FINAL REPORT

Retrofitting Existing Solar with Emerging Technologies [RESET]

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14. ABSTRACT
Retrofitting Existing Solar with Emerging Technologies [RESET] (ESTCP Project # EW20-5330) focuses on developing a repeatable project structure for retrofitting existing Department of Defense (DoD) renewable energy assets with resilience technologies. RESET assesses the cybersecurity, legal, engineering, and financial feasibility of retrofitting existing solar photovoltaic (PV) generation at a military installation with resilience capabilities. RESET identifies lessons learned and recommendations applicable across the DoD enterprise.

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ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
ASD(S)	Assistant Secretary of Defense for Sustainment
BESS	Battery Energy Storage System
CSL	Converge Strategies, LLC
DC	Direct Current
DER	Distributed Energy Resource
DoD	Department of Defense
ERCIP	Energy Resilience and Conservation Investment Program
EO	Executive Order
ESPC	Energy Savings Performance Contract
ESTCP	Environmental Security Technology Certification Program
FAR	Federal Acquisition Regulation
IRR	Internal Rate of Return
IT	Information Technology
KO	Contracting Officer
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt-hour
MERC	Military Energy Resilience Catalyst
MW	Megawatt
NDAA	National Defense Authorization Act
NPV	Net Present Value
OEA	Office of Energy Assurance
OSD	Office of the Secretary of Defense
OT	Operational Technology
PPA	Power Purchase Agreement
PV	Photovoltaic
RESERV	Resilient Energy Savings Resource Vault
RESET	Retrofitting Existing Solar with Emerging Technologies
SCE	Southern California Edison

UESC	Utility Program and Utility Energy Service Contract
USD(A&S)	Under Secretary of Defense for Acquisition and Sustainment

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ABSTRACT

INTRODUCTION AND OBJECTIVES

Retrofitting Existing Solar with Emerging Technologies [RESET] focused on developing a repeatable project structure for retrofitting existing Department of Defense (DoD) renewable energy assets with resilience technologies. RESET assessed the cybersecurity, legal, engineering, and financial feasibility of retrofitting existing solar photovoltaic (PV) generation with resilience capabilities at Edwards Air Force Base (AFB) in California. RESET also assessed the current resilience retrofit landscape and identified lessons learned from the Edwards AFB process demonstration and from interviews with more than 40 energy resilience practitioners. RESET captured recommendations that are applicable across the DoD enterprise.

TECHNOLOGY DESCRIPTION

A resilience retrofit is an upgrade of *existing* renewable energy assets (e.g., solar PV) with energy storage technologies (e.g., lithium-ion BESS, microgrid controllers) that is configured to allow DoD installations to "island" critical loads during grid power outages. The RESET approach is primarily focused on third party-owned systems, rather than DoD-owned systems.

PERFORMANCE AND COST ASSESSMENT

The resilience retrofit project was not feasible at Edwards AFB due to financing, legal/contracting, engineering, and cyber limitations - as well as a lack of Project Champion at neither the installation level nor the program office. However, lessons learned from the RESET project can be applied to future resilience retrofit projects if adopted more broadly by the DoD energy resilience community.

IMPLEMENTATION ISSUES

- *Demonstration Site-Specific Issues*. Implementation issues associated with the Edwards AFB RESET demonstration included a delayed project timeline between award and execution of the ESTCP contract. The installation experienced staff turnover and the loss of Project Champion which resulted in deprioritization of the project from the installation leadership. There was also a lack of overall transparency regarding the Air Force PPA extension/modification negotiating process, including which parties should be included, who was the decision making authority, and source of data used in negotiations.
- *DoD Enterprise Issues*. Lessons learned from the RESET project are outlined in the report, Lessons Learned from Retrofitting Existing Solar with Emerging Technologies. The report provides a staged approach for DoD to consider how a resilience retrofit initiative would move from the enterprise-level, to the military services, to the installations.

