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NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

A REPORT ON THE BENEFITS TO THE DEPARTMENT OF NAVY OF THE IMPLEMENTATION OF AN ENERGY SYSTEMS TECHNOLOGY EVALUATION PROGRAM

by

Brandon Naylor, Eva Regnier, Rabia Khan

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This report summarizes the benefits the Energy Systems Technology Evaluation Program (ESTEP) has provided to the Department of Navy (DON). The ESTEP provides funding for investigators to carry out projects demonstrating the value or feasibility of a proven or emerging technology in the context of DON energy, using DON installations and DON personnel. ESTEP technologies contribute to by assuring energy supply, and increasing energy resilience, while reducing costs and other resource requirements for installations and DON operations, enabling the DON to carry out and sustain its mission. This report documents the contributions of 55 ESTEP projects completed, or in progress, from fiscal year 2013 through fiscal year 2018.

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Ann E. Rondeau
President

Steven R. Lerman
Provost

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This report was prepared by:

Brandon Naylor
Author
Faculty Research Associate

Eva Regnier
Author
Associate Professor

Rabia Khan
Author
Faculty Research Associate

Reviewed by:

Keith Snider, Dean
Graduate School of Business and Public Policy

Released by:

Jeffrey D. Paduan
Dean of Research

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ABSTRACT

This report summarizes the benefits the Energy Systems Technology Evaluation Program (ESTEP) has provided to the Department of Navy (DON). The ESTEP provides funding for investigators to carry out projects demonstrating the value or feasibility of a proven or emerging technology in the context of DON energy, using DON installations and DON personnel. ESTEP technologies contribute to assuring energy supply, and increasing energy resilience, while reducing costs and other resource requirements for installations and DON operations, enabling the DON to carry out and sustain its mission. This report documents the contributions of 55 ESTEP projects completed, or in progress, from fiscal year 2013 through fiscal year 2018.

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TABLE OF CONTENTS

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LIST OF FIGURES

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LIST OF TABLES

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LIST OF ACRONYMS AND ABBREVIATIONS

ARL	Adoption Readiness Level
COTS	commercial-off-the-shelf
DOD	Department of Defense
DON	Department of Navy
ESTEP	Energy Systems Technology Evaluation Program
EXWC	Engineering and Expeditionary Warfare Center
FY	fiscal year
HVAC	heating, ventilation and air conditioning
IPR	Interim Program Review
NPS	Naval Postgraduate School
O&S	Operations & Support
PI	principal investigator
S&T	science and technology
SPAWAR	Space and Naval Warfare Systems Command
TRL	Technology Readiness Level

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I. INTRODUCTION

This report summarizes the benefits the Energy Systems Technology Evaluation Program (ESTEP) has provided to the Department of Navy (DON). Since 2013, the ESTEP provides funding for investigators to carry out projects demonstrating the value or feasibility of a proven or emerging technology in the context of DON energy, using DON installations and DON personnel.

As for any science and technology (S&T) effort, most of the value of ESTEP comes from the later implementation of the technological knowledge gained in the S&T phase. For late-stage S&T projects, such as demonstration projects, this value comes from learning whether and how to integrate the technology effectively and more broadly within the DON. Much of the value of a demonstration project will be realized in future adoption of the technology at a larger scale in the DON.

For ESTEP, this value is enhanced because each project includes DON civilians, service members, or veterans in key technical or business project roles. These personnel gain DON-energy-specific experience which stays within the organization after the completion of the project. Frequently, projects include new professionals in a DON S&T organization, such as Space and Naval Warfare Systems Command (SPAWAR) or Engineering and Expeditionary Warfare Center (EXWC), college student veteran interns via California State University San Marcos' Veterans to Energy Careers, and Naval Postgraduate School (NPS) students, providing real-world training and education opportunities for the future DON energy workforce. For example, as of 2017, over sixty student veterans had participated in ESTEP projects as interns, and over 80% of those went on to work in the Department of Defense (DOD) as contractors or civilian employees.

Most emerging energy technologies are targeted towards private industry and consumers whose requirements may be different from those within the DON. In ESTEP, technologies are demonstrated in DON-specific adaptations and applications. Consequently, project personnel develop DON-relevant workforce experience faster and/or more effectively, while working towards transition of the studied technology into the DON. Technologies studied in ESTEP become more adoption-ready, in terms of stakeholder support and alignment with organizational processes, as well as in terms of system readiness and the subsequent ease with which it can be integrated in the intended technology environment.

Once adopted and integrated operationally within DON energy systems, ESTEP technologies would provide benefits in operation (as distinct from adoption readiness and workforce development benefits). In operation, the technologies will contribute to national security by assuring energy supply, increasing energy resilience, and reducing costs and other resource requirements for DON operations, enabling the DON to carry out and sustain its mission.

In addition, ESTEP develops DON S&T personnel with experience in learning and applying skills in new energy technologies, as well as knowledge on how to navigate the challenges faced in integrating those new technologies into existing infrastructures and "ecosystems".

This report documents the contributions of 55 ESTEP projects, either completed or in progress from fiscal year (FY) 2013 through FY 2018. The report begins with a description of the research methodology in Chapter II, which is then followed by a discussion and categorization of projects into technology families in Chapter III. Chapters IV – VII follow, with a summary of ESTEP project contributions with respect to: benefits in operation, learning value, and workforce development. Finally, the report concludes with a discussion on adoption readiness levels and final notes on the value of ESTEP project implementation to the DON.

II. RESEARCH METHODOLOGY

Table 1 lists the ESTEP projects described in this report, along with each project's principal investigator (PI), period of performance, installation location, and a reference number that will be used to identify specific projects later in this report. Additionally, related or follow-on projects are also indicated by alternating color groupings.

The research for this report was primarily carried out by reviewing Interim Program Review (IPR) materials and other documentation from 55 ESTEP projects completed between FY13 and FY18 and conducting interviews with the PIs when possible. The project IPR slides were reviewed first to gain a basic understanding of the technologies employed in each ESTEP project and to develop a taxonomy of technology families, as described in Chapter III.

Each project's IPR material and any other accompanying documents were reviewed in more detail to determine an applicable technology family, and to evaluate the type of benefits that could be achieved by said technologies. After establishing taxonomies for technology families and benefits of the technology in operation, the researchers then attempted to contact the project PIs to discuss the projects in more detail. The purpose of these discussions was to confirm our understanding of the technologies in use and review the progress made during each project. These discussions and the IPR reviews formed the basis of a further analysis of each demonstrated technology and its readiness for further adoption at other DON installations.

To facilitate the discussions with project PIs and standardize the project information used in this study, the authors of this report created a standard form for recording project information from the IPRs and PI interviews. Using their best judgement, the authors of this report first filled out these forms given the information available in the IPRs. The authors then reached out to key project personnel to conduct phone interviews in an effort to fill in any information gaps or make corrections to the authors' assessments. These key personnel were then sent a copy of the completed form to give their final approval of the contents and correct any misunderstandings. In the case where authors were not successful in contacting a knowledgeable representative for a project, assessment was documented based on the author's best judgement. For reference, the complete set of final ESTEP project information forms is provided in Appendix B of this report.

Table 1. ESTEP projects

Ref #	Project Title	FY Start	FY End	Principal Investigator	Performing Organization
1	Wind Powered Cooling with Thermal Storage	13	14	Anthony Gannon	NPS
2	Uninterruptible, Renewable Augmented Building Power Circuits	15	17	Anthony Gannon	NPS
3	Building Scale Compressed Air Energy System (CAES)	16	17	Anthony Gannon	NPS
4	Self Contained Hydrogen to Electrical System	17	18	Garth Hobson	NPS
5	Virtual Smart Grids for Achieving Regional Net-Zero Energy Goals	15	17	Eric Evans	SSC PAC
6	Seamless Integration of GIS and Electrical Architecture Models for Smart Grids and Net-Zero Energy Goals	16	18	Eric Evans	SSC PAC
7	Real-Time Distribution Analysis for MCBP	16	17	Eric Evans	SSC PAC
8	Evaluation of Smart -Controllers for Distributed Energy Resources	16	17	Alan Williams	SSC PAC
9	Advance Power Electronics for PV Inverters	13	15	Ken Ho	EXWC
10	DC Micro-grid For Solid State Lighting	15	17	Ken Ho	EXWC
11	Networked Building Level Micro-grid	17	19	Bruce Garrett	EXWC
12	Cyber-SCADA Energy Capability (C-SEC): Evaluation, Development, and Demonstration	12	14	Jose Romero-Mariona	SSC PAC
13	Energy Efficient Cloud Computing Evaluationand Demonstration	14	17	Chris Chen	SSC PAC
14	RFID Reading Outlets for Device-level Granularity in Building Energy Control	14	18	Wayne Lie	SSC PAC
15	C-SEC On The Move	15	16	Jose Romero-Mariona	SSC PAC
16	Data Center Smart Metering Evaluation (DC Smart-E)	16	16	Chris Chen	SSC PAC
17	Building Energy Management Automation	16	16	Chris Chen	SSC PAC
18	Resilient Critical Infrastructures through Secure and Efficient Micro Grids (ReCIst)	16	17	Jose Romero-Mariona	SSC PAC
19	SCADA Deploy	16	18	Henry Au	SSC PAC
20	Joint Cyber SCADA Laboratory Workforce Development (SSC PAC and UHWO)	17	18	Jose Romero-Mariona	SSC PAC
21	Smart Plug Side Channel Analysis (SPAMSANDWICH)	17	18	Lawrence Kerr	SSC PAC
22	ENSURE (Ensuring Reliability and Efficiency)	17	18	Josiah Bryan	SSC PAC
23	Hypercritical Operational Technology Mitigation of Embedded SploitSyndrome (HOTMESS)	17	19	Geancarlo Palavicini	SSC PAC
24	Passive and Active Cyber-Defense for Cyber-Physical Systems –Strategies, Implementation, and Evaluation	17	18	Roger Hallman	SSC PAC
25	Deep Subgrid-parity Solar	15	17	Randall Olsen	SSC PAC
26	Energy and Water Recovery by Microbial Fuel Cells	14	17	Lewis Hsu	SSC PAC
27	Ad-hoc Portable Power Systems (APPS)	17	19	Wayne Liu	SSC PAC
28	Energy Village: A Littoral Energy Test Facility	16	18	Wayne Liu	SSC PAC
29	Decentralized Micro-grid with Fuel Cell Energy Storage: Feasibility Study	16	18	Arthur Rubio	SSC PAC
30	Optimization of a Decentralized Micro-grid with PEM Fuel Cell, Electrolyzer and H2 Storage	14	16	Arthur Rubio	SSC PAC
31	Mobile EMS	15	16	Giovanna Oriti	NPS
32	Photovoltaic Power Conditioning System for an Energy Management System (EMS)	16	18	Giovanna Oriti	NPS
33	RTU Challenge	13	17	Max Hogan	EXWC
34	Improved Wind Load Design for Rooftop PV Systems	14	15	Fernand Marquis	NPS
35	Marine Corps Base Hawaii Energy Management Evaluation(MCBH E-Manage) Seed	14	14	Tyler Chun	SSC PAC
36	Validate SIREN Computer Modeling	15	16	Ben Wilcox	EXWC
37	LIDAR Wind Measurement Experiments	15	16	Ben Wilcox	EXWC
38	Shroud with RF Mesh to Suppress Radar Cross-section of Small Wind Turbine	15	17	Ben Wilcox	EXWC
39	Liquid Air Energy Storage (LAES)	15	17	Ken Ho	EXWC
40	Waste to Energy Hydrogen Generation	15	18	Ken Ho	EXWC
41	Adhered PV Reliability (Completed)	15	16	Robert Schoff	EXWC
42	Optimized Cooling for Concentrated Photovoltaic Systems	15	17	Sanjeez Sathe	NPS
43	Shore Based Test of X-Band Radar Hardware on Mast for Real Time Hydrodynamic Control of Wave Energy Conversion	16	20	Ben Wilcox	EXWC
44	Valuation and Financing for Energy Storage	16	18	Dustin Talley	EXWC
45	Transportable Micro-grid with Storage	16	19	Paul Kistler	EXWC
46	Modular Micro grid (M2G) System	16	19	Yutaka Sugiyama	EXWC
47	Wind Effects on Sun Tracking PV Cell Solar Panels	16	17	M. S. Chandrasekhara	NPS
48	Grid Stability in High Penetration Renewables	17	19	Bruce Garrett	EXWC
49	NanolubricantHVAC Refrigerant	17	19	Paul Kistler	EXWC
50	Tunable White LED	17	19	Paul Kistler	EXWC
51	Waste Heat Recovery From Gas Turbine Exhaust	17	19	Garth Hobson	NPS
52	Efficient Implementation of Solid State Transformers (SST)	17	19	Todd Weatherford	NPS
53	HVAC Control by Means of Predicted Percentage of Dissatisfied Method	17	19	Arthur Rubio	SSC PAC
54	Develop Energy Use Trends with Innovative Visualization/Analysis	17	18	Chris Chen	SSC PAC
55	Green Data Center Software Product Evaluation	17	19	Mamadou Diallo	SSC PAC

Note: Follow-on or related projects are shown below the preceding project, in the same color.

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III. OVERVIEW OF TECHNOLOGY DEMONSTRATION FAMILIES

As explained in Chapter II, the technologies used in the ESTEP demonstration projects were categorized into technology families (defined in Table 2). This taxonomy was developed for the purposes of this report, to allow for easier comparison among projects, by highlighting the most significant ways in which ESTEP projects are intended to help reduce costs and improve DON installation energy assurance.

Table 3 indicates to which family each ESTEP project belongs. In many cases, the demonstrated technologies or systems used can be grouped under multiple technology families. An 'X' is used to indicate that a project belongs in that technology family, while an 'XXX' indicates the project's primary technology family. Figure 1 shows the distribution of projects by technology family.

Over half of the technology demonstration projects (N=29) are secondarily associated with the *Modeling, Optimization and Decision Support* family. Yet, a small number of the technology demonstration projects (N=7) fall within the *Modeling, Optimization and Decision Support* group as a primary technology family.

Table 2. Technology family definitions

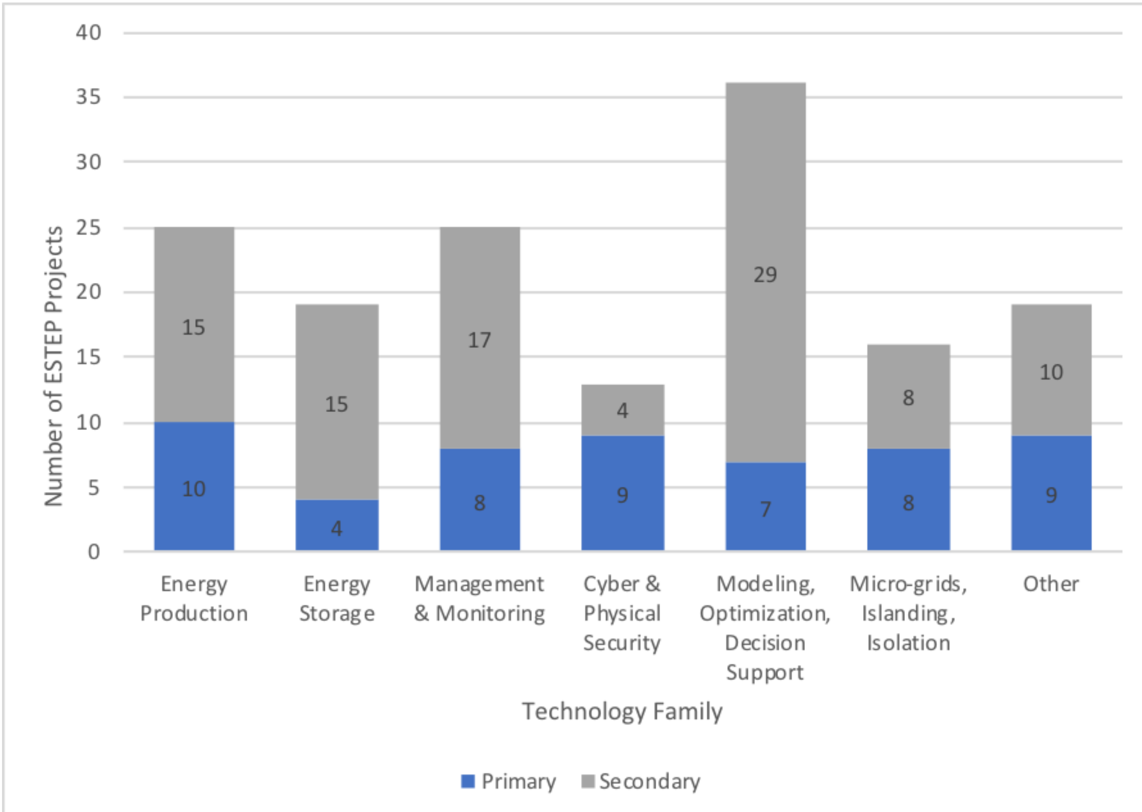
Technology Family	Description
Energy Production	Technologies that generate usable energy or covert other energy into a more usable form.
Energy Storage	Technologies that create independent supplies of stored energy that can be used later.
Management, Monitoring	Technologies that improve situational awareness and/or control capabilities of energy (usually electrical power) systems.
Cyber & Physical Security	Technologies that provide detection of, defense against, or minimize potential damage caused by malicious actions, attacks, natural events, or human error affecting the operation of energy systems or, via energy systems, affecting other systems they support.
Modeling, Optimization, Decision Support	Technologies that can be used to model energy (usually electrical power) systems to determine if systems are behaving as expected and analyze the expected impact of potential changes or events to inform future decisions[1]
Microgrids, Islanding, Isolation	Technologies that improve a facility's ability to function independently of the commercial electrical power grid or provide a greater degree of resilience against disturbances on the commercial grid
Other	Technologies that provide a significant energy-related capability outside of those categories listed above

[1] For more examples and detailed explanation of Modeling, Optimization and Decision Support Capability, see Seals (2017).

Table 3. List of projects and their technology families

Ref. #	Project Title	Energy Production	Energy Storage	Management & Monitoring	Cyber & Physical Security	Modeling, Optimization, Decision Support	Micro-grids, Islanding, Isolation	Other
1	Wind Powered Cooling with Thermal Storage		XXX					
2	Uninterruptible, Renewable Augmented Building Power Circuits		X				XXX	
3	Building Scale Compressed Air Energy System (CAES)		XXX				X	
4	Self Contained Hydrogen to Electrical System	X	XXX					X
5	Virtual Smart Grids for Achieving Regional Net-Zero Energy Goals			X		XXX		
6	Seamless Integration of GIS and Electrical Architecture Models for Smart Grids and Net-Zero Energy Goals			XXX	X	X		
7	Real-Time Distribution Analysis for MCBP			XXX	X	X		
8	Evaluation of Smart -Controllers for Distributed Energy Resources			XXX		X	X	
9	Advance Power Electronics for PV Inverters	XXX						
10	DC Micro-grid For Solid State Lighting	X	X	X			XXX	
11	Networked Building Level Micro-grid	X	X				XXX	
12	Cyber-SCADA Energy Capability (C-SEC): Evaluation, Development, and Demonstration			X	XXX	X		
13	Energy Efficient Cloud Computing Evaluationand Demonstration			X		X		XXX
14	RFID Reading Outlets for Device-level Granularity in Building Energy Control			XXX	X	X		
15	C-SEC On The Move				XXX	X		
16	Data Center Smart Metering Evaluation (DC Smart-E)			XXX		X		
17	Building Energy Management Automation			XXX	X	X		
18	Resilient Critical Infrastructures through Secure and Efficient Micro Grids (ReCIst)				XXX	X	X	
19	SCADA Deploy			X	XXX	X		
20	Joint Cyber SCADA Laboratory Workforce Development (SSC PAC and UHWO)				XXX	X		X
21	Smart Plug Side Channel Analysis (SPAMSANDWICH)			X	XXX			
22	ENSURE (Ensuring Reliability and Efficiency)			X	XXX			
23	Hypercritical Operational Technology Mitigation of Embedded SploitSyndrome (HOTMESS)			X	XXX	X		X
24	Passive and Active Cyber-Defense for Cyber-Physical Systems –Strategies, Implementation, and Evaluation			X	XXX	X		
25	Deep Subgrid-parity Solar	XXX						
26	Energy and Water Recovery by Microbial Fuel Cells	X	X					XXX
27	Energy Village: A Littoral Energy Test Facility	X	X				X	XXX
28	Ad-hoc Portable Power Systems (APPS)	X	X				X	XXX
29	Decentralized Micro-grid with Fuel Cell Energy Storage: Feasibility Study	X	X			X	XXX	
30	Optimization of a Decentralized Micro-grid with PEM Fuel Cell, Electrolyzer and H2 Storage	X	X			X	XXX	
31	Mobile EMS	X	X	X			XXX	
32	Photovoltaic Power Conditioning System for an Energy Management System (EMS)	XXX	X	X		X	X	
33	RTU Challenge			X		X		XXX
34	Improved Wind Load Design for Rooftop PV Systems	XXX				X		
35	Marine Corps Base Hawaii Energy Management Evaluation(MCBH E-Manage) Seed			XXX		X		
35	Validate SIREN Computer Modeling			X		XXX	X	
37	LIDAR Wind Measurement Experiments	X				XXX		X
38	Shroud with RF Mesh to Suppress Radar Cross-section of Small Wind Turbine	X						XXX
39	Liquid Air Energy Storage (LAES)		XXX	X				
40	Waste to Energy Hydrogen Generation	XXX	X			X		X
41	Adhered PV Reliability (Completed)	XXX				X		
42	Optimized Cooling for Concentrated Photovoltaic Systems	XXX						
43	Shore Based Test of X-Band Radar Hardware on Mast for Real Time Hydrodynamic Control of Wave Energy Conversion	XXX				X		
44	Valuation and Financing for Energy Storage		X			XXX		X
45	Transportable Micro-grid with Storage	X	X	X		X	XXX	
46	Modular Micro grid (M2G) System	X	X	X		X	XXX	
47	Wind Effects on Sun Tracking PV Cell Solar Panels	XXX				X		X
48	Grid Stability in High Penetration Renewables	X	X	XXX				
49	NanolubricantHVAC Refrigerant					X		XXX
50	Tunable White LED					X		XXX
51	Waste Heat Recovery From Gas Turbine Exhaust	XXX						X
52	Efficient Implementation of Solid State Transformers (SST)	X				X	X	XXX
53	HVAC Control by Means of Predicted Percentage of Dissatisfied Method			X		XXX		
54	Develop Energy Use Trends with Innovative Visualization/Analysis					XXX		X
55	Green Data Center Software Product Evaluation					XXX		X

Figure 1. Distribution of ESTEP projects by technology family



IV. TECHNOLOGY BENEFTIS IN OPERATION

Once adopted and operational, ESTEP technologies would provide benefits in operation – as distinct from benefits the demonstration provides via learning value, workforce development, or by improving a technology's adoption readiness.

ESTEP technologies provide different kinds of benefits in operation. Based on a review of ESTEP project documents, PI interviews, and a review of DOD and DON guidance on energy priorities (Simon et al., 2014; Whitney et al., 2013) we identified energy systems' benefits in operation that are most important to DOD and DON leadership, as detailed in Table 4.

The most fundamental benefits of investing in new DON energy technologies are that they can provide enhancements to energy resilience and energy assurance.[2] Energy is a requirement of almost every activity – both in support and operational roles in the DON – and making sure energy is available in the form usable (when and where required), is essential to the mission. "Assured access to reliable energy is critical to the DON's ability to accomplish its mission. Optimizing energy use by increasing energy efficiency and diversifying sources of supply enhances combat capability and operational flexibility, while reducing risk and logistical demands" (Department of the Navy, 2017).

The technologies demonstrated in ESTEP projects offer ways to ensure that DON installations are able to provide a supply of energy that meets the demands of mission assurance. In some cases, technologies provide resilience by providing services, or otherwise allow continued functionality if energy supplies are cut off. Other technologies, such as renewable energy generation, can generate usable energy independent of outside sources. Some technologies work to protect the infrastructure that distributes energy, by reducing risk or the frequency of disruptions. While it is difficult in some cases to assess the full operational impact of any given technology during the S&T stage, ESTEP

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[2] Energy assurance is making sure mission-demanded energy is available, while energy resilience emphasizes recovery from a disruption---it is defined in the U.S. Federal code as "the ability to avoid, prepare for, minimize, adapt to, and recover from anticipated and unanticipated energy disruptions". (U.S.C. Title 10 Section 101(e)(6).

projects have shown that many of these technologies have the potential to provide significant benefits when adopted and implemented on a larger scale. For example, the building-scale solid state lighting microgrid demonstration (Project 10) has made significant progress towards the development of a technology template and process roadmap to easily convert other buildings into standalone microgrids without the need to invest in a lengthy design process.

In addition to identifying the general categories of potential benefits that could be provided by demonstrated installation energy technology projects, the research conducted by the NPS team also broke out several sub-categories of benefits, for the general benefit categories described in Table 4. A breakdown of the sub-categories, mapped to the general benefit categories they are associated with, is also provided in Table 4.

Table 4. Benefit categories

Benefit Category	Description	Sub-categories
Introduce / Integrate New Energy Generation	Capability to generate electrical power on DON installations. This could take many forms such as capturing waste energy, new PV generation, technology that makes other power sources on installations more efficient, etc.	•Added renewable energy generation capability •Improved efficiency or effectiveness of existing renewable generation •Improved capability to integrate renewables into larger grid •Integrated alternative-powered backup power systems
Introduce / Integrate New Energy Storage	Capability for energy to be stored for later use. This could take many forms such as battery storage, compressed air energy storage, fuel cell systems, technology that makes existing storage more efficient, etc.	•Integrated or expanded renewable energy storage •Improved efficiency or effectiveness of existing renewable energy storage •Incorporated energy storage to reduce peak power demand •Increased energy storage capability for independent operation
Reduce Energy Demand on Bases	Capabilities that reduce base energy resource requirements without compromising operational capability. These could take many forms such as efficiency improvements at point-of-use or in the distribution infrastructure, reducing waste, or shifting to alternative sources of energy.	•Reduced installation power consumption through improved distribution efficiency •Reduced installation power consumption through building control automation •Reduced installation power consumption through improved end-user efficiency •Reduced natural gas needed for heating or installation operations •Improved efficiency or alternative fueled vehicles on installation

Table 4, Benefit Categories, continued:

Benefit Category	Description	Sub-categories
Reduced O&S Requirements	Reduction in the operation, maintenance, and support requirements for energy systems. This could take many forms such as technologies that reduce maintenance requirements on a heating, ventilation and air conditioning (HVAC) system, technologies that aid energy managers in diagnosing power grid problems, reduce failure rate, etc.	•Reduced contractor support required to install, maintain, or operate technology •Technology requires less maintenance labor than alternative systems •Technology requires fewer or less costly replacement components that alternative systems •Technology is easier to operate than alternative systems •Technology reduces need for specialized training •Reduced reliance on systems with expensive replacement parts •Increased ability to diagnose need for preventative maintenance •Reduced wear and tear on mechanical systems
Physical or Cyber Security, Resiliency, Redundancy	Capabilities that help safeguard energy supply or distribution resources. These could take many forms such as identifying vulnerabilities within critical systems, improving monitoring of electrical systems to detect abnormal activity, implementing measures to limit the potential damage of catastrophic events, improving ability to restore operations following a power failure, etc.	•Improved monitoring and detection of potential cyber threats •Improved capability to isolate potential vectors for cyber-attacks •Improved fail-safes or system logic to limit potential damage from cyber-attacks •Improved capability to restore operation after successful cyber-attacks •Improved islanding capability to isolate and protect critical systems •Improved fault isolation to prevent cascading blackouts •Automated backup systems for critical systems •Reduced reliance on outside energy suppliers •Improved capability to restore grid functionality after outages •Improved diagnostic capabilities for energy infrastructure components •Improved metering and monitoring of installation energy use •Real-time monitoring of energy systems •Improved documentation of infrastructure •Reduced frequency of backup generator use •Reduced requirement for backup generators to assure power

Table 4, Benefit Categories, continued:

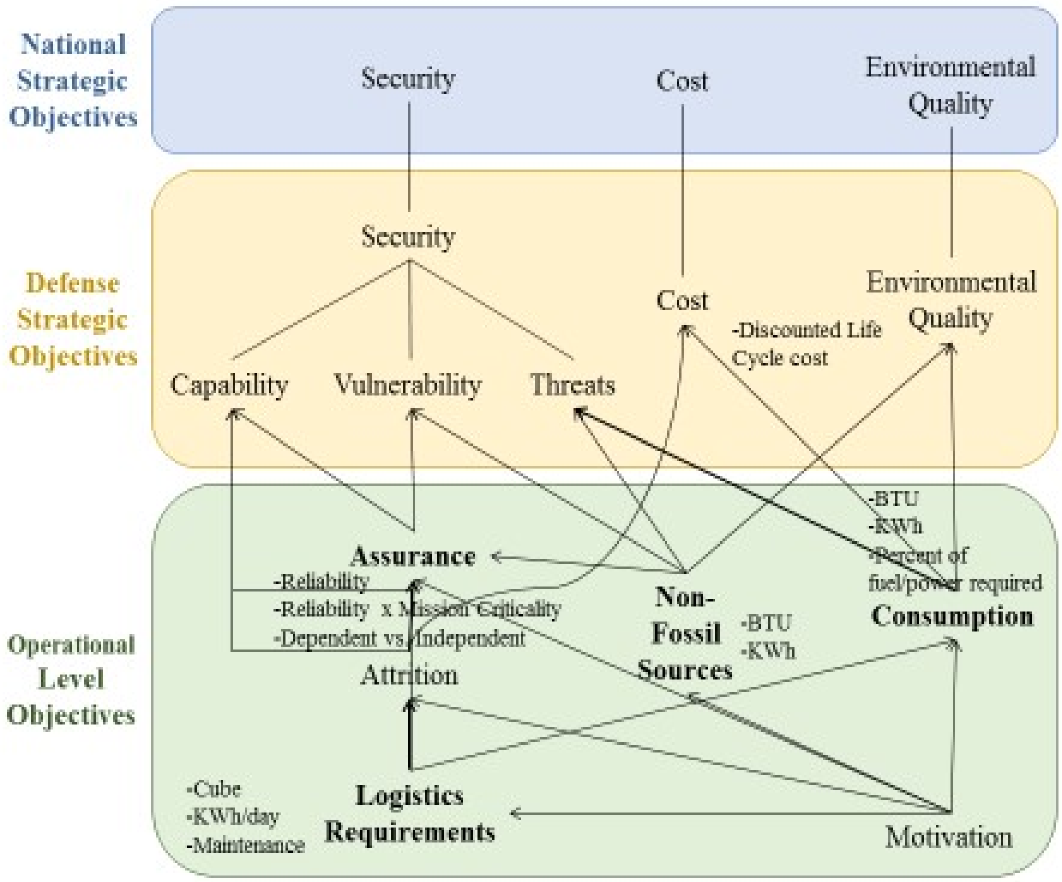
Benefit Category	Description	Sub-categories
Improved Modeling or Decision Support	Capabilities that allow facility decision makers to optimize grid operations, estimate returns on infrastructure projects, or otherwise provide valuable insight when considering installation energy projects. These could include improving ROI estimates of infrastructure improvements, properly sizing new infrastructure components, identifying power quality issues, etc.	•Improved decision support capability for sizing backup generators •Improved capability to estimate ROI of renewable systems •Improved decision support capabilities for investing in renewable systems •Power modeling used to optimize grid configuration or expansion •Modeling and simulation to inform energy infrastructure investments •Improved decision support tools to inform future investments or funding requirements
Mobile / Remote Power	Capabilities that lend themselves to improving energy access or reliability at remote outposts, in the field, remote locations on bases, or other areas where reliable power sources are limited or unavailable.	• Improved decision support capability for sizing backup generators • Improved energy capabilities at remote locations without energy infrastructure access • Improved energy capabilities on mobile platforms or temporary facilities

Estimating the magnitude of these benefits – e.g., how much can we improve wave energy generator output (Project 43), or how much energy can we save with improved heating, ventilation and air conditioning (HVAC) units (Project 33) – is one of the valuable contributions of some ESTEP demonstration projects. The magnitude of benefits provided by the technologies may be difficult to estimate because they will depend on the details of specific future adoption. In addition, estimating the value of many of the above-described benefits can be challenging, as many of the most important benefits are non-financial, such as assuring the supply of power to mission-critical capabilities.

