or not the DOD should pursue EMS efforts at installations on a broad scale. For individual installation managers, downstream benefits should be considered in deciding whether and at what level to pursue EMS investments.

Therefore, this thesis develops a taxonomy of the downstream benefits of installing and operating an EMS. Some of these benefits may be easily quantifiable, but many are not. In the future, some benefits may be predicted and appropriately included in determining the value of any potential investment. Some of these potential downstream benefits may be difficult to quantify, but qualitatively anticipating the type of benefits can help support decisions related to EMS investments.

C. STUDY ORGANIZATION

This study is presented in five chapters. Chapter I provides an introduction and context for further discussion of EMS and specifies the purpose of this study. Chapter II discusses background information on metering, EMSs, energy policy, and DOD energy projects, and describes the multiple-case study methodology. Chapter III relates narrative data from each of the four case studies conducted. Chapter IV presents an analysis of the data collected, identifying the recurring themes in the data. Finally, Chapter V presents the author's conclusions and recommendations based on the analysis.

1. Background

The federal government has made significant efforts to address climate change and mitigate carbon emissions. The 2014 *Quadrennial Defense Review* notes that "climate change may…undermin[e] the capacity of our domestic installations" (p. vi). The DOD has undertaken a variety of efforts to improve energy efficiency, including some advanced demonstration projects for EMSs, microgrids, extensive solar photovoltaic (PV) generation capacity, and others (Department of Defense [DOD], 2014a).

2. Methodology

The DOD's EMS demonstration projects are relatively young and data on the projects are still being collected (DOD, 2014a). In order to identify downstream benefits of EMSs, the author collected narrative data for four unique case studies, each at a different DOD installation. The intent is to evaluate the EMS at each installation, and then compare the data.

This multiple-case study is an ideal approach for evaluating EMSs at DOD installations. The DOD owns or manages more than 500 installations worldwide (DOD, 2014a, p. 7). Each installation is unique in terms of size, number and type of buildings, personnel onboard each day, mission requirements, etc. Additionally, DOD installations vary in climate, utility provider(s), and available renewable energy sources. Thus, each installation has its own unique energy requirements, and unique opportunities for energy projects and/or EMSs. This study, comprised of four DOD installations, reflects some of the variety of possibilities present across the DOD.

3. Narrative Data

The author conducted interviews with installation energy managers and others involved with energy related projects at the four installations. Throughout those discussions, the author identified various benefits associated with the EMSs, as well as potential future benefits. The data are presented in three categories: efficiency improvements, follow-on investment options, and anything else.

Efficiency improvements vary from minor items to correcting major issues. In one instance, installation personnel at Naval Support Activity Monterey (NSAM) discovered an HVAC control programming error that was responsible for estimated energy waste amounting to as much as $500,000 *per year*. Follow-on investments include hiring additional EMS technicians, pursuing demonstration projects, and a proposal for a heat and electricity cogeneration plant at NSAM, among other items. The last category includes anything noteworthy discovered during the research process that did not fit into the first two categories.

4. Analysis

The analysis compares the case study data. This section identifies types of benefits that are repeated across some or all of the case studies. Types of benefits that are not repeated but are important are also discussed. This section identifies repeated themes among the downstream benefits identified.

There are three common types of downstream benefits identified in this study. First, EMSs can yield benefits by allowing facility energy managers to correct operating or programming errors, thereby reducing energy waste. Second, EMS data can be used to identify buildings that will benefit most from in-depth testing, evaluation, and retrofitting of mechanical equipment, by singling out buildings whose energy consumption significantly exceeds expectations. Third, EMSs are a prerequisite for a variety of follow-on investment options, which can yield significant energy savings over time.

Additionally, there are a few common themes in the data. The data available from an EMS are valuable, even with no control functionality. Installation managers can use the output data to identify discrepancies and inform decisions regarding energy systems and equipment. Taking full advantage of the data available requires personnel who are trained to analyze the data, and have the time to do so. There is opportunity to develop automated analysis processes or algorithms, easing the manpower burden required to derive useful information from the EMS data available. EMS data may be used to influence individuals' behavior or decision-making, with significant positive effects on energy use. By presenting energy-related data in a simple, visual format, installation personnel may be able to make better energy-related decisions, and/or change their behavior to reduce total energy requirements.

5. Conclusions

This chapter presents conclusions based on the analysis of the data. Downstream benefits contribute to the value of an EMS, should be considered when evaluating EMS investment decisions. Additionally, to realize the full value of an EMS, thorough data analysis is necessary. There is room for improvement in both efficiency and effectiveness of analyses of EMS data.

For DOD installations, EMSs will be more critical in the future, improving resilience and enabling various energy savings projects, in line with meeting policy goals. Those installation managers who are best able to leverage the EMS data available will gain the most value from EMS investments.

Last, this chapter identifies opportunities for further research into downstream benefits of EMSs.

II. BACKGROUND AND METHODOLOGY

A. DEPARTMENT OF DEFENSE ENERGY POLICY

The U.S. federal government has been and remains focused on advancing energy security and confronting climate change. Both goals are relevant to U.S. national security; the most recent U.S. National Security Strategy explicitly addresses both energy security and climate change (White House, 2015, pp. 12, 16). Effective energy management should allow organizations to optimize energy use, ideally reducing total energy requirements through efficiency gains and identifying value-added energy-related projects.

Among federal agencies, the DOD is the largest energy consumer by far, accounting for approximately 80 percent of total federal energy consumption (DOD, 2014a, p. 17). A large portion of DOD's total energy consumption is operational energy (much of it in the form of petroleum fuels); this is distinct from "facility energy" (DOD, 2014a, p. 8). Worldwide DOD shore installations account for approximately 30 percent of total DOD energy use (DOD, 2014a, p. 7). Considering the number of installations and the total energy use by those facilities, DOD is a prime candidate for improved energy management efforts.

1. Metering and EMS

U.S. law dictates that all federal buildings be metered. The National Energy Conservation Policy Act (2005) directed all federal buildings have electric metering installed by October 1, 2012. Additionally, the statute set a deadline for natural gas and steam metering no later than October 1, 2016. As a result, the DOD adopted more accelerated goals.

In 2009, DOD Instruction 4170.11 directed implementation of electricity, natural gas, water, and steam metering for all appropriate DOD facilities. The instruction defines "appropriate facilities" as "those for which … metering would be cost effective and practical as a management tool" (DOD, 2009, p. 17), allowing exclusions for buildings with minimal energy use (such as guard shacks), minimal opportunity for energy savings (e.g., buildings near the end of their serviceable lives), or those otherwise deemed inappropriate for metering.

An advanced meter is one that records data at intervals of one hour or less and transmits the recorded data at least once per day to a central collection point (Department of Energy [DOE], 2014, p. 3). The U.S. Department of Energy (DOE) recently updated its federal building metering guidance, directing use of advanced meters or advanced metering devices to the maximum extent practical in meeting metering requirements (DOE, 2014). In 2013, the Deputy Undersecretary of Defense (Installations and Environment) (DUSD [I&E]) had already set ambitious goals for implementing advanced metering across a majority of DOD installations (DOD, 2013). Further, according to DOD's FY2014 *Annual Energy Management Report*, the Assistant Secretary of Defense (Energy, Installations, and Environment) intends to publish a strategy to help DOD components "leverage meter data to identify savings opportunities, prioritize investment decisions, and more effectively manage their building energy use" (DOD, 2014a).

The 2009 DOD instruction "encouraged [DOD components] to apply [EMSs] or other energy management technology on all new and existing system expansion applications" (DOD, 2009, p. 17). This indicates early recognition of the potential value of EMSs at DOD installations. The DUSD (I&E) 2013 policy memo, describing the purpose of advanced metering, indicated the advanced meters must communicate their data to a central system, which "must automatically and reliably collect *and analyze* regular interval data" (emphasis added) (DOD, 2013). Although the memo used the term "advanced metering system" (AMS), the intended product was a basic EMS.

The DOE has developed a prioritized list of facility types recommended for advanced metering. For existing facilities, data centers are the number two priority for advanced metering, second only to metering for self-generated energy sources (DOE, 2014). Data centers are a high priority because they are generally energy intensive. Following data centers, DOE lists "all other known energy-intensive building types" (DOE, 2014, pp. 8). The White House recently issued additional guidance, requiring advanced energy meters in all federal data centers by fiscal year 2018 (Executive Order No. 13693, 2015).

Table 1 reflects that DOD has made significant progress in metering all appropriate facilities, in accordance with directives. Table 2 shows DOD's progress in installing advanced meters (referred to as AMS) for electricity and natural gas.

