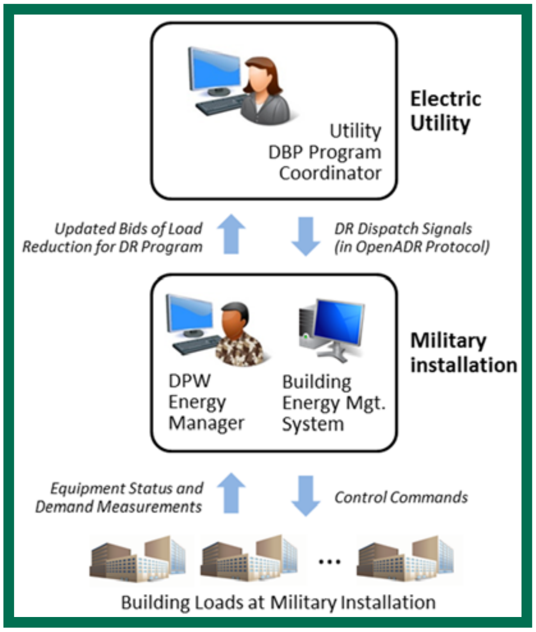
ESTCP
Cost and Performance Report

(EW-201256)



Automated Demand Response for Energy Sustainability

September 2015

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14. ABSTRACT

This project implemented and demonstrated an automated demand response (DR) system at Fort Irwin, CA. This demonstration employed industry-standard OpenADR (Open Automated Demand Response) technology to perform the key communication and control functions. OpenADR technology, when integrated with the necessary building energy management system (BMS) control strategies and appropriate user interfaces, can enable military installations to reduce their electric demand profiles in response to signals from electric utilities and grid operators. This project's demonstration testing produced a set of measured results which were analyzed to evaluate the system's performance against the project's stated performance objectives.

Emerging opportunities to participate in wholesale electricity markets can provide important economic, energy, and sustainability benefits to military installations. Military installations can benefit by tracking utility and grid operator DR programs (and related incentives) to identify ways to derive energy and economic benefits from DR participation. This project showed that the required technology (OpenADR) is readily available and mature. As seen in recent non-military demonstration projects and also in utility pilot programs, OpenADR is well accepted by electric utilities, grid operators, and BMS suppliers.

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ACRONYMS AND ABBREVIATIONS

Alliance	The OpenADR Alliance
ATO	Authorization to Operate
AutoDR	automated demand response
BLCC	building life-cycle cost
BMS	building energy management system
CAISO	California Independent System Operator
CHWS	chilled water supply
CoS	Catalog of Standards
DBP	demand bidding program
DIACAP	DoD Information Assurance Certification and Accreditation Process
DLA	Defense Logistics Agency
DoD	Department of Defense
DOE	Department of Energy
DPW	Directorate of Public Works
DR	demand response
DRAS	demand response automation server
DRRC	Demand Response Research Center
ECM	energy conservation measure
EO	Executive Order
ERDC-CERL	U.S. Army Engineer Research and Development Center's Construction Engineering Research Laboratory
ESTCP	Environmental Security Technology Certification Program
FEMP	Federal Energy Management Program
GHG	greenhouse gas
HVAC	heating, ventilation, and air conditioning
kW	kilowatt
kWh	kilowatt hour
LBNL	Lawrence Berkeley National Laboratory
LCC	life cycle cost
MOU	memorandum of understanding
NIST	National Institute of Standards and Technology
NTC	National Training Center

ACRONYMS AND ABBREVIATIONS (continued)

O&M	operations and maintenance
OpenADR	Open Automated Demand Response
PAP	Priority Action Plan
PO	performance objective
RLA	rated load amp
SCE	Southern California Edison
SGIP	Smart Grid Interoperability Panel
SIR	savings-to-investment ratio
%	percent

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EXECUTIVE SUMMARY

Military fixed installations have limited funding resources to meet future energy and sustainability objectives through 2020 (to reduce energy intensity, increase renewable energy use, and improve energy security). This funding limitation has been apparent for some time and will become more important as military capital improvement budgets come under increasing fiscal pressure. As wholesale electricity markets across the U.S. are opened to participation by demand-side resources, military installations will have an opportunity to participate and thereby receive energy reduction, cost savings, and energy security benefits that are made available through this participation.

This market participation by demand-side resources at military installations requires automating their response to signals received from grid operators and electric utilities. Automation is made possible by applying a key industry standard for automated demand response (Open Automated Demand Response [OpenADR]). This technology enables installations to reduce the electric demand of selected demand side resources—for example, by reducing (or shutting off) selected building equipment (e.g., heating and air conditioning equipment, lighting, etc.) as well as miscellaneous motor loads.

Revenues received from participation in the electricity markets (through utility bill credits, for example) can provide a significant new source of funding that a military installation can use to procure improvements to its energy infrastructure. These infrastructure improvements provide a means to achieve future energy and sustainability objectives. OpenADR provides the needed automation link for sending and receiving demand response (DR) signals between the utility or grid operator and a set of pre-programmed automated DR (AutoDR) strategies in the military installation’s building energy management system (BMS) and thereby, to the individual loads. This automated communication technology effectively joins an installation’s BMS with utility or grid operator DR programs.

OBJECTIVES OF THE DEMONSTRATION

This ESTCP project began in 2012 with the objective of demonstrating the use of OpenADR technology to enable Fort Irwin to participate in the wholesale electricity market. The original plan was to utilize an anticipated ancillary services pilot program to be offered by the electric utility provider for Fort Irwin. However, due to regulatory delays no wholesale DR programs were available to utilize in the project’s 2014 demonstration at Fort Irwin. For that reason, the project plan was revised to utilize the utility’s retail demand bidding program (DBP) to demonstrate the application of OpenADR.

Following a DR audit of a number of candidate buildings at Fort Irwin, the OpenADR communications and control technology was implemented for a set of selected electric loads at the installation (central cooling plant chillers). Utilizing the utility’s DBP program as a demonstration vehicle, the project generated performance data for acceptance and validation of OpenADR technology.

TECHNOLOGY DESCRIPTION

OpenADR provides the needed automation link between the utility or grid operator and a set of pre-programmed (automated) DR strategies in the building owner's BMS and thereby, to the individual loads. This automated communication technology effectively joins an installation's BMS with utility or grid operator DR programs. DR control strategies are implemented in the installation's BMS to adjust the operation of building loads in response to DR event commands from the utility or grid operator via the Demand Response Automation Server (DRAS). On a military installation, candidate electric loads for DR programs include heating, ventilation, and air conditioning (HVAC) equipment, lighting, water pumping, and other miscellaneous motor loads. A military installation can participate in a DR program by offering (bidding) their demand side resources via the utility's DR website. The bids offer stated amounts of electric demand reduction (in kilowatts [kW]) and specific hours of the day, depending on the type of DR program. The economic benefits of reducing electric demand are defined in the utility DR tariff, which in the future might also be based in part by prices in the wholesale electricity market. The bid can be modified (and can be resubmitted) as conditions change at the military installation. If desired, the bid can be considered a standing bid, which is valid until changed by the installation. If the operating conditions (and any special constraints) at the installation are unchanged, it may not be necessary to update the bid each day.

DEMONSTRATION RESULTS

The demonstration testing covered the 2014 DBP event season fairly well, with a combination of simulated events as well as scheduled DBP events that occurred during the demonstration period. The measured baseline and test data was sufficient to enable the project team to perform a comparison against the project performance objectives.

The test hypothesis acceptance criteria stated that (by employing OpenADR communication and control technology) DR controlled equipment can accurately follow commands that are issued by the pre-programmed demand response control strategies during a DBP event. The sampling results showed that the current limit commands (sent to the chillers) and the resulting chiller percent (%) rated load amps (RLA) showed very good tracking by the equipment during the DBP events.

Based on data collected during the demonstration period, the project team was able to show that OpenADR communication and control technology can effectively enable a military installation to respond to commands from utility and electric grid operators (and thereby participate in electricity markets).

IMPLEMENTATION ISSUES

A number of implementation issues should be addressed in planning an AutoDR project. These implementation topics, which should be investigated as part of a DR audit, are:

- Implementing OpenADR technology and interfacing with an existing BMS at the military installation. This is not a significant concern, because almost any BMS can interface with OpenADR.

- Technical design required for extensions to the military communications network at the installation to connect to the DR controlled loads (if required).
- Costs for the BMS supplier to acquire a Department of Defense (DoD) Information Assurance Certification and Accreditation Process (DIACAP) or Authorization to Operate (ATO) certification (if not already in place).
- Arrangements with a qualified DR controls provider, DR aggregator or other consultant, to perform an up-front DR audit of the installation, to identify the DR control opportunities, assess the economic potential, and assist in project planning.

These implementation issues are site-specific and must be addressed in planning a DR project.

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1.0 INTRODUCTION

Significant changes are occurring in the electric utility industry and associated energy markets as new regulatory requirements come into effect. This project has assessed the benefits of energy and cost reduction and increased energy security available to military installations through participation in wholesale electricity markets. This market participation is made possible by applying a key industry standard for automated demand response (AutoDR) (Open Automated Demand Response [OpenADR]).

Revenues received from participation in the electricity markets (for example through utility bill credits) can provide a significant new source of funding that a military installation can use to procure improvements to its energy infrastructure. These infrastructure improvements provide a means to achieve future energy and sustainability objectives. This finance process is shown in Figure 1.

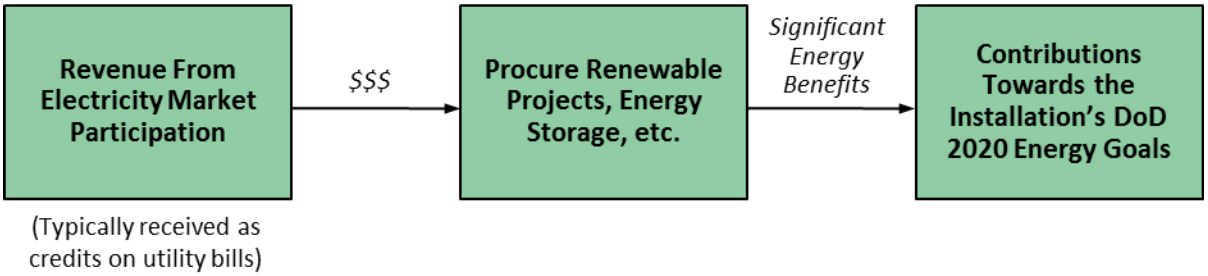

Figure 1. Energy and economic benefits process.

This document presents the results of a field demonstration of OpenADR control and communications technology as installed at Fort Irwin. The performance objectives, test design, performance results and cost assessment are presented in Sections 3 through 7.

Motivation: This project quantified the energy and cost benefits that can result from the application of OpenADR technology and participation in emerging opportunities in the electricity markets.

Intent: The project showed how military installations can take the steps necessary to participate in electricity markets and thereby realize economic benefits that help to achieve future energy and sustainability objectives.

Timeline: The electricity markets are being opened to demand-side resources, and grid operators and electric utilities will be introducing new programs that make it possible for electric customers to participate in these markets (Woolf et al., 2013).

