FINAL REPORT

Automated Demand Response for Energy Sustainability

ESTCP Project EW-201256

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Honeywell International, Inc.

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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

AutoDR	Automated demand response
AIRR	Adjusted Internal Rate of Return
ATO	Authorization to Operate
BMS	Building Energy Management System
BLCC	Building Life-Cycle Cost
CAISO	California Independent System Operator
CoS	Catalog of Standards
CPUC	California Public Utilities Commission
CHWS	Chilled Water Supply
DBP	Demand Bidding Program
DoD	Department of Defense
DPW	Directorate of Public Works
DR	Demand Response (a temporary reduction of electric power demand)
DER	Distributed Energy Resources (resources that tend to be smaller than utility-scale sources and are typically located closer to customer loads)
DIACAP	DoD Information Assurance Certification and Accreditation Process
DRAS	Demand Response Automation Server
DRRC	Demand Response Research Center (at LBNL)
EBI	Enterprise Buildings Integrator (a Honeywell BMS)
ECM	Energy Conservation Measure
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
FERC	Federal Energy Regulatory Commission
HVAC	Heating, ventilation, and air conditioning
GHG	Greenhouse gas
IOU	Investor Owned Utility
ISO	Independent System Operator
LBNL	Lawrence Berkeley National Laboratory
LCC	Life Cycle Cost
NEC	Network Enterprise Center
NIST	National Institute of Standards and Technology
O & M	Operations and Maintenance
OMB	Office of Management and Budget
PAP	Priority Action Plan
RLA	Rated Load Amps
RTO	Regional Transmission Organization
SCE	Southern California Edison
SIR	Savings-to-Investment Ratio
SGIP	NIST Smart Grid Interoperability Panel

GLOSSARY

Ancillary services	Electric grid resources (consisting of non-spinning reserve and other services) that are used to ensure grid reliability and support the transmission of electricity
Demand	The rate of electric energy usage (i.e., power, in kW) of a facility or individual load
Demand response	A temporary change in electricity usage by a demand side resource in response to market or reliability conditions
Demand Bidding Program	DR programs that encourage customers to bid into an electricity market and offer to provide load reductions which they are willing to curtail at a utility-posted price.
Demand Response Aggregator	A company authorized by an electric utility or grid operator to act as an intermediary or interface between the utility or grid operator and electric customers to deliver demand response capacity or load reductions. Also referred to as a 'curtailment service provider', or 'demand response provider'.
Non-spinning reserve	An operating reserve (supply or demand side) that can be synchronized and brought under the control of the grid operator within a specified period of time
OpenADR	An open industry standard communication protocol for transmitting automated DR instructions and other data
Telemetry	Real-time communication of measured electric consumption and demand data, for remote monitoring, display, or recording

ACKNOWLEDGEMENTS

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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, or 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 DR signals between the utility or grid operator and a set of pre-programmed (automated) DR 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.

To assess the economic and energy benefits of automated demand response, the project team of Honeywell, the Army Engineer Research and Development Center's Construction Engineering Research Laboratory (ERDC-CERL), and Lawrence Berkeley National Laboratory (LBNL) joined with the Directorate of Public Works at Fort Irwin, CA to demonstrate OpenADR technology and associated BMS demand response control strategies.

This ESTCP project began in 2012 with the objective of demonstrating the use of OpenADR technology. Using OpenADR would enable Fort Irwin to participate in the CAISO (California Independent System Operator) 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 Demand Bidding Program (DBP) 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 Program as a demonstration vehicle, the project generated performance data for acceptance and validation of OpenADR technology as a means for military installations to participate in wholesale electricity markets.

The demonstration testing measured the performance of the Honeywell DR control system in responding to DBP events dispatched by SCE. The DBP Program is a year-round demand

bidding program that offers day-ahead price incentives to customers for reducing energy consumption during a DBP Event. The DR controlled electric loads at Fort Irwin consisted of three chillers in DPW central cooling plants on the post.

The team developed a number of quantitative and qualitative performance objectives and defined associated performance metrics to assess the technology. The demonstration met our primary performance objectives of reducing electric demand by the commanded amount, high utilization of DR loads in the DBP events, and low requirements for operation and maintenance.

Based on the performance data collected during the demonstration period DBP events, we found that the chillers tracked the current limit command very closely (within the success criteria of ±20%), as expected. The utilization of the selected DR controlled loads (central plant chillers) was very good and there were no instances when these loads had to be opted-out of a DR event. (Note that some other types of loads might need to be opted-out at certain times at a given military installation, due to operational or mission requirements.) The operation and maintenance requirements, as expected, were no greater than in Honeywell’s commercial sector DR projects (i.e., they were similar to other building energy management systems in demand response applications).

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. Support from utility customer service representatives would also be helpful in determining the correct courses of action. 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.

In California, regulatory changes are currently being defined for how demand-side resources can participate in the wholesale electricity market. It is estimated that electric customers will be able to participate as a supply-side resource for the CAISO in 2017. When new regulatory DR policies are enacted, DR providers will be able to bid bundled customers into the CAISO wholesale electricity market. Similar opportunities currently exist or are being planned in other areas of the United States.

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 (Open Automated Demand Response, or 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.

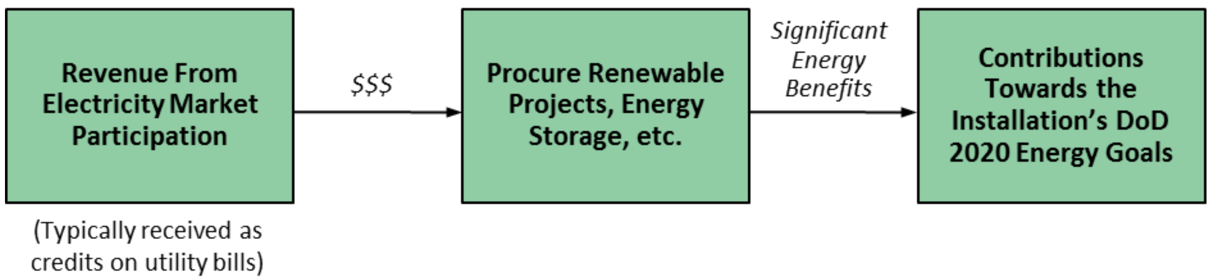

Figure 1. Energy and Economic Benefits Process

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. [DOE DR]

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 programs).

These load-side reductions could be either directly controllable (e.g., residential 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 demand response. 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).

The U.S. Department of Energy (DOE) defines demand response (DR) as: "a tariff or program established to motivate changes in electric use by end-use customers in response to changes in the price of electricity over time, or to give incentive payments designed to induce lower electricity use at times of high market prices or when grid reliability is jeopardized". [DOE EPACT] The U.S. Federal Energy Regulatory Commission (FERC) defines a demand response event as: "A period of time identified by the demand-response program sponsor when it is seeking reduced energy consumption and/or load from customers participating in the program. Depending on the type of program and event (economic or emergency), customers are expected to respond or decide whether to respond to the call for reduced load and energy usage. The program sponsor generally will notify the customer of the demand-response event before the event begins, and when the event ends." [FERC DR]

Smart Grid Overview

The National Institute of Standards and Technology (NIST) initiated the Smart Grid Interoperability Panel (SGIP) in 2009 to coordinate standards development for the Smart Grid. To accomplish this objective, the SGIP created a set of priority action plans (PAPs) to address specific standards-related gaps and issues for which resolution is most urgently needed. PAP09 (Standard DR and DER Signals) was chartered to specify a process for developing a common semantic model and requirements for standard automated DR signals [PAP09].

With the impetus of PAP09, a team of industry, customer, utility, regulatory and other stakeholders collaborated to develop the updated OpenADR 2.0 standard, which builds upon and extends the earlier OpenADR 1.0 specification. The OpenADR 2.0 standard enables automated communication of demand response commands from grid operations to customers as shown in Figure 2 [Framework].

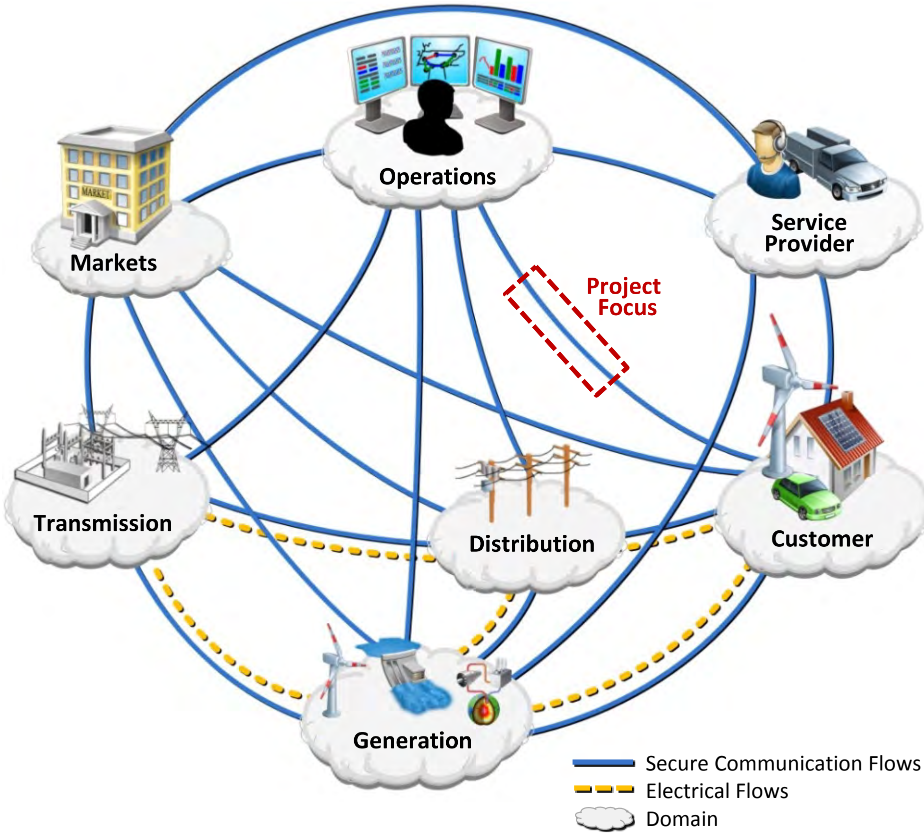

Figure 2. Smart Grid Communications

In areas where organized, open electric energy markets exist, changes have been made (or are being made) to enable electric customers to offer the use of their demand side resources by reducing the electric demand of selected equipment. Demand side load reductions can be offered contractually by the building owner in the electricity markets. These reductions in electric demand (or "negawatts") are utilized by the grid operator to fill imbalances between supply and demand on the electric grid, with the objective of ensuring grid reliability. Rulings by FERC and policy changes at independent system operators (ISOs) and regional transmission organizations (RTOs) are creating these new opportunities for building owners. [OATI] In the past, these services have been provided only by conventional electric power generation sources.

These demand side services are delivered by qualified providers (or through qualified intermediaries) to the electric grid operator. Except for very large electric customers, building owners will typically participate in these markets through a qualified intermediary, either by contracting with their electric utility for the appropriate electric tariff or by contracting with a qualified demand response aggregator. In arrangement, the electric utility or the DR aggregator participates in the electric grid market on the behalf of the building owner.

Market Participation

The procurement of electricity is orchestrated by the grid operator's wholesale market, which can include both supply-side and demand-side energy providers. A DOE technical report outlines the utilization of various demand response resources in the planning and operation of the electric grid, as shown in Figure 3. [DOE EPACT] Incentive-based demand response programs offer attractive economic benefits to electric customers who have flexibility in their operations and are able to respond to DR events.

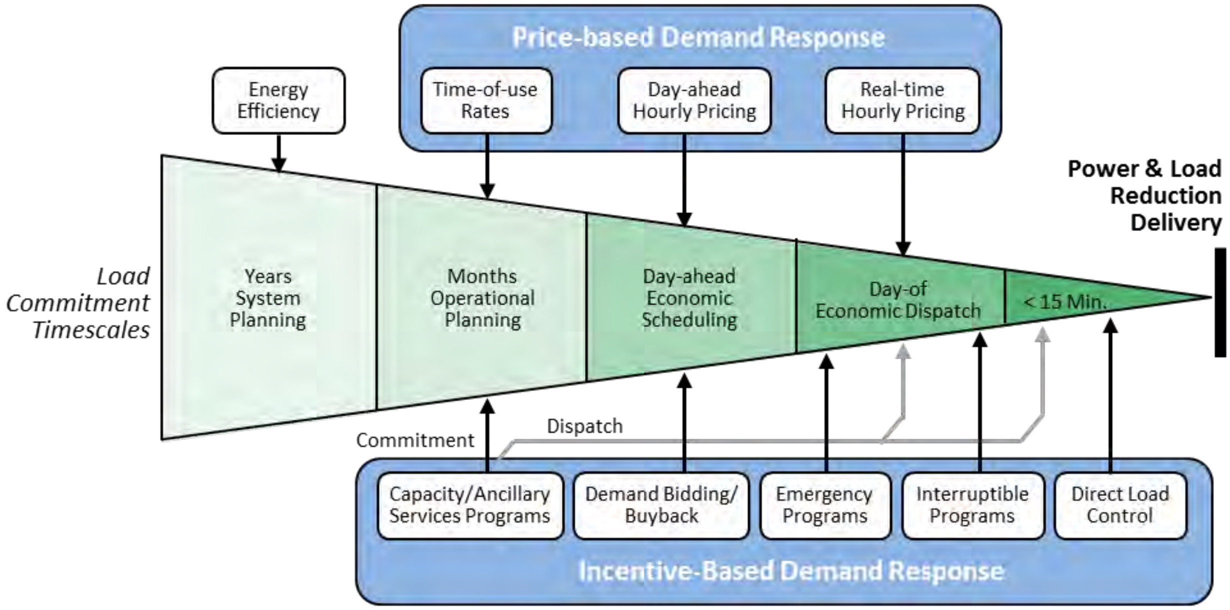

Figure 3. Electric Grid Planning and Operations

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 4 (adapted from [PAP19]). (Note: In areas that have adopted full retail-level competition, retail demand response arrangements may be different than shown.)

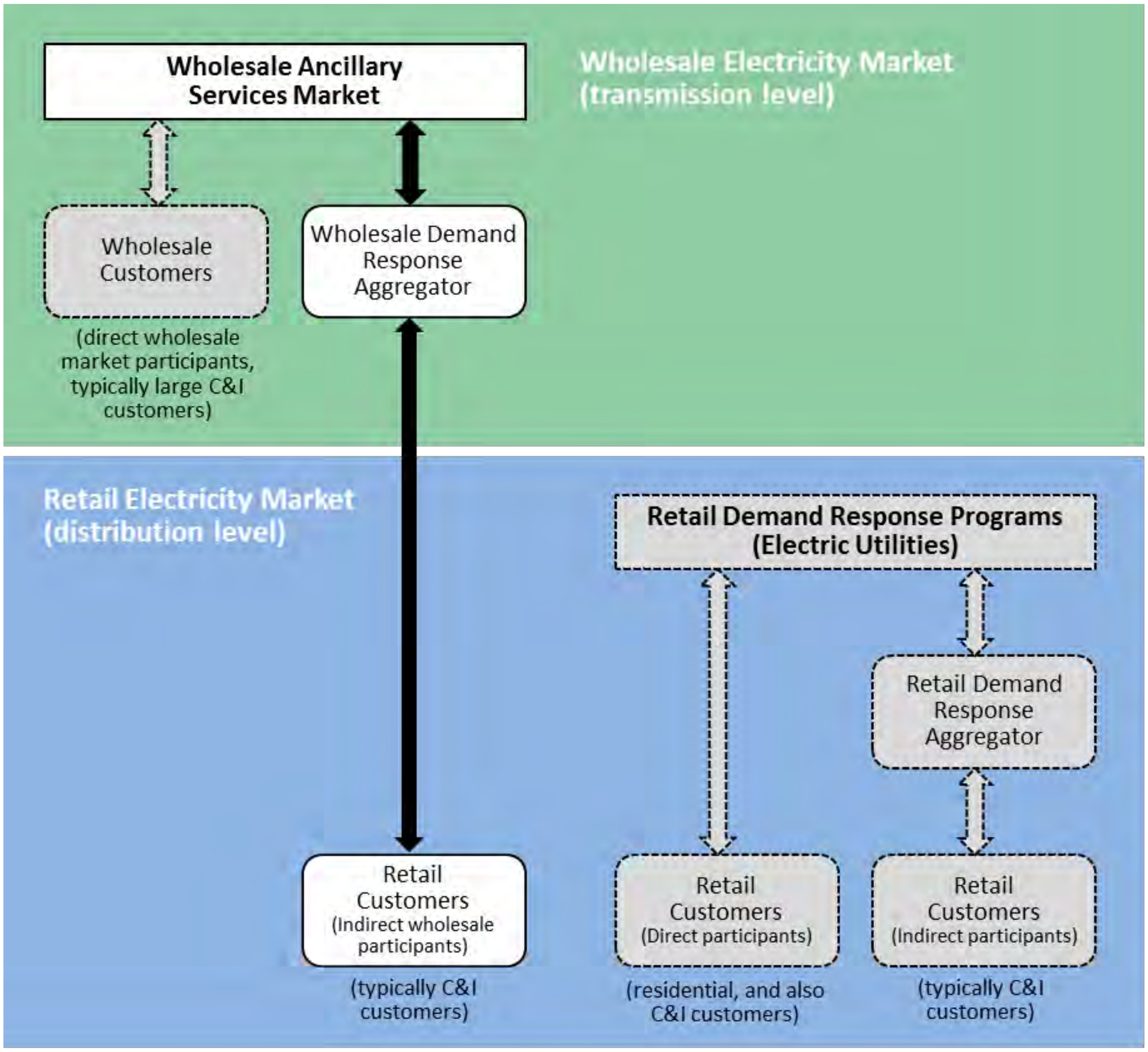

Figure 4. Demand Response in Wholesale Electricity Markets

Market-based Demand Response Programs

Referring to Figure 3 above, 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.

The simplest example of an ancillary service is the non-spinning reserve service. This service uses resources that can be quickly (typically within ten minutes) placed under direct control of the grid operator and made ready to respond to automated dispatch instructions. Non-spinning reserve ancillary service events are initiated by the grid operator when the service is needed. These events (typically lasting about 20 minutes) are infrequent and can occur at any time of day or week, but typically amount to only a small number of hours per year.

Wholesale-level demand bidding programs (DBP) have been in place for a number of years, enabling large electric customers to participate in the markets. The DOE defines demand bidding programs as: "programs that (1) encourage large customers to bid into a wholesale electricity market and offer to provide load reductions at a price at which they are willing to be curtailed, or

(2) encourage customers to identify how much load they would be willing to curtail at a utility-posted price". [DOE EPACT] 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. [DOE EPACT] DBP events may have a duration lasting from noon to 8pm.

Open Automated Demand Response Protocol (OpenADR)

Early efforts in automated demand response 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 NIST 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)
- 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 National Institute of Standards and Technology "Smart Grid Interoperability Standards Framework," as a key standard for demand response for the smart grid [Framework]. In 2012, the SGIP incorporated OpenADR into the SGIP Catalog of Standards (CoS) [CoS]. The SGIP activity is complemented by the efforts of the OpenADR 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 demand response. The Alliance currently includes more than 50 members made up of utility, nonprofit, government and corporate organizations [Alliance].

1.1.1 Current State of Technology in DoD

Few military installations are currently participating in wholesale electricity markets, because some of these markets are not yet open to demand-side resources, or installations are not aware of opportunities that are currently available or in planning.

The OpenADR protocol has been used widely for utility peak load management demand response programs (these DR programs are used by the utilities to mitigate periodic peaks in load side demand, but often are not directly related to wholesale electricity markets). Some military installations are currently enrolled in these utility programs and may be using OpenADR for that purpose. However, the use of OpenADR to enable electric customers (including military installations) to participate in the wholesale electricity markets is a very recent concept.

Building from the SGIP standards activity and a number of recent research or pilot projects, utility and electric grid operator DR programs will increasingly utilize the OpenADR 2.0 protocol to implement wholesale electricity market participation.

1.1.2 Technology Opportunity

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 problem has been apparent for some time and will become more important as military capital budgets come under increasing fiscal pressure.

As wholesale electricity markets across the U.S. are opened to participation by demand-side resources, many military installations will have an opportunity to participate and thereby receive energy, cost savings, and energy security benefits that are made available through this participation.

The system implemented at Fort Irwin showed that DPW (Directorate of Public Works) operators could modify the system configuration parameters in response to operational constraints at the installation (thereby avoiding adverse impacts on the mission at the facility).

DR Regulations at the Federal level

In May 2014 a ruling by the United States Court of Appeals for the District of Columbia vacated the Federal Energy Regulatory Commission (FERC) Order 745 (entitled "Demand Response Compensation in Organized Wholesale Energy Markets"). FERC Order 745 had required that demand response be fairly valued in wholesale energy markets, enabling it to compete on an equal level with traditional electricity generation resources.

This recent ruling by the Circuit Court has complicated efforts by state public utility commissions to design methods for demand side resources to participate in the electricity markets. As the debate continues, the Circuit Court's decision could be revisited and perhaps overturned. It is also possible that FERC will define new guidelines for how demand side resources can participate in the electricity markets. In any event, demand response will continue to play an important part in making the electricity grid more reliable and energy efficient.

DR opportunities in the California Electricity Market

At present, there are no opportunities for electric customers to directly participate in the CAISO electricity market. Per the California Public Utilities Commission (CPUC), "Currently, demand response programs are administered by California's three regulated investor-owned utilities ... The utilities also rely on third-party operators (known as 'aggregators', 'curtailment service providers', or 'demand response providers') to enroll customers in certain demand response programs or contracts ... ". [CPUC]

Regulatory Activity in California

Demand response programs in California are in a process of transformation. Currently, DR is presented to CAISO by investor owned utilities (IOUs) as a reduction in load forecasts. As a result, these resources are not visible to the CAISO and cannot directly compete with supply-side resources in the electricity market.

The CPUC is considering rules which will divide (or bifurcate) demand response into either 1) demand-side load-modifying resources (traditional utility DR programs) or 2) supply-side resources (bid into and dispatched by CAISO). The current demand-side utility programs have been extended through 2016, while the CPUC considers a number of policy issues about supply-side resources. These policies will include the setting of DR goals, addressing Resource Adequacy concerns, CAISO market integration costs, load-modifying and supply resource issues, establishing program budgets, and adoption of a Demand Response auction mechanism.

Utilities will continue their involvement in the decision making process through participation in CPUC working groups. Final direction will likely not be fully developed until the beginning of 2016, when the utilities will begin filing for new utility DR programs and pilots. At present, 2017 is being targeted as a timeline to enable electric customers to participate as a supply-side CAISO resource. When new CPUC demand response policies are enacted, DR providers will be able to bid bundled customers into the CAISO wholesale market.

Customer Investment in Demand Response Programs

Discussions around bifurcation in California are also concentrating on how to create value for DR resources. CAISO is working with the CPUC and local regulatory authorities to ensure flexible capacity resources are available to reliably operate the grid while fulfilling state energy mandates. In the future as this regulatory process unfolds, DR is envisioned to be available as a flexible capacity resource and thereby able to receive capacity payments (e.g., to invest in upfront improvements needed for automated controls and telemetry to the ISO). In other parts of the U.S. where capacity markets exist and DR resources are able to participate in the markets, these capacity payments are normally used by the electric customer or an aggregator to finance the investments.

The Role of Demand Response Aggregators

Aggregators typically recruit more sites (customers) and MWs than they bid into the market, while sharing capacity payments and passing through energy payments to their customers. Aggregators take the risk for non-performance while also sharing the economic benefits from DR programs. Some aggregators provide automation, which also can reduce the risk of underperformance. Automation costs are covered either through the technology incentives offered by the utilities, or through capacity payment investments that pay for themselves over time with participation.

Aggregators are especially important for smaller sites that cannot participate in the markets directly due to the minimum participation (kW) requirements. These smaller sites are aggregated with other sites and bid into the markets or programs. A large site, such as a military installation may be able to satisfy the minimum kW bidding requirements but may lack knowledge of the electricity markets or not have a desire to participate directly in the markets. In those cases, an aggregator can serve an important role in helping military installations to participate in the electricity markets.

Opportunities for Military Installations

Military installations can benefit by having 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. [LBNL-6155e]

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 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 Program as a demonstration vehicle, the project generated performance data for acceptance and validation of the OpenADR technology as a vehicle that will enable military installations to participate in wholesale electricity markets.

The SCE DBP Program is a year-round demand bidding program that offers Day-Ahead price incentives to customers for reducing energy consumption during a DBP Event. A Day-Ahead DBP Event may be called at SCE's discretion, when it is needed based on CAISO emergencies, day-ahead load and/or price forecasts, extreme or unusual temperature conditions impacting system demand and/or SCE's procurement needs. Additional information about the SCE DBP program is included in Appendix B.

1.3 REGULATORY DRIVERS

This project demonstrated a key technology (OpenADR) that will make it possible for 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, 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	Requirement	Relevance of this project
Executive Order EO 13423 "Strengthening Federal Environmental, Energy, and Transportation Management" http://energy.gov/eere/spo/downloads/executive-order-13423-strengthening-federal-environmental-energy-and	High Performance and Sustainable Buildings Guidance: Guiding Principles for Sustainable New Construction and Major Renovations II. Optimize Energy Performance On-Site Renewable Energy	Revenues or utility bill savings will enable installations to invest in new or retrofit renewable energy systems on the installation's facilities. This new source of funds could also be used to procure other upgrades which satisfy other parts of EO 13423.
Executive Order EO 13514 "Federal Leadership in Environmental, Energy, and Economic Performance" http://www.gpo.gov/fdsys/pkg/FR-2009-10-08/pdf/E9-24518.pdf	Recommendations for Vendor and Contractor Emissions: 1.1.2.2 Indirect Emissions: Scope 2 Emissions (Scope 2 emissions are a consequence of activities that take place within the organizational boundaries of the reporting agency, but physically occur at the facility where the electricity, steam, heating, or cooling is generated.)	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.
Energy Policy Act of 2005 (EPAct2005) http://energy.gov/sites/prod/files/2013/10/f3/epact_2005.pdf	Renewable Energy Requirement: the Federal Government's renewable electricity consumption must meet or exceed 7.5% in 2013 and thereafter	Revenues or utility bill savings will enable installations to invest in new or retrofit renewable energy systems on the installation's facilities. This new source of funds could also be used to procure other upgrades to satisfy other parts of EPAct2005.
Energy Independence and Security Act of 2007 (EISA 2007) http://www.gpo.gov/fdsys/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf	EISA 2007 Federal energy management requirements: Energy Reduction Goals for Federal Buildings	Revenues or utility bill savings will enable installations to invest in new or retrofit improvements that reduce energy consumption per gross square foot, as compared with the installation's buildings in fiscal year 2003.
Federal Leadership in High Performance and Sustainable Buildings MOU 2006 http://www1.eere.energy.gov/femp/program/m/sustainable_principles.html	Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings: II. Optimize Energy Performance Energy Efficiency: For major renovations, reduce the energy cost budget by 20 percent below pre-renovations 2003 baseline.	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.

Directive	Requirement	Relevance of this project
Department of Defense Strategic Sustainability Performance Plan FY 2011 http://denix.osd.mil/sustainability/upload/DoD-SSPP-FY11-FINAL_Oct11.pdf	Objective 1: The Continued Availability of Resources Critical to the DoD Mission is Ensured: Goal 1 The Use of Fossil Fuels Reduced • Sub-Goal 1.1: Energy Intensity of Facilities Reduced by 30% from FY 2003 by FY 2015 and 37.5% by FY 2020 • Sub-Goal 1.2: By FY 2020, Produce or Procure Energy from Renewable Sources in an Amount that Represents at Least 20% of Electricity Consumed by Facilities	Revenues or utility bill savings will enable installations to invest in new or retrofit improvements that reduce energy consumption or increase renewable energy use. This new source of funds could also be used to procure other upgrades to satisfy other parts of the DoD plan.

This project's technology and the related wholesale electricity market participation are also relevant to military microgrids and the goals for installation energy security. By providing demand response services, installations are supporting the regional commercial power grid. In times of high regional electrical demand, electric utilities sometimes struggle to meet customer demands, which can cause instability, rolling blackouts, and high energy prices. This technology enables the installation to curtail demand in response to these conditions in the regional power grid. Such participation enhances regional grid stability and security, which in turn improves the energy security and electrical reliability of the DoD installation.