PUBLICATIONS

- Considerations for Retrofitting Existing Solar with Emerging Technologies
- Lessons Learned from Retrofitting Existing Solar with Emerging Technologies
- Cyber-Risk Management Feasibility Study

1.0 INTRODUCTION

1.1 BACKGROUND

DoD has acquired a large fleet of power plants located on or near its military installations during the past decade, including more than 2,000 renewable energy plants that generated 3,700 GWh in 2020 (ASD(S), 2021). Despite this large portfolio of renewable energy plants, few of them have been configured to provide energy resilience to the installations they serve. While there are notable examples of greenfield microgrid projects incorporating solar PV - such as the 30 MW solar PV system at Pacific Missile Range Facility Barking Sands in Hawaii (Rickerson, W., et. al., 2021) - DoD continues to rely overwhelmingly on backup diesel generators to provide energy resilience (ASD(S), 2020a). Thus far, DoD has not realized the potential of its existing renewable energy plants as a significant energy resilience resource because DoD, and the federal government more broadly, lacks the policies and processes for improving energy resilience of existing renewable energy assets.

1.2 OBJECTIVE OF THE DEMONSTRATION

The primary objective of RESET was to demonstrate that existing solar PV systems located at Edwards Air Force Base (AFB) in California could be retrofitted to island critical loads and strengthen installation resilience by adding a battery energy storage system (BESS) and a microgrid controller. Currently, Edwards AFB maintains 3 MW of existing, grid-tied solar PV, but the systems cannot "island" from the grid, and the systems provide no resilience capabilities for the installation. The RESET project specifically investigates the financial, contractual, engineering, and cyber considerations related to energy resilience retrofits. Once the Project Team arrived at the "no-go" decision to move forward with the resilience retrofit project at Edwards AFB, the RESET analysis was redefined to focus more broadly on lessons learned from the Edwards AFB decision that could be applied to other existing renewable energy projects across the DoD enterprise that do not currently provide resilience.

1.3 REGULATORY DRIVERS

DoD is directed through federal Executive Orders (EOs), policies (e.g., DoD Directives (DoDD), and various legislative initiatives (e.g., National Defense Authorization Act (NDAA)) to meet renewable energy targets and to ensure energy resilience. Configuring renewable energy systems to provide energy resilience is consistent with, and specifically encouraged by, DoD energy policy. Examples of relevant regulatory drivers include: DoDD 4180.01 of 2014, NDAA for FY2018, NDAA for FY2022, EO 14057. A more detailed analysis of relevant regulatory drivers is summarized in Section 1.0 of the RESET report, Considerations for Retrofitting Existing Solar with Emerging Technologies.

2.0 TECHNOLOGY DESCRIPTION

2.1 TECHNOLOGY OVERVIEW

A resilience retrofit is an energy resilience project that upgrades existing renewable energy assets (e.g., solar PV) with energy storage technologies (e.g., lithium-ion BESS, microgrid controllers) enabling DoD installations to "island" critical loads during grid power outages. The RESET approach requires coordination and alignment of requirements and objectives across policy and leadership, contracting and legal, funding and financing, engineering, and cybersecurity. The DoD can apply this approach to some portion of the more than 2,000 renewable energy plants – including approximately 1,200 solar PV plants – located on or near DoD installations (ASD(S), 2021). However, the RESET approach is novel and the practice of retrofitting existing solar PV assets with battery storage is not widespread across DoD. The report, Considerations for Retrofitting Existing Solar with Emerging Technologies, provides a comprehensive technology overview of the resilience retrofit approach, including its theory, functionality, and operation.

2.2 TECHNOLOGY DEVELOPMENT

The Project Team consulted with industry experts and resilience stakeholders on opportunities and barriers to retrofitting existing solar PV, and reviewed DoD experience with adding resilience capabilities to existing renewable energy assets. The RESET Project Team conducted interviews with more than 40 subject matter experts - including project developers, financiers, energy service companies, utilities, national laboratories, DoD officials, and others - to inform and validate the structure and focus of the Edwards AFB demonstration project. The findings from these interviews are summarized in the report, Considerations for Retrofitting Existing Solar with Emerging Technologies. Based on these initial interviews, the Project Team concluded that while resilience retrofit projects are technically possible, there are few precedents or supportive policies within the DoD, and project developers have primarily focused on building new projects rather than retrofitting existing ones.

2.3 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

The RESET approach is unique because it seeks to leverage existing, third party-owned renewable energy assets,rather than building entirely new projects with DoD funds.