Table 1. Metering of Appropriate DOD Facilities

Utility	Cumulative # of Buildings, Standard Meters	Cumulative # of Buildings, Advanced Meters	Total % Appropriate Buildings Metered
Electricity	13,713	35,611	95%
Natural Gas	5,143	9,042	82%
Water	877	5,101	35%
Steam	697	861	72%

Source: Department of Defense. (2014a). *Annual energy management report FY2014*, 55. Washington, DC: Office of the Assistant Secretary of Defense (Energy, Installations, and Environment). Retrieved from http://www.acq.osd.mil/ie/energy/energymgmt_report/Tab%20B%20-%20FY%202014%20AEMR_FINAL.pdf

Table 2. DOD's Electricity and Natural Gas Advanced Metering Progress

Commodity	Total Consumption (BBTU)	Energy Consumption Captured by an AMS	% Energy Captured by an AMS	Number of Installations with Installation-level Advanced Meters	% Installations with Installation-level Advanced Meters
Electricity	99,723	18,930	19%	144	19%
Natural Gas	66,508	4,978	7%	51	7%

Source: Department of Defense. (2014a). *Annual energy management report FY2014*, 55. Washington, DC: Office of the Assistant Secretary of Defense (Energy, Installations, and Environment). Retrieved from http://www.acq.osd.mil/ie/energy/energymgmt_report/Tab%20B%20-%20FY%202014%20AEMR_FINAL.pdf

2. Energy Goals

The Energy Independence and Security Act of 2007 updated the facility energy reduction goals previously established by the Energy Policy Act of 2005. The 2007 statute required all federal agencies to reduce facility energy intensity 30 percent by fiscal year 2015, from a 2003 baseline. Energy intensity defined as consumption per interior square foot (Energy Independence and Security Act, 2007). As of FY 2014, DOD had not achieved its specified goals for reducing energy intensity. Table 3 shows DOD's progress as of FY 2014 toward energy intensity reduction goals.

Table 3. 2014 DOD Progress Toward Facility Energy Goals

Goals & Objectives	Metric	Entity	FY 2014 Performance	FY 2014 Target
Reduce Facility Energy Intensity relative to FY 2003 baseline (EISA 2007)	British thermal unit (Btu) of energy consumed per gross square foot of facility space.	DoD	-17.6%	-27%
		Army	-15.2%	
		Navy	-20.6%	
		Marine Corps	-18.7%	
		Air Force	-22.3%	

Adapted from: Department of Defense. (2014a). *Annual energy management report FY2014*, 9. Washington, DC: Office of the Assistant Secretary of Defense (Energy, Installations, and Environment). Retrieved from http://www.acq.osd.mil/ie/energy/energymgmt_report/Tab%20B%20-%20FY%202014%20AEMR_FINAL.pdf

Looking beyond 2015, the Assistant Secretary of Defense (Energy, Installations, and Environment) has established goals for ongoing energy efficiency improvements, challenging DOD to further reduce facility energy intensity by 37.5 percent below the 2003 baseline by fiscal year 2020 (DOD, 2014a, p. C-2). Additionally, the Assistant Secretary set goals for increasing renewable energy production and procurement: renewables should account for 15 percent of total facility energy by fiscal year 2018, and 25 percent of total facility energy by fiscal year 2025 (DOD, 2014a, p. C-2).

Although no directive explicitly requires DOD to install and operate EMS at shore installations, EMS will likely play a pivotal role in DOD's pursuit of stated energy policy goals. In conclusion to his 2013 policy memo, the DUSD (I&E) wrote:

> A widely-distributed and integrated network of advanced meters is foundational to gaining an in-depth understanding of how DOD uses energy and water. This understanding is essential to development of a strategic approach to reducing consumption, maintaining mission assurance, and providing reliable power to critical loads. (Deputy Undersecretary of Defense (Installations and Environment) [DUSD (I&E)], 2013, p. 4)

The DUSD (I&E)'s comments emphasize the potential value of advanced metering (EMSs) at DOD installations. In the future, EMSs will provide additional value beyond simply understanding and reducing energy use. EMSs will play a role in increasing installation resilience and incorporating increased use of variable-generating renewables (e.g., solar PV, wind), and there is potential for other additional benefits.

B. ADVANCED ENERGY PROJECTS

The Environmental Security Technology Certification Program (ESTCP) is a DOD initiative to demonstrate emerging advanced energy technologies in real-world shore installation environments. Through this program, DOD intends to "be a sophisticated first user of successful cutting-edge, transformational energy technologies" (DOD, 2014a, p. 47). Specifically, the ESTCP funds microgrids and other advanced energy management technology projects at DOD installations (DOD, 2014a). Advanced EMS technology would fit into this category.

DOD recognizes the value (energy cost savings) of microgrids (small-scale localized energy grids) and advanced EMS technology (DOD, 2014a). Through the ESTCP, DOD has funded integrated microgrid and energy management projects such as the one at Marine Corps Air Ground Combat Center (MCAGCC) in Twenty-Nine Palms, California. The project at Twenty-Nine Palms includes various on-base energy generation capabilities and an advanced microgrid, and is designed to allow the installation to operate completely off the commercial power grid (DOD, 2014a, p. 48–49). The interconnected nature and network-reliance of local microgrids presents cyber-security concerns for DOD installations. As the next phase in a series of microgrid projects, DOD is working to make Camp Smith, Hawaii, the first "completely 'always on, always sensing, islandable,' and cyber-secure… installation microgrid" (DOD, 2014a, p. 50).

These and other projects are part of DOD's ongoing effort to foster technology development, and to leverage emerging energy technologies to improve energy use and resilience at DOD installations.

C. MULTIPLE-CASE METHODOLOGY

This research is an analysis of multiple case studies. Each facility or EMS is treated as a separate case study, and the conclusions are drawn by examining and comparing the four cases.

1. Multiple-Case Study Design

This research is an analysis of multiple case studies. In designing this multiple-case research study, the author referred to Robert Yin's authoritative text on the subject (Yin, 2009). Yin provides a twofold definition of case studies. The first part addresses the scope of a case study: "[a] case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context…" (Yin, 2009, p. 18). For this study, the phenomenon in question is the use of EMSs at DOD installations. The context includes the policy environment and explicit energy goals, inherent budget limitations, and the suite of proposed energy projects vying for a portion of those limited funds. The second part of Yin's definition addresses data collection: "[t]he case study inquiry copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result relies on multiple sources of evidence, with data needing to converge in a triangulating fashion…" (Yin, 2009, p. 18). This research is an attempt to identify all downstream benefits of EMS, although it is inherently limited by the number of EMSs so far in place within the DOD, the recency of their implementation, and the lack of prior systematic collection of information on their effects. The results of this study are conclusions derived from the necessarily non-exhaustive narrative data collected in the multiple case study.

For this report, each facility is treated as an individual unit of analysis, whether the facility has an EMS covering the entire installation or some portion thereof. Each facility is treated as a "holistic single case," with its own context (Yin, 2009, pp. 46–50). Within DOD, energy is billed, accounted for, and reported up the chain of command at the facility scale. Additionally, each installation has its own unique energy challenges (e.g., age and number of buildings, transmission and distribution requirements, etc.). For these reasons, the unit of analysis is the installation and it is appropriate to consider each installation as a unique case. Installation energy managers are the primary source of data.

2. Data Collection

To collect data, the author interviewed energy managers and other cognizant individuals representing four DOD installations. Each installation has a different EMS, at a different stage of implementation. The author’s initial set of interview questions is included as appendix A, although those questions were re-scoped during the course of the research process to focus on data that were available and relevant.

The author initially set out to develop a baseline understanding of the EMS and/or energy management projects at each facility. Given the potential complexity of these systems, this was a nontrivial task.

After discussing the EMS and other energy projects, the author and the interlocutors for each case discussed benefits of the EMS. The conversations were specifically focused on trying to identify downstream benefits that could be directly related to the EMS in some way. Some interviewees proposed potential benefits that have not yet been realized, but may be possible in the future. Those conjectures are included in the narrative data for each case.

3. Theory and Qualitative Analysis

These systems have been installed over time, piecemeal, and funded by various sources (Tulley, 2015; D. Taber, interview with author, October 5, 2015). Moreover, the nature of the benefits of EMSs is still under study, and therefore quantifying these benefits financially is still impossible. In lieu of a quantitative business-case analysis for the EMSs in question, this research is focused on qualitatively characterizing the significant downstream benefits of installing and operating EMSs at DOD installations. Those benefits may not be immediately apparent and thus may not be identified, even qualitatively, in the course of a return-on-investment analysis or other cost-benefit type of analysis.