Many of these benefits are indirect. For example, a capability may enable end-user behavioral changes such as conservation by providing feedback to the end user regarding local power consumption or prices. The technology and its capability create benefits indirectly by enabling better downstream decisions, not directly as a result of the technology's implementation. It could enable changes in operational choices by providing system operational data or control capability. It could also improve infrastructure choices by providing information to inform design choices, e.g., sizing electrical equipment, and providing justification for use in procurement requests.

Energy technologies can also improve mission capability by reducing operating costs – either financial, or via the use of resources such as labor required for operating the energy system. While reducing operating costs associated with installation energy does not directly affect operational effectiveness, if a command can reduce its total energy costs, that potentially frees up funding for other programs, or for further energy improvements. Reductions in the total cost of energy from outside sources can also make an installation more financially resilient against changes in fuel or energy prices. A graphical representation of how operational DOD energy-related objectives, including reducing costs as discussed here, contribute to defense and national strategic objectives is shown in Figure 2.

Figure 2. Network of DOD energy-related objectives (adapted from Whitney et al., 2013)



of ESTEP. For this reason, we have used three different designations to classify the observed or potential benefits each project had/has to offer. A benefit was considered a "realized" benefit if it was observed at an operational scale during the demonstration projects. If not realized, a benefit could be classified as "demonstrated" if the ESTEP project had shown all of the capabilities needed to provide a given benefit, but was not yet functioning so as to provide this benefit at an operational capacity. Finally, a benefit would be considered a "potential" benefit if the technology provided most of the capabilities necessary to achieve a certain benefit, but would need to be further developed or integrated with a complementary system. A graphical summary depicting the total count of realized, demonstrated and potential benefits across the ESTEP projects is shown in Figure 3.

Figure 3. Distribution of ESTEP projects by benefit category

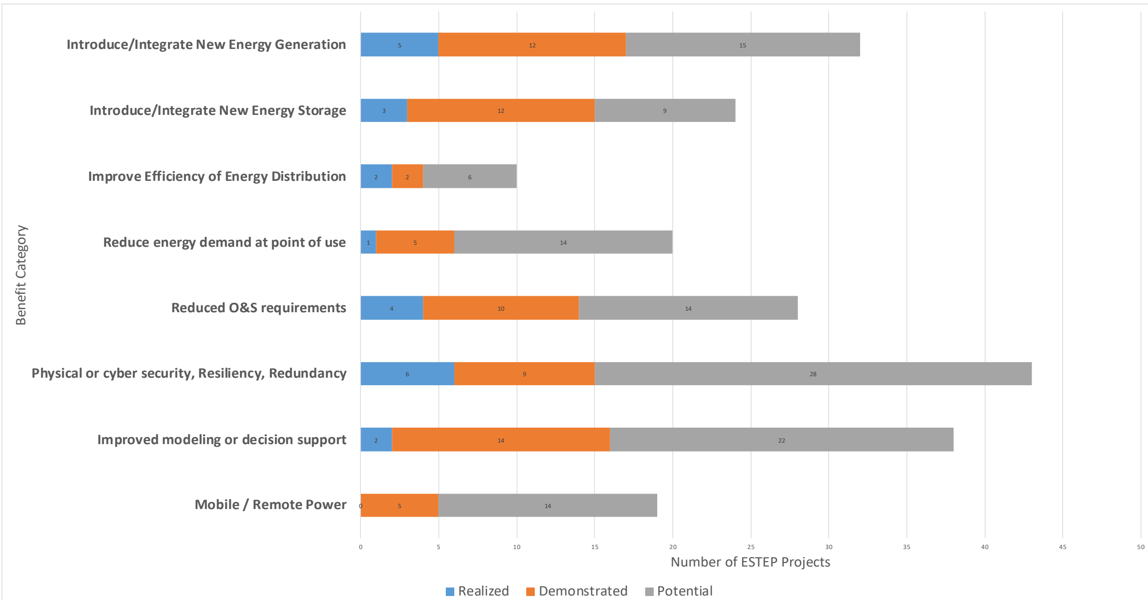


Table 5 provides a summary of the observed or expected benefits of the different ESTEP projects. Appendix A contains a series of figures [Figures A-1 to A-7], showing the *realized*, *demonstrated*, and *potential* benefits of each technology, for each benefit category, broken down by specific ways they provide benefits in each category described in Table 4.

Table 5. Summarized project benefits

Ref. #	Project Title	Introduce/integrate new energy generation	Introduce/integrate new energy storage	Improve efficiency of energy distribution	Reduce energy demand at point of use	Reduced O&S requirements	Physical or cyber security, resiliency, redundancy	Improved modeling or decision support	Mobile / Remote Power
1	Wind Powered Cooling with Thermal Storage		XXX		X				
2	Uninterruptible, Renewable Augmented Building Power Circuits		XXX	X		X	X		
3	Building Scale Compressed Air Energy System (CAES)		XXX		X	X	X		
4	Self Contained Hydrogen to Electrical System		XXX			X	X		X
5	Virtual Smart Grids for Achieving Regional Net-Zero Energy Goals			X		X	X	XXX	
6	Seamless Integration of GIS and Electrical Architecture Models for Smart Grids and Net-Zero Energy Goals			X		X	X	XXX	
7	Real-Time Distribution Analysis for MCBP			X		X	XXX	X	
8	Evaluation of Smart -Controllers for Distributed Energy Resources					X		XXX	
9	Advance Power Electronics for PV Inverters	XXX		X					
10	DC Micro-grid For Solid State Lighting	X	XXX	X	X	X	X		
11	Networked Building Level Micro-grid	X	XXX	X			X		
12	Cyber-SCADA Energy Capability (C-SEC): Evaluation, Development, and Demonstration					X	XXX		
13	Energy Efficient Cloud Computing Evaluation and Demonstration				XXX				
14	RFID Reading Outlets for Device-level Granularity in Building Energy Control				X	X		XXX	
15	C-SEC On The Move					X	XXX		
16	Data Center Smart Metering Evaluation (DC Smart-E)				XXX	X	X	X	
17	Building Energy Management Automation				XXX	X	X		
18	Resilient Critical Infrastructures through Secure and Efficient Micro Grids (ReCIst)			X		X	XXX		
19	SCADA Deploy			X		X	XXX	X	
20	Joint Cyber SCADA Laboratory Workforce Development (SSC PAC and UHWO)			X			XXX		
21	Smart Plug Side Channel Analysis (SPAMSANDWICH)					X	XXX	X	
22	ENSURE (Ensuring Reliability and Efficiency)			X		X	XXX	X	
23	Hypercritical Operational Technology Mitigation of Embedded SploitSyndrome (HOTMESS)					X	XXX	X	
24	Passive and Active Cyber-Defense for Cyber-Physical Systems –Strategies, Implementation, and Evaluation						XXX	X	
25	Deep Subgrid-parity Solar	XXX				X			
26	Energy and Water Recovery by Microbial Fuel Cells	X	X						XXX
27	Ad-hoc Portable Power Systems (APPS)	X	X			X			XXX
28	Energy Village: A Littoral Energy Test Facility	X	X			X			XXX
29	Decentralized Micro-grid with Fuel Cell Energy Storage: Feasibility Study	X	X				XXX		
30	Optimization of a Decentralized Micro-grid with PEM Fuel Cell, Electrolyzer and H2 Storage								
31	Mobile EMS							X	XXX
32	Photovoltaic Power Conditioning System for an Energy Management System (EMS)	X						X	XXX
33	RTU Challenge				XXX	X			
34	Improved Wind Load Design for Rooftop PV Systems	XXX				X			
35	Marine Corps Base Hawaii Energy Management Evaluation(MCBH E-Manage) Seed				XXX	X	X	X	
35	Validate SIREN Computer Modeling			X		X	X	XXX	
37	LIDAR Wind Measurement Experiments	X						XXX	X
38	Shroud with RF Mesh to Suppress Radar Cross-section of Small Wind Turbine	XXX				X	X	X	
39	Liquid Air Energy Storage (LAES)		XXX			X	X		
40	Waste to Energy Hydrogen Generation	X	X		X				
41	Adhered PV Reliability (Completed)	XXX				X			
42	Optimized Cooling for Concentrated Photovoltaic Systems	XXX							
43	Shore Based Test of X-Band Radar Hardware on Mast for Real Time Hydrodynamic Control of Wave Energy Conversion	XXX				X		X	
44	Valuation and Financing for Energy Storage		X			X	X	XXX	
45	Transportable Micro-grid with Storage	X	X			X	X		XXX
46	Modular Micro grid (M2G) System	X	X	X		X	XXX		
47	Wind Effects on Sun Tracking PV Cell Solar Panels	XXX				X	X		
48	Grid Stability in High Penetration Renewables			XXX		X	X	X	
49	NanolubricantHVAC Refrigerant				XXX	X			
50	Tunable White LED				XXX	X		X	
51	Waste Heat Recovery From Gas Turbine Exhaust	XXX			X				
52	Efficient Implementation of Solid State Transformers (SST)	XXX				X			
53	HVAC Control by Means of Predicted Percentage of Dissatisfied Method				XXX	X		X	
54	Develop Energy Use Trends with Innovative Visualization/Analysis					X		XXX	
55	Green Data Center Software Product Evaluation				XXX	X	X	X	

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V. LEARNING VALUE OF TECHNOLOGY DEMONSTRATION

As first-of-their-kind efforts, often small-scale and requiring substantial engineering and technical labor, few ESTEP projects will have positive net financial benefits if evaluated in isolation. In other words, evaluating the projects based only on the demonstration projects' direct impacts would undervalue these efforts' value to the DON. While many successful technology demonstration projects provide demonstrated benefits to their host installations, as for any research and development effort, the greatest value of ESTEP projects is in learning about technologies, and therefore will be realized in future adoption of the technology at a larger scale at installations. The learning gained from demonstration projects can add value in several different ways.

One of the key ways ESTEP projects add value is by S&T personnel learning how to integrate emerging technologies within a DON environment. Historically, the DOD was the developer and owner of the most advanced technologies in the world, but increasingly the DOD and DON are adopting technologies largely developed in the commercial sector. Even for the technologies that are in use operationally in private industry, in many cases the challenge is to integrate the technology in a DON context. The technology requires military-specific or even DON-specific adaptations, or perhaps may require experience in procuring, installing, and using a technology effectively. In DOD applications with more intensive system resiliency or cyber security requirements, special considerations are needed to integrate a system or technology that wasn't designed with these requirements in mind. To meet those requirements, DON engineers must find clever ways to add in safeguards or demonstrate that a new technology meets a given requirement that may have been written with a different technology in mind. Learning how to use energy management software across DON installation applications can help other installations adopt the technologies more effectively and rapidly, as similar technology is adopted and relevant learning occurs. For example, DON engineers can develop templates for integrated power conditioning systems for adding new alternative energy generation or backup sources to a base power grid, or develop a suite of tools to probe power distribution systems for various cyber security vulnerabilities.

A second way ESTEP projects add value through learning arises if an evaluation project compares multiple instances of a technology (e.g., equipment from multiple manufacturers, or comparing a new technology with the existing technology it would replace). Then, it provides information that helps the DON determine which is the better choice for future adoption and increases the likelihood that the DON will adopt the most effective and efficient technology in future investments. For example, comparing multiple photovoltaic roof-mounting technologies helps the DON acquire the one that is best-suited for widespread adoption or most appropriate for a specific climate or building type. In other cases, a project might demonstrate the potential applications and unique benefits of new applications such as using supercapacitors or chilled water as efficient forms of energy storage. In such instances, the demonstration project may help inform future decisions on which types of technologies to pursue further, even if the project doesn't evaluate products from specific vendors.

A third way ESTEP projects add value through learning is by speeding adoption of promising technologies. The processes within the DOD to certify a technology for use can create significant obstacles when integrating new technologies. The defense industry has very stringent requirements for vetting a new product and technology before accepting a system for wider use. Meeting these requirements often requires visibility into the inner workings of a system that is not required by the technology developer's main target market. Evaluating these products for acceptance often requires close coordination between defense personnel and technology developers. Implementing new technologies may also require the creation of a support mechanism, contract, or agreement that falls outside of the technology developers' primary business model. Add in mandates such as those that give preference to certain businesses, impose environmental constraints, and require multiple safety certifications, and it becomes clear that even purchasing a new technology can become a daunting task.

Technologies that have been demonstrated in a DON installation may fare better in competition for limited funds in the DON project selection processes. In addition, they may pass more quickly through the specification and contracting processes. In some cases, demonstration projects and the identification of new requirements as discussed above has even led to DON engineers having to draft and justify new requirements for their specific systems because existing mandates were poorly matched to the context of new technology applications. For example, many of these ESTEP projects required researchers to draft or otherwise identify an information security accreditation for their demonstration projects in order to collect energy use data through different automated systems. Setting a precedent could speed the process of getting accreditation for wider adoption. In this way, learning can accelerate the adoption of more efficient and effective installation energy technology, thus providing its benefit sooner.

In some cases, a desired capability is not available as a prepackaged commercially available system, but clever DON engineers can develop these capabilities by combining different commercial-off-the-shelf (COTS) products. Although an ESTEP project of this nature is unlikely to result in a fully mature technology solution, the demonstrated capabilities of the resulting systems can inform future efforts to collaborate with industry partners to develop a mature system, or demonstrate the application for a particular technology composed of already mature systems. For example, several different ESTEP projects used small single-board computers, microprocessors, or "smart" devices to develop novel means of assessing cyber vulnerabilities on existing power systems, or to monitor energy use to detect potential cyber-attacks. In other cases, researchers demonstrated the ability to generate and store energy using mechanical and electrical components not typically associated with larger energy applications.

The mechanisms by which learning could be acquired through ESTEP projects, were categorized as:

- integrating mature commercial technologies on DoN installations and adapting solutions to meet DON-specific challenges or requirements such as technical requirements or procedural compliance (**DON-Specific Adaptations**)
- evaluating an emerging technology's maturity, performance, or suitability so that it can be compared to alternative technologies **(Evaluate Competing Technologies)**
- determining a technology has met relevant requirements and regulations that can help streamline the process of future adoption efforts **(Justification For Wider Investment)**
- developing new energy applications using existing technologies **(New Capability Development)**

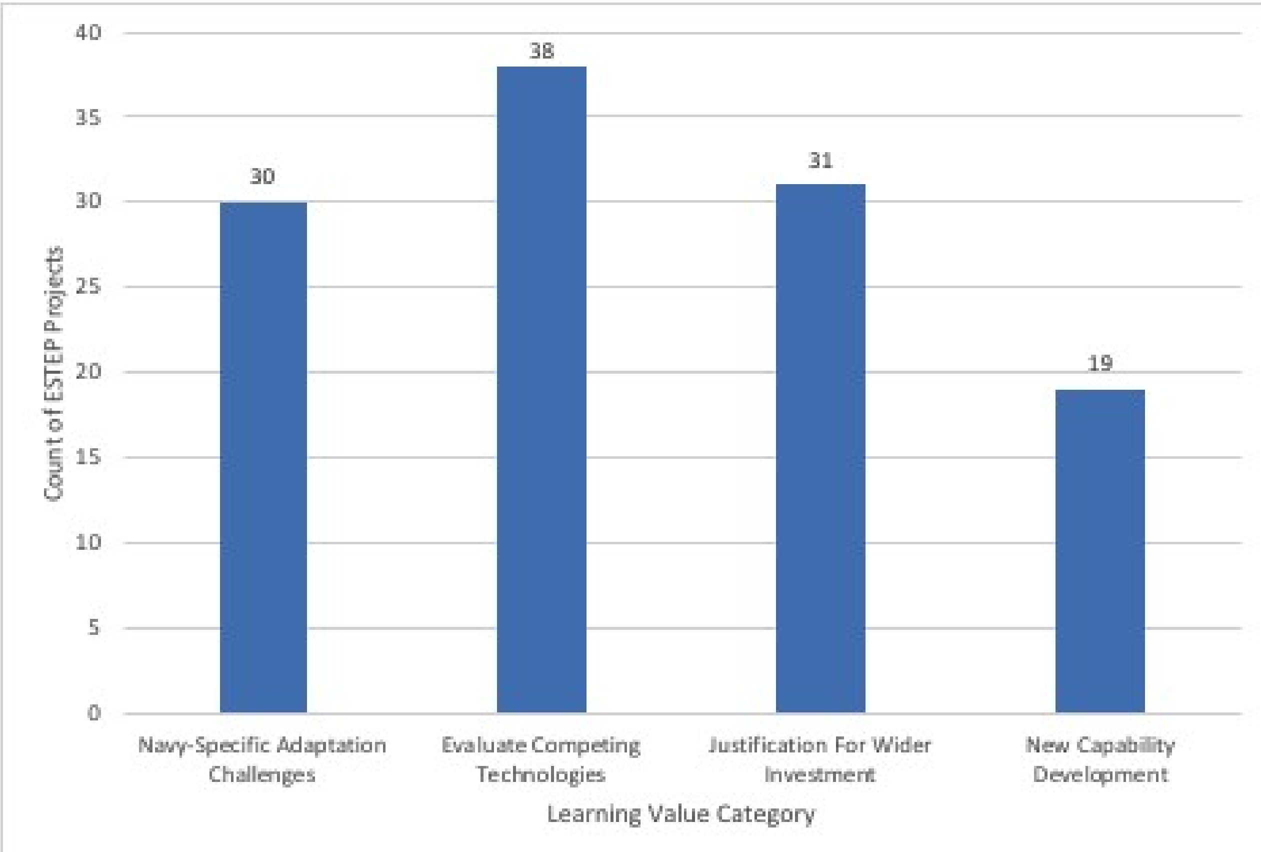
Table 6 shows the authors' assessment of the most significant ways in which learning provides value to each project in this study.

Table 6. Learning value mechanisms by ESTEP project

Project Title	Navy-Specific Adaptation Challenges	Evaluate Competing Technologies	Justification For Wider Investment	New Capability Development
Wind Powered Cooling with Thermal Storage		X		
Uninterruptible, Renewable Augmented Building Power Circuits		X	X	X
Building Scale Compressed Air Energy System (CAES)				X
Self Contained Hydrogen to Electrical System		X		X
Virtual Smart Grids for Achieving Regional Net-Zero Energy Goals	X	X	X	
Seamless Integration of GIS and Electrical Architecture Models for Smart Grids and Net-Zero Energy Goals	X	X	X	
Real-Time Distribution Analysis for MCBP	X		X	
Evaluation of Smart -Controllers for Distributed Energy Resources	X	X	X	
Advance Power Electronics for PV Inverters		X		
DC Micro-grid For Solid State Lighting	X	X	X	
Networked Building Level Micro-grid	X	X	X	
Cyber-SCADA Energy Capability (C-SEC): Evaluation, Development, and Demonstration	X		X	
Energy Efficient Cloud Computing Evaluationand Demonstration		X		
RFID Reading Outlets for Device-level Granularity in Building Energy Control	X	X	X	X
C-SEC On The Move			X	X
Data Center Smart Metering Evaluation (DC Smart-E)	X	X	X	
Building Energy Management Automation	X	X		
Resilient Critical Infrastructures through Secure and Efficient Micro Grids (ReCIst)	X		X	X
SCADA Deploy	X		X	X
Joint Cyber SCADA Laboratory Workforce Development (SSC PAC and UHWO)	X		X	
Smart Plug Side Channel Analysis (SPAMSANDWICH)	X		X	X
ENSURE (Ensuring Reliability and Efficiency)	X		X	X
Hypercritical Operational Technology Mitigation of Embedded SploitSyndrome (HOTMESS)		X		X
Passive and Active Cyber-Defense for Cyber-Physical Systems –Strategies, Implementation, and Evaluation		X		
Deep Subgrid-parity Solar		X		
Energy and Water Recovery by Microbial Fuel Cells		X		X
Ad-hoc Portable Power Systems (APPS)		X		X
Energy Village: A Littoral Energy Test Facility		X		X
Decentralized Micro-grid with Fuel Cell Energy Storage: Feasibility Study	X	X		
Optimization of a Decentralized Micro-grid with PEM Fuel Cell, Electrolyzer and H2 Storage		X	X	
Mobile EMS				X
Photovoltaic Power Conditioning System for an Energy Management System (EMS)		X		
RTU Challenge		X	X	
Improved Wind Load Design for Rooftop PV Systems	X		X	
Marine Corps Base Hawaii Energy Management Evaluation(MCBH E-Manage) Seed	X		X	
Validate SIREN Computer Modeling		X		
LIDAR Wind Measurement Experiments	X	X	X	X
Shroud with RF Mesh to Suppress Radar Cross-section of Small Wind Turbine	X	X	X	X
Liquid Air Energy Storage (LAES)		X	X	
Waste to Energy Hydrogen Generation	X	X	X	
Adhered PV Reliability		X		
Optimized Cooling for Concentrated Photovoltaic Systems		X		
Shore Based Test of X-Band Radar Hardware on Mast for Real Time Hydrodynamic Control of Wave Energy Conversion		X		X
Valuation and Financing for Energy Storage	X		X	
Transportable Micro-grid with Storage	X	X	X	
Modular Micro grid (M2G) System	X	X		
Wind Effects on Sun Tracking PV Cell Solar Panels	X		X	
Grid Stability in High Penetration Renewables	X		X	
NanolubricantHVAC Refrigerant		X	X	
Tunable White LED	X		X	
Waste Heat Recovery From Gas Turbine Exhaust	X	X		X
Efficient Implementation of Solid State Transformers (SST)	X	X		
HVAC Control by Means of Predicted Percentage of Dissatisfied Method		X		X
Develop Energy Use Trends with Innovative Visualization/Analysis	X		X	
Green Data Center Software Product Evaluation		X		

Figure 4 shows the distribution of ESTEP projects' learning contribution by mechanism, i.e., DON-Specific Adaptation Challenges, Evaluate Competing Technologies, Justification for Wider Investment and New Capability Development.

Figure 4. ESTEP projects' learning value contributions



As can be seen from Figure 4, a large majority of the 55 ESTEP projects added learning value by evaluating an emerging technology's maturity, performance, or suitability so that it can be compared to alternative technologies.

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VI. WORKFORCE DEVELOPMENT

In addition to promoting energy assurance on DON installations and reducing operating costs, projects funded under the ESTEP program have served to develop the DON workforce. PIs and key performers on these projects have gained technology-specific expertise and developed generalizable technical and professional skills. These projects have also promoted coordination between different DON organizations that must work together to implement large installation improvements. Many of these projects involved significant infrastructure upgrades or coordinating with outside organizations to complete construction projects or source specialty components. In the course of these projects, ESTEP PIs have built a stronger network of contacts within and outside the DOD and have gotten better at navigating the procedural hurdles required to bring different groups together to complete large projects. The projects under ESTEP represent not only an investment in installation energy improvements, but also an investment in the skills and capabilities of the DON workforce.

Many ESTEP projects also improved the DOD workforce by working with the California State University San Marcos Veterans to Energy Careers program.[3] This internship program recruited veterans pursuing STEM degrees and assigned them to work with PIs on ESTEP projects. The program also supported the students in other ways to aid in their transition to the workforce. As of July 2017, a total of 61 veteran student interns had participated in the program (reference Table 7; note that many of the 61 interns participated in multiple ESTEP projects). A third of student interns are still completing their degrees, and approximately 80% of those who have graduated went on to work within the DOD as either a civilian employee or contractor[4]. By partnering ESTEP projects with a successful internship program, the DON has been able to cultivate and retain the skills of our returning veterans.

By completing these ESTEP technology demonstration projects, DON S&T personnel have gained experience in navigating the process of transitioning a COTS

[3] Veteranstoenergycareers.org

[4] Intern employment numbers taken from ESTEP Workforce Development Fiscal Year 2018 proposal by Dr. Patricia Reily at California State University San Marcos

technology into a system that is actively in use at DON installations. In addition to the benefits of the technologies demonstrated, the ESTEP program has created value by providing a means for scientists and researchers to better understand the process through which future technologies will be integrated at DON installations. Even technologies that are shown not to be viable have contributed to the intellectual capital of the research communities and will help enable future technology integration efforts.

Table 7. Number of interns by ESTEP project

Project No.	Projects	Intern Count
1	Wind Powered Cooling with Thermal Storage	1
2	Uninterruptible, Renewable Augmented Building Power Circuits	N/A
3	Building Scale Compressed Air Energy System (CAES)	N/A
4	Self Contained Hydrogen to Electrical System	N/A
5	Virtual Smart Grids for Achieving Regional Net-Zero Energy Goals	5
6	Seamless Integration of GIS and Electrical Architecture Models for Smart Grids and Net-Zero Energy Goals	5
7	Real-Time Distribution Analysis for MCBP	N/A
8	Evaluation of Smart -Controllers for Distributed Energy Resources	4
9	Advance Power Electronics for PV Inverters	1
10	DC Micro-grid For Solid State Lighting	4
11	Networked Building Level Micro-grid	1
12	Cyber-SCADA Energy Capability (C-SEC): Evaluation, Development, and Demonstration	3
13	Energy Efficient Cloud Computing Evaluationand Demonstration	3
14	RFID Reading Outlets for Device-level Granularity in Building Energy Control	1
15	C-SEC On The Move	4
16	Data Center Smart Metering Evaluation (DC Smart-E)	3
17	Building Energy Management Automation	2
18	Resilient Critical Infrastructures through Secure and Efficient Micro Grids (ReCIst)	2
19	SCADA Deploy	1
20	Joint Cyber SCADA Laboratory Workforce Development (SSC PAC and UHWO)	N/A
21	Smart Plug Side Channel Analysis (SPAMSANDWICH)	4
22	ENSURE (Ensuring Reliability and Efficiency)	2
23	Hypercritical Operational Technology Mitigation of Embedded SploitSyndrome (HOTMESS)	N/A
24	Passive and Active Cyber-Defense for Cyber-Physical Systems –Strategies, Implementation, and Evaluation	1
25	Deep Subgrid-parity Solar	6
26	Energy and Water Recovery by Microbial Fuel Cells	6
27	Energy Village: A Littoral Energy Test Facility	4
28	Ad-hoc Portable Power Systems (APPS)	N/A
29	Decentralized Micro-grid with Fuel Cell Energy Storage: Feasibility Study	2
30	Optimization of a Decentralized Micro-grid with PEM Fuel Cell, Electrolyzer and H2 Storage	1
31	Mobile EMS	N/A
32	Photovoltaic Power Conditioning System for an Energy Management System (EMS)	N/A
33	RTU Challenge	N/A
34	Improved Wind Load Design for Rooftop PV Systems	N/A
35	Marine Corps Base Hawaii Energy Management Evaluation(MCBH E-Manage) Seed	N/A
36	Validate SIREN Computer Modeling	1
37	LIDAR Wind Measurement Experiments	2
38	Shroud with RF Mesh to Suppress Radar Cross-section of Small Wind Turbine	N/A
39	Liquid Air Energy Storage (LAES)	3
40	Waste to Energy Hydrogen Generation	1
41	Adhered PV Reliability (Completed)	1
42	Optimized Cooling for Concentrated Photovoltaic Systems	N/A
43	Shore Based Test of X-Band Radar Hardware on Mast for Real Time Hydrodynamic Control of Wave Energy Conversion	N/A
44	Valuation and Financing for Energy Storage	N/A
45	Transportable Micro-grid with Storage	N/A
46	Modular Micro grid (M2G) System	1
47	Wind Effects on Sun Tracking PV Cell Solar Panels	3
48	Grid Stability in High Penetration Renewables	N/A
49	NanolubricantHVAC Refrigerant	N/A
50	Tunable White LED	N/A
51	Waste Heat Recovery From Gas Turbine Exhaust	N/A
52	Efficient Implementation of Solid State Transformers (SST)	N/A
53	HVAC Control by Means of Predicted Percentage of Dissatisfied Method	2
54	Develop Energy Use Trends with Innovative Visualization/Analysis	2
55	Green Data Center Software Product Evaluation	N/A

Key: N/A – not available

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VII. ADOPTION READINESS ADVANCES

As discussed in Chapter VI, few ESTEP projects will have a positive net financial benefit if evaluated in isolation. However, the demonstrations pave the way for future adoption that can produce significant net benefits in the future. For these reasons, the progress towards resolving challenges in adopting the technology in a DON context is an important indicator of ESTEP projects' effectiveness.

Even if a new technology is proven effective in a demonstration environment, there are still significant barriers to cross before the technology can be adopted more broadly. For this reason, the Adoption Readiness Level (ARL) scale, developed as part of ESTEP (Regnier et al., 2017) is used to assess this progress.

The ARL system is an assessment used for measuring a new technology's progress from a successful conceptual demonstration to a system or process that can be readily implemented outside of the original testing or demonstration environment. ARL is different from the more well-known Technology Readiness Level (TRL) system in that TRL focuses solely on the given technology or product as an independent entity, but ARL is more focused on the non-technological challenges that must be met to integrate a mature technology. For example, a TRL assessment might reflect the developmental progress or maturity of a new type of air conditioning system, but ARL would assess the readiness of things such as the availability of a supplier for components, training programs for service technicians, and contractual mechanisms for installations.

The three major focus areas of ARL are systems-level technological integration, alignment with organizational processes, and stakeholder alignment. Systems-level technological integration relates not just to the maturity of the studied technology but its readiness to be integrated in the intended technology system, including components, software or adaptations necessary to connect it to any related systems. Alignment with organizational processes includes attaining any necessary certifications, securing funding, and procuring equipment or service contracts. Stakeholder alignment means acceptance and/or support from all stakeholder groups necessary for successful adoption. Each focus area of ARL is given a score from one to seven[5] based on a technology's progression toward adoption. A given technology's overall ARL level is equal to the lowest of its scores across the three areas. Table 8 defines each ARL level, while Table 9 gives the approximate ARL levels of each of the ESTEP projects evaluated in this report at the time of the FY17 IPR as reported by the PIs of each project.

[5] ESTEP project PIs used a seven step ARL ranking in their IPR report, where the official ARL rankings from Regnier et al is a six step scale. The ARL ranking system used by the ESTEP project PIs includes a separate ranking of "Locally Adopted" before a technology is considered "Fully Adoptable".