This technology, and the use of demand-side resources, will become more important in the future as renewable energy becomes a larger part of our electric grid energy portfolio. Demand-side resources will be valuable assets that grid operators can use to mitigate the intermittency of renewable sources. Military installations that have microgrids and significant on-site renewable energy resources can also benefit from this technology.

Targeted load reduction (made possible by this technology), particularly when coupled with an installation's microgrid control systems, could provide much needed stabilization. By causing load to follow the variable renewable power source, system stability is maintained. As DoD installations seek to implement renewable energy systems and achieve net-zero energy goals, the variability of renewable sources will become more concerning. While this problem can be addressed through costly energy storage, OpenADR technology offers a lower cost alternative and supplemental strategy.

The implementation of a microgrid at a DoD installation can include advanced energy control systems that provide load reduction services to non-critical loads. The microgrid system will use these controls to remove load from the microgrid under islanded conditions to maintain system stability and adequate energy resources to supply all critical loads. These same control systems can be used to provide electricity services to the electric grid under normal operations, by reducing load in response to signals from the grid operator. Thus, the technology creates a dual-use model for advanced microgrid controls.

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 5 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)
- 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 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. Additional information about the SCE DBP program is contained in Appendix B

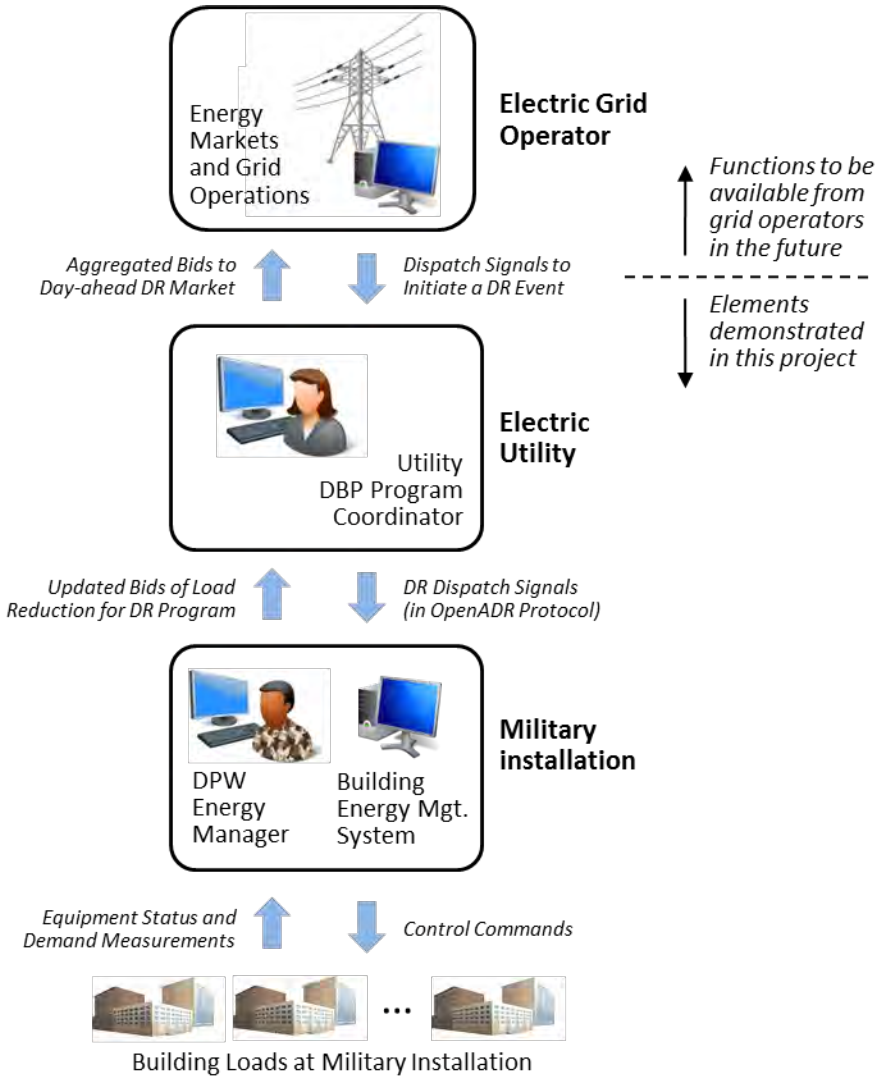

Figure 5. Demand Bidding Communication and Control

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 [LBNL-2945E].

2.1.2 Chronological Summary

Research work in automated demand response, 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 demand response programs.

The OpenADR 1.0 specification was incorporated into the NIST SGIP Catalog of Standards in 2012. The NIST Smart Grid Interoperability Panel (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 automated demand response [LBNL-5273E].

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 Catalog of Standards 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 [SB10]. 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

Demand response and energy efficiency are closely related. With appropriate control strategies, building operators can effectively utilize both energy efficiency and demand response to optimize their facility performance and participate in electricity markets. Lessons learned in demand response 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 demand response 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. [LBNL-58179] 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 demand response 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 [LBNL-59975].

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, (1) no cost limitations are foreseen in the use of OpenADR, and (2) no potential cost disadvantages (such as increased first cost, installation cost, and/or operations & maintenance 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 demand response in the commercial sector, have been very positive. Past experience with utility-level retail demand response applications at military installations have given positive results [DLA].

3.0 PERFORMANCE OBJECTIVES

The project's performance objectives enabled the verification of key performance indicators for OpenADR technology as applied in this project. These performance objectives 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 operations and maintenance costs to military installations.

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

3.1 SUMMARY OF PERFORMANCE OBJECTIVES

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

Note: Some of the performance objectives 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. Performance Objectives

Performance Objective	Metric	Data Requirements	Success Criteria	Results
	Quantitative Performance Objectives			
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 performance objective 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 performance objective 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 performance objective.

Performance Objective	Metric	Data Requirements	Success Criteria	Results
	Quantitative Performance Objectives			
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 performance objective.
PO5: Operation and maintenance of control and communication equipment	Need for maintenance beyond that expected for building energy management systems	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 performance objective was met.

3.2 PERFORMANCE OBJECTIVES DESCRIPTIONS

Subsections 3.2.1 through 3.2.5 describe the five performance objectives 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 demand response control strategies.

The data used to evaluate this performance objective 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 rated load amps (RLA). The hours which

had no demand control can be considered to be 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 vs. 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 performance objective 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 performance objective 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: >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 performance objective 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 (ECMs) and/or renewable energy projects.

Metric: Simple payback and savings-to-investment ratio (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 ("Working Towards Net Zero Energy at Fort Irwin, CA", Final report prepared for U.S. Army Corps of Engineers, ERDC/CERL TR-10-24, Sept. 2010. [NZERO]).

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 performance objective.

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 building energy management system 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 performance objective.

3.2.5 PO5: Operation and maintenance of control and communication equipment

Purpose: The amount of operation and maintenance 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 demand response 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 building energy management systems.

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

Analytical Methodology: The operation and maintenance cost or effort required for this DR control system should not be significantly greater than for typical building energy management systems with demand response applications.

Success Criteria: O&M cost is not significantly greater than typical building energy management systems (BMS) with demand response 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 performance objective was met.

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.
- 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.

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.

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.

Communications

The project team worked closely with DPW and the Fort Irwin Network Enterprise Center (NEC) to ensure that the demonstration system was installed in accordance with all applicable information security and information assurance requirements. This project's field implementation used an existing Authorization to Operate (ATO) certification received by Honeywell as part of the USACE Central Meter Data Management Systems program. [USACE]

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 6)

- Photos of each building (Figure 7)
- A photo of one of the chillers to be used in the project (Figure 8)
- Table 3 describes the controllable loads for this project. Note: All of these chillers are supplied by 480 volt 3-phase power.

Figure 6. 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 7. Demonstration Buildings

Figure 8. Chiller: Building 253 Central Cooling Plant

Table 3. Controllable Loads

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

4.2 FACILITY/SITE CONDITIONS

Geographic Criteria

No climate zone criteria were relevant to the selection of a demonstration site for this technology. Fort Irwin met the requirement that the electric utility must have a demand response program (the SCE DBP program) that is open to participation by retail customers. The DBP program enabled the installation to respond to DBP events through OpenADR communications and automated DR control strategies.

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.

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 demand response 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
  - Chilled water supply (CHWS) temperatures, which may increase slightly during DBP events as a result of chiller demand limiting
  - 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
  - No changes in HVAC control setpoints
- **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. Information about the SCE baseline protocol can be found in Appendix B. These variables should also be considered by the electric customer’s energy manager when preparing demand reduction bids.
- **Other variables:** A number of other affected variables, described in Table 4, were not measured during the demonstration.

Table 4. Other Variables

Variable	Description	Remarks
Economic return	Utility bill credits to the military installation	The scale of the demonstration system (i.e., kW shed capability as compared to the peak kW demand of the installation) was small. For this reason, no analysis of the installation's electricity bill DBP credits was performed. Economic benefits are addressed in Section 7.0 of this report.
O&M cost	Amount of operation and maintenance cost or effort associated with the system (in a full scale implementation)	The short period of the demonstration did not offer an opportunity to measure the O&M cost at full scale.
Management oversight required	Amount of time spent by the DPW energy manager (adjusting setpoints, overrides, general oversight, etc.)	Due to compressed timeframe of the demonstration, the test events were performed by the Honeywell project team.
Utilization of each of the controllable DR loads in the DBP events	This variable is related to how often the installation chooses to utilize a given load in its ADR bid. In a typical application, some loads might not be utilized at certain times so as not to impact operations or the mission of the installation.	In the DBP events conducted during the field demonstration, the project team did not experience any constraints due to operations or mission.

- **Hypothesis:** To answer the Demonstration Question posed above, we tested the following hypothesis:

  Employing OpenADR communication and control technology enables a military installation to automate its demand response 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 demand response control strategies during a DBP event.

- **Test design:** Because the buildings employed in the demonstration were each unique in their energy use profiles and occupancy schedules, it was impractical to construct a control group. The selected buildings made up the test group for the demonstration. The OpenADR communication and control technology was applied during the demonstration period, forming the test case. During this period, electric demand data was collected from electric submeters and other instrumentation. The testing included a representative number of DBP events.

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 demand response 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. Plots of the baseline data are included in Appendix C.

- **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.
  - % rated load amps (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.
  - Chilled water supply (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)
  - 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 Diagram

A high-level overview of the system is presented in Section 2, including a representation of the system (Figure 5). For convenience to the reader, this figure is also shown below as Figure 9.

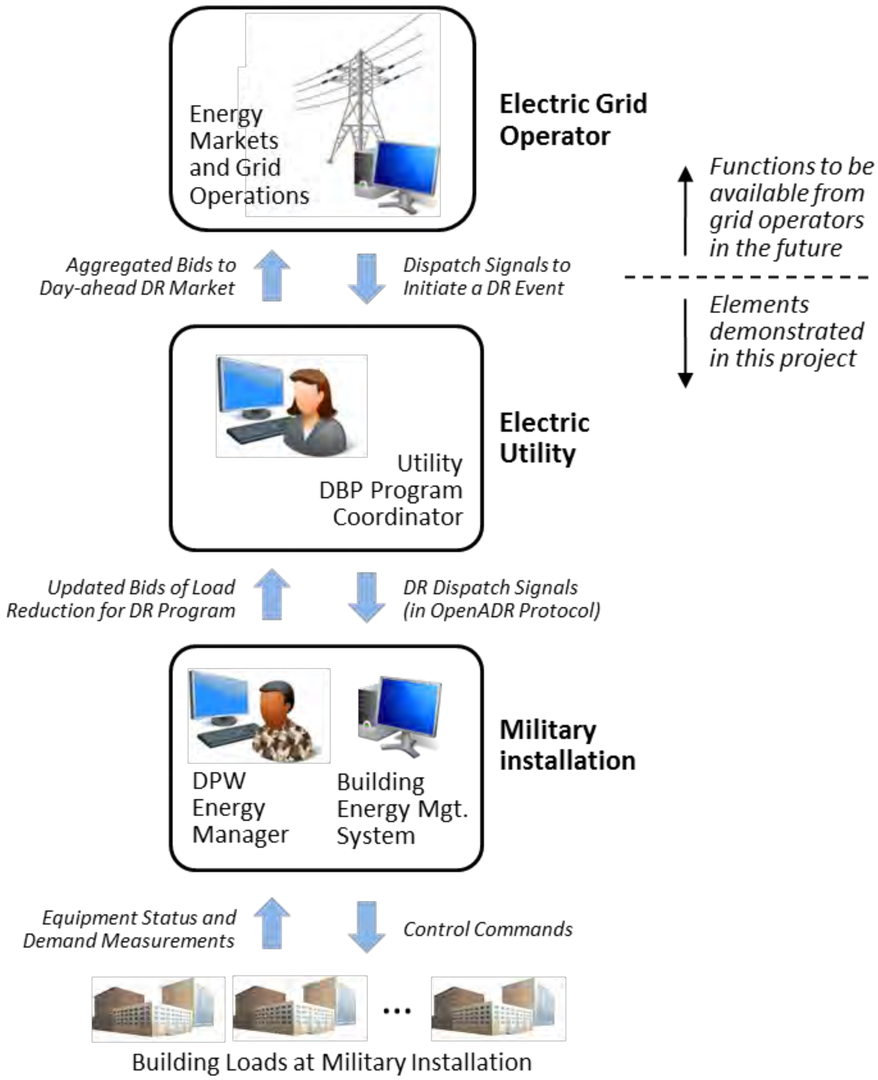

Figure 9. DBP Communication and Control

5.3.2 System Design

As described in Section 2.1, the demonstration at Fort Irwin was performed through participation in the SCE Demand Bidding Program. Utility customers are able to participate in the SCE DBP program by offering (bidding) their demand side resources via the DBP website. The bids offer stated amounts of electric demand reduction (in kW), and are specified by hour of day (noon to 8 pm). The financial benefit from reducing electric demand is defined in the SCE DBP tariff. The bid can be modified (and resubmitted to the utility) as conditions change at the customer site. If desired, the bid can be considered a standing bid, which is valid until changed by the customer. If the operating conditions (and any special constraints) at the customer site are unchanged, it may not be necessary to update the bid each day. Additional information about the SCE DBP program is contained in Appendix B.

Upon receiving a command that a DBP event has begun, a set of automatic control actions can be executed to perform pre-programmed DR strategies (resulting in a reduction in the electric demand of the controlled equipment). At the end of a DBP event, the automated DR strategies are terminated and equipment operation returns to normal. DBP participants receive a day-ahead advance notification of a pending DBP event. The timeline for a typical DBP event is shown in Figure 10 (adapted from [FERC M&V]).

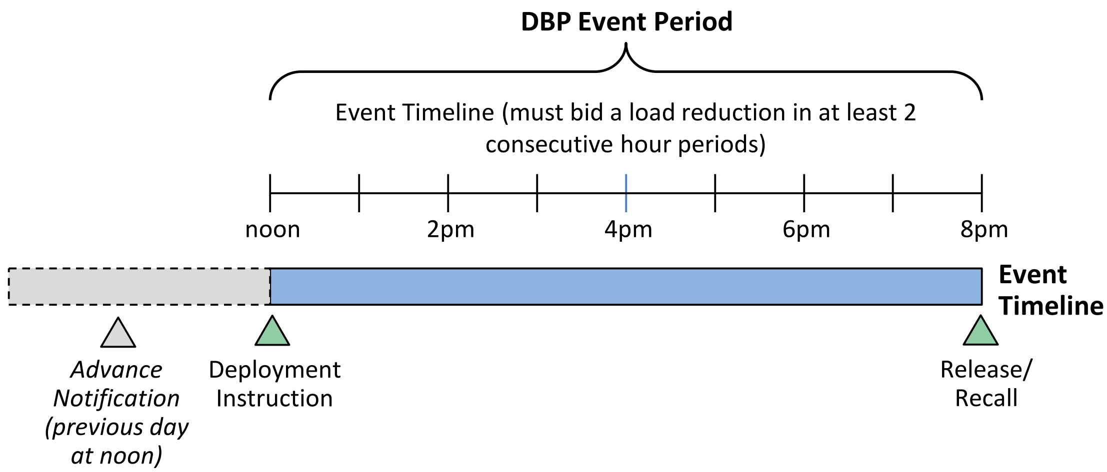

Figure 10. Typical DBP Event Timeline

The Honeywell control system included suitable user interface controls to ensure proper oversight by DPW staff. Interactions of the DPW energy manager and operating staff with the system are shown in Figure 11.

The controllable loads at Fort Irwin were carefully selected together with DPW, to be suitable for use in this demonstration project. Appropriate DR strategies were developed and verified during the system installation and commissioning process. If needed, a means of opting-out for specified loads or time periods was provided for the DPW energy manager and operating staff.

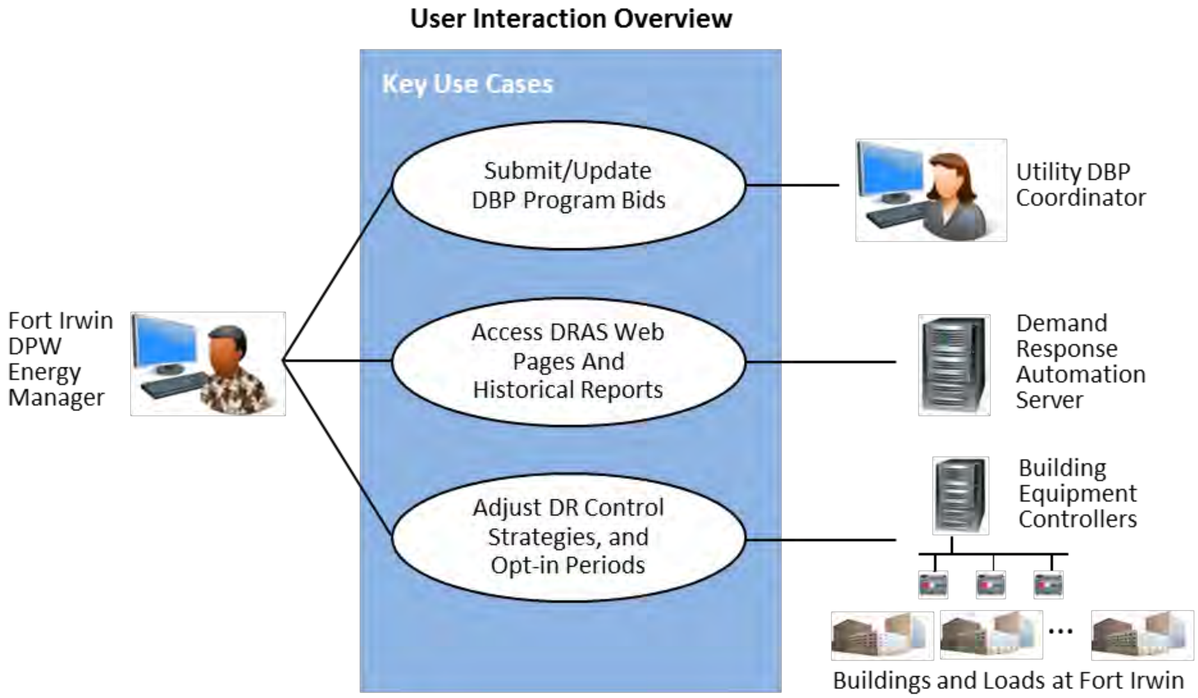

Figure 11. User Interaction Overview

Figure 12 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.).

The features in the operator interface screen shown in Figure 12 are described in more detail in Appendix D. As described earlier, 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 are shown in more detail in Appendix D.

The ability to opt-out of DBP events (during or prior to an event) was also included (i.e., to configure the system appropriately to account for changes in mission requirements at the installation). This interface can also be used to estimate the amount of demand reduction by hour (for use in preparing DBP bids to the electric utility).

Honeywell's DBP control implementation also included the ability to automatically override DBP event control actions due to over-temperature conditions in the occupied spaces of the affected buildings. These override conditions could occur if the bid profiles are set too aggressively, given the actual weather conditions during a DBP event.

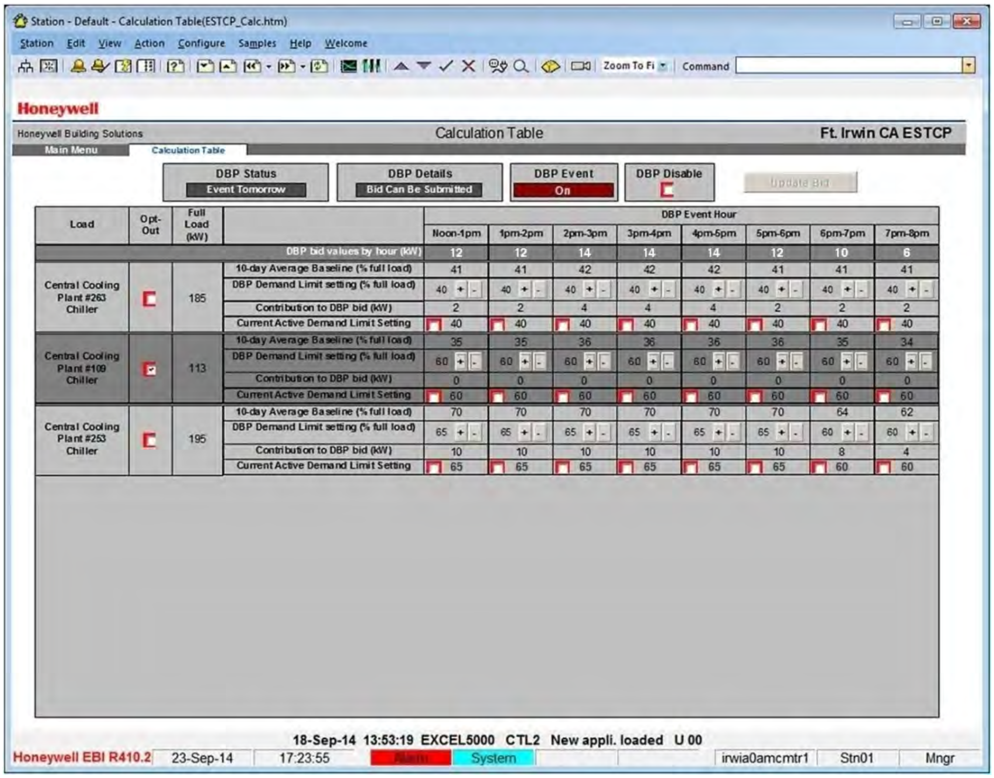

Figure 12. User Interface Screen

5.3.3 System Components

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

The demonstration system's building controllers and central server were connected via the Fort Irwin military communications network. These controllers carried out the DBP event commands to reduce electric demand in each of the controllable loads. The project team worked closely with the Fort Irwin Network Enterprise Center to ensure that the demonstration system was installed in accordance with all applicable information security requirements.

5.3.4 System Integration

The demonstration system interfaced directly with the controlled equipment. No interface to, or integration with, existing controls was required. This implementation approach was developed jointly with DPW.

5.3.5 System Controls

A riser diagram showing the field implementation of the overall system including the Honeywell building controllers and central server is shown in Appendix E.

The field implementation utilized an existing Authorization to Operate (ATO) certification received by Honeywell under a separate military contract. The application of that ATO in this project is highlighted in the riser diagram.

5.3.6 DBP Control Strategies

This subsection describes the demand response control strategies implemented at Fort Irwin.

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 rated load amps (RLA). The control ranges of the current limit analog inputs for the three chillers are shown in Table 5.

Table 5. 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

The % rated load amps (RLA) analog output from each chiller measures the amperage drawn by the compressor motor. It is an indicator of the load on the chiller, but does not directly measure the power (kW).

The project team utilized the %RLA chiller current limit control input (preferred for this DBP control application) because it is more easily understood by plant operators and energy managers as a more direct way to control electric demand. Other means (i.e., control of the CHWS setpoint) are also possible, but probably not as easily understood and converted into kW demand reductions for the purpose of bidding to the utility (because more complex modeling of demand as a function of CHWS and other variables is required).

A number of commonly-used DR practices could not be implemented in the demonstration at Fort Irwin due to constraints at the site. The following paragraphs describe design features that could not be included in the project. The lack of these features did not compromise the project's ability to demonstrate the OpenADR technology.

- The project's controls installation did not include locking of the CHWS pump speeds during DBP events (which is a customary practice in many chiller DR applications). We were unable to apply this strategy, due to complications in interfacing with other building control systems at Fort Irwin. This lack of CHWS pump control did not adversely affect the results of the project.
- Energy storage (or some other means of time-shifting electric load) can be a very useful feature in DR applications. However, at Fort Irwin there was no capability available for energy storage.
- The project's controls installation did not include pre-cooling prior to DBP events. The lack of control automation in most of the buildings served by these central cooling plants (along with the nature of the majority of HVAC equipment—fan-coil units with stand-

alone thermostat controls) made pre-cooling DR control strategies impractical. However, the lack of pre-cooling capability did not adversely affect the results of the project.

5.3.7 Demand Bidding Program Background

The SCE Demand Bidding Program (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.

Event Trigger:

A DBP event may be called at SCE's discretion when it is needed based on CAISO emergencies, day-ahead load and/or price forecasts, and extreme or unusual temperature conditions impacting system demand and/or SCE's procurement needs.

Notification and bidding:

Customers are notified of events by 12:00 noon on the previous day. Customer bids for demand reductions are accepted the day before the actual DBP event between 12 and 4pm. Bidding for the upcoming event must be established for at least two consecutive event hours and a minimum of 1kWh. When an event is called, enrolled customers may choose to modify their standing bids (load reduction amount) for the upcoming event. Bids can only be placed for future events and may vary the bid amount by hour.

Baselines:

For settlement billing credit purposes, the baseline electric load (in kWh) for each customer is calculated using a "10-Day Average Baseline." Under this method, each hour during the past ten similar days (excluding event days, weekends, and holidays) prior to an event day is averaged to establish an hourly average baseline for those ten days. Customers have the option to include a day-of adjustment (based on the ratio of the current day's pre-event usage level to the usage level in the same period in the reference baseline) that can shift the baseline up or down.

Accepted bids and incentive:

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 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.

Dual Enrollment:

If DBP customers dual enroll in another demand response (DR) program, that DR program must be a capacity-paying program with same day notification (e.g., Base Interruptible Program). For simultaneous or overlapping events, the dual-participants receive payment for the capacity-paying program and not for the simultaneous hours of the DBP event.

5.4 OPERATIONAL TESTING

The operational testing was performed with the assistance of Fort Irwin DPW. The results of the testing activity are described in the following subsections.

5.4.1 DBP Events

The demonstration test 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 event days that made up the demonstration are shown in Table 6.

Table 6. 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

The total number of DBP events was comparable to a typical year. SCE DBP program event historical data for recent years is presented in Appendix F.

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, which 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.

Central Plants 253 and 263 serve single soldier housing barracks, as well as military dining facilities. During the period of the demonstration, the project team strived to avoid impacting space comfort conditions in the dining facilities during their heavy use periods (around the noon and evening meal times). So, we employed relatively conservative current limit settings in our control response to the simulated as well as actual SCE DBP events.

Potential effects on indoor space temperature should be considered in selecting the amount of DBP demand reduction to bid (and setting the associated DBP control actions). Due to the brief amount of time that was available to perform the demonstration, the project team and DPW were not able to optimize the DBP control settings. This optimization can be accomplished as part of future use of the system at Fort Irwin.

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). This condition was not known by the project team earlier in the project. (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. The project team did not explore this approach during the demonstration because it was not consistent with the DR control method used for the chillers at Central Plants 253 and 263.)

5.4.2 DBP Program Participation

The project team did not submit DBP bids to SCE during the demonstration period since Fort Irwin DPW was also participating manually in the SCE DBP program with a number of much larger loads. Our bids would not have been a significant addition to the manual-only DBP bids from DPW.

Since approximately 2009, Fort Irwin DPW has been performing manual DBP control of a number of water pumping loads (which are much larger than the size of the loads controlled in this ESTCP demonstration project). At present, when a DBP event is called, DPW places a phone call to the owner/operator of the privatized water system to request a reduction in the pumping loads. The water system operator then manually reduces the pumping loads (within the limits of operational constraints). This manual DBP program protocol with the private water system operator will likely continue unchanged in the future. This manual DBP protocol also continued throughout our project demonstration period, but did not affect our testing activity.

At present, Fort Irwin DPW (in its manual participation in SCE's DBP Program) does not utilize the available "Day-of" adjustment in the tariff. So, the project team did not consider that option in performing the demonstration or in the analysis of results.

5.5 SAMPLING PROTOCOL

Table 7 describes the sources of the measured data, and the following paragraphs present other relevant information.