The analysis consists of a comparison of the cases, identification of common elements and those issues and events that stand out as unique. Referring to Yin’s text, the goal of case study research should be to develop “analytic generalizations” regarding the subject of the study (Yin, 2009, pp. 38–39). From the common themes identified in the data, the author develops some analytic generalizations regarding downstream benefits of EMSs.

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III. CASE STUDY NARRATIVES

This chapter includes narrative data gathered in each case study. Each case begins with a brief description of the EMS and/or energy projects, along with relevant discussion about the installation. The narrative data are organized in three categories: efficiency improvements, follow-on investment options, and anything else. These three categories were identified early in the study, and the data are organized as such for simplicity.

A. PRESIDIO OF MONTEREY

The Presidio of Monterey (POM) is a relatively small Army installation. It includes a few satellite sites, but the majority of POM's energy efforts are focused on two sites: the main site in Monterey, CA, home of the Defense Language Institute and various support functions (MWR, medical clinic, etc.), and the Ord Military Community of privatized housing. POM's main site encompasses approximately 150 buildings on about 350 acres of land (Google maps, 2015c). Annual utility costs for POM's main site are approximately $3.2 million (J. Tulley, personal communication, December 1, 2015).

Jay Tulley, Energy Manager at POM, gave a presentation at NPS August 28th, 2015, titled "Creating an Energy Culture at the Presidio of Monterey." Following that presentation, the author met with Tulley to discuss benefits of POM's EMS in more detail. Additionally, Brian Clark, a mechanical engineer with POM's Department of Public Works, gave a follow-on presentation at NPS. Clark is working on retro-commissioning (RCx) projects for several buildings at POM, and he discussed those efforts and also provided some broader context for the value of RCx efforts in general.

POM's EMS includes smart meters for individual buildings and HVAC controls for some buildings at the main site. POM's public works department uses energy meter data for energy use analysis, as well as to provide feedback to tenants on the installation. The HVAC control features are used by public works personnel and maintenance technicians to optimize HVAC operation and troubleshoot complaints.

As of April 2015, POM had installed smart meters at 71 buildings. Also, POM has a demonstration project with HVAC controls for eight buildings. POM personnel are working to resolve networking issues for the meters, and then to achieve accreditation in order to operate the EMS. Additionally, once the contractor has achieved satisfactory performance for the HVAC controls already installed, POM intends to expand the HVAC control functions to 35 buildings in total, all connected to the installation EMS.

POM personnel have set a goal to be an energy net-zero installation by 2030. The date is arbitrary, well ahead of requirements established by the Army or DOD (J. Tulley, interview with author, September 15, 2015). POM personnel are evaluating ways to produce more energy onsite as well as pursuing efficiency improvements. Tulley noted that a lot of efficiency improvements are "low-hanging fruit," easy to discover just by looking with an inquisitive eye. For example, a few years ago he noticed a barracks building with several windows open on a relatively cold winter day. After asking a few of the occupants, he discovered that the thermostats in each room were located behind a piece of furniture, and thus inaccessible. The occupants' only way to control room temperatures was to open the windows. Tulley's staff moved the thermostat in each room to an accessible location, allowing occupants to control their heating and thereby reduce energy waste.

Tulley also noted that a lot of the "low-hanging fruit" has already been discovered at POM that may also be available at other DOD sites. He believes there are opportunities for further efficiency improvements associated with POM's EMS, hence the ongoing project. Once complete, the EMS will allow POM's energy manager to monitor energy usage across the entire facility, and remotely monitor and program HVAC operation at the most energy-intensive buildings for optimal performance.

1. Efficiency Improvements

Tulley and Clark discussed several efforts at improving energy efficiency at POM.

a. Parking Lot Lighting

POM has numerous parking lots, most of them lit at night. In lieu of standard single-brightness lighting, POM recently replaced many of the parking lot lights with bilevel dimming lighting. Using a motion detector, these lights automatically dim when no one is present. They meet code requirements for night lighting, and save approximately 90 percent of the lighting energy used by the old lights. The lighting project is independent of POM's EMS, but verifying the energy savings is possible by energy metering.

b. Soda Vending Machines

There are numerous soda vending machines throughout buildings at POM. Many of those buildings are classroom buildings, or other buildings that are only occupied during daily working hours. Even in buildings that are unoccupied at night, the soda machines keep beverages cold through the night. Tulley projects that POM could save about $35,000 per year in energy costs simply by replacing glass-front soda machines with machines without glass fronts, and programming them to allow the product to warm up to 60 degrees Fahrenheit overnight (Tulley, 2015).

Currently, Tulley can ask the machine operators to replace and/or reprogram the vending machines. However, there is no simple way to incentivize the operators to comply. With POM's EMS, it would be possible to sub-meter energy for the vending machines, and then accurately track the machines' energy usage. Even without sub-metering, it is possible to verify energy savings over time as a result of replacing and/or reprogramming the machines.

c. RCx Efforts

During his presentation, Clark noted that air economizers are often not working correctly, with some estimates indicating that more than half of all building air economizers are not operating correctly (Clark, 2015). An economizer is designed to provide an optimal mix of ambient outside air and return air back to HVAC equipment in order to maintain an indoor space within a set temperature range.

Clark pointed out that this sort of problem is a prime target for RCx efforts. He referred to a 2009 study done by the Lawrence Berkeley National Laboratory on the value of RCx efforts. The study, encompassing 643 buildings, showed a median 16 percent energy savings and a median payback period of 1.1 years for RCx projects (Mills, 2009, p. 1). Clark went on to discuss several air economizer discrepancies he had discovered during RCx projects (unrelated to the EMS) in multiple buildings at POM.

In each of these cases, repairing or correctly adjusting the economizers (and any associated air-handling equipment) resulted in improved air quality in the buildings, and also reduced energy waste. Currently these optimization efforts are not dependent on POM's EMS, but the EMS allows POM personnel to quantify the resulting energy savings. However, the data that Clark used to identify issues during his RCx projects are the same sort of data that could be fed into an appropriately networked EMS (HVAC equipment operating status, ambient air temperatures). With a more capable EMS, POM personnel might be able to identify economizers that are performing sub-optimally simply by analyzing EMS data.

2. Follow-on Investment Options

Tulley discussed the following options for follow-on investment at POM.

a. HVAC Controls

While POM currently has eight buildings set up for HVAC controls, the installation's plan is for HVAC controls for 35 energy-intensive buildings. By connecting HVAC systems to POM's EMS, POM personnel will be able to optimize HVAC scheduling and detect signs of equipment not operating properly. This project is ongoing.

b. Demand Management

POM purchases power and natural gas from the local utility. Like other local energy users, POM is subject to demand charges based on time of day. Because of this, POM can potentially achieve energy cost savings by managing demand, and demand management is a potential benefit of the EMS. Currently, POM is not considering any energy storage projects. Such a project would not likely be cost-effective, although battery costs are currently dropping rapidly, and storage may be cost effective in the future. Instead, POM is focusing on demand management in order to reduce demand charges.

Tulley mentioned that POM has considered installing a large solar PV farm at one of its satellite sites (interview with author, September 15, 2015). Depending on the demand charges POM faces for energy, POM personnel could use the EMS trend data to determine the cost effectiveness of a renewable energy project or energy storage project.

3. Other Input

Tulley provided additional input regarding how POM's EMS is used, and how it might be used more effectively in the future.

a. Improved Analytics

Tulley pointed out that there is a lot of potential for improved EMS data analysis. For example, he discussed a scenario in which a technician had found the linkage for a damper on an HVAC duct disconnected from the actuator. He pointed out that instead of finding that during preventive maintenance, it could have been found with appropriate EMS data and a proper analysis algorithm (interview with author, September 15, 2015).

Using just the sensors that POM has already installed, Tulley has already conducted some analysis. As an example, he suggested using a simple regression model comparing natural gas usage (for heat) and outside air temperature (OAT), then comparing the model for all buildings on the installation. Although this comparison has not provided any conclusions on its own, it serves to identify buildings where heating systems may be operating inefficiently, and potentially to target future RCx projects.

b. Feedback to End Users

Tulley has used EMS data to create mock energy bills for some of the tenants on POM. He creates mock bills for barracks buildings, presenting them to those responsible for managing the personnel living in the barracks. This allows barracks personnel to track their energy efficiency, whether it is improving or not. Tulley sets goals for each building, and those living there can track their group's progress toward meeting those goals (interview with author, September 15, 2015).