Table 8. ARL Definitions

ARL Level[i]		Component Technology TRL	Technology Integration	Stakeholders[ii]	Processes[iii]
1	Solution Identified	5	Potential to satisfy an existing or anticipated need more effectively than alternatives.	N/A	N/A
2	Demonstration Project Formulated	5	Research plan developed, necessary facilities identified.	Stakeholders identified. Need verified. Objectives, metrics , and demonstration plan validated by stakeholders. Funding budgeted for demonstration phase.	Approvals required for demonstration identified.
3	Prototype Validation	6	Demonstrated at representative research site. Performance documented.	Prototype performance validated by stakeholders.	Approvals required for operational use identified and documented. Testing or modification requirements documented.
4	Representative Demonstration	7	Potential for broader application documented. O&S requirements and any training requirements for O&S documented.	Pilot performance demonstrated and validated by stakeholders. O&S funding levels and personnel requirements for sustainable support in operation estimated.	Process for obtaining necessary approvals for operational use has been documented.
5	Locally Adopted	7	In operational use at at least one installation, which could be the demonstration site.	O&S funding and personnel in place and stakeholders expect to continue funding.	All approvals received for local operational use.
6	Fully Adoptable	8	In sustained operational use at at least one installation for relevant period of time.	Validated and accepted by stakeholders, including budget for procurement and ongoing O&S.	All required technical approvals have been received. Any required updates to Unified Facilities Criteria or Guide Specifications have been made or in process of being updated.

ARL Level		Component Technology TRL	Technology Integration	Stakeholders	Processes
7	Adopted	8	In operational use at multiple installations.	Training and communication programs in place.	Technology installed and in operational use.

[i] Barriers in any one domain will be enough to prevent adoption of a technology. Therefore, the ARL definitions are non-compensatory: to achieve a given ARL level, a technology must satisfy the criteria in all three domains.
[ii] Stakeholders are individuals or entities that have an ongoing interest in the technology if adopted. Commonly overlooked stakeholders include maintenance technicians, trainers, safety managers (structural, fire protection) and information technology managers.
[iii] The processes domain refers to the administrative process of obtaining the authorizations necessary to implement a project, including budgeting the project under the correct color of money, ensuring that funds will be available for operation and support (O&S), and any legal or regulatory requirements that need to be met in areas including safety, environmental, and information assurance (IA).

Table 9. ARL Levels for each project

Ref #	Project Title	Tech	Process	Stakeholder	Overall
1	Wind Powered Cooling with Thermal Storage	N/A	N/A	N/A	N/A
2	Uninterruptible, Renewable Augmented Building Power Circuits	4	4	3	3
3	Building Scale Compressed Air Energy System (CAES)	4	3	4	3
4	Self Contained Hydrogen to Electrical System	N/A	N/A	N/A	N/A
5	Virtual Smart Grids for Achieving Regional Net-Zero Energy Goals	4	5	4	4
6	Seamless Integration of GIS and Electrical Architecture Models for Smart Grids and Net-Zero Energy Goals	4	5	4	4
7	Real-Time Distribution Analysis for MCBP	4	5	4	4
8	Evaluation of Smart -Controllers for Distributed Energy Resources	6	4	4	4
9	Advance Power Electronics for PV Inverters	N/A	N/A	N/A	N/A
10	DC Micro-grid For Solid State Lighting	3	4	4	3
11	Networked Building Level Micro-grid	4	5	4	4
12	Cyber-SCADA Energy Capability (C-SEC): Evaluation, Development, and Demonstration	N/A	N/A	N/A	N/A
13	Energy Efficient Cloud Computing Evaluationand Demonstration	6	6	6	6
14	RFID Reading Outlets for Device-level Granularity in Building Energy Control	7	7	7	7
15	C-SEC On The Move	4	3	3	3
16	Data Center Smart Metering Evaluation (DC Smart-E)	N/A	N/A	N/A	N/A
17	Building Energy Management Automation	4	4	4	4
18	Resilient Critical Infrastructures through Secure and Efficient Micro Grids (ReCIst)	5	4	3	3
19	SCADA Deploy	5	4	5	5
20	Joint Cyber SCADA Laboratory Workforce Development (SSC PAC and UHWO)	3	3	3	3
21	Smart Plug Side Channel Analysis (SPAMSANDWICH)	3	3	3	3
22	ENSURE (Ensuring Reliability and Efficiency)	4	5	5	5
23	Hypercritical Operational Technology Mitigation of Embedded SploitSyndrome (HOTMESS)	3	2	2	2
24	Passive and Active Cyber-Defense for Cyber-Physical Systems –Strategies, Implementation, and Evaluation	N/A	N/A	N/A	N/A
25	Deep Subgrid-parity Solar	N/A	N/A	N/A	N/A
26	Energy and Water Recovery by Microbial Fuel Cells	3	3	3	3
27	Ad-hoc Portable Power Systems (APPS)	TRL9	TRL9	TRL9	TRL9
28	Energy Village: A Littoral Energy Test Facility	TRL7	TRL7	TRL7	TRL7
29	Decentralized Micro-grid with Fuel Cell Energy Storage: Feasibility Study	3	2	1	1
30	Optimization of a Decentralized Micro-grid with PEM Fuel Cell, Electrolyzer and H2 Storage	N/A	N/A	N/A	N/A
31	Mobile EMS	N/A	N/A	N/A	N/A
32	Photovoltaic Power Conditioning System for an Energy Management System (EMS)	3	2	2	2
33	RTU Challenge	6	6	6	6
34	Improved Wind Load Design for Rooftop PV Systems	N/A	N/A	N/A	N/A
35	Marine Corps Base Hawaii Energy Management Evaluation(MCBH E-Manage) Seed	N/A	N/A	N/A	N/A
36	Validate SIREN Computer Modeling	4	1	3	1
37	LIDAR Wind Measurement Experiments	4	1	3	1
38	Shroud with RF Mesh to Suppress Radar Cross-section of Small Wind Turbine	3	3	3	3
39	Liquid Air Energy Storage (LAES)	4	3	2	2
40	Waste to Energy Hydrogen Generation	N/A	N/A	N/A	N/A
41	Adhered PV Reliability	5	5	5	5
42	Optimized Cooling for Concentrated Photovoltaic Systems	N/A	N/A	N/A	N/A
43	Shore Based Test of X-Band Radar Hardware on Mast for Real Time Hydrodynamic Control of Wave Energy Conversion	3	1	1	1
44	Valuation and Financing for Energy Storage	3	3	1	1
45	Transportable Micro-grid with Storage	6	6	6	6
46	Modular Micro grid (M2G) System	5	4	2	2
47	Wind Effects on Sun Tracking PV Cell Solar Panels	3	3	3	3
48	Grid Stability in High Penetration Renewables	N/A	N/A	N/A	N/A
49	NanolubricantHVAC Refrigerant	6	5	6	5
50	Tunable White LED	6	7	6	6
51	Waste Heat Recovery From Gas Turbine Exhaust	2	2	2	2
52	Efficient Implementation of Solid State Transformers (SST)	3	3	4	3
53	HVAC Control by Means of Predicted Percentage of Dissatisfied Method	2	1	1	1
54	Develop Energy Use Trends with Innovative Visualization/Analysis	7	7	5	5
55	Green Data Center Software Product Evaluation	2	2	2	2

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VIII. ARL ROADBLOCKS AND RECOMMENDATIONS

Consistent with the goals of the program, most of the demonstrated ESTEP technologies progress from ARL 1-2 to ARL 3-5 and few achieve the level of fully adopted (ARL 6). During research for this report, it became apparent that there were a few particular challenges that PIs frequently faced in their technology demonstration efforts. These frequently occurring roadblocks are described in the following paragraphs, along with our recommendations to help future PIs to navigate these challenges in future projects.

Common roadblocks related to systems-level technological integration typically involved pushing the limits of commercial technology solutions or using a technology in ways outside of its intended purpose. For example, in the Virtual Smart Grid projects at Camp Pendleton, the researchers used a commercial software tool to model portions of the base's electrical grid. The size and complexity of their model revealed a number of previously undiscovered bugs in the modeling software, and the research team worked extensively with the software vendor's support team to patch the software as new bugs were discovered. In the supercapacitor-based microgrid project at the Naval Postgraduate School, the research team found that there were not any readily available solar charge controllers or power inverters designed to work with supercapacitors as the primary means of energy storage. The research team was able to make the supercapacitor bank work with charge controllers and inverters designed for use with conventional batteries, but the battery protection mechanisms built into these devices placed an artificial limit on the amount of energy storage available from the supercapacitors. In several projects using smart outlets or point-of-use energy monitors, researchers encountered difficulties related to data transfer protocols and lack of access to technical documents or hardware specifications on vendors' products. As in the other projects mentioned above, this required researchers to spend extra time and resources to make a mature commercial technology function in an unexpected context.

To push through challenges related to systems-level technological integration, we recommend future researchers work to improve communication with technology providers to anticipate potential issues and find workarounds as problems arise.

Roadblocks related to systems-level technological integration were often the result of using a mature commercial technology in a way that was slightly outside of the technology's intended scope, so discussing projects with potential technology suppliers could help determine which commercial products would be the best fit for particular applications. When unexpected challenges appear, technology suppliers may be able to help identify solutions because they have access to proprietary documentation and source code.

Common roadblocks related to organizational process alignment were typically a result of delays in the bureaucracy such as when working with contracting or when getting special permitting or approvals. These types of issues would typically arise when researchers were unfamiliar with the types of approvals required to conduct certain work or when working with contracting offices to license technology or hire workers. In several instances, researchers had originally planned to install new technologies or components themselves but later learned that institutional processes required that installations be performed by facilities managers or outside contractors, resulting in significant delays. In many cases, researchers had difficulty determining which office or organization was responsible for approving certain types of work. In many projects, researchers were also plagued by process challenges beyond their control such as funding arriving late or delays in transferring funds to contractors or vendors, delays in the procurement, contracting, or permitting processes, or temporary rules preventing them from or delaying hiring personnel to work on a project. The most common symptoms of process challenges were delays that forced projects to reduce the scope of their work or extend the work into the next fiscal year.

In many instances, researchers encountered difficulties working within established processes because of a lack of familiarity with those processes and uncertainty regarding which processes or policies applied to different types of work. Research teams who were more familiar with existing policies (and knew contacts who could help navigate these processes), were generally more successful in completing their projects on time, and within the full scope of the original project description. In the supercapacitor microgrid project for example, the researchers knew that the installation and approval process would be managed by their installation's Public Works department, so the team made great efforts to keep public works involved or informed at every step of the system design and planning process. We believe future research teams can be more successful in avoiding unnecessary procedural delays by socializing their projects within their organization to gather input from individuals who might be more familiar with applicable process and approval requirements. These would include stakeholders such as Public Works, safety officers, contracting offices, or utility managers on bases.

Common roadblocks related to stakeholder alignment were typically associated with not carefully coordinating with groups who would be responsible for installing and maintaining equipment or ensuring compliance with applicable policies or regulations. These stakeholder engagement issues were especially persistent in projects related to cybersecurity or energy monitoring where research teams needed stakeholder buy-in to test emerging technologies on live power systems or networks. In many of these cases, the personnel who maintained or managed these systems were reluctant to allow researchers to connect new monitoring systems or probing technologies because they did not fully understand the potential risks and benefits of the technologies being researched. In other cases, research projects were held back due to unexpected challenges in coordinating with stakeholder groups who managed facilities, equipment, technologies, or utilities used in various research efforts. Like the challenges associated with processes, many of these stakeholder roadblocks resulted in delays as different groups struggled to coordinate schedules or establish that intended work was compliant with all applicable rules and requirements.

Like the process alignment challenges mentioned above, many stakeholder alignment issues could potentially be reduced, resolved, or prevented early on by socializing new or upcoming projects with potential stakeholder communities so that stakeholders can offer their input as early as possible. This would also provide researchers with realistic expectations for how quickly things move through the processes controlled by different organizations, allowing researchers to plan for these delays when defining a scope or timeline for their projects. This can help to set scheduling expectations for groups with limited manpower to assist projects and allow researchers to benefit from the institutional knowledge of stakeholders who are more familiar with the processes with their specific sub-organizations.

These organizational process and stakeholder roadblocks demonstrate why workforce development is so important to advancing the use of emerging energy technology in the DON. This reinforces the value of ESTEP program’s emphasis on DON personnel serving in key roles.

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IX. FINAL NOTES

The ESTEP program provides a significant benefit to the DON in future energy assurance. ESTEP is cultivating a knowledge base and workforce with the skills and experience to implement future energy technologies that improve the DON's capability to ensure the availability of critical energy resources. Although many of the ESTEP projects will not provide a significant operational or monetary benefit in the near term, the skills and experience gained in implementing new technologies will pay dividends as researchers determine which technologies merit further investment and overcome the challenges of implementing these technologies in a DON environment.

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APPENDIX A. DISTRIBUTION OF ESTEP PROJECTS BY BENEFIT SUB-CATEGORY

Figure A-1. Breakdown of ESTEP projects' contribution to introduce/integrate new energy generation

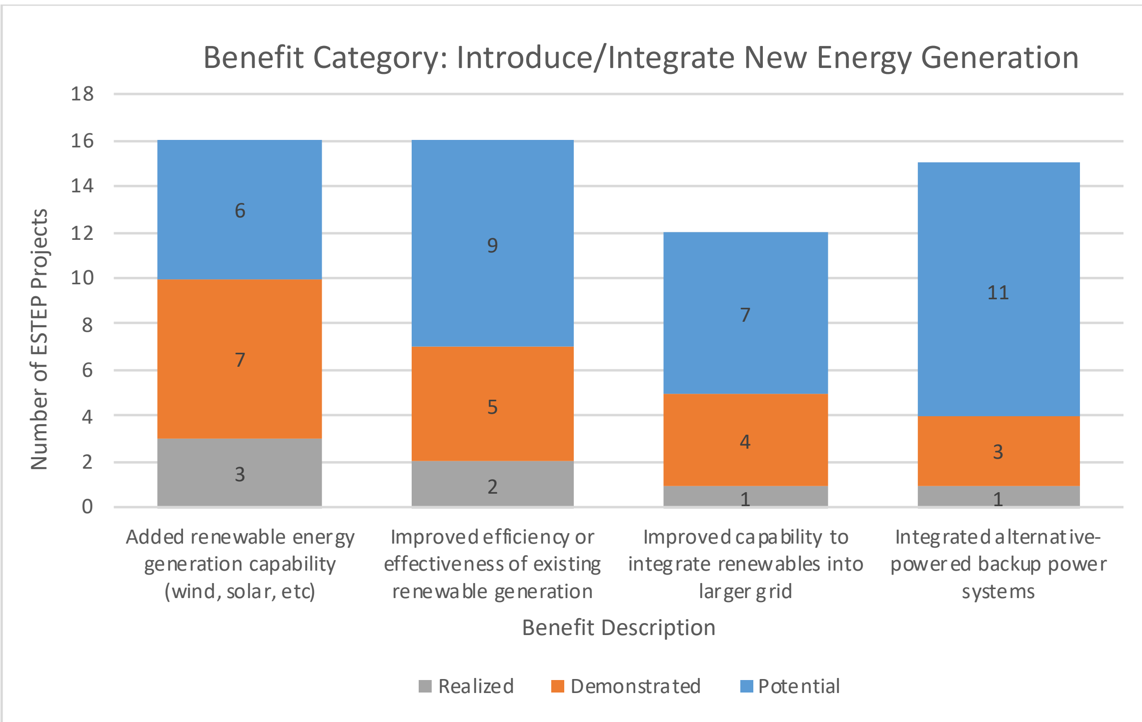


Figure A-2. Breakdown of ESTEP projects' contribution to introduce/integrate new energy storage

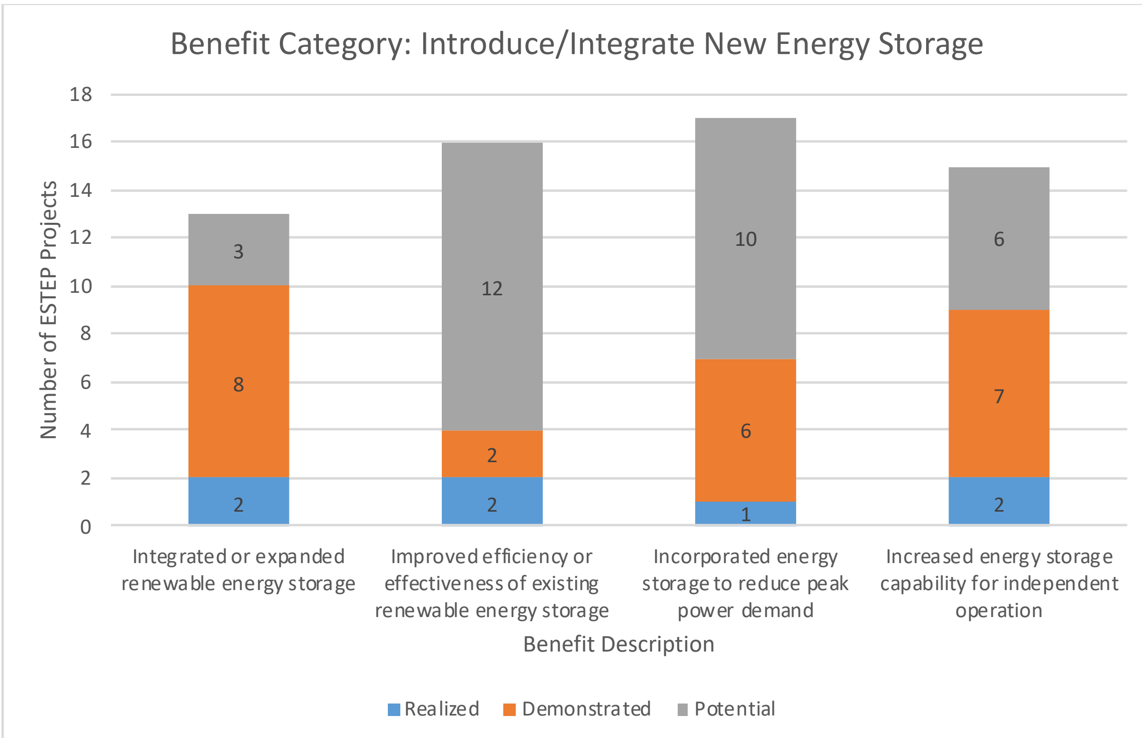


Figure A-3. Breakdown of ESTEP projects' contribution to reduce energy demand on bases

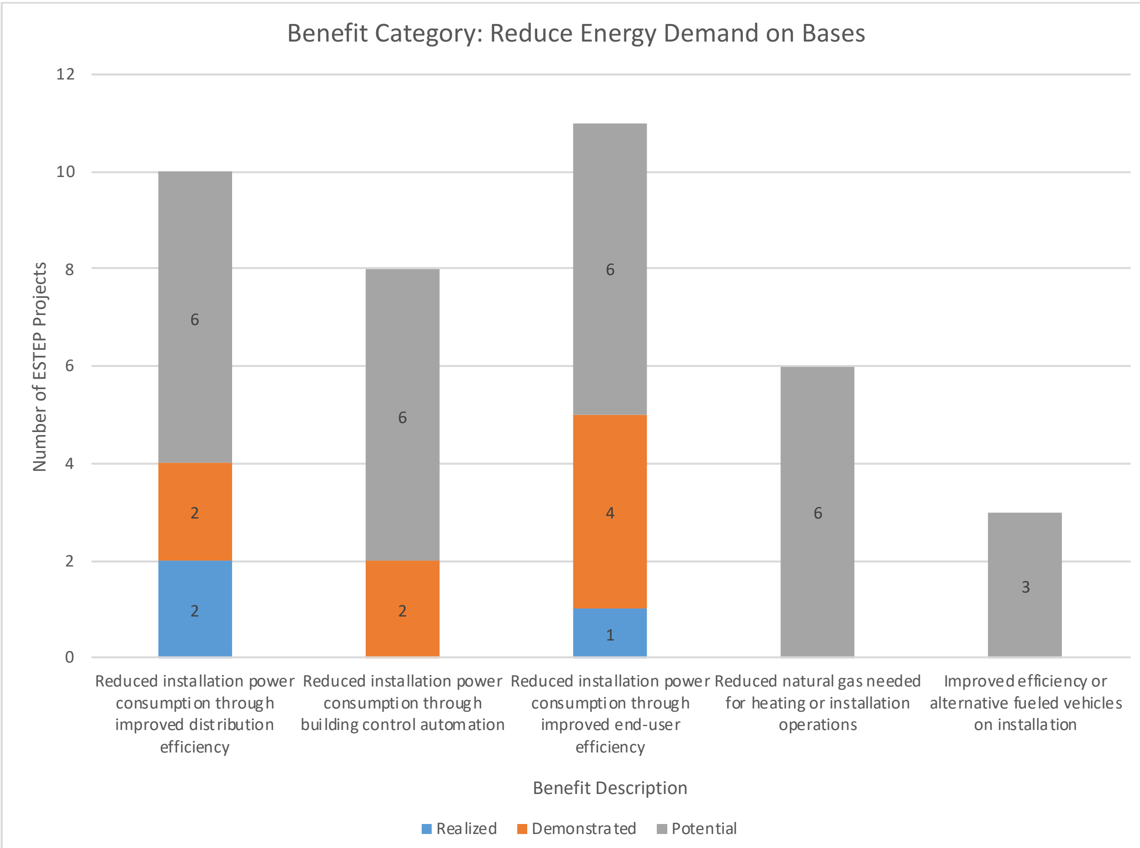


Figure A-4. Breakdown of ESTEP projects' contribution to reduced O&S requirements

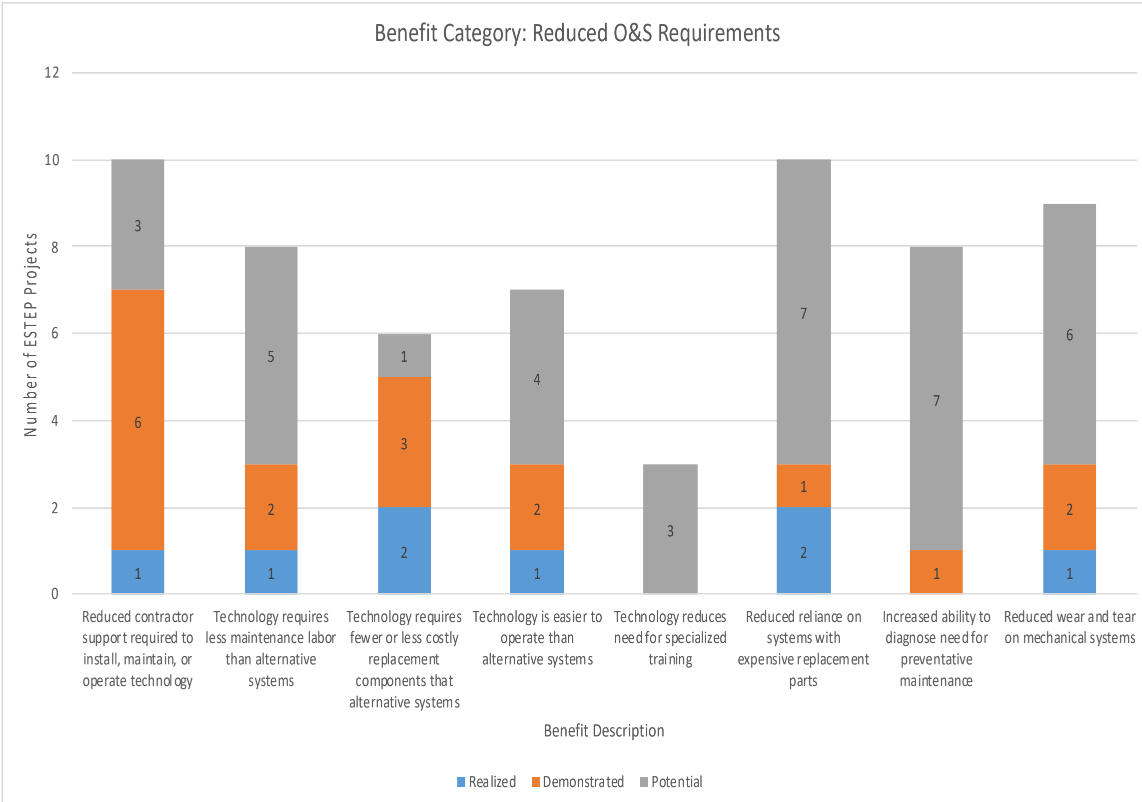


Figure A-5. Breakdown of ESTEP projects' contribution to physical or cyber security, resiliency, redundancy

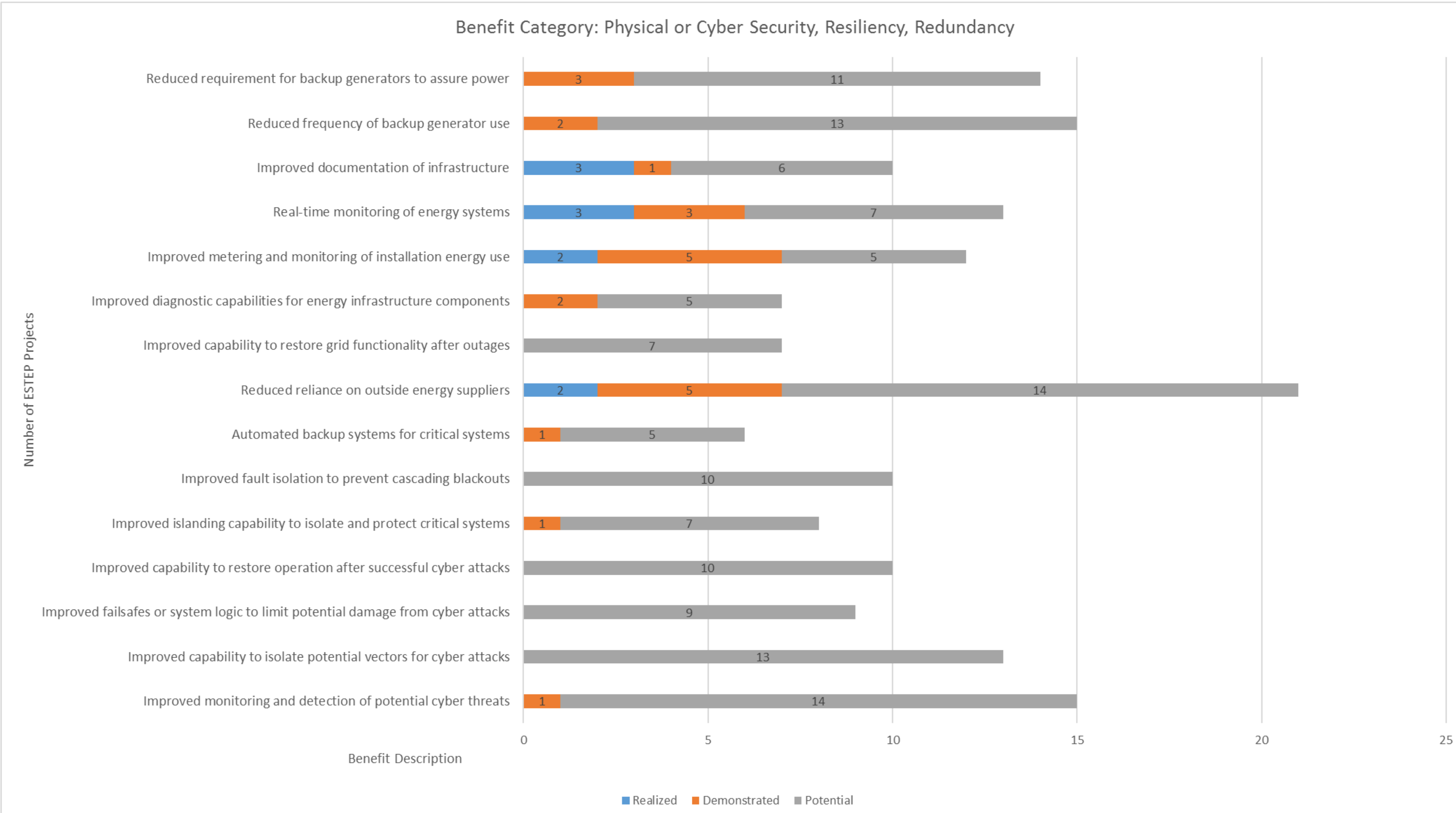


Figure A-6. Breakdown of ESTEP projects' contribution to improved modeling or decision support

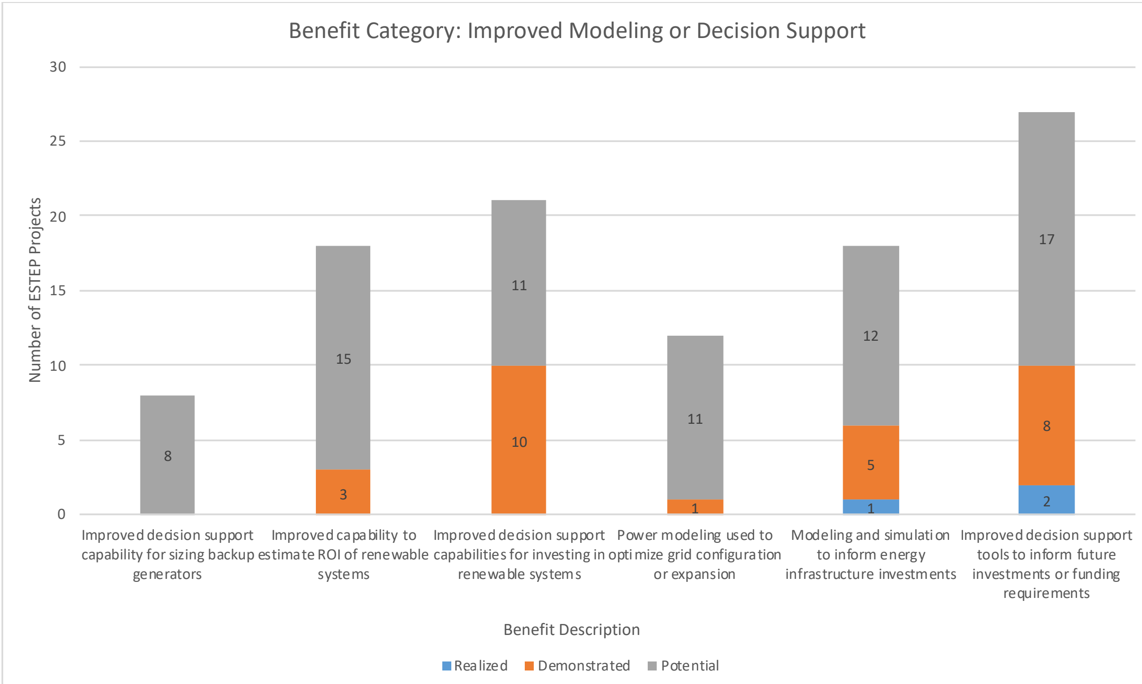
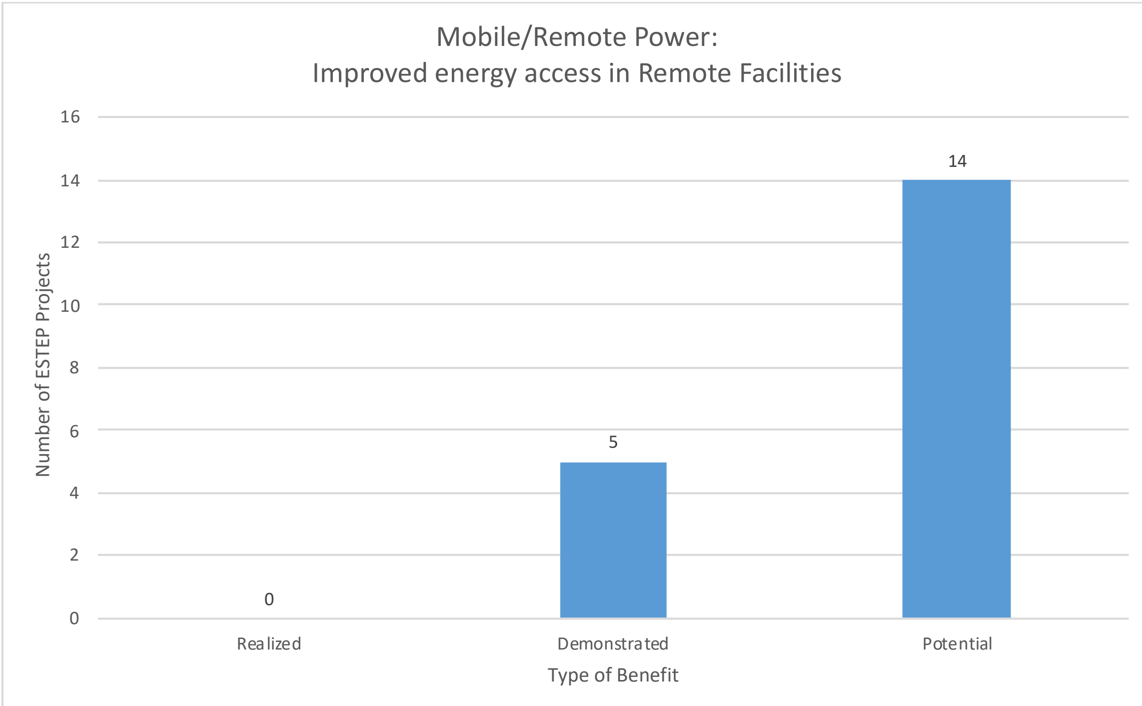


Figure A-7. Breakdown of ESTEP projects' contribution to improved energy access in remote facilities



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APPENDIX B. PROJECT INFORMATION FORMS

B.1 Project Information Form for Project 1: Wind Powered Cooling with Thermal Storage

Wind Powered Cooling with Thermal Storage

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Anthony Gannon	831-656-2880	ajgannon@nps.edu	PI
POC2				
POC3				

Period of Performance: FY13 --- FY14

Base / Installation: NPS

Technology Description

Provide a brief description of the technology being implemented in this research project

Integrate systems composed of wind turbine, chiller units, and ice-based thermal storage units to reduce the cost of cooling data centers and facilities where significant energy expenditures would go towards cooling

Select up to three different technology types to categorize this project

Technology Type 1	Energy Storage
Technology Type 2	
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

reduced cost of energy storage at facilities with large cooling demands

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Realized	Added renewable energy generation capability (wind, solar, etc)
Realized	Improved efficiency or effectiveness of existing renewable generation
Realized	Integrated or expanded renewable energy storage
Realized	Improved efficiency or effectiveness of existing renewable energy storage

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Demonstrate	Reduced installation power consumption through improved end-user efficiency
Demonstrate	Incorporated energy storage to reduce peak power demand

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Potential	Reduced contractor support required to install, maintain, or operate technology
Demonstrate	Technology requires fewer or less costly replacement components that alternative systems
Demonstrate	Technology is easier to operate than alternative systems

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems	

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure	

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above	
Potential	Reduced reliance on systems with expensive replacement parts
Potential	Reduced wear and tear on mechanical systems

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?	
What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?	
What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?	