Table 7. Measured Data

Data	Sensor or Source of the Data	Remarks
Chiller kW	Electric submeters	- - -
Chiller %RLA	Observations taken from the chiller controller's user interface	Analog outputs from the chiller controllers were also employed
Space temperatures	Battery -powered temporary sensors	The system also included wired sensors which were not operational in time for the data collection period
Outdoor ambient temperature	MesoWest data	(same as above)
Chilled water supply (CHWS) Temperatures	Observations taken from the Chiller controller	(same as above)
Chiller current limit command	Observations taken from the chiller controller, and from control system settings	- - -

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 The temperature data was measured at the KBYS Fort Irwin / Barstow station, which is located on the Bicycle Lake Army Airfield about three miles from the Fort Irwin cantonment area. 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.

Space temperature monitoring of representative occupied spaces in buildings served by the three chiller plants was performed. The selected measurement points are shown in Table 8.

Table 8. Space Temperature Data

Central Plant	Space Temperature Monitoring Location	Space Utilization
109	Bldg 109 office area	Office for providing services to new incoming personnel
253	Bldg 252 3rd floor corridor	Single soldier housing
263	Bldg 262 3rd floor corridor	Single soldier housing

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 performance objectives.

An example set of plots showing the measured results for one of the DBP events is shown in Figure 13. The complete set of measured results is presented in Appendix G.

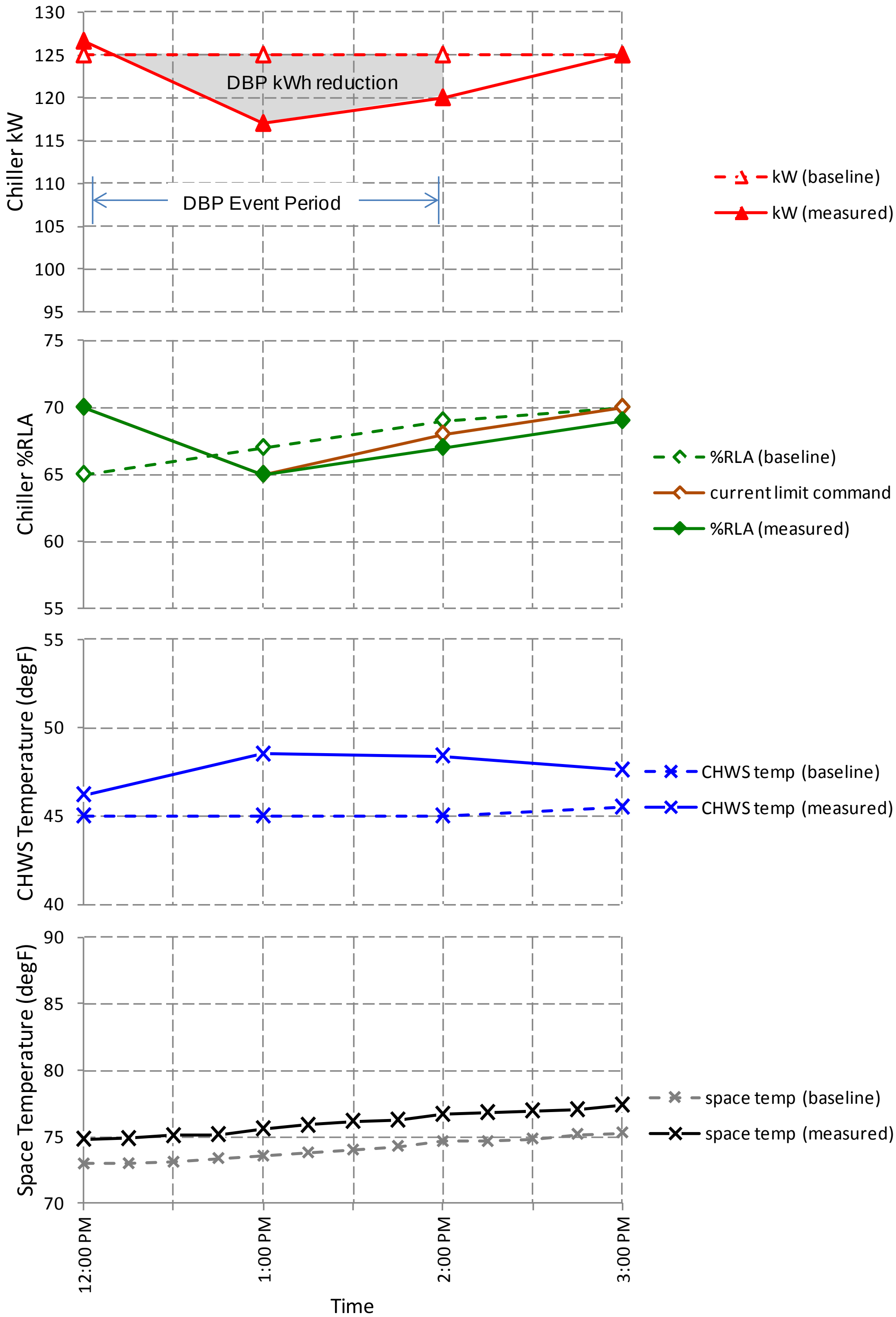

Figure 13. Measured Results for Central Plant 253, September 5, 2014

The plots in Figure 13 are arranged to highlight the following data:

- Duration of the DBP event
- Current limit command (displayed as % rated load amps). 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
    - Chiller % rated load amps (RLA), which are shown to respond to current limit commands from the Honeywell DBP control system during DBP events
    - Chilled water supply (CHWS) temperatures, which may increase slightly during DBP events as a result of chiller demand limiting
    - Indoor temperatures in occupied spaces, which may be impacted due to elevated CHWS temperatures during DBP events

Analysis of Measured Results

The measured data shown in Appendix G was analyzed to quantify the demand and energy reductions that occurred during the demonstration testing. The analysis results are shown in Appendix H.

Relevant Background

Other background information relevant to the demonstration testing and the measured results includes:

- During the previous year, the chiller in Central Plant 253 developed fouling in its condenser tubes. As a result, Fort Irwin plant operators limited that chiller to a maximum current of 70% RLA (rated load amps). This change resulted in periods when the chiller ran steadily at that 70% RLA limit, especially on warmer days. Under these conditions, the CHWS temperature could rise above the control setpoint of 44F by as much as 2 or 3 degrees. This condition also constrained the amount of demand reduction that the DBP controls could effectively utilize without further affecting the CHWS temperature and, hence, space comfort conditions. DPW and the plant operators planned to perform service on the condenser following the end of the cooling season in 2014.
- Some data points were taken slightly off from the top of each hour and are shown in our data plots at the nearest hour. This approach did not significantly affect the accuracy of the demonstration testing.

Observations from the Measured Data

The individual plots in Figure 13 enable a comparison of measured test results against baseline profiles. Analysis of the measured data yielded the following key observations:

- As well as maintaining the desired CHWS setpoint, the chiller internal controls are designed and tuned to seek an optimal operating point (for energy efficiency and equipment protection). This continual search for the optimum can result in some variation in operating point (this effect caused some variability in the data collected).
- The measured accuracy and tracking ability of the chillers' control response (as commanded via the %RLA current limit analog control input) was quite good and proved to be sufficient for this DR application. Note that the actual hourly measured kW reduction from the utility baseline (compared to the bid amount) is not critically

important for DBP applications (because the tariff's billing credit is paid for the measured kW reduction that is in the range of 50% to 200% of the hourly bid amount).

- Observations during the simulated and actual DBP events revealed that the chillers' response to DR control commands showed some time lag. As expected, the response to command updates is typically rather slow and can be characterized as a first-order response with a time constant of ten minutes or more. This rather slow response is due to the conservative tuning of the control laws in the chiller's internal controller (intended to protect the equipment from rapid swings in operating condition). This observation is consistent with that seen in commercial sector DR projects. The project team believes that chillers are good candidates for demand response applications, but they will typically have a slower response than some other types of equipment.
- The project team observed that kW demand sometimes remained lower than the baseline during recovery after the end of some of the DBP events. Note that these recovery-related kWh savings are not credited in the SCE DBP tariff if savings are outside of an hourly bid period.
- For Central Plant 253, space temperatures were measured in the top floor (3^{rd} floor) corridor of Building 252, which is a single soldier housing barracks. We found some variability in that space temperature during the baseline period. The project team did not collect data for space temperatures inside the soldiers' apartment units in Building 252.
- Similarly, for Central Plant 263, space temperatures were measured in the top floor (3^{rd} floor) corridor of Building 262, which is a single soldier housing barracks. We also found some variability in space temperature during the baseline period. The project team did not collect data for space temperatures inside the soldiers' apartment units in Building 262.
- The 48F CHWS setpoint for the chiller in Central Plant 263 at sometimes results in relatively high space temperatures for the area monitored in Bldg. 262, but this did not adversely affect the demonstration testing. The project team did not monitor the space temperature conditions in other buildings served by Central Plant 263. During the demonstration period, no complaints about space temperature conditions were received from occupants living in Buildings 252 or 262.

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 demand response control strategies during a DBP event.

The sampling results shown in Figure 13 (as well as other sampling results presented in Appendix G) for the current limit command (sent to the chiller) and the resulting chiller % rated load amps (RLA) showed very good tracking by the equipment. Also note remarks about the chillers presented in the observations paragraphs, above.

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.

Comments about the Sampling Results

The following paragraphs present additional information about the sampling results:

- In practice, demand reductions and economic benefits depend on how aggressively the DBP control settings are configured and the duration of the demand reductions. The DBP control settings used in demonstration testing were deliberately conservative. The brief time period available for the demonstration did not allow time to explore more aggressive DBP control settings. In future use of this system, Fort Irwin DPW can explore the performance and economic benefits of other control settings.
- No assessment of "DR rebound" (an increase in electric demand that is typically seen following the end of a DR period) was performed in analyzing the performance results. This rebound effect is not considered in computing utility bill credit payments for DBP programs.
- During the demonstration period, no bids for the loads controlled in this project were submitted to SCE. This was due to the small scale of these loads compared with the much larger magnitude of the loads that are utilized in the separate manual-only DBP participation by DPW at Fort Irwin (see the discussion of this subject in Sections 4.1 and 5.4 of this report).
- As described earlier in this section, DBP credits to the Fort Irwin utility bill are not reported, as the kWh savings were below the minimum measurement resolution of the SCE main meter (due to the relatively small magnitude of the demonstration-scale loads controlled and the load reductions measured in this demonstration project).
- One of the simulated DBP events (on August 28 at Chiller 253) was only one hour in duration. Each of the other events in our demonstration testing did meet the minimums specified in the DBP tariff. Nevertheless, this one-hour event did demonstrate the capabilities of OpenADR and DR control of building equipment.

6.0 PERFORMANCE ASSESSMENT

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

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 demand response control strategies.

The data used to evaluate this performance objective was:

- 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 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 vs. 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 14. Inspection of these results (and other measured results included in Appendix G) show that the accuracy and tracking ability of the chillers' control response (as commanded via the current limit control input) was very good. We 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 performance objective was met.

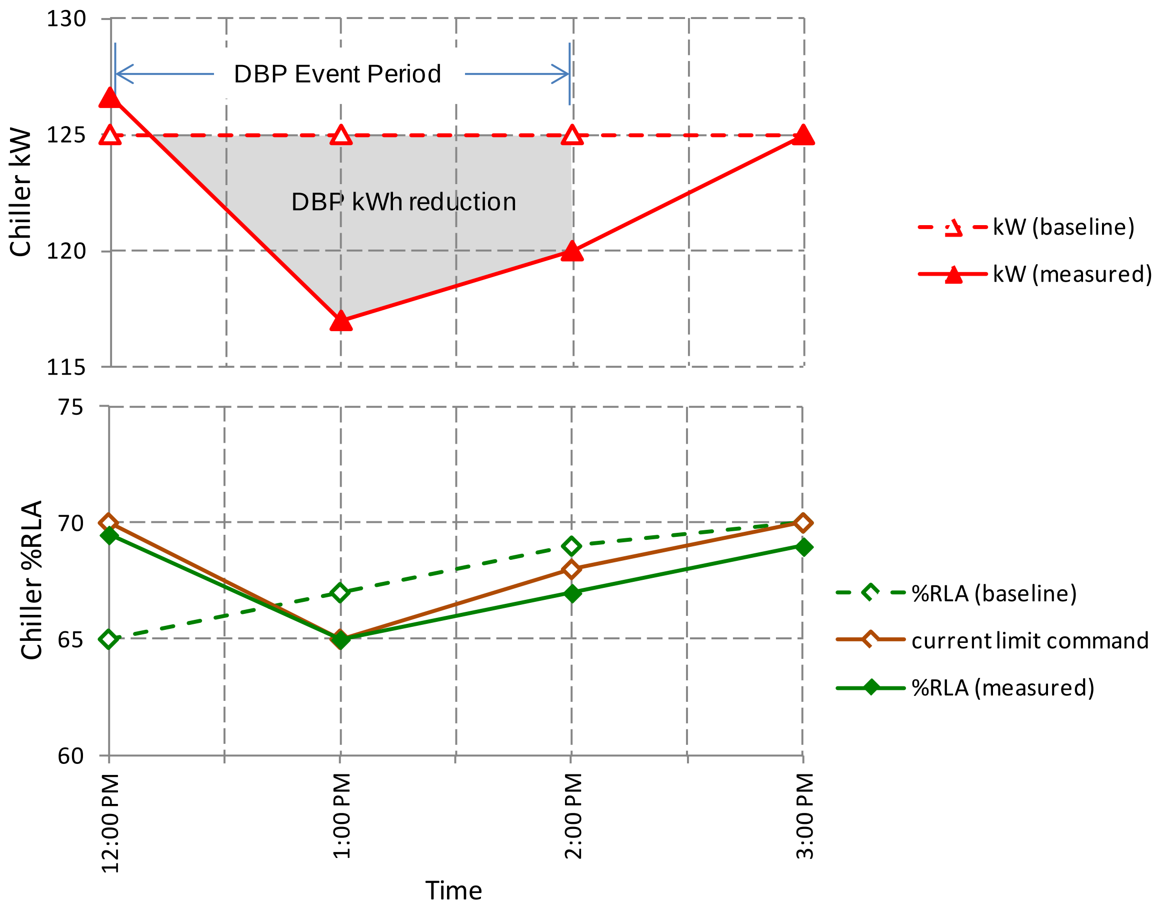

Figure 14. Measured Results for Performance Objective PO1

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 performance objective 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. Also 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, 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 verify this performance objective.

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 performance objective 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 performance objective.

Note: Much of the user interface was similar to that implemented in Honeywell demand response 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: OPERATION AND MAINTENANCE 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 building energy management systems with demand response applications.

Results: As described in Section 5, 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 operation and maintenance cost was incurred during the demonstration. Although the demonstration period was rather short in duration, we did not experience any unexpected O&M cost or effort. Based on this experience, we believe this performance objective was met.

Note: Because much of the control system hardware, software, and user interface was similar to that implemented in Honeywell demand response 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 automated demand response and OpenADR are site specific. Some general guidance about costs and an example life cycle cost comparison are discussed in this section.

7.1 COST MODEL

The primary cost elements of a field implementation of automated demand response using OpenADR technology are listed in Table 9.

Table 9. 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 demand response audit of the facility.
Facility operational costs (i.e. reduction in energy required vs. baseline data)	
Operation and maintenance	
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 building energy management system 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
- Costs for the BMS supplier to acquire a 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 demand response 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 life-cycle cost analysis of the technology, based on available and estimated data. This cost assessment was based on an example military installation participating in the SCE Demand Bidding Program. The SCE DBP Program is a year-round demand bidding program that offers Day-Ahead price incentives to customers for reducing energy consumption during a DBP Event. Additional information about the SCE DBP program is included in Appendix B.

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 demand bidding program. 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.

The results of the life-cycle cost analysis are presented in Appendix I. The analysis utilized the FEMP Building Life Cycle Cost (BLCC) Program http://www1.eere.energy.gov/femp/information/download_blcc.html#blcc.

8.0 IMPLEMENTATION ISSUES

A number of implementation issues should be addressed in planning an automated demand response project. Some of these issues are the same topics listed as cost drivers in Section 7 of this report. These implementation topics (which should be investigated as part of a demand response audit) are:

- Implementing OpenADR technology and interfacing with an existing building energy management system 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 which 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 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 demand response audit of the installation, to identify the DR control opportunities, assess the economic potential, and assist in planning the implementation.

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

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APPENDICES

Appendix A: Points of Contact

Key points of contact (POC) for project team involved in the demonstration

Point of Contact	Organization	Phone & E-mail	Role in Project
Steve Gabel	Honeywell ACS Labs	763-954-6512 steve.gabel@honeywell.com	Project Manager
Melanie Johnson	Army ERDC-CERL Lab	217-373-5872 melanie.d.johnson@usace.army.mil	ERDC-CERL project lead
Janie Page	LBNL	510-486-7015 jpage@lbl.gov	LBNL project technical lead
George Bell	Honeywell Smart Grid Solutions	951-273-9944 george.bell@honeywell.com	Technical Coordinator and Installation Project Manager

Appendix B: SCE Demand Bidding Program

The Southern California Edison Demand Bidding Program is a year-round bidding program that offers Day-Ahead price incentives to customers for reducing energy consumption during a DBP Event. A Day-Ahead DBP Event, may be called at SCE's discretion, when it is needed based on CAISO emergencies, day-ahead load and/or price forecasts, extreme or unusual temperature conditions impacting system demand and/or SCE's procurement needs.

Additional information about the SCE DBP program can be found at the following links:

- Demand Bidding Program Fact Sheet, Southern California Edison, NR-567-V2-0810, 2010 https://www.sce.com/wps/wcm/connect/96702c0a-c759-4efe-b302-f874e4407c32/090217_Demand_Bidding_Fact_Sheet.pdf?MOD=AJPERES
- Demand Bidding Program Tariff Sheet, Cal. PUC Sheet No. 52447-E, 2872-E-B, Southern California Edison, April 2013, https://www.sce.com/NR/sc3/tm2/pdf/ce185.pdf
- Demand Bidding Program: RTEM Metered Accounts - How to Use Online Tools, https://www.sce.com/wps/wcm/connect/1212718e-f6a0-4489-9bc0-77191fdc5309/5+DBP_OnlineInstruction_Rev1.1_05-RTEM+Accounts.doc?MOD=AJPERES
- SCE DBP bid form, https://www.sce.com/wps/wcm/connect/ecf42432-b0b0-4711-85d4-e588d0ded08a/7+DBP+Bidding+Form-ESC+Accts-1.pdf?MOD=AJPERES
- Demand Bidding Program FAQ, https://www.sce.com/wps/wcm/connect/7613a37e-2aed-4194-94c2-a22eb318e024/6++FAQ_DBP+ESC+Accts++7.16.13+mm1.pdf?MOD=AJPERES
- 10-Day Average Baseline, https://www.sce.com/wps/wcm/connect/c47fe131-45a5-4456-b3ad-f8a781a42bd6/10+Day+Avg+Baseline+%26+Day+Of+Adj_+NR-2225-V1-0413.pdf?MOD=AJPERES
- Demand Response Event History, https://www.sce.openadr.com/dr.website/scepr-event-history.jsf

Information about the SCE Automated Demand Response Technology Incentive (AutoDR TI) can be found at: https://www.sce.com/wps/wcm/connect/5f2efc73-a4fd-483b-b669-1c2866268b6b/AutoDR-TI%2BProgram%2BGuidelines_Jan2013-V4.0-StRes.pdf?MOD=AJPERES

Appendix C: Baseline Data

Graphs in this appendix plot baseline data for the buildings and equipment used in the demonstration. The table below describes the data plotted in each figure. Note that Figure 15 through Figure 17 include separate plots for each building.

Figure Number	Type of Baseline Data
Figure 15	The baseline electric demand profiles for the chillers in Buildings 109, 253, and 263
Figure 16	The baseline % rated load amps (RLA) profiles for the chillers in Buildings 109, 253, and 263
Figure 17	The baseline chilled water supply temperature (CHWS) profiles for the chillers in Buildings 109, 253, and 263
Figure 18	The average outdoor ambient temperature profile during the baseline calendar period
Figure 19	The average outdoor ambient temperature profile during the DBP event days
Figure 20	The average indoor space temperature profile for Building 109 during the baseline period
Figure 21	The average indoor space temperature profile for Building 252 during the baseline period
Figure 22	The average indoor space temperature profile for Building 262 during the baseline period

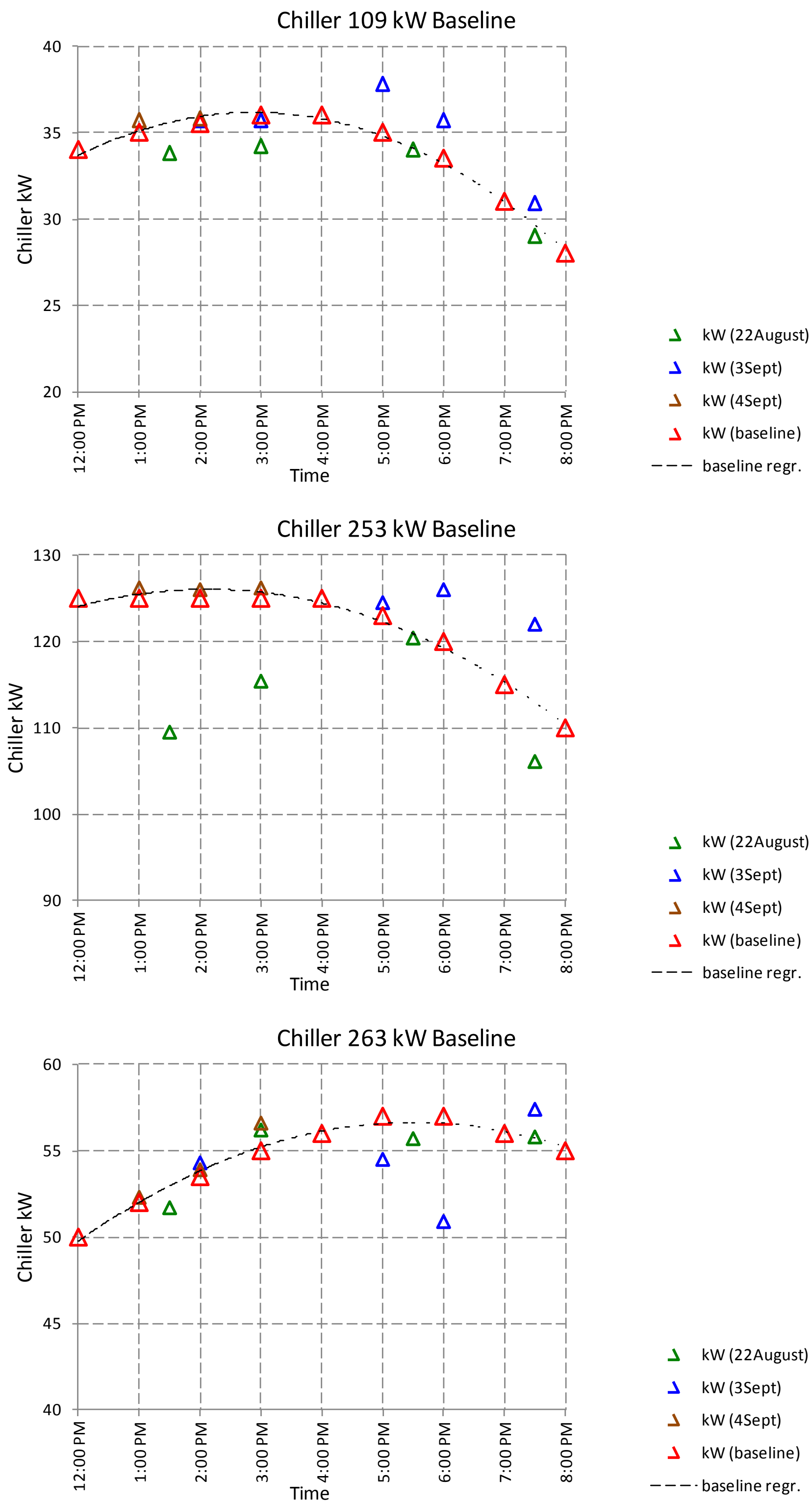


Figure 15. Baseline electric demand profiles for the chillers in Buildings 109, 253, and 263

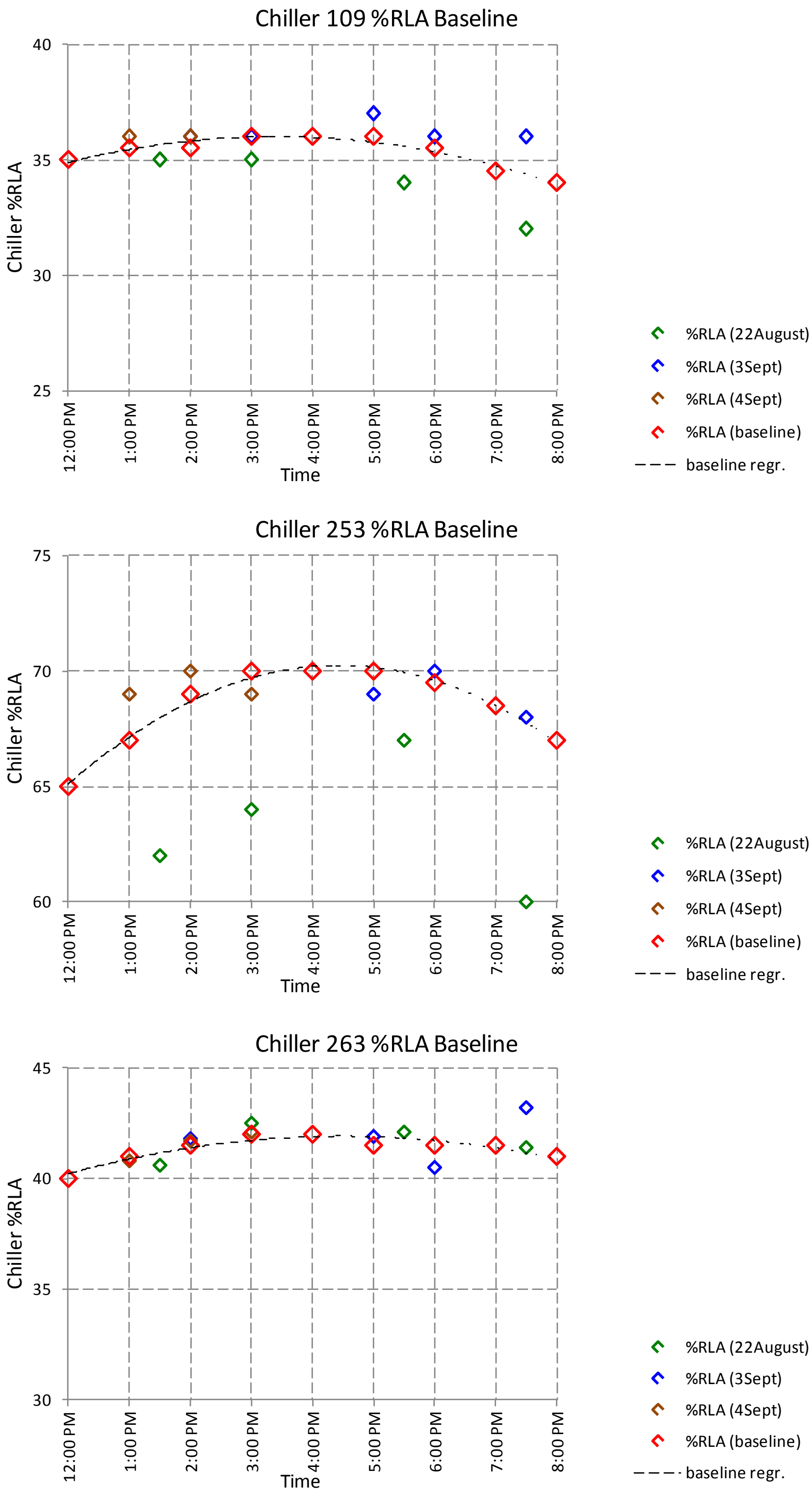


Figure 16. Baseline % rated load amps (RLA) profiles for the chillers in Buildings 109, 253, and 263