- *Advantages.* The primary advantage of the RESET approach is that the generation asset (e.g., solar PV) is already installed and operating on or near the installation. As a result, new generation assets do not need to be sited or procured by the installation, or third party owner, of the retrofit project.
- *Disadvantages.* The primary disadvantage of the RESET approach is contracting complexity in combination with a challenging market dynamic. DoD projects take significantly longer to develop and deploy, face greater uncertainty than civilian projects, and require case-by-case solutions (ODASD(Energy), 2020). These factors inhibit developer engagement and can lead to "deal fatigue" prior to successful project execution. The terms of PPA contracts, for example, may not permit solar PV generators to be included as part of larger energy resilience solutions, such as microgrids. In such a case, the terms of the PPA would need to be renegotiated (Kurnik & Voss, 2020).

The addition of new equipment (e.g. battery storage) under a PPA may also require the PPA to be competitively bid out to the market if there is not a contract line item that allows for it in the original contract. While other contracting mechanisms can be used to finance a resilience retrofit (e.g., ESPC/UESC), there is virtually no precedent across DoD, and significant contracting barriers remain.

The report, Considerations for Retrofitting Existing Solar with Emerging Technologies, provides a comprehensive overview of the advantages and limitations of the RESET approach.

The primary alternative paths for the RESET approach have been used across DoD for installation energy resilience and are outlined below:

- *Install building-level backup generators.* DoD relies overwhelmingly on backup diesel generators to provide energy resilience (ASD(S), 2020a). The major benefit of backup generators is that they are cost-effective relative to "next-generation technologies" such as solar PV, BESS, and microgrid controls. However, generators do not contribute to DoD's clean energy goals and require significant testing and maintenance to ensure they operate effectively during a power outage. Generators also rely on refueling and component supply chains for long duration operations, which are typically degraded during grid outage events.
- *Build new ("greenfield") energy resilience projects.* Military installations may be able to build new microgrid projects to accomplish energy resilience objectives. There are many examples of new microgrid projects that have been developed over the past decade at DoD installations. The major benefit of new energy resilience projects is that they ensure that energy resilience is baked into the original design of the project, and that the projects incorporate the latest energy resilience technologies. However, new microgrid projects are typically custom-built to the energy resilience requirements of the installation, and are expensive relative to generators. DoD funding for microgrid projects through programs such as the Energy Resilience and Conservation Investment Program (ERCIP) is limited, and private sector financing pathways remain time consuming and complex.

3.0 PERFORMANCE OBJECTIVES

The original performance objectives of the RESET project are summarized in Table 1 below:

Table 1. RESET Performance Objectives and Results

Performance Objective	Data Requirements	Success Criteria	Results
Awareness of cyber, legal, engineering and financial challenges	Surveys of DoD energy resilience practitioners after development of lessons learned document	Average responses >4 upon project completion for survey responses related to lessons learned document's accuracy, applicability, and usefulness	Energy resilience practitioners engaged minimally with the lessons learned document because it focused on systemic DoD challenges rather than site-specific success
Decision from current project owner on whether to move forward with resilience retrofit project	Interviews with project owner following technical assistance results	Project owners can make a fully informed decision on whether or not to invest.	The project owner made a "no-go" decision on the resilience retrofit project following protracted PPA negotiations with the Air Force.
Financial analysis outputs support conclusions	Net cash flows Project duration Discount rate Risk allocation matrix	• For DoD: NPV>0 using OMB-stipulated project discount rate • For Developer: IRR>investment hurdle rate • For both parties: satisfactory risk allocation matrix	A resilience retrofit project was not financially feasible due to the renegotiated ~$0.05/kWh PPA price offered by the Air Force. (The original PPA price was ~$0.16/kWh.)

Once the Project Team determined that the resilience retrofit project is not possible at Edwards AFB, the team redefined the focus of the project to address how lessons learned from the "no-go" decision at Edwards AFB could support future resilience retrofit efforts across the DoD enterprise. The results of this redefined objective are summarized in the report, Lessons Learned from Retrofitting Existing Solar with Emerging Technologies.