Further, energy and water usage data are presented in simple color-coded charts (red-yellow-green), and displayed publicly in the barracks. The data presented compare each barracks to the others on POM. With the help of the senior non-commissioned officers supervising the barracks, presenting the data has fostered a sense of friendly competition among those living in the barracks, prompting at least some of those living there to strive to use less energy and/or water, so their building will be "better" than the others (interview with author, September 15, 2015).

DOD installations do not normally charge tenant units based on energy use, but mock billing is a viable way to provide similar incentive for tenants to reduce energy use. The Navy is already developing programs to use EMS data to allocate energy consumption to installation tenant units (DOD, 2014a). Mock billing may be able to provide similar incentives to tenants, with minimal effort on the part of installation energy managers.

B. NAVAL SUPPORT ACTIVITY MONTEREY

NSAM is a relatively small Naval installation that includes the Naval Postgraduate School (NPS) and an annex site with a data center operated by Fleet Numerical Meteorology and Oceanography Center (FNMOC) (NSAM, n.d.). The installation covers approximately 150 acres (Google maps, 2015b). The installation has about 110 buildings, of which about 30 account for most of the energy usage. Total energy costs for NSAM are approximately $3 million annually (D. Taber, personal communication with author, November 5, 2015). The author interviewed Douglass Taber, the installation's energy manager, and Erik Abbott, the installation's industrial control systems engineering technician (he is the primary EMS operator).

NSAM has a highly capable EMS installed and operating. The installation has about 44,000 total sensors (including energy meters, operating status sensors for equipment, etc.). The data are fed in near real-time to a centralized web-based control system, designed by Automated Logic Corporation (ALC). From his workstation, or via a web connection from anywhere, Abbott can access the ALC user interface for NSAM's EMS and monitor or control all features of the system. Although the EMS does not automatically record historical sensor, it can be programmed to record trend data for up to one year for any given sensors (D. Taber & E. Abbott, interview with author, October 5, 2015).

1. Efficiency Improvements

Taber and Abbott discussed some situations in which NSAM's EMS has been used to improve energy efficiency at the installation.

a. DDC Programmed Incorrectly

Sometime in late 2011, Taber and his staff were evaluating Spanagel Hall, a building at NPS, looking for ways to reduce the building's energy consumption. Looking at the operating data the HVAC equipment (available via the EMS), they realized that the DDC for the HVAC system had been programmed incorrectly. The DDC were set up to flush the building with cool air each morning around 5:00 am, the coolest part of the day. The building then required heating for most of the morning hours to bring the interior spaces back up to a minimum comfortable temperature (65 degrees Fahrenheit) (D. Taber & E. Abbott, interview with author, October 5, 2015).

Taber's staff was able to reprogram the DDC to efficiently maintain the building within a designated comfortable temperature range (65–73 degrees Fahrenheit), and verify correct operation over time using EMS trend data. In this case, they estimated the programming error had resulted in up to $500,000 in excess energy costs *per year*. This is the high end of the estimated savings achieved by correcting the error (D. Taber & E. Abbott, interview with author, October 5, 2015). Even if the actual savings were somewhat less, that is still a significant portion of the installation's total energy cost.

b. Air Conditioning Chiller Stuck Running

Abbott recalled discovering an air conditioning chiller that had been constantly running due to a control error. In this case, the chiller had undergone routine maintenance during that period, but maintenance procedures had never indicated the stuck operating condition. At some point, Abbott reviewed the operating trend data for the chiller (available via the EMS) and realized the unit was running constantly. Upon identifying the discrepancy, it was determined that the chiller had almost certainly been running constantly for about five years, thus using excess energy during that five-year period (D. Taber & E. Abbott, interview with author, October 5, 2015).

c. Variable-Speed Air Handlers

Abbott pointed out that the EMS data allow more efficient operation of NSAM's variable-speed air handlers (for HVAC circulation). Over time, NSAM has replaced older single-speed air handler units with newer variable-speed units. Using EMS data to monitor pressure differentials across filters associated with the variable-speed units, Abbott is able to determine when filters have become soiled to the point that they affect the air handlers' operation. Rather than increase the speed of the variable-speed units, NSAM personnel can change the filters as soon as necessary, even if that occurs before routine scheduled filter replacement (D. Taber & E. Abbott, interview with author, October 5, 2015).

This process results in increased costs for filters, as some are changed more often than they would have been otherwise. But it allows the installation to save energy by running the air handlers at lower speeds. Power required for an air handler (fan) varies as the cube of fan speed, so NSAM is able to achieve significant savings by running the variable-speed units at lower speeds. The savings more than offset the increased filter costs, while also reducing the installation's total energy usage (D. Taber & E. Abbott, interview with author, October 5, 2015).

2. Follow-on Investment Options

Taber and Abbott discussed a variety of follow-on investment options that they are already pursuing.

a. Increased EMS Operating Staff

Currently, Abbott is the only NSAM employee who is intimately familiar with operating the installation's EMS. Taber and others at the installation recognize this is a weakness, because Abbott is a "single point of failure." NSAM has another EMS technician currently in training with ALC, who will return to the installation and assist

Abbott in operating the EMS (D. Taber & E. Abbott, interview with author, October 5, 2015).

Although Abbott is very capable at operating the EMS, he has a finite amount of time to analyze data and investigate discrepancies. Currently, NSAM pays for an EMS contractor to visit once every two weeks, to assist Abbott in investigating discrepancies and addressing any other issues with the EMS. Aside from eliminating the single-point of failure issue, an additional EMS technician will be able to help Abbott analyze the array of EMS data available, investigate discrepancies, and leverage the EMS data to resolve energy-related issues in a timely manner (D. Taber & E. Abbott, interview with author, October 5, 2015).

b. Auto-Commissioning Project

NSAM currently has two demonstration projects with Brightbox Technologies company (D. Taber & E. Abbott, interview with author, October 5, 2015). Brightbox is developing analytical models and software programs designed to perform building commissioning evaluation tasks (similar to RCx). The author interviewed Allan Daly, founder of Brightbox Technologies.

Brightbox is working to automate the commissioning process as much as possible, referred to as auto-commissioning (auto-Cx). Brightbox's systems use available sensor data for a facility to evaluate performance of HVAC equipment (or other energy-intensive equipment, as appropriate). The software identifies equipment that is operating sub-optimally, prompting users to address discrepancies (A. Daly, interview with author, October 9, 2015).

Brightbox received a grant for projects at two buildings at NPS. These projects are ongoing. Auto-Cx relies on an array of sensor data, the same data that are available via the installation's EMS. In this case, the EMS directly enables the two Brightbox projects as follow-on investments.

c. Cogeneration Project

NSAM has conducted a preliminary assessment for installing a power and heating cogeneration plant. The project, still in the planning stages, is planned as an energy savings performance contract (ESPC) (D. Taber, personal communication with author, November 5, 2015). Under the ESPC structure, the majority of the project will be financed by private capital and not appropriated funds, and DOD will repay the third-party financing over time out of realized cost savings generated by the cogeneration project (DOD, 2014a, p. 67).

NSAM has significant year-round heating requirements for buildings, and 24-hour power demand associated with the FNMOC data center as well as a data center on the NPS campus. Given these criteria, it was determined that NSAM can achieve significant annual energy-cost savings by installing a natural gas-powered electricity generation facility, with additional equipment to capture the associated waste heat to be used for steam generation, for heating. The preliminary analysis of the project indicated total cost savings for NSAM of over $11 million over the predicted 25-year lifespan of the project equipment (D. Taber, personal communication, November 5, 2015).

Without the EMS, this project would not be possible. EMS trend data facilitated the initial assessment, allowing proper determination of the optimal size cogeneration plant and detailed estimates of potential energy savings. Additionally, the EMS's control features are a prerequisite for the cogeneration plant, as the plant will require some automated controls for proper integration into the installation's electrical grid and steam distribution systems. Specifically, the EMS will allow electrical and steam load monitoring for the entire installation, and those inputs will be used to automatically modulate the output of the cogeneration equipment (D. Taber, personal communication, November 5, 2015). In this case, the EMS has clearly made this project possible, whereas it would not have been considered without the EMS in place.

3. Other Input

Taber discussed how NSAM's EMS will affect energy optimization and resilience in the future. Additionally, during the research process, Taber and Abbott discovered a heating issue with one of the NSAM buildings. They discussed how they had used the EMS to identify the cause of the problem: a temperature sensor was providing erroneous readings to the building's heating system. Additionally, Abbott described how he used the EMS to address the issue immediately, by programming a different temperature sensor to provide input to the building in question.

a. Energy Optimization and Resilience

Taber mentioned that local microgrids have the potential to increase security and resilience for DOD installations, by allowing facilities to operate independently from the local utility grid. An EMS, including load monitoring and automatic controls for local power generation equipment, is essential to properly manage a microgrid for a DOD facility (D. Taber, interview with author, October 5, 2015).

