Bonneville Power Administration
Technology Innovation Project 220

Smart End-Use Energy Storage and Integration of Renewable Energy

TI 220 Project Evaluation Report

Project Activities: September 2010 Through September 2012

September 30th, 2012

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Acknowledgments

This report is a reflection of the collaborative nature of the project and includes important contributions from many talented individuals. The author wishes to thank Ecofys' project partners, our utility partners, many staff at Bonneville Power Administration, from both inside and outside the Technology Innovation Program, and the Northwest Power and Conservation Council.

Acronyms:

BRD	Balancing Reserves Deployed
C&I	Commercial and Industrial
DEC	Decrease Generation Call (or increase load)
ETS	Electric Thermal Storage
EWH	Electric Water Heater
GETS	Grid-interactive Electric Thermal Storage (Steffes control strategy)
INC	Increase Generation Call (or decrease load)
T&D	Transmission and Distribution
WIT	Wind Integration Team

Executive Summary

Bonneville Power Administration (BPA) Technology Innovation Project 220, Smart End-Use Energy and Integration of Renewable Energy ("the Project"), was carried out by Ecofys over the two-year period from September 2010 to September 2012. One portion of the project showed how certain loads can be actively managed to provide power system balancing services. The Project built upon experience with demand response (DR) programs previously deployed in the region and across the US to develop approaches and technologies that can meet important needs of the Northwest regional retail utilities and BPA. The primary driver for the Project is the need to identify new cost-effective resources to integrate renewable energy generation, particularly wind. BPA currently has more than 4500 MW of wind power connected to its transmission system and within its Balancing Authority (BA). In the next fifteen years, an additional 2000 to 6000 MW will potentially also interconnect to the BPA Transmission system. BPA studies suggest that the Federal Columbia River Power System may not be able to provide balancing services for this amount of wind power. Other stakeholder interests that could be addressed with wide-spread implementation of flexible, grid-responsive load resources ("Smart DR") include relieving forecasted BPA capacity constraints, relieving ongoing transmission and distribution congestion/constraints, reducing periodic wind generation curtailments, and reducing power costs to BPA customer utilities by reducing peak demand charges.

The rising mandated levels of renewable energy resulting from state-adopted renewable energy standards are expected to result in a roughly two-thirds increase in qualifying renewable resources by 2020, and wind generation is likely to fulfill well over 50% of the new demand. The 2007 Northwest Wind Integration Action Plan recognized that accommodating the variability of wind generation on the Northwest power grid would require increasing levels of flexible resources capable of responding to variations in wind generation. By providing these services, Smart DR can alleviate the BA's need to rely on conventional balancing resources, potentially preventing the need to expand system reserve capacity under increased wind power integration.

Smart DR technology is in use in other parts of the United States as well as in Europe. A strong business case in support of investment in Smart DR technology can be made in the Pacific Northwest, at the utility, industry, and residential levels. It has been suggested[1], and this work supports that Smart DR can be a more cost-effective approach than other possible solutions, such as battery energy storage, while also supporting environmental efforts and legislative mandates.

Many end use technologies have an element of energy storage, and their electricity use can be managed with no reduction in service quality. Electric water heaters, space heating, or refrigerated warehouses are great examples of end uses with energy storage capacity or operational flexibility. The Ecofys Project is demonstrating the demand response benefits of all of these end uses. One of the project hypotheses is if Northwest utilities are considering investment in simple one way control technology for peak reductions, e.g., timers or RF direct load control, then for a marginal cost difference they could invest in Smart DR technology which would not only reduce load at defined times, but would be able to respond to other system signals, such as hourly pricing or requests for balancing service. These new Smart DR capabilities are becoming cost effective due to lower cost communication and control technologies, higher resolution information for load and price data, and policy efforts to allow demand and distributed resources to participate in traditionally supply only markets.

[1] See for example, "Meeting Renewable Energy7 Targets in the West at Least Cost: The Integration Challenge," Western Governors' Association, June 10, 2012, p. 76.

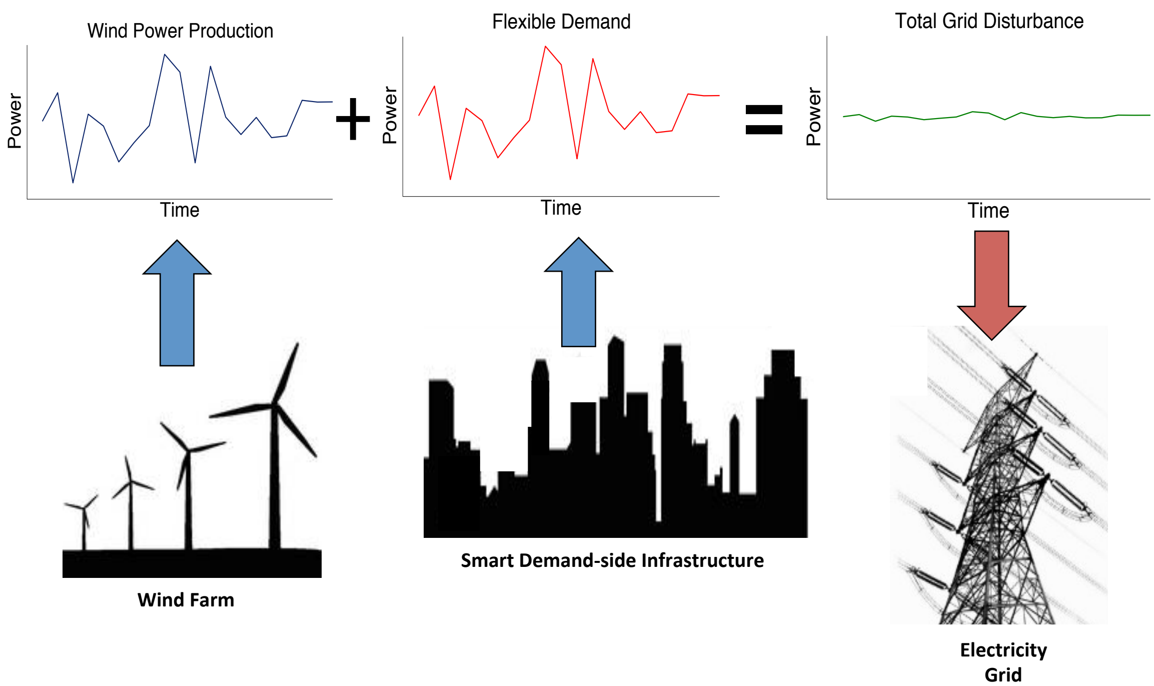

Figure 1: Smoothing wind power variability with Smart DR enabled demand-side infrastructure

The Project team included outstanding technical and engineering support from universities, national laboratories, the Northwest Power and Conservation Council, and private companies. The Project included eight BPA customer utilities participating with either direct technology demonstrations in their territory, or evaluation of potential future demand response (DR) projects through a Business Case tool developed within the Project.

The Project demonstrated the feasibility of developing a portfolio of Smart DR programs BPA customer utilities' territories. These flexible loads have an energy storage component that is characteristic of the load or process itself, i.e. the advantages of energy storage can be achieved at potentially lower costs than that of dedicated electrical energy storage technology, such as batteries. While historically DR has been used primarily to reduce loads, this project sought to take full advantage of the available energy storage, by both increasing and decreasing loads in response to needs for balancing reserves. In addition, the technology has the potential to provide other benefits such as load shaping and peak reduction. As a result, the Project examined maximizing value to the local host utility from multiple revenue streams.

The Project operated a 1.2 MW portfolio of assets composed of a combination of refrigerated storage warehouses, Steffes electric furnaces with thermal storage, Cypress wireless pneumatic thermostats, Steffes electric water heater controls and Carina electric water heater controls (see figure below).

Technology	Description	EWEB	Lower Valley	Cowlitz County	Forest Grove Power & Light	City of Richland	Clark County PUD	Consumers Power
Controllable Electric Water Heaters								
Steffes Water Heater Controllers		20		70				
Carina Water Heater Controllers - Existing Tanks	Includes mixing valves and expansion tanks on 30 units	100						
Carina Water Heater Controllers - New Tanks	These are 50 gallon Marathon heaters	10						
Electric Thermal Storage Furnaces								
Steffes 4120 ETS furnace (Whole House - forced air)			2					
Steffes 4140 ETS furnace (Whole House - forced air)			1					
Steffes 5140 ETS furnace (Whole House - hydronic)			1					
Steffes 5120 ETS furnace			*1 (i-p)*					
Steffes 9150 (1)/9180 (2) ETS furnace (Commercial Building)			*2 (i-p)*					
Pneumatic Thermostats								
Cypress wireless pneumatic thermostats	Installation completed March16th. 95 installed thermostats + spares, repeaters, hubs and servers						Ogden and Sac Schools	
Cold Storage Warehouses								
Cold Storage Warehouse - Enernoc	UISOL OpenADR platform at two locations: Forest Grove (Henningson) and Eugene (SnoTemp). Logix at both sites	*1 - SnoTemp (Logix) - 1*			1 - Henningson (Logix)	1 - Henningson (Logix)		2 - SnoTemp (Hench/Logix)

Figure 2: Summary of TI 220 Asset Portfolio

These are small-scale pilots, with total number of residential and C&I sites at around 130, spread across six utilities. These loads responded to the real-time needs of the BPA transmission system. The value to the transmission system, the host utility, and the end user was evaluated and the controls optimized to produce the best result from both a technical and economic perspective. The Project demonstrated that smart DR represents a nimble, cost-effective resource for renewable integration with a host of other benefits to the users of the Northwest electric system. Another important product of the work was a tool for retail utilities to perform an economic analysis of potential DR opportunities to establish a business case for their management.

The following chart provides estimates of costs for the various technologies demonstrated in the TI 220 project. These costs reflect pilot scale situations and can vary based on the size of the project, location and existing infrastructure.

Technology	Hardware costs	Approximate Installation Costs	DR Resource Size INC (Range in kW)	DR Resource Size DEC (Range in kW)	Approximate First Year Costs
Steffes WH*	$ 1,750	$ 850	.5-.8	3-3.5	$ 2,600
Carina W/Valve**	$ 600	$ 850	in testing	Not currently available	$ 1,450
Carina**	$ 600	$ 375	in testing	Not currently available	$ 975
Cold Storage***	$ 10,000	$ 20,000	50-400	50-400	$ 30,000
Furnace Small****	$ 1,375	$ 2,000	1-1.5	3	$ 3,375
Furnace Large****	$ 15,775	$ 40,000	20	60	$ 55,775
Cypress WPT	$ 14,038	$ 3,000	Load Shift Focus	Load Shift Focus	$ 17,038

Cold Storage and Water Heaters have year round DR capability…other technologies are seasonal
* Includes new hot water heater and significant costs for communication enablement (no longer required for new systems)
** Does not have traditional DEC capability at this time
*** Asset lifespan generally longer than other technologies in project
**** Does not include heat pump option
Note: communication subscription required for all technologies except Cypress Systems

Figure 3: Summary of TI 220 Asset Portfolio Costs

The Project showed that users experience no reduction in the quality of service, and in some cases had a service quality improvement because of increased storage capacity. We also demonstrated that with wider implementation, distribution utilities can reduce their cost for power service, and depending on program design, customers could see lower energy costs.

Over the life of the Project Ecofys received feedback from customers, utilities, BPA, and vendors and for this report distilled these views to address questions such as:

- What type of utility services can be provided by end-use storage devices?
- What types of demand response resources are cost effective for BPA and their utility customers?
- What are the approaches that lead to a cost-effective, successful Smart DR program implementation at the host utility?
- What policies or elements of program design would lead to BPA and regional utilities acquiring these Smart DR resources in significantly higher numbers?

Smart DR End Uses

Our initial analysis suggests that there is good potential for a cost effective Smart DR resource for BPA to pursue in the C&I sector, e.g., cold storage. There are over 300 frozen food processing and storage facilities in the PNW, and approximately 100 could be good candidates for the type of demand response BPA is looking for. Cold Storage is attractive because of several factors listed below.

1. Favorable Economics – $100-$500/kW upfront cost[2]. Cold Storage should be one of the first Smart DR resources to be targeted regionally. The most program benefit will be realized by targeting storage of refrigerated and frozen products, not food processing. The DR programs seem to be a good fit with energy efficiency programs, allowing significant gains in both flexibility and efficiency through the enabling of improved energy management systems and better understanding of the plant by site operators.
2. Mature Controls Technology – Control vendors have thorough understanding of enabling energy efficiency programs, and they have implemented demand response in other parts of the country.
3. Program Implementation - Industrial loads are easier to manage because the commercial and operational arrangements are done with only a few parties. These are also the customers with the operational scale appropriate to use equipment compliant with the OpenADR (Open Automated Demand Response) protocol. This configuration is well suited to enable full integration into BPA operations and use DR effectively for load following services.
4. Multiple benefits – The cold storage sector promises to provide BPA with a balancing reserve resource, and the distribution utility with demand reduction and load shifting.

Our experience in the Project has shown that the residential pilots have significant extra costs related to marketing, site selection, and installation. Typical costs for this pilot interactive water heater controller programs are in the range of $700/kW. It should be stressed that these pilots were designed as a "proof of concept", and that even at roll out far short of commercial deployment, significant reductions in program costs will result. These costs are expected to come down significantly when utilities get more experience with these technologies, and the programs are implemented on a larger scale. Utilities are unlikely to move forward with implementation of residential technologies without significant financial benefit from the sale of balancing services, in addition to the peak reduction and load shifting values. Nonetheless, the resource available from grid-interactive water heaters and ETS furnaces is outstanding from the perspective of operational flexibility, reliability of response, and visibility of the resource. In addition, there are no fuel costs or transmission constraints, both of which must be considered in the total cost and operations of a combustion turbine that is constructed to provide capacity or balancing reserves. Ecofys recommends continuing development of larger residential pilots and working with utilities and vendors to design programs that reduce the overall resource cost.

In October 2011, Bonneville Power Administration (BPA) implemented a new rate case, which changed the structure and price for its power services. For many utilities in the Pacific Northwest, there is now a clear price signal that encourages them to reduce their peak demand. Through the collaboration with BPA customer utilities in the use of the Business Case tool developed in The Project, it became clear that if Smart DR can be enabled for prices even close to the $200/kW-yr range, the incentive is there today for implementation. In comparison, variable and fixed operational costs for a gas turbine are estimated

[2] Compares with $610 per kilowatt (2006 dollars) for a frame combustion turbine reported in the Northwest Power and Conservation Council's Sixth Power Plan, Table 6-3, page 6-45.

to be $267/kW-yr[3]. In addition, utilities or other program designers must have confidence there will be stable peak demand charges (from BPA) and long-term contracts for supplying balancing reserves.

Because of BPA's new rate design, together with legislative mandates for renewable energy generation, utilities now face a new set of rules and costs that potentially could be reduced with targeted Smart DR programs. Specifically, smart DR programs could reduce utility costs in the following ways:

- Cost savings by reducing peak demand charges
- Cost savings by changing load shape (shifting energy use toward or away from certain hours of the day)
- Potential revenue from sale of balancing services
- Potential revenue from delaying investments in the distribution system (transformer, distribution lines, etc.)
- Reduced costs for integrating variable renewable energy generation (wind and solar)

The ideal Smart DR program would consist of a varied portfolio of assets: both large and small installations, across customer categories, distributed geographically across the Pacific Northwest region. The ideal Smart DR program as a whole would have the following characteristics:

- Low installation/enablement costs
- Short lead time for enablement
- Easy access to willing customers who feel "part of the solution"
- Low O&M (operation and maintenance) costs
- Easy measurement and verification of performance
- Long lifetime of assets

The Project has demonstrated a promising new resource for addressing the challenge of integrating larger amounts of variable renewable energy resources into the Northwest power grid. In the opinion of the project partners, the Smart DR approach is advantageous compared to other energy storage options such as pumped hydro and batteries because of its potential for lower overall costs and added value due to geographic dispersion across the transmission system. By using advanced communications and dispatch algorithms for controlling customer loads that have a thermal energy storage capacity, the transmission system operator, the load-serving utility, and the customer can all see significant benefits.

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[3] Cost And Performance Data For Power Generation Technologies (NREL) February 2012

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1 Introduction

Over the period from September 2010 to September 2012, Ecofys led an investigation into smart end-use energy storage approaches and technologies that can meet important needs of the Northwest regional utilities and the Bonneville Power Administration (BPA). The primary driver for this project is the need to identify new cost-effective resources to integrate renewable energy generation, particularly wind. BPA currently has more than 4500 MW of wind power connected within its balancing area, with an additional 2000 to 6000 MW potentially coming online over the next few years. BPA studies suggest that the Federal Columbia River Hydro System may not be able to provide balancing services for this amount of wind power. Other interests of stakeholders that could be addressed with wide-spread implementation of flexible demand-side resources include: forecasted BPA capacity constraints, delaying transmission and distribution infrastructure upgrades, and reduction in power costs to BPA customer utilities by reducing peak demand charges.

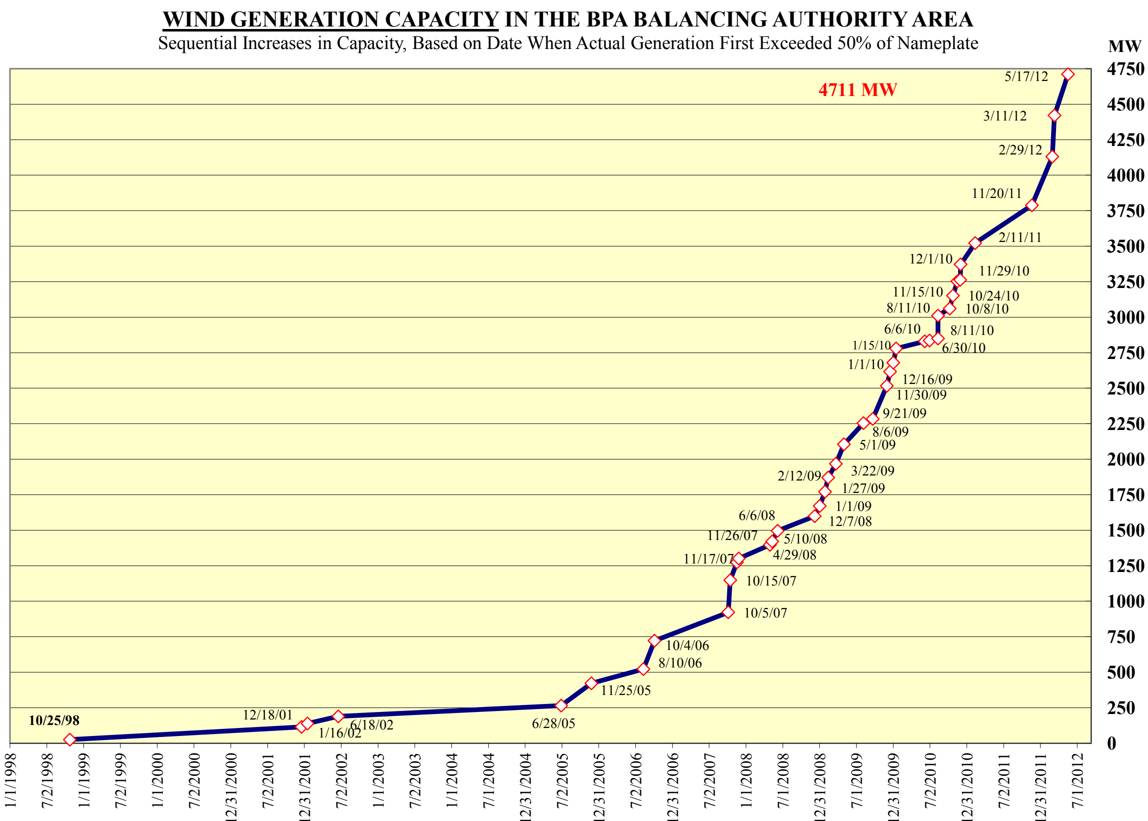

Figure 4: Evolution of the installed wind power capacity in the BPA balancing region [4]

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[4] Source: http://transmission.bpa.gov/business/operations/wind/ WIND_InstalledCapacity_Plot.pdf

The Project sought to show that in principle any service provided by generating units to ensure that loads can equivalently provide supply and demand balance. As modern information technology advances and continues to penetrate the market it is beginning to provide power system operators the ability to use demand side resources to provide services historically only provided by generation. Many end-uses contain inherent operational flexibility that can allow operation to be deferred to more cost-effective times without reducing end-use functionality. Specifically, thermal loads that are designed to operate over a range of conditions have inherent energy storage in the form of insulated thermal mass.