4.0 FACILITY / SITE DESCRIPTION

4.1 FACILITY/SITE LOCATION AND OPERATIONS

Edwards AFB is located in Kern County, California. It is the second largest base in the Air Force, comprising 481 square miles and 10,000 military, civilian, and contract personnel. The 412th Test Wing is the host wing for Edwards AFB. According to its website, "Edwards is the test-bed for today's premiere aerospace technology programs including the Global Hawk, Hypersonic flight, and of course the F-35 Joint Strike Fighter."

4.2 FACILITY/SITE CONDITIONS

Edwards AFB is supplied medium voltage electrical power from Southern California Edison (SCE) at 34.5 kV through three service entrance switching stations, located at: Main North Base - Switching Station 1, South Base - Switching Station 3 and Switching Station 4, AFRL - Switching Station 2. The incoming medium voltage conductors from the utility supplies an outdoor switching station equipped with medium voltage 35 kV outdoor circuit breakers.

The existing solar PV systems are adjacent to the respective switching stations and directly connected via three 1000 kVA transformers (200 V to 34.5 kV) using existing spare MV breakers at South Base - Switching Station 3, AFRL - Switching Station 2, and a newly installed 35 kV PV breaker at the Main North Base - Switching Station 1.

5.0 TEST DESIGN

5.1 CONCEPTUAL TEST DESIGN

The Edwards AFB RESET project explored whether three ~1 MW solar PV systems located on the installation could be retrofitted with resilience capabilities under the existing acquisition authority. The Project Team assessed resilience retrofit feasibility along five primary elements: policy and leadership, legal and contracting, funding and financing, engineering, and cybersecurity. Examples of assessment questions for the RESET approach are outlined below:

Assessment Area	Example Assessment Questions
Policy and Leadership	Are there “champions” at the installation level who support the resilience retrofit project?
Legal and Contracting	How does the underlying land lease compare to the energy contract term?
Funding and Financing	Will the project satisfy the risk allocation matrix for DoD and the project developer?
Engineering	How much of the distribution system equipment must be configured for islanded operation?
Cybersecurity	Is the system located inside or outside the DoD installation? Is the system connected to DoD networks?

5.2 BASELINE CHARACTERIZATION

A baseline characterization of each of the key RESET elements is summarized below:

- *Policy and Leadership Baseline.* The RESET project is aligned with existing regulatory drivers (see Section 1.3) and was notionally supported by the Edwards AFB installation leadership before the departure of a key Project Champion at the onset of the project.
- *Legal and Contracting Baseline.* The power for the project or the PPA is a fixed-price, commercial item contract for renewable solar energy with a firm 10-year term, running from February 12, 2012 through 11 February, 2022 (originally procured under FAR Part 52).
- *Funding and Financing Baseline.* Funding for the resilience retrofit is not considered because RESET is focused on leveraging financing; financing for the RESET project was ultimately not possible due to the cost model methodology employed by the Air Force (see Section 7.1).
- *Engineering Baseline.* A summary of each site’s solar PV generation is provided below in Table 2. The existing solar PV size is relatively undersized given the load profile of the installation. For example, the Main North Base peak solar PV production is 800 kW while the site has a peak demand of 2800 kW.

Table 2. Edwards AFB Solar PV Generation

Site Name	Solar PV Power Rating (kW DC)	Solar PV Generation (kWh)
Main North Base 9212	1135.68	2,515,940
AFRL 9211	1128.96	2,526,494
South Base 6639	1132.34	2,504,600

- *Cybersecurity Baseline.* The current system, even if networked, should be well-protected or isolated from the general IT DoD network. However, medium-to-high vulnerabilities may exist for the system given the fast development cycle and general lack of security considerations for OT and distributed energy resources (DERs) components.