1.1 BACKGROUND

In the mid-20th century and slightly later, electric grid operators in the United States generally had sufficient generating capacity (aside from occasional equipment outages or periods of extreme weather conditions), and used that capacity to satisfy electric demand. As the industry looked for ways to make the grid more energy and cost efficient, studies found that demand could be more flexible and that some electric customers were willing to occasionally reduce their demand in return for some form of economic benefit (i.e., through demand response [DR] programs). These load-side reductions could be either directly controllable (e.g., residential heating, ventilation, and air conditioning [HVAC]), or indirectly controllable at the option of the customer (e.g., for commercial building HVAC, lighting, etc.). Industrial customers have been able to identify similar DR opportunities in their operations. A number of different DR program types have been developed to meet the constraints of electric customers and the needs of utilities and grid operators. Some DR programs vary the price of electricity during periods of high demand, while other programs pay incentives to customers who are willing to provide a given amount of capacity (demand reduction) when the utility or grid operator indicates the need.

Early experience with DR programs revealed that initial manual communication (i.e., telephone and fax notification of pending DR events) and manual control of equipment (i.e., manually shutting off power to equipment) were less reliable or predictable than desired. For this reason, initial work began on ways to automate the DR. Over the past 20+ years, AutoDR has progressed to an advanced state that now enables new DR applications such as participating in the wholesale electricity markets, which requires the added reliability provided by OpenADR control and communications technology.

1.1.1 Market Participation

The primary electric loads at military installations (i.e., buildings, pumping, water treatment, etc.) are well suited to provide load reduction services to utilities and electric grid operators. The timing and duration of these load reductions can fit well with the requirements of incentive-based DR programs such as ancillary services or demand bidding.

Participation in the wholesale electricity market is different than the more common retail level peak load management DR programs that are operated by the electric utilities. This comparison is shown in Figure 2 (adapted from Priority Action Plan [PAP19]). (Note: In areas that have adopted full retail-level competition, retail DR arrangements may be different than shown.)

Incentive-based DR programs such as ancillary services or demand bidding can be a good fit for military installations. Payments for participation can be made as a credit to the monthly utility bill. Wholesale-level demand bidding programs (DBP) have been in place for a number of years, enabling large electric customers to participate in the markets. More recently, wholesale markets are being opened to medium and small retail electric customers as well, through the efforts of public utility commissions and electric grid operators. These load reductions are typically scheduled day-ahead, and incentive payments are valued and coordinated with day-ahead energy markets (U.S. Department of Energy [DOE], 2006) DBP events may have a duration lasting from noon to 8pm.

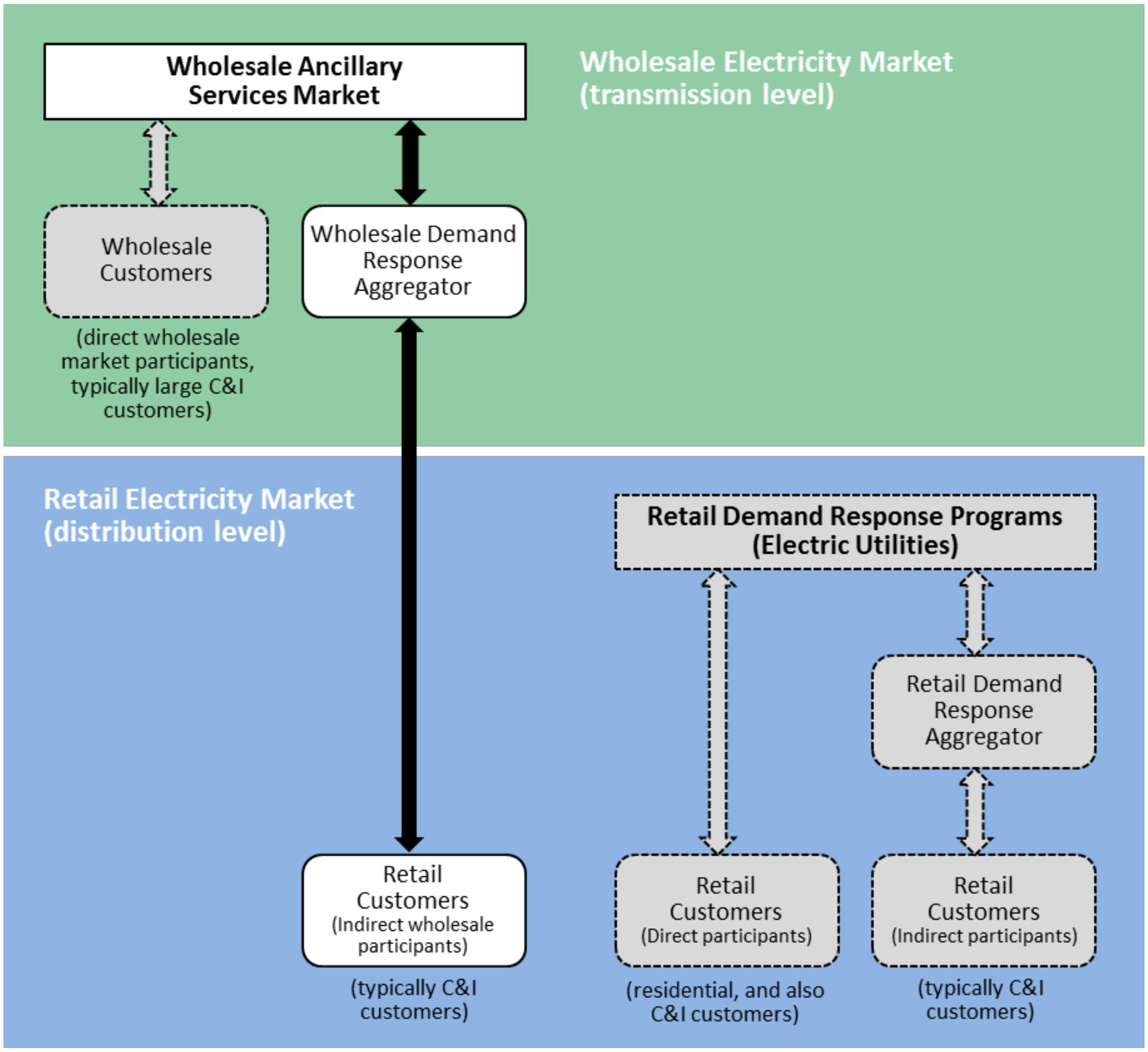

Figure 2. DR in wholesale electricity markets.

1.1.2 OpenADR Protocol

Early efforts in AutoDR that took place in California resulted in the development of the OpenADR 1.0 specification. This early work was led by Lawrence Berkeley National Laboratory (LBNL), with funding from the California Energy Commission. Beginning in 2009, the PAP09 activity under the National Institute of Standards and Technology (NIST) Smart Grid Interoperability Panel (SGIP) program led to the development of the updated OpenADR 2.0 industry standard.

OpenADR 2.0 includes two profiles of use or application:

- The OpenADR 2.0a profile is targeted at limited resource devices and simple DR applications (i.e., thermostats and other residential DR applications); and
- The OpenADR 2.0b profile is targeted at more robust devices and sophisticated DR applications (i.e., commercial and industrial DR applications).

DR applications at military installations are most similar to those found in the commercial sector, with typical DR applications being for building HVAC and lighting equipment as well as other applications such as large pumping loads. Some refrigeration and other specialty applications at military installations are relevant as well. For this reason, the project demonstration employed the OpenADR 2.0b profile in the field implementation.

The OpenADR 1.0 specification was included in the NIST "Smart Grid Interoperability Standards Framework," as a key standard for DR for the smart grid (NIST, 2014). In 2012, the SGIP incorporated OpenADR into the SGIP Catalog of Standards (CoS) (SGIP, 2015). The SGIP activity is complemented by the efforts of the OpenADR Alliance (Alliance), a nonprofit corporation created to foster the development, adoption, and compliance of the OpenADR 2.0 standard through collaboration, education, training, testing, and certification. The Alliance is promoting worldwide acceptance of OpenADR 2.0 for price- and reliability-based DR. The Alliance currently includes more than 50 members made up of utility, nonprofit, government, and corporate organizations (Alliance).

1.1.3 Opportunities for Military Installations

Military installations can benefit by having Directorate of Public Works (DPW) staff, who track utility, and grid operator DR programs (and incentives) to identify ways to create energy and economic benefit from DR participation. Support from utility customer service representatives would also be helpful in determining the best courses of action. More information about market opportunities can be found in the report from a recent DOE study (Cappers et al., 2013).

1.2 OBJECTIVE OF THE DEMONSTRATION

This ESTCP project began in 2012 with the objective of demonstrating the use of OpenADR technology to enable Fort Irwin to participate in the California Independent System Operator (CAISO) wholesale electricity market through an anticipated ancillary services pilot program to be offered by Southern California Edison (SCE), the electric utility provider for Fort Irwin. Regulatory delays prevented the use of a utility pilot program in the project's 2014 demonstration at Fort Irwin. For that reason, the project plan was revised to utilize the SCE DBP program to demonstrate the application of OpenADR.

Following a demand response audit of a number of candidate buildings at Fort Irwin, the OpenADR communications and control technology was implemented for a set of selected electric loads. Utilizing the SCE DBP as a demonstration vehicle, the project generated performance data for acceptance and validation of the OpenADR technology. Additional information about SCE DR programs can be found on the SCE DR website (SCE, 2015).

1.3 REGULATORY DRIVERS

This project demonstrated a key technology (OpenADR) that will make it possible for Department of Defense (DoD) installations to effectively tap into new DR and wholesale electricity market opportunities as sources of funding to procure improvements to its energy infrastructure. These improvements will help installations satisfy the requirements of applicable energy regulations, Executive Orders (EO), and DoD directives. Examples of the ways that this strategy contributes toward satisfying the various directives are shown in Table 1.

Table 1. Project satisfaction of DoD directives.

Directive	Relevance of this project
EO 13514 "Federal Leadership in Environmental, Energy, and Economic Performance" http://www.gpo.gov/fdsys/pkg/FR-2009-10-08/pdf/E9-24518.pdf	By allowing utility and electric grid operators to use an installation's demand-side resources to provide electricity services to the grid (rather than conventional generation providers), installations reduce Scope 2 emissions related to electricity consumption.
Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding (MOU) 2006 http://www1.eere.energy.gov/femp/program/m/sustainable_principles.html	Revenues or utility bill savings will enable installations to invest in new or retrofit improvements, which reduce energy consumption. This new source of funds could also be used to procure other upgrades to satisfy other parts of the MOU.

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2.0 TECHNOLOGY DESCRIPTION

This section describes the OpenADR technology and its application to this demonstration project.

2.1 TECHNOLOGY OVERVIEW

OpenADR provides the needed automation link between the utility or grid operator and a set of pre-programmed (automated) DR strategies in the building owner's building energy management system (BMS) and, thereby, to the individual loads. This automated communication technology effectively joins an installation's BMS with utility or grid operator DR programs. DR control strategies are implemented in the installation's BMS to adjust the operation of building loads in response to DR event commands from the utility or grid operator via the Demand Response Automation Server (DRAS). On a military installation, candidate electric loads for use in DR programs include HVAC equipment, lighting, water pumping, and other miscellaneous motor loads.