For the Project, Ecofys and its partners identified and applied responsive thermal end-use technologies that can provide conventional demand-side management, such as peak reduction and load shaping, as well as novel balancing services that assist with variable renewable generation integration and traditional unresponsive load variability. These technologies span the residential, commercial, and industrial end-use sectors and included:

1. Residential electric water heaters
2. Residential electric thermal storage furnaces
3. Commercial and industrial cold storage facilities
4. Commercial and institutional building HVAC systems

The scope of all demonstrations together is a portfolio of more than 1 MW of controllable load distributed throughout six regional utility territories.

Different load control strategies aimed at different operational objectives were implemented. Of particular interest to the project stakeholders is the ability to control the demand-side resources to provide both a decrease and increase in load. Bi-directional control allows for provision of bi-directional balancing services. The balancing services are needed as a result of over and under forecasts of both variable generation and load. Another value from some of the load control technologies allows consumer utilities to charge thermal mass during off-peak periods in order to reduce future demand peaks. Implementation of this type of control strategy involved installing communication infrastructure either directly on existing devices or during the retrofit stages. A major project objective was to define control strategies in a manner that seamlessly integrates these new resources within conventional power system management, while preserving the long-term performance of the resource.

The results of the project are encouraging. The large cold storage facilities have shown great potential to accurately respond to both balancing reserve and load shedding signals. Furthermore, the water heating systems have also displayed the ability to provide enough flexibility to take advantage of multiple value streams (balancing, peak reduction, and load-shaping), as well as enough visibility to the system operator to enable measurement and verification. In all cases, end-use functionality of participating units is maintained at levels commensurate with consumer satisfaction. Ecofys developed an in-house business case model that host utilities can use to develop future build-out plans for increasing the penetration of responsive end-use devices.

In general, the outcomes of this project show BPA and other regional utility districts can move forward with developing smart end-use energy resources. The Project provided real-world experience with applicability beyond the geography of the Northwest, to power systems across North America and abroad.

1.1 Goal and Scope of the Project

The purpose of this project was to facilitate the rapid development and deployment of end-use controllable loads to provide both balancing services in the BPA balancing area and localized benefits to BPA's load-serving utilities. The project supported procurement and implementation of more than 1 MW of demand response with energy storage in the service territories of several consumer-owned utilities: Lower Valley Energy, Eugene Water & Electric Board, Cowlitz PUD, City of Richland, Clark PUD, and Consumer's Power. Further, the project funded services to these utilities that were enthusiastic participants (on very short notice in some cases), but that might have needed assistance developing business cases and marketing programs. A summary of the business case development and marketing options, along with a technology overview of demand response and its applications, were combined into a Guidebook that was distributed to other load-serving utilities in the Northwest that may be interested in proceeding with independent, parallel demonstration or commercialization projects.

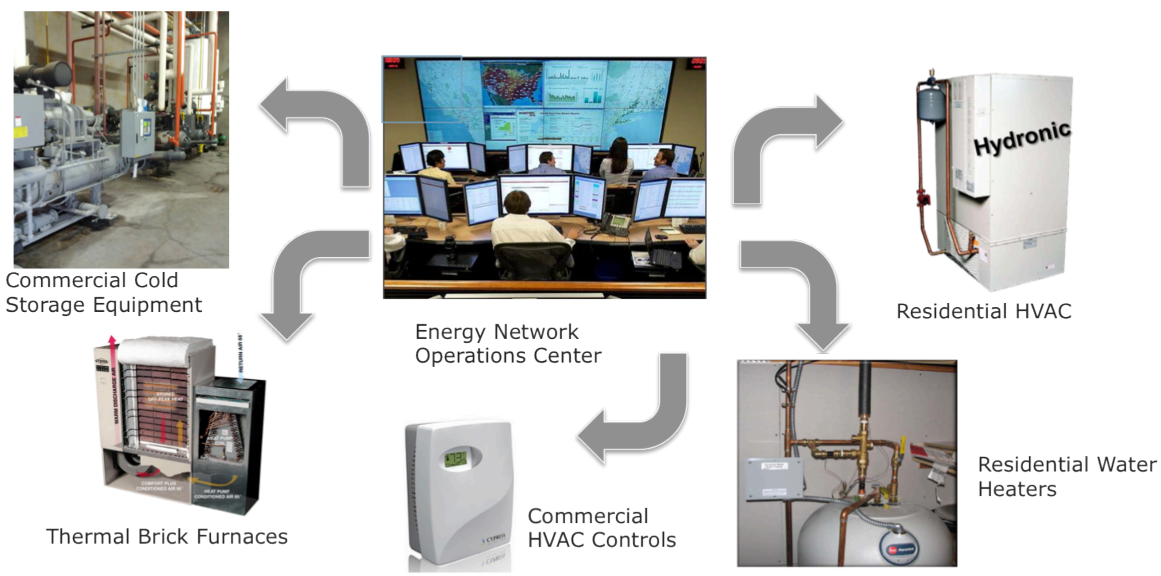

Figure 5: Coordination and interaction of technologies being used in TI 220

The project provided analytical capability for optimizing the dispatch and operation of end-use storage, and evaluation of the efficacy and economics of wide-scale adoption of dispatchable end-use loads for providing load following reserves. The work enables the rapid deployment of controllable loads to complement the work of the Smart Grid Demonstration Project by positioning more load serving utilities to take advantage of the communication protocols developed as part of that effort. The widespread installation of grid-responsive loads is expected to produce jobs at a time when new economic activity is sorely needed, reduce overall power system costs, and to enable a system capable of absorbing more renewable generation by reducing the share of reserves now provided by the hydro system.

The project expanded significantly beyond the initial proposal with the addition of nine tasks, involving three new technology demonstrations, through the execution of Modifications Nos. 001 and 002 of the Cooperative Agreement. These modifications are described further in the Project Management section below.

1.2 Project Team

Ecofys assembled a team of industry experts to execute this project. Ecofys US served as project manager.

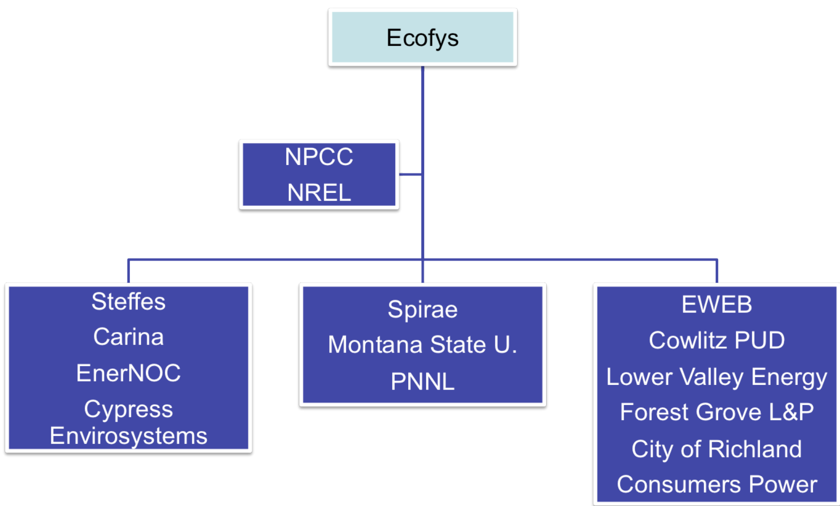

Figure 6: Initial Project Team

In the second quarter of fiscal year 2012 we had an addition to the team. Clark PUD and Vancouver School District participated in the wireless pneumatic thermostat project.

- Ecofys US (Project Lead)
- Spirae (Water heater modeling)
- Dr. Shuai Lu, PNNL (Water heater control theory)
- Dr. Hashem Nehrir, Montana State University (Water heater modeling and control theory)
- Ken Dragoon and Ken Corum, NPCC (Control planning)

- Michael Milligan and Brendan Kirby, NREL (Renewable integration and balancing studies)
- Steffes (Water heater controls, ETS space heaters and system management)
- EnerNoc (Cold storage system management)
- Carina Technologies (water heater controls and system management)
- Cypress Envirosystems (Wireless pneumatic thermostats)
- UISOL (A demand response management platform provider)
- IC Systems (GridLink OpenADR vendor)
- Logix (Refrigeration controls vendor)
- Sno-Temp Corporation (Cold storage participant)
- Henningsen Cold Storage (Cold Storage participant)
- Vancouver School District (Wireless thermostat participant)

Utility Partners:

- Clark PUD (Wireless thermostats)
- Lower Valley Energy (Steffes thermal brick furnaces and heat pumps)
- Eugene Water & Electric Board (Cold storage, Steffes and Carina hot water heaters)
- Cowlitz Co. PUD (Steffes hot water heaters)
- Forest Grove Light & Power (Cold Storage)
- City of Richland (Cold Storage)
- Consumers Power (Cold Storage)
- City of Port Angeles (General program information sharing)
- Emerald PUD (Business case tool)

1.3 Current Task Status

Listed below are the overall objectives of the project, organized into 22 tasks, which were expected to take 25 months to complete. Updates on the current state of these tasks are provided in the activities and accomplishments section. Please see the appendices for historical background details on these tasks.

Task 1 - Organize Technical Advisory Panel (TAP)	✔ Complete
Task 2 - Develop Business Case	✔ Complete
Task 3 - Create Technology Survey	✔ Complete
Task 4 - Produce Guidebook for Consumer-Owned Utilities	✔ Complete
Task 5 - Develop Utility Marketing Materials	✔ Complete
Task 6 - Site Selection	✔ Complete
Task 7 - Dispatch Optimization Support	✔ Complete
Task 8 - Technology Installations	✔ Complete
Task 9 - Dispatch Review Period	✔ Complete
Task 10 - Interim Report	✔ Complete

Task 11 - Balancing Services Contract Template	✔ Complete
Task 12 - Customer Satisfaction Survey	✔ Complete
Task 13 - Project Evaluation	✔ Complete
Task 14 - More Rapid Data Analysis	✔ Complete
Task 15 - Additional Control Approaches	✔ Complete
Task 16 - Commercial Building ETS Furnace Demonstration	✔ Complete[5]
Task 17 - Wireless Pneumatic Thermostats Demonstration	✔ Complete
Task 18 - Customize Demand Response Business Case	✔ Complete
Task 19 - Carina Water Heater Controller Demonstration	✔ Initial phase complete[6]
Task 20 - Additional Steffes Water Heater Controllers	✔ Complete
Task 21 - Additional Cold Storage Demo	✔ Complete
Task 22 - Carina Water Heater Controller Demo (New Tanks)	✔ Complete

1.4 Outline of this Report

The purpose of this report is to document the success of the project in development and deployment of end-use controllable loads to provide both balancing services in the BPA region and localized benefits to BPA's customer utilities. The evaluation will show techniques used for optimizing the dispatch and operation of end-use storage, and for efficient and cost-effective integration of the controllable loads into the utility's existing operations. Another focus is the efficacy and economics of wide-scale adoption of dispatchable end-use loads for providing load-following reserves.

The report is comprised of an Executive Summary, introduction to the Project, evaluation of Project activities by technology type, a description of the Business case model, and conclusion summarizing the Project findings.

2 Project Activities And Smart DR Resource Development

2.1 General Approach

As the goal of the project has been to enable and deploy loads that have the flexibility to both increase and decrease load the project has required finding much more specific loads than a typical DR project. Increasing load is fairly simple (e.g., resistive load banks), but increasing load to a useful purpose is the challenge faced by the Project. As a result, the Project focused on loads associated with thermal storage, where increases in load could potentially be stored for later use.

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[5] Enhanced program extended through September 2013

[6] Extended program in place through December 2012

The thermal nature of the storage informs the control strategy decisions. The goal of the project has been to explore how the end units respond under varying conditions during the day and day of the week, as well as their seasonal variability. Understanding the specific demographics of the families hosting residential loads and the nature of the commercial facilities is important to assessing resource capability. Examining which facilities performed well and why they did so has been a major goal of the project. Ecofys employed a multi-pronged approach to identifying robust protocols for controlling end use storage devices.

Determining effective control strategies was an important objective of the Project. In the first phase, many of our project partners collaborated on creating many different control strategies for the electric water heaters (EWH). This included models and strategies developed by Ken Corum and Ken Dragoon of the Northwest Power Planning and Conservation Council (NWPPC), a range of constantly evolving control strategies from Steffes, a hybrid approach based on Steffes that Spirae developed, some modeling and control produced by Shuai Lu of PNNL, and some interim strategies developed by Ecofys. Ecofys worked to keep project partners communicating and from duplicating work.

Early on, Ecofys and BPA settled on using a publicly available near real-time indication of BPA's deployment of balancing reserves. The "Balancing Reserves Deployed" (BRD) was deemed a reasonable proxy for the need for balancing reserves as a system operator might view them. The BRD, made available on BPA's public website and updated every 5 minutes, is actually a retrospective look at the need for reserves over the previous five minute period. As such, it represents a fairly accurate persistence forecast of system needs.

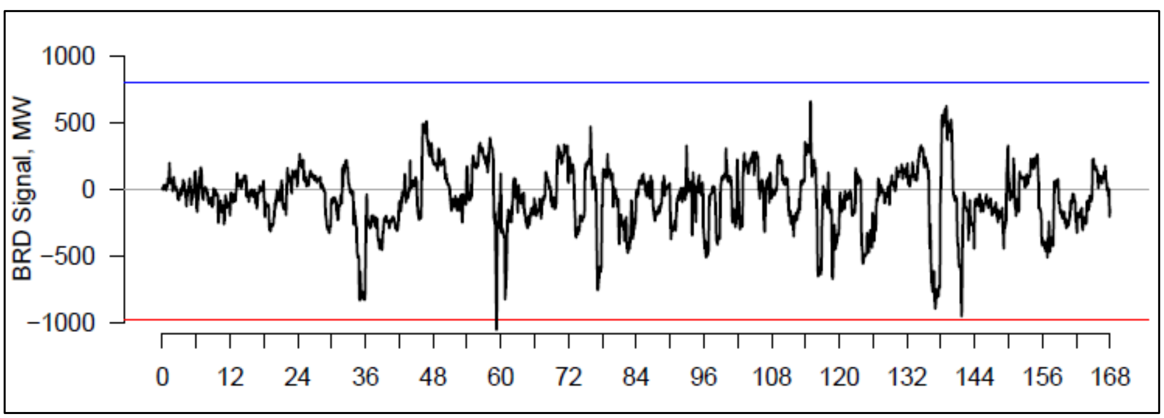

Figure 7: Sample BRD used for modeling, MW by hour of week.

Figure 5 is a representative sample of the BRD. Negative values correspond to decreased generation (DEC) requests and, conversely, positive signals correspond to increased generation (INC) requests. The red and blue horizontal lines demark the magnitude of the DEC and INC values contained in the BRD signal at or above which 100% of the distributed assets will be dispatched. DEC requests can be met with an increase in load, and INC requests can be met with a decrease in load.

During this early "proof of concept" trial, the EWHs were intentionally restricted from directly responding proportionately to the BRD. This strategy was implemented for two reasons. First, to avoid over-dispatching of the EWHs during small deviations from zero; without constraining the dispatch signal in this manner one would generally observe the capacity to deploy DECs would rapidly disappear because the overall mean EWH water temperatures would quickly reach the upper limit of 170 °F. Secondly, it is assumed that smaller excursions like these will be handled by the hydro system and DR resources like those modeled would be dispatched only after the hydro resources were utilized.

The general goals of controlling end use loads were three-fold:

1) Maintain operation such that the end user services remain within acceptable levels. It is extremely important for any DR project that the customers are not inconvenienced by the project. That means maintaining all temperatures at acceptable levels, whether for showers or for frozen blueberries.
2) Provide benefits to the host utilities. The utilities bear the brunt of operation and maintenance for these programs, and as such need to receive significant compensating benefits. For the most part, that benefit took the form of peak shaving or load shaping, but it may also be the added efficiencies of transmission at night.
3) Provide balancing services, or at least show proof of concept. The main goal of the project is demonstrating the abilities of these resources to provide grid balancing services.

Based on these goals, the project team developed control strategies that balanced using the resources with maintaining end-user services. However, it was also useful to occasionally push the limits to understand how much could reasonably be expected during extreme events and explore when a resource might become exhausted.

2.2 Commercial and Industrial Cold Storage

The lead contractor for the Commercial and Industrial (C&I) load following pilot project was Ecofys US, Inc., and EnerNOC, Inc. subcontracted a portion of the overall project.

2.2.1 Technology and Communication Infrastructure

The technology and communication infrastructure used in the C&I load following project allows an event signal to be sent and received by each facility's refrigeration control system. Upon receipt of the signal, the refrigeration control system responds by implementing the appropriate load curtailment or increase strategy. The system architecture required for establishing this communication over the Internet consisted of two major elements: (1) a server for dispatching the event signal, and (2) a client located at each facility to monitor the signal and interface with the refrigeration control system.

During phase I of this project EnerNOC's Network Operations Center (NOC) was used to dispatch event signals to all the facilities. One of the facilities received signals dispatched from a demand response automation server (DRAS) operated by Utility Integration Solutions (UISOL).

At each facility, EnerNOC installed a hardware device called an EnerNOC Site Server (ESS). The ESS is a two-way communications solution that (1) captures near real-time electricity consumption data on 1-minute intervals and (2) relays the event signals to the centralized refrigeration control system at the participating facilities. The ESS that was installed at some of the facilities in this project is shown in Figure 5 below. The ESS was typically installed in the electrical room at the facilities and was equipped to read and record electrical data through the use of KYZ pulse outputs provided by the utility meter. The ESS received event signals from the NOC or the UISOL DRAS, and sent electric energy and demand data to the NOC, by using secure communication protocols through a wireless (cellular) internet connection.

Figure 8: EnerNOC Site Server

The following figure illustrates the technology and communication infrastructure used in the C&I commercial cold storage project.

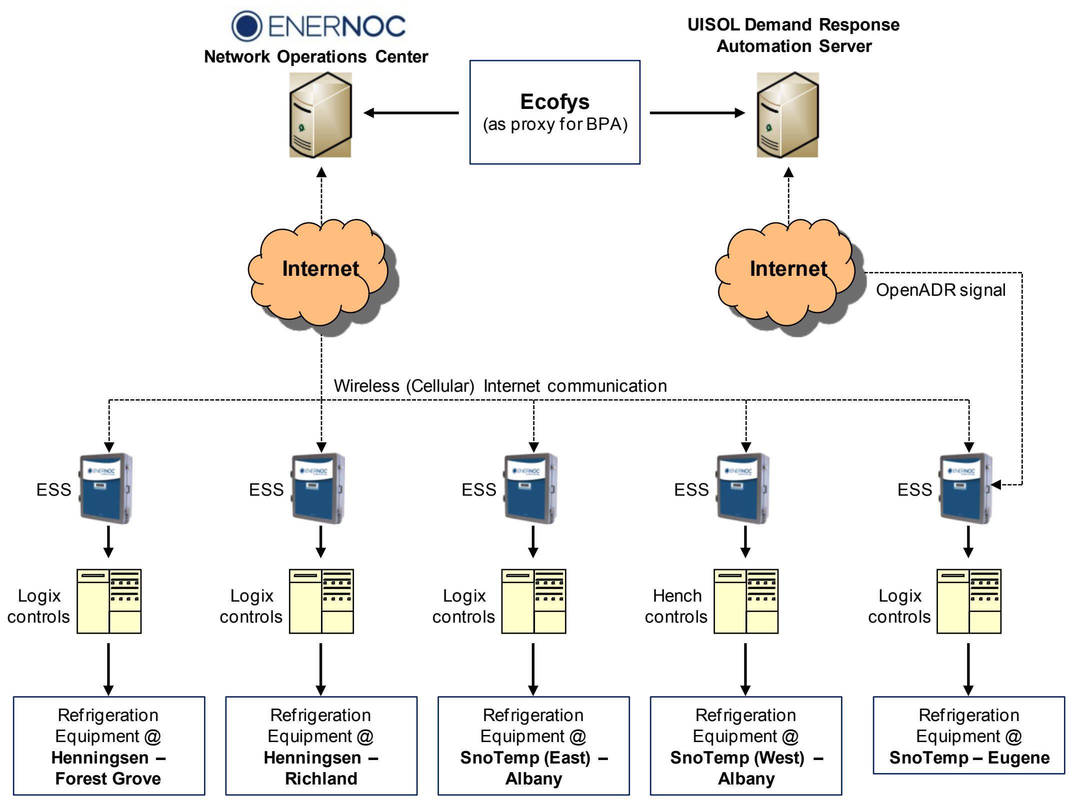

Figure 9: Technology and Communication Infrastructure

2.2.2 Loads Controlled

The C&I load following pilot project focused on controlling components of the facilities' refrigeration system in order to increase or decrease electric demand. Table 3-2 provides a summary of the loads controlled and targeted amount of load curtailment/increase at each of the participating facilities. The load control strategy involved selectively energizing the ammonia compressors and evaporators at each facility, with the exception of Henningsen – Forest Grove where only the compressor set points were controlled. When a load following event was dispatched, the centralized refrigeration control system decreased or increased the operation of the ammonia compressors and evaporators by modifying the appropriate temperature and pressure set points of these components.