5.3 DESIGN AND LAYOUT OF TECHNOLOGY COMPONENTS

Edwards AFB was selected because it aligned with key RESET elements:

- *Policy and Leadership Design*. The Project Team selected a demonstration site with a known Project Champion from the Military Energy Resilience Catalyst [MERC] program who would support the novel resilience retrofit project concept.
- *Contracting and Legal Design*. The Project Team sought a renewable energy contract that was nearing the end of its original term so that the renegotiation period could be used to advocate for and incorporate energy resilience modification technologies.
- *Funding and Financing Design*. The Project Team included CleanCapital, the owner of the existing solar PV assets. CleanCapital advocated for and engaged in lengthy renegotiations with the Air Force to extend the PPA. Unfortunately, the agreed upon contract price rendered the addition of energy resilience modification technologies infeasible.
- *Engineering Design*. The Project Team collected energy resilience data from the installation to determine whether a proposed resilience retrofit could support critical loads. The team also conducted a site visit to review the existing energy infrastructure.
- *Cybersecurity Design*. The Project Team, led by Idaho National Laboratory, compared the current cyber risk of the solar PV system to the hypothetical resilience retrofit system to determine if the proposed changes were acceptable and identified improvement measures..

5.4 OPERATIONAL TESTING

Not applicable to the RESET project.

5.5 SAMPLING PROTOCOL

Not applicable to the RESET project.

5.6 SAMPLING RESULTS

Not applicable to the RESET project.

6.0 PERFORMANCE ASSESSMENT

The results of the original performance objectives of the RESET project are summarized in Table 1 (Section 3.0). The rationale for not moving forward with Edwards AFB resilience retrofit project is defined in the Task 2.9 report, Feasibility Summary of Retrofitting Existing Solar with Emerging Technologies [RESET] (available in the SEMS portal only). A summary the key RESET elements is provided below:

- *Policy and Leadership "No-go" Decision.* Despite alignment with DoD policies, the RESET project lacked coordination at the energy program office and installation levels. There was no OEA guidance to the installation for participation in the RESET project, and resilience retrotifts are not currently being prioritized as project concepts. Additional implementation issues associated with Edwards AFB demonstration site are identified in Section 8.0.
- *Funding and Financing "No-go" Decision.* While the proposed project may have been eligible for funding, such as from the Air Force's Resilient Energy Savings Resource Vault (RESERV), additional funding was not pursued due to the delayed project execution timeline. In addition, the project was not financially feasible due to the renegotiated $0.05/kWh PPA price offered by the Air Force. (The original PPA price was $0.16/kWh.) Due to the lower PPA price, CleanCapital could not pay for the cost of new energy resilience equipment while continuing to deliver the required rate of return for investors. (The original 10-year PPA agreement was extended after a protracted renegotiation period, and the existing solar PV will continue to serve Edwards AFB for an additional 10 years.)
- *Legal and Contracting "No-go Decision.* FAR Part 52 PPA extensions are not common within DoD and have not previously been used to retrofit existing solar PV projects with resilience capabilities. Legally, the existing PPA *could* have been renegotiated and amended to include energy resilience modifications – but the process would be lengthy and complex.
- *Engineering "No-go" Decision.* The relatively small size of each solar PV system, when compared to the installation electrical load, limited the size of any proposed BESS and would result in a system with minimal resilience benefit but a substantially increased project cost.
- *Cybersecurity "No-go" Decision.* A new storage system with a cloud-based controller has the potential to significantly increase the cyber-risk of the system. This increase in cyber-risk could be offset by using simple and cost-effective risk mitigation measures, potentially enabling the energy resilience retrofit to generate economic value for the system. However, without these mitigation measures, the resilience retrofit would not be advisable due to the increase in cyber-risk.

7.0 COST ASSESSMENT

7.1 COST MODEL

Key cost considerations for the RESET approach are outlined below:

Table 3. Cost Elements and Estimated Cost Impact

Cost Element	Estimated Cost Impact	Data Tracked
Site Selection	High	Support from installation and energy program office
Data Collection	Medium	Energy consumption data, one-line diagrams, cybersecurity architecture
Design	Low	Size of solar PV, size of installation critical load, proximity of solar PV generation to load and substation
Proposals	Low	N/A - the RESET team project made a "no-go" decision
Contracting	High	Number of meetings between solar PV asset owner and Military Service, time spent reviewing existing acquisition authority, time spent renegotiating new PPA price

This cost model was not employed by the RESET project team because of the implementation issues cited in Section 8.0.