Taber also noted that NSAM has exceeded energy intensity reduction goals for FY 2015, and is making good progress toward meeting future energy intensity reduction goals specified for DOD installations. Over the last ten years, NSAM has steadily reduced its energy intensity. As anticipated by policy guidance directing EMS use, some of these results have been directly attributed to energy optimization efforts associated with EMS data (E. Abbott & D. Taber, interview with author, October 5, 2015).

b. Trouble-Shooting a Temperature Sensor

In October of 2015, Taber's staff was alerted to an issue with one of the buildings at the FNMOC annex. Building 715 is a relatively new building, and the occupants reported that the heat was not working in the mornings. Reviewing EMS data, Abbott discovered that the building's boiler was not operating during the morning hours, meaning no heat was available although the building's interior temperatures were below a minimum comfort level (personal communication, November 5, 2015).

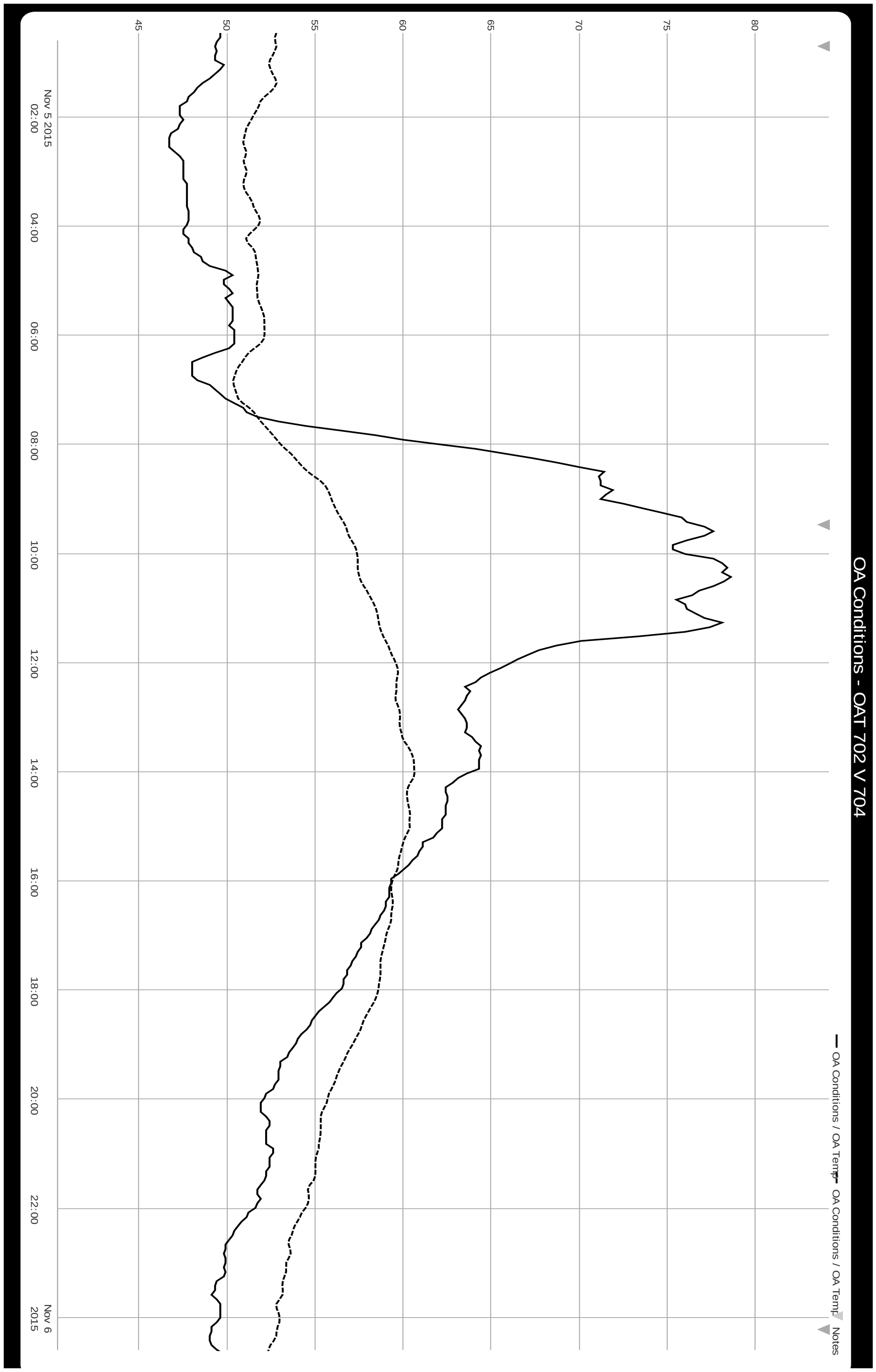
Abbott recognized that the boiler was prevented from operating by a temperature lockout, dependent on OAT. Building 715's DDC received OAT input from a sensor on building 704, nearby. When the OAT is above 65 degrees Fahrenheit, building 715's boiler is locked out. Reviewing data available via the EMS, Abbott discovered that building 704’s OAT sensor indicated a significant temperature spike in the mornings. For comparison, he plotted the OAT data from building 704 along with OAT from another nearby building, 702. Figure 1 shows the OAT data for one 24-hour period from the two buildings: building 704 is the solid line and building 702 the dashed line (E. Abbott, personal communication with author, November 5, 2015).

Abbott discovered that building 704’s OAT sensor was located on the exterior of the building, and with the seasonal change in sun angle, the sensor was receiving direct morning sun, causing the indicated temperature spike. Although the ambient temperatures were cool in the mornings, the sensor data prevented building 715’s heating equipment from providing heat (E. Abbott, personal communication with author, November 5, 2015).

The near-term solution was simple. Using the EMS, Abbott was able to configure building 715 to take OAT inputs from the sensor on building 702 instead of 704. Building 702’s sensor was providing more accurate temperature data, and this alleviated the boiler lockout problem. After the initial correction, Abbott and others discussed either relocating the OAT sensor on building 704, or building an enclosure to shade it from direct sun to provide more accurate data (personal communication with author, November 5, 2015).

In this case, the EMS sensors and trend data provided the information necessary to correctly diagnose the problem, once Abbott recognized the likely issue (the OAT lock-out). Additionally, the advanced control functionality of the EMS provided a simple solution that required no hardware modification or further effort.

Figure 1. November 5, 2015, OAT Data: Building 704 versus 702



Source: E. Abbott, personal communication, November 10, 2015.

C. MARINE CORPS BASE CAMP PENDLETON

Marine Corps Base Camp Pendleton (MCBP) is a large USMC installation in Southern California, covering over 125,000 acres and a variety of different types of training facilities, including 2,600 buildings (A. Williams, personal communication, December 9, 2015; MCBP, n.d.). The installation is working to install energy meters across all its facilities; some portions of the installation are more densely metered than others. Currently, MCBP does not have any centralized energy control systems (E. Evans & A. Williams, interview with author, October 21, 2015). The author interviewed two personnel working on an energy project at the installation: Eric Evans and Allan Williams.

In this case, the interview subjects are working on an energy-systems modeling project called the virtual smart grid (VSG). The project is focused on areas of MCBP that are thoroughly metered, and includes about 1,945 buildings on approximately 19,200 acres of the installation (A. Williams, personal communication, December 9, 2015). The VSG project will provide highly detailed, accurate, and near real-time modeling of energy transmission, distribution, and usage within the covered area of the base. Accurate modeling will allow technicians to quickly recognize discrepancies with energy-related equipment, and will allow thorough evaluation of the outcomes of potential energy-related improvement projects. The first two years of the project were spent inputting equipment and local grid data into a computer model database. Much of this information was previously recorded only in hard-copy documents, and in some cases no documentation was available. In those cases, project personnel had to directly verify the type and specifications of the equipment. Now that the energy systems and equipment are well documented in the model, project participants are working to incorporate accurate geospatial reference information for all equipment, in order to more accurately model line lengths, and equipment and facility locations (E. Evans & A. Williams, interview with author, October 21, 2015).

1. Efficiency Improvements

The VSG project is still in progress. Improving efficiency at the installation is one of the project's goals, so project personnel anticipate finding an array of opportunities for improving efficiency in the future.

Even in the process of developing the model, the team did find an opportunity for one easy improvement. During the model development process, MCBP experienced an electrical transformer failure. A 30 kilovolt-ampere (kVa) transformer had melted, and installation personnel were preparing to procure and install a replacement. Looking at the VSG model, project personnel noticed that 30 kVa seemed a surprisingly low capacity for the buildings served by the transformer. Upon further examination, the team determined that a *300* kVa transformer was required (E. Evans & A. Williams, interview with author, October 21, 2015).