Figure 3 shows a high-level diagram for the OpenADR control and communications system at Fort Irwin. The system is made up of two key components:

- OpenADR messages to and from Fort Irwin and the SCE DBP program coordinator (DBP event dispatches and electric meter data sent through the DRAS); and
- Building control automation at the installation (to automatically carry out equipment control actions in response to OpenADR event commands received from the utility DR program coordinator).

A military installation can participate in a DR program by offering (bidding) their demand side resources via the utility's DR website. The bids offer stated amounts of electric demand reduction (in kilowatts [kW]) and specific hours of the day, depending on the type of DR program. The economic benefits of reducing electric demand are defined in the utility DR tariff, which in the future might also be based in part by prices in the wholesale electricity market.

The bid can be modified (and can be resubmitted) as conditions change at the military installation. If desired, the bid can be considered a standing bid, which is valid until changed by the installation. If the operating conditions (and any special constraints) at the installation are unchanged, it may not be necessary to update the bid each day.

2.1.1 Comparison to Existing Technology

Participation in wholesale electricity markets requires electronic communications and automated control capability. These key functions are provided through the OpenADR industry standard protocol. A number of research and proof-of-concept demonstration projects applying OpenADR communications to wholesale electricity markets have been performed over the past few years (Kiliccote et al., 2009).

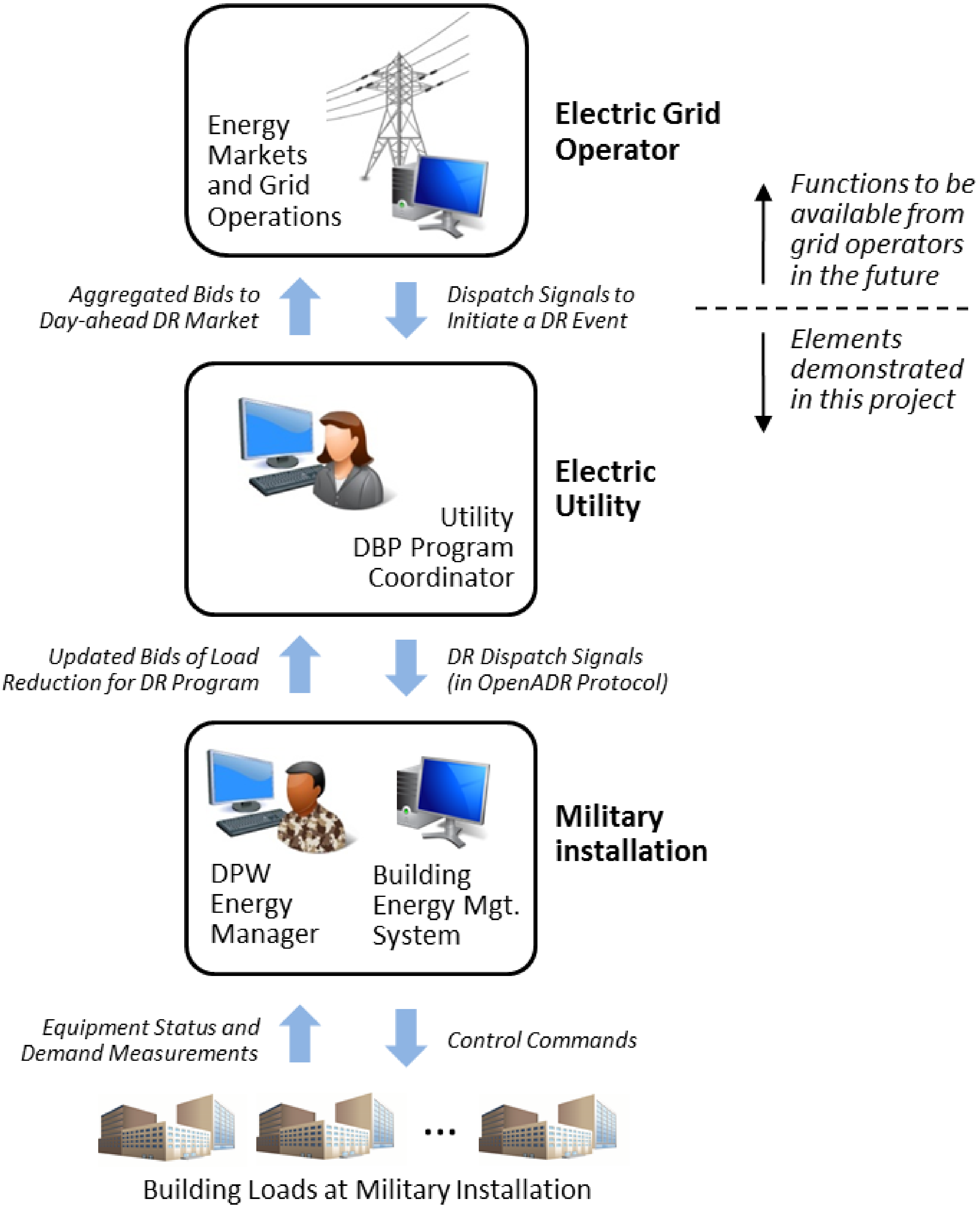

Figure 3. Demand bidding communication and control.

2.1.2 Chronological Summary

Research work in AutoDR, beginning in 2002, yielded a series of technical advancements and successful utility pilot demonstrations and commercial installations. OpenADR standard development has evolved through initial work at LBNL's Demand Response Research Center (DRRC). This early work was funded by the California Energy Commission, and resulted in the publication of a formal specification: OpenADR 1.0. This technology has been used widely for utility peak load management DR programs.

The OpenADR 1.0 specification was incorporated into the NIST SGIP CoS in 2012. The NIST SGIP activity extended this earlier work into the current OpenADR 2.0 standard, with the support of a wide range of industry stakeholders. Ongoing related efforts are expected to lead to a worldwide standard for AutoDR (Ghatikar and Beinert, 2011).

OpenADR 2.0 includes an up-to-date set of cyber security protocols, ensuring secure communication of DR events to participating electric customers. The OpenADR 2.0 industry standard was incorporated into the NIST SGIP CoS in 2013.

2.1.3 Future Potential for DoD

A recent industry study points out that the OpenADR standard makes it possible for demand side resources to enter the wholesale electricity markets (Bloom and Gohn, 2012). This market opportunity opens a path to a new source of funds for military installations to apply to renewable energy and conventional energy efficiency improvements. Many of the electric loads on military installations are similar to those found in commercial buildings, so the current body of knowledge about DR applications can be applied to military installations as well. Field implementations of OpenADR can easily incorporate the means to opt-out of DR events when needed, to ensure the installation's mission requirements can be met.

2.1.4 Anecdotal Observations

DR and energy efficiency are closely related. With appropriate control strategies, building operators can effectively utilize both energy efficiency and DR to optimize their facility performance and participate in electricity markets. Lessons learned in DR events can inform permanent energy efficiency improvements and vice versa. Fine tuning facilities to be energy efficient and demand responsive allows for greater flexibility and the potential to better serve the facility, utility, and grid. Past research in DR has revealed a complementary effect between DR and energy efficiency. Improved building controls, when implemented for DR, typically also result in improved system monitoring and insight for building operators. The effects of DR strategies overlap with strategies for energy efficiency (Kiliccote and Piette, 2005). This improvement in operations for DR also provides energy use reduction (the amount of which is site specific).

2.2 TECHNOLOGY DEVELOPMENT

The OpenADR 2.0 industry standard was developed at NIST outside of this ESTCP project through an industry-wide effort including electric utilities, control system vendors, and smart grid leaders. This standard employs the latest advances in information security and improved interoperability between utilities, grid operators, and building control system vendors who offer OpenADR-compliant products and systems. In a separate, parallel activity, Honeywell developed an OpenADR 2.0b compliant client device that enables communication of DR signals and demand data with an OpenADR 2.0b compliant DRAS.

No development of OpenADR protocols or devices took place as part of this ESTCP project. This project utilized the OpenADR 2.0b standard to satisfy the technical requirements of the DR application at Fort Irwin (specifically, the building loads selected by DPW for this project). Details of the field implementation are presented in Section 5.3.

2.3 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

The following subsections describe performance and cost advantages and limitations of OpenADR.

2.3.1 Performance Advantages

Use of OpenADR technology does not directly provide increases in energy efficiency or improved system performance. Its advantages, as described earlier, accrue from revenues received through utility DR tariffs or from participation in the electricity markets to provide a new source of funding that a military installation can use to procure improvements to its energy infrastructure. Those infrastructure improvements will deliver increased energy efficiency, improved system performance, and other performance or energy security benefits to military installations.

2.3.2 Cost Advantages

Similar to performance advantages, the primary cost advantages resulting from the utilization of utility DR tariffs or participation in electricity markets will be derived from the associated improvements to the military installation’s energy infrastructure. Those infrastructure improvements will deliver improvements in first cost, installation cost, and/or operations and maintenance costs to military installations.

2.3.3 Performance Limitations

The OpenADR standard, and its application to wholesale electricity markets, is being developed to meet the performance requirements of the electric grid operators and utility scheduling coordinators. No significant performance limitations are foreseen.

Potential risks of electricity market participation (such as shortened equipment lifetime, increased maintenance, or system complexity) will be driven by the nature of the DR control strategies chosen by the military installation facilities staff. Properly designed DR control strategies should not affect equipment life expectancy or energy efficiency. Examples of well-proven DR control strategies can be found in published literature (Motegi et al., 2007).

2.3.4 Cost Limitations

With the efforts of the SGIP described earlier in this document, most industry experts believe that wholesale electricity market DR communications will be standardized using OpenADR.
As an open industry standard, no cost limitations are foreseen in the use of OpenADR, and no potential cost disadvantages (such as increased first cost, installation cost, and/or operations and maintenance [O&M] costs) are expected.

2.3.5 Social Acceptance

No barriers to acceptance by operators, maintenance staff, or facility management are foreseen. Experience with other applications of DR in the commercial sector, have been very positive. Past experience with utility-level retail DR applications at military installations have given positive results (Defense Logistics Agency [DLA], 2011).

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3.0 PERFORMANCE OBJECTIVES

The project's performance objectives (PO) enabled the verification of key performance indicators for OpenADR technology as applied in this project. These POs measured the ability of OpenADR (through participation in the SCE DBP program) to deliver a new source of revenue for energy infrastructure improvements.

Energy Security: Revenues received from participation in electricity markets can provide a new source of funding that installations can use to procure improvements to energy infrastructure that will deliver energy security benefits.

Cost Avoidance: Cost advantages resulting from participation in electricity markets can be derived from the associated improvements to the military installation's energy infrastructure. Those infrastructure improvements can also deliver improvements in O&M costs to military installations.

Greenhouse Gas (GHG) Reduction: Energy infrastructure improvements can deliver reductions in Scope 1 and Scope 2 GHG emissions to military installations.

3.1 SUMMARY OF POs

Table 2 gives a high-level summary of the demonstration project's POs.

Note: Some of the POs are expressed in terms of DBP-related metrics (rather than the originally-intended ancillary services related metrics). The change reflects the utilization of the SCE DBP program during the demonstration at Fort Irwin.

Table 2. POs.