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Reduced cost of energy storage by storing energy in the form in which it will be used later

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

reduced cost of energy storage for cooling applications, limited/no capability to use stored energy in other ways

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	
Environmental or Installation-specific challenges	technology only applicable at facilities with significant cooling needs
Accessibility of required components	

Process Challenges

Certification or Approval requirements	
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	
Contracting / Procurement	

Stakeholder Challenges

Impact on and Approval of certain stakeholders	coordination with public works required to install renewable energy sources and chillers
Limitations from stakeholder needs	
Operation and support labor requirements	
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B.2 Project Information Form for Project 2: Uninterruptible, Renewable Augmented Building Power Circuits

Uninterruptible, Renewable Augmented Building Power Circuits

Other Names, Abriviations, etc: Supercapacitor Based Microgrid for Renewable Augmented Circuits

Contacts	Name	Phone	Email	Role
POC1	Anthony Gannon	831-656-2880	ajgannon@nps.edu	PI
POC2	Andria Holmes			Co-PI
POC3	Alexander Julian			Co-PI

Period of Performance: FY15 --- FY17

Base / Installation: NPS

Technology Description

Provide a brief description of the technology being implemented in this research project

Microgrid that uses supercapacitors instead of conventional battery storage to store energy from renewable sources, integrating renewable energy into backup systems

Select up to three different technology types to categorize this project

Technology Type 1	Microgrids, Islanding, Isolation
Technology Type 2	Energy Storage
Technology Type 3	Implementation, Integration, Adaptation

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Microgrids using supercapacitors are able to avoid many of the difficulties associated with battery storage such as restrictions on the use of lithium batteries or battery capacity degradation

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Realized	Integrated alternative-powered backup power systems
Potential	Reduced frequency of backup generator use
Demonstrate	Reduced requirement for backup generators to assure power

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Realized	Integrated or expanded renewable energy storage
Realized	Improved efficiency or effectiveness of existing renewable energy storage
Potential	Improved capability to estimate ROI of renewable systems
Demonstrate	Improved decision support capabilities for investing in renewable systems

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Demonstrate	Reduced installation power consumption through building control automation
Demonstrate	Incorporated energy storage to reduce peak power demand

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Demonstrate	Reduced contractor support required to install, maintain, or operate technology
Realized	Technology requires less maintenance labor than alternative systems
Realized	Technology requires fewer or less costly replacement components that alternative systems
Realized	Technology is easier to operate than alternative systems

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Realized	Reduced reliance on outside energy suppliers
Realized	Increased energy storage capability for independent operation

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Realized	Reduced reliance on systems with expensive replacement parts

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

Potential	Improved energy access in remote facilities

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Potential	Improved access to energy use data

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Learning process of discovering how to use super capacitors for building-scale energy storage while using components designed to work with battery systems

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

equipment designed to work with batteries would not allow full discharge of capacitors, limiting effective energy storage

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Demonstrated feasibility of using supercapacitors in microgrids, enabling microgrid technologies to be implemented in environments that would preclude battery-based energy storage

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

System would benefit from power electronics designed to make full use of capacitors' stored energy

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

More expensive than battery storage in terms of upfront cost, but supercapacitors would never need replaced like batteries would. Supercapacitors can also be transported with zero charge, which would enable construction of microgrids in austere environments

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

Demonstrated feasibility of large scale supercapacitor energy storage

What new skills, competencies, or experience were gained within the Navy workforce during this project?

experience working with supercapacitors in novel applications

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Maturity of supercapacitor market would lower costs, enabling further implementation
Maturity/suitability of specific systems used in this project	Power electronics designed to work with batteries, so protective features limit energy storage potential
Integration with Navy-specific systems	
Environmental or Installation-specific challenges	Supercapacitor energy density (KWH per unit volume) is less than that of batteries, which would limit their use in certain applications
Accessibility of required components	Market for backup power systems using supercapacitors has not yet fully matured

Process Challenges

Certification or Approval requirements	PW approval to integrate new power systems
Initial Funding or Resource Allocation issues	high upfront cost
Continued Funding or Resource Allocation issues	
Contracting / Procurement	Currently no commercial providers of supercapacitor-based microgrid systems

Stakeholder Challenges

Impact on and Approval of certain stakeholders	
Limitations from stakeholder needs	Limited storage capacity may not meet demand
Operation and support labor requirements	
Necessary Funding Streams: Integration	large upfront costs compared to comperable battery systems
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	Control optimization needed to improve system utilization

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)
Gabriel Hernandez	

B.3 Project Information Form for Project 3: Building Scale Compressed Air Energy System (CAES)

Building Scale Compressed Air Energy System (CAES)

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Anthony Gannon	831-656-2880	ajgannon@nps.edu	PI
POC2	Andrea Holmes			
POC3				

Period of Performance: FY16 --- FY17

Base / Installation:

Technology Description

Provide a brief description of the technology being implemented in this research project

Construct a building-scale system using excess renewable generation to compress and store air for later energy generation

Select up to three different technology types to categorize this project

Technology Type 1	Energy Storage
Technology Type 2	Microgrids, Islanding, Isolation
Technology Type 3	Implementation, Integration, Adaptation

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Provides robust and cost-effective energy storage without the use of chemical batteries or other components subject to degradation or special handling concerns

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Integrated alternative-powered backup power systems
Potential	Reduced frequency of backup generator use
Potential	Reduced requirement for backup generators to assure power

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Demonstrate	Integrated or expanded renewable energy storage
Demonstrate	Improved efficiency or effectiveness of existing renewable energy storage

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Potential	Incorporated energy storage to reduce peak power demand

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Demonstrate	Technology requires fewer or less costly replacement components that alternative systems
Demonstrate	Technology is easier to operate than alternative systems

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems	
Potential	Automated backup systems for critical systems
Potential	Reduced reliance on outside energy suppliers
Demonstrate	Increased energy storage capability for independent operation

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure	

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above	
Potential	Reduced reliance on systems with expensive replacement parts

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?	
Potential	Improved energy access in remote facilities
What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?	
What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?	
Potential	Improved control capabilities for future experiments

Other

	Compressed air can be used in systems such as wind tunnels or pneumatic tools

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

No small-scale compressed air generators commercially available, required integrating technology from different industries. Small scale generator design required more detailed design than anticipated

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

Lengthy process of designing generator and acquiring components

What would you describe as the greatest benefit(s) of having completed this demonstration project?

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	No small-scale compressed air generators commercially available
Maturity/suitability of specific systems used in this project	generator design optimization still a work in progress
Integration with Navy-specific systems	
Environmental or Installation-specific challenges	
Accessibility of required components	System requires integrating components from different industries in a novel configuration

Process Challenges

Certification or Approval requirements	Approval required for installation of components and integration with building wiring
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	
Contracting / Procurement	System will require contracting/procurement process to source components

Stakeholder Challenges

Impact on and Approval of certain stakeholders	Approval required to install CAES system
Limitations from stakeholder needs	
Operation and support labor requirements	Operation and maintenance considerations
Necessary Funding Streams: Integration	Integration with other renewable systems may require specialized training
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)
LT Thomas Prinsen	Renewable Powered Compressor System Design
LT Cory McLaughlin	Small Scale Air Driven Demonstation Generator
LT Joshua Williams	Control System Design for Renewable Powered Compression System
LT Todd Vranas	Small Scale Air Driven Generator Control System
LT Nathaniel Pelletier	Ejector Based Small-Scale Air Generator
Michael Souza	Generator Demonstration Unit Design and Build

B.4 Project Information Form for Project 4: Self Contained Hydrogen to Electrical System

HYDROGEN IN AMBIENT AIR AS A RENEWABLE ENERGY SOURCE

Other Names, Abriviations, etc: Self Contained Hydrogen to Electrical System

Contacts	Name	Phone	Email	Role
POC1	Garth Hobson	831-656-2165	gvhobson@nps.edu	PI
POC2	Andrea Holmes			Co-PI
POC3				

Period of Performance: FY17 --- FY18

Base / Installation: NPS

Technology Description

Provide a brief description of the technology being implemented in this research project

Small scale hydrogen collection from water in ambient air to power fuel cells and provide potable water

Select up to three different technology types to categorize this project

Technology Type 1	Renewable Generation
Technology Type 2	Energy Storage
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

enable energy storage from renewable systems in the form of hydrogen fuel cells or stored hydrogen gas for use in other applications

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Improved efficiency or alternative fueled vehicles on installation

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Demonstrate	Integrated or expanded renewable energy storage
Potential	Improved efficiency or effectiveness of existing renewable energy storage

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Potential	Incorporated energy storage to reduce peak power demand

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Reduced reliance on outside energy suppliers
Potential	Increased energy storage capability for independent operation

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

Potential	Improved energy access in remote facilities

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

H2 pressure in fuel cell, scalability challenges, consistency of H2 flow, storage, and compression

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

System required continous reconfiguration to address emergent issues

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Mature system would enable remote facil

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Need capability to assess suitability of system in different environments

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

Improved energy storage capability and potential to generate potable water in austere environments

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?
Progress to TRL 7

What new skills, competencies, or experience were gained within the Navy workforce during this project?
Familiarity with H2 systems and integrating solar energy in small-scale applications

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Technology remains to be proven functional on a large enough scale to be particularly useful
Maturity/suitability of specific systems used in this project	system custom made from mature components, but not yet optimized as a system
Integration with Navy-specific systems	need to comply with compressed gas storage regs
Environmental or Installation-specific challenges	System would be less effective in arid environments
Accessibility of required components	system is custom-built from COTS components

Process Challenges

Certification or Approval requirements	approval for compressed H2 storage and solar integration
Initial Funding or Resource Allocation issues	acquisition costs and installation costs for energy source
Continued Funding or Resource Allocation issues	periodic maintenance
Contracting / Procurement	

Stakeholder Challenges

Impact on and Approval of certain stakeholders	possible noise considerations
Limitations from stakeholder needs	
Operation and support labor requirements	
Necessary Funding Streams: Integration	component installation
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)
LCDR Ed Fosson	
LT San Yu	
LT Angel Aviles	Renewable Production of Water, Hydrogen and Power from Ambient Moisture

B.5 Project Information Form for Project 5: Virtual Smart Grids for Achieving Models for Smart Grids and Net-Zero Energy Goals

Virtual Smart Grids for Achieving Regional Net-Zero Energy Goals

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Eric Evans	619-553-2808	eric.evans@navy.mil	PI
POC2	Ron Gauthier	619-553-1597		
POC3				

Period of Performance: FY15 --- FY17

Base / Installation: MCBP

Technology Description

Provide a brief description of the technology being implemented in this research project

Develop a virtual smart grid to manage and achieve net-zero energy goals at the regional scale Demonstrate the system in collaboration with Marine Corps Installation West (MCI West) capability as a smart customer in achieving energy independence and net-zero compliance

Select up to three different technology types to categorize this project

Technology Type 1	Modeling, Optimization, Decision Support
Technology Type 2	Management, Monitoring
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Improved capability to model and plan power grid expansions and improve distribution efficiency

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Improved decision support capability for sizing backup generators

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Potential	Improved efficiency or effectiveness of existing renewable generation
Potential	Improved efficiency or effectiveness of existing renewable energy storage
Potential	Improved capability to estimate ROI of renewable systems
Potential	Improved decision support capabilities for investing in renewable systems

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Realized	Reduced installation power consumption through improved distribution efficiency

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Potential	Power modeling used to optimize grid configuration or expansion
Demonstrate	Improved metering and monitoring of installation energy use
Demonstrate	Improved diagnostic capabilities for energy infrastructure components
Realized	Modeling and simulation to inform energy infrastructure investments

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Improved fault isolation to prevent cascading blackouts
Potential	Improved islanding capability to isolate and protect critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Potential	Improved monitoring and detection of potential cyber threats
Potential	Improved capability to isolate potential vectors for cyber attacks

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Demonstrate	Increased ability to diagnose need for preventative maintenance
Realized	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

Realized	Improved documentation of infrastructure
Potential	Real-time monitoring of energy systems

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Demonstrate	Improved access to energy use data
Potential	Improved control capabilities for future experiments

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

ETAP software not yet fully mature for applications of this scale, original power grid documentation did not match actual systems

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

research team worked with software developers to identify bugs within ETAP, research team had to devote extra time to updating or correcting grid documentation

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Improved documentation of grid infrastructure and identifying areas for improvement in documentation practices

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

grid modeling software needs to become fully mature

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

software models of power infrastructure would make it easier to keep documentation up to date and to model the impact of future grid projects

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?
identified key shortcomings in documentation practices and discovered (and corrected) inefficiencies in power distribution network that provide cost savings greater than the cost of VSG modeling costs

What new skills, competencies, or experience were gained within the Navy workforce during this project?
Hired ESTEP intern Alan Williams to continue work at MCBP

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Grid modeling software is not fully mature
Maturity/suitability of specific systems used in this project	ETAP software is not fully mature
Integration with Navy-specific systems	Specific navy-specific systems may require coordination with software developers to model accurately
Environmental or Installation-specific challenges	Each naval installation will require a custom model
Accessibility of required components	limited number of software vendors

Process Challenges

Certification or Approval requirements	software licensing and support agreements
Initial Funding or Resource Allocation issues	funding for software and labor to construct installation model
Continued Funding or Resource Allocation issues	funding required labor to keep model up to date
Contracting / Procurement	software continued support contract

Stakeholder Challenges

Impact on and Approval of certain stakeholders	Requires coordination with maintenance and public works to construct software models accurate to actual power infrastructure
Limitations from stakeholder needs	
Operation and support labor requirements	Labor needed to keep model up to date, requires coordination between modelers and facilities personnel conducting maintenance
Necessary Funding Streams: Integration	funding for labor
Necessary Funding Streams: Continued Support	funding for labor
Continued feedback and improvement	feedback process needed to ensure model reflects changes and behavior of grid

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Alan Williams		

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B.6 Project Information Form for Project 6: Seamless Integration of GIS and Electrical Architecture Models for Smart Grids and Net-Zero Energy Goals

Seamless Integration of GIS and Electrical Architecture Models for Smart Grids and Net-Zero Energy Goals

Other Names, Abriviations, etc: ETAP Virtual Smart Grid: Real-Time Power Monitoring in a Geospatial Environment

Contacts	Name	Phone	Email	Role
POC1	Eric Evans	619-553-2808	eric.evans@navy.mil	PI
POC2	Alan Williams			
POC3				

Period of Performance: ---

Base / Installation: MCBP Camp Pendleton

Technology Description

Provide a brief description of the technology being implemented in this research project

Integrate geospatial data and real-time monitoring into virtual smart grid system

Select up to three different technology types to categorize this project

Technology Type 1	Management, Monitoring
Technology Type 2	Modeling, Optimization, Decision Support
Technology Type 3	Cyber & Physical Security

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Improved documentation of base power architecture and ability to identify or diagnose issues in real-time

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use	
Potential	Improved decision support capability for sizing backup generators
Potential	Reduced requirement for backup generators to assure power

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management	
Potential	Improved capability to integrate renewables into larger grid
Potential	Improved capability to estimate ROI of renewable systems
Demonstrate	Improved decision support capabilities for investing in renewable systems
Demonstrate	Improved efficiency or effectiveness of existing renewable energy storage

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption	
Demonstrate	Reduced installation power consumption through improved distribution efficiency
Potential	Reduced installation power consumption through improved end-user efficiency
Potential	Reduced installation power consumption through building control automation

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions	
Potential	Power modeling used to optimize grid configuration or expansion
Demonstrate	Improved metering and monitoring of installation energy use
Potential	Improved diagnostic capabilities for energy infrastructure components
Demonstrate	Modeling and simulation to inform energy infrastructure investments

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Realized	Reduced contractor support required to install, maintain, or operate technology
Potential	Technology is easier to operate than alternative systems

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Improved fault isolation to prevent cascading blackouts
Potential	Automated backup systems for critical systems
Potential	Improved capability to restore grid functionality after outages

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Potential	Improved monitoring and detection of potential cyber threats
Potential	Improved capability to isolate potential vectors for cyber attacks
Potential	Improved capability to restore operation after successful cyber attacks

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Potential	Increased ability to diagnose need for preventative maintenance
Potential	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

Realized	Real-time monitoring of energy systems
Realized	Improved documentation of infrastructure

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Difficulty translating existing grid documentation into computer model due to inaccuracies or inconsistencies in original documents; power modeling and monitoring software still in its infancy; existing architecture was not able to transmit live usage data

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

PIs had to survey existing power architecture to verify or correct records before entering into software model; PIs had to work with software developers to troubleshoot issues from immature software; models used recorded logs instead of real-time data

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Improved documentation of power grid and related utilities will make future repairs or upgrades easier. Monitoring capabilities allow energy managers to identify potential problems and efficiency improvements to reduce maintenance or ownership costs.

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Software needs to fully mature in order to be implemented on additional installations. A specific contract mechanism would be required to ensure a sustainable and suitable arrangement between naval facilities and software providers to ensure support

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?
electronic utility monitoring and documentation would improve energy and facility managers' abilities to address maintenance issues, improve efficiencies, and identify potential vulnerabilities
What advances or observations were made in this demonstration project that could help justify continued investment in this technology?
Current infrastructure documentation methods were shown to be woefully unreliable, and real-time monitoring reveild possible corrections that would drastically reduce facility operating costs
What new skills, competencies, or experience were gained within the Navy workforce during this project?
ESTEP researchers gained skills and experience relating to documenting power infrastructure, developing software models, and improving grid efficiency

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Few software vendors available with products that are not yet fully mature or suitable to the DOD's needs
Maturity/suitability of specific systems used in this project	Few software vendors available with products that are not yet fully mature or suitable to the DOD's needs
Integration with Navy-specific systems	Special agreements needed to sustain software support with vendor and interact with utility provider
Environmental or Installation-specific challenges	Certain facilities may have limitations on sensitivity of energy usage data or ability to transmit data
Accessibility of required components	Software is available, but would require a continued support arrangement

Process Challenges

Certification or Approval requirements	Various cyber requirements for transmitting energy usage data
Initial Funding or Resource Allocation issues	Large initial manpower investment required to build database/model
Continued Funding or Resource Allocation issues	Continual effort needed to update and ensure accuracy of database/model
Contracting / Procurement	Contracts will be required to ensure a sustained support arrangement with software provider

Stakeholder Challenges

Impact on and Approval of certain stakeholders	Requires buy-in and cooperation of facilities and PW personnel to gather documentation and build power system models
Limitations from stakeholder needs	certain energy usage data may be considered sensitve, utility providers may place certain limitations
Operation and support labor requirements	labor required to maintain database/model
Necessary Funding Streams: Integration	large initial cost to develop database/model
Necessary Funding Streams: Continued Support	upkeep required
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Alex Arguelles		
Andrew Grewe		
Ammar Ameen		
Bashar Ameen		
Ankit Panchal		

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B.7 Project Information Form for Project 7: Real-Time Distribution Analysis for MCBP

Seamless Integration of GIS and Electrical Architecture Models for Smart Grids and Net-Zero Energy Goals

Other Names, Abriviations, etc: ETAP Virtual Smart Grid: Real-Time Power Monitoring in a Geospatial Environment

Contacts	Name	Phone	Email	Role
POC1	Eric Evans	619-553-2808	eric.evans@navy.mil	PI
POC2	Alan Williams			
POC3				

Period of Performance: ---

Base / Installation: MCBP Camp Pendleton

Technology Description

Provide a brief description of the technology being implemented in this research project

Integrate geospacial data and real-time monitoring into virtual smart grid system

Select up to three different technology types to categorize this project

Technology Type 1	Management, Monitoring
Technology Type 2	Modeling, Optimization, Decision Support
Technology Type 3	Cyber & Physical Security

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Improved documentation of base power architecture and ability to identify or diagnose issues in real-time

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use	
Potential	Improved decision support capability for sizing backup generators
Potential	Reduced requirement for backup generators to assure power

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management	
Potential	Improved capability to integrate renewables into larger grid
Potential	Improved capability to estimate ROI of renewable systems
Demonstrate	Improved decision support capabilities for investing in renewable systems
Demonstrate	Improved efficiency or effectiveness of existing renewable energy storage

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption	
Demonstrate	Reduced installation power consumption through improved distribution efficiency
Potential	Reduced installation power consumption through improved end-user efficiency
Potential	Reduced installation power consumption through building control automation

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions	
Potential	Power modeling used to optimize grid configuration or expansion
Demonstrate	Improved metering and monitoring of installation energy use
Potential	Improved diagnostic capabilities for energy infrastructure components
Demonstrate	Modeling and simulation to inform energy infrastructure investments

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.	
Realized	Reduced contractor support required to install, maintain, or operate technology
Potential	Technology is easier to operate than alternative systems

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems	
Potential	Improved fault isolation to prevent cascading blackouts
Potential	Automated backup systems for critical systems
Potential	Improved capability to restore grid functionality after outages

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure	
Potential	Improved monitoring and detection of potential cyber threats
Potential	Improved capability to isolate potential vectors for cyber attacks
Potential	Improved capability to restore operation after successful cyber attacks

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above	
Potential	Increased ability to diagnose need for preventative maintenance
Potential	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?	
What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?	
Realized	Real-time monitoring of energy systems
Realized	Improved documentation of infrastructure
What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?	

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Difficulty translating existing grid documentation into computer model due to inaccuracies or inconsistencies in original documents; power modeling and monitoring software still in its infancy; existing architecture was not able to transmit live usage data

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

PIs had to survey existing power architecture to verify or correct records before entering into software model; PIs had to work with software developers to troubleshoot issues from immature software; models used recorded logs instead of real-time data

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Improved documentation of power grid and related utilities will make future repairs or upgrades easier. Monitoring capabilities allow energy managers to identify potential problems and efficiency improvements to reduce maintenance or ownership costs.

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Software needs to fully mature in order to be implemented on additional installations. A specific contract mechanism would be required to ensure a sustainable and suitable arrangement between naval facilities and software providers to ensure support

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

electronic utility monitoring and documentation would improve energy and facility managers' abilities to address maintenance issues, improve efficiencies, and identify potential vulnerabilities

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

Current infrastructure documentation methods were shown to be woefully unreliable, and real-time monitoring reveild possible corrections that would drastically reduce facility operating costs

What new skills, competencies, or experience were gained within the Navy workforce during this project?

ESTEP researchers gained skills and experience relating to documenting power infrastructure, developing software models, and improving grid efficiency

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Few software vendors available with products that are not yet fully mature or suitable to the DOD's needs
Maturity/suitability of specific systems used in this project	Few software vendors available with products that are not yet fully mature or suitable to the DOD's needs
Integration with Navy-specific systems	Special agreements needed to sustain software support with vendor and interact with utility provider
Environmental or Installation-specific challenges	Certain facilities may have limitations on sensitivity of energy usage data or ability to transmit data
Accessibility of required components	Software is available, but would require a continued support arrangement

Process Challenges

Certification or Approval requirements	Various cyber requirements for transmitting energy usage data
Initial Funding or Resource Allocation issues	Large initial manpower investment required to build database/model
Continued Funding or Resource Allocation issues	Continual effort needed to update and ensure accuracy of database/model
Contracting / Procurement	Contracts will be required to ensure a sustained support arrangement with software provider

Stakeholder Challenges

Impact on and Approval of certain stakeholders	Requires buy-in and cooperation of facilities and PW personnel to gather documentation and build power system models
Limitations from stakeholder needs	certain energy usage data may be considered sensitve, utility providers may place certain limitations
Operation and support labor requirements	labor required to maintain database/model
Necessary Funding Streams: Integration	large initial cost to develop database/model
Necessary Funding Streams: Continued Support	upkeep required
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Alex Arguelles		
Andrew Grewe		
Ammar Ameen		
Bashar Ameen		
Ankit Panchal		

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B.8 Project Information Form for Project 8: Evaluation of Smart-Controllers for Distributed Energy Resources

Evaluation of Smart-Controllers for Distributed Energy Resources

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Alan Williams	619-553-2808	alan.d.williams@navy.mil	PI
POC2	Eric Evans			
POC3	Matt Bond			

Period of Performance: FY16 --- FY17

Base / Installation: SPAWAR Energy Innovation Lab

Technology Description

Provide a brief description of the technology being implemented in this research project

Create a virtual microgrid for evaluating advanced management and control architectures

Select up to three different technology types to categorize this project

Technology Type 1	Modeling & Optimization
Technology Type 2	Microgrids, Islanding, Isolation
Technology Type 3	Decision Support

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Assessment of different micro-grid smart controller capabilities for future micro-grid applications in order to determine which control architectures are best-suited for different applications. This project will produce a standardized and unbiased assessment of the capabilities offered by the different platforms.

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Improved decision support capability for sizing backup generators

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Potential	Improved efficiency or effectiveness of existing renewable generation
Potential	Improved efficiency or effectiveness of existing renewable energy storage
Potential	Improved capability to integrate renewables into larger grid
Potential	Improved decision support capabilities for investing in renewable systems

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Potential	Power modeling used to optimize grid configuration or expansion
Potential	Modeling and simulation to inform energy infrastructure investments

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure	

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above	
Potential	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?	

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?	

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?	

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Delays in purchasing and software licensing processes

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

delays

What would you describe as the greatest benefit(s) of having completed this demonstration project?

standardized unbiased assessment of different microgrid control capabilities

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Cyber security adaptations?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Technologies are somewhat mature, but not yet widespread enough for a standard comparison or ranking system to show which products are best for a given application
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	
Environmental or Installation-specific challenges	
Accessibility of required components	

Process Challenges

Certification or Approval requirements	Need to establish official standards/feature requirements for selecting a specific micro-grid control system
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	Software will require continued operational support and possible tech support contracts
Contracting / Procurement	Purchasing and software licensing processes

Stakeholder Challenges

Impact on and Approval of certain stakeholders	software and hardware must meet installation energy manager needs
Limitations from stakeholder needs	
Operation and support labor requirements	microgrid hardware/software maintenance and updates
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Andrew Grewe		
Amar Ameen		
Bashar Ameen		
Trever Calton		

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B.9 Project Information Form for Project 9: Advance Power Electronics for PV Inverters

Advance Power Electronics for PV Inverters

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Ken Ho	805-982-1636	ken.ho@navy.mil	PI
POC2	Todd Weatherford	831-656-3044	tweatherford@nps.mil	Co-PI
POC3				

Period of Performance: FY13 --- FY15

Base / Installation: NBVC

Technology Description

Provide a brief description of the technology being implemented in this research project

The project will evaluate IPC's PV inverters, which incorporates newer electronic components and a novel topology. The Universal Power Converter™ Platform will be studied and criteria for a "Universal Converter" for renewable energy generation will be developed.