With limited records, no one could determine how or why the inadequate transformer was there initially. Most likely, some of the buildings served had changed uses over time, significantly increasing the transformer capacity required. In any case, without information from the VSG model, MCBP personnel would likely have installed another 30 kVa transformer. It almost certainly would have quickly failed (E. Evans & A. Williams, interview with author, October 21, 2015).

This scenario demonstrates the value of accurate and centralized information. With the detailed model available, personnel were able to diagnose the problem without extensive investigation, and they avoided destroying the second transformer that would otherwise have been installed.

2. Follow-on Investment Options

Although MCBP does not have an advanced EMS, the metering efforts at the installation are a necessary precursor to the VSG project. Energy metering facilitates development of the VSG model, which should help identify and evaluate follow-on investment options.

The goal of the VSG project is to provide accurate modeling and simulation, for use in determining the effects of improvements or changes to the energy systems on the installation. The model will allow the users to simulate various improvements, allowing detailed "what-if" comparisons. Modeling may also help users identify some specific downstream benefits of any proposed changes (E. Evans & A. Williams, interview with author, October 21, 2015).

3. Other Input

Given that this project is relatively young, project personnel are still working to identify potential uses for the model. They made a few suggestions for how the VSG project might improve energy management and efficiency at MCBP.

a. Optimizing Energy Systems

The interviewees noted the episode with the 30 kVa transformer. The VSG model will allow MCBP energy managers to identify changing needs over time, and optimize the installation's energy systems accordingly (E. Evans & A. Williams, interview with author, October 21, 2015).

Evans suggested that the model could be used to display an image of the installation's grid on a map, with data on the last decade of wildfires overlaid. This may help installation managers decide if it is cost-effective to replace above-ground transmission lines with buried lines (E. Evans & A. Williams, interview with author, October 21, 2015).

b. Personnel Effectiveness

He noted that accurate modeling of energy systems has two personnel-related benefits. First, it allows effective management of energy systems by fewer people than would otherwise be required. That is, the investment in VSG will yield labor savings. Additionally, it ensures some continuity of knowledge of energy systems, regardless of any personnel turnover. At MCBP where records for some of the energy equipment and systems were poorly documented or not documented at all, this seems particularly valuable (E. Evans & A. Williams, interview with author, October 21, 2015).

D. MARINE CORPS AIR STATION MIRAMAR

Marine Corps Air Station (MCAS) Miramar is a medium-scale installation in Southern California, with approximately 600 buildings on approximately 23,000 acres and about 15,000 personnel on board each day (Google maps, 2015a; M. Wasco, interview with author, October 23, 2015). The installation's utility costs are approximately $12 million to $13 million per year. MCAS Miramar has energy meters installed for nearly all buildings on the installation, and has some buildings connected to a centralized energy control system (M. Wasco, interview with author, October 23, 2015). The author interviewed Mick Wasco, the installation energy manager.

MCAS Miramar has metering data for nearly all buildings on the base, recorded at 15-minute intervals. Meter data are collected monthly, although the data are not always analyzed. The installation has had 80 buildings on a centralized EMS for the last ten years, with some ability to control energy and HVAC systems in those buildings.

MCAS Miramar has invested in several standalone energy demonstration projects, with few improvements to the installation's EMS. Currently, Wasco is working on a project to integrate all sensor information for one building (the one where he works) and develop a control system to compare real-time metering data with expected energy use (accounting for time of day, outside temperature, etc.). Once complete, this project will allow personnel to identify discrepancies in real time, and address them accordingly. This project will demonstrate advantages associated with improved EMS capabilities.

1. Efficiency Improvements

Wasco discussed some general efficiency improvements made at MCAS Miramar.

Wasco noted that HVAC scheduling issues have been a common problem. He stated that building energy audits have nearly always revealed some discrepancies that can be easily corrected (interview with author, October 23, 2015).

Wasco also pointed out that analyzing meter data takes personnel, training, and time. He indicated that he and his staff do not have enough time to sufficiently analyze all the data available to identify discrepancies and opportunities for efficiency improvements. Wasco reiterated that MCAS Miramar receives between 500 and 600 utility bills per billing cycle, and about 150 buildings account for 90 percent of the installation's total energy usage. With the large amount of meter data associated with energy use, it is not feasible to manually analyze all the data available, even if his staff focused on the 150 buildings that account for the majority of energy used (interview with author, October 23, 2015).

As an example, Wasco related an anecdote regarding a malfunctioning water meter. A few years back, someone on his staff was looking at water usage data for the installation. He noticed one building where water use had spiked nine months prior, and then stayed at the elevated level for the ensuing nine months. Upon further investigation, it turned out that the water meter had failed and was reading higher than the actual use. Additionally, the local utility had been billing MCAS Miramar based on the meter readings. In this case, once the issue was resolved, MCAS Miramar received a credit from the local utility of about $90,000 for the excess water charges over the nine-month period. Wasco noted that this discrepancy was discovered by a stroke of luck. He pointed out that the excess water charges could easily have been dismissed as “noise” in the installation's total annual utility cost of more than $12 million (interview with author, October 23, 2015).

Identifying the water meter discrepancy was possible because the data were collected and available. No automated algorithm indicated the need for further investigation, although it is possible such an algorithm could be developed and implemented.

Although water meters are not necessarily part of an EMS, they can be incorporated. In this case, the installation energy manager is responsible for all utility costs, including water. Wasco and his staff use water meter data similarly to energy meter data as they review utility costs to identify any issues. This discrepancy is representative of errors that could be discovered using EMS data.

2. Follow-on Investment Options

Wasco discussed how he and his staff are using the EMS output data to identify opportunities for follow-on investment or other energy related improvements.

a. Energy Star Portfolio Manager Tool

Wasco and his staff have started to take advantage of DOE's Energy Star Portfolio Manager (ESPM) tool, using EMS meter data along with other inputs. This online tool is free to use. To use the tool (available at http://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager), facility managers input various building data points (square footage, type of HVAC equipment, personnel in the building each day, etc.) and energy use data (provided by metering). The tool generates an expected baseline based on the building data and compares the building's actual energy use with that baseline (M. Wasco, interview with author, October 23, 2015).

Wasco's goal for this effort is to target individual buildings for RCx efforts. In this case, the EMS provides some of the necessary data for the ESPM tool, but it still takes significant human effort to gather the requisite building information, as well as inputting the data. These efforts are ongoing (M. Wasco, interview with author, October 23, 2015). Here, the EMS data facilitates selection of buildings with the most potential gains for RCx projects.

b. Further EMS Data Analysis

Wasco mentioned a few times that MCAS Miramar could take advantage of more personnel to analyze and make use of the array of EMS data available. MCAS Miramar hired a DDC-expert who previously worked for Johnson Controls (a leading provider of EMS products), and there is still opportunity for more staff to make effective use of the data available (M. Wasco, interview with author, October 23, 2015).

Although Wasco did not mention it specifically, there is opportunity for investments in analytics software, or perhaps some analytics training for personnel, in order to more efficiently analyze the data available. Certainly, there are also potential gains from hiring additional energy management staff to make use of the EMS data, and manage the EMS effectively.

3. Other Input

The USMC recently implemented a program at MCAS Miramar to provide a unit energy manager for each tenant unit on the base. This assignment is a collateral duty for one or more Marines in each command on board. Unit energy managers are intended to serve as a liaison between tenant commands and installation energy management personnel. Wasco's staff is able to leverage the unit energy managers to help collect the necessary building data required for the ESPM tool. Additionally, unit energy managers can inform installation energy management personnel of changes in building use (M. Wasco, interview with author, October 23, 2015).

IV. QUALITATIVE ANALYSIS

The EMSs in these four cases have different capabilities, and each is used differently. Still, some downstream benefits are replicated in multiple cases. This chapter compares the four EMSs, catalogs the downstream benefits associated with each, and identifies patterns present in the data.

A. EMS COMPARISON

NSAM has the most capable EMS of the four cases, with remote web-access and a wide range of control features available to EMS operators. MCAS Miramar's EMS has some control capabilities and collects a large amount of data, but the installation has limited manpower resources to take full advantage of the EMS. POM's EMS is largely a data collection tool, although POM plans to install more extensive HVAC controls on completion of the eight-building demonstration project. Still, Tulley and his staff have found opportunities to leverage the data available. The VSG project at MCBP is still in development, but has already produced valuable benefits. In the future, VSG will better inform installation managers in making energy-related decisions. Table 4 presents a comparison of the four installations and their associated EMSs.