PO	Metric	Data Requirements	Success Criteria	Results
Quantitative POs				
PO1: Reduce electric demand by the amount specified in the DBP bid	Ability to deliver the planned (bid) amount of demand reduction	Electric demand data measured for each controlled load.	Demand reduction in each DBP interval period is achieved within ±20%	This PO was met.
PO2: Maximize the DBP bids across a typical year	Utilization of each DR load in each DBP bid	Bid profile history, and measured kW data collected during DBP events	>90% average utilization of each DR load in each DBP bid	This PO was met.
PO3: Produce a recurring source of funds to invest in energy infrastructure	Simple payback and savings-to-investment ratio (SIR)	Initial investment cost, utility-offered incentive rebates, utility bill credits, and annual maintenance cost	Simple payback time < 3 years, SIR >> 1	The project team was not able to assess this PO.

Table 2. POs (continued).

PO	Metric	Data Requirements	Success Criteria	Results
Quantitative POs				
PO4: User interface effectiveness for DBP event opt-outs by DPW operators	Ability of operators to assess potential impacts of pending DBP events and adjust, if necessary	Feedback from DPW staff about the quality of the user interface, and actions taken to respond to changes in mission requirements	A skilled DPW energy manager can effectively use the interface with little or no training	The project team was not able to assess this PO.
PO5: O&M of control and communication equipment	Need for maintenance beyond that expected for BMSs	Observations, maintenance records from DPW, records of control or communications equipment replacement, and system downtime	O&M cost is not significantly greater than typical BMS DR applications	This PO was met.

%= percent

3.2 POs DESCRIPTIONS

Subsections 3.2.1 through 3.2.5 describe the five POs for this project.

3.2.1 PO1: Reduce Electric Demand by the Amount Specified in the DBP Bid

Purpose: It is important to be able to deliver the bid amount of demand reduction (within an acceptable range) when an event is called by the utility or grid operator. The ability to accurately deliver the bid amount of demand reduction helps maximize the energy and economic benefits to the installation.

Metric: Ability to deliver the bid amount of demand reduction during each hour of each DBP event. The units are kW of measured demand reduction, as compared to the bid amount.

Data: The desired result is that the reduction in electric demand (in kW) during each hour of the event should closely match the amount of the bid for that hour. Note that the project did not submit DBP bids to SCE during the demonstration period because Fort Irwin DPW was also participating manually in the SCE DBP program with a number of much larger loads. So, the project team analyzed the performance of each controlled load (chillers at Fort Irwin) individually to determine how closely the measured electric load reduction matched the DR control command issued by the pre-programmed DR control strategies.

The data used to evaluate this PO was:

- To indicate electric load reduction, the analysis utilized data from the % rated load amps (RLA) analog output from each chiller. This data measures the amperage drawn by the compressor motor, and is an indicator of the electric load of the chiller.

- The demand reduction command to each chiller was implemented via control adjustments to the chiller's current limit control input (this is an analog input to the chiller's internal controller). This control input specifies the maximum amount of compressor motor amperage (and hence, cooling capacity or load) at which the chiller can operate. This current limit setting is expressed as percent of RLAs. The hours that had no demand control can be considered equivalent to hours when the demand reduction bid would have been zero.

The chiller's full load RLA and the %RLA current limit control command are useful as proxies for the full load kW, and a commanded kW operating limit (and are therefore useful for calculating the DBP bid to the utility). These relationships were used in Honeywell's user interface for DBP control, as described in Section 5.3.

Analytical Methodology: The project team analyzed the measured data for each chiller collected during each DBP event in the demonstration period. In this analysis, the measured results for the current limit command (sent to the chiller) were compared to the resulting chiller % RLA operating amperage.

Success Criteria: In future practice, an installation energy manager's bid strategies will strongly influence the bid performance. For this demonstration testing, the project team sought to achieve a chiller control tracking accuracy of ±20% (i.e., the difference between the current limit control command to the chiller versus the measured %RLA operating amperage). The project team sought to meet the ±20% control accuracy goal for at least 90% of the hourly intervals encountered during the demonstration period.

Results: Analysis of measured data showed that this PO was met.

3.2.2 PO2: Maximize the DBP Bids Across a Typical Year

Purpose: When no mission constraints are present, installations should strive to maximize their DBP bids (and thus economic benefits) within the limits of non-mission-related operational constraints (i.e., acceptable trade-offs against comfort, service, or other operational constraints).

Metric: Utilization of each DR load in each DBP bid submitted to the SCE DBP program coordinator.

Data: The desired data for this PO was the bid profile history during the demonstration. However, as described earlier, the project did not submit DBP bids to SCE during the demonstration period. So, the project team assessed the number of times that one or more of the controlled loads was not available for use in a DBP event (i.e., due to some operational or mission-related constraint).

Analytical Methodology: The project team assessed the number of times that one or more of the controlled loads was not available for use in a DBP event (or opted-out of an event).

Success Criteria: A >90% average utilization of each DR load in each DBP bid (or event).

Results: During the demonstration's DBP events, there were no instances when any of the controlled loads were not available for use (or opted-out of an event). As a result, this PO was met.

3.2.3 PO3: Produce a Recurring Source of Funds to Invest in Energy Infrastructure

Purpose: Participation in electricity market DR programs can produce utility bill credits that the installation can use to invest in improvements to its energy infrastructure. These improvements could be commonly used energy conservation measures (ECM) and/or renewable energy projects.

Metric: Simple payback and SIR.

Data: Initial investment cost, utility bill credits from participation electricity markets or utility DR programs, and annual maintenance cost of the technology (all taken from data collected during the demonstration period).

Analytical Methodology: Utilize the above data to compute the above metrics. Also use results of a recent study at Fort Irwin of relevant ECMs (Underwood et al., 2010).

Success Criteria: Simple payback time < 3 years, SIR >> 1

Results: The project team was not able to perform this analysis due to a lack of the necessary data (as a result of the relatively small demonstration-scale scope of the project).

The scope (i.e., the size of the installed system) in this project was relatively small, due to its scope (demonstration-scale). For this reason, the project could not produce the data necessary to perform this analysis. The needed information (at full-scale) about upfront construction cost, utility incentives, and economic benefits, could not be determined from the data produced in this project. Therefore, the project team was not able to assess this PO.

3.2.4 PO4: User Interface Effectiveness for DBP Event Opt-Outs by DPW Operators

Purpose: An effective user interface is needed to enable the DPW energy manager to easily make changes to the system's control settings and other key parameters.

DPW energy managers and facility operators need the ability to adjust the system in response to changes in operational or mission requirements. A change in these requirements may dictate that certain controllable loads must be opted-out of a DBP bid/event or that a DBP event must be opted-out altogether.

Metric: Ability of operators to assess potential impacts of pending DBP events and adjust DBP bids and/or DR control strategies accordingly.

Data: Feedback from DPW staff about the quality of the user interface, and experience from actions taken in response to changes in operational or mission requirements.

Analytical Methodology: Collect information from interviews with the DPW energy manager and facility operators about situations where operations or mission requirements required changes to the DBP bids or control settings. Determine whether it was sufficiently easy to make changes to DBP control settings. Make comparisons against the ease of use for typical BMS functions.

Success Criteria: A skilled DPW energy manager can effectively use the control system's user interface with little or no training.

Results: The project team had planned to collect the data by interviewing the DPW energy manager and operating staff at various times throughout the demonstration. However, DPW's role during the demonstration was very limited, so they were not able to provide feedback about the usability of the control system interface. Therefore, the project team was not able to assess this PO.

3.2.5 PO5: O&M of Control and Communication Equipment

Purpose: The amount of O&M cost or effort required is an important indicator of system performance. This technology uses hardware and software components that are commonly used for building energy management and DR applications in the commercial sector. The level of O&M cost required for those applications is the baseline for comparison.

Metric: Need for maintenance beyond that typically expected for BMSs.

Data: Observations, maintenance records from DPW, records of control or communications equipment replacement and system downtime.

Analytical Methodology: The O&M cost or effort required for this DR control system should not be significantly greater than for typical BMSs with DR applications.

Success Criteria: O&M cost is not significantly greater than typical BMSs with DR applications.

Results: Although the demonstration period was rather short in duration, we did not experience any unexpected O&M cost or effort required. Based on this experience, we believe this PO was met.

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4.0 FACILITY/SITE DESCRIPTION

This section describes the selected demonstration site at Fort Irwin, CA.

4.1 FACILITY/SITE LOCATION AND OPERATIONS

The project team worked closely with the Fort Irwin DPW to select three buildings on the post for use in this project. The key controllable loads in these buildings were well-suited to the demonstration objectives of this project. The following characteristics of the selected buildings fit well with the needs of the demonstration:

- The operating requirements of the selected loads had the desired degree of flexibility (ability to reduce demand for short periods, without impacting the mission of the installation);
- HVAC loads are an acceptable type of load for the SCE DBP program; and
- The peak demand at Fort Irwin is well above the minimum of 200kW required by the SCE DBP program.

For several years prior to this project, Fort Irwin had been participating in the SCE DBP program by controlling (shedding load from) a number of large water system pumps as well as a number of building loads (using telephone/fax communications and manual ON/OFF control of the loads). This manually controlled DBP participation at Fort Irwin continued unchanged during the project demonstration (but did not have an impact on the performance or results of the ESTCP project).

An overview of the Fort Irwin installation and associated details regarding the demonstration are presented below.

4.1.1 Demonstration Site Description

Fort Irwin is a large military installation located northeast of Barstow, California. The numerous buildings and other facilities on the post are representative of a typical military installation.

4.1.2 Key Operations

Fort Irwin has a daily population of up to 25,000 military and civilian personnel. Fort Irwin is the home of the National Training Center (NTC), a world-class training center whose mission is to provide tough, realistic joint and combined arms training in a contemporary operating environment. The NTC trains the transformed Army by conducting force-on-force and live-fire training for ground and aviation brigades in a joint scenario across the spectrum of conflict, using a live-virtual constructive training model.

4.1.3 Location/Site Map

The following information about the demonstration site is shown in the figures below:

- A site map showing the location of the buildings (Figure 4)
- Photos of each building (Figure 5) and

- Table 3 describes the controllable loads for this project.

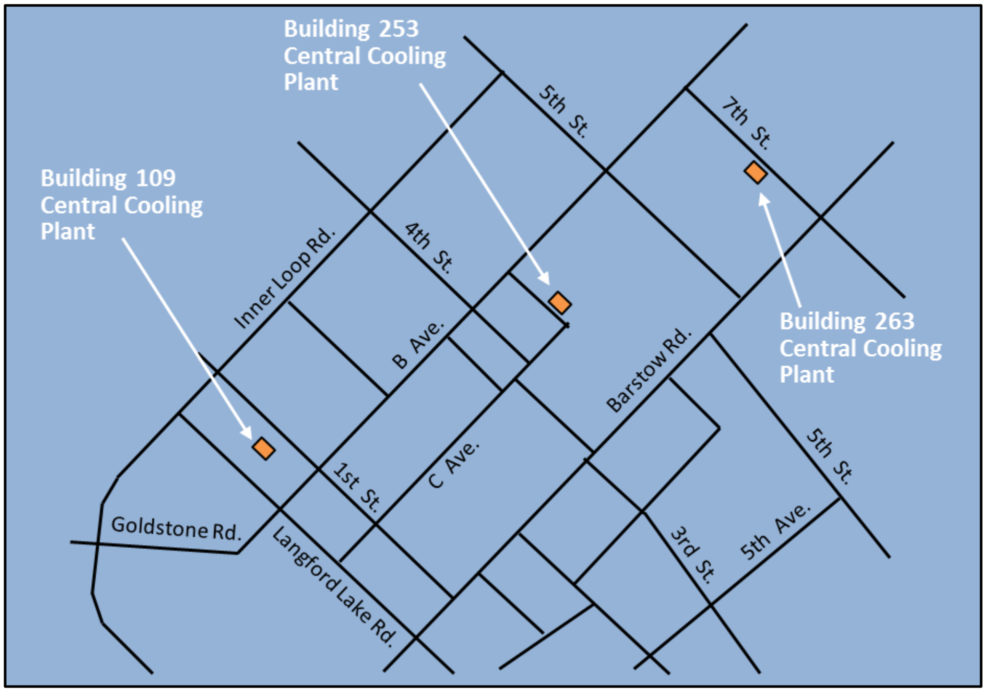

Figure 4. Site location map.