Participant	Control System Manufacturer	Controlled Refrigeration System Components	Targeted Amount of Demand Curtailment/Increase
Henningsen Cold Storage – Forest Grove, OR	Logix	Ammonia Compressors	200 kW curtailment; 200 kW increase
Henningsen Cold Storage – Richland, WA	Logix	Ammonia Compressors, Evaporators	200 kW curtailment; 100 kW increase
SnoTemp Cold Storage (East) – Albany, OR	Logix	Ammonia Compressors, Evaporators	200 kW curtailment; 50 kW increase
SnoTemp Cold Storage (West) – Albany, OR	Hench Control	Ammonia Compressors, Evaporators	200 kW curtailment; 100 kW increase
SnoTemp Cold Storage – Eugene, OR	Logix	Ammonia Compressors, Evaporators	200 kW curtailment; 200 kW increase

Figure 10: Project Activities And Smart DR Resource Development loads controlled at all sites

Cold storage testing was defined by two phases. Phase I consisted of testing at the two Albany SnoTemp sites and the two Henningsen sites. Phase II added in the third SnoTemp site in Eugene Oregon for a final total of 5 cold storage sites participating in the program. In Phase I of the C&I load following project, a total of 24 load curtailment and load increase tests were conducted during the period between August 2011 and May 2012. Eight of the Phase I tests called for load curtailment, while the remaining 16 tests called for load increase. In Phase II, a total of 27 tests were conducted between June and August 2012. Fifteen of the Phase II tests called for load curtailment, while the remaining 12 tests called for load increase. There were a total of five instances when two tests were dispatched on the same day, and two instances when a test was conducted on a weekend.

All but one of the test dispatches were thirty (30) minutes in length on ten minutes notice. The exception was one Phase II test. Appendix A contains tables showing the exact date and time of the test dispatches.

2.2.3 Test Results

The amount of load curtailment or increase was evaluated by comparing the demand data for the test period to a baseline. For each event, a baseline was developed using the "10 of 10" methodology.[7] This baseline methodology established the average "shape" of the participants'

[7] The "10 of 10" methodology establishes a baseline by averaging the demand over 10 days prior to the event but excluding weekend days, holidays, and event days. See figures 12 and 13 for specific examples of load response.

demands based on the previous ten days, and a day-of adjustment was applied in order to calibrate the baseline shape to the level of the test day demand.

The following tables show the amount of load curtailment or increase during the tests.

Date	Event Type	Henningsen - Forest Grove Average kW	Henningsen - Richland Average kW	SnoTemp (East) - Albany Average kW	SnoTemp (West) -Albany Average kW	Total Average kW Curtailed
8/15/2011	CURTAIL	157	71	238	412	877
8/17/2011	CURTAIL	339	180	229	469	1,218
8/20/2011	CURTAIL	1,046	-167	411	639	1,928
9/19/2011	CURTAIL		145	583	320	1,048
9/22/2011	CURTAIL		-95	180	485	570
12/2/2011	CURTAIL	164	39	363	271	836
1/18/2012	CURTAIL	-29	168		483	621
1/20/2012	CURTAIL	295	16	238	161	710
Average		**329**	**44**	**320**	**405**	**976**

Note: Blank entries indicate that the facility did not participate in the test.

Figure 11: Load curtailment during test events – Phase I

Date	Event Type	Henningsen - Forest Grove Average kW	Henningsen - Richland Average kW	SnoTemp (East) - Albany Average kW	SnoTemp (West) -Albany Average kW	Total Average kW Increase
8/29/2011	INCREASE	436	206	327		969
9/1/2011	INCREASE	-24	169	490	3	640
9/19/2011	INCREASE			340	49	389
9/21/2011	INCREASE		86	121	-66	141
11/29/2011	INCREASE	678		171	-322	527
11/30/2011	INCREASE	740	-297	231	183	856
12/1/2011	INCREASE		139	229	24	392
3/12/2012	INCREASE			8	231	239
3/14/2012	INCREASE			3	178	182
3/29/2012	INCREASE			14	272	287
Average		**458**	**61**	**193**	**61**	**462**

Note: Blank entries indicate that the facility did not participate in the test.

Figure 12: Load increase during test events – Phase I

The following observations are made regarding the Phase I load curtailment tests and results:

- The four phase I participants combined for an average of 976 kW of load curtailment. This amount is greater than the aggregate load curtailment goal of 800 kW (200 kW per participant).
- SnoTemp (West) – Albany achieved the largest average load curtailment (405 kW per test) amongst the four Phase I participants. Henningsen – Richland was the only participant that achieved less than the goal (averaged only 44 kW curtailment per test).
- The amount of load curtailment during the winter test dates tend to be smaller than that of the summer test dates because the refrigeration systems at the facilities were often operating at lower capacities (due to lower ambient temperatures). For example, when there are less compressors operating, the facilities' ability to turn off the remaining compressors is limited because doing so could affect their capacity to maintain the cold storage temperature.
- There were a few instances where typical facility operations contributed to low curtailment performance. For example, during the tests on January 18, 2012, Henningsen – Forest Grove's load curtailment performance did not meet expectations because the facility personnel operated a set of compressors that was not earmarked for curtailment. As such, when the test was dispatched, none of the operating compressors curtailed.
- In some cases, "aiming" for a specific kW target such as 200 kW created perverse outcomes. For example, the programming at the Richland facility called for only certain compressors to be

shut off during a demand response dispatch. If those compressors were already off at the time of dispatch, the signal resulted in those compressors turning on, thereby increasing load, before eventually turning back off. EnerNOC spent significant time working with the facility and control vendor to mitigate this issue while still aiming for a 200 kW reduction target.

The following observations are made regarding the Phase I load increase tests and results:

- The four participants combined for an average of 462 kW of load increase. This amount is slightly greater than the aggregate load increase goal of 450 kW.
- Although Henningsen – Forest Grove only participated in four of the ten load increase tests, this participant had the highest average load increase per test (458 kW per test). This amount of load increase was too high and risked increased demand charges for the facility, and thus prompted the facility's personnel to remove one of the ammonia compressors from the load increase strategy.
- SnoTemp (East) – Albany participated in every load increase test and achieved an average of 193 kW of load increase per test, which is well above the goal of 50 kW. Henningsen – Richland and SnoTemp (West) – Albany averaged only 61 kW of load increase per test, which is below their goal of 100 kW.
- Compared to the load curtailment tests, there were more instances where the facilities did not (or could not) participate in the load increase tests. The main reason for this is that EnerNOC had established demand thresholds that limited the facilities' participation in order to minimize the risk that the test would increase the facilities' peak demand charges. During many of the tests, the facilities were restored to normal operations because their demand exceeded the established thresholds or not dispatched at all.

Date	Event Type	Henningsen – Richland Average kW	SnoTemp (East) – Albany Average kW	SnoTemp – Eugene Average kW	Total Average kW Curtailed
7/10/2012	Curtail	-35	13	235	213
7/11/2012	Curtail	24	26	236	287
7/19/2012	Curtail	22	197	253	473
7/19/2012	Curtail	55	14	329	398
7/27/2012	Curtail	34	279	349	662
7/30/2012	Curtail	66	0	341	407
8/10/2012	Curtail	107	316		423
8/13/2012	Curtail	63	210	360	632
8/15/2012	Curtail	109	139		248
8/17/2012	Curtail	64	136		201
8/23/2012	Curtail	93	165	289	547
8/28/2012	Curtail	9	102		111
8/29/2012	Curtail	43	235		278
Average		**50**	**141**	**299**	**375**

Note: Blank entries indicate that the facility did not participate in the test.

Figure 13: Load curtailment during test events – Phase II

The following observations are made regarding the Phase II load curtailment tests and results:

- The three participants Albany East, Eugene and Richland (Albany West did not participate due to equipment problems and Forest Grove operated on a separate system), combined for an average of 375 kW of load curtailment. This amount is virtually identical to the aggregate load curtailment goal of 373 kW.
- SnoTemp – Eugene achieved the largest average load curtailment (299 kW per test) amongst the three participants. Henningsen – Richland's performance in the curtailment tests was the lowest at an average of 50 kW per test.
- Henningsen – Richland and SnoTemp (East) – Albany were the two facilities that also participated in the Phase I tests. The average load curtailment achieved by Henningsen – Richland in the two phases was similar (average of 44 kW per test in Phase I and 50 kW per test in Phase II). However, SnoTemp (East) – Albany achieved a lower load curtailment in Phase II (average of 320 kW per test in Phase I compared to 153 kW per test in Phase II).

- There was one instance where a facility's compressors faulted after receiving the test dispatch signal. During the test on July 30, 2012, the high-side compressors at SnoTemp – Eugene faulted due to a technical issue related to the pressure set points. This prompted EnerNOC and the refrigeration controls contractor (Logix) to make corrections to the control system in order to prevent further problems.

Date	Event Type	Henningsen - Richland Average kW	SnoTemp (East) - Albany Average kW	SnoTemp -Eugene Average kW	Total Average kW Increase
7/12/2012	Increase	9	0	81	90
7/13/2012	Increase	19	254	70	343
7/18/2012	Increase	62	27	114	203
7/18/2012	Increase	-1	217	154	369
7/27/2012	Increase	-24	12	-9	-21
7/31/2012	Increase	-95	45		-50
8/17/2012	Increase	-80	1		-79
8/23/2012	Increase	-23	253	206	436
8/27/2012	Increase	-46	155		109
8/30/2012	Increase	-34	160		126
Average		**-21**	**112**	**103**	**153**

Note: Blank entries indicate that the facility did not participate in the test.

Figure 14: Load increase during test events – Phase II

The following observations are made regarding the Phase II load increase tests and results:

- The three participants identified in figure 11 combined for an average of 153 kW of load increase. This amount is lower than the aggregate load increase goal of 298 kW. Also the load increase performance during Phase II is lower than that of Phase I. This can be mostly attributed to the fact that two of the Phase I facilities were no longer participating in Phase II. It is also partly due to the fact that all of the Phase II tests occurred during the summer period, when ambient temperatures are warm and the refrigeration systems are often operating at full capacity. In this case, there is diminished incremental capacity for the facilities to increase.
- SnoTemp (East) – Albany achieved the largest average load increase (112 kW per test) amongst the three participants, and was the only facility that had an average load increase exceeding the goal of 50 kW. This facility also participated in every load increase test in Phase II.

- Henningsen – Richland and SnoTemp (East) – Albany were the two facilities that also participated in the Phase I tests. The average load increase achieved by SnoTemp (East) – Albany in the two phases was comparable (average of 193 kW per test in Phase I and 112 kW per test in Phase II). However, Henningsen – Richland achieved a substantially lower load increase in Phase II (average of 61 kW per test in Phase I compared to -21 kW per test in Phase II).
- Henningsen – Richland participated in every load increase test in Phase II. However, during many of the tests, the loads at this facility actually decreased relative to the baseline. Part of this is due to the fact that there was a technical issue related to incorrect wiring during the tests that occurred at the beginning of Phase II. The wiring issue caused the facility's control system to be unable to distinguish between UP and DOWN events. As a result, the system ordered the same response regardless of the event.

The following figures are examples of the aggregated load profile of the participants during a successful load curtailment and load increase test during Phase II.

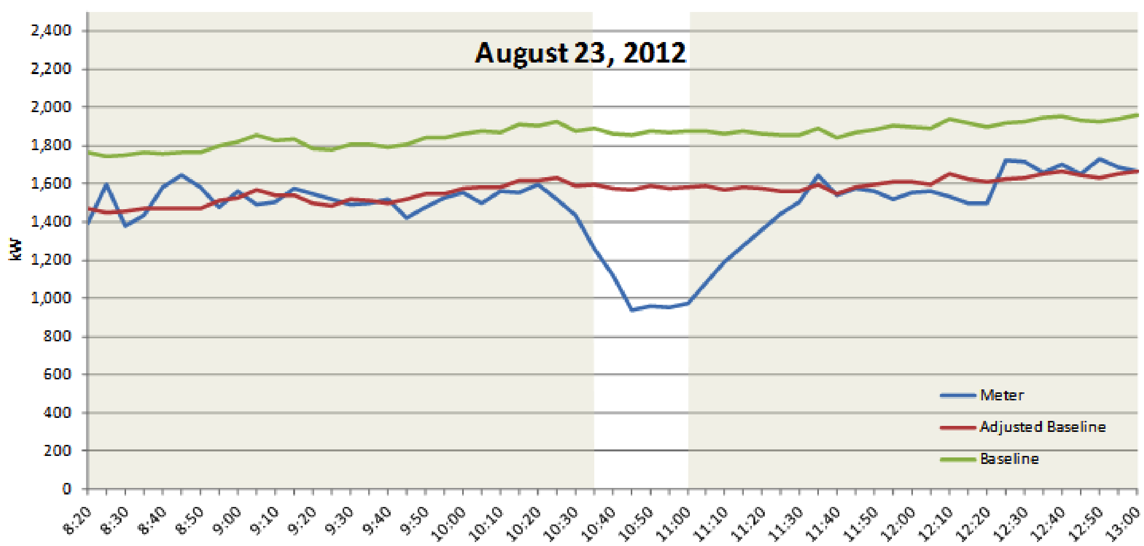

Figure 15: Load profile of a load curtailment test

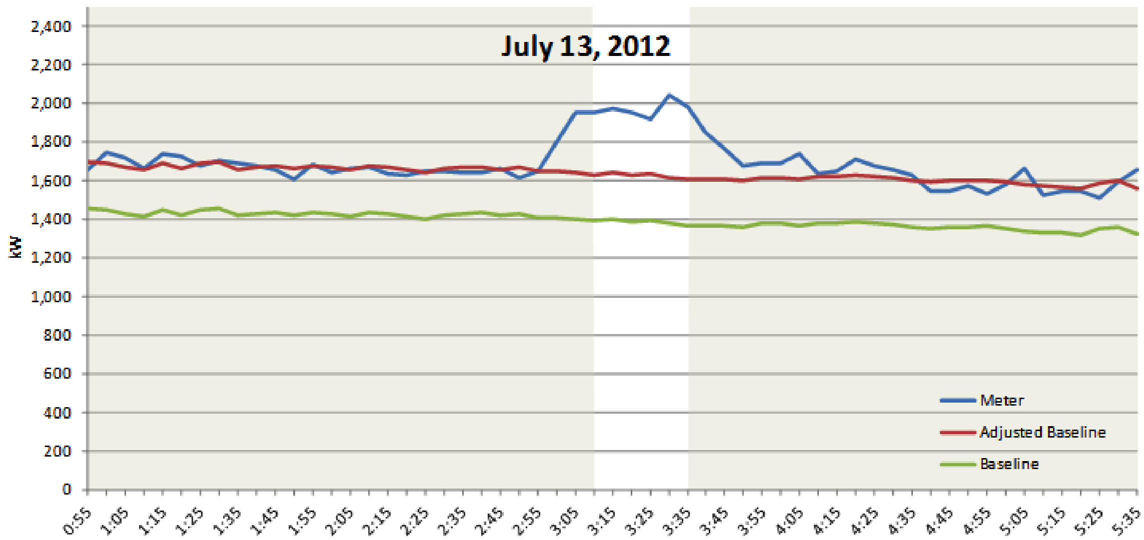

Figure 16: Load profile of a load increase test

Lastly we show a box plot of the average error in response, showing both that some sights respond more consistently as well as the value of a diverse portfolio. In this box plot the central mark is the median, the edges of the box are the 25th and 75th percentiles, the whiskers extend to the most extreme data points not considered outliers, and the outliers are plotted individually. The outliers are data points that fall outside a 99% confidence interval.

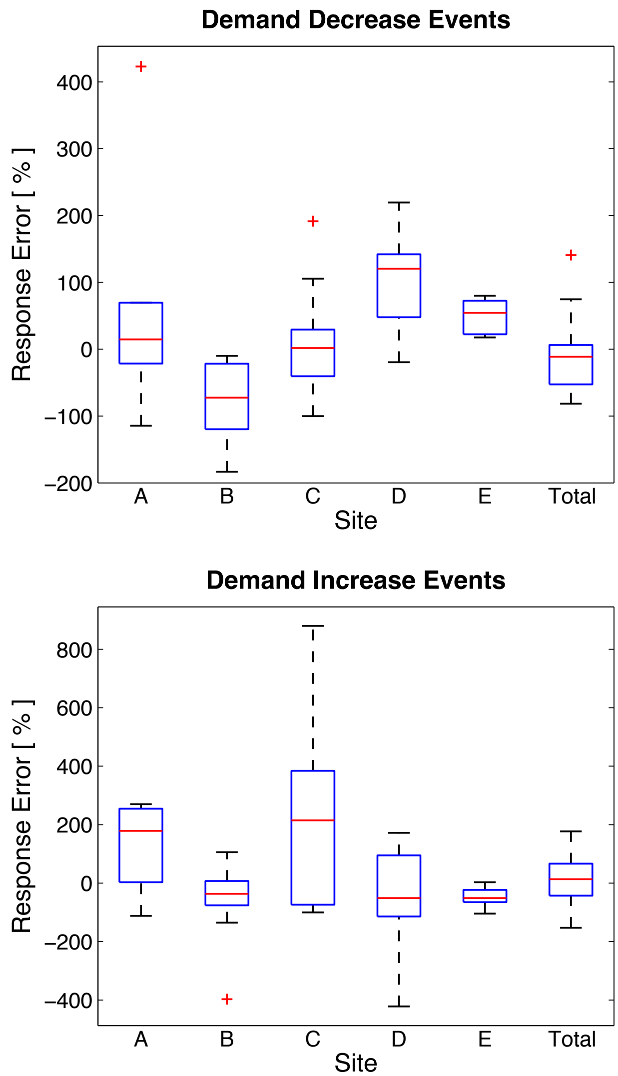

Figure 17: Variability of goal vs. attainment in cold storage DR events

2.2.4 Observations

Phase I testing clearly demonstrated the ability of cold storage loads to provide a load following resource. Despite several obstacles (including risk of incurring demand charges and changing operating conditions at sites), the facilities curtailed and increased load within ten minutes' notice in response to dispatches. Phase I also showed that these loads perform variously depending on their initial state (e.g., number of compressors available to turn on) and the aggregate response varied due to the relatively small sample size of customer sites. That underscored the importance of developing larger portfolios of warehouses that would be able to smooth out resource variability. In addition, more testing may be necessary to help to understand load availability by hour of day.