Table 4. Installation Comparison

	POM (Main Site)	NSAM	MCBP*	MCAS Miramar
Size	~350 acres	~150 acres	~19,200 acres	~23,000 acres
Number of Buildings	~150	~110	~1945	~600
Annual Utility Costs	$3.2 million	$3 million	unknown	$12-$13 million
EMS Capabilities	Advanced metering HVAC monitoring & control demonstration project	Advanced metering Web-based HVAC, lighting, & energy systems monitoring & control	Energy metering Detailed modeling of energy-related systems	Advanced metering HVAC, lighting, & energy systems monitoring and some centralized controls

*Values indicate data for the portion of the installation covered by VSG

B. DOWNSTREAM BENEFITS

In all four cases, installation managers have realized some downstream benefits associated with the EMSs. Further, they have identified some significant potential future benefits that depend on the EMS capabilities. Table 5 lists the downstream benefits identified in each case, including some that have yet to be realized.

There are several types of benefits repeated across the case studies. First, installation managers can use EMS data to discover and diagnose suboptimal or incorrect operation of equipment that might otherwise go unresolved. Second, installation managers can use EMS data and other resources to predict expected energy use, known as *benchmarking*. By comparing actual consumption to benchmarks, they can identify buildings whose energy consumption exceeds expectations or is significantly higher than average. Identifying those buildings provides opportunities to maximize energy savings resulting from adjusting, repairing, or upgrading equipment. Third, EMSs aid managers in identifying valuable follow-on investments, and in some cases EMSs are a prerequisite for those follow-on projects.

1. Addressing Errors

Some of the errors discovered using EMSs in the four cases resulted in significant energy savings, most notably the DDC error in Spanagel Hall at NSAM. Other problems were ongoing, and likely would have persisted much longer in the absence of an EMS. The bad water meter at MCAS Miramar resulted in excess utility charges averaging $10,000 per month, but installation personnel did not recognize the discrepancy for several months because that amount was a small fraction of the installation’s approximately $1 million total monthly utility cost. The A/C chiller that was stuck running at NSAM had been so for five years. Presumably, the unit had undergone some preventive maintenance during that time, but without trend data no one recognized the problem. In each instance, installation personnel leveraged the EMS capabilities to identify a significant and costly equipment error.

Table 5. Downstream Benefits in Each Case

	POM Main Site	NSAM	MCBP	MCAS Miramar
Realized Benefits	Determined energy savings from various improvements	Discovered Spanagel DDC error, costing up to $500K annually	Discovered 30kVa transformer inadequate for current needs	Identified bad water meter, recouped $90K excess utility charges
	Targeted RCx efforts for maximum energy savings	Reduced variable air handler fan speed to save energy	Updated and replaced inaccurate information with detailed model	Found various HVAC scheduling and operating issues
	Used mock tenant utility billing to influence behavior	Hired & trained additional EMS technician		Used ESPM tool to compare buildings to established baselines
		Identified OAT sensor discrepancy, resolved it using EMS		
		Found A/C chiller stuck on for five years		
		Began auto-Cx demonstration project		
	POM Main Site	**NSAM**	**MCBP**	**MCAS Miramar**
Potential Future Benefits	Install facility-wide automated HVAC scheduling and control	Install cogeneration plant (ESPC proposal submitted)	Prepare detailed what-if models, to inform decisions	Leverage unit energy managers' input using ESPM tool
	Improve and/or automate EMS data analytics	Improve resilience - potentially operate off the local grid	Identify or recognize changing requirements over time	Conduct more data analysis in conjunction with ESPM tool
	Incentivize vending machine operators to make machines more efficient		Compare model expectations and real-time data to identify equipment errors	Monitor and compare actual and expected energy use in real time (upon success of demonstration project)
	Improve demand management - could make solar PV or energy storage project feasible		Use accurate data and modeling to reduce manpower required	

Further, NSAM's highly capable EMS with extensive control functionality allowed the EMS technician to immediately correct the building OAT sensor discrepancy and restore heat to the affected building, using a simple software solution. Without the control features built into the EMS, restoring heat to the building would have required significantly more man-hours to either reposition the sensor or otherwise shield it from the morning sun.

2. Benchmarking

This benefit is likely present in each case, although it was not specifically mentioned in each. At POM, RCx projects are at least sometimes the result of unexpected increases in a building's energy use or perceived excessive energy use in a particular building (Clark, 2015). Energy meter data then play a role in deciding which buildings to target for RCx. Tulley specifically discussed improved analytics, which might allow him to better identify buildings with specific opportunities for improvement, upgrades, or repairs.

At NSAM, Spanagel Hall is a relatively energy-inefficient building just by its design (D. Taber & E. Abbott, interview with author, October 5, 2015). Taber and his staff likely pay more attention to that building than others simply because there may be opportunities for significant improvements, but the EMS facilitated discovery of the error and a determination of its magnitude. The erroneous OAT readings did not result in energy waste, as the discrepancy rendered the heating system inoperative during the cool hours of the morning. However, the discrepancy made the building uncomfortably cold in the mornings, likely resulting in decreased productivity and discontent among those who work there.

The VSG project at MCBP will help installation managers recognize changing needs over time. Although the scenario with the 30 kVa transformer shows what can happen when energy needs are underserved, the opposite is also possible as buildings' uses change over time. In the future, installation managers might identify equipment that has far greater capacity than needed. If a 300 kVa transformer failed and the VSG model revealed that only 30 kVa were necessary for the circuit in question, managers could elect to purchase the smaller transformer, thus meeting requirements without unnecessary excess capability and cost. The same logic could be applied to energy-intensive equipment within individual buildings, depending on the level of detail of the final model.

Wasco's effort to leverage the ESPM tool at MCAS Miramar is a systematic way to identify wasteful buildings. By using the tool to compare buildings to nominal baselines, his staff are able to identify buildings that stand out by their above-baseline energy use and focus analysis efforts on those buildings, where there is likely the potential for efficiency improvements. Wasco did not specify whether HVAC scheduling errors had been discovered using EMS data or via other means, but certainly analysis of the EMS data would aid in identifying some of those errors.

3. Follow-on Investments

In all four cases, installation managers have identified potentially valuable follow-on investments enabled by the EMSs. Managers at POM intend to pursue facility-wide integration of HVAC systems into the EMS following the demonstration project currently underway. This integration should allow close monitoring, analysis, and optimization of HVAC systems across the installation. At NSAM, a detailed proposal for a cogeneration plant has already been submitted, including estimates for net energy and cost savings over the life of the equipment. VSG personnel at MCBP mentioned using the model to identify critical transmission and distribution infrastructure and evaluating the risks associated with wildfires, enabling sound decisions on whether or not to invest in underground wiring. Once complete, the VSG model will allow evaluation of a wide variety of potential investments in generation, transmission, and distribution equipment, providing managers detailed projections of the effects on the installation's energy systems. At MCAS, if Wasco's real-time monitoring demonstration project at his own building yields potential benefits, he may expand the effort to other buildings on the base.

EMS data or controls may be necessary to allow some of these follow-on investments, and EMS data may contribute to cost-benefit analyses as well. The proposed cogeneration plant at NSAM would not be feasible without the load monitoring and control capabilities of the installation's EMS: the EMS makes the project feasible. Using the VSG model, MCBP managers will be able to accurately project the effects of a transmission line compromised by wildfire, and determine the associated costs.

C. COMMON THEMES

There are several common themes in the data. Even with no control functionality, an EMS is valuable by virtue of the data provided. To take full advantage of the EMS data, an installation requires one or more sufficiently trained technicians with the time and resources necessary to analyze the data and make necessary adjustments to optimize the energy systems onboard the installation. These tasks are labor-intensive.

1. Data Are Valuable

Installation managers have found several ways to analyze the data, such as looking at long-term trends for individual buildings, or comparing OAT and energy use across several buildings. Additionally, the data can be used to project effects of equipment or system changes, either by modeling or careful analysis.

In some cases, technical records of energy-related equipment and systems are inaccurate, incomplete, or outdated. The process of networking meters and sensors across an installation results in development of a digital record of the location, type, and characteristics of energy-related equipment across an installation. Even without developing a detailed, geospatially accurate model such as the VSG, an EMS serves as a data repository, accessible to anyone trained in using the system.