Select up to three different technology types to categorize this project

Technology Type 1	Energy Production
Technology Type 2	
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Lower cost and improved reliability of new PV installations

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Integrated alternative-powered backup power systems
Potential	Reduced requirement for backup generators to assure power

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Potential	Added renewable energy generation capability (wind, solar, etc)
Demonstrate	Improved efficiency or effectiveness of existing renewable generation
Potential	Improved capability to integrate renewables into larger grid
Potential	Improved capability to estimate ROI of renewable systems

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Demonstrate	Reduced contractor support required to install, maintain, or operate technology

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Reduced reliance on outside energy suppliers

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Potential	Reduced reliance on systems with expensive replacement parts
Potential	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Potential	Improved control capabilities for future experiments

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Evaluate new inverters with the potential to enable future PV integration, Developed criteria for "Universal Converter" for renewable energy systems

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Thorough vetting for assurance and cyber security requirements

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

Reduce the cost of implementing renewable energy systems

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	novel inverter topology requires further testing and vetting
Maturity/suitability of specific systems used in this project	novel inverter topology requires further testing and vetting
Integration with Navy-specific systems	
Environmental or Installation-specific challenges	integration may be limited by existing electrical infrastructure at some facilities
Accessibility of required components	

Process Challenges

Certification or Approval requirements	
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	
Contracting / Procurement	

Stakeholder Challenges

Impact on and Approval of certain stakeholders	Need maintenance, facilities, and Public Works buy-in
Limitations from stakeholder needs	
Operation and support labor requirements	long term support labor tbd
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Darren Parsons		

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B.10 Project Information Form for Project 10: DC Micro-grid For Solid State Lighting

DC Micro-grid For Solid State Lighting

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Ken Ho	(805) 982-1636	ken.ho@navy.mil	PI
POC2	Ming Liu			
POC3	Bruce Garrett		bruce.garrett@navy.mil	

Period of Performance: FY15 --- FY17

Base / Installation: Port Hueneme

Technology Description

Provide a brief description of the technology being implemented in this research project

Develop a low cost building level microgrid integrating new multi-port PV inverters from prior ESTEP project (Advance Power Electronics for PV Inverters) and storage from prior NSETTI project (Containerized Micro-grid Battery Storage). Install a DC Micro-grid with 380VDC bus, 15kW PV, 25kWh Li-ion battery, that is grid-tied and islandable. Use microgrid to power LED lighting throughout building using low cost COTS products under MILCON threshold.

Select up to three different technology types to categorize this project

Technology Type 1	Microgrids, Islanding, Isolation
Technology Type 2	Energy Storage
Technology Type 3	Implementation, Integration, Adaptation

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Will enable cost-effective integration of microgird (including renewable generation and energy storage) into existing buildings and power infrastructure. Low cost components and navigating Li-Ion battery approval process will make it easier for installations to acquire these systems.

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Integrated alternative-powered backup power systems
Potential	Reduced frequency of backup generator use
Potential	Reduced requirement for backup generators to assure power

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Realized	Added renewable energy generation capability (wind, solar, etc)
Realized	Integrated or expanded renewable energy storage
Potential	Improved capability to integrate renewables into larger grid
Demonstrated	Improved decision support capabilities for investing in renewable systems
Potential	Improved capability to estimate ROI of renewable systems

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Realized	Incorporated energy storage to reduce peak power demand

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Realized	Technology requires fewer or less costly replacement components that alternative systems

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems	
Realized	Reduced reliance on outside energy suppliers
Realized	Increased energy storage capability for independent operation

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure	

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above	
Realized	Reduced reliance on systems with expensive replacement parts
Demonstrated	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?	

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?	

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?	

List and describe any benefits this technology has or may have that aren't described above	

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Discovered bug in Power Converter that reduced total PV capacilty; Lack of expertise on PV and energy storage, NBVC PW and EXWC safety rules would not allow self-install; delays in construction due to local base support; utility interconnect agreement on hold due to telemetry issues; BSSM failed, DC bus has suspected occasional spikes; Li-ion battery safety certifications; Base PW wanted warranties and bonding; MILCON $1M threshold for custs

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

Reduced power quality, limited total PV potential, caused significant delays in getting system operational

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Gained experience implementing PV and energy storage systems; system reduces base energy demand and provides energy-secure lighting

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Address bugs/failures in IPC and BSSM, streamline process for approving use of Li-Ion battery energy storage

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

Cost-competitive with high ROI/rapid cost recovery; microgrid can be built in stages (one building at a time) to ease the integration process

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?
Successful integration of low-cost microgrid at building-scale makes it easier to fund infrastructure projects one building at a time

What new skills, competencies, or experience were gained within the Navy workforce during this project?
Gained experience working with PV systems, energy storage, and microgrids. Lessons Learned: LED lighting controls more complicated than originally thought, system resiliency subject to hardward faults and software bugs in components, utility grid interconnect rules vary by region, system integration costs are the largest costs

Technology Integration

Maturity of the technology family	New technology still has undiscovered bugs and faults
Maturity/suitability of specific systems used in this project	IPC bug discovered during commissioning. Had to reduce total PV by 5kW. BSSM failed, DC bus has suspected occasional spikes
Integration with Navy-specific systems	Each building would require its own custom installation of microgrid system
Environmental or Installation-specific challenges	Navy bases in different regions will have to comply with different standards in order to connect facility microgrids to larger power grid
Accessibility of required components	Li-ion battery power storage requires special approval and certifications

Process Challenges

Certification or Approval requirements	Interconnect agreements may prevent microgrid integration into larger power grid; some facilities may require insurance or bonding that vendors are unwilling to provide
Initial Funding or Resource Allocation issues	More experience is needed integrating these systems in order to improve cost estimates and avoid unexpected cost overruns
Continued Funding or Resource Allocation issues	Batteries will need periodic replacement and regular maintenance
Contracting / Procurement	Facilities commands may require assurances and warranties that suppliers may be unwilling to issue.

Stakeholder Challenges

Impact on and Approval of certain stakeholders	Base Support must approve the use of Li-Ion battery storage on a case-by-case basis. Utility companies may restrict microgrid interconnections
Limitations from stakeholder needs	Warranty or Assurance requirements may limit number of suitable vendors
Operation and support labor requirements	Batteries require period maintenance to ensure system health
Necessary Funding Streams: Integration	Installation and Construction require significant time investment from Public Works
Necessary Funding Streams: Continued Support	Labor funding needs to be reserved for system maintenance
Continued feedback and improvement	Additional microgrid configurations may be needed to meet the needs of certain buildings

Intern Involvement

Please list any interns who were involved in this project, as well as the year(s) they worked and where they are now (if known).
If necessary, use an "x" to represent any interns whose names are unknown.

Intern Name	Year (if known)	Where are they now? (if known)
Kyle Abrahamsen		
Dustin Talley		
Bashar Ameen		

References

Please list any technical papers, publications, or theses that resulted from this project.

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title
Ken Ho	NAVFAC EXWC Demonstrates New Renewable Energy Power Management Systm - Currents. Winter 2016-17, 22-27

NPS Student Theses

Author(s)	Title (if known)

B.11 Project Information Form for Project 11: Networked Building Level Micro-Grid Demonstration

Networked Building Level Micro-Grid Demonstration

Other Names, Abriviations, etc: DC microgrid for Solid State Lighting

Contacts	Name	Phone	Email	Role
POC1	Bruce Garrett	805-982-5615	bruce.garrett@navy.mil	PI
POC2	Kyle Abrahamsen	805-982-3893		Co-PI
POC3	Ken Ho			

Period of Performance: FY17 --- FY19

Base / Installation: NBVC Port Hueneme

Technology Description

Provide a brief description of the technology being implemented in this research project

Combine multiple building-level micrograms into a larger networked microgrid

Select up to three different technology types to categorize this project

Technology Type 1	Microgrids, Islanding, Isolation
Technology Type 2	Implementation, Integration, Adaptation
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Will increase the Navy's ability to implement microgrids by simplifying the process of sourcing components and systems to meet unique design needs while keeping costs below Milcon thresholds,

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Demonstrated	Integrated alternative-powered backup power systems
Potential	Reduced requirement for backup generators to assure power

Page 1

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Demonstrated	Added renewable energy generation capability (wind, solar, etc)
Demonstrated	Integrated or expanded renewable energy storage
Demonstrated	Improved capability to integrate renewables into larger grid
Potential	Improved capability to estimate ROI of renewable systems

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Demonstrated	Incorporated energy storage to reduce peak power demand

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Reduced reliance on outside energy suppliers
Demonstrated	Increased energy storage capability for independent operation

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Potential	Improved monitoring and detection of potential cyber threats
Potential	Improved capability to restore operation after successful cyber attacks

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above	
Potential	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?	
Potential	Improved energy access in remote facilities
What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?	
What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?	

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Discovered bug in Power Converter that reduced total PV capacilty; Lack of expertise on PV and energy storage, NBVC PW and EXWC safety rules would not allow self-install; delays in construction due to local base support; utility interconnect agreement on hold due to telemetry issues; BSSM failed, DC bus has suspected occasional spikes.

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

Delays caused by acquisition process, difficulties in networking microgrids due to cybersecutiry and utility interconnect issues

What would you describe as the greatest benefit(s) of having completed this demonstration project?

demonstrate capability to scale building-level microgrid systems into a larger base-wide architecture

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

approval for cyber requirements, utility interconnect parameters,

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

This technology would allow base-wide microgrids to be build in smaller sections that don't have as stringent funding requirements

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

Improved capability to integrate microgrids at different scales

What new skills, competencies, or experience were gained within the Navy workforce during this project?

PV and energy storage, familiarity with cyber requirements, familiarity with PW and other processes required to integrate base power systems.

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Individual components are mature, but configuration of system isn't
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	undefined cybersecurity requirements and troubles with utility interconnect
Environmental or Installation-specific challenges	specific cyber or utility interconnect challenges
Accessibility of required components	potential battery safety issues

Process Challenges

Certification or Approval requirements	Utility interconnect challenges, need a process for working with PW
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	Need a process to fund microgrid maintenance
Contracting / Procurement	

Stakeholder Challenges

Impact on and Approval of certain stakeholders	Need buy-in from PW
Limitations from stakeholder needs	Utility interconnect poses integration challenges
Operation and support labor requirements	PW buy-in for maintenance, energy manager approval
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	Maintenance funding
Continued feedback and improvement	

Intern Involvement

Please list any interns who were involved in this project, as well as the year(s) they worked and where they are now (if known).
If necessary, use an "x" to represent any interns whose names are unknown.

Intern Name	Year (if known)	Where are they now? (if known)

References

Please list any technical papers, publications, or theses that resulted from this project.

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title
Ken Ho	NAVFAC EXWC Demonstrates New Renewable Energy Power Management Systems (Currents, Winter 2016-17)

NPS Student Theses

Author(s)	Title (if known)

B.12 Project Information Form for Project 12: Cyber-SCADA Energy Capability (C-SEC): Evaluation, Development, and Demonstration

Cyber-SCADA Energy Capability (C-SEC): Evaluation, Development, and Demonstration

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Jose Romero-Mariona	619-553-8119	jose.romeromariona@navy.mil	PI
POC2	John San Miguel		john.m.sanmiguel@navy.mil	
POC3				

Period of Performance: FY15 --- FY16

Base / Installation: SSC PAC San Diego CA

Technology Description

Provide a brief description of the technology being implemented in this research project

C-SEC On The Move (OTM), will enable much quicker evaluations and demonstrations of Cyber SCADA technologies as they operate in their Navy environment. In addition, it will also provide the ability to address problems found with specific solutions/mitigation strategies.

Select up to three different technology types to categorize this project

Technology Type 1	Cyber
Technology Type 2	Energy Management & Monitoring
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

C-SEC mobile app will allow evaluation team to leverage C-SEC's evaluation capabilities to assess cyber vulnerability, monitor SCADA systems, and diagnose potential issues in a way that does not interfere with SCADA operation

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Potential	Technology is easier to operate than alternative systems

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Improved fault isolation to prevent cascading blackouts

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Potential	Improved monitoring and detection of potential cyber threats
Potential	Improved capability to isolate potential vectors for cyber attacks
Potential	Improved capability to restore operation after successful cyber attacks

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

the nature of the work (critical infrastructure and electrical grid: 1) get a concensus of people that we can reach out and ask question 2) hard to demonstrate work because no one is willing to let us connect to live systems

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

didn't allow technology proof of concept to scale up, still working on testing on a scaled-up system

Page 2

What would you describe as the greatest benefit(s) of having completed this demonstration project?

1) developed cadre of scientists/engineers who have appreciation/skills in energy systems & cyber security and ability to collaborate 2) the ability to develop capabilities in csec to do things like baselining crit infrastructure network be developing "gentle" techniques 3) grow interactions between gov, academics, industry in working through these challenges

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

NESSUS vulnerability scanner needed adaptation for use in critical infrastructure to scan different types of components

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

CSEC allows you to look at health of network and also holds a library of potential cyber solutions that evaluates suitability of different solutions to address issues

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

nothing like this exists in gov capacity that provides objective answers to cyber questions, provides reusability to streamline multiuse, technology being gov-owned includes training component with gov mentality and meeting requirements

What new skills, competencies, or experience were gained within the Navy workforce during this project?

energy & cyber systems (and appreciation of such systems), ability to collaborate with academia and commercial

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	implementation requires scaled-up testing
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	requires access to critical infrastructure
Environmental or Installation-specific challenges	each installation is different, requires access to critical infrastructure
Accessibility of required components	Requires "samples" of industry cyber security techology

Process Challenges

Certification or Approval requirements	
Initial Funding or Resource Allocation issues	Access to critical infrastructure is difficult to get
Continued Funding or Resource Allocation issues	hard to make a case for continued funding/development due to questions of responsibility
Contracting / Procurement	contracting shops are overtasked

Stakeholder Challenges

Impact on and Approval of certain stakeholders	requires approval of energy managers to get access to infrastructure
Limitations from stakeholder needs	mission critial energy infrastructure limits access
Operation and support labor requirements	
Necessary Funding Streams: Integration	need to identify org responsible for funding integration & support
Necessary Funding Streams: Continued Support	need to identify org responsible for funding integration & support
Continued feedback and improvement	feedback systems in place for gov and industry partners

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
David Bright		
Tenika Grant		

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B13. Project Information Form for Project 13: Energy Efficient Cloud Computing Evaluation and Demonstration

Energy Efficient Cloud Computing Evaluation and Demonstration

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Chris Chen	619-553-6852	chris.s.chen@navy.mil	PI
POC2	Bobby Nutting			
POC3	Paul Plummer			

Period of Performance: FY17 --- FY17

Base / Installation: SPAWAR Systems Center PAC

Technology Description

Provide a brief description of the technology being implemented in this research project

Install Open Compute Project (OCP)-based server and racks in data center and evaluate its computing performance and energy use with non-production Navy workload. Verify OCP claims that the data center will be 38% more efficient and 24% less expensive to build and run by adopting its server technology.

Select up to three different technology types to categorize this project

Technology Type 1	Energy Management & Monitoring
Technology Type 2	Implementation, Integration, Adaptation
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Reduce energy costs and total ownership costs associated with running virtualization/cloud computing data center, allowing the savings to be put into more computing capabilities or avoiding expensive power infrastructure upgrades

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Page 1

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Potential	Reduced installation power consumption through improved end-user efficiency

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Potential	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Energy consumption from servers is hard to benchmark effectively, process and procurement challenges

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

delays

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Demonstrate potential cost and energy savings of OCP server architecture

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

reduce total cost of ownership of advanced computing facilities

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Still needs to be officially verified in a DOD capacity
Maturity/suitability of specific systems used in this project	Still needs to be officially verified in a DOD capacity
Integration with Navy-specific systems	Possible restrictions associated with using open source hardware in DoD
Environmental or Installation-specific challenges	possible limits on allowable applications due to open source hardware
Accessibility of required components	limited number of vendors to compete for bids

Process Challenges

Certification or Approval requirements	Possible restrictions associated with using open source hardware in DoD
Initial Funding or Resource Allocation issues	large upfront cost for installing new server systems
Continued Funding or Resource Allocation issues	need continued validation and security reivew processes
Contracting / Procurement	Challenges in acquisition process

Stakeholder Challenges

Impact on and Approval of certain stakeholders	new server architecture must meet user needs such as not sacrificing speed for reduced operating costs
Limitations from stakeholder needs	possible limitations on allowable computing projects
Operation and support labor requirements	maintenance and monitoring
Necessary Funding Streams: Integration	buy-in needed from DOD IT professionals
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Tim Jordon		
Steve Kuczka		Currently at SSC Pacific
Ayron Solomakos		

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B14. Project Information Form for Project 14: RFID Reading Outlets for Device-level Granularity in Building Energy Control

RFID Reading Outlets for Device-level Granularity in Building Energy Control

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Wayne Liu	619-553-1900	wayne.p.liu@navy.mil	PI
POC2	Timi Adeyemi			
POC3	Mike Murphy			

Period of Performance: FY14 --- FY17

Base / Installation: MCAS Miramar

Technology Description

Provide a brief description of the technology being implemented in this research project

use Smart outlets to measure, monitor, and control building electrical loads to advance towards Net Zero goals, integrated with MCAS Miramar Public Utility Awareness Display

Select up to three different technology types to categorize this project

Technology Type 1	Energy Management & Monitoring
Technology Type 2	Cyber
Technology Type 3	Implementation, Integration, Adaptation

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Better control of plugs and lighting, ROI < 5 years in high energy cost environments, better access to energy use data

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Reduced natural gas needed for heating or installation operations
Potential	Improved decision support capability for sizing backup generators

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Potential	Improved capability to estimate ROI of renewable systems
Potential	Improved decision support capabilities for investing in renewable systems

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Potential	Reduced installation power consumption through building control automation

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Demonstrated	Improved metering and monitoring of installation energy use
Potential	Improved diagnostic capabilities for energy infrastructure components

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Potential	Increased ability to diagnose need for preventative maintenance
Potential	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

Potential	Increased awareness of energy use

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

Demonstrated	Real-time monitoring of energy systems
Potential	Improved documentation of infrastructure

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Potential	Improved access to energy use data
Potential	Improved control capabilities for future experiments

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Introducing new plug load monitors introduces changes to data collection software and potential network vulnerabilities

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Improved access to energy use data, detection of energy disturbances, cost savings by shutting off "phantom loads"

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	
Maturity/suitability of specific systems used in this project	Cybersecurity requirements?
Integration with Navy-specific systems	Integration process will vary with energy management software used at different installations
Environmental or Installation-specific challenges	
Accessibility of required components	

Process Challenges

Certification or Approval requirements	cybersecurity requirements? Permitting process to install smart outlets? Compatible with protocols and regulations?
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	
Contracting / Procurement	Contracting to install outlets

Stakeholder Challenges

Impact on and Approval of certain stakeholders	
Limitations from stakeholder needs	RFID outlet shutoff may not be suitable for all loads / users
Operation and support labor requirements	special training required to service smart outlets?
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Sam Skinner		

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B15. Project Information Form for Project 15: C-SEC on the Move

C-SEC On The Move

Other Names, Abbreviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Jose Romero-Mariona	619-553-8119	jose.romeromariona@navy.mil	PI
POC2	John San Miguel			Co-PI
POC3				

Period of Performance: FY15 --- FY16

Base / Installation: SSC PAC

Technology Description

Provide a brief description of the technology being implemented in this research project

Develop mobile tools for analyzing SCADA systems in order to assess performance and cyber vulnerabilities, and to explore possible mitigation measures

Select up to three different technology types to categorize this project

Technology Type 1	Cyber
Technology Type 2	Modeling & Optimization
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Improved capability to assess health and vulnerability in SCADA systems

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Reduced frequency of backup generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Potential	Improved capability to integrate renewables into larger grid

Page 1

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Potential	Technology is easier to operate than alternative systems
Potential	Technology reduces need for specialized training

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Improved fault isolation to prevent cascading blackouts
Potential	Improved capability to restore grid functionality after outages

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Potential	Improved monitoring and detection of potential cyber threats
Potential	Improved capability to isolate potential vectors for cyber attacks
Potential	Improved failsafes or system logic to limit potential damage from cyber attacks
Potential	Improved capability to restore operation after successful cyber attacks

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Potential	Increased ability to diagnose need for preventative maintenance
Potential	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

Potential	Improved documentation of infrastructure
Potential	Real-time monitoring of energy systems

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Potential	Improved access to energy use data

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

infrastructure access, limitations from needing to physically interact with components

What would you describe as the greatest benefit(s) of having completed this demonstration project?

take work from the lab (CSEC) out into the field to stakeholders

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

(see CSEC), would allow additional feedback and engagement/interaction

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

just scratched the surface, openned trust pathways to more progress

What new skills, competencies, or experience were gained within the Navy workforce during this project?

energy & cyber systems (and appreciation of such systems), ability to collaborate with academia and commercial

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	still a proof of concept
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	access to infrastructure components
Environmental or Installation-specific challenges	need access to equipment and site documentation, knowledge of day-today operations
Accessibility of required components	takes a while to order stuff

Process Challenges

Certification or Approval requirements	TBD, not "blessed" yet
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	need funds to continue development and taking to different sites
Contracting / Procurement	see above

Stakeholder Challenges

Impact on and Approval of certain stakeholders	approval of Energy managers and operators
Limitations from stakeholder needs	TBD
Operation and support labor requirements	Will eventually transition to a team performing these cyber evaluations
Necessary Funding Streams: Integration	Not clear who will take ownership
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
David Bright		
Tenika Grant		
Henry Brooks		
Geancarlo Coca		

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title
	Security in the Industrial Internet of Things: The C-SEC Approach

NPS Student Theses

Author(s)	Title (if known)

B16. Project Information Form for Project 16: Data Center Smart Metering Evaluation (DC Smart-E)

Data Center Smart Metering Evaluation (DC Smart-E)

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Daniel Grday	619-553-2793	daniel.grady@navy.mil	PI
POC2	Chris Chen			
POC3				

Period of Performance

FY16 --- FY16

Base / Installation

SSC PAC San Diego

Technology Description

Provide a brief description of the technology being implemented in this research project

Consolidate data centers in order to converve energy and implement more effective metering

Select up to three different technology types to categorize this project

Technology Type 1	
Technology Type 2	
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Reduced energy consumption through larger, more efficient data centers, estimated 5%-20% annual reduction in power and energy costs

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Realized	Reduced installation power consumption through improved end-user efficiency

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Demonstrated	Improved metering and monitoring of installation energy use

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Potential	Reduced contractor support required to install, maintain, or operate technology

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Potential	Improved monitoring and detection of potential cyber threats

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Demonstrated	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

Demonstrated	Real-time monitoring of energy systems

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Realized	Improved access to energy use data

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

Page 2

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Reduced O&S cost of data center operation, improved ROI analysis for data center metering

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	possible challenges in migrating data centers for consolidation
Environmental or Installation-specific challenges	possible challenges in migrating data centers for consolidation
Accessibility of required components	

Process Challenges

Certification or Approval requirements	Potential lengthy approval process to migrate data centers
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	
Contracting / Procurement	

Stakeholder Challenges

Impact on and Approval of certain stakeholders	
Limitations from stakeholder needs	Stakeholder needs present potential limitations on data center consolidation
Operation and support labor requirements	
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	Feedback needed to ensure energy conservation measures do not negatively impact data center performance

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Alex Salerno		
Ayron Solomakos		
Dondi Jones		

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B17. Project Information Form for Project 17: Building Energy Management Automation

Building Energy Management Automation

Other Names, Abriviations, etc: Office Buildings Energy Management Automation

Contacts	Name	Phone	Email	Role
POC1	Chris Chen	619-553-6852	chris.s.chen@navy.mil	PI
POC2				
POC3				

Period of Performance: FY16 --- FY17

Base / Installation:

Technology Description

Provide a brief description of the technology being implemented in this research project

Use RF and IOT smart devices to and sensors to automate building controls in a way that facilitates data collection and is cyber secure. Integrate smart light bulbs with occupancy and ambient light sensors, and use IoT devices to share data for smarter energy management

Select up to three different technology types to categorize this project

Technology Type 1	Energy Management & Monitoring
Technology Type 2	Cyber
Technology Type 3	Implementation, Integration, Adaptation

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Improved efficiency in building control and improved access to building energy use data

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Reduced natural gas needed for heating or installation operations

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Potential	Reduced installation power consumption through building control automation

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Potential	Improved metering and monitoring of installation energy use

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

Potential	Real-time monitoring of energy systems

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Potential	Improved access to energy use data
Potential	Improved control capabilities for future experiments

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Page 2

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Improved understanding of how IoT devices can be used in an installation energy context, reduce energy consumption in buildings

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Cyber security features, compliant with existing policies

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

Technology is scalable with new IoT devices

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	IoT cybersecurity is not yet fully developed
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	cybersecurity concerns
Environmental or Installation-specific challenges	calibration required for various lighting and climate controls
Accessibility of required components	

Process Challenges

Certification or Approval requirements	cyber approval required for transmitting devices
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	
Contracting / Procurement	

Stakeholder Challenges

Impact on and Approval of certain stakeholders	Require stakeholder buy-in on automated controls
Limitations from stakeholder needs	certain stakeholders may not be willing to cede manual control
Operation and support labor requirements	
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	calibration for climate and lighting systems

Intern Involvement

	Year (if known)	Where are they now? (if known)
Tim Jordon		
Jason Sneddon		

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B18. Project Information Form for Project 18: Resilient Critical Infrastructures through Secure and Efficient Micro Grids (ReCIst)

Resilient Critical Infrastructures through Secure and Efficient Micro Grids (ReCIst)

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Jose Romero-Mariona	619-553-8199	jose.romeromariona@navy.mil	
POC2	Maxine Major			
POC3	Eva Regnier			

Period of Performance: FY16 --- FY18

Base / Installation: SSC PAC

Technology Description

Provide a brief description of the technology being implemented in this research project

Scan ICS and SCADA components within microgrids to assess security and efficiency

Select up to three different technology types to categorize this project

Technology Type 1	Cyber
Technology Type 2	Microgrids, Islanding, Isolation
Technology Type 3	Modeling & Optimization

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Improved assessment of cyber vulnerabilities and estimated ROI for ICS and SCADA systems in micro-grids

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Potential	Improved decision support capabilities for investing in renewable systems

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Potential	Modeling and simulation to inform energy infrastructure investments

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Improved fault isolation to prevent cascading blackouts
Potential	Improved capability to restore grid functionality after outages

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Potential	Improved monitoring and detection of potential cyber threats
Potential	Improved capability to isolate potential vectors for cyber attacks
Potential	Improved failsafes or system logic to limit potential damage from cyber attacks
Potential	Improved capability to restore operation after successful cyber attacks

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Potential	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

tried to develop model ROI for costs/risks of cyber security, never done before

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

Page 2

What would you describe as the greatest benefit(s) of having completed this demonstration project?

can assess the ROI and other benefits of cyber security and energy investments

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

provides modeling capability on ROI investments, some folks mifght not like the results

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

being done by Gov helps preserve knowledge & compliance, helps build skillsets, helps inform future investments

What new skills, competencies, or experience were gained within the Navy workforce during this project?

energy & cyber systems (and appreciation of such systems), ability to collaborate with academia and commercial

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Technology must be able to probe ICS and SCADA systems without interfering with operations
Maturity/suitability of specific systems used in this project	still a proof-of-concept
Integration with Navy-specific systems	(see CSEC)
Environmental or Installation-specific challenges	Technology must be adapted to work with different ICS and SCADA components employed at different naval installations
Accessibility of required components	

Process Challenges

Certification or Approval requirements	Requires approval to probe ICS and SCADA systems while in use. Accrediation issues to implement suggested solutions
Initial Funding or Resource Allocation issues	justification of need to model or use system
Continued Funding or Resource Allocation issues	need funding to continue support/improvements
Contracting / Procurement	hardware components must be produced/acquired in sufficient quantities to conduct testing at multiple installations

Stakeholder Challenges

Impact on and Approval of certain stakeholders	pushback on results
Limitations from stakeholder needs	Testing/probing cannot interfere with SCADA/ICS operations, identified cyber securitity measures must be implemented without interfering with SCADA/ICS operations
Operation and support labor requirements	
Necessary Funding Streams: Integration	ownership
Necessary Funding Streams: Continued Support	ownership
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Giancarlo Coca		
Henry Brooks		

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B19. Project Information Form for Project 19: SCADA Deploy

SCADA Deploy

Other Names, Abriviations, etc: Deployable SCADA Architecture for Non-Intrusive Energy System Evaluation (SCADA Deploy)

Contacts	Name	Phone	Email	Role
POC1	Henry Au	808-474-4179	henry.au@navy.mil	PI
POC2	Richard Kam			
POC3	Brian Tagami			

Period of Performance: FY16 --- FY17

Base / Installation: MCBH - Hawaii

Technology Description

Provide a brief description of the technology being implemented in this research project

Map existing SCADA systems at various Commands and Joint Bases in Hawaii to develop SCADA network models for legacy and next gen SCADA integration. Determine network availability for newer technology and cyber security.

Select up to three different technology types to categorize this project

Technology Type 1	Cyber
Technology Type 2	Energy Management & Monitoring
Technology Type 3	Modeling & Optimization

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from

Improved documentation and assessment of SCADA systems at Marine Corps Base Hawaii to determine cyber vulnerabilities and best strategies for improvements/upgrades

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Potential	Reduced installation power consumption through improved distribution efficiency

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Potential	Power modeling used to optimize grid configuration or expansion
Potential	Improved diagnostic capabilities for energy infrastructure components
Demonstra	Modeling and simulation to inform energy infrastructure investments

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability,

Potential	Improved fault isolation to prevent cascading blackouts
Potential	Improved capability to restore grid functionality after outages

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure	
Demonstra	Improved monitoring and detection of potential cyber threats
Potential	Improved capability to isolate potential vectors for cyber attacks
Potential	Improved failsafes or system logic to limit potential damage from cyber attacks
Potential	Improved capability to restore operation after successful cyber attacks

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above	
Potential	Increased ability to diagnose need for preventative maintenance
Demonstra	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?	
What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?	
Potential	Real-time monitoring of energy systems
Demonstra	Improved documentation of infrastructure
What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?	
Potential	Improved access to energy use data

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?	Scale of PH shipyard, difficulties in coordinating with contractors responsible for SCADA systems
In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?	
What would you describe as the greatest benefit(s) of having completed this demonstration project?	Improved assessment of SCADA cyber vulnerabilities and improved documentation of existing SCADA systems
What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?	
Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?	
What advances or observations were made in this demonstration project that could help justify continued investment in this technology?	Identified vulnerability to cyber threats can justify improvements in SCADA infrastructure
What new skills, competencies, or experience were gained within the Navy workforce during this project?	

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	
Maturity/suitability of specific systems used in this project	Existing systems lack updated documentation and the institutional knowledge required to effectively maintain and operate these SCADA systems has been lost
Integration with Navy-specific systems	Improving SCADA situation will require certifying a new SCADA architecture and navigating the contracting process to implement new systems
Environmental or Installation-specific challenges	Each installation will have a unique layout and individual challenges
Accessibility of required components	

Process Challenges

Certification or Approval requirements	Reliance on SCADA systems and inability to tolerate disruptions will create challenges during aproval process
Initial Funding or Resource Allocation issues	Scale and depth of SCADA system use will make improvements an expensive and lengthy process
Continued Funding or Resource Allocation issues	Scale and depth of SCADA system use will make improvements an expensive and lengthy process
Contracting / Procurement	

Stakeholder Challenges

Impact on and Approval of certain stakeholders	Improving SCADA architecture will likely result in disruptions to energy availability
Limitations from stakeholder needs	
Operation and support labor requirements	O&S personell will need to be trained on new SCADA systems
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Timothy Gunderson	FY16	

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B20. Project Information Form for Project 20: Joint Cyber SCADA Laboratory Workforce Development (SSC PAC and UHWO)

Joint Cyber SCADA Laboratory Workforce Development (SSC PAC and UHWO)

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Jose Romero-Mariona	619-553-8199	jose.romeromariona@navy.mil	PI
POC2	Geancarlo Palavicini			
POC3	Matt Chapman			

Period of Performance

FY17 --- FY18

Base / Installation

SSC PAC & UHWO

Technology Description

Provide a brief description of the technology being implemented in this research project

Build a formal collaboration link and Joint Cyber-SCADA lab environment in order to better coordinate with Univeristy of Hawaii on energy projects to engage students & academia and build intellectual capital.