7.2 COST DRIVERS

The primary cost drivers that should be considered when selecting resilience retrofits for future implementation across the Services are summarized below:

- *Stakeholder Alignment*. Significant resources will be expended if the proposed resilience retrofit does not have a Project Champion at the installation and if the Service and project developer are not aligned in support of the resilience objectives.
- *Site Selection*. DoD lacks a service-wide database of its existing renewable energy assets, including the characteristics that would determine if they are eligible for resilience retrofits to support critical missions (Section 8.0). Selecting the "right" site is time-intensive and costly.
- *Data Collection Site Visit Coordination.* Collecting relevant energy resilience data from the site, reviewing the data fidelity, and coordinating site visits with installation stakeholders to validate the data and existing energy infrastructure is time-intensive.
- *Contract Renegotiation.* Modifying and extending contract terms to incorporate resilience is lengthy and complex because there is little precedent across DoD. Contracting offices (KOs) may also be reluctant to modify the original scope of the contract to enable the novel resilience retrofit approach.

7.3 COST ANALYSIS AND COMPARISON

The primary consideration for retrofitting existing solar PV for resilience is how to pay for the additional equipment required. DoD has limited bandwidth to evaluate energy resilience project concepts from installation energy leadership and DoD has limited funding (e.g., through the ERCIP program) to pursue energy resilience projects across the Services. The RESET approach sought to remove the energy resilience cost burden from DoD by identifying third party-owned solar PV assets whose resilience retrofit would be paid for by a third-party capital provider. If the resilience retrofit could be financed by a third party, it would reduce the overall project timeline and DoD staff resources typically associated with standard DoD procurements.

8.0 IMPLEMENTATION ISSUES

8.1 DEMONSTRATION SITE-SPECIFIC IMPLEMENTATION ISSUES

Implementation issues associated with the RESET demonstration included:

- *Delayed Project Timeline.* The RESET project was delayed by more than a year from award announcement to contracting, resulting in reduced timelines from the end of the original 10-year Edward AFB PPA, and the time required to renegotiate a new/extended contract.
- *Installation Staff Turnover.* Installation energy leadership turned over during the year between project award and execution, resulting in the loss of a MERC Project Champion and leadership familiarity with the project objectives.
- *Lack of Installation Leadership Buy-In.* Installation energy leadership did not prioritize RESET; leadership was amenable to adding BESS as a potential source of revenue generation but not as a resilience solution.
- *Lack of DoD Guidance.* Retrofitting of existing renewable energy assets to provide resilience capabilities is not currently prioritized by the Air Force OEA or OSD, and there is no existing guidance regarding this topic area.

8.2 DOD ENTERPRISE IMPLEMENTATION ISSUES

Lessons learned from the RESET project are summarized in the report, Lessons Learned from Retrofitting Existing Solar with Emerging Technologies. The report provides a framework by which DoD could establish a resilience retrofit initiative and tap into its expansive portfolio of existing renewable energy assets; it is not intended to be exhaustive or capture the full suite of barriers, lessons learned, and best practices. Key takeaways are summarized below:

#	Lesson Learned	Recommendation
1	DoD lacks a service-wide database of its existing renewable energy assets, including the characteristics that would determine if they are eligible for resilience retrofits to support critical missions.	DoD should survey their existing renewable energy assets to better understand which renewable energy assets meet baseline requirements for energy resilience retrofits.
2	DoD has not previously retrofitted existing third-party owned solar PV systems to incorporate resilience and has no documented and coordinated processes on which to build.	DoD should use a database of existing renewable energy assets (Recommendation 1) to select projects that are suitable candidates for resilience retrofit demonstration and complete retrofit pilots.
4	DoD energy leadership has not issued policy for retrofitting existing solar PV with resilience capabilities.	DoD should develop policy that specifically promotes resilience retrofits for existing renewable energy assets.
5	DoD engineering organizations have not established a standard process for retrofitting solar PV with battery storage and service energy program offices have not coordinated resilience retrofits across the military services.	DoD should assign military service entities the responsibility to centrally identify and coordinate projects with installation civilian personnel.
6	Installation energy leadership often has not prioritized retrofitting solar PV nor understands how it could be accomplished using existing procurement pathways.	DoD installation energy leadership should identify project champions within their organization who are capable of prioritizing resilience retrofit projects and guiding them from ideation to execution.

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