Response from the sites' managers was positive. Site managers invested significant time cooperating with EnerNOC and Ecofys to explore site capabilities and work through root cause analysis to identify drivers behind underperformance to improve response at their sites. Site managers also showed a willingness to adjust performance parameters, such as increased event frequency per week during Phase II dispatches. Unfortunately, time constraints did not allow exploration of longer event duration with site managers. EnerNOC's experience in other markets indicates capability for refrigerated warehouses to curtail significantly longer than the 30 minutes used for this pilot. The Project's load response incentive was below the market value for the resource provided, even though the demands of the Project tended to be more strenuous than at other sites within EnerNOC's portfolio in other markets. While customers showed the ability to provide more than 200 kW of load management, the incentives were not high enough for the sites to invest in higher levels of response.

The following aspects were extremely important during the Phase II planning stages:

- **Demand charges** – Providing DEC resources (increasing load) was significantly hamstrung by the risk of setting new monthly peaks that would affect the sites' demand charge.
- **Granularity** – The project aimed for 200 kW DECs and 50 to 200 kW INCs, but sites may have been capable of far more capacity. Aiming for only a portion of a facility's load can create perverse outcomes (like the Richland load increasing in response to an INC signal, as discussed in Chapter 4).
- **Further testing** – For Phase II the plan was to 1) test the boundaries of per-site parameters (event duration, response time, etc.) and 2) find a proxy, such as the Balancing Reserves Deployed (BRD) signal, to approximate BPA's actual system need.
- **OpenADR** – EnerNOC, Ecofys, EWEB, UISOL, and SnoTemp collaborated to enable a new facility in Eugene to respond to an OpenADR signal using EnerNOC's OpenADR compliant hardware.

During Phase II, Ecofys and EnerNOC worked to find solutions to the obstacles identified in Phase I, the most significant of which was detrimental peak demand charges resulting from load increase events. It became apparent in Phase I that DEC dispatches would put customers at risk of setting a monthly demand peak, thus exposing them to charges significantly higher than the participation incentive. For example, the monthly demand charge for the Albany sites is $4.70/kW month, more than double the incentive for participation in the pilot ($1.67/kW month). To mitigate this risk, the team worked with the sites in Albany and Forest Grove to reprogram the refrigeration management systems to aim for DEC amounts below the 200 kW cap.

As facility usage dropped during the winter months, the risk of setting a monthly demand peak intensified. At the Richland facility, for example, usage that fluctuated between 500 and 900 kW during the August and September billing periods settled down to a 250 kW to 400 kW fluctuation during the winter months. Such a narrow kW range meant that adding 100 kW of load at any given time introduced significant risk of setting a new monthly peak. Similar trends were observed in the Forest Grove and Albany facilities resulting in a decision not to test DEC dispatches unless the utilities would agree to ignore peak demand data recorded during test events.

The team approached Consumers Power and City of Richland Energy Services (RES) to highlight the challenge and discuss potential solutions that would allow for DEC testing without subjecting the utilities to any risk of setting a monthly peak on their BPA bills. Potential solutions included testing DEC dispatches during the middle of the night when there is zero risk of the utility setting a coincident system peak.

Consumers Power agreed to provide demand charge 'immunity' for testing activity between 11 PM and 4 AM. This was contingent on keeping a monthly record of test dates and times. The agreement further stipulated that no DEC testing activity occurred during the last week at the end of each billing cycle. This scheduled "rest period" for DEC events, allowed Consumers Power time to correlate and adjust their bill data.

RES agreed to allow DEC testing during the night. Specifically, they agreed to allow load increase testing without the risk of facility to peak demand charges for peaks that occur between 9:01 PM and 5:59 AM from June 1 through September 30, 2012. RES facilitated this testing by replacing the meter at the facility with a meter capable of measuring demand based on a historic TOU rate structure, where the new meter could be set to collect separate data for High Load Hour and Low Load Hour demand. RES then ignores any peak demand set during the LLH period when there is no risk of a coincident system peak, and assesses all monthly peak demand charges based on HLH activity.

For the Eugene site, EWEB agreed from the initial project discussion that they would back out any peak demand set during a DEC test. As a result, the team recommenced DEC testing at the Albany facilities during March and April of 2012, and incorporated the Eugene and Richland facilities in DEC testing in May 2012.

Overall, the sites delivered 77% of goal in Phase II. The average curtailment performance was 101% of goal while the average increase was 47% of goals. The Henningsen – Richland facility's curtailment and increase nominations were the smallest of the three facilities participating in Phase II, its responses were the least consistent – particularly during increase events.

During seven of the 10 increase events, the response by Henningsen - Richland was opposite of the desired response. If Henningsen – Richland's response during increase events is disregarded, then the average performance during increase events jumps from 47% to 67%. Again, this problem appeared to stem from a control wiring issue, so if this had been a real program with a pay-for-performance incentive the site would have had greater motivation to rapidly investigate underperformance, or they would have been removed from the portfolio pending further investigation.

Open Automated Demand Response (OpenADR) compliant device systems allow communication between a BPA dispatcher or aggregator and demand response sites using a specific communication standard. Two different types of devices were used at the Forest Grove and Eugene sites during the phase II testing. By utilizing different OpenADR systems at these sites, Ecofys was able to analyze the capability and compatibility of both platforms with established BPA systems and protocols. EnerNOC installed and managed their EnerNOC version of OpenADR equipment at the Eugene SnoTemp facility. Ecofys installed the IC Systems GridLink OpenADR device at the Forest Grove facility.

The GridLink OpenADR device was used during the latter part of phase II testing at the Forest Grove site. Although OpenADR compliant, this system operated differently than the EnerNOC system. The use of the communication registers and system protocols between UISOL and the GridLink system varied from the protocols between UISOL and the EnerNOC system. This was due in part to the differing control strategies at the two pilot sites.

Enabling the GridLink system at the Forest Grove site was not as simple as swapping out different brands of communication equipment, but ultimately provided an effective method of enabling demand response at this facility. It required time to understand both the capability of the GridLink system and how to most effectively manage it. Data from the Forest Grove site is in the process of being collated and analyzed and will be included in the addendum to this report which is scheduled to be delivered at the end of December along with the extended Carina pilot data. It should be noted that the Forest Grove facility responded well during the test events and performance was consistent with the other higher performing sites in this demonstration.

The user dashboards for both the EnerNOC and IC Systems (GridLink) equipment are effective, capable and user-friendly interfaces. The GridLink system (see figure 14 below) while typically operating in a fully automated process allows the user the option of manually creating an INC or DEC event. In addition, the dashboard informs the end user of the current status of the system. Among other things, it warns the end user of pending events and displays current system energy use and total KWH consumed.

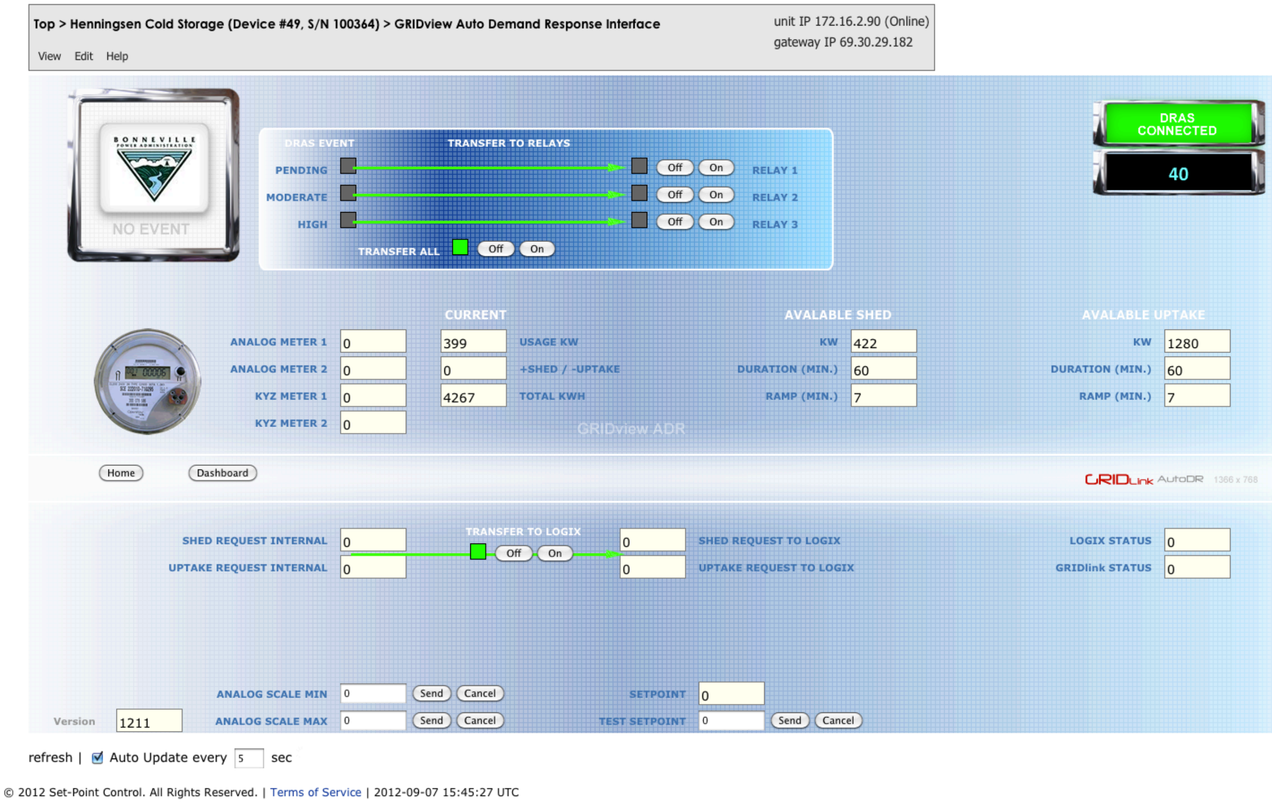

Figure 18: GridLink user interface

The EnerNOC portal (see figure 15 below) is designed more for monitoring purposes than anything else. It allows the user to view energy usage in a graphical manner, adjust which meters within the site are shown and gives an excellent historical usage graph for baseline comparison purposes. However it is not designed as an interface for initiating events.

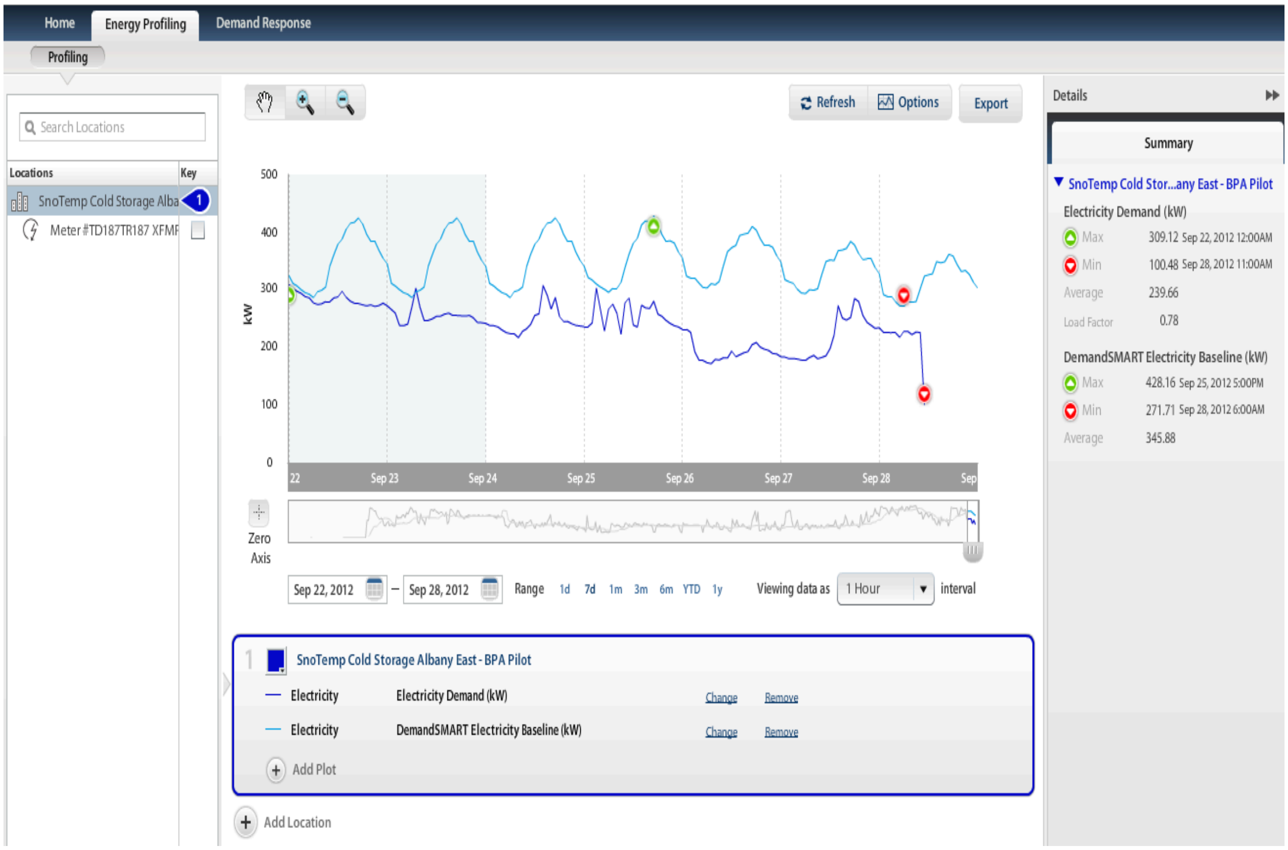

Figure 19: EnerNOC DemandSmart portal

2.2.5 Conclusions

Many important lessons were learned from this pilot. The following summary highlights the most important ones:

- First and foremost, participating sites proved that refrigerated warehouse loads are capable of responding to frequent dispatch signals for up and down load control., Performance was highly variable due to the small size of the portfolio, but on average the sites delivered at 77% of expectation in Phase II.
- While the performance from Richland was particularly volatile, overall the portfolio consistently delivered both INC and DEC performance. Building off of the Phase II results and EnerNOC's experience in other markets, we anticipate that a 10 (or larger) MW resource would be able to reliably deliver both INCs and DECs with a high degree of predictability and reliability even with variability in site loads due to seasonality, operational needs and maintenance events.
- For frequent, automated load control, investment in advanced refrigeration control systems and subsequent programming made a difference, particularly when targeting specific kW increases or decreases.

- Even with automation, participation requires routine involvement from facility staff to ensure load control scripts reflect seasonal refrigeration programming changes. Additionally, site managers are critical for the performance of root-cause analysis stemming from underperformance.
- Performance incentives alone ultimately must motivate facility staff to invest time and energy in program participation. By the end of this pilot, facility staff was somewhat fatigued in part because financial incentives were not tied to performance.
- Sites are periodically unavailable for planned and unplanned maintenance. In some cases sites were offline for weeks at a time to perform compressor maintenance.
- One site that had not participated in events for an extended period of time found it difficult to respond to events initially due to a lack of practice and equipment readiness.
- The event responses by several sites were smaller than anticipated due to equipment failure or the inability of the control system script to deal with the existing refrigeration load during events. In some cases, compressor interlocks or pressure set points were inappropriate for the event conditions. This may point to additional testing of individual sites considering participation in future programs to ensure they are able to react to the event and handle the existing refrigeration loads without failing.
- Site loads vary by season. For this portfolio, significantly less load was available for INC (load decrease) in the winter than the summer, and vice versa when it came to DEC (load increase).
- It is important to understand each site in terms of product mix, types of operations being conducted (warehouse storage, processing and freezing, etc.) and overall operational needs. These factors can heavily influence the performance of a site even when seasonal factors and maintenance are taken into consideration. An example of this would be that one of the warehouses actually increases load during the month of October has it has a large amount of product to process and freeze. This runs counter to the typical expectation that cold temperatures translate to lower power usage.
- Alignment across participants and stakeholders is crucial. Peak demand charges were a great example – while BPA was interested in seeing results of the pilots, customer demand charges created a disincentive for sites to add load. Aligning utility, customer, and system interests will be key to developing a full-scale program.
- Both EnerNOC and IC Systems OpenADR platforms performed well. Either technology can be used separately or in unison over multiple sites in a portfolio of assets to provide significant demand response capability.
- Cold storage provides a large INC and DEC capability but is not instantaneous in responding to events, as compressor loading and unloading must occur in stages to prevent damaging the refrigeration equipment.
- Cold storage demand response capability has a lower cost per kilowatt of response than other DR technologies discussed in this report. It is however not as fast acting nor as predictable as hot water heaters due to equipment ramping, seasonal variability and weather conditions.

2.3 Steffes ETS Furnaces and Water Heaters

Figure 20: Installed 105 gallon water heater with Steffes mixing valve and interactive controls

2.3.1 Computer Modeling

Spirae produced two reports over the course of the project, the first focusing on quantifying the balancing services which could be expected from an average water heater EWH over the course of a random week, and the second doing an in depth examination of the feasibility of deferring a transformer upgrade on the Freedom line within Lower Valley Energy (LVE) territory.

Spirae modeled a high-penetration network of “smart charging” EWHs and conducted simulation studies to examine the potential benefits and limitations of demand response (DR) with respect to three perspectives: the transmission services level, the distribution utility’s level, and the consumer level. In particular, their studies sought to examine the potential to shift peak hour loading to off-peak hours and to quantify the network’s capability to respond to the BRD signal (see figure 5).

The simulation study assumed that the distribution operator had some discretion in deploying their assets, i.e., the fleet of EWHs, and did not need to respond to small deviations from zero of the balance reserve deployment (BRD) signal, both to more accurately mimic how an operator might deploy the resources and to prevent the EWHs from "saturating."

Their key results are summarized as follows:

- Deployment of "smart charging" EWHs has a positive impact on the load profiles at each node within the network. In particular, there are significant shifts of peak hour loading to non-peak hours and the overall load profiles are "flattened," i.e., the extreme loads (both the peaks and troughs) are smaller in magnitude relative to the mean load.

- Peak load management (PLM) is critical to guarantee protection of network nodes from over-loading.
    - Peak loads in excess of 100% capacity observed during simulation in the absence of PLM are successfully reduced in both magnitude and duration, thereby protecting the system assets.
    - The following figure illustrates the peak load management at two nodes in the simulation network; the red lines indicate unconstrained loading and the black lines assume PLM being employed.

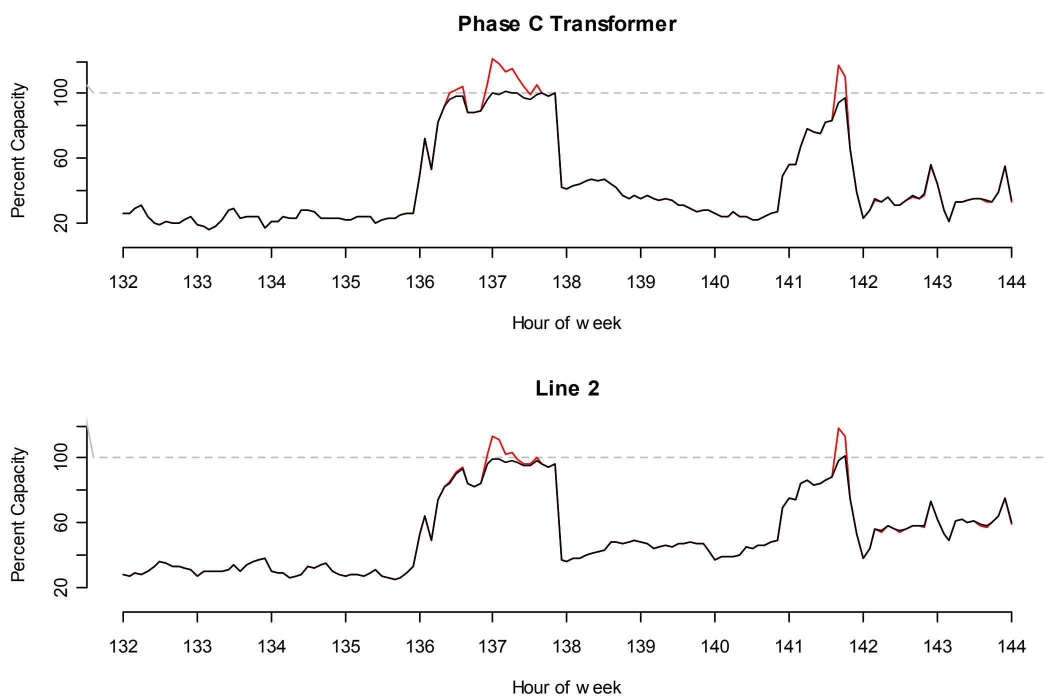

Figure 21: Spirae Peak Load Management

- As implemented, the 8 hour off-peak charging schedule (Steffes control) was able to maintain water temperatures in excess 110°F for 93% of the time assuming a 24 hour BRD dispatch and for 70% of the time assuming an 8 hour off-peak BRD dispatch (105 gallon EWHs).
    - This result was likely due to an artifact in the model implementation and may require further investigation. However, improved results are likely given that the temperature band did not rise near the saturation point of the EWH (170 degrees) in our testing which suggests opportunities for tuning.