Select up to three different technology types to categorize this project

Technology Type 1	Cyber
Technology Type 2	Other
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

increased capability to link DoD personnel with academia and student interns for coordinated research efforts in the field of cyber security, SCADA, and critical energy infrastructure protection

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Potential	Improved monitoring and detection of potential cyber threats
Potential	Improved capability to isolate potential vectors for cyber attacks
Potential	Improved failsafes or system logic to limit potential damage from cyber attacks
Potential	Improved capability to restore operation after successful cyber attacks

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

scheduling

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

What would you describe as the greatest benefit(s) of having completed this demonstration project?

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	
Environmental or Installation-specific challenges	Difficulties associated with tailoring cyber solutions to site-specific hardware
Accessibility of required components	

Process Challenges

Certification or Approval requirements	Approval to work with a non-DOD agency
Initial Funding or Resource Allocation issues	Difficult to determine ROI calculation for initial investment
Continued Funding or Resource Allocation issues	Will require continual funding renewal
Contracting / Procurement	

Stakeholder Challenges

Impact on and Approval of certain stakeholders	DOD needs vs UHWO needs
Limitations from stakeholder needs	
Operation and support labor requirements	
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B21. Project Information Form for Project 21: Smart Plug Side Channel Analysis (SPAMSANDWICH)

Smart Plug Side Channel Analysis (SPAMSANDWICH)

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Lawrence Kerr	619-553-7907	lkerr@spawar.navy.mil	PI
POC2	Maxine Major			
POC3	Johnny Phan			

Period of Performance: FY17 --- FY18

Base / Installation: SSC Pacific Cyber SCADA lab

Technology Description

Provide a brief description of the technology being implemented in this research project

Evaluate COTS smart-plug technologies to determine their suitability for use in larger energy monitoring efforts and using data collected by the smart plugs to detect possible cyber attacks

Select up to three different technology types to categorize this project

Technology Type 1	Energy Management & Monitoring
Technology Type 2	Cyber
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Realtime electrical outlet monitoring will allow improved monitoring of potential cyber threats or attacks against energy infrastructure, as well as provide researchers with additional data into facility energy use. Monitoring power consumption at outlets allows nonintrusive analysis of SCADA systems

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Page 1

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Potential	Improved decision support capabilities for investing in renewable systems

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Potential	Reduced installation power consumption through improved end-user efficiency
Potential	Reduced installation power consumption through building control automation

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Potential	Power modeling used to optimize grid configuration or expansion
Demonstrated	Improved metering and monitoring of installation energy use
Potential	Modeling and simulation to inform energy infrastructure investments

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure	
Potential	Improved monitoring and detection of potential cyber threats
Potential	Improved capability to isolate potential vectors for cyber attacks
Potential	Improved failsafes or system logic to limit potential damage from cyber attacks

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above	
Potential	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?	
Potential	Increased awareness of energy use
What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?	
Potential	Real-time monitoring of energy systems
What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?	
Demonstrated	Improved access to energy use data
Potential	Improved control capabilities for future experiments

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Lack of clear product specifications, limited vendor response, limited number of COTS high sampling rate devices, DoD security policies

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

Limited ability to purchase and install systems for testing

What would you describe as the greatest benefit(s) of having completed this demonstration project?

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Limited number of vendors, and published specs don't provide enough information to properly guage a product's performance in this application
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	Multiple DoD security constraints
Environmental or Installation-specific challenges	
Accessibility of required components	Difficult to determine which products are suitable for this application

Process Challenges

Certification or Approval requirements	required security certifications?
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	Ideal application will require regular updates to improve detection of emerging cyber attack vectors
Contracting / Procurement	

Stakeholder Challenges

Impact on and Approval of certain stakeholders	
Limitations from stakeholder needs	
Operation and support labor requirements	
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	Labor required to continually improve data analysis as installation energy use changes over time

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B22. Project Information Form for Project 22: ENSURE (Ensuring Reliability and Efficiency)

ENSURE (Ensuring Reliability and Efficiency)

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Josiah Bryan	619-553-7193	josiah.bryan@navy.mil	
POC2	Jose Romero-Mariona			
POC3	John San-Miguel			

Period of Performance: FY17 --- FY18

Base / Installation: SSC Pacific - San Diego

Technology Description

Provide a brief description of the technology being implemented in this research project

evaluate and monitor Energy Critical Infrastructures and SCADA technologies by creating an integrated framework of binary analysis tools, security technologies, and efficiency metrics on small single board computer devices to discover embedded firmware functionality that could cause devices to waste resources.

Select up to three different technology types to categorize this project

Technology Type 1	Cyber
Technology Type 2	Energy Management & Monitoring
Technology Type 3	Modeling & Optimization

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Improved efficiency and cyber security of SCADA devices

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Reduced frequency of backup generator use

Page 1

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Potential	Reduced installation power consumption through improved distribution efficiency

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Potential	Improved diagnostic capabilities for energy infrastructure components

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Improved fault isolation to prevent cascading blackouts
Potential	Improved capability to restore grid functionality after outages

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure	
Potential	Improved monitoring and detection of potential cyber threats
Potential	Improved capability to isolate potential vectors for cyber attacks
Potential	Improved failsafes or system logic to limit potential damage from cyber attacks
Potential	Improved capability to restore operation after successful cyber attacks

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above	
Potential	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?	

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?	

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?	
Potential	Improved control capabilities for future experiments

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Hiring freeze reduced team effectiveness

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

Project delays due to lack of workers

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Improve capability to detect vulnerabilities embedded within power control firmware

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Technology may require tailoring to specific systems in use at naval facilities

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

Technology produced in-house will reduce risk of using power management technologies with known vulnerabilities

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Human-Machine Interface flexibility, Communication Extensibility & Autonomy, Scalability and Analysis performance
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	Specific hardware systems may require updates or additions to ENSURE framework
Environmental or Installation-specific challenges	Technology must adapt to the specific systems used across different installations
Accessibility of required components	

Process Challenges

Certification or Approval requirements	Approvals required for testing detection systems on live SCADA components
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	
Contracting / Procurement	supply chain considerations for ENSURE device

Stakeholder Challenges

Impact on and Approval of certain stakeholders	Energy manager and Cyber approval needed to interface with live SCADA components
Limitations from stakeholder needs	
Operation and support labor requirements	Need to determine who will conduct testing across installations
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	usability vetting by operators

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
David Bright		

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B23. Project Information Form for Project 23. Hypercritical Operational Technology Mitigation of Embedded SploitSyndrome (HOTMESS)

Hypercritical Operational Technology Mitigation of Embedded SploitSyndrome (HOTMESS)

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Geancarlo Palavicini	619-553-7904	geancarlo.palavicini@navy.mil	PI
POC2	Jose Romero-Mariona			
POC3	Josiah Bryan			
POC1	Francisco Tacliad		francisco.c.tacliad@navy.mil	PI

new owner

Period of Performance: FY17 --- FY19

Base / Installation: NAVFAC PMW130

Technology Description

Provide a brief description of the technology being implemented in this research project

Dynamic analysis & vulnerability research and embedded software security assessment using network and protocol dynamic analysis

Select up to three different technology types to categorize this project

Technology Type 1	Cyber
Technology Type 2	
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Discover and mitigate potential cyber vulnerabilities in JACE-like devices and SCADA systems

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Reduced frequency of backup generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Page 1

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Improved fault isolation to prevent cascading blackouts
Potential	Improved capability to restore grid functionality after outages

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Potential	Improved monitoring and detection of potential cyber threats
Potential	Improved capability to isolate potential vectors for cyber attacks
Potential	Improved failsafes or system logic to limit potential damage from cyber attacks
Potential	Improved capability to restore operation after successful cyber attacks

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

Potential	Improved documentation of infrastructure

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Many SCADA devices have proprietary system architecures, which makes in-depth analysis more difficult. Labor constraints and purchasing delays

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Improved capability to assess the security posture of deployed JACE / SCADA devices within DON. Improved understanding and awareness of vulnerabilities, as well as mitigation solutions

Page 2

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Improved access to inner workings of JACE and SCADA devices would improve ability to analyze devices for potential vulnerabilities

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

Improved capability to assess the security of JACE and SCADA energy management devices, discover inherant vulnerabilities, and protect against known and discovered vulnerabilities

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

Discovered vulnerabilities, presented technical paper

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Penetration testing capabilities not yet mature
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	large variety of systems that need to be tested
Environmental or Installation-specific challenges	limited capability to test systems while in use: specific naval installations may present greater challenges to finding time to conduct testing
Accessibility of required components	

Process Challenges

Certification or Approval requirements	Approval needed to access SCADA systems while in operations
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	Continual funding needed for testing as vulnerability discovery capability improves
Contracting / Procurement	possible contractor support needed to safely access power systems

Stakeholder Challenges

Impact on and Approval of certain stakeholders	Need approval and support of PW to access power systems
Limitations from stakeholder needs	Stakeholder operational needs limit ability to test on live systems
Operation and support labor requirements	Volume of systems requires considerable man-hours for testing
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	Periodic updates to testing procedure as new vulnerability vectors discovered

Intern Involvement

Page 3

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title
	IoDDoS - The Internet of Denial of Service Attacks

NPS Student Theses

Author(s)	Title (if known)

B24. Project Information Form for Project 24. Passive and Active Cyber-Defense for Cyber-Physical Systems – Strategies, Implementation and Evaluation

Passive and Active Cyber-Defense for Cyber-Physical Systems –Strategies, Implementation, and Evaluation

Other Names, Abriviations, etc: PACDCPS

Contacts	Name	Phone	Email	Role
POC1	Roger Hallman	619-553-7905	roger.hallman@navy.mil	PI
POC2	Joseph DiVita			
POC3	Geancarlo Palavicini			

Period of Performance: FY17 --- FY18

Base / Installation: SPAWAR SCPAC, San Diego CA

Technology Description

Provide a brief description of the technology being implemented in this research project

Our objective is to develop an understanding of how newer Active Cyber-Defense technologies can be utilized and implemented into DoD-owned energy (and other) Cyber-Physical Systems. Strategies for integrating Active Cyber-Defense technologies into Cyber-Physical Systems will be tested in a controlled laboratory environment where their performance can be monitored.

Select up to three different technology types to categorize this project

Technology Type 1	
Technology Type 2	
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Improved effectiveness of active cyber defense technologies

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Reduced frequency of backup generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Potential	Improved diagnostic capabilities for energy infrastructure components

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Improved fault isolation to prevent cascading blackouts
Potential	Improved islanding capability to isolate and protect critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Demonstrated	Improved monitoring and detection of potential cyber threats
Realized	Improved capability to isolate potential vectors for cyber attacks
Potential	Improved failsafes or system logic to limit potential damage from cyber attacks
Potential	Improved capability to restore operation after successful cyber attacks

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Improved situational awareness of Navy Cyber-Physical Power System use, earlier indications of compromise, faster reactions to new threats

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Expand to the wide variety of systems in use at naval facilities

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Active cyber defense tools are immature and constantly evolving
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	wide variety of systems in use at naval facilities may require multiple active cyber defense tools to cover all systems
Environmental or Installation-specific challenges	possibility of unique equipment or cyber requirements at specific installations
Accessibility of required components	

Process Challenges

Certification or Approval requirements	Approval required to interface with cyber systems
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	
Contracting / Procurement	Software solutions require long term licensing

Stakeholder Challenges

Impact on and Approval of certain stakeholders	
Limitations from stakeholder needs	
Operation and support labor requirements	Monitoring and updating cyber defense tools requirement
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	continued evaluation needed to ensure that active cyber defense tools are adapting to meet evolving threats

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Page 3

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B25. Project Information Form for Project 25: Deep Subgrid-parity Solar

Deep Subgrid-parity Solar

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Randall Olsen	619-553-8713	randall.olsen@navy.mil	PI
POC2	Nathan Stevens			
POC3				

Period of Performance: FY16 --- FY17

Base / Installation: SSC PAC, Miramar

Technology Description

Provide a brief description of the technology being implemented in this research project

Concentrated solar panel system composed of mirror arrays reflecting light on to PV panels in order to reduce the cost required for PV generation.

Select up to three different technology types to categorize this project

Technology Type 1	Renewable Generation
Technology Type 2	Renewable Integration
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Reduced cost PV generation achieved by using inexpensive mirrors to concentrate light onto fewer expensive PV panels

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Integrated alternative-powered backup power systems
Potential	Reduced requirement for backup generators to assure power

Page 1

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Demonstrated	Added renewable energy generation capability (wind, solar, etc)
Demonstrated	Improved efficiency or effectiveness of existing renewable generation

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Potential	Technology requires less maintenance labor than alternative systems
Potential	Technology requires fewer or less costly replacement components that alternative systems

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Reduced reliance on outside energy suppliers

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Potential	Reduced reliance on systems with expensive replacement parts

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

Potential	Improved energy access in remote facilities

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Installation quoting, and procurement far slower than expected. Late in the process, NAVFAC decided this was Construction. Electrical production lower than theoretical estimate, exacerbated by mirror degradation. Degraded coating on mirrors required new (more expensive) vendor

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

Delayed acquisitions process, reduced output from theoretical expectations

Page 2

What would you describe as the greatest benefit(s) of having completed this demonstration project?

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

UV stabilizers in mirror coating formula, determine nature of "construction" classification, identify causes for discrepencies between theoretical and actual energy production, research long-term duribility

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

Lower cost compared to traditional PV generation

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Long-term duration / UV stabilization of mirror coating solution
Maturity/suitability of specific systems used in this project	identify causes of discrepencies between actual and theoretical energy yield
Integration with Navy-specific systems	integration with larger utility grid
Environmental or Installation-specific challenges	cost/benefit assessment for installations with less sunlight available
Accessibility of required components	Need to establish partnerships to produce components in larger quantities

Process Challenges

Certification or Approval requirements	Construction approval for solar projects
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	
Contracting / Procurement	technology licensing approval for private industry partnerships

Stakeholder Challenges

Impact on and Approval of certain stakeholders	Required agreements for utility grid tie-in
Limitations from stakeholder needs	possible rooftop installation or space use considerations from stakeholders, reliability concerns
Operation and support labor requirements	maintencance considerations
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
John Hernandez		
Dan Reil		
Chris Hardy		
Gaston Ragazzo		
Jeff Leigh		

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B26. Project Information Form for Project 26. Energy and Water Recovery by Microbial Fuel Cells

Energy and Water Recovery by Microbial Fuel Cells

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Lewis Hsu	619-553-4934	lewis.hsu1@navy.mil	PI
POC2				
POC3				

Period of Performance: FY14 --- FY17

Base / Installation: RTS Warner Springs, MCB Hawaii

Technology Description

Provide a brief description of the technology being implemented in this research project

expand and test microbial fuel cell (MFC) technology for wastewater treatment at Navy facilities to generate electrical power & reusable water from wastewater, resulting in reduced environmental risks/costs associated with crude wastewater practices, useable power generation, and potable water recovery

Select up to three different technology types to categorize this project

Technology Type 1	Waste Energy Recovery
Technology Type 2	Renewable Generation
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Helps reduce water treatment costs and meet Navy Net-Zero goals by reducing impact from wastewater, recovering water for reuse, and generating power, thereby improving energy security

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Improved efficiency or alternative fueled vehicles on installation

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Demonstrated	Added renewable energy generation capability (wind, solar, etc)
Demonstrated	Integrated or expanded renewable energy storage

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Potential	Incorporated energy storage to reduce peak power demand

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Reduced reliance on outside energy suppliers
Demonstrated	Increased energy storage capability for independent operation

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Demonstrated	Reduced permitting costs for wastewater treatment

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

Potential	Improved energy access in remote facilities

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Demonstrated	Potable water recovery

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Contractor was unable to perform awarded contract (notified in March 2017)

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

Must now reissue contract for reactors, container latrine, RDTE support personnel

What would you describe as the greatest benefit(s) of having completed this demonstration project?

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Challenges exist in bringing lab-scale pilot programs into relevant environments
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	
Environmental or Installation-specific challenges	Scalability, restrictions regarding large-scale use of certain microbes in protected environments? Climate impact on microbes?
Accessibility of required components	Commercial design and speed of manufacturing challenges

Process Challenges

Certification or Approval requirements	certifications for reuse of recovered water, health & safety, regulatory compliance
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	
Contracting / Procurement	Contracts for system maintenance

Stakeholder Challenges

Impact on and Approval of certain stakeholders	stigma associated with reused water
Limitations from stakeholder needs	
Operation and support labor requirements	O&M requirements still unknown for large-scale projects
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B27. Project Information Forms for Project 27: Ad-Hoc Portable Power Systems (APPS)

Ad-hoc Portable Power Systems (APPS)

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Wayne Liu	619-553-1900	wayne.p.liu@navy.mil	PI
POC2	Lewis Hsu			
POC3	Nathan Johnson			

Period of Performance: FY17 --- FY19

Base / Installation: SSC PAC San Diego

Technology Description

Provide a brief description of the technology being implemented in this research project

Evaluate systems and methods for providing Ad-Hoc or temporary power at water-side or remote field test sites around naval test facilities using waterside energy generation and storage systems. 500W fuel cells are mounted to golf carts with solar charging systems.

Select up to three different technology types to categorize this project

Technology Type 1	Renewable Generation
Technology Type 2	Energy Storage
Technology Type 3	Microgrids, Islanding, Isolation

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Would enable cost-effective power for testing facilities, TRL demonstrations, and other applications that don't require a permanent grid infrastructure

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use	
Demonstrated	Reduced reliance on portable fossil fuel power generators
Demonstrated	Improved efficiency or alternative fueled vehicles on installation

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management	
Demonstrated	Added renewable energy generation capability (wind, solar, etc)
Demonstrated	Integrated or expanded renewable energy storage
Potential	Improved decision support capabilities for investing in renewable systems

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption	

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions	

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.	
Potential	Reduced contractor support required to install, maintain, or operate technology
Potential	Technology requires less maintenance labor than alternative systems
Potential	Technology reduces need for specialized training

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems	
Demonstrated	Reduced reliance on outside energy suppliers
Demonstrated	Increased energy storage capability for independent operation
Potential	Improved islanding capability to isolate and protect critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure	
Potential	Improved capability to restore operation after successful cyber attacks

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above	
Potential	Reduced reliance on systems with expensive replacement parts
Demonstrated	Reduced wear and tear on mechanical systems

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?	
Demonstrated	Improved energy access in remote facilities

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?	

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?	
Demonstrated	Improved control capabilities for future experiments

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Pierside conditions can lead to degradation of equipment and fuel cells

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

Page 2

What would you describe as the greatest benefit(s) of having completed this demonstration project?

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Fuel cell systems, packaging with legacy transport vehicles

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Must become cost competitive with portable conventional generators
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	Scalability issues will need to be addressed for certain applications or test sites
Environmental or Installation-specific challenges	Long term suitability subject to factors such as corrosion resistance. Effectiveness subject to solar availability
Accessibility of required components	Limited number of suppliers available

Process Challenges

Certification or Approval requirements	pressurized hydrogen gas storage?
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	
Contracting / Procurement	System procurement as a complete package (including vehicle) or retrofitting existing vehicles

Stakeholder Challenges

Impact on and Approval of certain stakeholders	
Limitations from stakeholder needs	
Operation and support labor requirements	system operation training
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	Fuel cell and related system maintenance training
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B28. Project Information Forms for Project 28: Energy Village: A Littoral Energy Test Facility

Energy Village: A Littoral Energy Test Facility

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Wayne Liu	619-553-1900	wayne.p.liu@navy.mil	PI
POC2	Alan Williams			
POC3	Max Kerber			

Period of Performance: FY16 --- FY18

Base / Installation: SSC San Diego

Technology Description

Provide a brief description of the technology being implemented in this research project

Microgrid for pierside UUV testing consisting of a microgrid with solar panels, microbial fuel cells, and underwater charging connectors

Select up to three different technology types to categorize this project

Technology Type 1	Microgrids, Islanding, Isolation
Technology Type 2	Implementation, Integration, Adaptation
Technology Type 3	Other

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Microgrids integrating underwater charging connectors will allow more efficient testing of UUVs in pierside and litoral environments where researchers have traditionally had to rely on batteries and generators for power

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Demonstrated	Reduced frequency of backup generator use
Demonstrated	Reduced requirement for backup generators to assure power
Potential	Integrated alternative-powered backup power systems

Page 1

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Demonstrated	Added renewable energy generation capability (wind, solar, etc)
Demonstrated	Integrated or expanded renewable energy storage
Demonstrated	Improved efficiency or effectiveness of existing renewable energy storage

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Demonstrated	Reduced installation power consumption through improved distribution efficiency
Demonstrated	Incorporated energy storage to reduce peak power demand

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Demonstrated	Reduced contractor support required to install, maintain, or operate technology
Potential	Technology is easier to operate than alternative systems

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Automated backup systems for critical systems
Demonstrated	Reduced reliance on outside energy suppliers
Demonstrated	Increased energy storage capability for independent operation
Potential	Improved islanding capability to isolate and protect critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Potential	Reduced reliance on systems with expensive replacement parts
Potential	Reduced wear and tear on mechanical systems

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

Demonstrated	Improved energy access in remote facilities

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

Demonstrated	Real-time monitoring of energy systems

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Demonstrated	Improved control capabilities for future experiments
Potential	Improved access to energy use data

Other

Demonstrated	Supports continuous UUV operation and data transfer

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

purchasing delays

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

What would you describe as the greatest benefit(s) of having completed this demonstration project?

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

Allows for continuous UUV operations in environments where conventional grid power is limited or impractical, does not require replenishment of liquid fuel for generators, and facilitates data transfer in addition to energy production/transfer

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	few if any commercial suppliers available for MFC and charging systems. System endurance considerations?
Maturity/suitability of specific systems used in this project	(still in development)
Integration with Navy-specific systems	Operational UUVs will need be equiped with the proper hardware to interface with the charging and data transfer mechanisms
Environmental or Installation-specific challenges	Undersea environments may limit space available for MFC chargers
Accessibility of required components	few if any commercial suppliers available for MFC and charging systems

Process Challenges

Certification or Approval requirements	Will require environmental permitting, data transmission cyber security certifications
Initial Funding or Resource Allocation issues	Difficult to establish a ROI to justify funding
Continued Funding or Resource Allocation issues	
Contracting / Procurement	Limited number of suppliers?

Stakeholder Challenges

Impact on and Approval of certain stakeholders	Charging and data transfer interface places design constraints on UUV platforms, or vice-versa
Limitations from stakeholder needs	
Operation and support labor requirements	special training requirements
Necessary Funding Streams: Integration	Ambiguity as whether this would be funded under operational energy or installational energy?
Necessary Funding Streams: Continued Support	Funding tied to UUV operations support?
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Amar Ammeen		
Bashar Ammeen		
Jeff Kadis		
Nataly Pestana		

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B29. Project Information Form for Project 29: Decentralized Micro-Grid with Fuel Cell Energy Storage: Feasibility Study

Decentralized Micro-grid with Fuel Cell Energy Storage: Feasibility Study

Other Names, Abriviations, etc: Facility-Scale Decentralized Micro-grid with PEM fuel cell, H2 Production and storage, and PV feasibility

Contacts	Name	Phone	Email	Role
POC1	Arthur Rubio	619-553-1904	rubio@spawar.navy.mil	PI
POC2	Jeremy Poche			
POC3	Mike Putman			

Period of Performance: FY16 --- FY17

Base / Installation: TBD

Technology Description

Provide a brief description of the technology being implemented in this research project

Determine if implementing a hybrid decentralized micro-grid with energy storage is a feasible solution for increasing energy security. Microgrid will include PV generation, H2 fuel cell storage, H2 production from PEM.

Select up to three different technology types to categorize this project

Technology Type 1	Microgrids, Islanding, Isolation
Technology Type 2	Energy Storage
Technology Type 3	Renewable Integration

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Increased energy independence and assurance as energy is stored and harvested from renewable sources. Modeling and simulation used to size and select components for microgrid implementation

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Integrated alternative-powered backup power systems
Potential	Improved efficiency or alternative fueled vehicles on installation
Potential	Improved decision support capability for sizing backup generators
Potential	Reduced requirement for backup generators to assure power

Page 1

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Potential	Improved efficiency or effectiveness of existing renewable energy storage
Potential	Improved capability to estimate ROI of renewable systems
Demonstrated	Improved decision support capabilities for investing in renewable systems

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Demonstrated	Incorporated energy storage to reduce peak power demand

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Potential	Power modeling used to optimize grid configuration or expansion
Demonstrated	Modeling and simulation to inform energy infrastructure investments

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Reduced reliance on outside energy suppliers
Potential	Increased energy storage capability for independent operation

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Potential	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

Potential	Improved energy access in remote facilities

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

Page 2

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Improved capability to estimate ROI for fuel cell energy storage projects

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Identification of contractors with experience installing large scale fuel cells

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

Reduced maintenance needs, higher up-front costs and lower efficiency

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	large scale fuel cells not yet commerically mature, requires coordination with multiple contractors
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	
Environmental or Installation-specific challenges	Possible barriers in allocating space for large fuel cell and hydrogen storage, dependent on scale of project
Accessibility of required components	must coordinate with multiple contractors to build a complete system

Process Challenges

Certification or Approval requirements	interconnect agreements needed to facilitate grid-tied systems
Initial Funding or Resource Allocation issues	large up front cost
Continued Funding or Resource Allocation issues	possible contractual delays may force continuation of funds to complete projects
Contracting / Procurement	difficulties in coordinating multiple contractors for sourcing parts and installing components

Stakeholder Challenges

Impact on and Approval of certain stakeholders	location of hydrogen storage could impact certain stakeholders
Limitations from stakeholder needs	limitations on available space suitable for system
Operation and support labor requirements	
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	possible maintenance considerations
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Jeremy Poche		

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B30. Project Information Form for Project 30: Optimization of a Decentralized Micro-grid with PEM Fuel Cell, Electrolyzer and H2 Storage

Optimization of a Decentralized Micro-grid with PEM Fuel Cell, Electrolyzer and H2 Storage

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Arthur Rubio	6195531904	rubio@spawar.navy.mil	PI
POC2	Jeremy Poche			
POC3				

Period of Performance

Base / Installation

Technology Description

Provide a brief description of the technology being implemented in this research project

Decrease the overall power consumption and improve the power stability of Navy and Marine Corps facilities by: Installing and evaluating a micro-grid with a polymer electrolyte membrane (PEM) fuel cell energy storage system; Developing an optimization and control scheme that would allow this system to function efficiently and robustly in a distributed network of similar systems relative to the load profile of a particular building.

Select up to three different technology types to categorize this project

Technology Type 1	Microgrids, Islanding, Isolation
Technology Type 2	Modeling, Optimization, Decision Support
Technology Type 3	Energy Storage

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Improved capability to deploy independent or networked microgrids on naval facilities to improve energy assurance through energy storage and islanding capabilities

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Reduced natural gas needed for heating or installation operations
Potential	Integrated alternative-powered backup power systems
Potential	Reduced frequency of backup generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Potential	Improved efficiency or effectiveness of existing renewable generation
Potential	Improved efficiency or effectiveness of existing renewable energy storage
Potential	Improved capability to integrate renewables into larger grid
Realized	Improved decision support capabilities for investing in renewable systems

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Demonstrated	Incorporated energy storage to reduce peak power demand

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Demonstrated	Modeling and simulation to inform energy infrastructure investments

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Automated backup systems for critical systems
Demonstrated	Reduced reliance on outside energy suppliers
Demonstrated	Increased energy storage capability for independent operation
Potential	Improved islanding capability to isolate and protect critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Potential	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

Potential	Improved energy access in remote facilities

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Issues related to test system setup: software communications, deionized water conductivity, labview integration. Personnel leaving and acquisition issues

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Demonstrated increased capability to integrate cost-effective energy storage and improve power stability on naval facilities

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Improved capability to intregrate with existing systems

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

system would require less maintenance than alternative energy storage systems due to lack of moving parts or battery degradation

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

Achieved TRL5 for PEM microgrid system

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	system ROI limited by efficiency of PEM fuel cell technology maturity
Maturity/suitability of specific systems used in this project	limitations due to test bed setup
Integration with Navy-specific systems	Efficiency of system limits potential use cases
Environmental or Installation-specific challenges	
Accessibility of required components	

Process Challenges

Certification or Approval requirements	approval required to integrate system with larger power grid or as a backup power supply
Initial Funding or Resource Allocation issues	cost of components limits scale of demonstration project
Continued Funding or Resource Allocation issues	
Contracting / Procurement	Possible lengthy procurement process for components

Stakeholder Challenges

Impact on and Approval of certain stakeholders	approval and support from PW needed to integrate large scale systems
Limitations from stakeholder needs	limited efficiency of fuel cell system may limit potential applications
Operation and support labor requirements	
Necessary Funding Streams: Integration	large up front cost for installing system
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Jeremy Poche		

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B31. Project Information Forms for Project 31: Mobile EMS

Mobile EMS

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Dr. Giovanna Oriti	831-656-2637	goriti@nps.edu	PI
POC2	Dr. Julian			
POC3				

Period of Performance: FY15 --- FY16

Base / Installation: NPS

Technology Description

Provide a brief description of the technology being implemented in this research project

The goal of this project is to design and build an energy management system (EMS) packaged so that it can be moved to different locations for practical demonstrations and microgrid studies. It is also used as an educational platform for NPS students.The EMS prototype allows a microgrid to operate connected to the grid or in islanding mode when power from the main grid is not available

Select up to three different technology types to categorize this project

Technology Type 1	
Technology Type 2	
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Improved microgrid demonstration and education capabilities to justify further expansion of larger microgrid projects

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Integrated alternative-powered backup power systems
Potential	Reduced requirement for backup generators to assure power

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Potential	Added renewable energy generation capability (wind, solar, etc)
Potential	Integrated or expanded renewable energy storage
Potential	Improved capability to estimate ROI of renewable systems
Potential	Improved decision support capabilities for investing in renewable systems

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Potential	Incorporated energy storage to reduce peak power demand

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Potential	Technology reduces need for specialized training

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Reduced reliance on outside energy suppliers
Potential	Increased energy storage capability for independent operation
Potential	Improved islanding capability to isolate and protect critical systems
Potential	Improved capability to restore grid functionality after outages

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Realized	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

Potential	Increased awareness of energy use
Demonstrated	Improved energy access in remote facilities

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Potential	Improved control capabilities for future experiments

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Demonstration of intelligent energy management capabilities that could be integrated into larger microgrid systems

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

Demonstration project, would need to be scaled up to be practical for long term installation use

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

Demonstrate EMS capabilities for larger microgrids

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Limited availability of prepackaged COTS systems for larger integration
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	
Environmental or Installation-specific challenges	Interconnection issues with base power grid
Accessibility of required components	

Process Challenges

Certification or Approval requirements	interconnect agreements with local utility providers
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	funding for traveling demonstrations
Contracting / Procurement	

Stakeholder Challenges

Impact on and Approval of certain stakeholders	PW approval needed to connect into larger power grid
Limitations from stakeholder needs	
Operation and support labor requirements	support labor needed for traveling demonstrations
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	System must be updated periodically to adapt to changing needs

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B32. Project Information Form for Project 32: Photovoltaic Power Conditioning System for an Energy Management System (EMS)

Photovoltaic Power Conditioning System for an Energy Management System (EMS)

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Giovana Oriti	831-656-2637	goriti@nps.edu	PI
POC2	Alex Julian			
POC3				

Period of Performance: FY16 --- FY18

Base / Installation: NPS

Technology Description

Provide a brief description of the technology being implemented in this research project

Continue development of Energy Management Systems to incorporate supercapacitor energy storage to increase battery life and improve the effectiveness of energy storage. Improvement of solar energy controller to maximize energy production from PV

Select up to three different technology types to categorize this project

Technology Type 1	Energy Storage
Technology Type 2	Renewable Integration
Technology Type 3	Microgrids, Islanding, Isolation

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Improved efficiency of energy management system

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use	
Potential	Integrated alternative-powered backup power systems
Potential	Reduced frequency of backup generator use
Potential	Reduced requirement for backup generators to assure power

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management	
Potential	Improved efficiency or effectiveness of existing renewable generation
Potential	Improved efficiency or effectiveness of existing renewable energy storage
Potential	Improved capability to estimate ROI of renewable systems

Page 1

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption	
Potential	Incorporated energy storage to reduce peak power demand
Potential	Reduced installation power consumption through improved distribution efficiency

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions	
Potential	Power modeling used to optimize grid configuration or expansion

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.	