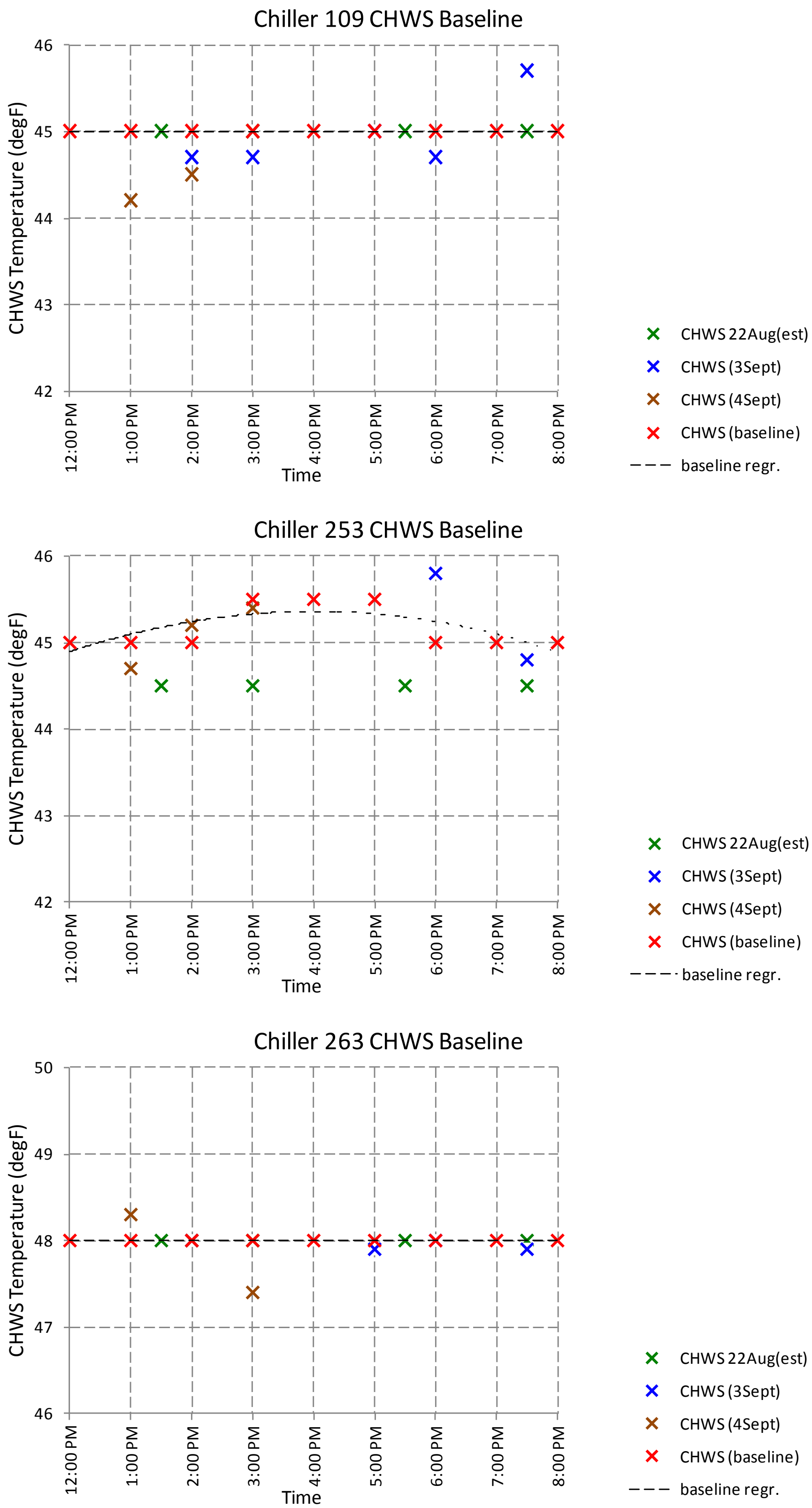


Figure 17. Baseline CHWS profiles for chillers in Buildings 109, 253, and 263

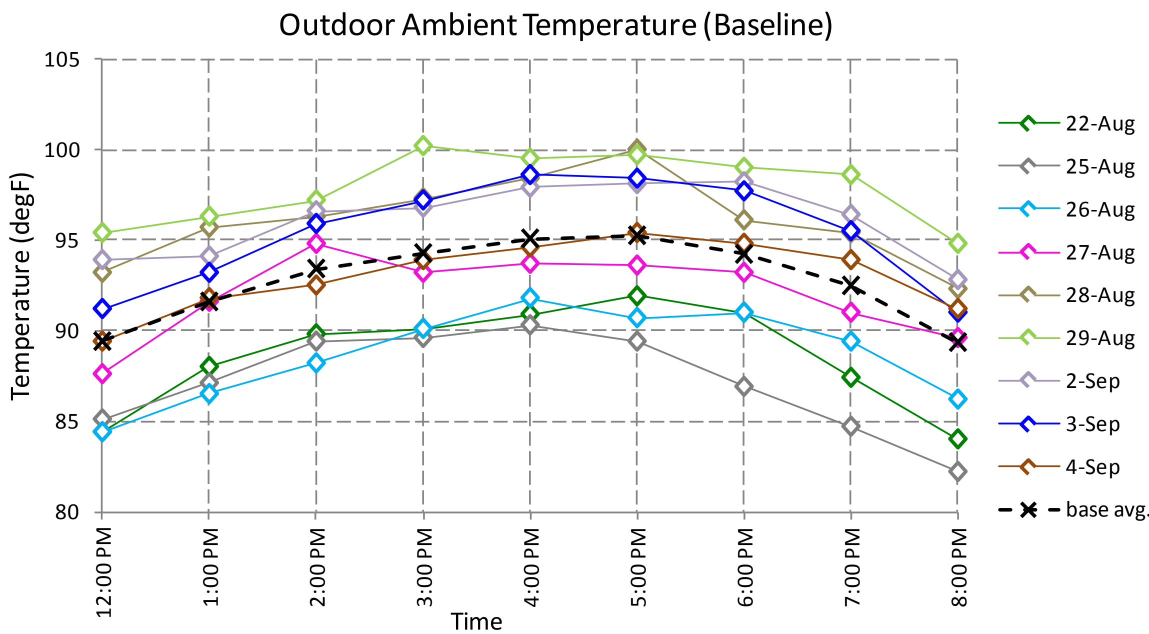


Figure 18. Average outdoor ambient temperature profile during the baseline calendar period

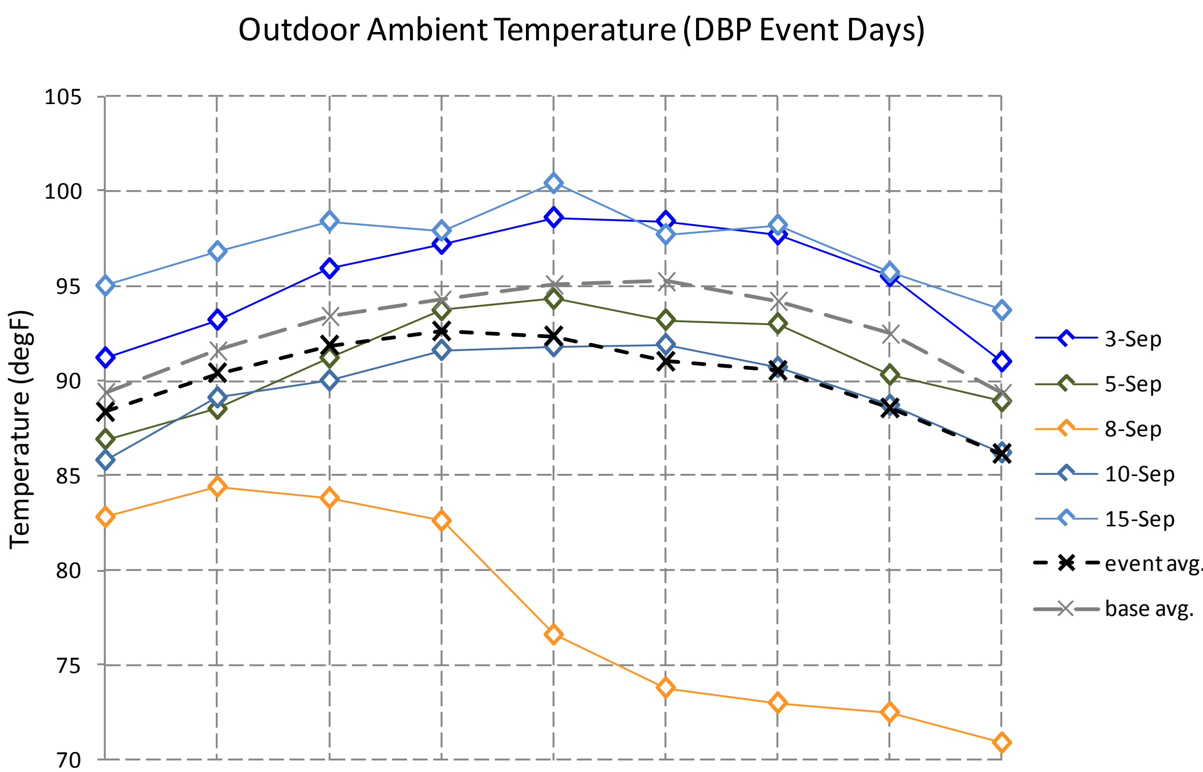


Figure 19. Average outdoor ambient temperature profile during the DBP event days

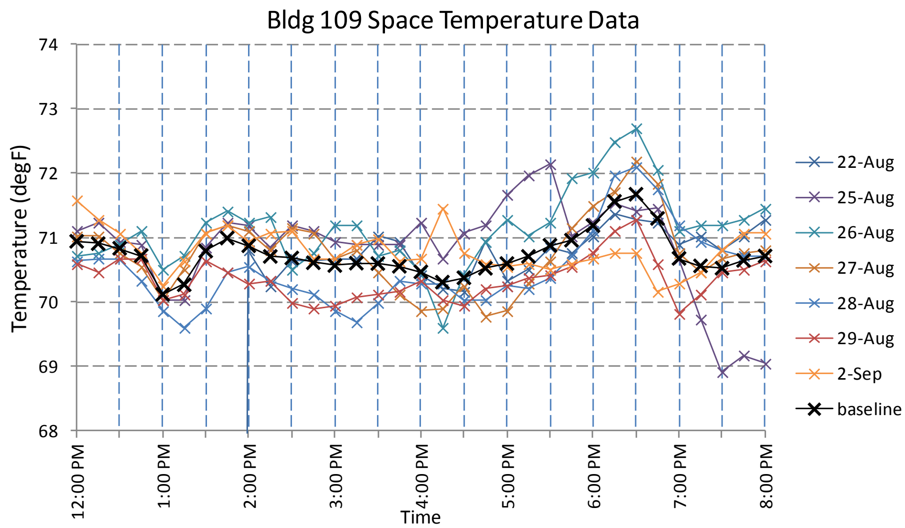


Figure 20. Average indoor space temperature profile for Building 109 during the baseline period

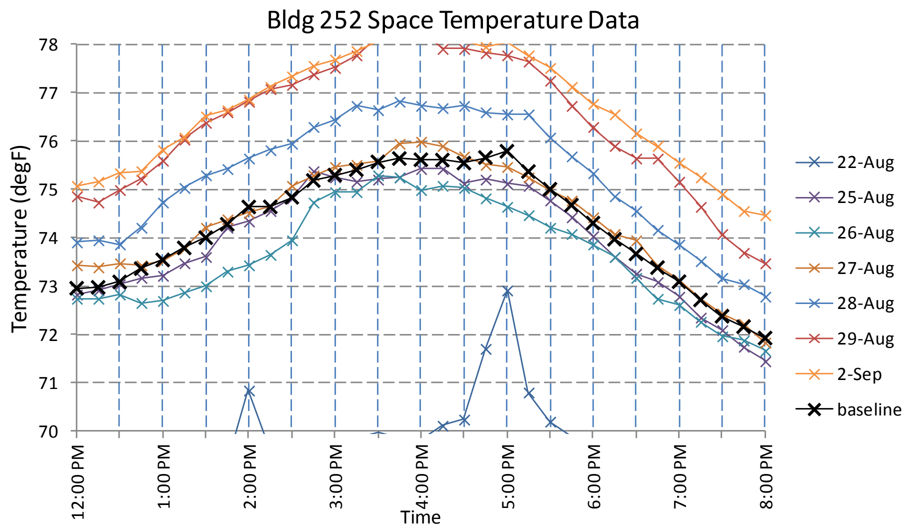


Figure 21. Average indoor space temperature profile for Building 252 during the baseline period

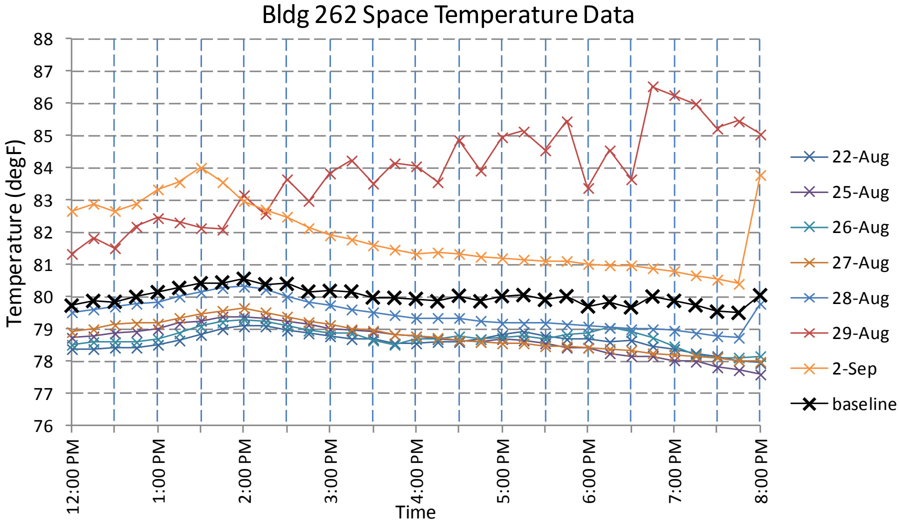


Figure 22. The average indoor space temperature profile for Building 262 during the baseline period

Appendix D: DBP Control Table

The user interface screen for demand bidding control is shown Figure 23. This screen enables the user to set the control parameters for responding to SCE demand bidding events.

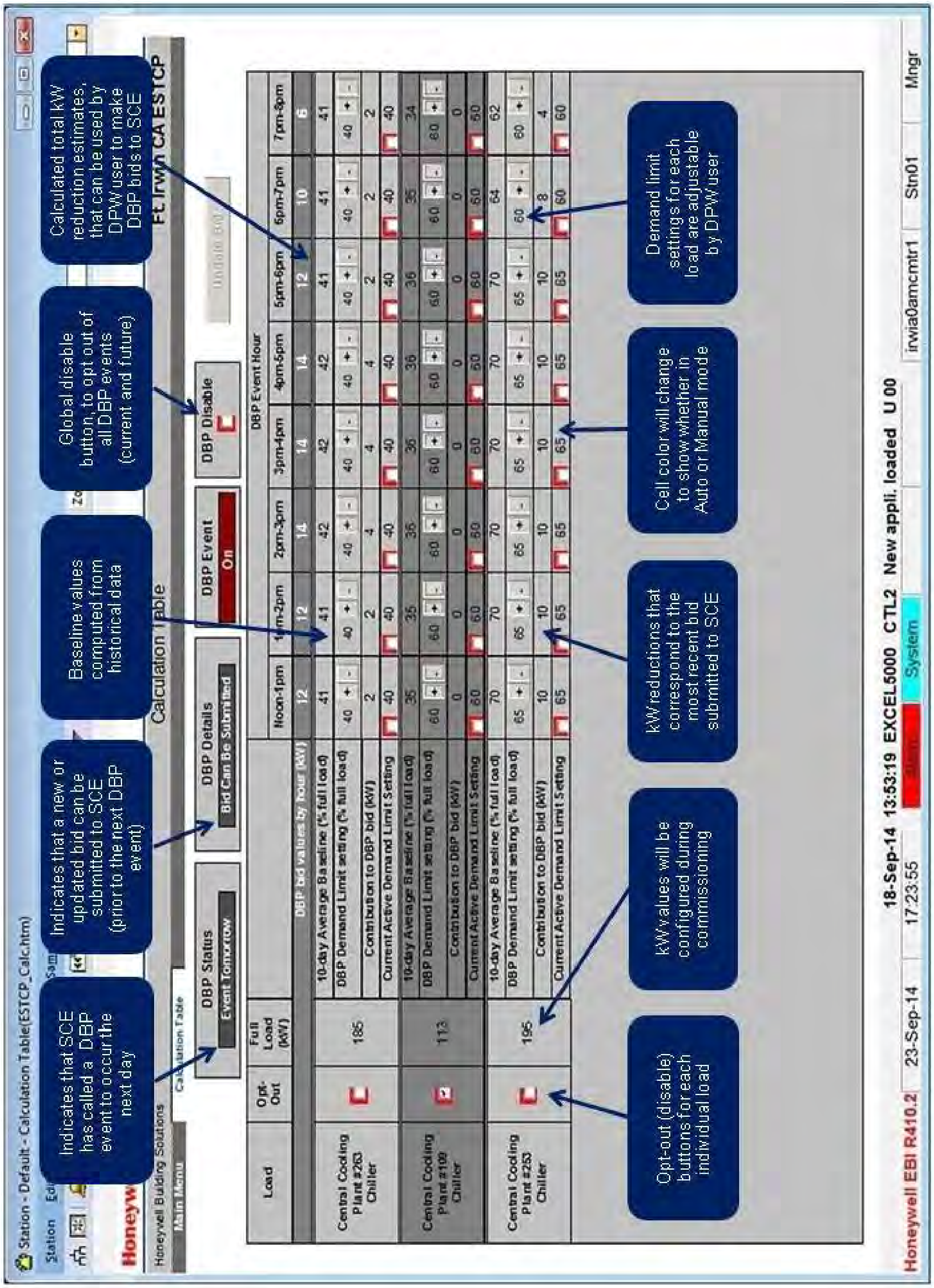


Figure 23. User Interface Screen for Demand Bidding Control

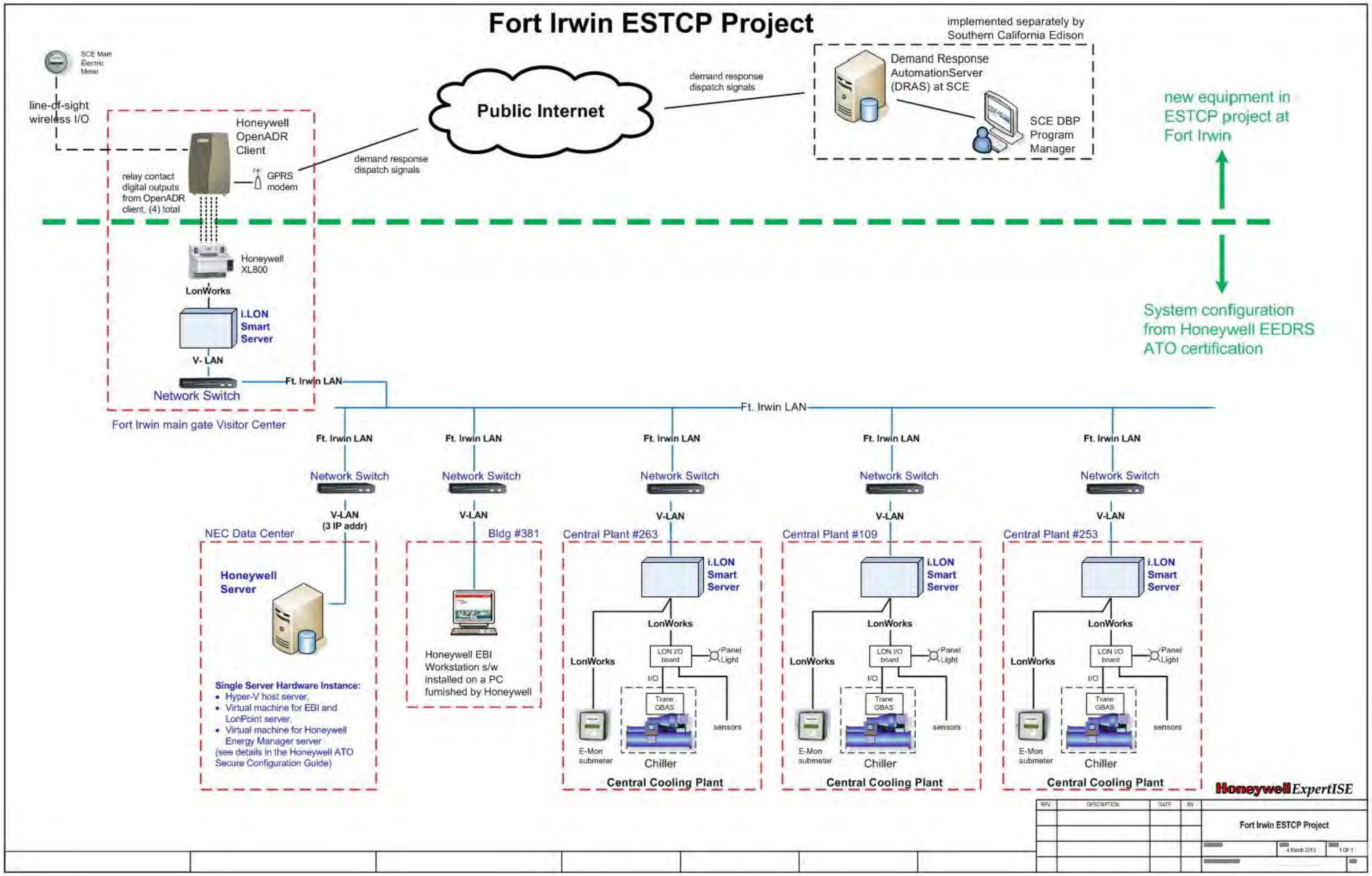


Figure 24. DBP Control System Configuration

Appendix F: SCE Demand Bidding Program Event History

The history of scheduled SCE DBP events can be found at this website:
https://www.sce.openadr.com/dr.website/scepr-event-history.jsf

A summary of recent DBP event history is shown in Figure 25 and Table 10 below.

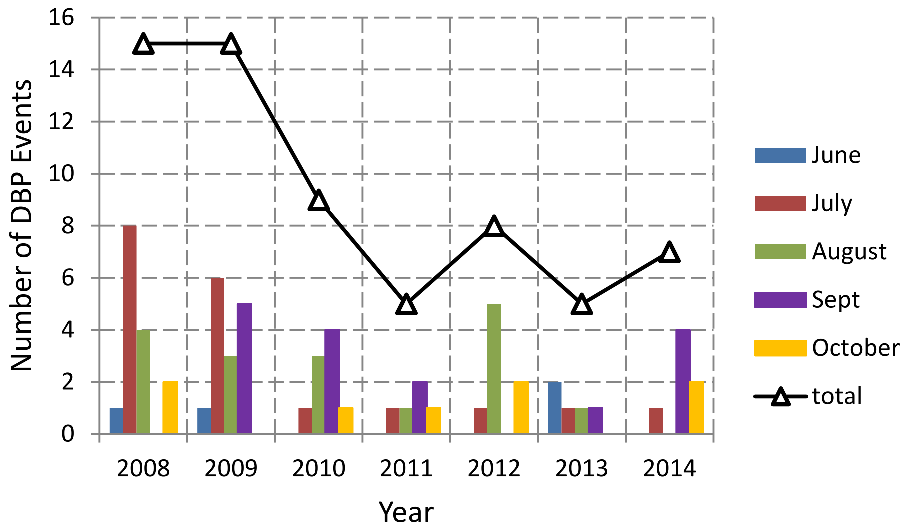


Figure 25. Scheduled DBP Events 2008–2014

Table 10. Scheduled DBP Events 2008–2014

	Number of DBP Events by year						
	2008	2009	2010	2011	2012	2013	2014
June	1	1	0	0	0	2	0
July	8	6	1	1	1	1	1
August	4	3	3	1	5	1	0
Sept	0	5	4	2	0	1	4
October	2	0	1	1	2	0	2
total	15	15	9	5	8	5	7

Appendix G: Measured Data

This appendix includes twelve sets of plots showing measured data for the six DBP events and their impact on the operation of the chillers at central cooling plants 253 and 263.

Index to DBP Event Data

Figure	Event Date	Plant
Figure 26	August 28, 2014	253
Figure 27	August 28, 2014	263
Figure 28	September 3, 2014	253
Figure 29	September 3, 2014	263
Figure 30	September 5, 2014	253
Figure 31	September 5, 2014	263
Figure 32	September 8, 2014	253
Figure 33	September 8, 2014	263
Figure 34	September 10, 2014	253
Figure 35	September 10, 2014	263
Figure 36	September 15, 2014	253
Figure 37	September 15, 2014	263

The plots in the above figures are arranged to highlight the following data:

- Duration of the DBP event
- Current limit command (displayed as % rated load amps). 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
    - Chiller % rated load amps (RLA), which are shown to respond to current limit commands from the Honeywell DBP control system during DBP events
    - Chilled water supply (CHWS) temperatures, which may increase slightly during DBP events as a result of chiller demand limiting
    - Indoor temperatures in occupied spaces, which may be impacted due to elevated CHWS temperatures during DBP events