Central Cooling Plant, Bldg. 253
(4th St. off 'B' Ave.)
(Chiller mechanical room is on the left side of the building)

Central Cooling Plant, Bldg. 263
(7th St. off Barstow Rd.)

Central Cooling Plant, Bldg. 109
(Langford Lake Rd. off 'B' Ave.)
(Mechanical room is at the rear of the building)

Figure 5. Demonstration buildings.

Table 3. Controllable loads.

Building	Controlled Loads	Max Load (kW)	RLAs	Lowest Current Limit Setting	CHWS Setpoint	Date Manufactured
Bldg #263 Central Cooling Plant	325 ton centrifugal chiller	185	235	40% RLA	48 EF	2012
Bldg #253 Central Cooling Plant	350 ton centrifugal chiller (est.)	195	270	40% RLA	44 EF	2005
Bldg #109 Central Cooling Plant	170 ton rotary chiller	113	172	60% RLA	45 EF	2012
	Total	**493**				

Note: All of these chillers are supplied by 480 volt 3-phase power.
CHWS = chilled water supply

4.2 FACILITY/SITE CONDITIONS

4.2.1 Geographic Criteria

No climate zone criteria were relevant to the selection of a demonstration site for this technology. The SCE DBP program enabled the installation to respond to DBP events through OpenADR communications and AutoDR control strategies.

4.2.2 Other Selection Criteria

Fort Irwin has some flexibility in the operation of the candidate buildings and controllable loads (i.e., it is possible to curtail the selected equipment in response to DR event dispatch signals from the utility). Opt-outs for selected periods and overrides of individual DR events could be easily accommodated to comply with changes in mission requirements.

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5.0 TEST DESIGN

This section provides a detailed description of the system design and testing conducted during the demonstration.

Fundamental Problem: Military installations need increased funding resources to meet future energy and sustainability objectives through 2020 (to reduce energy intensity, increase renewable energy use, and improve energy security). Participation in emerging wholesale electricity markets can provide new sources of funding to procure improvements to the DoD energy infrastructure.

Demonstration Question: Can OpenADR technology effectively enable a military installation to participate in electricity markets?

5.1 CONCEPTUAL TEST DESIGN

The test design for this demonstration addressed the variables associated with the operation of the selected HVAC loads (chillers in three central cooling plants) at Fort Irwin. A set of test variables was defined for the purpose of the field demonstration. The test variables are:

Independent Variable: For this project, the independent variable (i.e., the input to the test or cause of the results of the test) was the utilization of OpenADR communication and control technology to automate the DR of the selected building electric loads.

Dependent Variables: These are measured variables that change as a result of applying the OpenADR communication and control technology. The dependent variables measured during the demonstration were:

- Electric demand (kW) reduction in response to DBP events;
- CHWS temperatures, which may increase slightly during DBP events as a result of chiller demand limiting; and
- Indoor temperatures in occupied spaces, which may increase slightly due to elevated CHWS temperatures during DBP events.

Controlled Variables: These are variables that were held constant during the demonstration. The controlled variables were:

- No increase or decrease in electric loads or cooling in the buildings selected for the demonstration;
- No changes in building occupancy levels or scheduling; and
- No changes in HVAC control set points.

Uncontrolled Variables: Variations in weather (i.e., ambient temperature, humidity, solar insolation, wind, etc.) were measured during the testing, but were not addressed in the test design. While these variables affect the potential amount of electric demand reduction available at any point in time, these effects (as well as day of week) are accounted for in computing the utility DR baseline.

Other Variables: A number of other variables were not measured during the demonstration. These included utility bill credits; O&M cost, management oversight, and utilization of controlled loads.

Hypothesis: To answer the demonstration question posed above, the project team tested the following hypothesis:

> *Employing OpenADR communication and control technology enables a military installation to automate its DR actions, and to accurately shed electric load from selected equipment.*

The acceptance criterion for the hypothesis was: DR controlled equipment can accurately follow commands that are issued by the pre-programmed DR control strategies during a DBP event.

Test Design: To test the hypothesis, the project team conducted the demonstration as a set of demand bidding events. During these events, the project team collected measured data for the commands issued by the pre-programmed DR control strategies and for each key dependent variable.

5.2 BASELINE CHARACTERIZATION

Measured data for the characterization of baselines for key dependent variables was collected prior to the demonstration test period. This baseline data is described in the following paragraphs.

Chiller Electric Demand: Electric demand data (in kW) was collected for each chiller. The baseline kW profiles for each chiller were fitted manually, based on measured data from the available periods. (The SCE 10-day baseline algorithm could not be applied due to a lack of sufficient historical data.) The chiller baseline kW profiles gave good results during the demonstration period.

Other Chiller Data: Data for these additional variables were collected for each chiller. These baseline profiles for each chiller were also fitted manually. The resulting baseline profiles gave good results during the demonstration period.

- % RLA analog output from each chiller. This data measures the amperage drawn by the compressor motor. This data is an indicator of the electric load on the chiller.
- CHWS temperature.

Indoor Space Temperatures: Temperature data for affected indoor spaces was collected prior to the demonstration test period. The baseline temperature profiles for each space were computed as an average by hour, based on measured data from the baseline period. Baselines for the following indoor spaces were prepared:

- Building 109 (to monitor effects of demand reductions at the chiller in Central Plant 109);
- Building 252 (to monitor effects of demand reductions at the chiller in Central Plant 253); and
- Building 262 (to monitor effects of demand reductions at the chiller in Central Plant 263).

Outdoor Ambient Temperature: Profiles of ambient temperature for periods prior to and during the demonstration were prepared for reference purposes.

5.3 DESIGN AND LAYOUT OF TECHNOLOGY COMPONENTS

The technical features and component layout of the OpenADR control and communications system are described in the following paragraphs.

5.3.1 System Design

A high-level overview of the system is presented in Figure 3. The timeline for a typical DBP event is shown in Figure 6 (adapted from Goldberg and Agnew, 2013). Figure 7 shows the key operator screen used in the demonstration. This control interface is used for monitoring and modifying DBP control parameters (demand limit settings, opt-out periods, etc.).

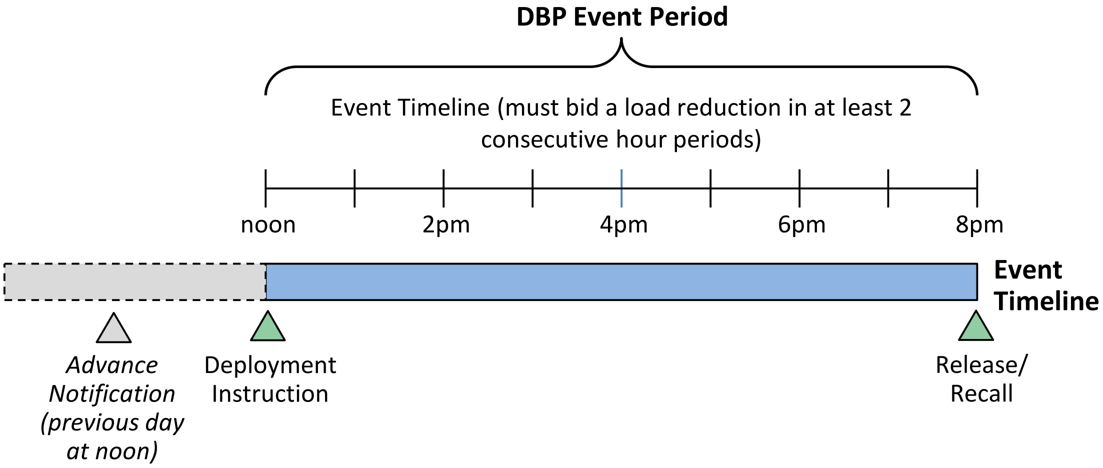
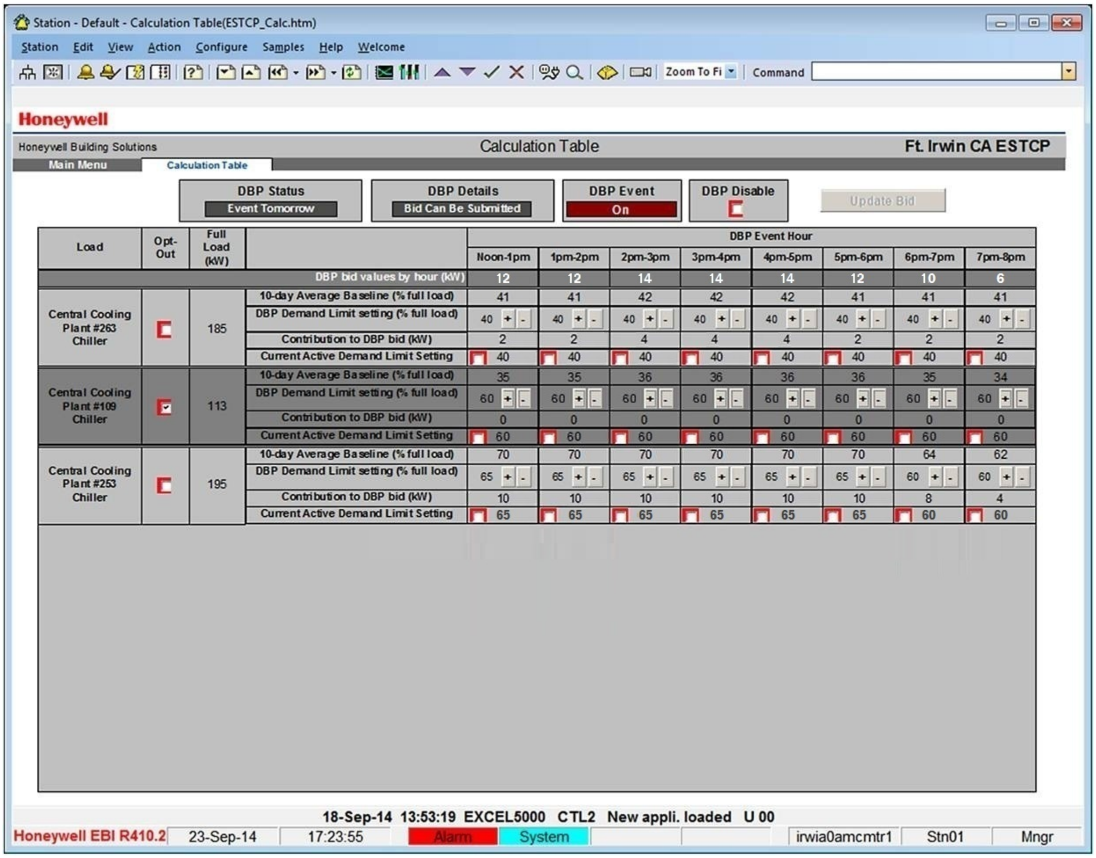


Figure 6. Typical DBP event timeline.