- The available INCS and DECs are strongly dependent on the charging scheme; most importantly how many hours per day are used for charging the EWH. Denser charging plans lend themselves to more INCs and less DECs. Striking a useful balance will depend on the economics and transmission constraints on any given system.
    - Additionally peak load limiting had a negligible effect on INCs and DECs available, a positive result.

In Spirae's second analysis the Project took a more narrow focus on the Freedom line within LVE territory. The goal was to examine how adding the previously modeled EWHs might defer the need for an upgrade to the Freedom line. The line was trimmed to ease modeling, after which simulations over the next few years tested how much benefit the transmission operator and the utility might see.

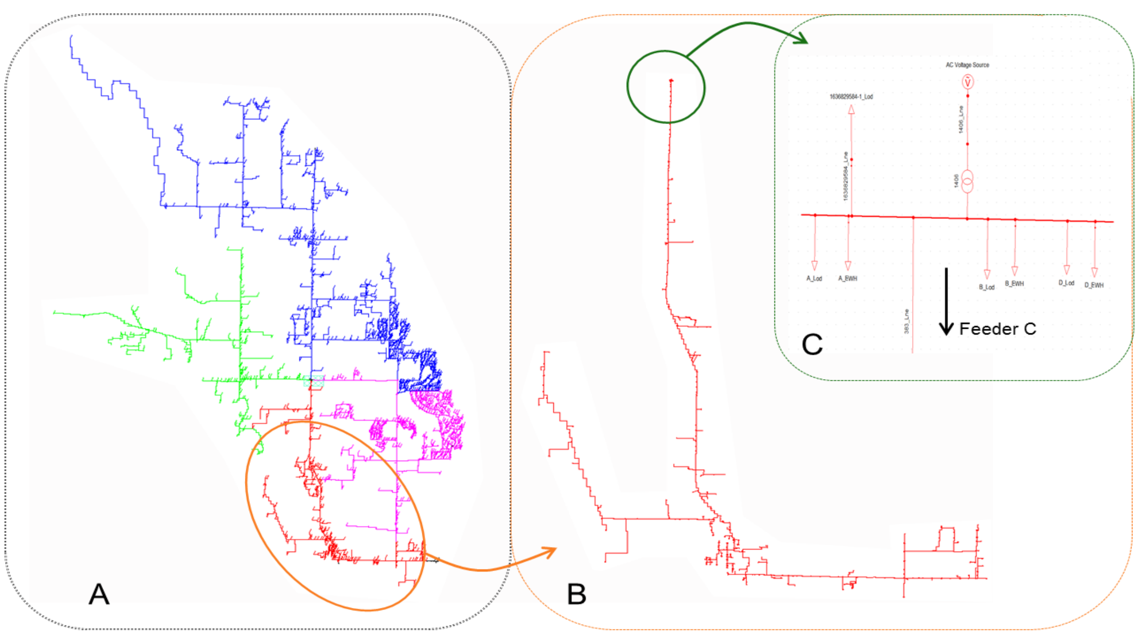

Figure 22: Spirae's Trimmed Feeder Line

Spirae's results were not as encouraging, here. They found that although the EWHs showed the ability to defer transmission upgrades at least through the winter of 2014 and potentially into 2015, results diminished after that. However the modeling did not include ETS furnaces and the charging strategy did not attempt to pre-charge. With both of those included we expect the results might have been better, potentially enough to try rerunning the scenarios. Spirae noted that these results are at odds with field-testing with conventional water heaters and simple timer switches performed by LVE during a pilot program in 2011/2012.

Throughout the course of the modeling Spirae found that it was possible to do a significant portion of the charging of EWHs in response to DEC events. Field-testing by Steffes backs this up. It is worth noting that both Spirae and Steffes base these results on somewhat simplistic charging strategies. The project team is confidant that more advanced methodologies will lead to better results.

Spirae also notes:

From the perspective of the distribution utility, the results of the simulations are less than dramatic, with only a modest reduction in peak load and time over peak threshold even at the highest penetration level. This result stands in contrast to Lower Valley Energy's experience during the 2011/2012 winter season, when a pilot program for dispatching conventional water heaters (with a penetration level comparable to those studied in the experiments) showed promise for peak load reduction. To explain the apparent discrepancy, it should be noted that the simulations performed could were limited by the data available in three important ways:

1. Water usage profiles were not captured in the modeled territory at the time of the modeled peak load week. In particular, the water usage peak may not align correctly with the substation load peak.
2. Resolution of substation load profiles (1 hour) did not match resolution of water usage profiles (5 min)
3. Finally, when the limited number of available water usage profiles were averaged the results were not smoothed before they were used to adjust the uncontrollable portion of the loads for those customers with a deployed EWH.

Thus, the benefit of the controllable load was not fully realized in the simulation. Nonetheless, the experiments do show that coordinated load control could successfully extend the life of the substation transformer through the 2013/2014 peak load season.

As both Spirae reports are lengthy they are not included here but are available on request.

2.3.2 Steffes Water Heater Results

Initial results from Steffes immediately showed that it was possible to charge the EWH at times when the BRD was negative, corresponding to times with excess generation. Initial Steffes control was purely proof of concept, showing that the Steffes EWH units could respond rapidly to the changing BRD.

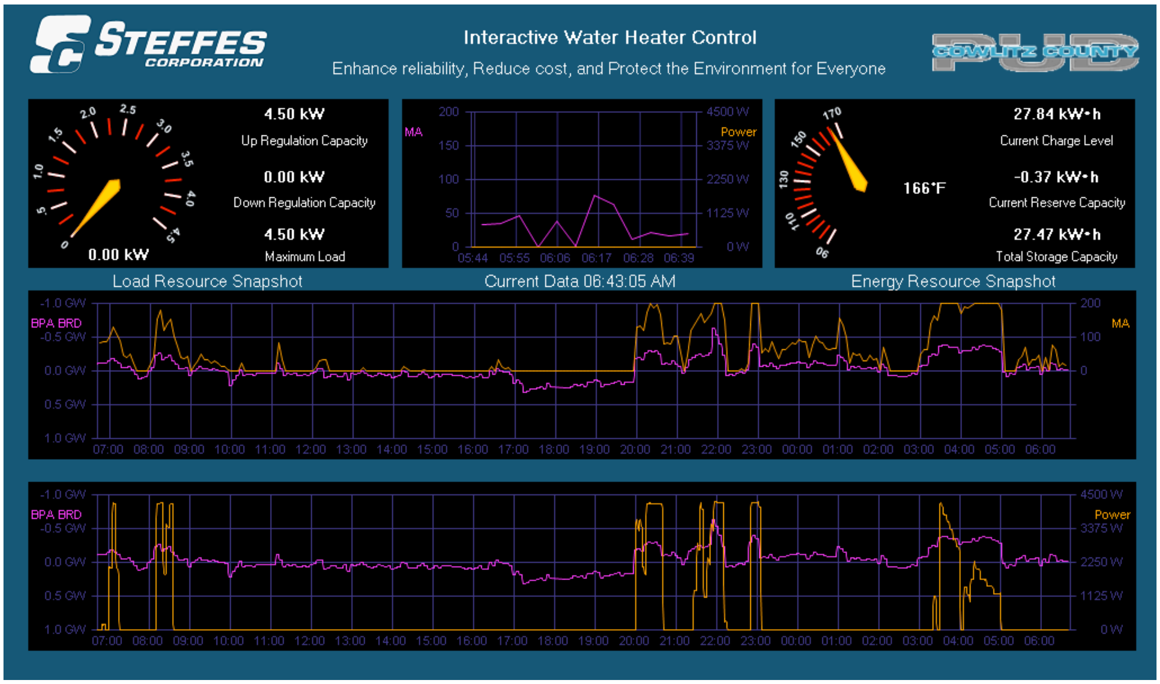

Figure 23: Early Steffes Control

Steffes deployed several different control strategies over the course of the project. Only Dynamic Dispatch, which was only deployed to several units for test purposes only, used any direct pre-charging of EWHs to limit charging during high load hours. As such it is difficult to make strong statements about the effectiveness of pre-charging. One can see from Spirae modeling that there are definite benefits to the utility. These benefits may be less than initially anticipated, however.

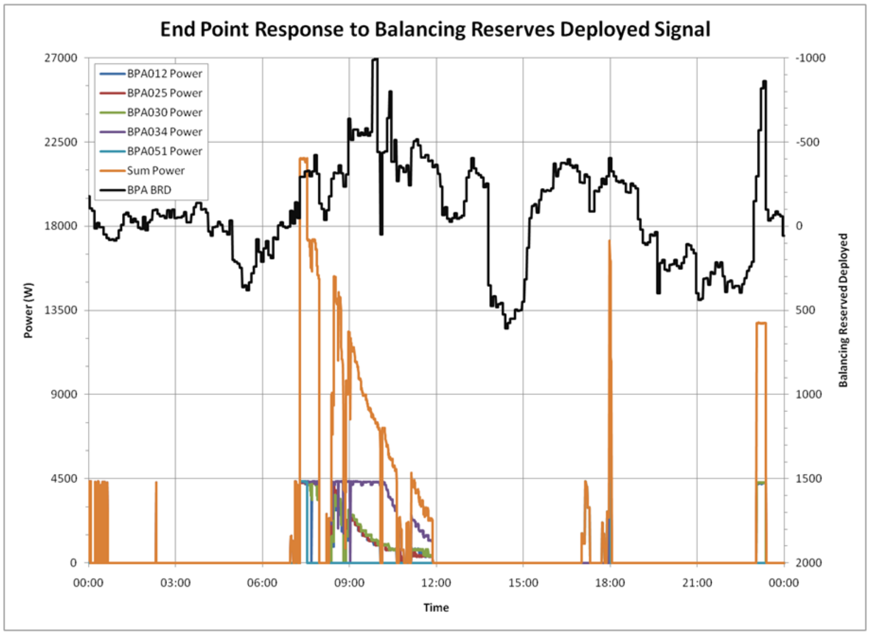

Figure 24: BPA Quick Control

From these charge rate graphs below one can observe several things.
First, the units can be very effective at providing rapidly providing DECing service. We can see that the 5 units together provided nearly 22.5 kW, almost 4.5 kW per unit. Secondly, though they may have very good quick response capabilities, they are limited in their total energy storage capabilities, and thus may not provide long-term responses. Still, if used judiciously we see that we could have easily provided 3 kW of response per unit for an hour.

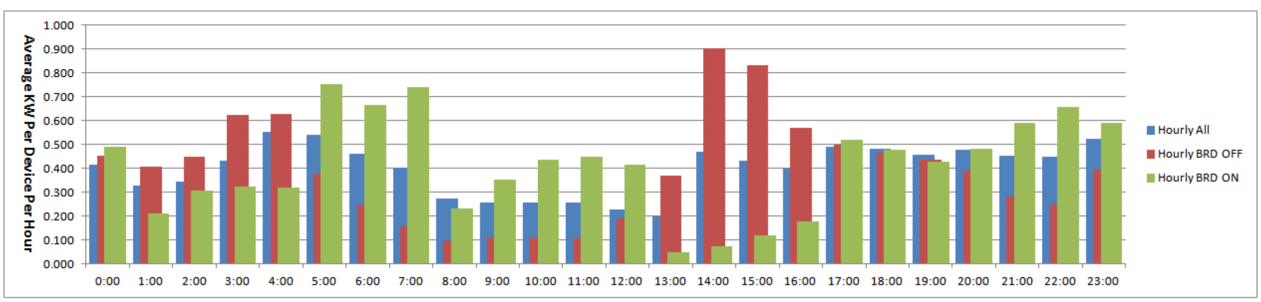

Figure 25: Steffes electrical use by hour with and without BRD

Note from this figure that the BRD ON energy use does a very good job shifting energy out of the traditional heavy load hours. This graph seems to correlate loosely with the average BRD signal compiled by Ecofys.

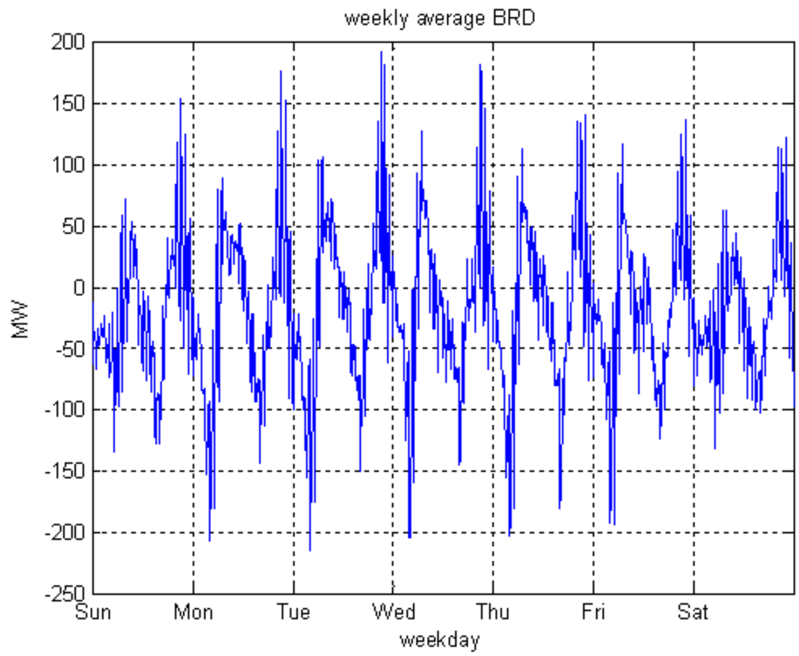

Figure 26: Average BRD by day and hour

Note that this graph does not have a very high statistical significance, but it still is interesting.

Additionally Steffes found that the EPRI model of water heater use does not match perfectly with usage patterns that we observed during the course of the project. Usage was later in the day. The project does not have a large enough sample size to definitively say that our data is completely correct, though, especially when planning for the availability of a balancing fleet.

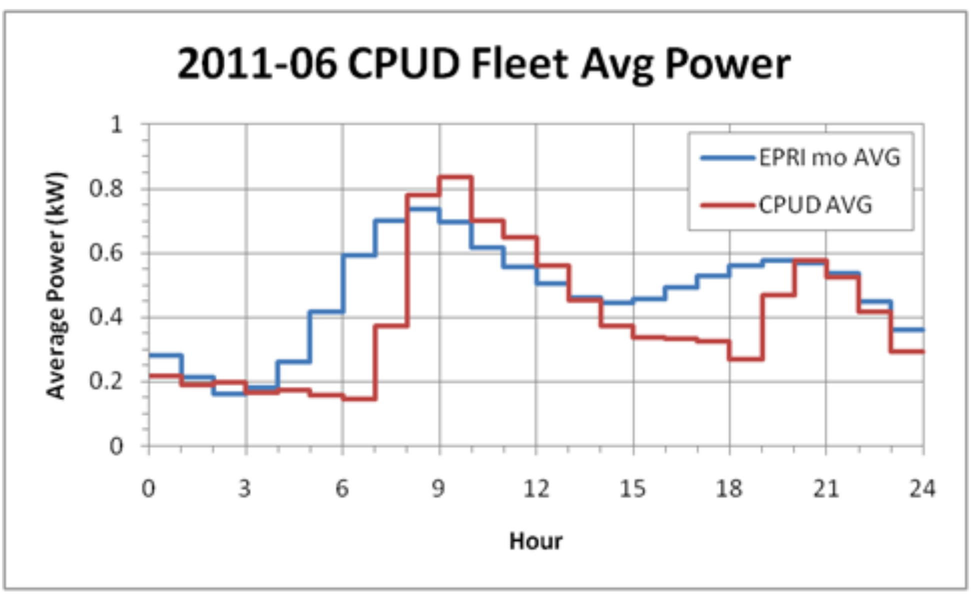

Figure 27: Average power by hour of day

Note from figure 25 that currently there is not a lot of energy use during the evening. However, with a control scheme that moves the load out of peak hours, such as Dynamic Dispatch, the newest Steffes control scheme, more load would be available in low load hours for balancing purposes and less load would stress the transmission system during high load hours.

Additionally it is easy to imagine setting the control schedule such that there is next to no load in some pre-defined high load hours, say 8 AM to 12 PM. Some charging might be allowed after that time, around 0.5 kW, all of which could be used easily for an hour long INC.

Conservatively we can say that this project shows that each EWH has the potential to provide 2.5 kWh of load shifting and at least a 3 kW DEC or 0.5 kW INC during non-load shift hours, each for an hour. That is using these as one might use a more traditional DR resource. They could be used to respond very quickly to an INC or DEC, providing time for a slower resource to come online. In addition their ability to provide frequency regulation is intriguing, but beyond the scope of this project.

Steffes enabled one EWH in EWEB territory with Dynamic Dispatch (See Appendix A) near the end of the project. Results were very encouraging.

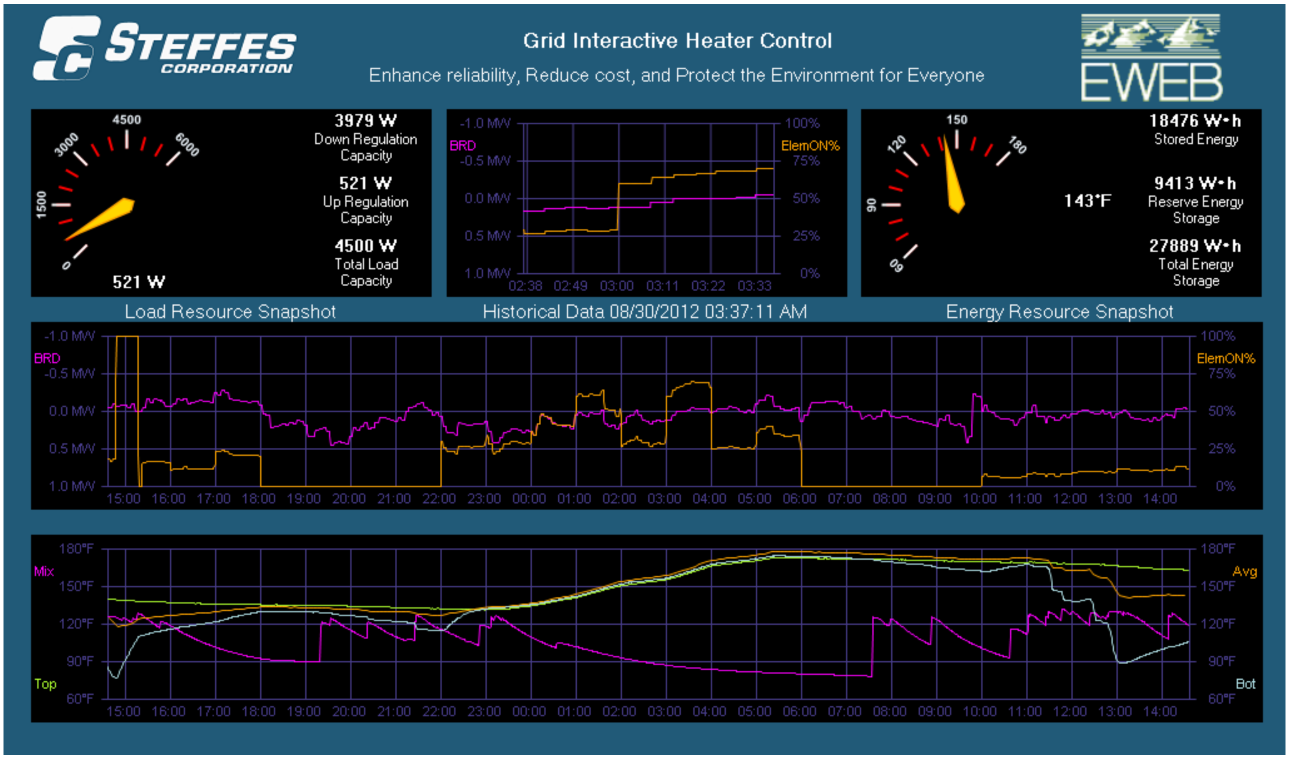

Figure 28: Steffes Dynamic Dispatch

The figure above shows Dynamic Dispatch in action. There are two blackout times in which no charging occurs and one can see that the charging that does occur during allowed hours is based on the BRD but scaled by a pre-set factor for each hour. This lets an operator effectively pre-schedule the load, a very interesting development.