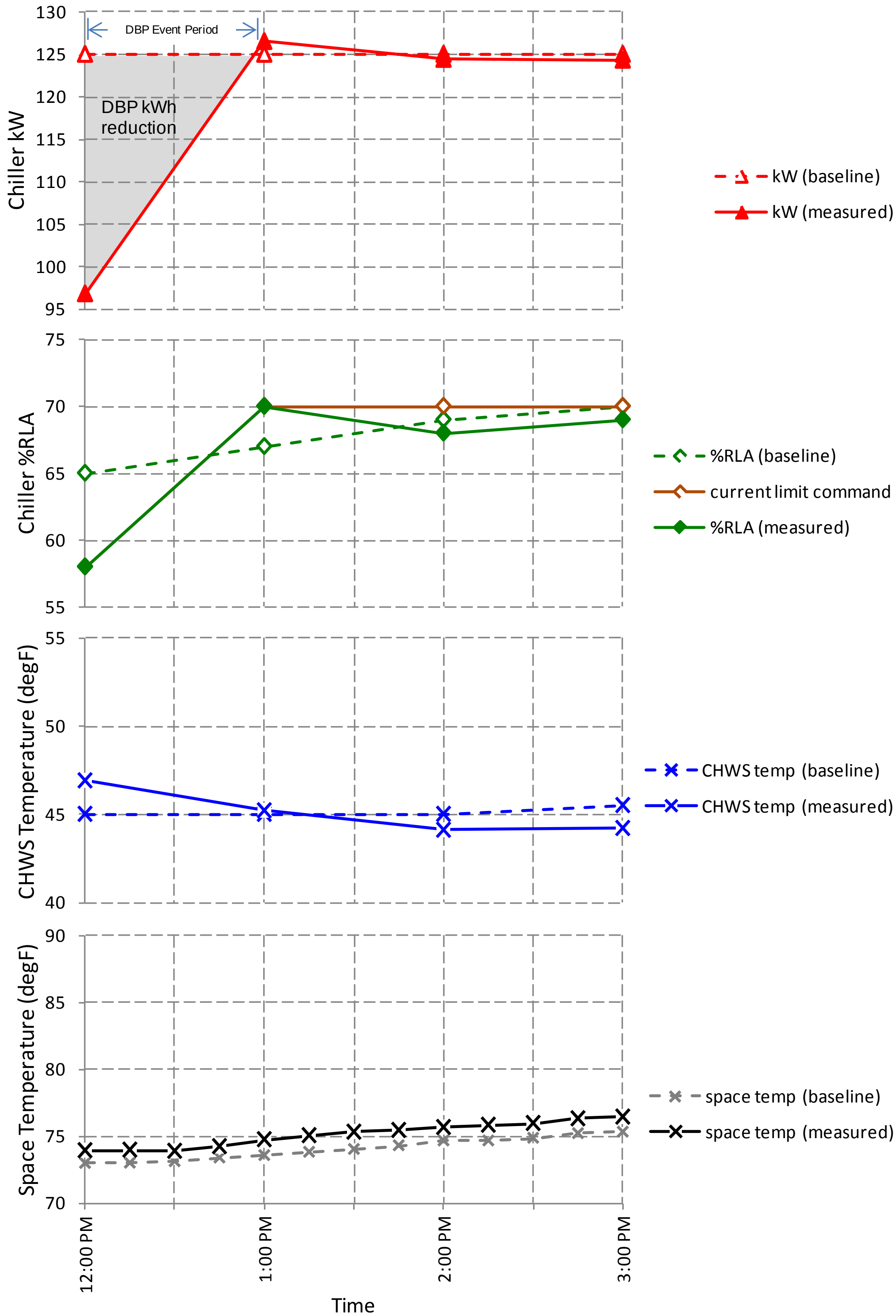


Figure 26. Central Plant 253, August 28, 2014

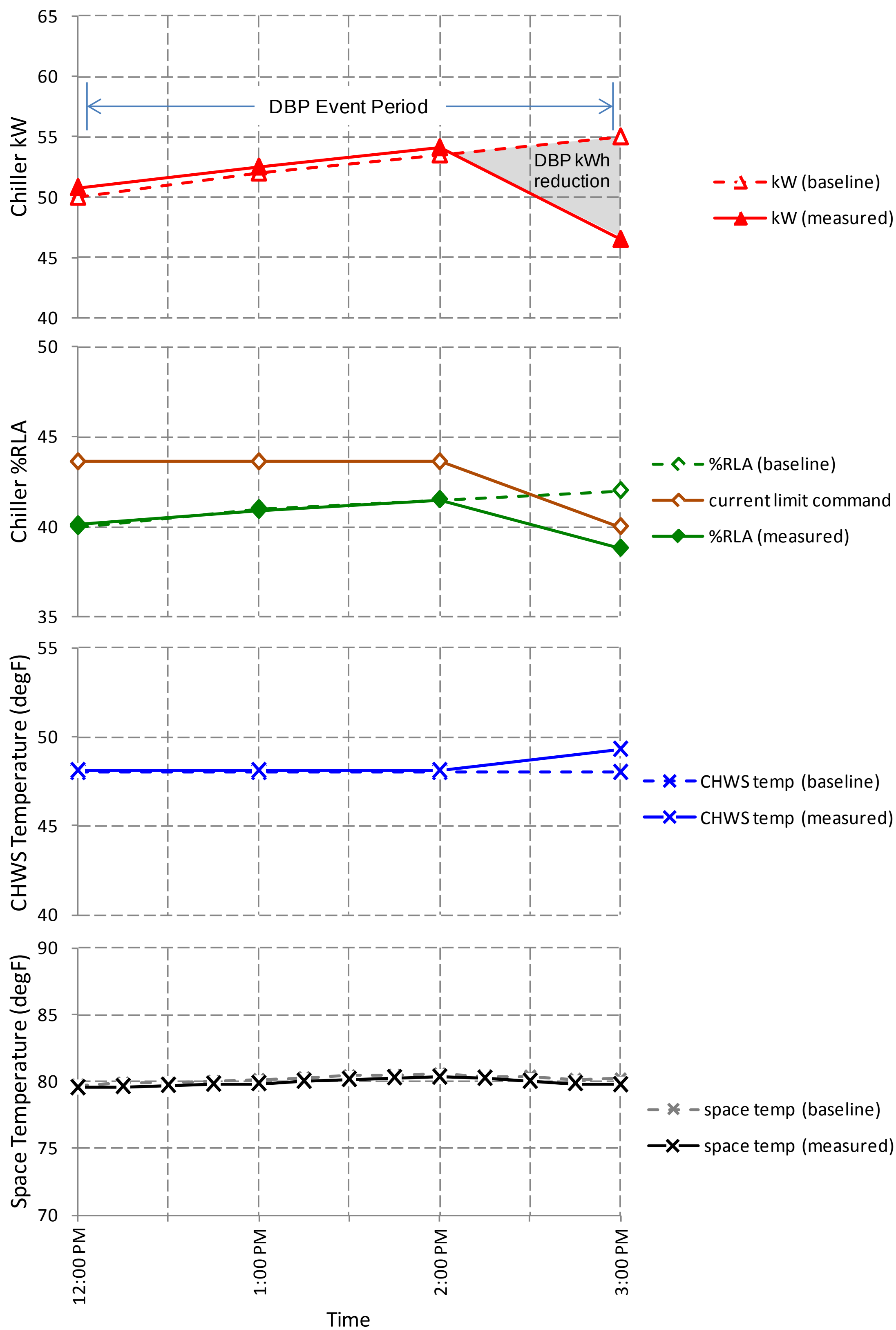


Figure 27. Central Plant 263, August 28, 2014

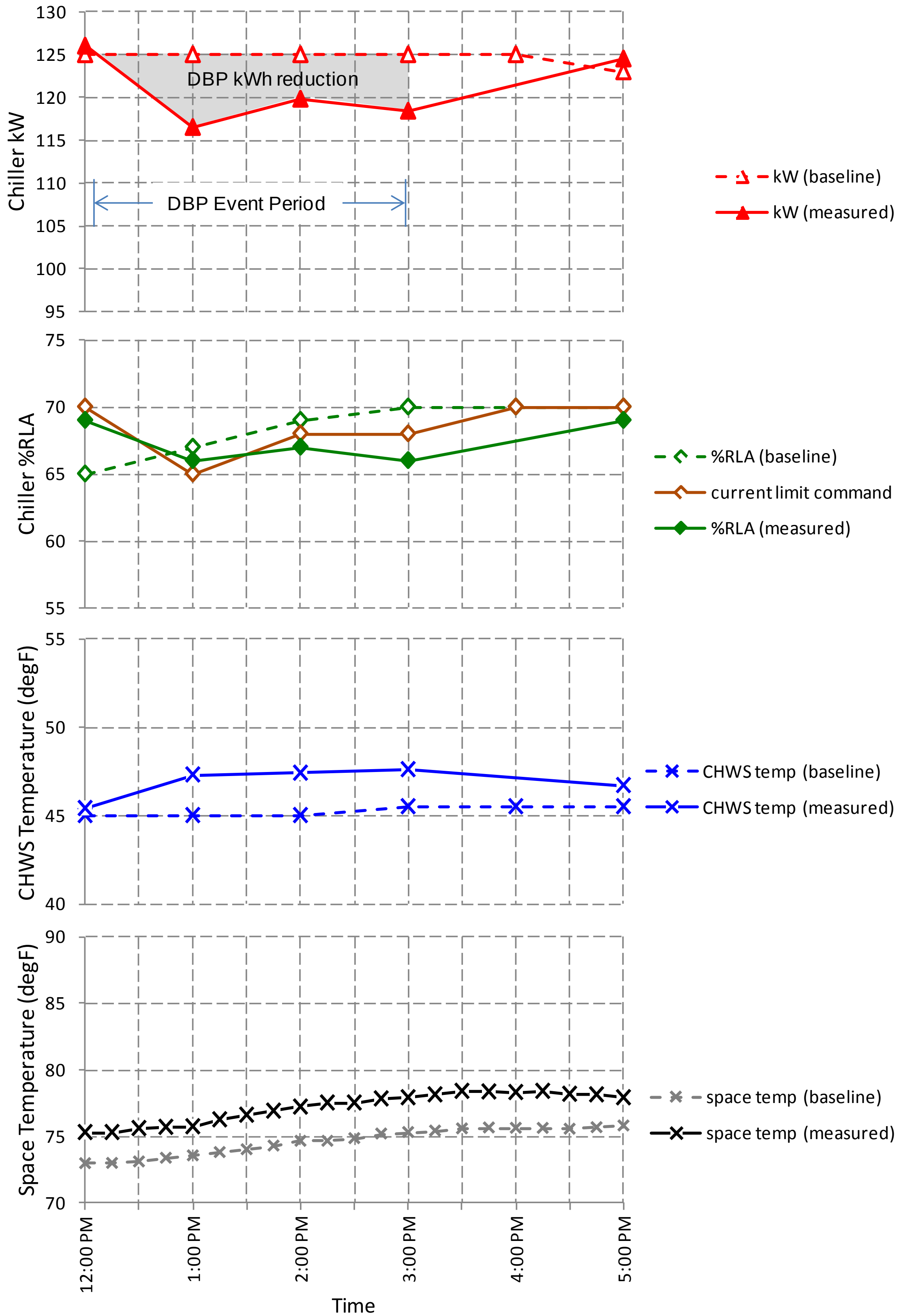


Figure 28. Central Plant 253, September 3, 2014

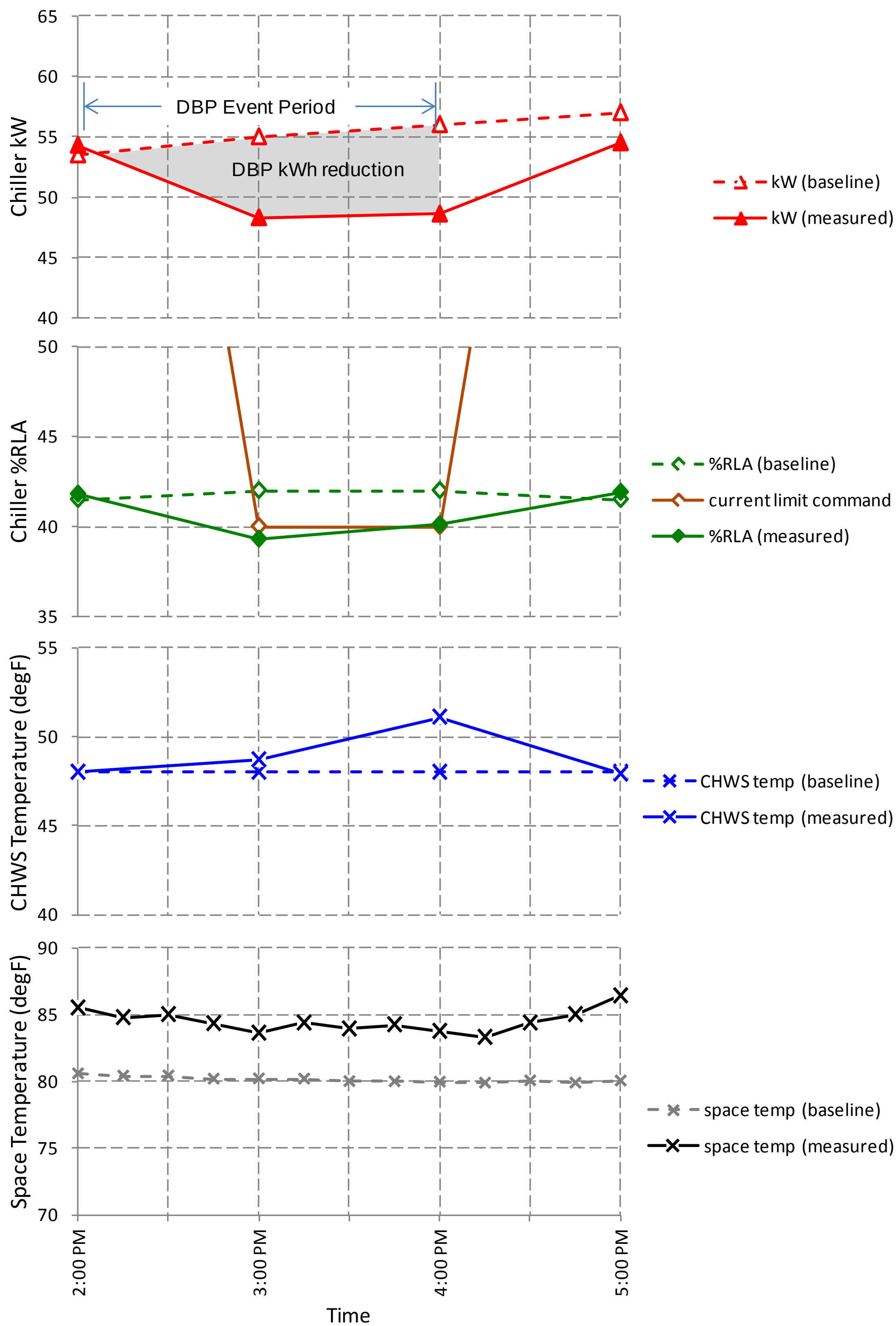


Figure 29. Central Plant 263, September 3, 2014

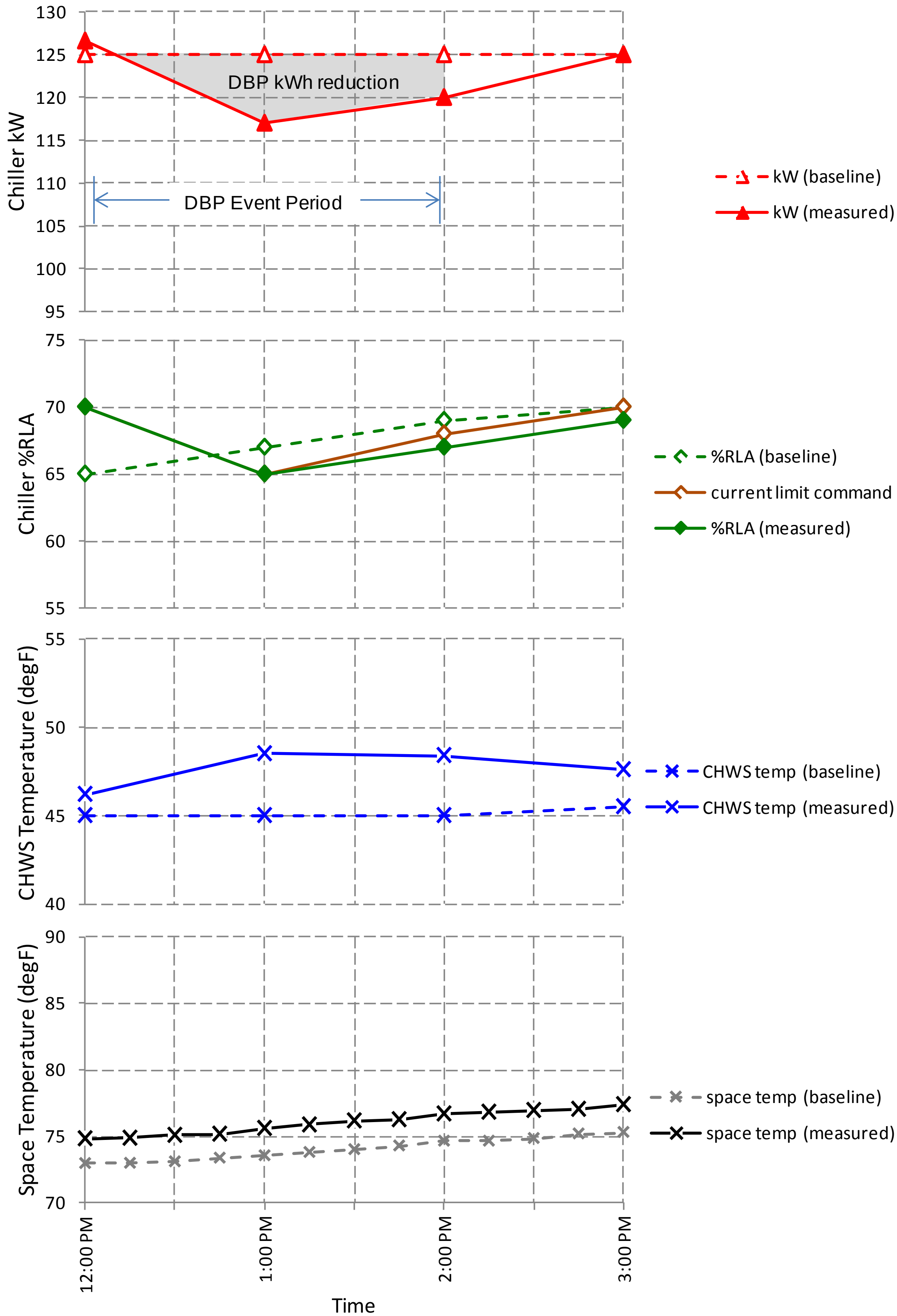


Figure 30. Central Plant 253, September 5, 2014

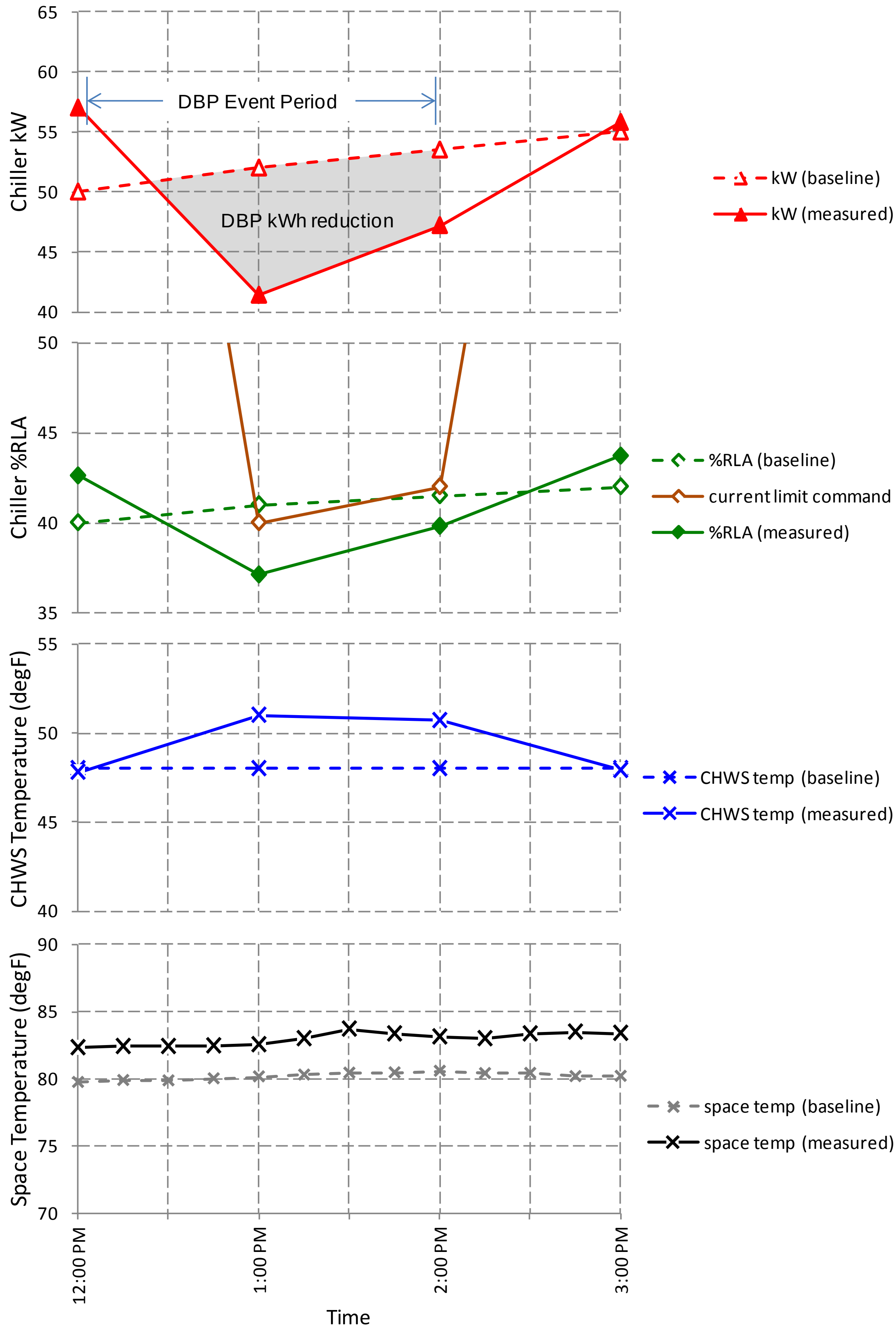


Figure 31. Central Plant 263, September 5, 2014

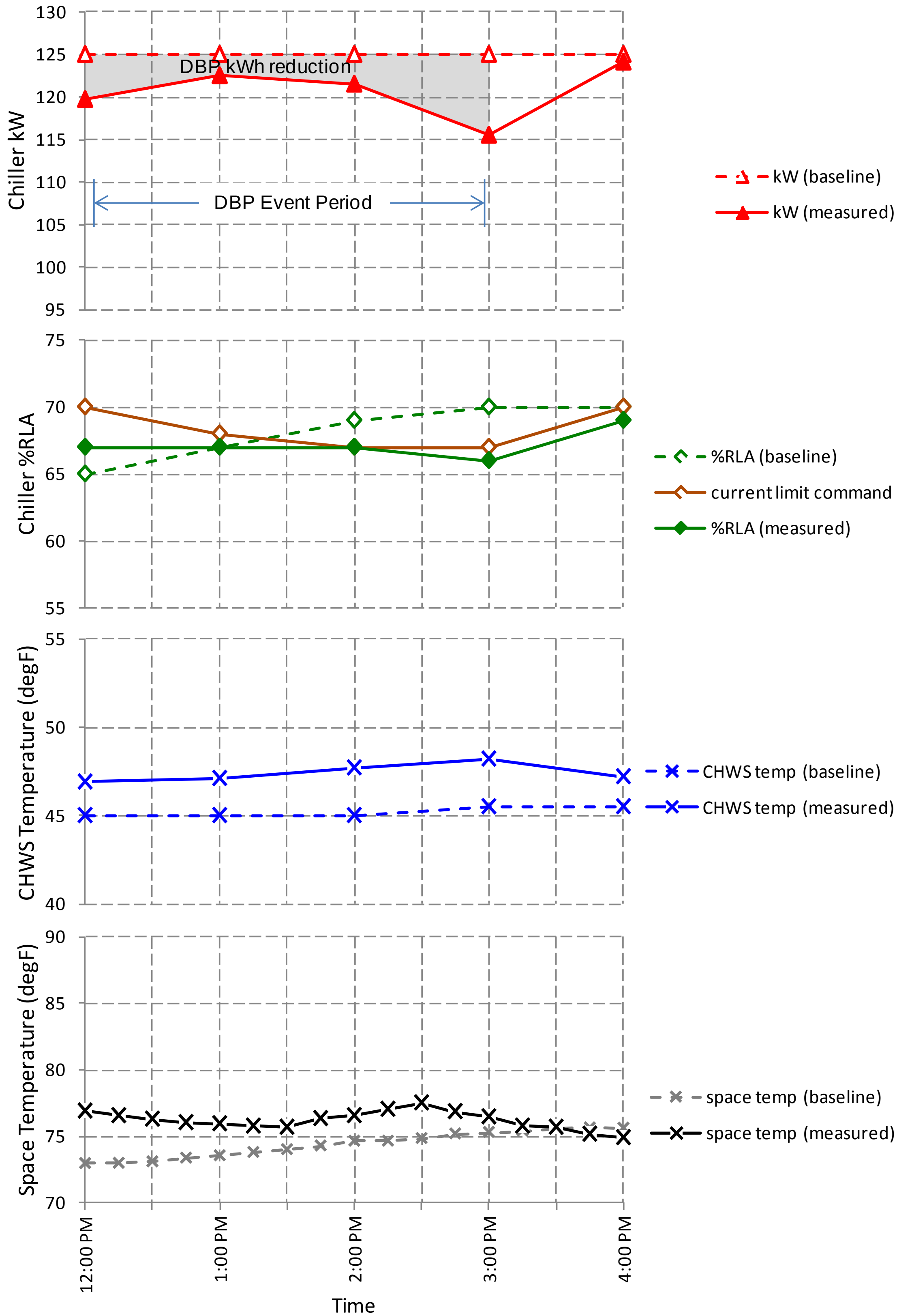


Figure 32. Central Plant 253, September 8, 2014

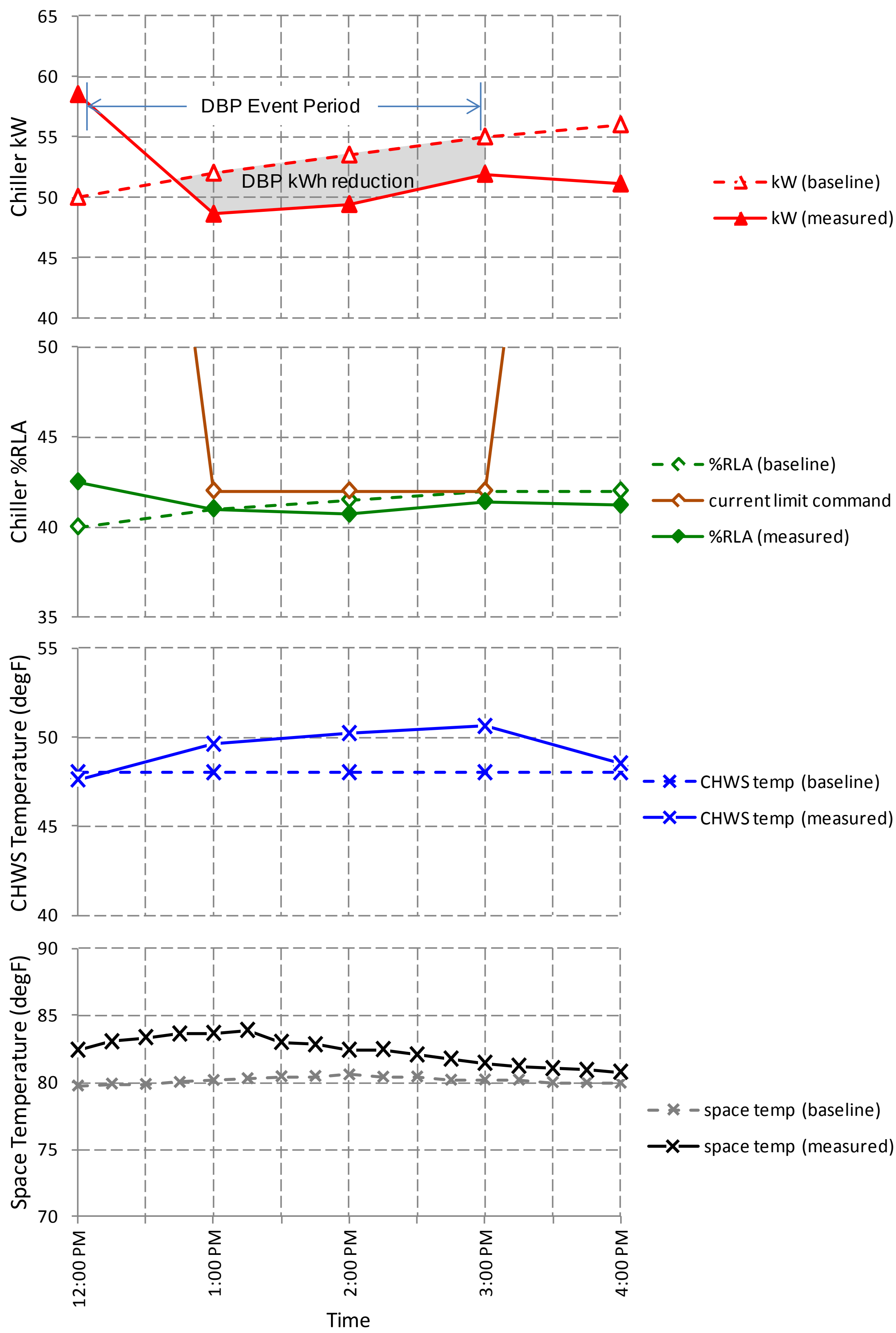


Figure 33. Central Plant 263, September 8, 2014

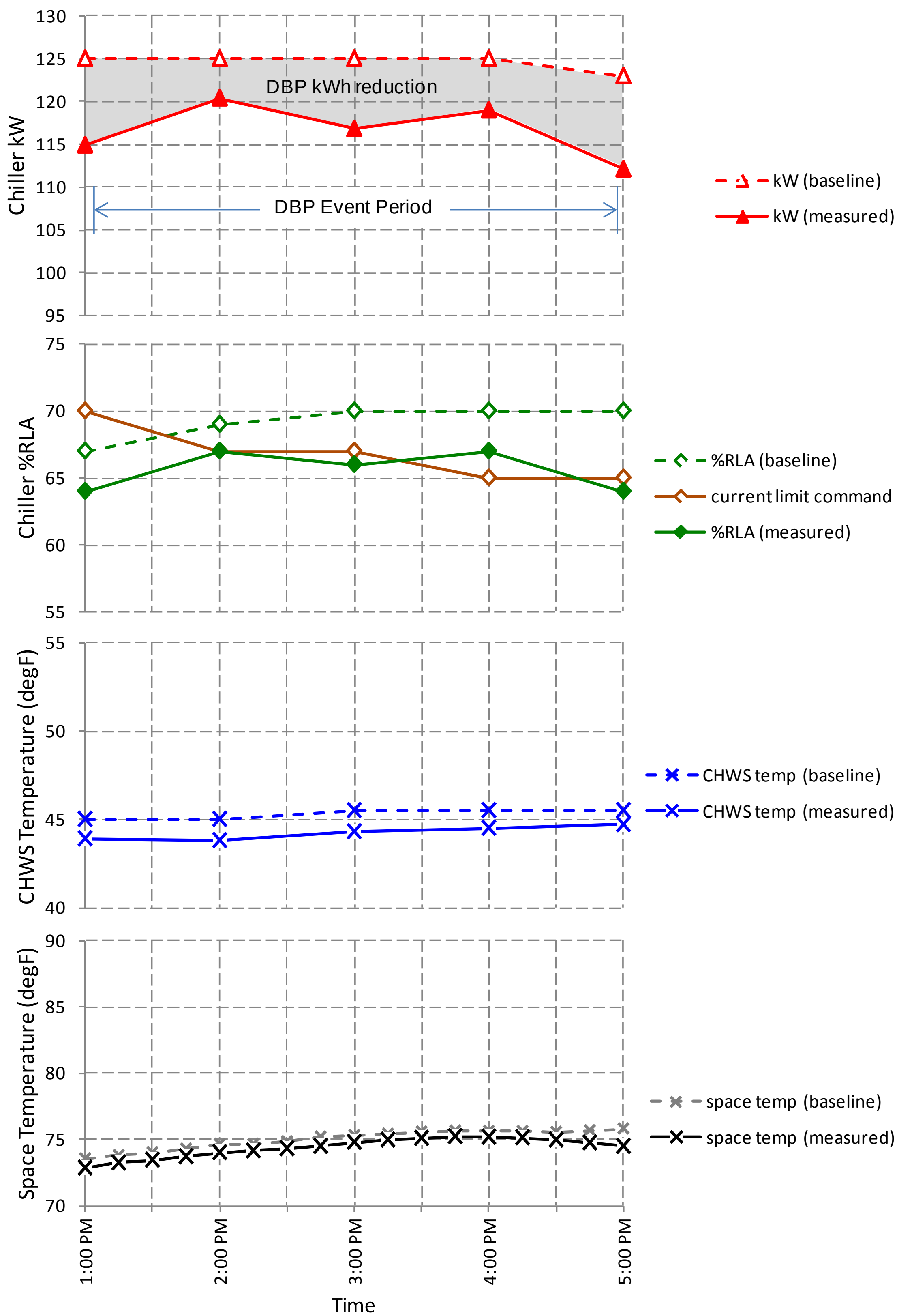


Figure 34. Central Plant 253, September 10, 2014

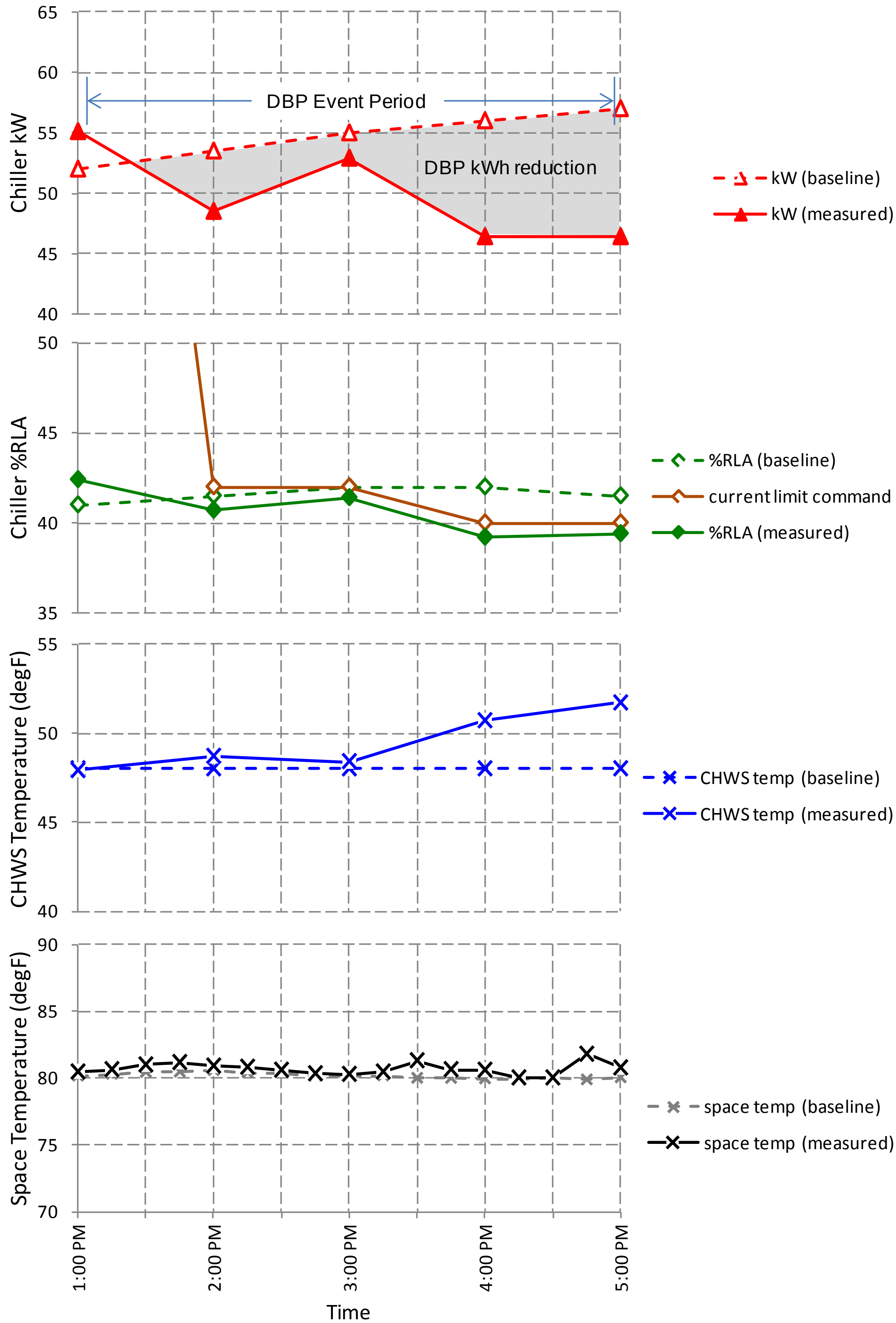


Figure 35. Central Plant 263, September 10, 2014

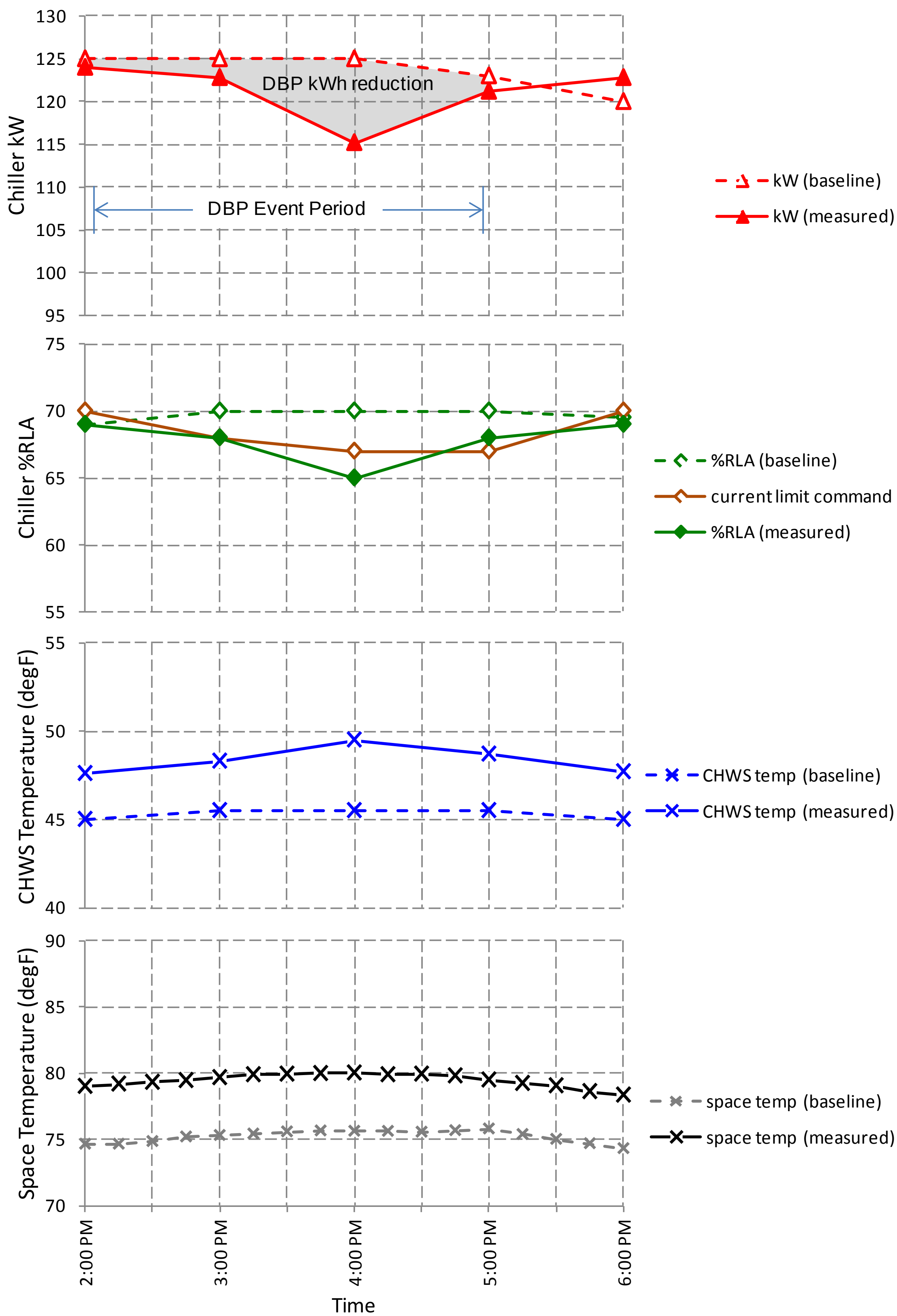


Figure 36. Central Plant 253, September 15, 2014

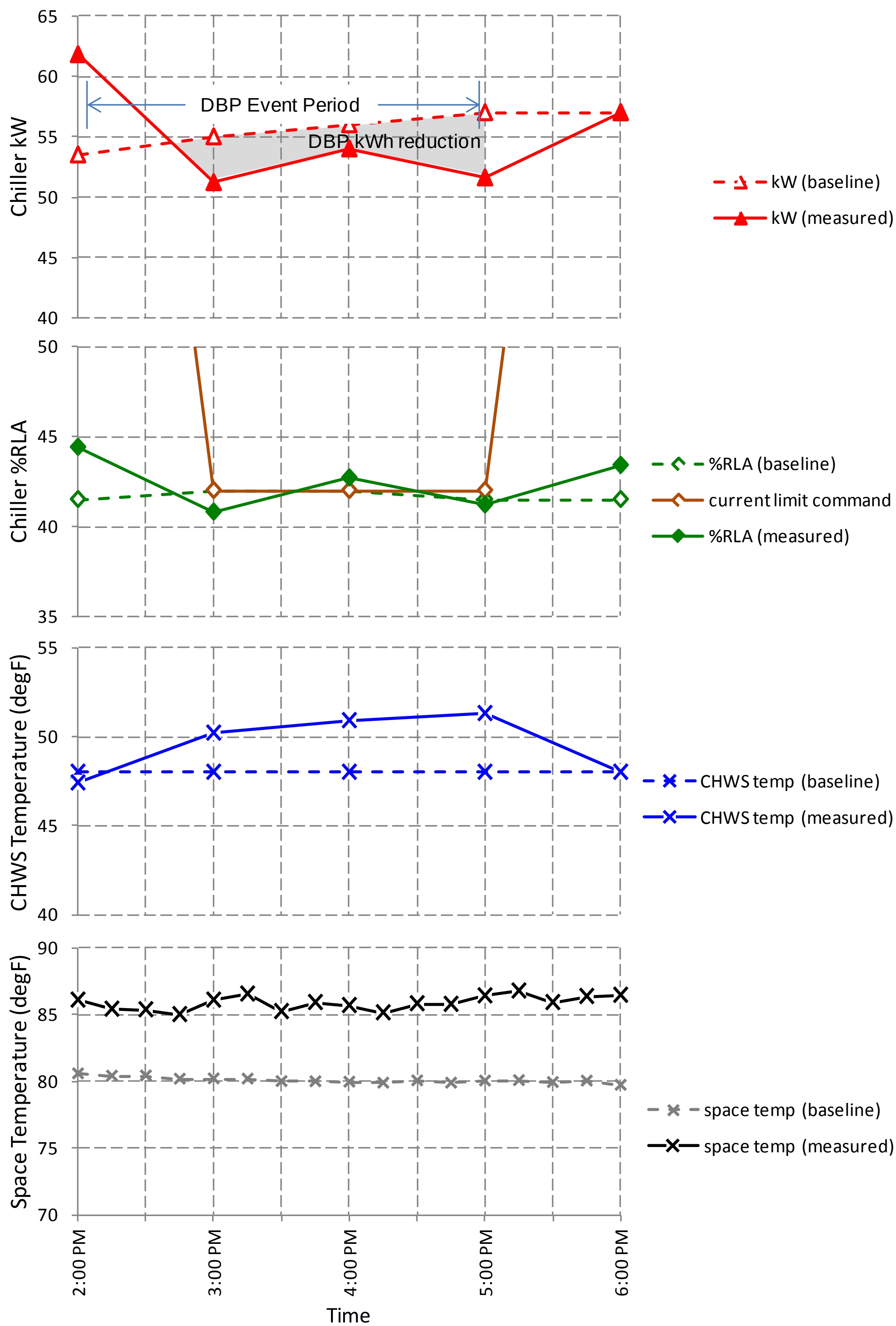


Figure 37. Central Plant 263, September 15, 2014

Appendix H: Analysis of Measured Results

The measured data shown in Appendix G was analyzed to quantify the demand and energy reductions that occurred during the demonstration testing. The following paragraphs present the analysis results.

Overview of DBP Events

An overview of the DBP events during the demonstration period is shown in Table 11.

Table 11. DBP Event Information

DBP event date	Simulated or Actual DBP Event	Hours of Participation		DR control action
		Building 253	Building 263	
Aug 28, 2014	Simulated	1200 – 1300	1200 – 1500	via signals from the Honeywell control system
Sept 3, 2014	Simulated	1200 – 1500	1400 – 1600	Manual
Sept 5, 2014	Simulated	1200 – 1400	1200 – 1400	Manual
Sept 8, 2014	Actual Event	1200 – 1500	1200 – 1500	Manual
Sept 10, 2014	Actual Event	1300 – 1700	1300 – 1700	Manual
Sept 15, 2014	Actual Event	1400 – 1700	1400 – 1700	Manual
Note: Technically the August 28 event for Building 253 might not qualify under SCE rules because participation requires a bid for at least two (2) consecutive hours. However, there is no penalty for non-performance, so we can consider this to be equivalent to having a bid made but not acted upon for the second hour.				

DR Commands to the Equipment

Control of equipment was performed using the current limit command to the chiller to alter the percentage of rated load amps (RLA) for the given chiller. Table 12 and Table 13 illustrate the chiller current limit command values for each chiller plant. Shaded cells represent DBP event control periods.

Table 12. Control commands at Building 253 (%RLA)

DBP Event Date	Hour				
	12-1	1-2	2-3	3-4	4-5
August 28	58	70	70	70	70
Sept 3	65	68	68	70	70
Sept 5	65	67	69	70	70
Sept 8	70	68	67	67	70
Sept 10	70	70	67	67	65
Sept 15	70	70	70	68	65

Table 13. Control commands at Building 263 (%RLA)

DBP Event Date	Hour				
	12-1	1-2	2-3	3-4	4-5
Aug 28	43.6	43.6	43.6	40	40
Sept 3	100	100	40	40	100
Sept 5	40	42	100	100	100
Sept 8	42	42	42	100	100
Sept 10	100	42	42	40	40
Sept 15	40	41	41.5	42	42

Measured Data

Test results for each event day across both chiller plants show a range of demand response across the test periods, as shown in Table 14 through Table 19.

Table 14. Demand response on August 28

Aug 28, 2014	Min (kW)	Max (kW)
12 - 1	-1.5	-0.5
1 - 2	-0.6	0.0
2 - 3	0.0	8.5
Average for event	-0.7	2.7

Table 15. Demand response on September 3

Sept 3, 2014	Min (kW)	Max (kW)
12 - 1	0.0	8.5
1 - 2	0.0	5.2
2 - 3	6.6	6.7
3 - 4	0.0	7.4
Average for event	*1.7*	*7.0*

Table 16. Demand response on September 5

Sept 5, 2014	Min (kW)	Max (kW)
12 - 1	8	10.6
1 - 2	5	6.3
Average for event	*6.5*	*8.5*

Table 17. Demand response on September 8

Sept 8, 2014	Min (kW)	Max (kW)
12 - 1	3.4	4.6
1 - 2	4.1	8.2
2 - 3	3.1	6.0
Average for event	*3.5*	*6.3*

Table 18. Demand response on September 10

Sept 10, 2014	Min (kW)	Max (kW)
1 - 2	4.6	5.0
2 - 3	2.1	8.2
3 - 4	6.0	9.6
4 - 5	10.6	10.9
Average for event	*5.8*	*8.4*

Table 19. Demand response on September 15

Sept 15, 2014	Min (kW)	Max (kW)
2 - 3	2.2	3.8
3 - 4	2	9.8
4 - 5	1.8	5.4
Average for event	*2.0*	*6.3*

The range of demand response across the test periods (total energy reduction in kWh from the baseline), is shown in Table 20.

Table 20. Total energy reduction during each event day

Event Day	Chiller 253 (kWh)	Chiller 263 (kWh)
Aug 28, 2024	-1.5	7.4
Sept 3, 2014	20.3	14.1
Sept 5, 2014	13	16.9
Sept 8, 2014	15.5	10.6
Sept 10, 2014	29.7	27.3
Sept 15, 2014	13.8	11.2
TOTAL	90.8	87.5

Table 21summarizes the typical demand response by hour of day.

Table 21. Demand response by hour for all DBP events

Overall by hour	Min (ΔkW)	Max (ΔkW)	Average (ΔkW)
12–1	-1.5	10.6	4.1
1–2	-0.6	8.2	3.8
2–3	0	8.5	4.7
3–4	0	9.8	5.8
4 –5	0	10.9	4.5
Overall	*-1.5*	*10.9*	*4.6*

In general, the demand response was spread across the timeframe of each event, with a slight trend towards more demand reduction later in the events.

Summary of Results

Table 22 and Table 23 summarize the data collected during the demonstration testing.

Table 22. Summary of demand response results at Chiller Plant 253

Chiller 253	Aug 28	Sept 3	Sept 5	Sept 8	Sept 10	Sept 15
Duration	1 hr test	3 hr test	2 hr test	3 hr test	4 hr test	3 hr test
Approximate current limit (maximum limit for this unit is 70%)	58%	65%	65%	67%	65%	67%
CHWS °F min	45.2	45.4	46.2	46.9	43.9	47.6
CHWS °F max	46.9	47.6	48.4	48.2	44.7	48.7
Min space temp, °F	73.9	75.3	74.8	75.7	72.8	79.0
Max space temp °F	74.7	77.9	76.7	77.5	75.2	80.0
Space temp at conclusion of event, °F	74.7	77.9	76.7	76.5	74.5	79.5
DBP credit (estimated)	No credit	$10.15	$6.50	$7.75	$14.85	$6.90

- Overall DBP billing credit for chiller 253: $46.15
- Participating hours: 16 ($2.88/hour)
- Cumulative energy reduction over all tests 90.8 kWh

Table 23. Summary of demand response results at Chiller Plant 263

Chiller 263	Aug 28	Sept 3	Sept 5	Sept 8	Sept 10	Sept 15
Duration	3 hr test	2 hr test	2 hr test	3 hr test	4 hr test	3 hr test
Approximate current limit	43.6%	40%	40%	42%	40%	42%
CHWS °F min	48.1	48.0	47.8	47.6	47.9	47.7
CHWS °F max	49.3	51.1	50.7	50.6	51.7	51.3
Min space temp °F	79.5	83.6	82.3	81.4	80.0	85.0
Max space temp °F	80.3	85.5	83.7	83.9	81.8	86.5
Space temp at conclusion of event, °F	79.8	83.7	83.1	81.4	80.8	86.4
DBP credit (estimated)	$4.25	$7.05	$8.45	$5.30	$13.65	$5.60

- Overall DBP billing credit for chiller 263: $44.30
- Participating hours: 17 ($2.61/hour)
- Cumulative energy reduction over all tests: 87.5 kWh

The results of these tests show that it is possible to reduce electric demand for short periods of time while retaining the ability to cool the associated space, with limited impact on indoor space temperature. We found minimal changes in space temperature during the tests for the indoor spaces served by the chillers controlled during these events. In the area served by Chiller 253, the space temperature at the conclusion of DBP events was lower than the maximum space temperature during the event for three of six events. In the area served by Chiller 263, the space temperature at the conclusion of DBP events was lower than the maximum space temperature during the event for all of the events.

The estimated DBP bill credit for each of the controlled loads was calculated using the difference between the baseline and measured demand for each hour of the DBP event. That is, for an event called from noon to 3pm, data reported at 1pm, 2pm, and 3pm reflect the demand reductions over the course of the event.

While the estimated DBP utility bill credits are relatively small, they represent a small fraction of what could be achieved at a military site in a full-scale implementation of automated control of demand bidding. The experience of this demonstration shows that potentially significant savings could be achieved using relatively simple control strategies to reduce the electric demand of chillers during DBP events without significantly impacting the comfort of building occupants.