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems	
Potential	Automated backup systems for critical systems
Potential	Reduced reliance on outside energy suppliers
Potential	Increased energy storage capability for independent operation

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure	

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above	
Potential	Improved decision support tools to inform future investments or funding requirements
	Improved battery cycle life on microgrids

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?	
Potential	Improved energy access in remote facilities

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?	

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?	

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

Page 2

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Improved efficiency in energy management systems that can be scaled up to larger microgrid systems

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Need to develop a commercially-available product or system that provided the same benefits of the custom-build lab solution

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

Improved efficiency in energy management systems that can be scaled up to larger microgrid systems

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

Adding supercapacitors to battery systems improves battery life and may improve cost effectiveness of battery energy storage systems

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	lack of mature COTS solutions
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	
Environmental or Installation-specific challenges	possible challenges when integrating with power grids at specific bases
Accessibility of required components	lack of mature COTS solutions

Process Challenges

Certification or Approval requirements	approval required for integration into larger grid or power distribution networks
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	periodic battery replacement
Contracting / Procurement	component procurement, possible contracting challenges when integrating larger systems

Stakeholder Challenges

Impact on and Approval of certain stakeholders	Installation of EMS must not interfere with grid operation, need to coordinate with PW
Limitations from stakeholder needs	
Operation and support labor requirements	maintenance needed to ensure battery health and replace degraded batteries
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title
Oriti et all	Power Electronics Enabled Energy Management Systems
Oriti et all	SLR Converter Design for Multi-Cell Battery Charging
Oriti et all	Reducing Fuel Consumption in a Forward Operating Base using an Energy Management System

Journal Articles, Publications

Author(s)	Title
Oriti et all	Reducing fuel consumption at a remote military base: introducing an energy management system
Oriti et all	Battery Management System with Cell Equalizer for Multi-Cell Battery Packs
Oriti et all	PV Power Conditioning System with LLC Resonant Converter in DCM

NPS Student Theses

Author(s)	Title (if known)
LCDR Gabe Hernandez	
LT Jason Valiani	
LT Cody Keesee	

B33. Project Information Form for Project 33: RTU Challenge

RTU Challenge

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Max Hogan	805-982-1557	max.hogan@navy.mil	
POC2	Paul Kistler	805-982-1387	paul.kistler@navy.mil	
POC3				

Period of Performance: FY14 --- FY17

Base / Installation: NAS Key West

Technology Description

Provide a brief description of the technology being implemented in this research project

Test and implement new-to-market high efficiency roof top air conditioning units with potential energy savings of 40%

Select up to three different technology types to categorize this project

Technology Type 1	Implementation, Integration, Adaptation
Technology Type 2	
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Reduce the energy demands of HVAC systems by adopting new energy efficient rooftop AC units

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Demonstrated	Reduced installation power consumption through improved end-user efficiency

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Significant delays caused by changing requirements, manufacturing delays, and an incorrect equipment order

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

Project completion date delayed by three years

Page 2

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Demonstrated the viability of new RTUs

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Ensure RTUs won't corrode in a coastal environment

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

More efficient than systems currently in use

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

RTU measured performance appears to reflect manufacturures rating (after adjusting for local climate conditions)

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Possible delays in manufacturing of new units
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	
Environmental or Installation-specific challenges	System efficiency will vary based on local climate
Accessibility of required components	Limited number of new high efficiency RTUs available

Process Challenges

Certification or Approval requirements	Vendor approval authorizations
Initial Funding or Resource Allocation issues	Must secure funding for installation costs
Continued Funding or Resource Allocation issues	New RTU design may require additional maintenance funding
Contracting / Procurement	Vendor approval and contracting authorizations to install and maintain units

Stakeholder Challenges

Impact on and Approval of certain stakeholders	End user approval of new AC systems
Limitations from stakeholder needs	Possible reliability considerations with new technology
Operation and support labor requirements	Maintenance requirements unknown
Necessary Funding Streams: Integration	Up front installation costs
Necessary Funding Streams: Continued Support	Maintenance requirements unknown
Continued feedback and improvement	environmental operating conditions could necessitate further modifications

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B34. Project Information Sheet for Project 34. Improved Wind Load Design for Rooftop PV Systems

Improved Wind Load Design for Rooftop PV Systems

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Fernand Marquis	8316562880	fmarquis@nps.edu	PI
POC2				
POC3				

Period of Performance: FY14 --- FY15

Base / Installation: NPS

Technology Description

Provide a brief description of the technology being implemented in this research project

Designwindresistantrooftopphotovoltaicsystems(systems,aerospace,mechanical,andmaterialsdesign). Develop light-weight, non-adhesive, non-ballasted and non-penetrating, rooftop PV mounting solutions. Demonstratethattheintegratedsystemscanwithstanda3-second gust wind speed of 150 mph without the use of adhesives or additional ballasts. Validate that the product will last up to 20 years such as through the use of accelerated weathering tests

Select up to three different technology types to categorize this project

Technology Type 1	Energy Production
Technology Type 2	
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Improved ROI on PV systems by preventing extreme weather damage to systems, and enabling PV systems at locations with more extreme weather events

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Potential	Added renewable energy generation capability (wind, solar, etc)
Demonstrated	Improved efficiency or effectiveness of existing renewable generation
Demonstrated	Improved capability to estimate ROI of renewable systems
Demonstrated	Improved decision support capabilities for investing in renewable systems

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Potential	Modeling and simulation to inform energy infrastructure investments

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Demonstrated	Reduced contractor support required to install, maintain, or operate technology
Demonstrated	Technology requires less maintenance labor than alternative systems

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Realized	Reduced wear and tear on mechanical systems
Demonstrated	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

Potential	Improved energy access in remote facilities

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Scheduling for wind tunnel use and coordinating testing dates with completion of scale models

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Improved capability to extend lifetime of PV installations in areas with frequent extreme weather events

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	limited availablity of mature commercial solutions that meet navy-specific needs
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	
Environmental or Installation-specific challenges	PV mounting constraints dependent on facility roof types
Accessibility of required components	Delays for Commercial production of NPS-designed mounting systems

Process Challenges

Certification or Approval requirements	PW and contracting approval to install PV systems, possible interconnect agreements with local utilities
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	
Contracting / Procurement	Contracting to install PV systems

Stakeholder Challenges

Impact on and Approval of certain stakeholders	
Limitations from stakeholder needs	Limitiation based on roof type of specific buildings
Operation and support labor requirements	
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	Long term feedback needed to ensure that system life cycle performance matches scale model results

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B35. Project Information Sheet for Project 35: Marine Corps Base Hawaii Energy Management Evaluation (MCHB E-Manage) Seed

Marine Corps Base Hawaii Energy Management Evaluation (MCBH E-Manage) Seed

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Tyler Chun	808-471-3494	tyler.chun@navy.mil	PI
POC2	Jack Munechika			
POC3	Eric Inouye			

Period of Performance: FY13 --- FY14

Base / Installation: MCBH

Technology Description

Provide a brief description of the technology being implemented in this research project

From "Bases to Battlefield", infuse an energy ethos into USMC culture, manage energy performance, and reduce energy intensity. The objective is to evaluate a cost-effective energy management approach at MCB Hawaii. Financial –Capital Investment (Return on Investment (ROI), Easeof Integration, Easeof Utility –Human Interaction

Select up to three different technology types to categorize this project

Technology Type 1	
Technology Type 2	
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Improved awareness of energy use on base, data regarding specific energy use

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Page 1

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Demonstrated	Reduced installation power consumption through improved end-user efficiency
Demonstrated	Reduced installation power consumption through building control automation

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Potential	Power modeling used to optimize grid configuration or expansion
Realized	Improved metering and monitoring of installation energy use
Potential	Improved diagnostic capabilities for energy infrastructure components
Demonstrated	Modeling and simulation to inform energy infrastructure investments

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Potential	Improved monitoring and detection of potential cyber threats

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Potential	Increased ability to diagnose need for preventative maintenance
Realized	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

Realized	Increased awareness of energy use

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

Realized	Real-time monitoring of energy systems

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Realized	Improved access to energy use data

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

Page 2

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Improved energy monitoring capabilities

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	Energy monitoring systems must interface with legacy systems
Environmental or Installation-specific challenges	
Accessibility of required components	

Process Challenges

Certification or Approval requirements	possible permitting requirements
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	
Contracting / Procurement	

Stakeholder Challenges

Impact on and Approval of certain stakeholders	Coordination with public works to install energy monitoring system
Limitations from stakeholder needs	
Operation and support labor requirements	
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B36. Project Information Form for Project 36: Validate SIREN Computer Modeling

Validate SIREN Computer Modeling

Other Names, Abriviations, etc:	

Contacts	Name	Phone	Email	Role
POC1	Ben Wilcox	805-982-2180	benjamin.p.wilcox@navy.mil	PI
POC2	Yuktaka Sugiyama			
POC3	Kurt Myers			

Period of Performance		
FY14	---	FY16

Base / Installation
NBVC San Nicolas Island

Technology Description

Provide a brief description of the technology being implemented in this research project

Further develop SIREN microgrid design software utilizing weather models to predict power generation from wind & solar and changes in load caused by weather conditions (heating & cooling), incorporate stored energy management, and integrate with LIDAR wind measurement trailer

Select up to three different technology types to categorize this project

Technology Type 1	Modeling & Optimization
Technology Type 2	Microgrids, Islanding, Isolation
Technology Type 3	Decision Support

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

SIREN model can help reduce costs of microgrid planning (especially storage) and simplify acquisition by providing better estimates of electrical load changes and renewable generation changes due to weather events

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Improved decision support capability for sizing backup generators

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Potential	Improved decision support capabilities for investing in renewable systems
Potential	Improved capability to estimate ROI of renewable systems
Potential	Improved efficiency or effectiveness of existing renewable energy storage

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Potential	Reduced installation power consumption through improved distribution efficiency

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Demonstrated	Power modeling used to optimize grid configuration or expansion
Demonstrated	Modeling and simulation to inform energy infrastructure investments
Potential	Improved metering and monitoring of installation energy use

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Demonstrated	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

Demonstrated	Improved documentation of infrastructure

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Potential	Improved access to energy use data
Potential	Improved control capabilities for future experiments

Other

B37. Project Information Sheet for Project 37: LIDAR Wind Measurement Experiments

LIDAR Wind Measurement Experiments

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Ben Wilcox	805-982-2180	benjamin.p.wilcox@navy.mil	PI
POC2	Yuktaka Sugiyama			
POC3	Kurt Myers			

Period of Performance: FY14 --- FY16

Base / Installation: NRS Jim Creek

Technology Description

Provide a brief description of the technology being implemented in this research project

Develop portable trailer with LIDAR mast system and software used to measure wind energy potential at sites with rough terrain or open ocean.

Select up to three different technology types to categorize this project

Technology Type 1	Modeling & Optimization
Technology Type 2	Decision Support
Technology Type 3	Renewable Generation

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Improved capability to size renewable production resources (wind and solar) for microgrids in austere environments; Improved ability to estimate electrical load and generation potential in response to weather events

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Demonstrated	Improved capability to estimate ROI of renewable systems
Demonstrated	Improved decision support capabilities for investing in renewable systems

Page 1

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Potential	Modeling and simulation to inform energy infrastructure investments

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Demonstrated	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

	Improved wind modeling capability

Other

B38. Project Information Form for Project 38: Shroud with RF Mesh to Suppress Radar Cross-Section of Small World Turbine

Shroud with RF Mesh to Suppress Radar Cross-section of Small Wind Turbine

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Ben Wilcox	805-982-2180	benjamin.p.wilcox@navy.mil	Co-PI
POC2	David Jenn	831-656-2254	jenn@nps.navy.mil	Co-PI
POC3				

Period of Performance: FY15 --- FY17

Base / Installation: NBVC Port Hueneme

Technology Description

Provide a brief description of the technology being implemented in this research project

Radar absorbent material shrouds used to suppress Doppler filtered radar cross-section of wind turbine rotors in order to prevent wind turbine interference near line-of-sight radars, permitting wind power generation near installations with these radar systems

Select up to three different technology types to categorize this project

Technology Type 1	Renewable Generation
Technology Type 2	Other
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Enables wind generation at sites that would otherwise not allow it due to radar interference

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Potential	Added renewable energy generation capability (wind, solar, etc)
Potential	Improved efficiency or effectiveness of existing renewable generation

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Reduced reliance on outside energy suppliers

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Delays in shroud fabrication, loss of key personnel, unexpected properties of RF mesh

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

Missed window for testing at US Army 7X10 wind tunnel tests in FY17

What would you describe as the greatest benefit(s) of having completed this demonstration project?

enable wind turbine energy at naval installations using line-of-sight radar systems

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

demonstrate that wind turbine shrouds increase wind power output and prevent radar interference

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

Enable new wind installations, improving diversity of naval facility energy sources

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

Demonstrated reduced radar interference in 1/30 scale model shroud configurations

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Exposure to windfarm compatability issues

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Shroud Technology still in early stages of development
Maturity/suitability of specific systems used in this project	unable to test systems at larger scales thus far
Integration with Navy-specific systems	radar interference measurements are done on a case-by-case basis
Environmental or Installation-specific challenges	radar interference measurements are done on a case-by-case basis
Accessibility of required components	difficulty in fabricating radar shrouds. No commercially available shrouds yet

Process Challenges

Certification or Approval requirements	Approval process needed to approve shrouded wind turbines for use at airfields and other locations with line-of-sight radar
Initial Funding or Resource Allocation issues	funding timelines must agree with availability of testing facilities
Continued Funding or Resource Allocation issues	possible maintenance considerations on shrouded turbines
Contracting / Procurement	contracting mechanism to install shrouds on turbines

Stakeholder Challenges

Impact on and Approval of certain stakeholders	need buy-in of PW or contractors who would install shrouds on turbines
Limitations from stakeholder needs	safety and design constraints in adding shrouds to existing available wind turbines
Operation and support labor requirements	possible maintenance considerations
Necessary Funding Streams: Integration	site-specific testing requires funding to line up with availability of personnel
Necessary Funding Streams: Continued Support	maintenance
Continued feedback and improvement	need to establish mechanism to receive feedback on long-term performance of shrouded turbines

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B39. Project Information Form for Project: Liquid Air Energy Storage (LAES)

Liquid Air Energy Storage (LAES)

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Ken Ho	(805) 982-1636	ken.ho@navy.mil	PI
POC2	Dustin Talley			
POC3	Matthew Barnet			

Period of Performance: FY15 --- FY17

Base / Installation: JBPHH

Technology Description

Provide a brief description of the technology being implemented in this research project

Excess or off-peak power is used to power an air liquefier. Liquid air is stored in tanks at low pressure until needed. Liquid air is pumped to high pressure, evaporated, and heated. The resulting high pressure gas drives a turbine to generate electricity. This effort included a laboratory mockup and analysis of costs & efficiency for full scale design.

Select up to three different technology types to categorize this project

Technology Type 1	Energy Storage
Technology Type 2	Waste Energy Recovery
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Research endeavors to determine optimal operational conditions and financial justification for LAES, to provide safe and environmentally benign large scale energy storage solution, and to increase renewable energy penetration and micro-grid energy resiliency.

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Integrated alternative-powered backup power systems
Potential	Reduced frequency of backup generator use
Potential	Reduced requirement for backup generators to assure power

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Demonstrated	Integrated or expanded renewable energy storage
Demonstrated	Improved capability to estimate ROI of renewable systems
Potential	Improved efficiency or effectiveness of existing renewable energy storage

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Potential	Incorporated energy storage to reduce peak power demand

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Automated backup systems for critical systems
Potential	Reduced reliance on outside energy suppliers
Demonstrated	Increased energy storage capability for independent operation

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

Potential	Improved energy access in remote facilities

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Potential	Improved control capabilities for future experiments

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

High system costs >$50M, only cost competitive at large scale >10MW; Requires lots of land >35,000sqft

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

Only able to complete a mock-up and cost analysis

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Established techinal requirements, stakeholder buy-in, and business case;

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Technology needs to become economically viable at a smaller scale to fit within budget constraints.

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

Technology requires significant upfront investment >$50M and can only be implemented effectively at large scales. Technology uses combination of relatively mature technologies that should be fairly robust with long life cycle once the market matures

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

High potential return on investment when technology matures at a smaller scale

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Thermodynamics analysis, business case study, procedural experiences

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Few large-scale demonstration projects exist; technology market is not yet mature.
Maturity/suitability of specific systems used in this project	Demonstration components were only a mock-up
Integration with Navy-specific systems	Technology is only cost-competitive on large-scale systems, which would require large investments that would be hard to fund
Environmental or Installation-specific challenges	Technology is only cost-competitive on large-scale systems, which would require large amounts of land. Cost-effective operation would require existing renewable generation capabilities and/or utility provider grid integration agreements
Accessibility of required components	market not yet fully mature

Process Challenges

Certification or Approval requirements	Market is not mature, so small number of vendors would impede contracting process. Cost effective operation would require integrating with larger grid and would involve utility interconnection agreements
Initial Funding or Resource Allocation issues	Requires enormous upfront investment.
Continued Funding or Resource Allocation issues	Mechanical components may require periodic maintenance
Contracting / Procurement	Not enough suitable vendors for equipment,

Stakeholder Challenges

Impact on and Approval of certain stakeholders	Large land requirement might infringe upon other stakeholders
Limitations from stakeholder needs	
Operation and support labor requirements	periodic maintenance for mechanical components
Necessary Funding Streams: Integration	No current funding streams exist to support the large front-end cost of $50M
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	Further study required to optimize effectiveness of stored energy use

Intern Involvement

Please list any interns who were involved in this project, as well as the year(s) they worked and where they are now (if known).
If necessary, use an "x" to represent any interns whose names are unknown.

Intern Name	Year (if known)	Where are they now? (if known)
Andria Marquez		
Michalla Geer		(STEM, not ESTEP)
Bashar Ameen		
Kyle Abrahamson		

References

Please list any technical papers, publications, or theses that resulted from this project.

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B40. Project Information Form for Project 40: Waste to Energy Hydrogen Generation

Waste to Energy Hydrogen Generation

Other Names, Abriviations, etc: Waste to Hydrogen

Contacts	Name	Phone	Email	Role
POC1	Ken Ho	805-982-1636	ken.ho@navy.mil	
POC2	Keith Archbold			
POC3	Bryan Law			

Period of Performance: FY15 --- FY18

Base / Installation:

Technology Description

Provide a brief description of the technology being implemented in this research project

Plasma Enhanced Melter processes hazardous waste and recovers hydrogen gas and recyclable materials to achieve a net positive energy recovery and reduce costs associated with disposing of hazardous materials

Select up to three different technology types to categorize this project

Technology Type 1	Renewable Generation
Technology Type 2	Waste Energy Recovery
Technology Type 3	Decision Support

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

PEM waste-to-H2 production offers the capability to create a means of producing H2 gas which can be easily stored, transported, and burned to offset energy demand.

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Integrated alternative-powered backup power systems
Potential	Improved efficiency or alternative fueled vehicles on installation

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Potential	Added renewable energy generation capability (wind, solar, etc)
Potential	Integrated or expanded renewable energy storage
Potential	Improved efficiency or effectiveness of existing renewable energy storage

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Potential	Incorporated energy storage to reduce peak power demand

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Reduced reliance on outside energy suppliers
Potential	Increased energy storage capability for independent operation

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure	

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above	

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?	
What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?	
What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?	

Other

Potential	Provides added benefits to waste management processes as a way to process hazardous wastes, recover recyclable metals, etc

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Environmental permitting process for gas recovery and hazardous materials handling

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

Page 2

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Established process for design, permitting, and construction of PEM melter system

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Environmental certifications to comply with federal regulations

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

Reduces costs associated with preparing hazardous wastes for shipment/disposal; recovers net positive energy in the form of useful hydrogen gas that can be used for electricity generation, power alternative-fueled vehicles, etc; recovers recyclable metals

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	
Environmental or Installation-specific challenges	Novel waste disposal concept requires new permitting process? Installations require special equipment or infrastructure to benefit from hydrogen production
Accessibility of required components	

Process Challenges

Certification or Approval requirements	Special permits required to handle hazardous wastes
Initial Funding or Resource Allocation issues	large upfront investment required
Continued Funding or Resource Allocation issues	
Contracting / Procurement	Limited number of technology providers?

Stakeholder Challenges

Impact on and Approval of certain stakeholders	
Limitations from stakeholder needs	
Operation and support labor requirements	Special training or equipment requirements for handling hazardous materials in this way?
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	Special training or equipment requirements for handling hazardous materials in this way?
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Andria Marquez		

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B41. Project Information Form for Project 41: Adhered PV Reliability (Completed)

Adhered PV Reliability & Performance Validation

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Robert Schoff	805-982-3572	robert.schoff@navy.mil	PI
POC2	Peter Ly			
POC3	Rob Tyzzer			

Period of Performance: FY14 --- FY16

Base / Installation: Guam, Port Hueneme

Technology Description

Provide a brief description of the technology being implemented in this research project

Thin-layer PV panels that adhere directly to rooftop surfaces to minimize wind exposure and penetrations. Effort also included power modeling/measurements for thin film panels

Select up to three different technology types to categorize this project

Technology Type 1	Renewable Generation
Technology Type 2	Implementation, Integration, Adaptation
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Thin-film adhered PV panels offer renewable generation capabilities on rooftop surfaces that can not support panel-mounted PV cells for reasons such as rooftop penetration issues, security concerns, etc

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Reduced natural gas needed for heating or installation operations
Potential	Integrated alternative-powered backup power systems
Potential	Reduced requirement for backup generators to assure power

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Demonstrated	Added renewable energy generation capability (wind, solar, etc)
Demonstrated	Improved decision support capabilities for investing in renewable systems
Potential	Improved efficiency or effectiveness of existing renewable generation

Page 1

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Demonstrated	Modeling and simulation to inform energy infrastructure investments

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Demonstrated	Reduced contractor support required to install, maintain, or operate technology

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Demonstrated	Reduced reliance on outside energy suppliers

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure	

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above	
Potential	Reduced wear and tear on mechanical systems

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?	

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?	

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?	

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Limited number of thin film panel vendors, Increase heat flux creates complicates energy economics (possible increased AC costs)

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

difficult purchasing process, additional study needed for rooftop heat retention

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Improved understanding of adhered thin film PV performance, heat transfer, and suitability for different roof types

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

Thin film adhered PV allows installation of PV capabilities on rooftops that could not support pannel-mounted PV arrays

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

Improved understanding of performance characteristics to help determine suitability for future applications

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Thin film PV is less efficient, leading to lower ROI
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	Thin Film pv system used dependent on rooftop material
Environmental or Installation-specific challenges	In hot climates, increased heat flux from adhered PV panels might create additional demand for cooling, offsetting energy generation
Accessibility of required components	COTS product but only available from a few suppliers

Process Challenges

Certification or Approval requirements	environmental considerations for increased heat flux
Initial Funding or Resource Allocation issues	System acquisition and rooftop surface prep
Continued Funding or Resource Allocation issues	Requires a further understanding of long term maintenance requirements / repair / replacement
Contracting / Procurement	Limited number of suppliers complicates procurement process

Stakeholder Challenges

Impact on and Approval of certain stakeholders	increased heat flux in buildings with thin film PV
Limitations from stakeholder needs	Buildings with certain climate needs (datacenters) may be inelligible for thin film rooftop pv due to heat flux
Operation and support labor requirements	periodic cleaning and checking adhesion
Necessary Funding Streams: Integration	Installation costs of PV and associated power systems
Necessary Funding Streams: Continued Support	periodic cleaning and checking adhesion
Continued feedback and improvement	Need process to reassess thin film pv application if increased cooling costs or complaints become cumbersome.

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B42. Project Information Form for Project 42: Optimized Cooling for Concentrated Photovoltaic Systems

Optimized Cooling for Concentrated Photovoltaic Systems

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Dr. Sanjeev Sathe	831-656-6288	sbsathe@nps.edu	PI
POC2	Dr. Knox Millsaps			
POC3	Dr. Dan Nussbaum			

Period of Performance

FY15 --- FY17

Base / Installation

NPS

Technology Description

Provide a brief description of the technology being implemented in this research project

Find Optimized Cooling Solutions for Concentrated Photovoltaic System (currently showing high promise for highest cell level efficiencies) w.r.t Cost, Efficiency or Reliability for the DoD Energy-grids

Select up to three different technology types to categorize this project

Technology Type 1	
Technology Type 2	
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Improved PV efficiency

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Demonstrated	Improved efficiency or effectiveness of existing renewable generation
Demonstrated	Improved capability to estimate ROI of renewable systems
Demonstrated	Improved decision support capabilities for investing in renewable systems

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Reduced reliance on outside energy suppliers

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Demonstrated	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

Potential	Improved energy access in remote facilities

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Improved understanding of design-space tradeoffs for different PV cooling systems

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

Improved power output from PV systems

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

improved understanding of design space tradeoffs reduces risk of incorporating sub-optimal solutions

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Limited availability of COTS PV cooling solutions
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	
Environmental or Installation-specific challenges	Environmental conditions may limit effectiveness of cooling solutions
Accessibility of required components	high cost of cooling solutions creates restrictions on ROI used to justify cooling projects

Process Challenges

Certification or Approval requirements	
Initial Funding or Resource Allocation issues	high up-front cost of implementing solutions
Continued Funding or Resource Allocation issues	
Contracting / Procurement	Contractor support required to implement cooling solutions

Stakeholder Challenges

Impact on and Approval of certain stakeholders	
Limitations from stakeholder needs	Existing PV installations may be built in a way that precludes installing cooling systems
Operation and support labor requirements	
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	Possible periodic maintenance requirements
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)
LT Robert Riley	
LT Derek Fletcher	
LT Matt Hayes	

B43. Project Information Form for Project 43: Shore Based Test of X-Band Radar Hardware on Mast for Real Time Hydrodynamic Control of Wave Energy Conversion

Shore Based Test of X-Band Radar Hardware on Mast for Real Time Hydrodynamic Control of Wave Energy Conversion

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Ben Wilcox	805-982-2180	benjamin.p.wilcox@navy.mil	
POC2	Warren Bartel			
POC3	Umesh Korde			

Period of Performance: FY16 --- FY18

Base / Installation: NBVC Port Hueneme

Technology Description

Provide a brief description of the technology being implemented in this research project

Use X-band radar and computer modeling to predict wave forces on a wave-energy generating system and apply controls to maximize power generation

Select up to three different technology types to categorize this project

Technology Type 1	Renewable Generation
Technology Type 2	Modeling & Optimization
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Increased energy generation and ROI from wave energy generation

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Potential	Improved efficiency or effectiveness of existing renewable generation
Potential	Improved capability to estimate ROI of renewable systems

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Contracting challenges and changes to test site

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

Delays in experimental validation

What would you describe as the greatest benefit(s) of having completed this demonstration project?

demonstrated method for improving efficiency of wave energy generation

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

prepackaged solution to implementing effective wave energy generation

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

improved efficiency of wave energy generation mechanisms

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Improved modeling skills

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	technology not yet mature enough for wide-scale deployment
Maturity/suitability of specific systems used in this project	further testing needed
Integration with Navy-specific systems	possible adaptations needed to integrate with Navy bouy characteristics
Environmental or Installation-specific challenges	Complications arriving from using radar systems at naval facilities,
Accessibility of required components	

Process Challenges

Certification or Approval requirements	approval needed for radar applications
Initial Funding or Resource Allocation issues	site-specific calibrations may be needed, requiring extra funding for labor
Continued Funding or Resource Allocation issues	
Contracting / Procurement	Possible contracter support may be needed to integrate radar data with bouy controls

Stakeholder Challenges

Impact on and Approval of certain stakeholders	non-interference with other shore-based radar applications at naval bases
Limitations from stakeholder needs	bouy controls may increase maintenance requirements of wave-energy systems, collaboration needed with maintainers
Operation and support labor requirements	bouy controls may increase maintenance requirements of wave-energy systems, collaboration needed with maintainers
Necessary Funding Streams: Integration	possible calibration requirements for new installations
Necessary Funding Streams: Continued Support	long term maintenance condsiderations
Continued feedback and improvement	feedback needed from maintenance crews and energy managers

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B44. Project Information Form for Project 44: Valuation and Financing for Energy Storage

Valuation and Financing for Energy Storage

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Dustin Talley	805-982-5987	dustin.talley@navy.mil	PI
POC2	Ming Liu			
POC3	Ken Ho			

Period of Performance: FY16 --- FY17

Base / Installation: EXWC

Technology Description

Provide a brief description of the technology being implemented in this research project

Develope a financial model that captures the financial benefits of energy storage projects that would not be accounted for under current eROI model to make energy storage projects "affordable" under current policy

Select up to three different technology types to categorize this project

Technology Type 1	Energy Storage
Technology Type 2	Decision Support
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

New ROI model would enable increased funding for energy storage projects, enabling future efforts that would otherwise be unattainable

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Potential	Improved decision support capabilities for investing in renewable systems
Potential	Improved capability to estimate ROI of renewable systems

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Potential	increased ability to estimate full value of electricity storage, therefore clearer understanding of power consumption limits

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Potential	New model provides more accurate capacity and clearer costs, allowing for more efficient fund distribution

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Potential	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Potential	Improved ability to justify funding for future energy storage projects

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Obtaining an unlocked copy of the eROI tool that is currently used to estimate the value of installation energy projects; different organizations use different metrics to assess the value of energy resiliency and assurance; getting high-level decision makers to accept new metrics

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

Going against an established process makes implementing new metrics more difficult

Page 2

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Demonstrate an improved process for assessing the potential value of energy storage projects, which will make it easier for future PIs to receive funding for innovative energy storage efforts

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Defense sector and private industry have different priorities and motivations when implementing energy storage technologies, which commercial energy models would need to be adapted to represent the Navy's needs

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

This new energy storage value assessment process would improve access to energy storage technologies on installations

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

Promoting new energy valuation methodology will improve installations' access to technologies that improve energy resilience

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	New energy valuation system has yet to be tested in real world case studies
Maturity/suitability of specific systems used in this project	N/A
Integration with Navy-specific systems	Inputs into energy valuation tool amy be subjective or vary by installation needs
Environmental or Installation-specific challenges	Installations with different functions or priorities may value energy differently
Accessibility of required components	Possible lack of data required for accurate assessments

Process Challenges

Certification or Approval requirements	New ROI method for energy storage investments would require official approval/adoption
Initial Funding or Resource Allocation issues	new eROI method requires labor for accurate assessment of installation energy assets
Continued Funding or Resource Allocation issues	Energy valuation and resiliency assessments will need to be updated over time
Contracting / Procurement	Accurate energy infrastructure assessments may require coordinating with contractors responsible for infrastructure

Stakeholder Challenges

Impact on and Approval of certain stakeholders	New stored energy valuation metrics may make other infrastructure improvement projects less desirable
Limitations from stakeholder needs	Time required to gather data and perform evaluation limit potential depth of energy valuation analysis for new projects
Operation and support labor requirements	New energy valuation metrics will need to consider the O&S costs of supporting new energy storage projects
Necessary Funding Streams: Integration	Time and labor required for new assessment of energy projects
Necessary Funding Streams: Continued Support	Periodic study may be needed to ensure new energy valuation metrics are updated as Navy needs change over time
Continued feedback and improvement	Case studies needed to validate new energy resiliency valuation method

Intern Involvement

Please list any interns who were involved in this project, as well as the year(s) they worked and where they are now (if known).
If necessary, use an "x" to represent any interns whose names are unknown.