2.3.3 Steffes Electric Thermal Storage results

The Project also involved several Electric Thermal Storage (ETS) furnaces built by Steffes. They present a very interesting opportunity for areas with high heating needs and time of use rates, as they provide the ability to preheat ceramic bricks that are then used to heat a building during the day with little further electrical use. Each unit has a large storage load, 180 kWh with peak input of 28.8 kW. This may allow for large utility benefit with load shaping and the ability to INC and DEC during the nighttime charging hours.

Ecofys worked on creating an ETS model in MATLAB to better understand the devices and for potential modeling efforts in the future.

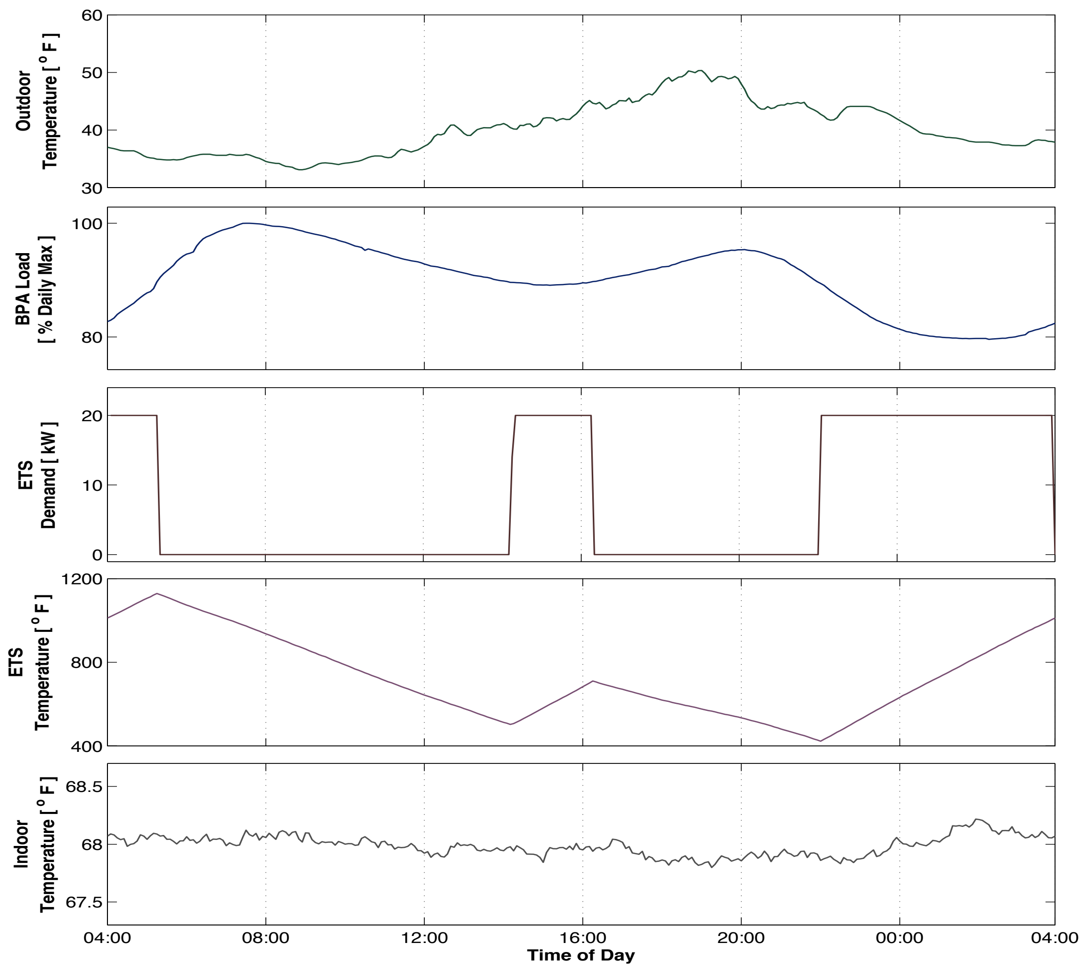

Figure 29: ETS Furnace Model

Unfortunately The ETS furnaces are a very seasonal resource. The project did not have a robust control scheme in place for the 2011-2012 heating season, so there is no data to include at this point. Instead the ETS portion has been extended through the 2012-2013 heating season to better understand the resource.

2.3.4 Conclusions

- EWH units are very good at responding rapidly to a control signal. It is not hard to imagine a fleet of units being deployed for frequency response purposes. Although this is less of a priority for an entity like BPA with a huge hydro resource, nonetheless the speed of response is exciting.
- Program costs for implementation of interactive water heater controls need to be considered. There are costs associated with marketing and maintaining customer relations. These costs are expected to decrease with expanded program deployment and if controls are integrated into water heaters at the factory.
- In this early trial certain add-on components, most particularly the netbook computers (used for default data collection and communication) proved unreliable. The number of equipment failures

contributed to the larger than anticipated staff requirements. The Gen 2 controllers have eliminated the netbooks, which will eliminate the hard drive and battery equipment failures. The new systems will use Ethernet connections instead of wireless. This will also improve reliability.

- The new Dynamic Dispatch control was outside of the project scope, but we were able to do some small scale testing. The results were highly encouraging, as it will allow for choosing which hours to do the bulk of the charging while also allowing balancing.
- Dynamic Dispatch shows very interesting promise for pre-scheduling the load. The operator could actually choose when and how much energy the end use loads use, an extremely exciting result.

2.4 Carina Water Heater Controls

The Carina WISE control system operates under a different set of protocols than the Steffes system. The maximum water temperature stays at the typical water heater setting of 125-135 degrees Fahrenheit. In the Carina system, demand is largely moved into the hours around the utility's peak morning and afternoon hours by maintaining normal water heater temperatures prior to the peak periods and allowing them to fall through the peak hours. As the Carina WISE does not require mixing valves, end users will experience the temperature range normally exhibited by the water heater thermostat settings. Carina's WISE solution utilizes temperature settings to ensure consumers have hot water while maximizing the load shifted and stored.

The Carina system currently allows for real time monitoring of the temperatures of the units, but only allows for control strategies to be downloaded once per day. As a result the Carina units are currently not suited for response to real-time needs of the grid.

The lower temperature range reduces the overall thermal storage capability of the system compared to the Steffes controllers, which are designed to operate at temperatures up to 170 degrees Fahrenheit. Building codes in most areas do not require the use of mixing valves or expansion tanks due to the lower operating temperatures. This in turn, reduces the installation costs in comparison to the Steffes system, as fewer parts and labor are required. However it is highly important that any entity considering deploying these units understands the building code where they intend to deploy. Due to the sensitivity of implementing a pilot program and avoiding potential end user safety concerns, EWEB installed mixing valves and expansion tanks on all of their Carina installations. Another important difference in the Carina system is that it was limited in responding only to INC events (decreased demand). Without mixing valves the WISE units did not have the capability to artificially absorb energy during DEC events (increased demand). Future enhancements to the Carina system may allow for responding to DEC events.

The Carina WISE devices move load by responding to a utility defined control schedule, based on peak load periods, and optimize the hot water availability to the consumer by creating a "Zero Discomfort" scenario. Currently WISE devices are set for two control periods, based on utility preference and requirements, during which the water temperature is generally allowed to drop. Outside of those control periods the EWH load is feathered back in as groups to prevent large bounce-back (rebound) to the utility load. The intelligent feathering application can be matched to the daily load shape given 24 hours notice in advance.

For the purpose of this study and evaluation, the 30 Carina WISE controllers were controlled by the following schedule (Figure 30), which consisted of EWEB's Winter Control Schedule.

Control Strategy Name	EWEB Winter Control Schedule (November 1 through April 30)			
Control Period	Start Date	11/1/2012	End Date	4/30/2013
Control Time (Schedule A)	Start Time	7:00	Stop Time	11:00
Control Time (Schedule B)	Start TIme	17:00	Stop Time	21:00
Non-Peak Temp Threshold Settings	Top Temperature	135	Bottom Temperature	135
Peak Temp Threshold Settings	Top Temperature	110	Bottom Temperature	51
Control Time Exceptions	Control Weekends	No	Control Holidays	No

Figure 30: EWEB Control Schedule for Carina Controllers

Figure 31 illustrates the energy usage of a conventional electric water heater that is not subjected to control. In the illustration, red represents the measured demand of the electric water heater over a two day period. The measured demand is evident during the course of the time period, with the load represented during water heater usage. The small usage intervals that are shown between the demand spikes represent normal water heater 'maintenance' where the electric water heater is maintaining its hot water temperature. The blue line on the graph represents the temperature at the top element, and the yellow line represents the temperature at the bottom element. These measurements are important characteristics of Carina's patented WISE solution because temperature is monitored to maximize the results of the WISE switch, but also to ensure that the consumer doesn't experience cold water. By monitoring the temperatures, Carina can turn off the WISE load control switch for optimum periods of time, often much longer than traditional 3 hour industry standards, yet continue to ensure minimal to no discomfort for the consumer.

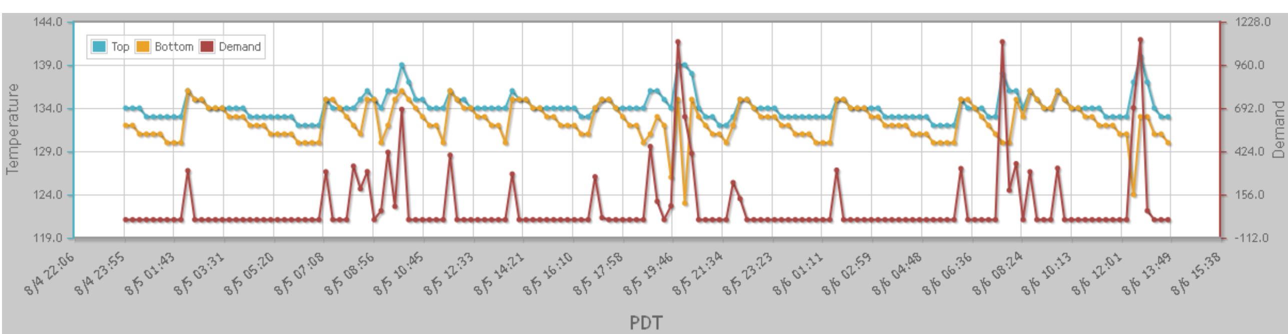

Figure 31: Energy usage for conventional water heater

Figure 32 illustrates the operation of the Carina WISE solution during a shifted load event. By comparison to Figure 31, it is possible to see that the electric water heaters are turned off for long periods of time, across the entire peak period, and then reactivated after the peak period has ended. The yellow line represents the water temperature at the bottom of the water heater tank, which decreases. The blue represents minimal temperature degradation at the top of the water heater tank, which ensures the consumer maintains hot water during the peak reduction event.

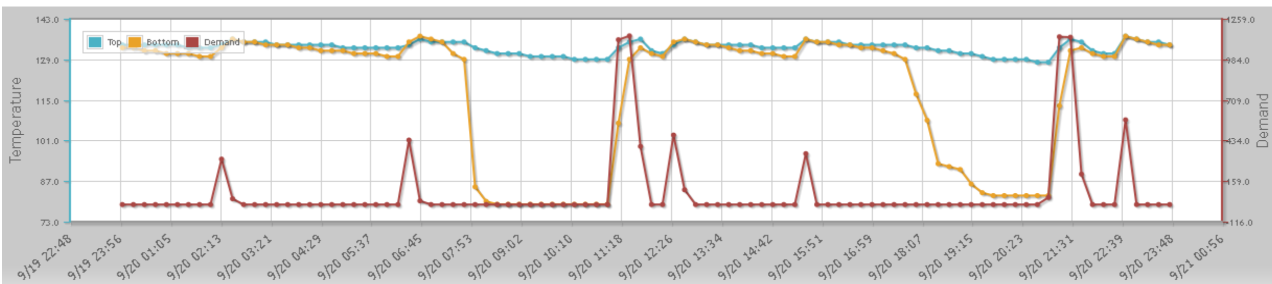

Figure 32: Shifted load with Carina controller

It should be noted in Figure 32 that the large red spikes reflect the rebound that was generated when the water heaters were turned on after the peak period ended. In order to mitigate the effect of the rebound spike, which is often caused by traditional and AMI load control switches, Carina has developed proprietary firmware and software algorithms that 'feather' the rebound by turning water heaters back on in stages. By 'feathering' the load back onto the grid, Carina can turn on water heaters based on immediate need versus later requirements for consumer hot water. Therefore, the added load onto the grid is spread over a longer period of time, creating a gradual load increase on the electrical grid. The feathered load can not only avoid an artificial rebound, but can be utilized to meet the needs of the generator to 'flatten' their daily load shape and avoid costly generator turn downs.

A beneficial attribute of using software to manage the daily load shape, beyond simply shifting the load to off peak, is to use the data derived from the demand and temperatures to apply, or store, load during an off-peak period. By using data analytics applied to the information measured by Carina's WISE solution, utilities can choose when they want to add load during off-peak hours.

Carina has explored programming ETS units for much longer periods of shifting, with the units trying to defer charging from 3 PM to 3 AM in other projects. For this project we tried the same time frame to see just how long an ETS could coast. As the unit has a customer comfort setting built in there was some energy usage to maintain sufficient hot water, but overall there were not problems with the longer duration.

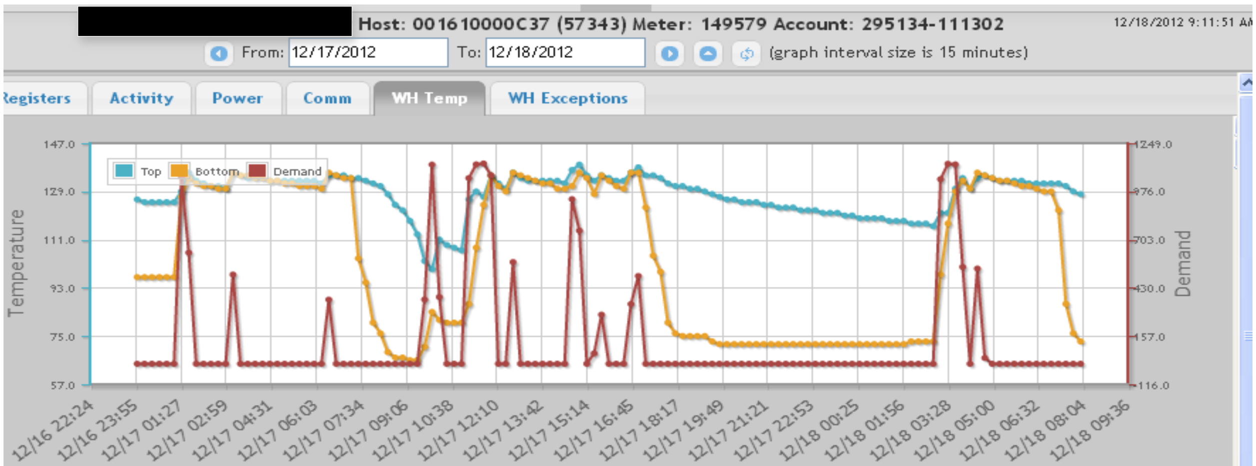

Figure 33: Carina WISE – Shift and Store – EWEB 12/17/12 – 12/18/12

In figure 33 above, note that the Carina WISE unit is controlled from 5pm to 3am. Energy is applied at 3am which provides over 3kWh in a 45 minute time frame (shown in green, note that units are Wh, so at just over 1,100 Wh in 15 minutes the EWHs are fully on) of load to add to the off-peak period. Due to the flexibility of the WISE solution, load can be added at any time as requested by BPA, which is noted in the temperature and load logs below in figure 34.

Dec 17 2012 4:55PM	137	135		Relay Disconnected
Dec 17 2012 4:55PM	137	135		Heating Element Off
Dec 17 2012 5:00PM	138	136	497	
Dec 17 2012 5:15PM	135	123	0	
Dec 17 2012 5:30PM	135	105	0	
Dec 17 2012 5:45PM	134	99	0	
Dec 17 2012 6:00PM	132	80	0	
Dec 17 2012 6:15PM	131	76	0	
Dec 17 2012 6:30PM	131	75	0	
Dec 17 2012 6:45PM	130	75	0	
Dec 17 2012 7:00PM	130	75	0	
Dec 17 2012 7:15PM	129	75	0	
Dec 17 2012 7:30PM	128	73	0	
Dec 17 2012 7:45PM	127	72	0	
Dec 17 2012 8:00PM	126	72	0	
Dec 17 2012 8:15PM	126	72	0	
Dec 17 2012 8:30PM	125	72	0	
Dec 17 2012 8:45PM	125	72	0	
Dec 17 2012 9:00PM	125	72	0	
Dec 17 2012 9:15PM	124	72	0	
Dec 17 2012 9:30PM	124	72	0	
Dec 17 2012 9:45PM	123	72	0	
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Dec 18 2012 1:15AM	119	72	0	
Dec 18 2012 1:30AM	118	72	0	
Dec 18 2012 1:45AM	118	72	0	
Dec 18 2012 2:00AM	118	72	0	
Dec 18 2012 2:15AM	117	73	0	
Dec 18 2012 2:30AM	117	73	0	
Dec 18 2012 2:45AM	117	73	0	
Dec 18 2012 3:00AM	116	73	0	
Dec 18 2012 3:01AM	116	73		Relay Connected
Dec 18 2012 3:01AM	116	73		Heating Element On
Dec 18 2012 3:15AM	121	98	1045	
Dec 18 2012 3:30AM	121	117	1132	
Dec 18 2012 3:45AM	130	129	1129	
Dec 18 2012 3:52AM	135	134		Heating Element Off
Dec 18 2012 3:53AM	135	135		Relay Disconnected
Dec 18 2012 4:00AM	134	133	548	
Dec 18 2012 4:15AM	130	130	0	
Dec 18 2012 4:21AM	130	129		Relay Connected
Dec 18 2012 4:22AM	130	129		Heating Element On
Dec 18 2012 4:30AM	134	136	539	
Dec 18 2012 4:30AM	135	136		Relay Disconnected
Dec 18 2012 4:30AM	135	136		Heating Element Off
Dec 18 2012 4:45AM	135	135	33	
Dec 18 2012 5:00AM	134	134	0	

Note: Controlled from 5PM to 3 AM - No customer discomfort Lowest top element temp 116

Note: over 3KW available for valley or for DECS

Figure 34: Carina WISE – Shift and Store – EWEB Log File – 12/17/12 – 12/18/12

For the study, utility and consumer participation adversely affected the opportunity to fully evaluate and study the capabilities of the Carina WISE controllers. It was difficult finding pilot sites for the Carina controllers. This was due to several factors. First, the incentive to the customers was limited to a gift card and did not include a new water heater. Considering the disruption during installation to the customer, this was not typically a significant enough incentive. Second, the potential benefit to the utilities was not as great due to thermal storage limitations and unidirectional load change. Another difficulty was that the controllers could not operate in a 3-phase circuit. Several educational institutions would have participated but were unable to do so due to this equipment incompatibility. Another problem incurred was austerity cuts to public utility budgets. One utility backed out of the program due to this reduction of funds.

Conclusion

The Carina controllers are a high quality resource for reducing peak demand from water heaters. The controllers are reliable and do not require the use of a laptop to operate and can be controlled by cellular communications or through the consumer's internet connection. The installation cost savings was lower than was hoped for due to the use of mixing valves and expansion tanks. The amount of load that could be shifted was slightly higher than expected, but as there is no ability to preheat the water the overall thermal storage capacity was less than the Steffes units.