DBP Status: Event Tomorrow
DBP Details: Bid Can Be Submitted
DBP Event: On
DBP Disable: ☐

Load	Opt-Out	Full Load (kW)		DBP Event Hour							
				Noon-1pm	1pm-2pm	2pm-3pm	3pm-4pm	4pm-5pm	5pm-6pm	6pm-7pm	7pm-8pm
			DBP bid values by hour (kW)	12	12	14	14	14	12	10	6
Central Cooling Plant #263 Chiller	☐	185	10-day Average Baseline (% full load)	41	41	42	42	42	41	41	41
			DBP Demand Limit setting (% full load)	40 + -	40 + -	40 + -	40 + -	40 + -	40 + -	40 + -	40 + -
			Contribution to DBP bid (kW)	2	2	4	4	4	2	2	2
			Current Active Demand Limit Setting	☐ 40	☐ 40	☐ 40	☐ 40	☐ 40	☐ 40	☐ 40	☐ 40
Central Cooling Plant #109 Chiller	☑	113	10-day Average Baseline (% full load)	35	35	36	36	36	36	35	34
			DBP Demand Limit setting (% full load)	60 + -	60 + -	60 + -	60 + -	60 + -	60 + -	60 + -	60 + -
			Contribution to DBP bid (kW)	0	0	0	0	0	0	0	0
			Current Active Demand Limit Setting	☐ 60	☐ 60	☐ 60	☐ 60	☐ 60	☐ 60	☐ 60	☐ 60
Central Cooling Plant #253 Chiller	☐	195	10-day Average Baseline (% full load)	70	70	70	70	70	70	64	62
			DBP Demand Limit setting (% full load)	65 + -	65 + -	65 + -	65 + -	65 + -	65 + -	60 + -	60 + -
			Contribution to DBP bid (kW)	10	10	10	10	10	10	8	4
			Current Active Demand Limit Setting	☐ 65	☐ 65	☐ 65	☐ 65	☐ 65	☐ 65	☐ 60	☐ 60

18-Sep-14 13:53:19 EXCEL5000 CTL2 New appli. loaded U 00

Honeywell EBI R410.2 | 23-Sep-14 | 17:23:55 | Alarm | System | irwia0amcmtr1 | Stn01 | Mngr

Figure 7. User interface screen.

5.3.2 System Components

The key components in the OpenADR control and communications system (as described above) are the BMS's controllers and server, along with the OpenADR client, which communicates with the SCE DBP program coordinator's DRAS. SCE provided the DRAS for use in this demonstration project.

5.3.3 DBP Control Strategies

DBP control (demand reduction) was performed by commanding the chiller's current limit input (this is an optional analog input to the chiller's internal controller). This control input specifies the maximum amount of compressor motor amperage (and hence, cooling capacity or load) at which the chiller can operate. This current limit setting is expressed as percent of RLAs. The control ranges of the current limit analog inputs for the three chillers are shown in Table 4.

Table 4. Control inputs to chillers.

Central Plant	Current Limit Control Range
109	60% to 100% RLA
252	40% to 100% RLA (but limited to 70% RLA maximum during the demonstration due to a fouling condition in the chiller's condenser)
263	40% to 100% RLA

5.3.4 Demand Bidding Program Background

The SCE DBP is a year-round, flexible, Internet-based bidding program that offers business customers credits for voluntarily reducing power when a DBP event is called. A DBP event may occur any weekday (excluding holidays) between the hours of noon and 8:00 p.m., and are triggered on a day-ahead basis. These events may occur at any time throughout the year.

Credits are based on the difference between the customers' actual metered load during an event to the hourly baseline load that is calculated from each customer's usage data prior to the event. Credit amounts are based on whether or not the bid and actual power reduction fulfilled DBP bidding criteria. To determine the billing credit, the measured energy reduction during each hour of the event is multiplied by the DBP incentive rate of $0.50 per kilowatt hour (kWh).

Customers whose bids meet the bidding criteria must reduce load by a minimum of 50 percent of their hourly bid amount to qualify for a credit. Bidding customers are paid for measured load reductions between half and twice their bid amount with no credit for reductions outside of these amounts. There are no penalties for submitting a bid and not reducing power.

5.4 OPERATIONAL TESTING

The demonstration test made use of actual DBP event days (scheduled by SCE), as well as a number of simulated DBP event days (initiated by the project team). The event days are shown in Table 5. The total number of DBP events was comparable to a typical year.

Table 5. DBP event dates.

Date	Day of Week	Simulated DBP Event	Actual SCE DBP Event
Aug 28	Thursday	x	
Sept 3	Wednesday	x	
Sept 5	Friday	x	
Sept 8	Monday		x
Sept 10	Wednesday		x
Sept 15	Monday		x

During the demonstration period, some of the DBP control actions were accomplished via control signals from the Honeywell control system and others were performed manually at the equipment. The performance results observed were consistent. No differences in performance between these two schemes were noted.

The demand reduction periods during each of the DBP events had relatively short durations. The hours, which had no demand control, can be considered to be equivalent to hours when the demand reduction bid would have been zero. This is compliant with the terms of the SCE DBP program and is a condition that can occur in real operation (e.g., to avoid impacting operations or the mission of the installation during critical periods). These effective "zero" hourly bids did not diminish the ability of our DBP events to demonstrate the technology. The project team employed relatively conservative current limit settings in our control response to the simulated as well as actual SCE DBP events.

The chiller in Central Plant 109 was utilized sparingly during the demonstration period, because the unit was very lightly loaded. Its normal electric amperage was typically 35% to 40% RLA. The current limit control range on that unit is limited to the range of 60% to 100% RLA, thereby making it unsuitable for demand reduction (given its typically very light cooling load). (Note: For use in a future DR program, Fort Irwin DPW could choose to change to a DR control strategy of raising the leaving CHWS setpoint during a DR event.)

5.5 SAMPLING PROTOCOL

Table 6 describes the sources of the measured data. The source of the outdoor air temperature data is the MesoWest site at the University of Utah, Department of Atmospheric Sciences, http://mesowest.utah.edu. MesoWest is a cooperative project between researchers at the University of Utah, the National Weather Service, and personnel in participating agencies, universities, and commercial firms. The temperature data was measured at the KBYS Fort Irwin / Barstow station, which is located on the Bicycle Lake Army Airfield about 3 miles from the Fort Irwin cantonment area.

Table 6. Measured data.

Data	Sensor or Source of the Data
Chiller kW	Electric submeters
Chiller %RLA	Observations taken from the chiller controller's user interface
Space temperatures of occupied spaces in buildings served by the three chiller plants	Battery-powered temporary sensors
Outdoor ambient temperature	MesoWest data
CHWS temperatures	Observations taken from the chiller controller
Chiller current limit command	Observations taken from the chiller controller and from control system settings

5.6 SAMPLING RESULTS

The demonstration testing covered the 2014 SCE DBP event season fairly well, with a combination of simulated events and actual SCE DBP events that occurred during the demonstration period. The measured baseline and test data was sufficient to enable the project team to perform a comparison against the project POs. An example set of plots showing the measured results for one of the DBP events is shown in Figure 8. The plots in Figure 8 are arranged to highlight the following data:

- Duration of the DBP event;
- Current limit command (displayed as % RLAs). This data is an indicator of the independent variable (utilization of OpenADR communication and control technology);
- Dependent variables, which change as a result of applying the OpenADR communication and control technology:
    - Electric demand (kW) reduction in response to DBP events; and
    - Chiller % RLAs, which are shown to respond to current limit commands from the Honeywell DBP control system during DBP events;

- CHWS temperatures, which may increase slightly during DBP events as a result of chiller demand limiting; and
- Indoor temperatures in occupied spaces, which may be impacted due to elevated CHWS temperatures during DBP events.

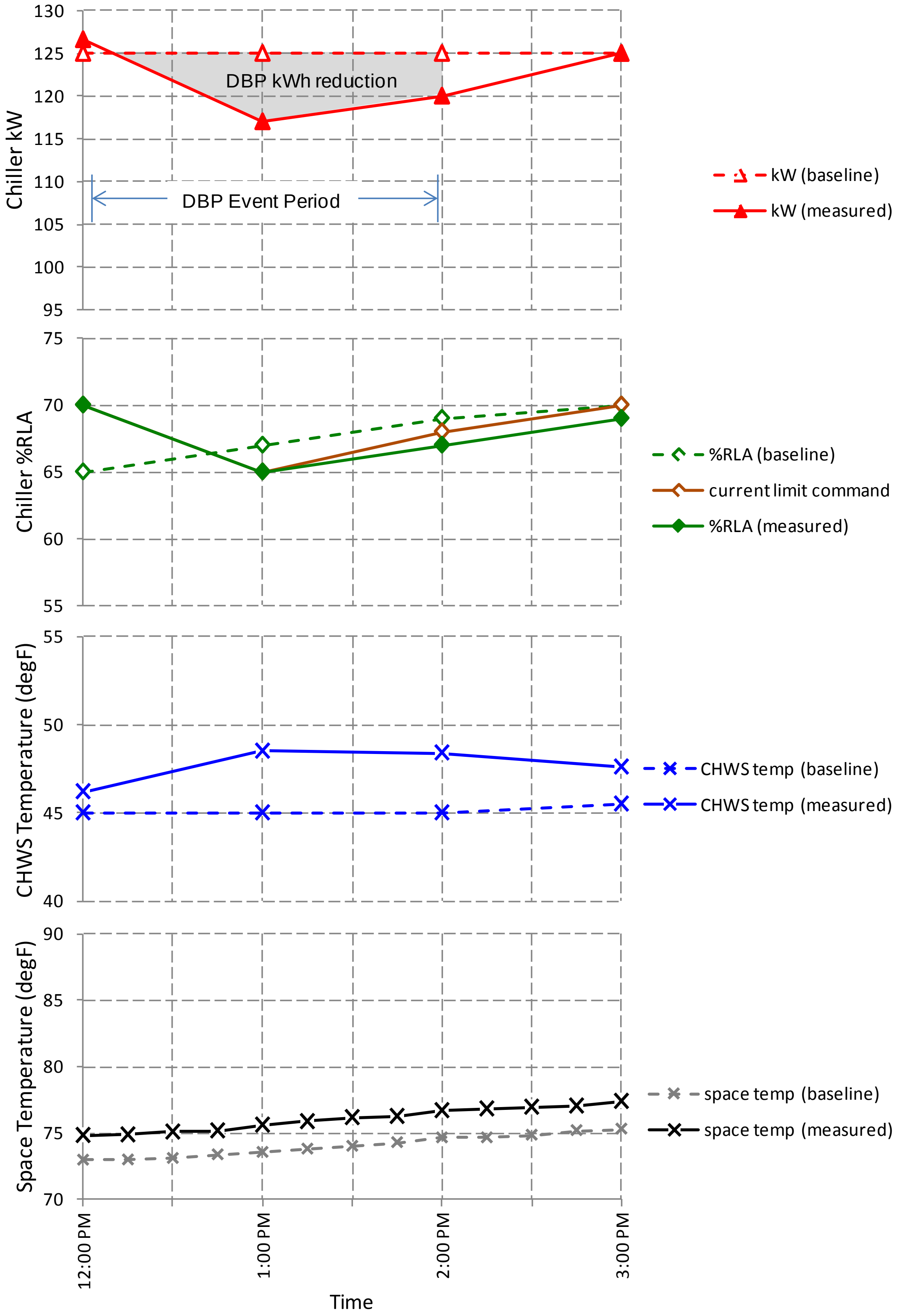


Figure 8. Measured results for Central Plant 253, September 5, 2014.