Intern Name	Year (if known)	Where are they now? (if known)

References

Please list any technical papers, publications, or theses that resulted from this project.

Tech papers

Author(s)	Title
	Internal NAVFAC deliverable report

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B45. Project Information Form for Project 45: Transportable Micro-Grid with Storage

Transportable Micro-grid with Storage

Other Names, Abriviations, etc: Relocatable Microgrid with Storage

Contacts	Name	Phone	Email	Role
POC1	Paul Kistler	805-982-1387	paul.kistler@navy.mil	
POC2	Bruce Garrett			
POC3	Scott Miller			

Period of Performance: FY17 --- FY19

Base / Installation: NBVC Port Hueneme

Technology Description

Provide a brief description of the technology being implemented in this research project

Create and demonstrate portable microgrid system that can be controlled in a cyber secure manner, integrate emerging energy storage technologies,

Select up to three different technology types to categorize this project

Technology Type 1	Microgrids, Islanding, Isolation
Technology Type 2	Energy Storage
Technology Type 3	Implementation, Integration, Adaptation

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

adaptable, portable microgrid to reduce energy demand and allow islanding to provide energy assurance

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Demonstrated	Integrated alternative-powered backup power systems
Demonstrated	Reduced frequency of backup generator use
Demonstrated	Reduced requirement for backup generators to assure power

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Demonstrated	Integrated or expanded renewable energy storage
Demonstrated	Improved capability to integrate renewables into larger grid
Demonstrated	Improved decision support capabilities for investing in renewable systems

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Potential	Incorporated energy storage to reduce peak power demand

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Demonstrated	Automated backup systems for critical systems
Demonstrated	Reduced reliance on outside energy suppliers
Demonstrated	Increased energy storage capability for independent operation
Demonstrated	Improved islanding capability to isolate and protect critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

Demonstrated	Improved energy access in remote facilities

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Construction contractor went bankrupt mid-project; project funding delayed, RMF, EPRI has had issues getting material (batteries) from Tesla, limited info from Tesla is holding up approval process (fire hazard)

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

Project delays,

Page 2

What would you describe as the greatest benefit(s) of having completed this demonstration project?

allows testing various microgrid components in specific applications/settings

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Mostly a matter of finding which specific (combinations of) COTS components work together to meet Navy needs

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

This program will allow testing components before implenting operationally and possibly discovering bugs

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

examples of microgrids that had issues due to lack of test bed

What new skills, competencies, or experience were gained within the Navy workforce during this project?

training on how to operate ca microgrid

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	specific components are mature, but in what combination
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	not yet
Environmental or Installation-specific challenges	integration with existing infrastructure, fire protection, potential for environmental toxins
Accessibility of required components	issues getting complete data from manufacturors, proprietary nature of battery technology details required for approvals

Process Challenges

Certification or Approval requirements	Certifications/approvals for Li-Ion batteries, infrastructure upgrades, interconnect agreement with utility company, everything will be site-specific (loads, tolerance, power quality)
Initial Funding or Resource Allocation issues	installation site-specific funding streams dealing with energy resiliency
Continued Funding or Resource Allocation issues	Periodic battery replacements, trading components
Contracting / Procurement	Challenges in construction contracting process, occasional upgrades to increase capability, parts manufacturors can go out of business

Stakeholder Challenges

Impact on and Approval of certain stakeholders	Must get approval for batteries
Limitations from stakeholder needs	
Operation and support labor requirements	Training required for battery maintenance, long term support with components
Necessary Funding Streams: Integration	funding comes from customers wanting to use test bed
Necessary Funding Streams: Continued Support	battery maintenance and replacement
Continued feedback and improvement	expect to continually upgrade to add testing capability

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B46. Project Information Form for Project 46: Modular Micro-gird (M2G) System

Modular Micro grid (M2G) System

Other Names, Abriviations, etc: M2G

Contacts	Name	Phone	Email	Role
POC1	Robert Okwera	805-982-5177	robert.okwera@navy.mil	
POC2	Yutaka Sugiyama	805-982-1608	yutaka.sugiyama@navy.mil	
POC3	Mark Tukeman			

Period of Performance: FY16 --- FY19

Base / Installation: EXWC

Technology Description

Provide a brief description of the technology being implemented in this research project

Solar PV, EV equipped with V2G exportable power, energy storage (Li-ion/BMS) alone with conventional backup diesel genset to robustly serve critical connected loads while minimizing the use of the utility grid power feed

Select up to three different technology types to categorize this project

Technology Type 1	Renewable Generation
Technology Type 2	Energy Storage
Technology Type 3	Microgrids, Islanding, Isolation

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Improved energy security through standardized microgrids incorpating renewable generation and storage with conventional diesel backup

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Demonstrated	Improved efficiency of fossil fuel backup power systems
Demonstrated	Integrated alternative-powered backup power systems
Demonstrated	Reduced frequency of backup generator use
Demonstrated	Reduced requirement for backup generators to assure power

Page 1

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Demonstrated	Improved capability to integrate renewables into larger grid
Demonstrated	Added renewable energy generation capability (wind, solar, etc)
Demonstrated	Integrated or expanded renewable energy storage

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Demonstrated	Incorporated energy storage to reduce peak power demand

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Automated backup systems for critical systems
Demonstrated	Reduced reliance on outside energy suppliers
Demonstrated	Increased energy storage capability for independent operation

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure	

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above	
Demonstrated	Reduced wear and tear on mechanical systems

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?	
What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?	
What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?	

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Southern California Edison interconnect agreement, managing grid stability, balancing an ad-hoc modular approach

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Demonstrate the feasibility of a robust modular microgrid featuring PV, storage, and backup diesel generation

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Create a standard interconnect agreement for working with utilities, standardize battery storage processes

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

This system would be more robust than alternative microgrid designs

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Mature individual components, but still needs further testing as a complete system
Maturity/suitability of specific systems used in this project	Mature individual components, but still needs further testing as a complete system
Integration with Navy-specific systems	Specific utility or infrastructure interconnect requirements may pose challenges
Environmental or Installation-specific challenges	
Accessibility of required components	Difficult to acquire batteries

Process Challenges

Certification or Approval requirements	Battery acquisition and utility interconnect agreements
Initial Funding or Resource Allocation issues	Funding for equipment and labor for installation
Continued Funding or Resource Allocation issues	funding for maintenance and periodic battery replacement
Contracting / Procurement	contracting labor needed to install specialty equipment

Stakeholder Challenges

Impact on and Approval of certain stakeholders	Require approval from PW
Limitations from stakeholder needs	Possible system maintenance limitations
Operation and support labor requirements	periodic battery health maintenance and replacing old batteries
Necessary Funding Streams: Integration	Need to identify funding stream for acquisition and installation
Necessary Funding Streams: Continued Support	Need to identify funding stream for maintenance
Continued feedback and improvement	Need to establish process for monitoring energy use of microgrid and extra maintenance costs

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Christopher Phelps		

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B47. Project Information Form for Project 47: Wind Effects on Sun-Tracking PV Cell Solar Panels

Wind Effects on Sun Tracking PV Cell Solar Panels

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	M. S. Chandrasekhara	650-604-4269	mchandra@nps.edu	Co-PI
POC2	Randall Olsen	619-553-8713	randall.olsen@navy.mil	Co-PI
POC3				

Period of Performance: FY16 --- FY18

Base / Installation: NPS, Miramar MCAS

Technology Description

Provide a brief description of the technology being implemented in this research project

obtain wind load data and use data to design structural components of sun-tracking PV systems in order to minimize structual loads caused by winds and storm conditions

Select up to three different technology types to categorize this project

Technology Type 1	Renewable Generation
Technology Type 2	Renewable Integration
Technology Type 3	Implementation, Integration, Adaptation

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Increased ability to field sun-tracking PV systems for enhance energy generation in austere environments

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use	

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management	
Potential	Added renewable energy generation capability (wind, solar, etc)
Potential	Improved efficiency or effectiveness of existing renewable generation
Potential	Improved decision support capabilities for investing in renewable systems

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption	

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions	

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy	
Potential	Technology requires less maintenance labor than alternative systems

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from	
Potential	Reduced reliance on outside energy suppliers

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure	

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above	
Potential	Reduced wear and tear on mechanical systems

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?	
Potential	Improved energy access in remote facilities

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?	

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?	

Other

Technology Demonstration Results

Page 2

What were the most significant obstacles encountered in this technology demonstration project?

Site access, panel fabrication delays due to contracting process, coordination issues with PW

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

delays in project progress

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Improved design of panel systems, scale models verified in wind tunnel tests; improved understanding of structural requirements

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

Improved survivability in extreme weather events, but at increased costs

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

Designs have proven successful in scale model wind tunnel tests, need further verification of full size components

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Designs still require testing at full scale
Maturity/suitability of specific systems used in this project	Design of wind-resistant PV arrays may impose constraints on where these PV systems can be installed
Integration with Navy-specific systems	
Environmental or Installation-specific challenges	Technology may still need to address retrofitting existing PV arrays to reduce wind loads
Accessibility of required components	Acquisition challenges yet to be met if these improved designs are to be deployed at larger scales

Process Challenges

Certification or Approval requirements	
Initial Funding or Resource Allocation issues	new wind-resistant PV system design may incur a higher up-front cost to integrate new systems
Continued Funding or Resource Allocation issues	
Contracting / Procurement	PI still needs to identify a supplier or means to mass produce the improved PV systems

Stakeholder Challenges

Impact on and Approval of certain stakeholders	
Limitations from stakeholder needs	
Operation and support labor requirements	Maintenance and operation funding
Necessary Funding Streams: Integration	funding for installation or modification of existing systems
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
John Hernandez	2014-2015	
Gaston Ragazzo	2016	
Youseff Elkassis		

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)
LCDR C J Wagner	

B48. Project Information Form for Project 48: Grid Stability in High Penetration Renewables

Grid Stability in High Penetration Renewables

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Bruce Garrett	805-982-5615	bruce.garrett@navy.mil	PI
POC2	Ken Ho			
POC3	Bob Love			

Period of Performance: FY16 --- FY18

Base / Installation: JBPHH - HI

Technology Description

Provide a brief description of the technology being implemented in this research project

Use mobile power quality meters to assess the performance of power infrastructure in terms of its ability to handle the stresses of high penetration renewable energy sources

Select up to three different technology types to categorize this project

Technology Type 1	Renewable Integration
Technology Type 2	Energy Management & Monitoring
Technology Type 3	Implementation, Integration, Adaptation

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Increased understanding of the problems caused by high penetration PV generation and how it impacts grid stability, and how to mitigate these effects to improve energy resilience

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Reduced frequency of backup generator use
Potential	Reduced requirement for backup generators to assure power

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Potential	Improved efficiency or effectiveness of existing renewable generation
Potential	Improved decision support capabilities for investing in renewable systems

Page 1

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Potential	Power modeling used to optimize grid configuration or expansion
Potential	Improved metering and monitoring of installation energy use
Potential	Improved diagnostic capabilities for energy infrastructure components
Potential	Modeling and simulation to inform energy infrastructure investments

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Improved fault isolation to prevent cascading blackouts
Potential	Improved capability to restore grid functionality after outages

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Potential	Increased ability to diagnose need for preventative maintenance
Potential	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

Potential	Increased awareness of energy use

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

Potential	Real-time monitoring of energy systems
Potential	Improved documentation of infrastructure

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Potential	Improved access to energy use data

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Improved understanding of how to prevent damage to shore power systems and mitigating the effects of instabilities caused by intermittent renewable energy sources.
Improved understanding of JBPHH electrical infrastructure performance

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

This project helps researchers understand the nature and depth of the problem, but does not yet propose full solutions

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	unknown maturity of technologies used to counter the instability effects of intermittent distributed energy sources
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	
Environmental or Installation-specific challenges	Integrating specific systems to improve grid stability will vary from base to base
Accessibility of required components	

Process Challenges

Certification or Approval requirements	Approvals / permitting required to tap into power grid
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	
Contracting / Procurement	

Stakeholder Challenges

Impact on and Approval of certain stakeholders	Results to be shared with NAVFAC energy managers to coordinate on implementing proposed solutions
Limitations from stakeholder needs	
Operation and support labor requirements	
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	Continued support necessary to adapt grid as more renewables installed
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B49. Project Information Form for Project 49: Nanolubricant HVAC Refrigerant

Nanolubrication HVAC Refrigerant

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Paul Kistler	805-982-1387	paul.kistler@navy.mil	
POC2	Mark Kedzierski			
POC3				

Period of Performance: FY17 --- FY19

Base / Installation: TBD, NIST Lab

Technology Description

Provide a brief description of the technology being implemented in this research project

Test nanolubricant refrigerants in waterside chillers with typical COP ratings to determine operating efficiencies and discover potential maintenance issues

Select up to three different technology types to categorize this project

Technology Type 1	Implementation, Integration, Adaptation
Technology Type 2	Other
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Incorporate nanolubricant refrigerant materials to increase the efficiencies of chiller systems with typical COP ratings.

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Potential	Reduced installation power consumption through improved end-user efficiency

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Potential	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Limited number of nanolubricant manufacturers. Difficult funding transfer process, NIST (national institute of science n technology) is doing lab testing for us, but Navy has never really done work with them creating a big process with lawyers and contractors to transfer funds

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

huge project delays

Page 2

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Energy savings with payback period of 2 years?

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Process to avoid voiding warranties on HVAC equipment with new nanolubricant refrigerant

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

Potential of voiding warranties on HVAC equipment, but this can be mitigated through a recent legislative process

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

significant HVAC energy savings

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	new technology requires vetting to avoid voiding warranties
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	Possible maintenance considerations
Environmental or Installation-specific challenges	
Accessibility of required components	few nanolubricant refrigerant manufactureres available

Process Challenges

Certification or Approval requirements	Approval requirements to integrate new refrigerants that may potentially void chiller warranties, implementation would require a change in Unified Facilities Criteria guide/specs
Initial Funding or Resource Allocation issues	could potentially be purchased from ops/maintenance budget
Continued Funding or Resource Allocation issues	possible maintenance funding considerations
Contracting / Procurement	only one nanolubricant refrigerant manufacturer known

Stakeholder Challenges

Impact on and Approval of certain stakeholders	PW buy-in needed to install new nanolubricant refrigerant
Limitations from stakeholder needs	
Operation and support labor requirements	possible maintenance considerations
Necessary Funding Streams: Integration	need to fund PW time to install new refrigerant
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B50. Project Information Form for Project 50: Tunable White LED

Tunable White LED

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Paul Kistler	805-982-1387	paul.kistler@navy.mil	PI
POC2	Konstantinos Papamicha			
POC3	Bang Duong			

Period of Performance: FY17 --- FY19

Base / Installation: NAVFAC EXWC

Technology Description

Provide a brief description of the technology being implemented in this research project

Spectrally Enhanced Lighting and Correlated Color Temperature lighting controls can be implemented to enhance productivity, even at lower light levels which can produce potential energy savings. This project will test new lighting controls giving personnel control over the lighting in their environment.

Select up to three different technology types to categorize this project

Technology Type 1	Implementation, Integration, Adaptation
Technology Type 2	Other
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Allow personnel to control the spectral and CCT properties of the light in their work environments, allowing them to be more productive at potentially lower lighting levels, resulting in potential energy savings

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Potential	Reduced installation power consumption through improved end-user efficiency
Potential	Reduced installation power consumption through building control automation

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Potential	Improved control capabilities for future experiments

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

difficulties in approving lighting control systems, difficulties in attempting to involve UC Davis, contracting vehicles, RMF (risk management framework, cybersecurity) because of required approvals, don't have the people, funding, facilities to go through the RMF process

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

delays, 5 month delay to determine if project would be considered "human testing"

What would you describe as the greatest benefit(s) of having completed this demonstration project?

will give info on lighting if people will dim light when at certain colors/hues, give experience with tunable LED, assuming people dim bluer lights will use less energy, theoretical savings of up to 20% compared to undimmed LED

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

no necessary

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

Increased installation costs due to control systems

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

not yet

What new skills, competencies, or experience were gained within the Navy workforce during this project?

learning what is required for RMF

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Tunable LEDs are readily commercially available
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	Cyber requirements may preclude certain systems based on control architecture
Environmental or Installation-specific challenges	Personal lighting preference may vary
Accessibility of required components	

Process Challenges

Certification or Approval requirements	Got to go through site approval, safety plans, public works, contracting
Initial Funding or Resource Allocation issues	most energy projects are alternative-financed, need to convince that it is a good (profitable) technology.
Continued Funding or Resource Allocation issues	
Contracting / Procurement	ESPC or UESC (Utility Energy Saving Contract), contractor or utility is responsible for operation/maintenance

Stakeholder Challenges

Impact on and Approval of certain stakeholders	will need to be a change to unified facilities criteria (UFC) for lighting design, currently requires maximum cct of 4100k, minimum illumination requirements, 30-18 ft-candles
Limitations from stakeholder needs	
Operation and support labor requirements	requires less labor that replacing flourescent tubes (longer life), but slightly different skill set
Necessary Funding Streams: Integration	Requires additional time to calibrate lighting to individuals' needs
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	Need to evaluate energy savings from new lighting after user calibration

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B51. Project Information Form for Project 51: Waste Heat Recovery from Gas Turbine Exhaust

Waste Heat Recovery From Gas Turbine Exhaust

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Garth Hobson	831-656-2888	gvhobson@nps.edu	PI
POC2	Doug Seivwright			Co-PI
POC3				

Period of Performance

FY18 --- FY19

Base / Installation

NPS

Technology Description

Provide a brief description of the technology being implemented in this research project

Develop a waste heat recovery system using organic working fluids (CO_2 Brayton cycle) to improve the efficiency of gas turbine systems

Select up to three different technology types to categorize this project

Technology Type 1	Waste Energy Recovery
Technology Type 2	
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Improved energy efficiency and lowered fuel costs in a scalable system

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Reduced natural gas needed for heating or installation operations
Potential	Improved efficiency of fossil fuel backup power systems

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Demonstrated	Added renewable energy generation capability (wind, solar, etc)

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Potential	Reduced installation power consumption through improved distribution efficiency

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Potential	Reduced reliance on outside energy suppliers

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Optimization of non-recuperated CO_2 thermodynamic cycle, integration of industrial hardware in a scaled demonstrator

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

Page 2

What would you describe as the greatest benefit(s) of having completed this demonstration project?

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	waste heat recovery technology mature on utility scale applications but not building scale.
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	
Environmental or Installation-specific challenges	Certain installations are using centralized steam heating systems that may need to be replaced
Accessibility of required components	Will have to source custom advanced heat exchangers (non COTS item)

Process Challenges

Certification or Approval requirements	Installation will be a very involved process for large scale operations, environmental permitting for natural gas systems
Initial Funding or Resource Allocation issues	large upfront cost
Continued Funding or Resource Allocation issues	
Contracting / Procurement	Procurement of advanced heat exchangers (non-COTS item)

Stakeholder Challenges

Impact on and Approval of certain stakeholders	may require significant infrastructure work to integrate waste heat recovery systems
Limitations from stakeholder needs	operations or climate will constrain when upgrades can take place.
Operation and support labor requirements	
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)
LT Aaron Vandenberg	
LT Coria Buck	

B52. Project Information Form for Project 52: Efficient Implementation of Solid State Transformers (SST)

Efficient Implementation of Solid State Transformers (SST)

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Todd Weatherfort	831-656-3044	trweathe@nps.edu	PI
POC2	Andrew Parker			
POC3	Matthew Porter			

Period of Performance: FY16 --- FY17

Base / Installation: NPS, NCSU

Technology Description

Provide a brief description of the technology being implemented in this research project

Integrate software control for "Smart" transformers, Dual active Bridge Solid State Transformer topology to control the exchange of power between the microgrid and the utility power infrastructure

Select up to three different technology types to categorize this project

Technology Type 1	Microgrids, Islanding, Isolation
Technology Type 2	Modeling & Optimization
Technology Type 3	Other

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

improved energy transfer efficiency and ability to establish mobile microgrids

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Demonstrated	Improved efficiency or effectiveness of existing renewable generation
Potential	Improved efficiency or effectiveness of existing renewable energy storage
Realized	Improved capability to integrate renewables into larger grid
Potential	Improved capability to estimate ROI of renewable systems

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Realized	Reduced installation power consumption through improved distribution efficiency

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Potential	Power modeling used to optimize grid configuration or expansion

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Demonstrated	Reduced contractor support required to install, maintain, or operate technology
Demonstrated	Technology requires less maintenance labor than alternative systems
Demonstrated	Technology requires fewer or less costly replacement components that alternative systems
Potential	Technology is easier to operate than alternative systems

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Potential	Reduced reliance on systems with expensive replacement parts

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

Potential	Improved energy access in remote facilities

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

contract parts availability, SST/MUSE testbed integration, contract execution

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Improved understanding of performance of new solid state devices, improved capability to establish microgrids in remote facilities due to compact size/weight of new technology

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Vetting to ensure standards for reliability, safety are met

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

Improved capability to establish compact microgrids at remote installations

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Technology must still be properly vetted to ensure component reliability needs are met
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	
Environmental or Installation-specific challenges	
Accessibility of required components	limited number of vendors

Process Challenges

Certification or Approval requirements	
Initial Funding or Resource Allocation issues	large component cost
Continued Funding or Resource Allocation issues	
Contracting / Procurement	Contracting support needed to acquire and install systems

Stakeholder Challenges

Impact on and Approval of certain stakeholders	High demands for power quality and reliability that cannot be sacrificed for efficiency
Limitations from stakeholder needs	
Operation and support labor requirements	possible maintenance/servicability complications
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	Feedback needed to ensure systems are meeting power quality and reliability needs in the field

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)
CDR Martino	

B53. Project Information Form for Project 53: HVAC Control by Means of Predicted Percentage of Dissatisfied Method

HVAC Control by Means of Predicted Percentage of Dissatisfied Method

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Arthur Rubio	619-553-1904	rubio@spawar.navy.mil	PI
POC2	Alan Williams			
POC3				

Period of Performance: FY17 --- FY19

Base / Installation: SSC PAC Building 111

Technology Description

Provide a brief description of the technology being implemented in this research project

Implement Predictive Mean Vote (PMV) and Predictive Percentage Dissatistfied (PPD) to provide high resolution HVAC controls to optimized energy usage in HVAC systems

Select up to three different technology types to categorize this project

Technology Type 1	Modeling & Optimization
Technology Type 2	Energy Management & Monitoring
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Reduce energy and maintenance cost associated with running HVAC systems by using smart sensors and polling to automate HVAC controls and reduce runtime.

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Potential	Reduced natural gas needed for heating or installation operations

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Potential	Reduced installation power consumption through building control automation

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Potential	Modeling and simulation to inform energy infrastructure investments

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Potential	Reduced wear and tear on mechanical systems

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

Potential	Real-time monitoring of energy systems

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Potential	Improved access to energy use data
Potential	Improved control capabilities for future experiments

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Design of sensors and communication infrastructure to be compliant with cyber and networking protocols

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Decreased energy consumed by HVAC systems and reduced maintenance requirement due to decreased run time

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	Design of sensors and communications infrastructure in progress
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	
Environmental or Installation-specific challenges	Cyber concerns regarding wireless sensors
Accessibility of required components	Custom-built solution, needs to be further developed into an off-the-shelf solution

Process Challenges

Certification or Approval requirements	Approval required for wireless transmitting devices
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	
Contracting / Procurement	Possible contractor labor needed to integrate sensor input into HVAC control systems

Stakeholder Challenges

Impact on and Approval of certain stakeholders	impact on building occupant comfort level
Limitations from stakeholder needs	Stakeholder's desire for manual climate control
Operation and support labor requirements	periodic maintenance to replace sensor batteries
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	periodic maintenance to replace sensor batteries
Continued feedback and improvement	Feedback required to ensure building occupant comfort within allowable percentage satisfied

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)
Jeremy Poche		
Justin Hartline		

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B54. Project Information Form for Project 54: Develop Energy Use Trends with Innovative Visualization/Analysis

Develop Energy Use Trends with Innovative Visualization/Analysis

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Chris Chen	619-553-6852	chris.s.chen@navy.mil	PI
POC2	David Borroel			
POC3	Kerrie Trotter			

Period of Performance: FY17 --- FY18

Base / Installation:

Technology Description

Provide a brief description of the technology being implemented in this research project

The goals for this project is to fuseexisting datasets (i.e. CIRCUITS, Maximo, INFADS, AMI, audit data) to better understand the factors that have high correlations with energy usage in naval facilities.

Select up to three different technology types to categorize this project

Technology Type 1	Decision Support
Technology Type 2	Other
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

AA

Fuse existing datasets (i.e. CIRCUITS, Maximo, INFADS, AMI, audit data) to better understand the factors that have high correlations with energy usage in naval facilities

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Potential	Modeling and simulation to inform energy infrastructure investments

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy

Potential	Technology is easier to operate than alternative systems

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Potential	Improved decision support tools to inform future investments or funding requirements

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

Potential	Increased awareness of energy use

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

Potential	Improved documentation of infrastructure

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Potential	Improved access to energy use data

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

Normalizing reporting in a way that considered different factors such as floor area, building/facility type, local climate, etc; gaining access to data

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Improved capability to compare energy use data across dissimilar buildings in a meaningful way

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

Improved capability to compare datasets from separate archives with their own formats

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	databases are mature, but there is no mature way to format/transfer data between them
Maturity/suitability of specific systems used in this project	
Integration with Navy-specific systems	Verification & Validation needed to confirm accuracy of data conversion
Environmental or Installation-specific challenges	
Accessibility of required components	

Process Challenges

Certification or Approval requirements	
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	
Contracting / Procurement	

Stakeholder Challenges

Impact on and Approval of certain stakeholders	
Limitations from stakeholder needs	
Operation and support labor requirements	
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	funding may be necessary to periodically update data sets
Continued feedback and improvement	

Intern Involvement

	Year (if known)	Where are they now? (if known)
Tim Jordon		
Jason Sneddon		

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

B55. Project Information Form for Project 55: Green Data Center Software Product Evaluation

Green Data Center Software Product Evaluation

Other Names, Abriviations, etc:

Contacts	Name	Phone	Email	Role
POC1	Mamadou Diallo	9494001735	mamadou.h.diallo@navy.mil	PI
POC2	Michael August			
POC3	Scott Slayback			

Period of Performance: FY17 --- FY19

Base / Installation: NACS lab

Technology Description

Provide a brief description of the technology being implemented in this research project

Perform a comparative study of the effectiveness of major commercial power management technologies in saving energy in data centers (Microsoft System Center Virtual Machine Manager on Microsoft Hyper-V, Eaton Intelligent Power Management on Citrix XenServer, and vSphere Distributed Power Management on VMWare vSphere Distributed Power Management).

Select up to three different technology types to categorize this project

Technology Type 1	Other
Technology Type 2	
Technology Type 3	

Anticipated Benefits of this Technology

Bottom Line Up Front: Describe the biggest anticipated benefit of successfully implementing this technology **operationally** (may be different from demonstration)

Reduced energy consumption at Navy datacenters

Fossil Fuel Consumption

List and describe any benefits this technology has or may have on installation fossil fuel consumption or backup power generator use

Page 1

Renewable Energy

List and describe any benefits this technology has or may have on installation renewable energy generation, storage, integration, or management

Power Consumption

List and describe any benefits this technology has or may have on installation power consumption

Potential	Reduced installation power consumption through improved end-user efficiency

Power Modeling & Management

List and describe any benefits this technology has or may have on installation power modeling, management, or investment decisions

Operation and Support Requirements

List and describe any benefits this technology has or may have on the labor, materials, training, or contracting needed to support and operate installation energy infrastructure.

Energy Assurance, Independence, & Resiliency

List and describe any benefits this technology has or may have on installation energy assurance and resiliency, such as islanding or isolation capability, recovery from disruptions, or non-disruption of critical systems

Cyber Security

List and describe any benefits this technology has or may have on the cyber security of installation energy infrastructure

Costs

List and describe any benefits this technology has or may have on installation energy costs that aren't described above

Potential	Reduced wear and tear on mechanical systems

Second Order Impacts

What additional benefits, information, feedback, or control does this technology offer to the installation energy end user?

What additional benefits, information, feedback, or control does this technology offer to the installation energy manager?

What additional benefits, information, feedback, or control does this technology offer to future R&D efforts?

Other

Technology Demonstration Results

What were the most significant obstacles encountered in this technology demonstration project?

In what ways did these obstacles hinder the implementation, operation, or effectiveness of the demonstrated technology?

Page 2

What would you describe as the greatest benefit(s) of having completed this demonstration project?

Virtualized data center Energy Management Testbed for deploying and evaluating energy management systems

What specific adaptations (if any) would be required to make the commercially available technology more suitable for Navy-specific use?

Once operationally mature, what benefits and/or drawbacks would this technology have over other (mature) alternative technologies?

Improved capability to compare data center energy optimization technologies

What advances or observations were made in this demonstration project that could help justify continued investment in this technology?

What new skills, competencies, or experience were gained within the Navy workforce during this project?

Intern Involvement

Intern Name	Year (if known)	Where are they now? (if known)

References

Tech papers

Author(s)	Title

Journal Articles, Publications

Author(s)	Title

NPS Student Theses

Author(s)	Title (if known)

Technology Adoption Considerations

Technology Integration

Maturity of the technology family	
Maturity/suitability of specific systems used in this project	It remains to be seen which particular product is best suited for DoD use
Integration with Navy-specific systems	Installations using different hardware or software configurations might benefit more from different specific implementations or versions of energy management technology
Environmental or Installation-specific challenges	
Accessibility of required components	

Process Challenges

Certification or Approval requirements	Approval required for implementation across DOD data centers
Initial Funding or Resource Allocation issues	
Continued Funding or Resource Allocation issues	
Contracting / Procurement	

Stakeholder Challenges

Impact on and Approval of certain stakeholders	
Limitations from stakeholder needs	Energy management software may not significantly impact data center performance
Operation and support labor requirements	
Necessary Funding Streams: Integration	
Necessary Funding Streams: Continued Support	
Continued feedback and improvement	Continued support needed to implement software updates

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