As the BPA TI 220 project is directed toward thermal storage applications, not something the Carina WISE system is originally designed to do, coupled with only one utility participant; the Carina units did not show as much promise as initially hoped. In November and December of 2012 Carina began applying storage algorithms on weekends with very encouraging results, however. Further studies with more advanced control strategies might show a much wider range of benefits than we saw during this project

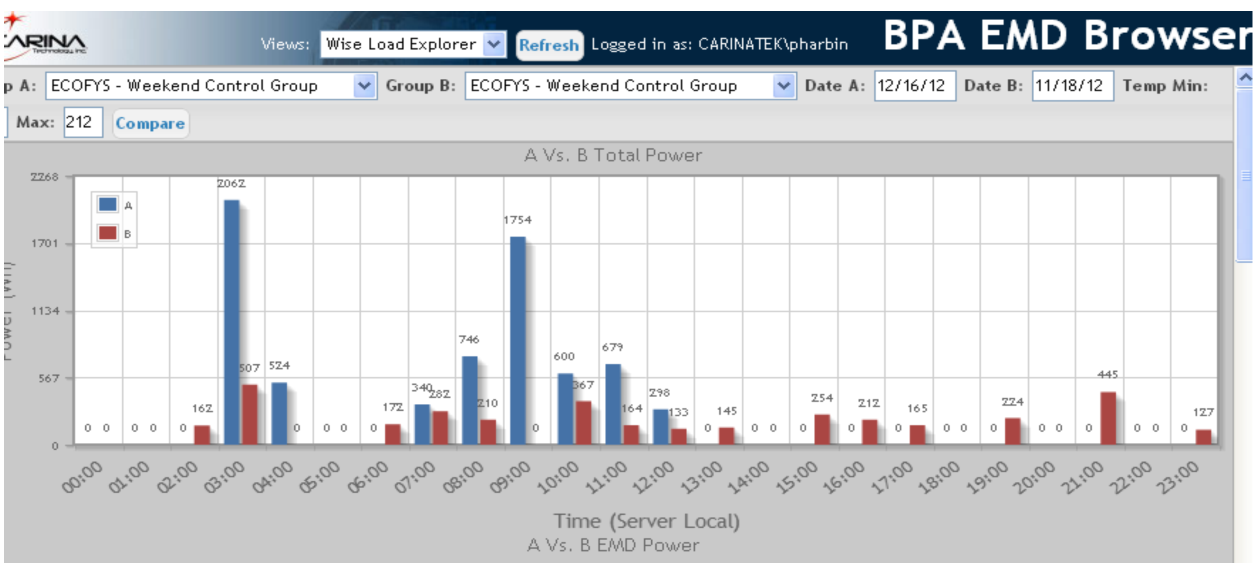

Figure 35: Carina WISE – Weekend Store

The screenshot in figure 35 above illustrates the benefits of weekend control for Carina's WISE solution. In this chart, there is a comparison of weekend control versus non control during the 'valley' period of 3am to 5am. The red bars represent no control for the entire day of Sunday, November 18, 2012. The blue bars represent controlling the electric water heater from 5pm to 3am, and energizing the load at 3am. This yields over 2.0kW of load on December 16, 2012. Again, as previously noted, Carina's WISE solution has the flexibility to shift and store loads at different time periods for different groups.

The relatively lower storage capability combined with shaping much of the load out of peak usage hours results in a lower availability (fewer hours in a day) when the Carina systems can also provide a response to INC events. Despite these limitations, the Carina system is able to reduce utility peak demand and provide INC services outside those few peak hours of the day at a somewhat lower cost than the Steffes system.

The ability to defer the load back on to the grid until as late as 3 AM is interesting to observe; it shows strong potential for future developments. If the Carina system had the ability to change control strategies more dynamically the ETS units could add that load back in at the time that it was most useful for the grid based on current operating conditions. With a large enough fleet of EWH units it would be possible to provide a nighttime DEC for an hour or more.

The overall ability of the Carina WISE units to provide balancing services is currently still under investigation, but at present they are not programmed to do so in a rapidly responding manner. The ability to support balancing services is slated as a future enhancement to the Carina WISE solution, which will incorporate similar intelligent software control algorithms as those applied to the current product.

2.5 Cypress Wireless Pneumatic Thermostats

System operation and pilot site background:

Traditional pneumatic thermostats are manual devices with no functionality for remote readings, diagnostics, or set point control. The most common option for upgrading the older technology involves replacing the system with newer Direct Digital Control (DDC) systems that tend to be costly, time-consuming and expensive to install.

Cypress Envirosystems' Wireless Pneumatic Thermostat advertises similar functionality as DDC thermostats but can be installed in as little as 20 minutes for a fraction of the cost. Unlike DDC systems, the Cypress devices give building operators the flexibility to retrofit only selected zones rather than an entire building all at once. In addition to the direct replacement benefits of these devices, the remote controllability of thermostats offer potential functionality for providing dynamic load control of HVAC systems.

In the demonstration program, Cypress units were used to replace older thermostats in two schools in the Vancouver, Washington School District. When the thermostats sense that more heating or cooling is needed, the pressure to the appropriate damper actuator is increased to open hot or cool air dampers to allow the hot or cool air to enter the room.

Each Cypress thermostat communicates through a repeater to the “green box” (GB or on site controller) every 15 minutes. One way Cypress devices keep installation costs low is in eliminating the need for electrical wiring by relying on battery power at each thermostat. Limiting the frequency of communication provides a 2-year battery life on the thermostats. Multiple thermostats must share a repeater. There are 44 thermostats located in Ogden School and 51 thermostats located in Sacagawea School (Sac). A total of 8 repeaters are used to facilitate communication with two green boxes (one at each school). Dent data logging meters were placed on the 4 electric boilers (two in each school). These meters measured the amperage of all 4 boilers in real time.

Testing procedures:

Initial testing involved adjusting the entire system 3 degrees Fahrenheit. This simulated a typical BRD load following signal scenario where an INC call would be issued and the cypress system would respond by lowing the zone set point -3 degrees to reduce load. The duration of the tests initially was only 30 minutes. The event duration was increased over time to approximately 2 hours to determine the impact if any on zone temperatures. During testing, the Vancouver School District (VSD) monitored both schools for occupant discomfort and complaints.

Advanced testing during the summer time occurred at Ogden. The summer school program did not utilize all areas of the school and was therefore an ideal situation for evaluating the occupancy zone features of the system. It should be noted that heating requirements were virtually non-existent but that cooling was actively utilized during much of the testing. Because of the segregation of the cooling equipment from the heating equipment, the zone or damper pressure readings were used to determine the effectiveness of the HVAC system response.

Overall System Feedback:
The Cypress user interface is excellent and provides information on each thermostat and zone within the system (see figure below). This includes current set point, actual temperature, damper pressure to indicate the amount of heating or cooling being allowed into the room, battery status, occupancy status and alarm notification. The user interface also has the capability to set up multiple schedules within the system. The schedules can be customized to each zone or used in a system wide scenario where all thermostats can be adjusted simultaneously.

NodeID	Alarm	ACK	Node Name	Setpoint (°F)	Cool Above (°F)	Heat Below (°F)	Zone Temp (°F)	Branch Pressure (PSI)	Battery Level	Occupancy State	Time
101B			Yellow Bath Rm.	71			69.35	2.63	OK	Occupied	9/7/2012 8:30:12 AM
101D			Yellow Cust. Rm	71			73.40	11.58	OK	Occupied	9/7/2012 8:31:15 AM
101E			Yellow Open Are	71			69.35	0.00	OK	Occupied	9/7/2012 8:30:15 AM
102D			Yellow Resource	71			71.60	6.05	OK	Occupied	9/7/2012 8:30:30 AM
117A			Yellow Rm. 17	71			71.38	7.37	OK	Occupied	9/7/2012 8:31:27 AM
118A			Yellow Rm. 18	71			70.93	9.74	OK	Occupied	9/7/2012 8:31:11 AM
119A			Yellow Rm. 19	71			70.70	8.42	OK	Occupied	9/7/2012 8:30:27 AM
120A			Yellow Rm. 20	71			71.15	8.68	OK	Occupied	9/7/2012 8:16:28 AM
121A			Yellow Rm. 21	71			68.00	0.00	OK	Occupied	9/7/2012 8:30:11 AM
122A			Yellow Rm. 22	71			67.33	0.00	OK	Occupied	9/7/2012 8:30:10 AM
200C			Green Media	71			69.58	5.00	OK	Occupied	9/7/2012 8:32:15 AM
201A			Green Rm 1	71			73.63	14.74	OK	Occupied	9/7/2012 8:32:29 AM
201D			Green Conf Rm A	71			72.05	8.68	OK	Occupied	9/7/2012 8:32:15 AM
201E			Green Open Area	71			70.70	6.84	OK	Occupied	9/7/2012 8:17:32 AM
202B			Green Rm 2 Bth	71			73.18	0.00	OK	Occupied	9/7/2012 8:31:29 AM
202D			Green Conf Rm B	71			71.60	7.89	OK	Occupied	9/7/2012 8:17:16 AM
202E			Green Corner Rm	71			73.85	12.11	OK	Occupied	9/7/2012 8:17:17 AM
203A			Green Rm 3	71			72.05	11.05	OK	Occupied	9/7/2012 8:32:12 AM

Figure 36: Cypress System Interface

In addition, the diagnostic capability of the system is quite valuable. The Vancouver School District maintenance department reported that several stuck dampers were identified through the cypress system alarm interface. As a result, valuable maintenance man-hours were not required to manually inspect large sections of the HVAC system in an effort to locate the stuck dampers. The on-site maintenance personnel were able to quickly resolve the problem before any of the building occupants reported any discomfort.

An issue with the cooling system was also identified during the summer school test schedule. During one test, it was observed that thermostats were opening dampers but that the room temperatures were still increasing. Maintenance resources were dispatched to the school and the cooling system was quickly brought back online.

Test Results:

- The measured demand response to INC events was 20 kW, which was unexpectedly small. This was most likely due to the low heating requirements being placed on the buildings system during the early summer months.
- Response time for all zones to react to test event signals and report back to the user interface was 30 minutes.
- Test duration was easily lengthened to two hours without occupant complaints or other adverse effects.
- Zone scheduling demonstrated excellent control of temperatures in occupied areas even during extreme cooling needs. The zone scheduling simultaneously supported the elimination of energy use in unoccupied areas.

Conclusion:

Each type of demand response (DR) asset has different capabilities, weaknesses and strengths. It should be noted that in a standard school district setting, this application of the Cypress technology would provide a seasonal resource. The Cypress system is not a fast-acting balancing resource in this specific application. More frequent communication with the thermostats would marginally improve response time but conversely shorten battery life and increase maintenance costs. However, unlike some other demand response assets, this particular technology is able to respond to long duration events. Through the use of zone scheduling, this system can be used as a load shifting or peak demand reduction tool.

The real strength of this system resides in benefits beyond DR and peak demand reduction notably facilities management. Building maintenance departments would find significant value in using this technology to identify, diagnose and resolve HVAC related maintenance issues. There are obvious energy benefits, which are difficult to quantify. An example of this would be the energy wasted when a damper is stuck in the open position, thereby sending un-regulated amounts of heating or cooling into an occupied or unoccupied space. Another non-DR benefit is that the entire HVAC system can be adjusted, shut down or turned on remotely through the web interface. While not the most effective fast-acting balancing resource available to BPA, the Cypress technology is an effective energy management and maintenance management tool for many commercial, institutional and industrial applications, especially those with large occupancy densities and variable occupancy schedules. It should be noted that while this test showed little benefit to providing grid balancing services, much of that result may be specific to this technology and not a conclusion to be drawn about the set point control of HVAC systems in general. The Cypress system is constrained with respect to how quickly it can respond to a deployment signal. That is not necessarily the case for other options such as direct boiler control which can be throttled back or increase electricity consumption very quickly.

2.6 Customer and Utility Perceptions, Marketing and Potential Job Creation

2.6.1 Customer Feedback (hot water heaters)

Customer surveys have been conducted for the both the Steffes and Carina water heater systems. The response has been excellent with many happy program participants. Here are some of the basic statistics regarding the hot water heater participants:

1. All of these customers are taking showers less than or equal to 15 minutes.
2. Only 6% of these customers use hot water when washing their laundry.
3. 25% of these households have tweens (10-14) &/or teenagers (15-19) and 8% of these households have children under the age of 9 years old.
4. 48% of these households have 2 adults working outside of the home.
5. 84% of these customers are employed during the normal business day.

A summary of customer satisfaction is shown below.

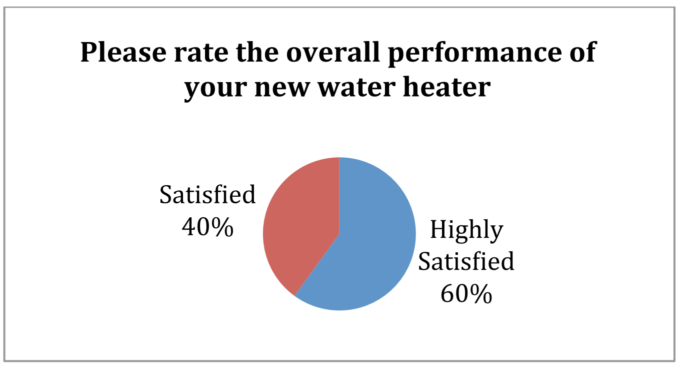

Figure 37: Summary of performance for new water heater

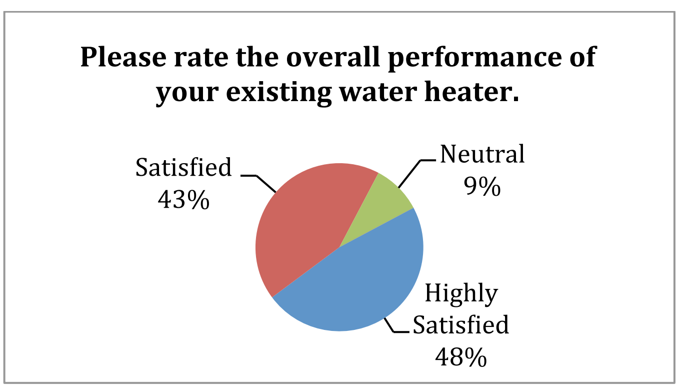

Figure 38: Summary of existing water heater performance among program participants

In general, the comments provided by the participants were very enthusiastic. Here are some of the quotes:

"It is absolutely amazing! We have LOTS of hot water, the temperature doesn't fluctuate in the shower, and we have a giant increase in our water pressure. All around super excellent!!"

"Our old water heater was not supplying enough hot water and my daughter and I constantly had to time our showers so that we didn't shower too close together or do laundry or dishes anytime close to showering. The water seems to heat up more quickly and maintains heat without adjusting through an entire shower. We can shower, do laundry and dishes with plenty of hot water to spare!"

"I am never without hot water."

"Keeps water hot and have not ran out yet :)… it is cooler then our old water heater, but maybe that is good?"

"Seems to supply more hot water instantaneously than previous heater."

"There is a plentiful amount of hot water for our needs."

"Works well and haven't run out of hot water while showering"

"It works as well as the old water heater, so I'm not anything less than satisfied. I'd like to know how much I'm saving in energy costs as a result of the installation. I was also hoping that water might get hot faster. It still takes quite a while (20-30 seconds) for water to heat up."

"Once the water heats up, which takes much less time than before it seems to maintain its temperature without adjusting (particularly in the shower). the temperature seems overall to be hotter. I'm not sure I have noticed a difference in water quantity (unless you mean how long it stays hot)"

"The supply temperature was a bit high at first, but that was sorted out by the end of the second work session."

2.6.2 Customer incentives (hot water heaters)

Participating utilities used a diversity of incentives to induce customer participation in the residential programs. Common to the utility efforts were a combination of mass mailings and local advertisements to enlist residential customers. Portland General Electric offered an eighty dollar gift card to customers signing up for the program (example of past or existing incentives) Eugene Water and Electric Board also offered customers a $50 gift card. Residential Steffes participants received a new high-efficiency water heater (great incentive especially for those with old water heaters). Steffes ETS furnace participants were given equipment including cold weather heat pumps (new incentive and very effective…additional inquiries are being received to participate in the program). Utilities and program participants were not charged monthly subscription fees for water heater programs (in other regions, depending on sales volume, Steffes charges $1 - 6/month/water heater).

2.6.3 Cold Storage Incentive

EnerNOC offered cold storage customers the equivalent of $1.67/kW month for 200kW of nominal load response.

2.6.4 Conclusions

Project costs associated with this effort are not reflective of what it would cost for a full commercial implementation. A number of factors contribute the heightened costs associated with the pilot. Cost for a larger scale project would be reduced in several ways. For example, working with larger numbers of installation would allow contracting with larger construction firms or contractors that would allow for much reduced marketing and installation costs. Another important cost mitigating factor would be integrating controls into new water heaters at the factory that will vastly reduce installation costs and would enhance widespread product availability to potential customers. Further, as a demonstration project, at-site data gathering and adjustments to control and communication technology added significant costs that would not be incurred in a commercial scale implementation.

Warehouse management and staff were enthusiastic and creative in fostering the program in their facilities. Future cold storage incentives should be increased and based on a combination of availability and performance. This would encourage broader participation and improve delivered response.

The water heater program encountered technical challenges that were not originally foreseen. For example, there were some hard drive failures on the Steffes netbooks used to monitor individual water heaters on-site. Battery issues with Steffes netbooks required hard reboots after a power interruption and this required human intervention. For that reason, the Steffes GEN 2 controller was developed to eliminate the netbook computer and battery. One trial benefit was the discovery that water heaters became RF sponges essentially eliminating the original Wi-Fi communication scheme. Steffes second-generation products are now designed to be hard wired to routers for greater communication reliability. This also results in a lower overall cost for the system.

The water heater program was designed to have zero negative impacts on the homeowner's domestic water heater experience. Water temperatures were generally held at higher levels in what were often larger tanks. Mixing valves at the outlets of the water heaters were designed to ensure constant outlet temperatures to household taps irrespective of the water heater temperature. EWEB did receive one complaint of fluctuations in water temperature but this appeared to be a one time occurrence without additional issues.

2.6.5 Cost of Widespread installation of storage devices and the impact on job creation:

The water heater installations required approximately 5 hours of skilled labor—2 hours each for plumber and electrician and an hour of IT specialist support. At an average rate of $125, large scale installation costs would be about $675 per water heater installation. This would scale up to 1,000 worker-hours for 200 water heaters, or 10,000 worker-hours (about 5 worker-years) for 2,000 units. At higher scales it would likely be more cost effective to install communication, control, and mixing valves in the water heater manufacturing process that would obviate most of the on-site labor requirement, something which Steffes has been actively pursuing with major water heater manufactures. EWEB and Cowlitz both required a full time person to manage their water heater program, including installations. In addition, Steffes has full time staff to support and enhance control software.

The cost to enable a cold storage facility with a modern existing controls infrastructure is $15k-$25k. The cost of adding OpenADR interface equipment is an additional $5k-$7.5k. Installation and programming labor for cold storage site enablement was in the range of $10k-$20k. In addition to the at-site costs additional subscription costs are needed to enable control and dispatch. EnerNOC has 24hr 7 days/week control center for dispatching the resources. There are more than 100 cold storage warehouses in the Northwest that might be accessed for demand response for a nominal technical potential of roughly 20 MW at 200 kW each.

3 Business Case Model

3.1 Model Description

Ecofys has created a software tool that can be used by utilities to develop a business case for demand response projects. The enhanced business case tool was developed to help utility companies understand the benefits and opportunities of smart DR projects. Each utility is unique and operates within a business plan, which fits their operational needs, situations and demographics (see figure below). Therefore a "cookie-cutter" approach typically used for most software development was ill suited for this situation.