As described earlier in this report, 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, due to its scope (demonstration-scale). For this reason, the energy and economic benefits presented above are not representative of a full-scale implementation of OpenADR technology for participation in a demand bidding program at a military installation. A discussion of the potential energy and economic benefits in a typical installation is presented in Section 7 and Appendix I of this report.

Appendix I: Life Cycle Cost Analysis

This section presents the results of a Life Cycle Cost Analysis of OpenADR technology for an example military installation, based on participation in the SCE Demand Bidding Program. This analysis utilized the FEMP Building Life Cycle Cost (BLCC) Program http://www1.eere.energy.gov/femp/information/download_blcc.html#blcc.

LCC Analysis Approach

This life cycle cost (LCC) analysis of OpenADR technology follows the energy and cost benefit strategy described in Section 1 for a typical installation:

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

This finance process shown in Figure 38 (taken from Figure 1, earlier in this document) will deliver key contributions toward meeting an installation's energy savings and energy security goals.

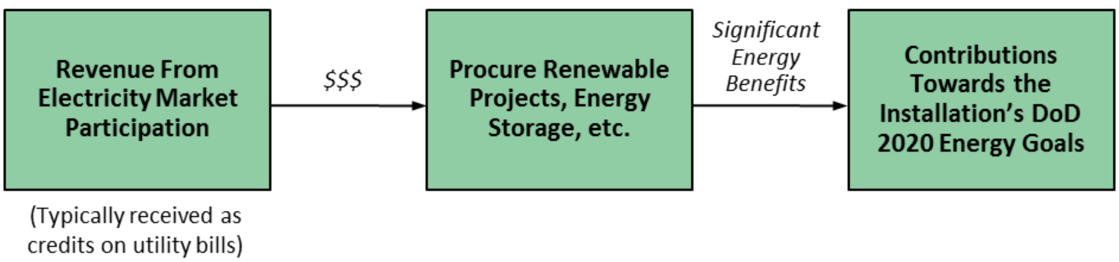


Figure 38. Energy and Economic Benefits Process

In preparing the LCC analysis, we have broken the process down into three phases, as described in Table 24.

Table 24. LCC Project Phases

	Description	Timing of this LCC analysis
Phase1	Invest in DBP control system, and enroll in SCE DBP program	Start in 2016
Phase2	Participate in DBP events, to payback the original investment	Start in 2016
Phase3	Use the utility bill credits (cost savings) to invest in other energy infrastructure improvements.	Implement other ECM projects after the DBP project investment is paid off. This process can be repeated as more DBP proceeds become available.

This cost assessment is based on a military installation's participation in a utility demand bidding program. Energy and economic benefits from participation in wholesale electricity market programs (when and where available) will likely be different depending on market prices and other factors.

Key Assumptions

The key assumptions behind the analysis are presented in Table 25.

Table 25. Key Assumptions

Subject	Discussion
Availability of the technology	This OpenADR technology can be integrated with almost any manufacturer's building energy management system (this technology is not specific to Honeywell). The underlying technology (OpenADR 2.0) is an industry and Smart Grid standard.
Project lifetime	A 10-yr project lifetime is assumed for the DBP OpenADR control and communications equipment. Other related energy improvements can have lifetimes that continue beyond the initial 10 years.
Number of DBP events per year	The analysis assumed no opt-outs of DBP events by DPW operators. Each year in the analysis assumes the same number of DBP events. This number of annual events is an estimate, based on historical data taken from the SCE demand response history website (see SCE weblink contained in Appendix B).
Installation cost is estimated to be $50/kW for each kW of demand reduction.	This cost covers material and labor cost for control hardware, I/O interfacing to the controlled loads, software programming, startup, commissioning, and operator training. Our approach assumes a typical military installation which has an existing Building Energy Management System (BMS). The installation cost used in the analysis, is an estimate of the typical investment required for a commercial building owner to install OpenADR 2.0 technology. In many commercial installations, the electric utility offers an economic incentive to install AutoDR. In the case of SCE, they offer an incentive of up to $300/kW reduction (SCE's Automated Demand Response Technology Incentive program). The total installed cost will also be affected by the cost drivers discussed in Section 7.2 of this report. In some cases, the total cost of installing AutoDR can exceed the AutoDR TI incentive. For the purpose of this cost assessment study, a customer investment of $50/kW reduction is a conservative estimate of the additional cost that may be required. Note: In a recent AutoDR study by LBNL, the average cost of AutoDR technology enablement within the SCE territory was estimated to be approximately $234/kW. [LBNL-6560E]
Cost savings	Cost savings (utility bill credits) result from participation in the SCE DBP program. These funds are assumed to be used to procure (invest in) improvements to the installation's energy infrastructure (e.g., adding renewable energy systems, improved mechanical equipment, new lighting equipment, improvements to the building envelopes, etc.).
Source of energy savings	Energy savings result from energy improvements that are paid for using the DBP utility bill credits. No direct energy savings from the OpenADR technology (i.e., responding to each DBP event) is assumed (i.e., by responding to a DBP event, a portion of the electric load is simply shifted to a time later on the same day).
Other tangible or intangible benefits	In many AutoDR projects in the commercial sector, there exist additional tangible or intangible economic or energy related benefits. For this cost assessment, no additional benefits are assumed.

Subject	Discussion
Source of ECM projects	Projects are taken from a net-zero energy study of Fort Irwin, performed by the Army ERDC-CERL Lab. [NZERO]
Scale of the analysis	The scale of the analysis was chosen to match a large military installation having a variety of types of electric loads (including HVAC loads) which can be curtailed or reduced on DBP event days. This assessment assumes a total of 5000kW of electric load can be partially reduced when needed, with a maximum reduction of 8% or 400kW (4% or 200kW during cooler months). Note: Earlier studies of AutoDR in the commercial sector have shown that electric demand can be reduced by up to 9% for moderate periods of time (and more in some cases). [CEC 2008] [Berkeley ADR] For reference, normalized plots of Fort Irwin's total electric load for example days in each month of 2011 are shown in Appendix J. The plots reflect an estimate of the baseload, made from examining the data (i.e., total electric load not including seasonal cooling equipment). This data shows commonly seen seasonal variation that is in part due to HVAC cooling loads.
Annual operations and maintenance cost	Annual operating cost of the OpenADR technology consists of irregular service visits when there is a problem with the OpenADR software or the control hardware that interfaces to the controlled equipment. An estimate of this cost was prepared for use in this analysis.
real discount rate	A discount rate of 1.0% was used in this analysis (assuming a project life of 10 years). This rate was taken from OMB Circular A-94 (most recent revision, dated December 2013) www.whitehouse.gov/omb/circulars/a094/a94_appx-c.html Results for discount rates of 4% and 7% are also presented.
electricity cost	A blended rate of $0.10 per kWh was used. Fort Irwin's actual rate is not available.
cost of LP gas	A cost of $3/gal. ($3.28/therm) was used. A brief survey of retail prices nearby Fort Irwin showed a typical price of $3 to $4 per gal.

Estimated DBP Event Schedule

Recent history of DBP program events at SCE are summarized in Table 26. (A weblink to SCE DR program event history is included in Appendix B). A schedule of DBP events used in this cost assessment is also shown.