5.6.1 Acceptance of the Test Hypothesis

As described earlier, the test hypothesis acceptance criteria stated that (by employing OpenADR communication and control technology) DR controlled equipment can accurately follow commands that are issued by the pre-programmed DR control strategies during a DBP event. The sampling results shown in Figure 8 for the current limit command (sent to the chiller) and the resulting chiller % RLAs showed very good tracking by the equipment.

Based on the acceptance of the test hypothesis, we have answered the demonstration question posed earlier in this section, and have shown that OpenADR communication and control technology can effectively enable a military installation to participate in electricity markets.

6.0 PERFORMANCE ASSESSMENT

The following subsections describe the performance assessment results for each of the POs.

6.1 PO1: REDUCE ELECTRIC DEMAND BY THE AMOUNT SPECIFIED IN THE DBP BID

Data: The desired result is that the reduction in electric demand (in kW) during each hour of the event should closely match the amount of the bid for that hour. The project team analyzed the performance of each controlled load individually to determine how closely the measured electric load reduction matched the DR control command issued by the pre-programmed DR control strategies.

The data used to evaluate this PO was:

- The % RLAs analog output from each chiller. This data measures the amperage drawn by the compressor motor, and is an indicator of the electric load on the chiller.
- The demand reduction command to each chiller (the current limit analog input to the chiller's internal controller). This control input specifies the maximum amount of compressor motor amperage (and hence, cooling capacity or load) at which the chiller can operate.

Success Criteria: In future practice, an installation energy manager's bid strategies will strongly influence the bid performance. For this demonstration testing, the project team sought to achieve a chiller control tracking accuracy of ±20% (i.e., the difference between the current limit control command to the chiller versus the measured %RLA operating amperage). The project team sought to meet the ±20% control accuracy goal for at least 90% of the hourly intervals encountered during the demonstration period.

Results: Example results (for Central Plant 253 on Sept. 5, 2014) are shown in Figure 9. Inspection of these results (and other measured results included in the Final Report) show that the accuracy and tracking ability of the chillers' control response (as commanded via the current limit control input) was very good. The project team found that the chillers' operating amperage in %RLA tracked the current limit command very closely (within the success criteria of ±20%), as expected (as described in Section 5.6 of this report). These results show that this PO was met.

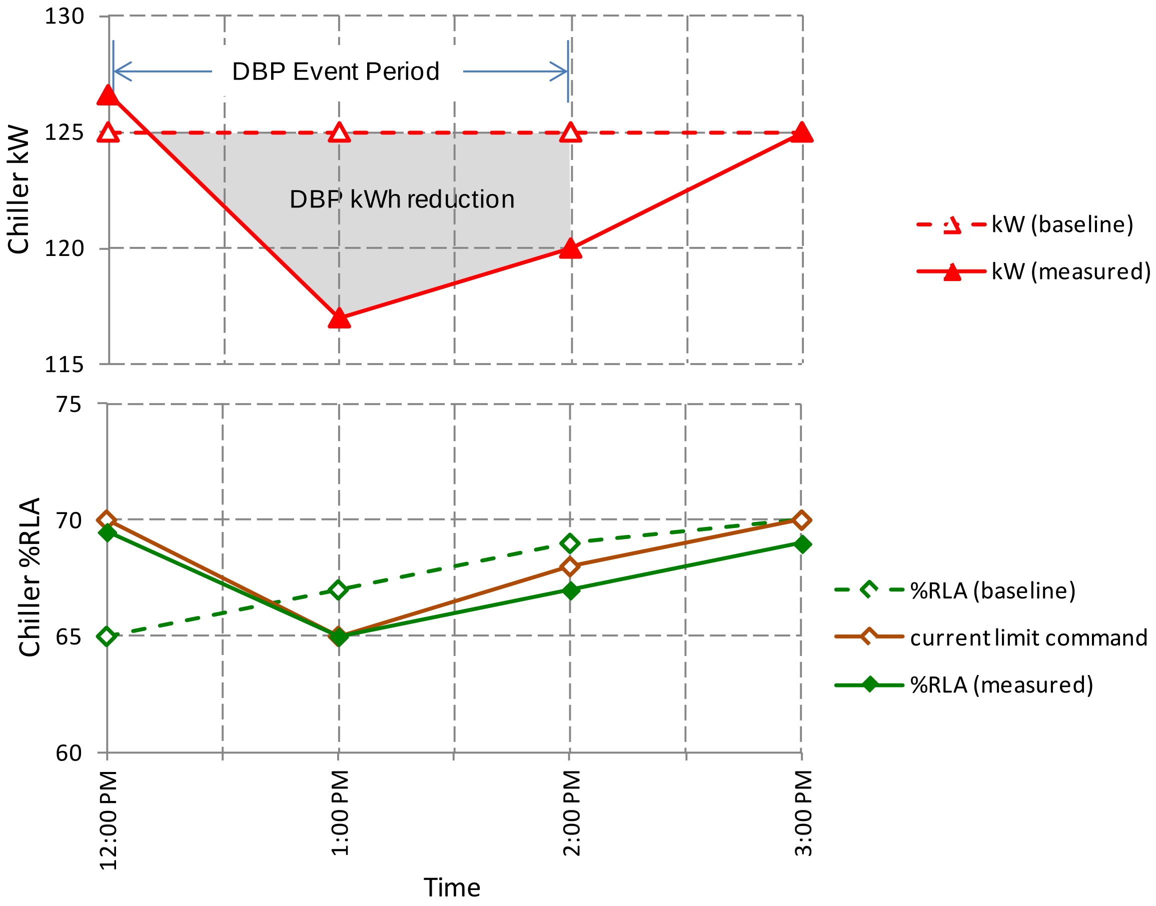


Figure 9. Measured results for PO1.

6.2 PO2: MAXIMIZE THE DBP BIDS ACROSS A TYPICAL YEAR

Data: The project team assessed the number of times that one or more of the controlled loads was not available for use in a DBP event, or opted-out of an event (i.e., due to some operational or mission-related constraint).

Success Criteria: >90% average utilization of each DR load in each DBP bid (or event).

Results: During the demonstration's DBP events, there were no instances when any of the controlled loads were not available for use (or opted-out of an event). As a result, this PO was met.

Note: Because this was a demonstration project, the DBP controlled loads were selected by Fort Irwin DPW in a rather conservative fashion (the chillers served only buildings that are not very impactful on operations or the mission at the installation).

In future practice at a typical military installation, there are likely to be occasional situations (such as operational needs or mission-related constraints) in which the DPW energy manager may need to opt-out certain loads. Careful selection of the loads could minimize these opt-out conditions, thereby maximizing the value of energy and economic benefits to the installation.

6.3 PO3: PRODUCE A RECURRING SOURCE OF FUNDS TO INVEST IN ENERGY INFRASTRUCTURE

Data: Initial investment cost, utility bill credits from participation electricity markets or utility DR programs, and annual maintenance cost of the technology as well as use results of a recent study at Fort Irwin of relevant ECMs.

Success Criteria: Simple payback time < 3 years, SIR >> 1

Results: The project team was not able to perform this analysis due to a lack of the necessary data (as a result of the relatively small demonstration-scale scope of the project).

The scope (i.e., the size of the installed system and its kW shed capability compared to Fort Irwin's peak kW demand) in this project was relatively small. For this reason, the project could not produce the data necessary to perform this analysis. The needed information (at full-scale) about upfront construction cost, utility incentives, and economic benefits, could not be determined from the data produced in this project. Therefore, the project team was not able to verify this PO.

In a typical DR project in the commercial sector, the electric customer takes advantage of up-front utility economic incentive payments to offset the initial construction cost, which enables the project to be implemented at full-scale. That mechanism (the use of utility incentives) was not possible in this ESTCP demonstration project without a long-term commitment by DPW that would have been required by the utility.

6.4 PO4: USER INTERFACE EFFECTIVENESS FOR DBP EVENT OPT-OUTS BY DPW OPERATORS

Data: Feedback from DPW staff about the quality of the user interface, and experience from actions taken in response to changes in operational or mission requirements.

Success Criteria: A skilled DPW energy manager can effectively use the control system's user interface with little or no training.

Results: As described in Section 5, the demonstration made use of actual DBP event days (scheduled by SCE in advance), as well as a number of simulated DBP event days (initiated by the project team). The project team served as the system operator during the demonstration, and employed relatively conservative control settings per the request of DPW. This approach was intended to maximize our collection of measured data during the short time available for the demonstration.

The project team had planned to collect the data required for this PO by interviewing the DPW energy manager and operating staff at various times during the demonstration. However, DPW's role during the demonstration was very limited, so they were not able to provide feedback about the usability of the control system interface. Therefore, the project team was not able to verify this PO.

Note: Much of the user interface was similar to that implemented in Honeywell DR projects in the commercial sector, which have been well received by those customers. The new features developed as part of this ESTCP project were incorporated into the overall user interface design taken from earlier projects.

6.5 PO5: O&M OF CONTROL AND COMMUNICATION EQUIPMENT

Data: Observations, maintenance records from DPW, records of control or communications equipment replacement, and system downtime.

Success Criteria: No significant increase in control and communication equipment maintenance required, as compared to typical BMSs with DR applications.

Results: As described earlier, the project team served as the system operator during the demonstration, and performed any adjustments or other service that was required during the test period. No other added O&M cost was incurred during the demonstration. Although the demonstration period was rather short in duration, the project team did not experience any unexpected O&M cost or effort. Based on this experience, this PO was met.

Note: Because much of the control system hardware, software, and user interface was similar to that implemented in Honeywell DR projects in the commercial sector, the project team did not expect significantly different O&M costs in this project.

7.0 COST ASSESSMENT

This section presents a cost assessment of the OpenADR technology. The investment requirements and economic benefits of AutoDR and OpenADR are site specific. Some general guidance about costs and an example life cycle cost (LCC) comparison are discussed in this section.

7.1 COST MODEL

The primary cost elements of a field implementation of AutoDR using OpenADR technology are listed in Table 7.

Table 7. Cost elements.