There is significant opportunity across the DOD to make energy use data more readily available, as has been done at POM. A recent article in the Washington Post described the problem of *rational inattentiveness*: most energy users (service members aboard a DOD installation in this case) do not have any idea how much energy they are using at any given time, and consequently they do not consider it important (Mooney, 2015). Tulley and his staff have demonstrated that synthesizing and presenting energy efficiency data in a straightforward manner can make DOD personnel change their behavior, by combating that rational inattentiveness. This has not yet been widely adopted across the DOD, although the Navy has begun an initiative to allocate utility costs to individual tenant commands onboard installations (DOD, 2014a).

Additionally, personnel developing the VSG model intend it to be used for what-if modeling, to better inform decisions regarding the installation's energy systems. They intend to present simple, graphical results of the scenario modeling to allow installation managers to readily comprehend the effects of proposed changes, and take those into account in deciding on improvements or changes to the installation's energy equipment.

2. EMS Operation and Data Analysis Are Labor-Intensive

An EMS can be a very complex system, even for a small installation. NSAM has a EMS technician currently in training (in addition to Abbott), and is still receiving contractor support in operating its EMS. At MCAS Miramar, Wasco recognizes that he does not have sufficient staff to analyze all the data available. At POM, Tulley acknowledges there is opportunity for much more data analysis, either by algorithm or human effort. In each case, installation personnel recognize that to gain the maximum value from the EMS, they must have sufficient personnel to operate the system and review the data. Without the appropriate personnel, the value of the EMS data is significantly reduced.

In some cases, errors have been discovered by coincidence. It happened that Williams was curious about the failed transformer, and started looking at that area in the VSG model, when he recognized the equipment was inadequate for the requirements. Wasco's staff discovered the failed water meter while investigating trend data nine months after the failure occurred. These instances indicate the potential for increased value associated with sufficient personnel to analyze the EMS data in a timely, proactive manner.

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V. CONCLUSIONS

Most of the benefits of EMSs are not specifically identified in advance. It is hard to estimate the present value of those unforeseen benefits when an upgrade or investment in a new capability is proposed, thus they may not be properly included in a return-on-investment analysis. A further challenge in developing a business case for an EMS is that an EMS is usually not a one-time investment. Instead an EMS, consisting of hardware, software, and human capability, is normally built up over time. Attributing specific benefits to an individual investment is challenging, and may not be feasible.

A. DOWNSTREAM BENEFITS CONTRIBUTE TO AN EMS'S VALUE

This study identifies three categories of likely downstream benefits resulting from investments in EMSs.

- Troubleshooting: discovering and diagnosing discrepancies with HVAC, lighting, and other energy-intensive equipment
- Benchmarking: identifying buildings that waste significant amounts of energy, so that they may be targeted for efficiency improvements
- Follow-on investments: identifying and enabling valuable follow-on investments, resulting in increased efficiency and reductions in energy intensity

These three types of benefits can all provide significant value in the form of reduced energy costs and improved efficiency at DOD installations. The results of this analysis indicate that the DOD's 2009 instruction encouraging adoption of EMSs at shore installations has resulted in some benefits for DOD installations. In each of the four cases presented, the EMS has provided valuable downstream benefits that were not anticipated at the time of investment in the EMS. These types of benefits should be considered in evaluating the return on future EMS investments at DOD installations.

B. OPPORTUNITIES ABOUND FOR IMPROVED EMS DATA ANALYSIS

Each of these types of benefits may be realized using an EMS that collects and aggregates data, whether or not the EMS has any control functionality. In considering an

EMS investment at a DOD installation, much of the potential downstream value will be derived from the data collected. Thus, installation managers should consider prioritizing advanced metering and other sensors over centralized control functions.

Beyond investing in meters and sensors, getting the most value from an EMS investment requires investment in human capability. On a small installation, one or two technicians may be able to effectively analyze EMS data and identify opportunities to improve energy efficiency. At a larger installation, a sufficient number of staff with appropriate training on the EMS is necessary to take full advantage of the data provided.

Additionally, there are opportunities for significant improvements in automated data analysis. The Brightbox project at NSAM is an example of a software-intensive solution. If successful, the project should identify the same types of issues and opportunities that a human-led RCx effort otherwise would, but with significantly less manpower invested. Tulley's proposed regression model at POM (comparing natural gas use vs. OAT for all buildings across the installation) should identify particularly inefficient buildings. If an EMS included an appropriate algorithm, the system could automatically run a similar model for all buildings across an installation, and yield the same useful information. Further, the EMS could run the comparison every day (or more often, if desired), identifying potential issues in near-real time. Any such automated effort would allow installation managers to leverage EMS data to their benefit, without significantly increasing the burden on personnel. Thus, there are opportunities for more effective analysis of EMS data, and there are also opportunities to conduct that analysis more efficiently.

C. EMSs WILL PLAY A CRITICAL ROLE IN ENERGY EFFICIENCY AND OPTIMIZATION EFFORTS

The case studies presented in this report indicate the potential value of EMS data at DOD installations. Given the policy initiatives for advanced metering and EMS investment, EMSs will become more prevalent among DOD installations. As EMSs become more widespread, those installations that are best able to take advantage of EMS data will likely realize the greatest benefits resulting from their EMS investments.

As DOD installation managers look for further ways to reduce energy intensity in accordance with policy goals, those with EMS data available will likely have greater opportunities to improve installation efficiency, making it easier to meet future energy intensity goals. Additionally, reduced total energy loads may make local energy generation projects economically feasible. Reduced total energy requirements could allow an installation to meet renewable or other on-base generation requirements with smaller, less costly capabilities. Where appropriate, these projects may be more appealing to private companies who could accept ESPCs with less capital required up front. For those projects funded with appropriated funds, reduced total energy requirements would allow installation managers to meet given requirements using less of their total budget authority. The resulting savings could be used for myriad unfunded priorities, perhaps even improvements to an installation's EMS.

D. FURTHER RESEARCH OPPORTUNITIES

As EMSs become more prevalent, there will be opportunities to quantify some of the various downstream benefits. Research in quantifying EMS downstream benefits would be invaluable to producing thorough return-on-investment analyses for EMSs across the DOD. As the EMSs and associated projects in these four cases progress, it would be valuable to return to them and accurately determine energy and cost savings associated with individual investments in particular capabilities.

Data centers are particularly energy-intensive; hence, they are specifically addressed in various policy statements. Further research on downstream benefits of EMSs specifically associated with data centers might reveal additional categories of downstream benefits, or more specific benefits within the three categories identified in this study. It would be valuable to identify, and try to quantify, the benefits of operating EMSs at installations with large data centers, as these installations likely have significant opportunities for energy efficiency improvements associated with those data centers.

The DOD has made efforts to improve energy resilience at shore installations, to ensure uninterrupted capabilities (DOD, 2014a). As EMSs become more prevalent, it will be valuable to identify those specific EMS capabilities that most significantly contribute to an installation's energy resilience. EMS capabilities that allow an installation to use local renewables or other generation capabilities to operate while disconnected from the local power grid may be particularly valuable. The demonstration project at MCAGCC Twenty-Nine Palms will provide invaluable insight into this opportunity.

APPENDIX. INITIAL INTERVIEW QUESTIONS

1. Briefly describe the Energy Management System (EMS) installed at your facility. What is the output from the system? How is it used, and by whom?

2. What was the approximate cost to install the system? What are the operating costs for the system? Does the system require additional personnel, training, security investments, or other expenses?

3. What business case analysis, or cost-benefit analysis (CBA), was performed before the EMS installation, to justify the expenditure (if any)? Is that analysis documented? Did the project manager (or whoever made the decision to install) forecast a net savings in energy (or money) as a result of installing the EMS? Assuming so, what is/was the expected payback period? (Any documentation of a pre-install CBA would be very helpful.)

4. Now that the EMS is installed, how are the energy and money savings measured or tracked? Does the system generate more than, less than, or about equal the amount of savings expected?

5. Ensure we have captured the costs and benefits of the installation, the operation, gathering the output and using the output as designed.

6. Now that the system is in use, are there added operating or maintenance costs that were not anticipated? Are there added personnel costs associated with operating the EMS? Are there security risks that must be addressed, (i.e., cybersecurity risks or otherwise)? Conversely, have the operating costs been lower than expected? In either case, what are the reasons for any variance (if known)?

7. Are there benefits that were not anticipated, but have become apparent now that the EMS is in use? Has the system facilitated any unanticipated behavioral changes that result in energy savings? Conversely, have the anticipated benefits not been fully realized? Either way, what are the reasons for any variance (if known)?

8. **Are there further energy-saving investment opportunities that are now available/apparent as a result of installing and operating the EMS? For instance, are there opportunities for precisely targeted energy-saving investment, where the target was not known or apparent prior to installing the EMS?** This question became the focus of this research effort.

9. What lessons can be taken from your project and potentially applied to others at various Naval installations?

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