Table 26. Recent history of DBP program events at SCE

	Number of DBP Events						Total
	May	June	July	August	Sept	Oct	
2014	0	0	1	0	3	2	6
2013	0	2	1	1	1	0	5
2012	0	0	1	5	0	2	8
2011	0	0	1	1	2	1	5
2010	0	0	1	3	4	1	9
2009	0	1	6	3	5	0	15
2008	0	1	8	4	0	2	15
Typical year*	0	1	3	3	2	1	10

*an estimate for a typical year, used in the LCC analysis

A profile of DBP bids and DR control actions used in this cost assessment is shown in Table 27. Many of the DBP controlled loads are assumed to be HVAC cooling related equipment. In order to better manage the impact on indoor space comfort conditions, DR control actions are not in effect during the 2pm and 5pm hours.

Table 27. DBP Bid and Demand Reduction Schedule

	hour beginning							
	12pm	**1pm**	**2pm**	**3pm**	**4pm**	**5pm**	**6pm**	**7pm**
DPB bid and active demand reduction	x	x		x	x		x	x

Inputs to the LCC Analysis (OpenADR technology for DBP application)

Key project data and resulting inputs to the NIST BLCC tool are shown in Table 28.

Table 28. DBP Project Input Data to LCC Analysis

Data	Value	Remarks
Project start date	2016	- - -
Project lifetime	10 years	- - -
Maximum electric demand from OpenADR controlled loads	5000 kW	- - -
% chiller kW reduction (May, Oct)	4%	- - -
% chiller kW reduction (June-Aug)	8%	- - -
Maximum kW demand reduction	400 kW	5000kW * 8%
Electrical cost savings (per kWh of demand reduction)	$0.50	See description of SCE DBP program in Appendix B
Electrical cost savings from DBP participation (due to reduced kWh consumption)	zero	Assumes no reduction in total kWh consumption, due to rebound effect at the end of each DBP event
Installation cost ($/kW red.)	350	- - -
Utility incentive ($/kW red.)	300	SCE AutoDR TI funding
Net investment cost ($/kW red.)	50	350 – 300 = 50
Installation cost ($)	$140,000	400 * 350
Utility incentive ($)	$120,000	400 * 300
Net investment cost ($)	$20,000	- - -
Annual DBP reduction (kWh)	22,800	- - -
Annual utility bill credit ($)	$11,400	- - -
Annual O&M cost ($)	$2000	- - -

Based on previously stated assumptions, the resulting energy reduction totals (due to DBP control actions) are shown in Table 29.

Table 29. DBP Energy Reduction Totals (kWh)

	hour beginning								
	12pm	**1pm**	**2pm**	**3pm**	**4pm**	**5pm**	**6pm**	**7pm**	**total**
May	0	0	0	0	0	0	0	0	0
June	400	400	0	400	400	0	400	400	2400
July	1200	1200	0	1200	1200	0	1200	1200	7200
August	1200	1200	0	1200	1200	0	1200	1200	7200
Sept	800	800	0	800	800	0	800	800	4800
Oct	200	200	0	200	200	0	200	200	1200
total	3800	3800	0	3800	3800	0	3800	3800	22,800

Energy Improvement Projects (ECMs)

The energy improvement projects selected for this analysis were taken from the ERDC-CERL Fort Irwin net zero energy study report. [NZERO] These ECMs are shown in Table 30.

Table 30. 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	$ 9600	$ 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	$ 7199	3.6 yrs	renewable energy project	p. 124-126

Note: All data is taken from Fort Irwin Net Zero Energy Report [NZERO].

Cost Assessment Summary Results

Summary results of the BLCC analysis are shown in Table 31.

Table 31. Cost Assessment Summary Results

Investment					Annual Cash Flow				Totals		
		ECM Projects				ECM Projects					
year	DBP project	Bldg 254/271 HVAC Controls	Bldg 263 Boiler Controls Project	Bldg 325 Solar Thermal Project	DBP project	Bldg 254/271 HVAC Controls	Bldg 263 Boiler Controls Project	Bldg 325 Solar Thermal Project	Investment	Annual Cash Flow	Total Cash Flow
2016	($20,000)				($10,620)				($20,000)	($10,620)	($10,620)
2017					$9,340					$9,340	($1,280)
2018					$9,298					$9,298	$8,018
2019					$9,256					$9,256	$17,274
2020		($23,912)			$9,214	($1,516)			($23,912)	$7,698	$24,972
2021			($11,650)		$9,170	$21,872	($7,848)		($11,650)	$23,194	$48,166
2022				($26,309)	$9,125	$21,945	$3,464	($18,018)	($26,309)	$16,516	$64,682
2023					$9,080	$21,986	$3,463	$7,536		$42,065	$106,747
2024					$9,033	$22,058	$3,470	$7,562		$42,123	$148,870
2025					$8,986	$22,185	$3,489	$7,566		$42,226	$191,096

Note: ECM investments are escalated 1.5% per year from the values shown in the Net Zero Energy Report [NZERO].

A plot of the annual cash flow and total cost savings for the OpenADR DBP project, when combined with the three associated ECM projects is shown in Figure 39. If additional energy improvement projects are procured using future DBP utility billing credits, the annual cash flow and total cost savings will increase accordingly.

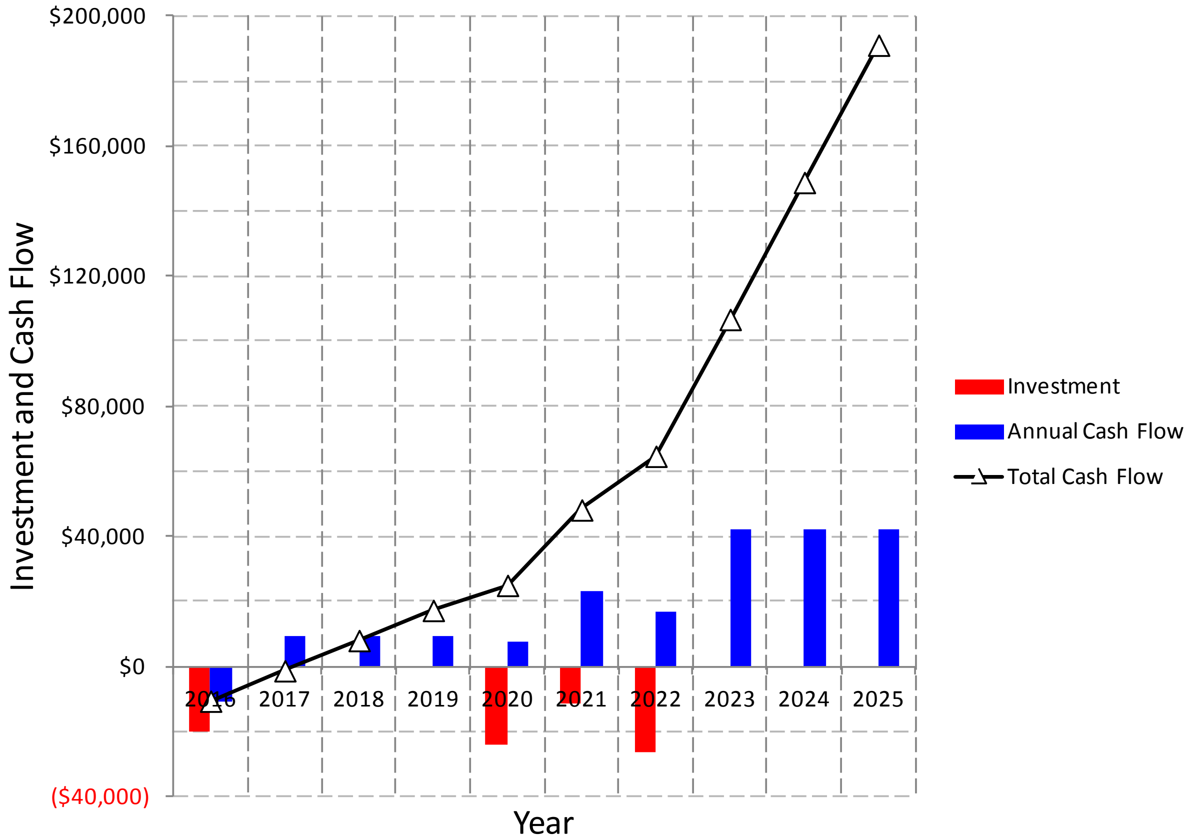


Figure 39. LCC Cash Flow and Total Cost Savings for DBP Project + ECM Projects

LCC Analysis Results: OpenADR DBP Project

High level results of the LCC analysis for the OpenADR DBP Project are shown in Table 32.

Table 32. BLCC Results: OpenADR DBP Project

Project / Timeframe	Savings-to-Investment Ratio (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% discount rate • 7% discount rate	4.37 3.81 3.35	17.06% 18.87% 20.74%	<3 years	$20,000	$67,492 $56,114 $46,926

LCC Analysis Results: ECM Projects

High level results of the LCC analysis for each of the ECMs are shown in Table 33.

Table 33. BLCC Results: ECM Projects

Project / Timeframe	Savings-to-Investment Ratio (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) • 4% discount rate • 7% discount rate	9.06 7.87 6.91	25.91% 27.83% 29.81%	<2 years	$23,211	$187,149 $159,435 $137,084
Bldg 263 Boiler Controls (2021) • 1% discount rate (baseline) • 4% discount rate • 7% discount rate	2.94 2.55 2.24	12.49% 14.21% 15.99%	<4 years	$11,308	$21,903 $17,539 $14,018
Bldg 325 Solar Project (2022) • 1% discount rate (baseline) • 4% discount rate • 7% discount rate	2.89 2.51 2.20	12.32% 14.03% 15.79%	<4 years	$25,537	$48,280 $38,537 $30,680

Comparative Analysis Results

The standard BLCC comparative analysis report of cost, energy, and emissions for the OpenADR Demand Bidding Program project, is shown in Appendix K.

Standard BLCC comparative analysis reports for the ECMs are shown as follows:

- Bldg 254/271 HVAC Controls Project comparative results are shown in Appendix L.
- Bldg 263 Boiler Controls Project comparative results are shown in Appendix M.
- Bldg 325 Solar Thermal Project comparative results are shown in Appendix N.

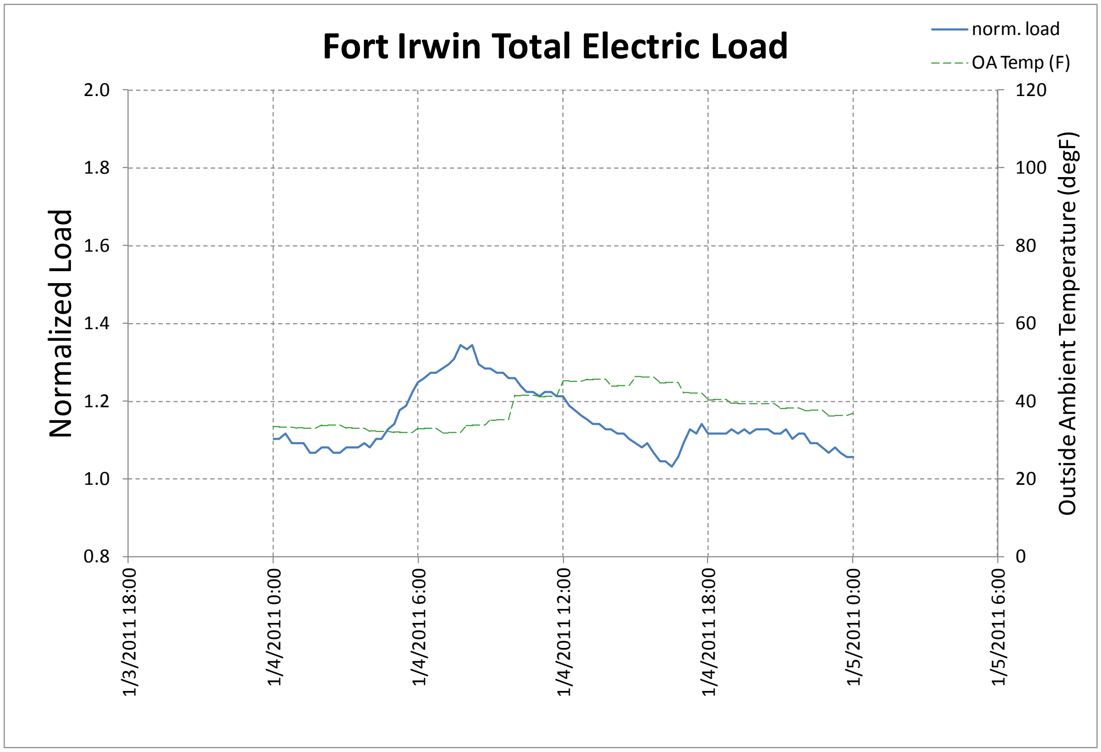
Notes about the LCC Results

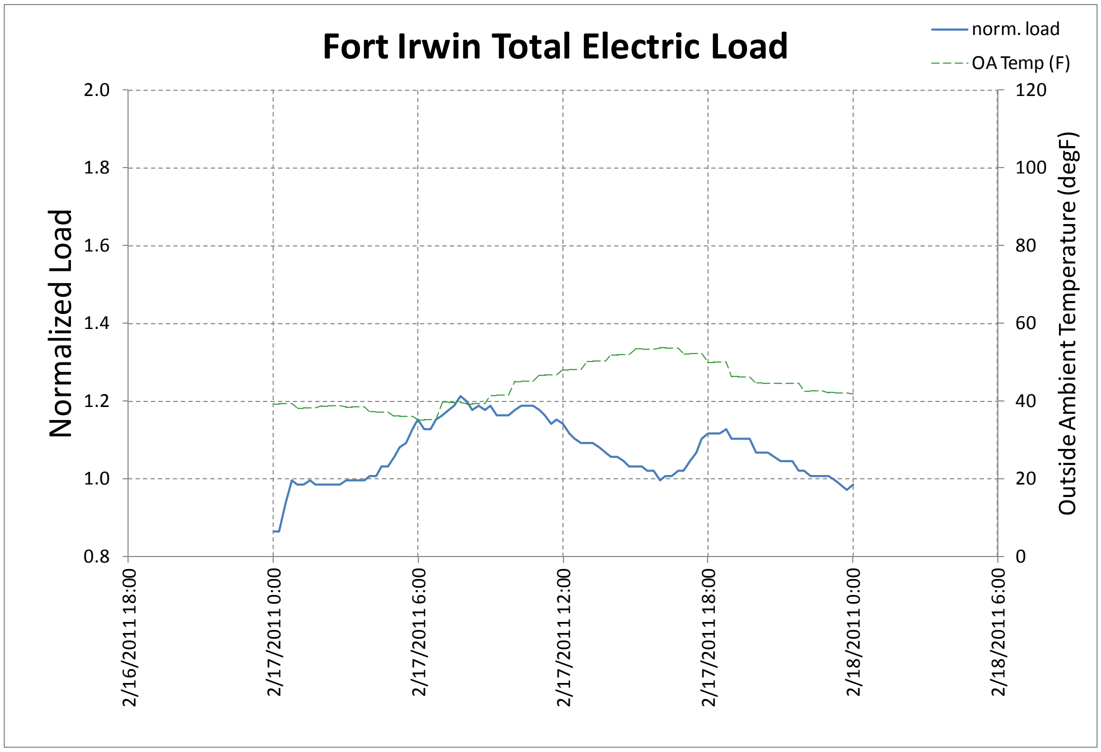
Measured performance in the field will be a function of a number of variables. Actual results will depend on a number of factors, including:

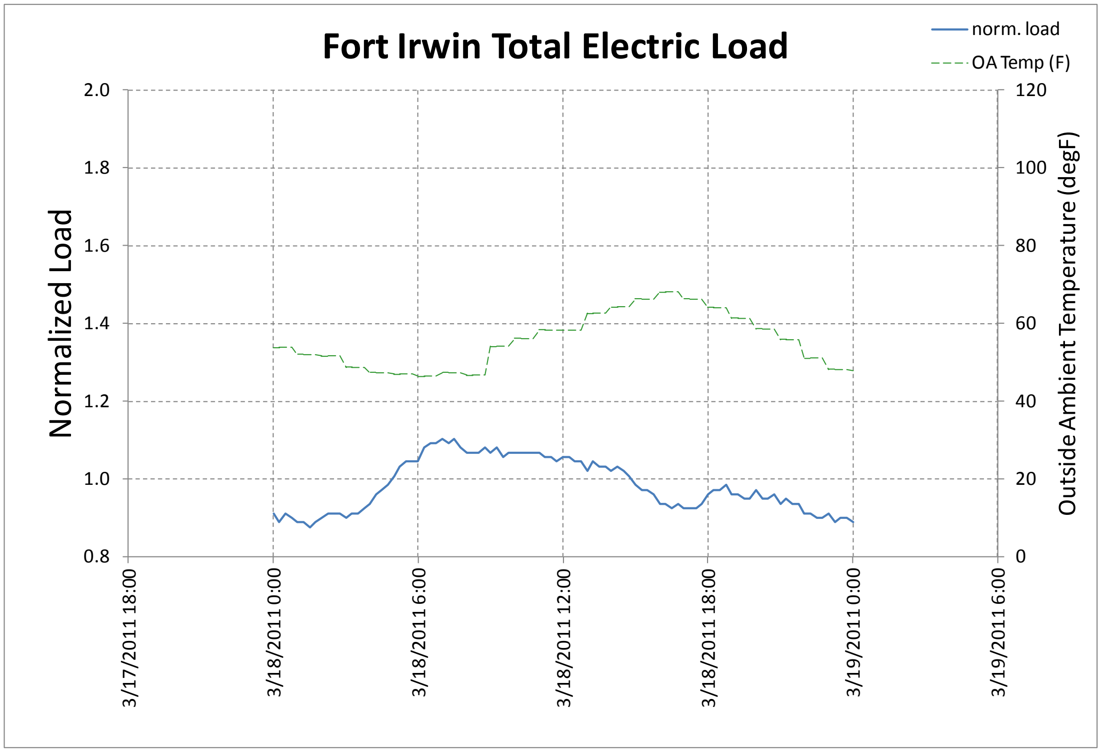
- How aggressive the DPW energy managers want to be in their use of a utility demand bidding program (i.e., how much demand to shed during a DBP event).
- The number of DBP events, and their timing (by month) that occur in a given year.
- The severity of weather conditions during the events.

Appendix J: Normalized Total Electric Consumption at Fort Irwin

Plots of total installation-level electric load for example days in each month of 2011 are shown in the figures below. The plots reflect an estimate of the normal baseload, which was made by examining the data from months when HVAC cooling equipment is not in operation.






Fort Irwin Total Electric Load
norm. load
OA Temp (F)
Normalized Load
Outside Ambient Temperature (degF)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
120
100
80
60
40
20
0
3/17/2011 18:00
3/18/2011 0:00
3/18/2011 6:00
3/18/2011 12:00
3/18/2011 18:00
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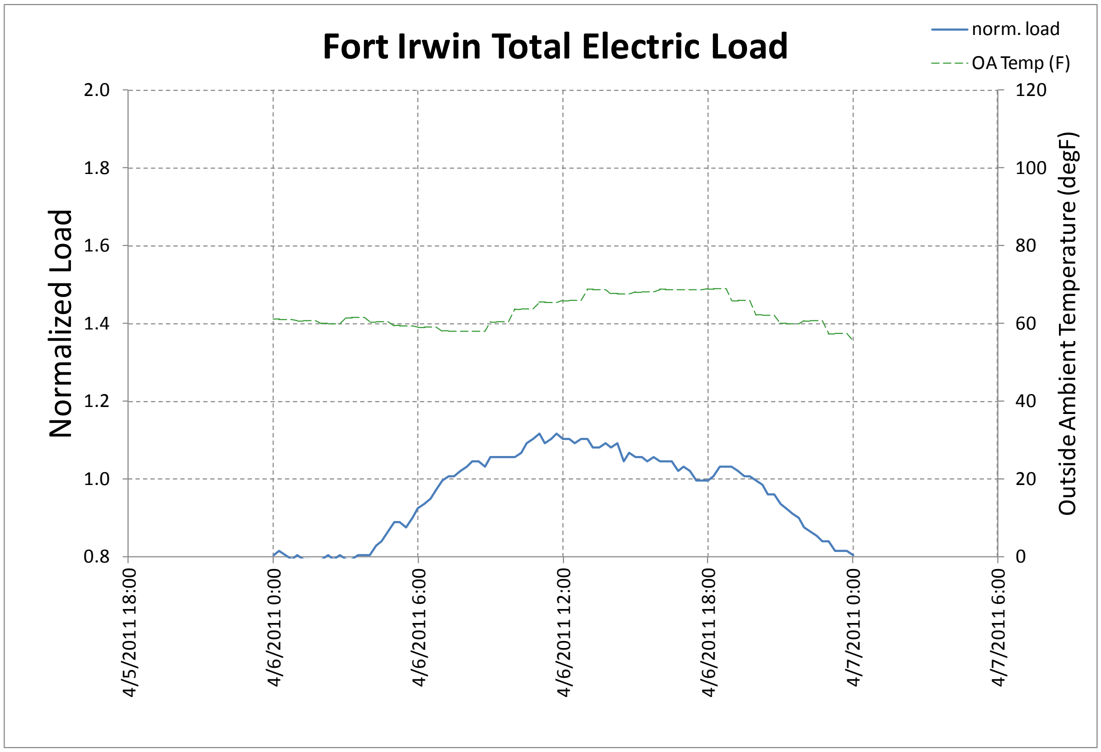
3/19/2011 6:00


Fort Irwin Total Electric Load
norm. load
OA Temp (F)
Normalized Load
Outside Ambient Temperature (degF)
2.0
1.8
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120
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4/6/2011 18:00
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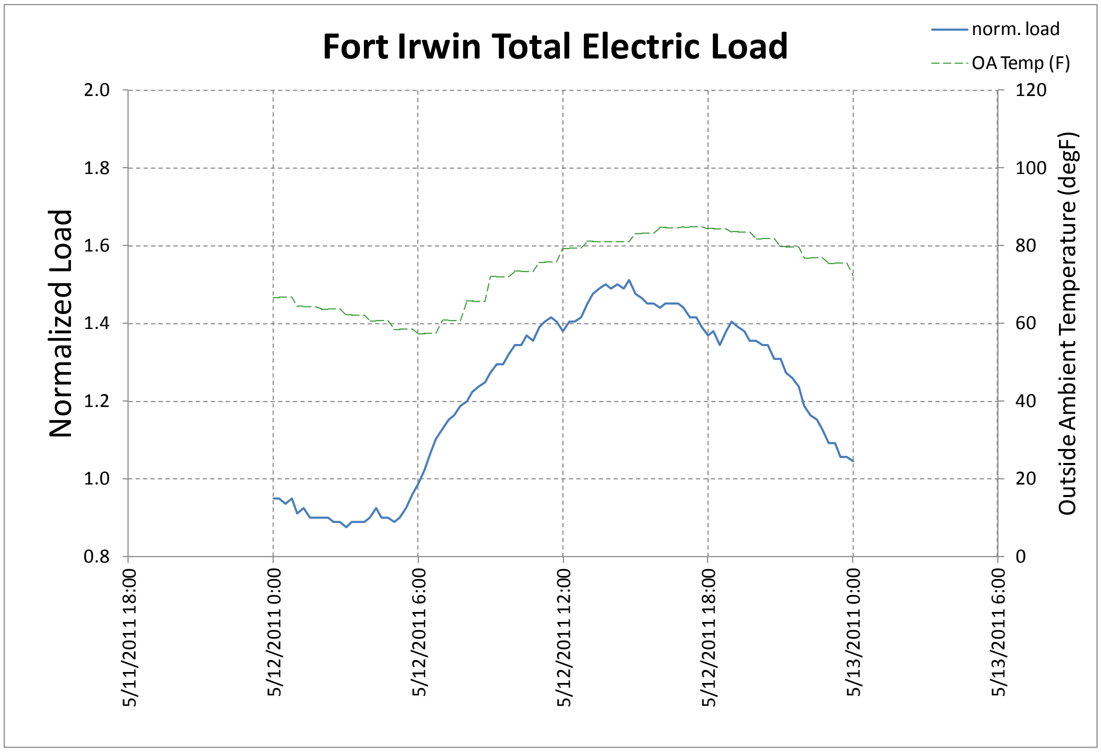
4/7/2011 6:00


Fort Irwin Total Electric Load
norm. load
OA Temp (F)
Normalized Load
Outside Ambient Temperature (degF)
2.0
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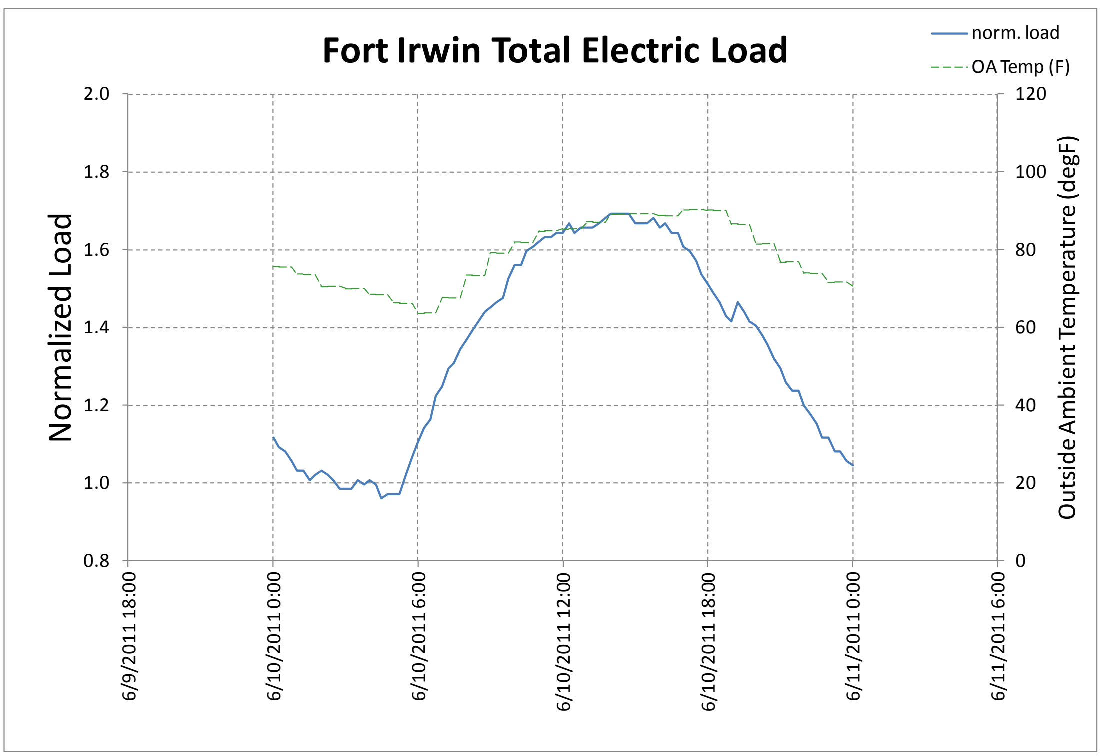
Fort Irwin Total Electric Load
norm. load
OA Temp (F)
Normalized Load
Outside Ambient Temperature (degF)
2.0
1.8
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6/10/2011 12:00
6/10/2011 18:00
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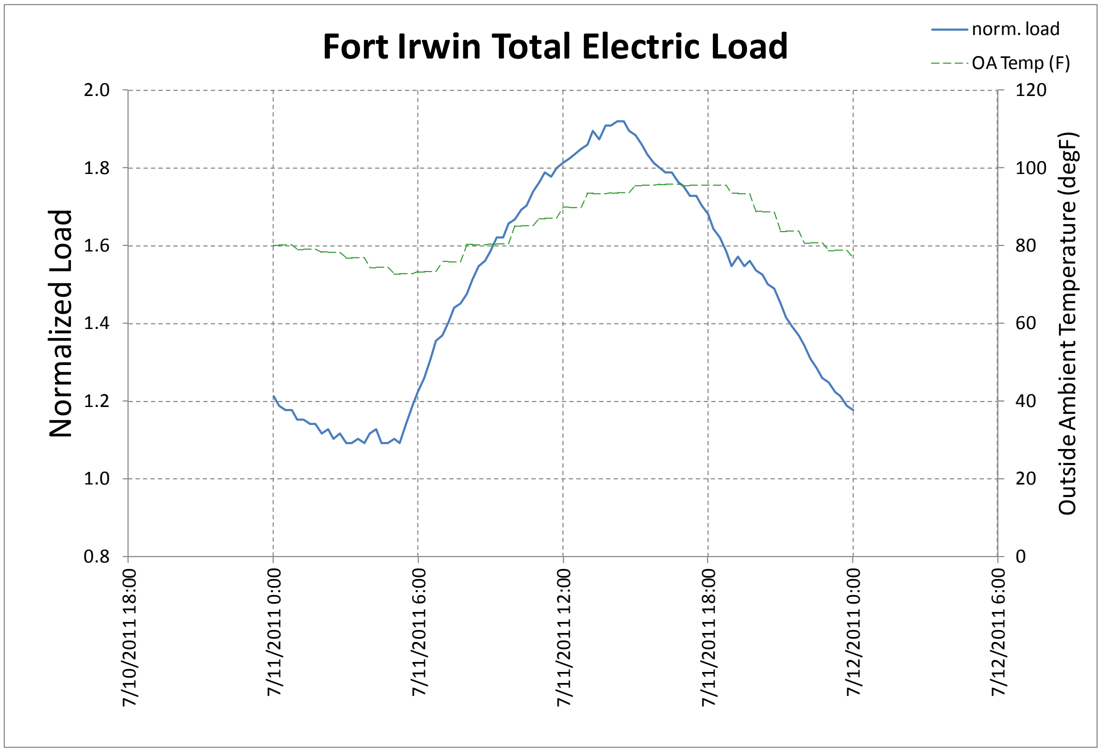
Fort Irwin Total Electric Load
norm. load
OA Temp (F)
Normalized Load
Outside Ambient Temperature (degF)
2.0
1.8
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1.4
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7/11/2011 0:00
7/11/2011 6:00
7/11/2011 12:00
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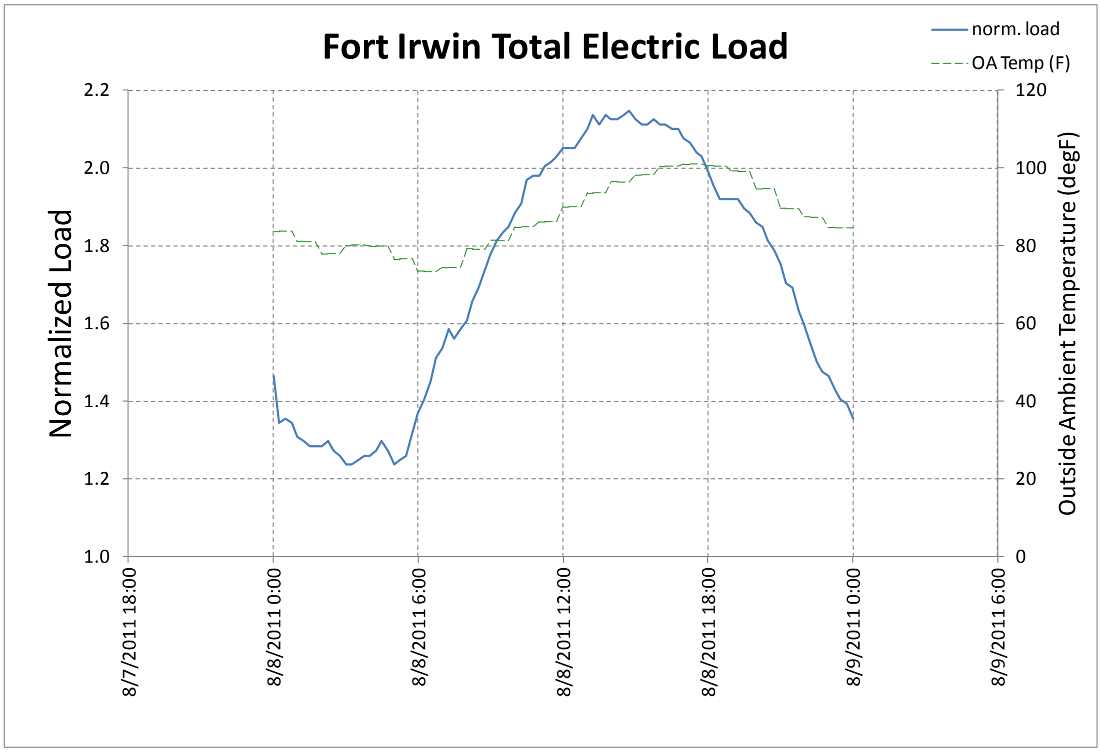
7/12/2011 6:00