Cost Element	Description
Hardware capital costs, and field installation costs	These cost elements are site specific and will vary widely. Estimates for these items for a specific installation can be developed through a DR audit of the facility.
Facility operational costs (i.e., reduction in energy required versus baseline data)	
O&M	
Operator training	
Consumables	(not required by this technology)
Hardware lifetime	10 years or more

7.2 COST DRIVERS

Cost drivers that affect the economics of a field implementation of OpenADR technology include the following:

- The economic benefits that are associated with the various DR programs offered by the military installation's electric utility provider or electric grid operator;
- Availability and specifics of front-end financial incentives from electric utilities or other sources;
- A BMS at the military installation (the presence of an existing BMS will reduce the initial investment required);
- Costs for extending the military communications network at the installation, to connect to the DR controlled loads (if required);
- Costs for telemetry of electric meter data, if required; and
- Costs for the BMS supplier to acquire a DoD Information Assurance Certification and Accreditation Process (DIACAP) or Authorization to Operate (ATO) certification (if not already in place).

The impacts of the above cost drivers are site-specific. These issues should be investigated as part of a DR audit in planning a DR project. A DR audit (to identify the DR control opportunities, assess the economic potential, and assist in planning the implementation) can be performed by a qualified DR controls provider or a DR aggregator. Financial support for a DR audit may be available from the military installation's electric utility provider.

7.3 COST ANALYSIS AND COMPARISON

The project team performed a LCC analysis of the technology, based on available and estimated data. This cost assessment was based on an example military installation participating in the SCE DBP. The SCE DBP is a year-round DBP that offers day-ahead price incentives to customers for reducing energy consumption during a DBP Event.

For this cost assessment, the size of the controlled loads and the amount of demand reduction were developed as an example, and are based on experience with large DR projects in the commercial sector. Similar results are expected for a typical military installation. The inputs to this LCC analysis, and the resulting economic performance, are not indicative of Fort Irwin or any other specific military installation. The economic benefits of a specific military installation can be estimated as part of a DR audit by a controls provider or DR aggregator.

This cost analysis is based on participation in a utility DBP. The economic benefits associated with other utility DR programs and DR opportunities in the wholesale electricity markets will vary. The benefits of specific DR programs can be quantified as part of a DR audit.

7.3.1 LCC Analysis Approach

The details of the LCC analysis are presented in the project Final Report. The analysis utilized the Federal Energy Management Program (FEMP) Building Life Cycle Cost (BLCC) Program http://www1.eere.energy.gov/femp/information/download_blcc.html#blcc. This LCC analysis of OpenADR technology assumes the following steps for implementing a project at a typical military installation:

- Implement the OpenADR technology and receive utility bill credits; and
- Invest the proceeds of the utility bill credits to implement other improvements to the energy infrastructure (i.e., ECMs or renewable energy projects).

This finance process is shown in Figure 10 (taken from Figure 1, earlier in this document).

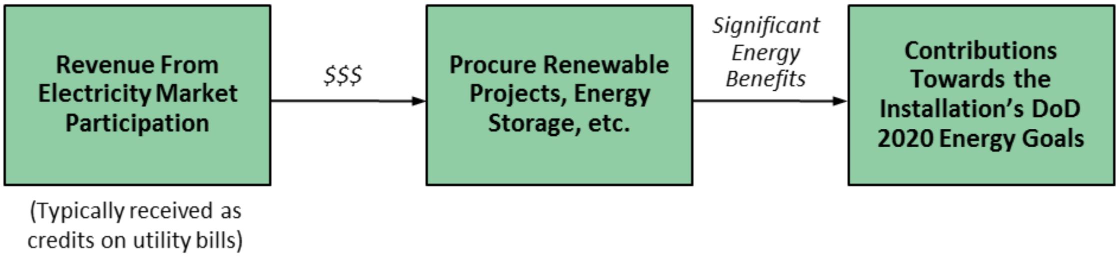


Figure 10. Energy and economic benefits process.

The analysis is based on a full-scale implementation of AutoDR (OpenADR) technology at a military installation (in a manner similar to AutoDR projects in the commercial sector). The associated energy improvement projects selected for this analysis were taken from the U. S. Army Engineer Research and Development Center's Construction Engineering Research Laboratory (ERDC-CERL) Fort Irwin net zero energy study report (Underwood et al., 2010). These ECMs are shown in Table 8.

Table 8. ECM projects for LCC cost assessment.

ECM Project at Fort Irwin	Description	Start Date	Initial Investment Cost	Annual Savings	Simple Payback	Project Type	ref. NZERO report
Buildings 254 and 271	Turn off HVAC equipment during unoccupied hours in dining facilities	2020	$ 20,000	$ 18,470	1.1 yrs	HVAC controls upgrade	p. 101-102
Building 263	Turn off boilers when no heating demand is present	2021	$ 9,600	$ 2,900	3.3 yrs	HVAC controls upgrade	p. 55-56
Building 325	Install solar thermal system for pool heating in fitness Bldg 325	2022	$ 21,359	$ 7,199	3.6 yrs	Renewable energy project	p. 124-126

Note: All data is taken from the Fort Irwin Net Zero Energy Report (Underwood et al., 2010).

7.3.2 LCC Analysis Results

High level results of the LCC analysis for the OpenADR DBP Project are shown in Table 9.

Table 9. BLCC results: OpenADR DBP project.

Project / Timeframe	SIR	Adjusted Internal Rate of Return	Simple Payback	Initial Investment Cost	Total PV Life-Cycle Savings
OpenADR DBP Project (2016)					
• 1% discount rate (baseline)	4.37	17.06%			$67,492
• 4% discount rate	3.81	18.87%			$56,114
• 7% discount rate	3.35	20.74%	<3 years	$20,000	$46,926

7.3.3 LCC Analysis Results: ECM Projects

High level results of the LCC analysis for each of the associated ECMs are shown in Table 10.

Table 10. BLCC results: ECM projects.

Project / Timeframe	SIR	Adjusted Internal Rate of Return	Simple Payback	Initial Investment Cost	Total PV Life-Cycle Savings
Bldg 254/271 HVAC Controls (2020)					
• 1% discount rate (baseline)	9.06	25.91%			$187,149
• 4% discount rate	7.87	27.83%			$159,435
• 7% discount rate	6.91	29.81%	<2 years	$23,211	$137,084

Table 10. BLCC results: ECM projects (continued).

Project / Timeframe	SIR	Adjusted Internal Rate of Return	Simple Payback	Initial Investment Cost	Total PV Life-Cycle Savings
Bldg 263 Boiler Controls (2021)					
• 1% discount rate (baseline)	2.94	12.49%			$21,903
• 4% discount rate	2.55	14.21%			$17,539
• 7% discount rate	2.24	15.99%	<4 years	$11,308	$14,018
Bldg 325 Solar Project (2022)					
• 1% discount rate (baseline)	2.89	12.32%			$48,280
• 4% discount rate	2.51	14.03%			$38,537
• 7% discount rate	2.20	15.79%	<4 years	$25,537	$30,680

A plot of the net annual cash flow and total cost savings for the OpenADR DBP project, when combined with the three associated ECM projects, is shown in Figure 11. If additional energy improvement projects were procured using future DBP utility billing credits, the annual cash flow and total cost savings would increase accordingly.

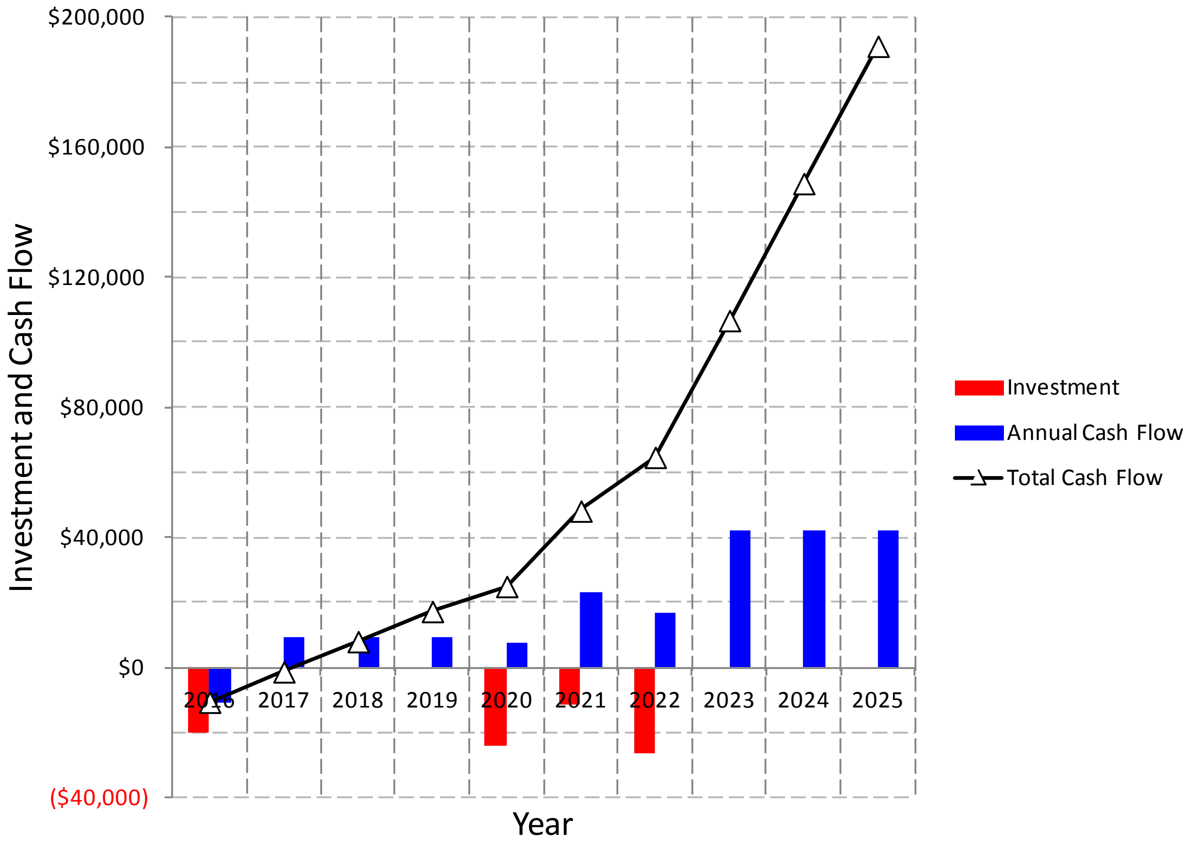


Figure 11. LCC cash flow and total cost savings for DBP project + ECM projects.

8.0 IMPLEMENTATION ISSUES

A number of implementation issues should be addressed in planning an AutoDR project. These implementation topics, which should be investigated as part of a DR audit, are:

- Implementing OpenADR technology and interfacing with an existing BMS at the military installation. This is not a significant concern, because almost any BMS can interface with OpenADR. The key technical requirement is the procurement of a client communications device that is compliant with OpenADR (for communications with the utility's DRAS).
- Technical design required for extensions to the military communications network at the installation to connect to the DR controlled loads (if required).
- Costs for the BMS supplier to acquire a DIACAP or ATO certification (if not already in place).
- Arrangements with a qualified DR controls provider, DR aggregator or other consultant, to perform an up-front DR audit of the installation, to identify the DR control opportunities, assess the economic potential, and assist in planning the implementation.

These implementation issues are site-specific and must be addressed in planning a DR project.

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APPENDIX A

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