Fort Irwin Total Electric Load
norm. load
OA Temp (F)
Normalized Load
Outside Ambient Temperature (degF)
2.2
2.0
1.8
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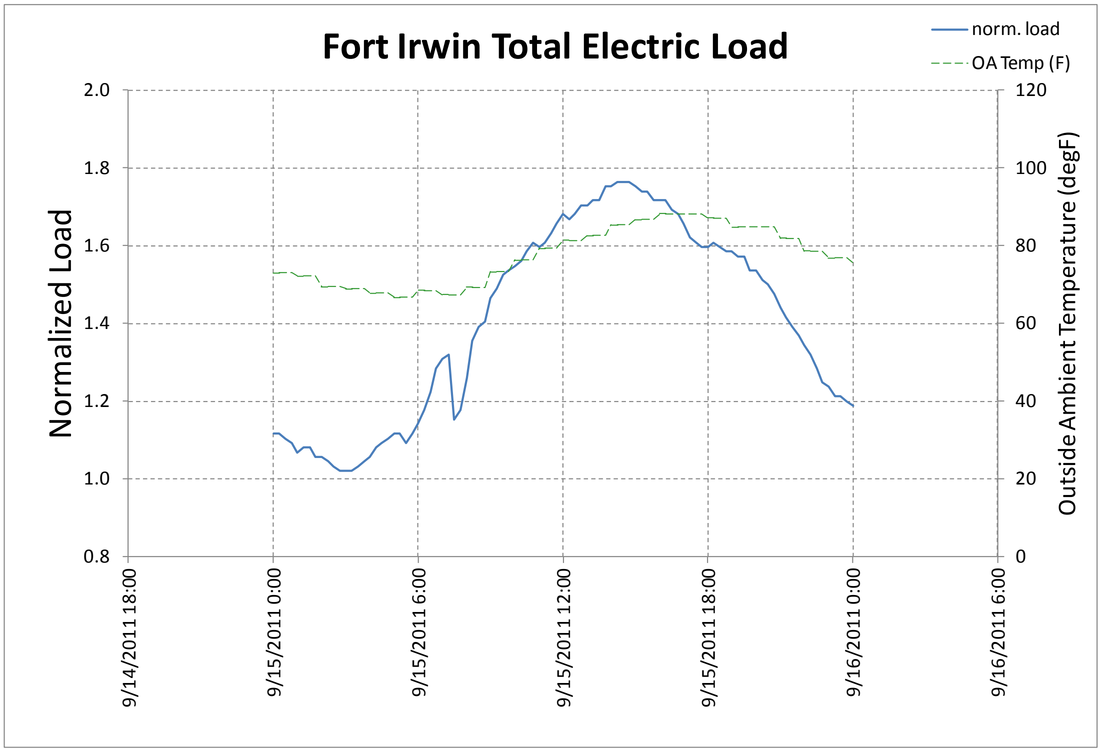
8/7/2011 18:00
8/8/2011 0:00
8/8/2011 6:00
8/8/2011 12:00
8/8/2011 18:00
8/9/2011 0:00
8/9/2011 6:00



Fort Irwin Total Electric Load
norm. load
OA Temp (F)
Normalized Load
Outside Ambient Temperature (degF)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
120
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60
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20
0
9/14/2011 18:00
9/15/2011 0:00
9/15/2011 6:00
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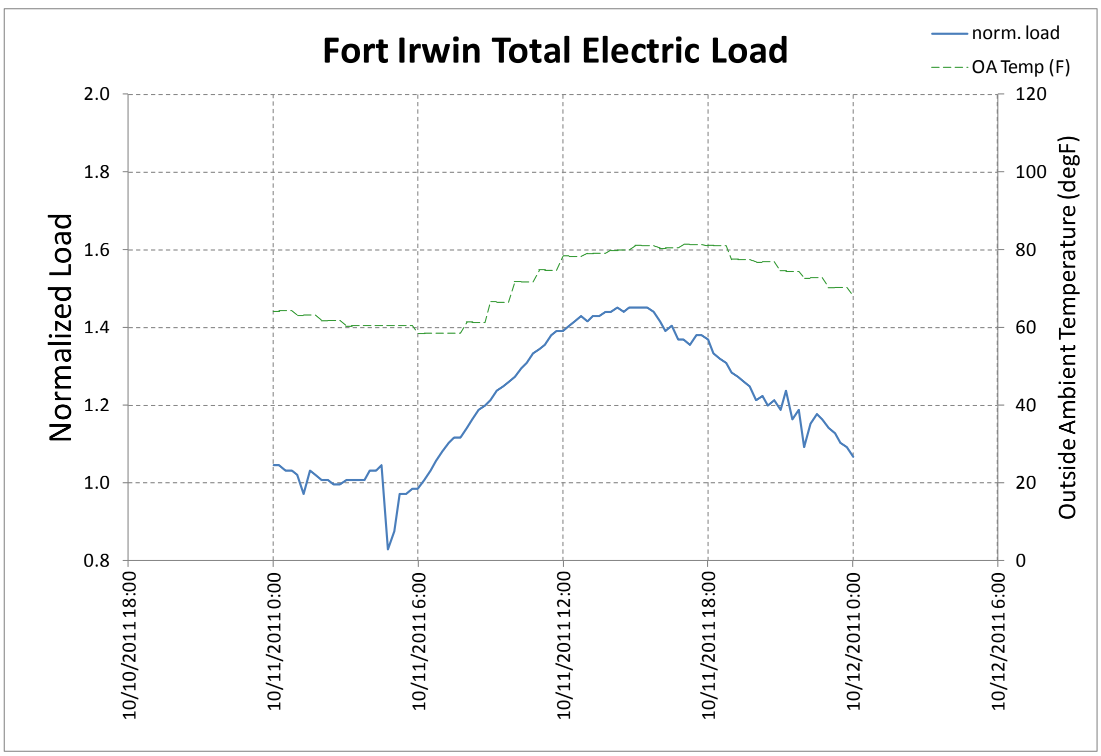
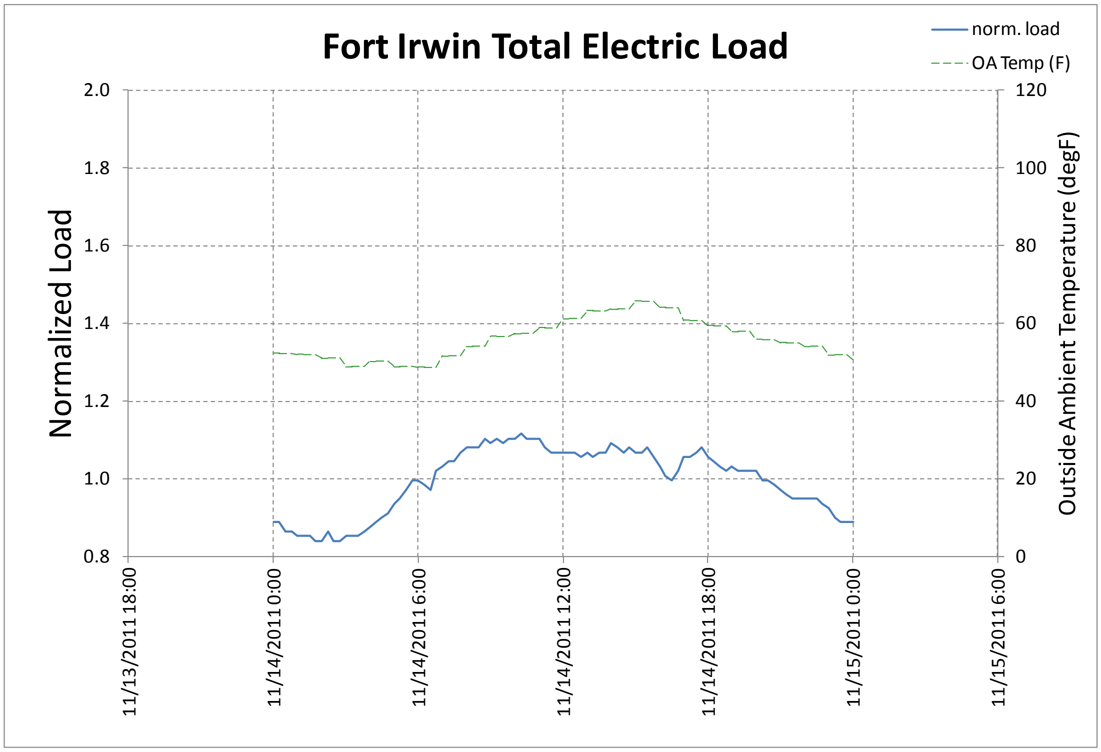
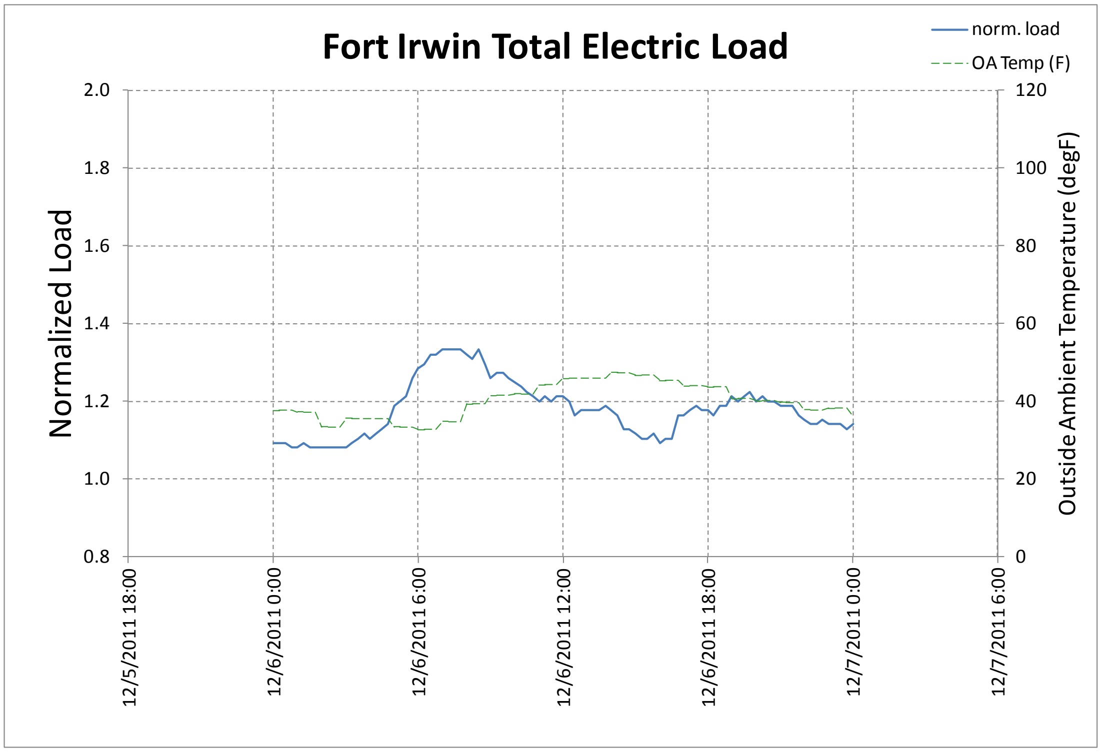
9/16/2011 0:00
9/16/2011 6:00



Fort Irwin Total Electric Load
norm. load
OA Temp (F)
Normalized Load
Outside Ambient Temperature (degF)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
120
100
80
60
40
20
0
10/10/2011 18:00
10/11/2011 0:00
10/11/2011 6:00
10/11/2011 12:00
10/11/2011 18:00
10/12/2011 0:00
10/12/2011 6:00


Fort Irwin Total Electric Load
norm. load
OA Temp (F)
Normalized Load
Outside Ambient Temperature (degF)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
120
100
80
60
40
20
0
11/13/2011 18:00
11/14/2011 0:00
11/14/2011 6:00
11/14/2011 12:00
11/14/2011 18:00
11/15/2011 0:00
11/15/2011 6:00


Fort Irwin Total Electric Load
norm. load
OA Temp (F)
Normalized Load
Outside Ambient Temperature (degF)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
120
100
80
60
40
20
0
12/5/2011 18:00
12/6/2011 0:00
12/6/2011 6:00
12/6/2011 12:00
12/6/2011 18:00
12/7/2011 0:00
12/7/2011 6:00

Appendix K: Comparative Analysis: OpenADR DBP Project

NIST BLCC 5.3-13: Comparative Analysis

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

Base Case: base (no DBP participation)

Alternative: OpenADR and DBP participation

General Information

File Name:	C:\Program Files (x86)\BLCC5\projects\DBP project.xml
Date of Study:	Mon Jan 19 14:11:55 CST 2015
Project Name:	Demand Bidding Program: Fort Irwin, CA
Project Location:	California
Analysis Type:	MILCON Analysis, Energy Project
Analyst:	Steve Gabel, Honeywell ACS Labs
Base Date:	January 1, 2016
Beneficial Occupancy Date:	January 1, 2016
Study Period:	10 years 0 months(January 1, 2016 through December 31, 2025)
Discount Rate:	1%
Discounting Convention:	Mid-Year

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	**Alternative**	**Savings from Alternative**
Initial Investment Costs:			
Capital Requirements as of Base Date	$0	$20,000	-$20,000
Future Costs:			
Energy Consumption Costs	$0	$0	$0
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Routine Recurring and Non-Recurring OM&R Costs	$0	-$87,492	$87,492
Major Repair and Replacements	$0	$0	$0
Residual Value at End of Study Period	$0	$0	$0
	------------	------------	------------
Subtotal (for Future Cost Items)	$0	-$87,492	$87,492
	------------	------------	------------
Total PV Life-Cycle Cost	$0	-$67,492	$67,492

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$87,492
- Increased Total Investment	$20,000

Net Savings	$67,492

Savings-to-Investment Ratio (SIR)

SIR = 4.37

Adjusted Internal Rate of Return

AIRR = 17.06%

Payback Period

Estimated Years to Payback (from beginning of Beneficial Occupancy Period)

Simple Payback occurs in year	3
Discounted Payback occurs in year	3

Energy Savings Summary

Energy Savings Summary (in stated units)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings

Energy Savings Summary (in Mbtu)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings

Emissions Reduction Summary

Energy Type	-----Average Base Case	Annual Alternative	Emissions----- Reduction	Life-Cycle Reduction
Electricity				
CO2	0.00 kg	0.00 kg	0.00 kg	0.00 kg
SO2	0.00 kg	0.00 kg	0.00 kg	0.00 kg
NOx	0.00 kg	0.00 kg	0.00 kg	0.00 kg
Total:				
CO2	0.00 kg	0.00 kg	0.00 kg	0.00 kg
SO2	0.00 kg	0.00 kg	0.00 kg	0.00 kg
NOx	0.00 kg	0.00 kg	0.00 kg	0.00 kg

Appendix L: Comparative Analysis: Bldg 254/271 HVAC Controls Project

NIST BLCC 5.3-13: Comparative Analysis

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

Base Case: Base case (without the controls upgrades)

Alternative: with HVAC controls upgrade

General Information

File Name:	C:\Program Files (x86)\BLCC5\projects\Bldg254&271 HVAC project.xml
Date of Study:	Mon Jan 19 14:42:53 CST 2015
Project Name:	Bldg 254 & Bldg 271 HVAC controls project: Fort Irwin, CA
Project Location:	California
Analysis Type:	MILCON Analysis, Energy Project
Analyst:	Steve Gabel, Honeywell ACS Labs
Base Date:	January 1, 2020
Beneficial Occupancy Date:	January 1, 2020
Study Period:	10 years 0 months(January 1, 2020 through December 31, 2029)
Discount Rate:	1%
Discounting Convention:	Mid-Year

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$0	$23,211	-$23,211
Future Costs:			
Energy Consumption Costs	$0	-$231,378	$231,378
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Routine Recurring and Non-Recurring OM&R Costs	$0	$21,019	-$21,019
Major Repair and Replacements	$0	$0	$0
Residual Value at End of Study Period	$0	$0	$0
	------------	------------	------------
Subtotal (for Future Cost Items)	$0	-$210,360	$210,360
	------------	------------	------------
Total PV Life-Cycle Cost	$0	-$187,149	$187,149

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$210,360
- Increased Total Investment	$23,211

Net Savings	$187,149

Savings-to-Investment Ratio (SIR)

SIR = 9.06

Adjusted Internal Rate of Return

AIRR = 25.91%

Payback Period

Estimated Years to Payback (from beginning of Beneficial Occupancy Period)

Simple Payback occurs in year	2
Discounted Payback occurs in year	2

Energy Savings Summary

Energy Savings Summary (in stated units)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	0.0 kWh	-91,200.0 kWh	91,200.0 kWh	911,875.2 kWh
Liquefied Petroleum Gas	0.0 Therm	-4,410.0 Therm	4,410.0 Therm	44,094.0 Therm

Energy Savings Summary (in Mbtu)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	0.0 Mbtu	-311.2 Mbtu	311.2 Mbtu	3,111.4 Mbtu
Liquefied Petroleum Gas	0.0 Mbtu	-441.0 Mbtu	441.0 Mbtu	4,409.4 Mbtu

Emissions Reduction Summary

Energy Type	-----Average Base Case	Annual Alternative	Emissions----- Reduction	Life-Cycle Reduction
Electricity				
CO_2	0.00 kg	-59,626.15 kg	59,626.15 kg	596,179.87 kg
SO_2	0.00 kg	-300.45 kg	300.45 kg	3,004.13 kg
NO_x	0.00 kg	-88.99 kg	88.99 kg	889.75 kg
Liquefied Petroleum Gas				
CO_2	0.00 kg	-27,664.77 kg	27,664.77 kg	276,609.85 kg
SO_2	0.00 kg	-223.37 kg	223.37 kg	2,233.35 kg
NO_x	0.00 kg	-41.93 kg	41.93 kg	419.22 kg
Total:				
CO_2	0.00 kg	-87,290.92 kg	87,290.92 kg	872,789.72 kg
SO_2	0.00 kg	-523.82 kg	523.82 kg	5,237.48 kg
NO_x	0.00 kg	-130.91 kg	130.91 kg	1,308.97 kg

Appendix M: Comparative Analysis: Bldg 263 Boiler Controls Project

NIST BLCC 5.3-13: Comparative Analysis

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

Base Case: Base case (no mods)

Alternative: with the Boiler controls upgrades

General Information

File Name:	C:\Program Files (x86)\BLCC5\projects\Bldg263 boiler project.xml
Date of Study:	Mon Jan 19 14:46:36 CST 2015
Project Name:	Bldg 263 Boiler controls project: Fort Irwin, CA
Project Location:	California
Analysis Type:	MILCON Analysis, Energy Project
Analyst:	Steve Gabel, Honeywell ACS Labs
Base Date:	January 1, 2021
Beneficial Occupancy Date:	January 1, 2021
Study Period:	10 years 0 months(January 1, 2021 through December 31, 2030)
Discount Rate:	1%
Discounting Convention:	Mid-Year

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$0	$11,308	-$11,308
Future Costs:			
Energy Consumption Costs	$0	-$35,313	$35,313
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Routine Recurring and Non-Recurring OM&R Costs	$0	$2,102	-$2,102
Major Repair and Replacements	$0	$0	$0
Residual Value at End of Study Period	$0	$0	$0
	------------	------------	------------
Subtotal (for Future Cost Items)	$0	-$33,211	$33,211
	------------	------------	------------
Total PV Life-Cycle Cost	$0	-$21,903	$21,903

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$33,211
- Increased Total Investment	$11,308

Net Savings	$21,903

Savings-to-Investment Ratio (SIR)

SIR = 2.94

Adjusted Internal Rate of Return

AIRR = 12.49%

Payback Period

Estimated Years to Payback (from beginning of Beneficial Occupancy Period)

Simple Payback occurs in year 4
Discounted Payback occurs in year 4

Energy Savings Summary

Energy Savings Summary (in stated units)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	0.0 kWh	-18,800.0 kWh	18,800.0 kWh	187,922.8 kWh
Liquefied Petroleum Gas	0.0 Therm	-540.0 Therm	540.0 Therm	5,397.8 Therm

Energy Savings Summary (in Mbtu)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	0.0 Mbtu	-64.1 Mbtu	64.1 Mbtu	641.2 Mbtu
Liquefied Petroleum Gas	0.0 Mbtu	-54.0 Mbtu	54.0 Mbtu	539.8 Mbtu

Emissions Reduction Summary

Energy Type	-----Average Base Case	Annual Alternative	Emissions----- Reduction	Life-Cycle Reduction
Electricity				
CO_2	0.00 kg	-12,294.72 kg	12,294.72 kg	122,896.73 kg
SO_2	0.00 kg	-61.95 kg	61.95 kg	619.27 kg
NOx	0.00 kg	-18.35 kg	18.35 kg	183.41 kg
Liquefied Petroleum Gas				
CO_2	0.00 kg	-3,388.45 kg	3,388.45 kg	33,870.59 kg
SO_2	0.00 kg	-27.36 kg	27.36 kg	273.47 kg
NOx	0.00 kg	-5.14 kg	5.14 kg	51.33 kg
Total:				
CO_2	0.00 kg	-15,683.17 kg	15,683.17 kg	156,767.32 kg
SO_2	0.00 kg	-89.31 kg	89.31 kg	892.74 kg
NOx	0.00 kg	-23.48 kg	23.48 kg	234.75 kg

Appendix N: Comparative Analysis: Building 325 Solar Thermal Project

NIST BLCC 5.3-13: Comparative Analysis

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

Base Case: Base case (no solar)

Alternative: with solar thermal system

General Information

File Name:	C:\Program Files (x86)\BLCC5\projects\Bldg325 solar project.xml
Date of Study:	Mon Jan 19 14:48:38 CST 2015
Project Name:	Bldg 325 Solar Thermal project: Fort Irwin, CA
Project Location:	California
Analysis Type:	MILCON Analysis, Energy Project
Analyst:	Steve Gabel, Honeywell ACS Labs
Base Date:	January 1, 2022
Beneficial Occupancy Date:	January 1, 2022
Study Period:	10 years 0 months(January 1, 2022 through December 31, 2031)
Discount Rate:	1%
Discounting Convention:	Mid-Year

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	Alternative	Savings from Alternative
Initial Investment Costs:			
Capital Requirements as of Base Date	$0	$25,537	-$25,537
Future Costs:			
Energy Consumption Costs	$268,608	$173,773	$94,835
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0
Routine Recurring and Non-Recurring OM&R Costs	$0	$21,018	-$21,018
Major Repair and Replacements	$0	$0	$0
Residual Value at End of Study Period	$0	$0	$0
	------------	------------	------------
Subtotal (for Future Cost Items)	$268,608	$194,791	$73,817
	------------	------------	------------
Total PV Life-Cycle Cost	$268,608	$220,328	$48,280

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$73,817
- Increased Total Investment	$25,537

Net Savings	$48,280

Savings-to-Investment Ratio (SIR)

SIR = 2.89

Adjusted Internal Rate of Return

AIRR = 12.32%

Payback Period

Estimated Years to Payback (from beginning of Beneficial Occupancy Period)

Simple Payback occurs in year	4
Discounted Payback occurs in year	4

Energy Savings Summary

Energy Savings Summary (in stated units)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	0.0 kWh	2,000.0 kWh	-2,000.0 kWh	-19,991.8 kWh
Liquefied Petroleum Gas	8,224.0 Therm	5,263.0 Therm	2,961.0 Therm	29,597.8 Therm

Energy Savings Summary (in Mbtu)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	0.0 Mbtu	6.8 Mbtu	-6.8 Mbtu	-68.2 Mbtu
Liquefied Petroleum Gas	822.4 Mbtu	526.3 Mbtu	296.1 Mbtu	2,959.8 Mbtu

Emissions Reduction Summary

Energy Type	-----Average Base Case	Annual Alternative	Emissions----- Reduction	Life-Cycle Reduction
Electricity				
CO2	0.00 kg	1,307.95 kg	-1,307.95 kg	-13,074.12 kg
SO2	0.00 kg	6.59 kg	-6.59 kg	-65.88 kg
NOx	0.00 kg	1.95 kg	-1.95 kg	-19.51 kg
Liquefied Petroleum Gas				
CO2	51,604.85 kg	33,024.85 kg	18,580.01 kg	185,723.75 kg
SO2	416.66 kg	266.64 kg	150.02 kg	1,499.54 kg
NOx	78.21 kg	50.05 kg	28.16 kg	281.48 kg
Total:				
CO2	51,604.85 kg	34,332.80 kg	17,272.06 kg	172,649.63 kg
SO2	416.66 kg	273.23 kg	143.42 kg	1,433.66 kg
NOx	78.21 kg	52.00 kg	26.21 kg	261.96 kg