Utility District	Contract	Drivers	Sensitivities
Cowlitz Public Utility District	S&B*	• Balancing • Residential load shaping • Large commercial base	• Balancing price • Future DR technologies • Return on investment
Emerald Public Utility District	S&B	• Residential peak shaving • High energy costs during peak events	• Rural base • Low capital cost requirements
Eugene Water and Electric Board	S&B	• Balancing • Load shaping • Energy market impacts	• Balancing price • Natural gas and carbon costs • DR software costs and ownership • Open market power price
Forest Grove Light and Power	LF*	• Balancing • DR program financing	• Balancing price • Future program costs
Lower Valley Energy	LF	• Balancing • Load shaping • Peak shaving • Equipment infrastructure deferral	• Balancing price • Cost of DR technology • Return on investment
City of Port Angeles Electric Utility	LF	• Contingency reserve	• DR technology reliability
City of Richland Electric Utility	LF	• Balancing • Equipment infrastructure deferral	• Balancing price • Future program costs

Figure 39: Summary of various utility business models

In order for the business case tool to be effective, it was designed to be adaptable to the needs of those who use it. Some utilities preferred simple selection menus and graphical results. They were more interested in general trends. Other utilities were concerned with developing a portfolio of projects that would maximize a business need such as capital equipment deferral or balancing capacity. They wanted NPV, IRR and ROI calculations to assist in project justification.

As a result, the business case software is a balanced tool, which can fit the needs of most end users. It has preloaded BPA rates, simple selector buttons and several demand response technologies built into the input page (see figure below). This makes it easy to use by those who may not be experts in Excel or in financial analysis. The business case tool can simply and quickly illustrate the potential benefit of demand response solutions to those users.

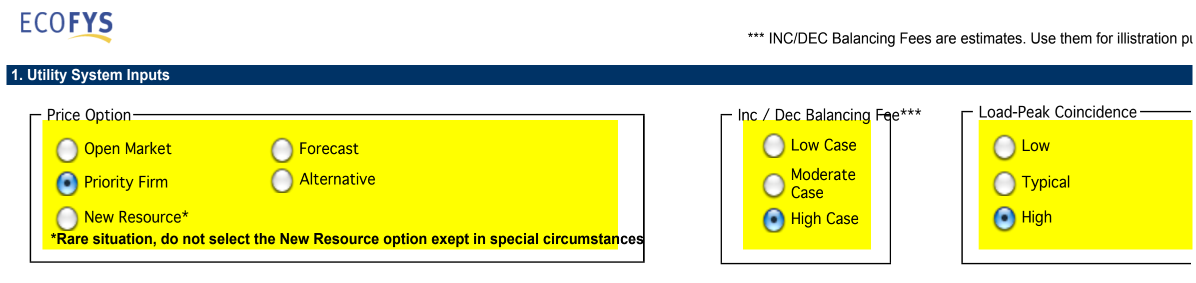

Figure 40: Sample of simple selector buttons on business case tool

On the other end of the spectrum are those utilities with complicated and unique business models in their operations. These utilities typically employ full time analysts who are proficient in Excel and financial analysis. Feedback from these utilities determined that they found value in having an adaptable framework allowing users to modify input values and variables to fit their needs (see figure below). This led to the development of the more sophisticated portions of the tool. The tool includes basic costs to purchase, install, and manage communicate with various controllable loads. It also has a scenario builder so that higher penetration levels through a stepped installation process can be evaluated. There is even a section, which evaluates demand response effects on the deferral of equipment for infrastructure improvements.

Price Input Options		**Price Option**	Jan	Feb
Mid-C historical monthly average 2002-2010	On-Peak	1	0.048	0.048
	Off-Peak		0.041	0.044
BPA Priority Firm Rate (*Ref: Rates Sheet*)	HLH 6:00 AM - 10:00 PM	2	0.040	0.041
BPA PF-12, BP-12-E-BPA-09, Page 5	LLH		0.032	0.033
BPA New Resource	HLH	3	0.074	0.075
BPA NR-12, BP-12-E-BPA-09, Page 13	LLH		0.066	0.067
Wholesale Price Forecast		4		
Alternative Rate		5		

Figure 41: Example of adaptable rate modification options within business case tool

Over the course of the project task, Ecofys has met with PNGC and multiple utilities throughout BPA's service area and presented the business case tool. The visits focused three major areas:

1) Helping the utilities better understand potential demand response projects and business opportunities.
2) Training of key individuals such as analysts on the capability, use and adaptability of the tool.
3) Soliciting feedback from the utilities regarding improvements, ease of use, value and relevancy to their business model.

This task was completed earlier in the year 2012. Ecofys is in the process of providing training to additional groups and utilities through the use of on site presentations and webinars and will continue to do so in 2013. A separate report was generated for this task, which includes two case studies-- a load following utility and a slice utility.

4 Conclusion

The Smart End-Use Energy Storage and Integration of Renewable Energy project (TI-220) accomplished the mandated tasks set for it. This report documents the utility successes along with the challenges of implementing load control programs to provide balancing services to help integrate renewable energy into the power system. Several technologies demonstrated the ability to respond to control signals deriving from the need to provide balancing services. The Project demonstrated not only the feasibility of the technologies examined in providing balancing services, but also showed they could do so in a cost competitive manner in many cases. Protocols were established for controlling the resources and work was done to optimize the operation of the resources. The project showed that the resources could perform with a measurable and verifiable response. Payback times were estimated at the pre-commercialization stage, job impacts estimated, customer acceptance was assessed as very high, marketing incentives identified and implemented.

Overall, the project showed the technical feasibility of using a variety of end use loads to provide power system balancing services as well as other valuable functions that included peak reduction, scheduling of load in the case of water heaters, and benefits to reducing peak demands on distribution systems. The project demonstrated that the participating loads could contribute to power grid needs without being adversely affected, or in cases where end-use needs were degraded; service levels were not reduced at noticeable levels.

An important finding of the Project is that there was sufficient interest among regional utilities and end users to participate. In a few cases there were early challenges finding customers, but for the most part end-use participants were easily found and enthusiastic supporters. Support did not wane through the study period for the most part, even with the expected challenges and setbacks associated with a new technology.

At the outset, Ecofys was confident that the technologies examined had the potential to provide the services proved out under the contract. Much was learned along the way about challenges associated with implementing these technologies. For example:

- Cold storage warehouses are varied in their response and sufficiently individual in their operations to warrant a coordinator who can understand their circumstances, interface with the utilities and provide a more consistent portfolio response than an ad-hock random participant recruitment program would provide.
- The Steffes Gen I technology's early reliance on customer Wi-Fi proved insufficiently reliable. As mentioned earlier, the challenges of Wi-Fi created solutions such as direct ethernet wired connection and ethernet to powerline carrier connection, which still utilize the client's internet.
- Much of the expected Carina benefit accrued from lower hardware and associated installation costs, but that savings was countered by the local utility that required installation of mixing valves to limit its perceived liability.
- Response time in the HVAC thermostat technology was unexpectedly long (~30 minutes) due to an artifact of saving battery life in the thermostats for the particular technology examined.

As is often the case, the details of a project are important, and a significant value of the work here was to find and work through those challenges. Although challenges such as the ones listed above were found, no prohibitive challenges were seen in implementing the technologies and the future appear promising. Nevertheless, it should be emphasized that although these technologies were clearly shown to be able to provide grid balancing and other valuable services, the technologies have not for the most part been commercialized.

Although some demand response technologies may be cost effective today, significant cost savings can likely be found under commercialization. The chief example of this is residential water heater control. Very large economies of scale can be achieved by incorporating the communication and control systems into the water heaters during their manufacture. Cost is a major challenge associated with residential sector programs due to the distributed nature of the resource and the need to visit thousands or tens of thousands of homes in order to exploit the resource at scale. Nevertheless, implementing water heater control technology at the manufacturing level can likely reduce the simple payback for water heater control to two to five years.

One surprising and very encouraging finding of the water heater program is that with larger water heaters and Steffes control technology, virtually all of the load can be served in providing dec services. In other words, water heater loads can be served in the process of providing an important balancing service—potentially removing water heater loads from peak demand and load forecasts. The prospect of simultaneously reducing load while providing balancing services is especially enticing.

While water heater loads can provide rapid and precise response, the characteristics of cold storage warehouses are somewhat slower and less predictable. On the other hand, the larger loads have lower installation costs. Where water heater costs were on the order of hundreds of dollars per kW (absent noted potential cost reductions), similar to combustion turbine costs, cold storage warehouses provide somewhat lesser service for costs of tens of dollars per kilowatt. This is a very exciting finding and suggests other commercial and industrial loads may be similarly positioned to provide very competitive services.

Clearly, more work could be done to better characterize the resources. Specifically, there continue to be questions regarding the optimal operation of a large portfolio of water heaters. The problem of operating water heaters is mathematically very similar to operating hydro projects. Hydro projects have fixed storage capability, uncertain and stochastic inflows, and controllable outflows. Water heaters are similar except that the energy outflows are stochastic and the inflows are controlled. In both cases the stochastic nature of the energy flows (inflows for hydro reservoirs, hot water use for water heaters) can be characterized and rules developed to control energy levels (reservoir contents for hydro projects, temperatures in water heaters). Early on, a number of operating strategies were developed for the water heaters, but the last word on that topic has not been written.

Although the experience with controlling HVAC set points suggested a more restricted resource, some of the results appeared to be less a characteristic of the resource than they were a result of the particular implementation tested. It appears that additional testing of HVAC set points with other control technologies than the one examined under this contract may be in order.

Finally, Ecofys would like to acknowledge its appreciation for BPA in allowing us to be a part of this important and groundbreaking project. It is a testament to the vital role BPA’s Technology Innovation work can provide to the region, and to the country as well. We hope that BPA finds the results of this project as interesting and useful as the study team found them to be.

Appendix A – Timeline of control approaches, both deployed and in development

Steffes Layered Control Strategy (February to March 2011)
- Layer 1: Define Peak/Off Peak
  Includes off-peak, soft peak and hard peak (results in charging desired/allowed/disallowed)
- Layer 2: Determine Customer Need
  Intelligent controller "learns" the customer's usage pattern by logging a 30-day rolling average
- Layer 3: Set a Nominal Charge Rate
  Based on output of Layers 1 and 2, sets # of kW per hour (e.g., 16 kWh of energy needed during an 8-hour off-peak period = 2kW/hr)
- Layer 4: Follow the Control Signal
  BPA Balancing Reserve Deployment signal will be used, with units responding symmetrically to calls for INCs and DECs
- Layer 5: Handle Exceptions
  Ensures customer comfort with automatic override if temp in ETS unit is too low; also responds to local out-of-normal conditions (outages, etc.)

This is more of an overall idea, not a specific plan for implementation. Although very little of this layered approach was implemented in the early stages it is instructive to see, as much of it was reincorporated into the GETS (Grid-interactive Electric Thermal Storage) strategy.

Steffes Initial strategy (up to August 2011):
- Set charge rate based on target end of day temperature
- INC and DEC around that charge rate (symmetrical charging)
- End of day temperature based on historic usage patterns

Outcome:

Spirae was unable to model this control strategy successfully due to stability issues.

Removed from Steffes' control plans and was never implemented on any water heaters. However several elements of this plan have been incorporated into new control strategies.

Steffes ZeroBRD (August 2011 to January 2012)

The ZeroBRD control strategy access the most recent BRD value, along with the maximum amount of extra generation available to BPA (MaxDEC), every five minutes and uses it to control the EWH. Overall the EWHs are controlled based on the relationship between the BRD and a rolling average of the BRD and the max DEC available.

The ZeroBRD's use of a rolling average has the potential, albeit slight, to result in EWH energy usage responses in the opposite direction of the BRD. In addition the strategy responds to small scale deviations of the BRD around zero, areas where BPA uses the hydro system almost exclusively for balancing. The response of ZeroBRD in this area has the potential to exhaust the EWH resource, limiting its ability to respond to large BRD calls, an area where the hydro system does not respond well. Modifications to the control methods that were based on ZeroBRD eliminated these concerns.

There are several water heaters currently using this control strategy while the majority of the fleet collects baseline data. The exciting part about it is that so far the water heaters do almost all of their charging when the BRD is negative, most of it when the BRD is strongly negative and the system needs DECs.

There are no blackout hours or ways to do load shaping, nor does the system provide INCs in a direct way. Instead INCs are implied in as much as there is no charging when the BRD is positive.

However the ZeroBRD has worked well as a proof of concept and has shown that EWH have the ability to charge only during times when the BRD is negative. The method is not what we want, overall, but the outcome has been quite useful as a proof of concept. Steffes seems to realize that this is not a long-term solution.

Ken Dragoon's reservoir model

- Treat each EWH like a hydro system, in that it is capacity limited more than power limited.
- Based on historical usage, set a target temperature for the beginning of the water heating day.
- Set average charge rate based on that target temperature. Average charge rate varies hour by hour and is normalized.
- Use a deadband approach for the BRD.

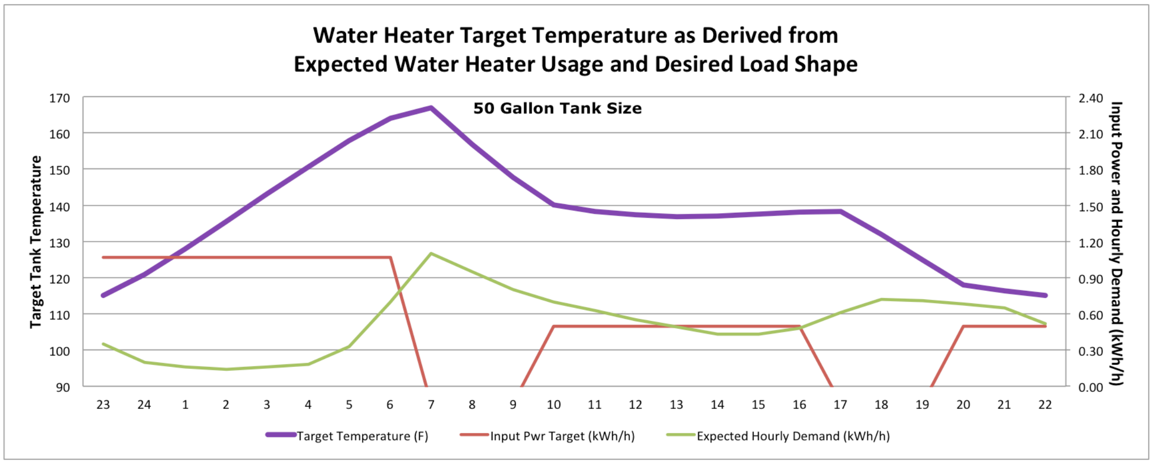

Figure 42: Ken Dragoon's reservoir model

The goal of this approach is to always have the system ready to respond. It is not intended to maximize amount of response time, but instead to mimic use when the system most needs it.

Ken Dragoon proposed this approach to Steffes and they were receptive to the plan. It seems several aspects have been incorporated into the GETS plan, most notably the "pre-set charging" approach.

Note that this is a temperature based control approach. While this is, in and of itself, not a major problem, it does lead to potential control stability issues and relies on a more stochastic approach to load availability.

Ken Corum's proportional deadband approach

-Divide the 2-D graph of the BRD and EWH temperature into 4 quadrants.

-The two triangles are zones where the water heater does not respond, but in other locations the water heater has the ability to respond to an INC or DEC command and increase or decrease its temperature as necessary.

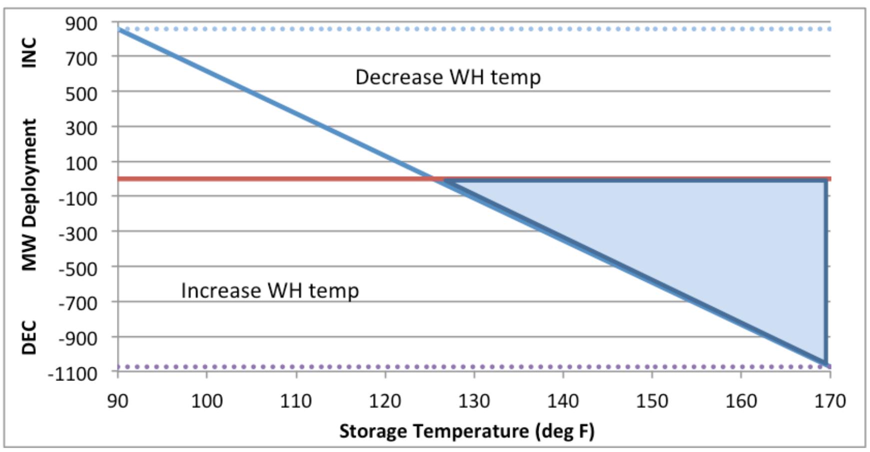

Figure 43: Ken Corum's proportional deadband approach

This control scheme's goal is to maximize the amount of time that an EWH is available to respond to an INC or DEC, while decreasing the time that an EWH might respond spuriously to low value calls.

Steffes "BPA Quick Control" (Late January 2012)

The first part of the system is an hour-by-hour preset charge rate. This visualizer is scheduled ahead of time and adjustable by the system operator, with maximum and minimum lines to guide the operator as to what the system is capable of providing.

Each end point (water heater or electric space heater) is relaying its current temperatures to the aggregator regularly to be able to determine how much power is available at any given time.

The operator sends a signal to Steffes requesting a certain amount of INC or DEC. That signal is then compared to the tank temperatures and a control signal is sent out that leads to the exact power increase or decrease, with preference given based on tank temperatures (i.e. cooler tanks charge more on DECs).

The Dynamic Dispatch approach, as currently designed, will be a power based control strategy. This should be more robust, but will rely upon a very good understanding of water usage patterns. However with a large enough fleet the random nature of individual home use should smooth out significantly. As it is a power based control strategy, measurement and verification shoul

Each water heater will spend 2 weeks in either "standard operation" or following the "BPA Quick Control", after which it will switch to the other control strategy. This is intended to provide baseline data and allow comparing energy use in similar situations.

Standard operation is similar to how a standard water heater acts, with the water heater staying between 115 and 120 degrees.

The BPA Quick Control strategy based on the ZeroBRD strategy, using the same algorithm to create the ZeroBRD average.

One of the main changes is that the variable called Aggressiveness Factor can be set in advance for every hour of the day, with the current default being 3. For 8 hours each day, 4 in the morning, 4 in the evening, the Aggressiveness Factor is set to 0 to create blackout hours removing the EWH from peak utility load. This provides benefits to utilities, but it means that EWHs can provide no INCs or DECs during those hours.

The relationship between the BRD, ZeroBRD, and the MaxDEC is used to create the Control Signal. Any time the BRD signal is greater than the ZeroBRD (positive numbers mean calls for increased generation) the water heater does not charge. The Control Signal is then translated by the water heater into an amount of power to draw based on its tank temperature. The units can be set to different average temperatures based on historic usage. One of the main improvements over ZeroBRD is the ability to consistently call for the full 4.5 kW of power at a much wider range of times.

There are several extra safeguards to protect customer comfort; Comfort Assurance, which monitors the temperature so that if the tank ever falls below 120 degrees the heating elements turn all the way on to bring the temperature up to 120, and ComfortGuard, which monitors the mixing valve, ensuring that in the unlikely event that the temperature exceeds 135 degrees for an extended time the tank does not charge until the tank temperature drops below 120.

In addition, should a communication failure occur the tank reverts to standard operation, but with the tank temperature target the nominal temperature set point, usually 135, until communication is restored.

Steffes Dynamic Dispatch control strategy (Late March/early April 2012)

Steffes did not intend to update all the EWHs to Dynamic Dispatch control during the course of this project. However several units did switch to it for proof of concept purposes in August. Dynamic Dispatch is a large part of Steffes' control plans moving forward.
d be much more straightforward than temperature based controls, as the units are charging on a preset charge rate and statistical models of expected charge are not involved.

Additionally flexible grouping of end units could be used to mitigate transmission bottleneck down to a feeder level.

Appendix B – Task Summaries

***Task 1-* Organize Technical Advisory Panel (TAP):** The Grant Team will recruit subject matter experts tasked with providing guidance and wider perspective to the Project Team.

***Task 2-* Develop Business Case:** The Technical Advisory Panel will work with the participating utilities to develop a business case, i.e. a financial model that details investments, revenues, resources needed (people and equipment), expected pay-back period, and any possible break-points at increasing levels of implementation of controllable loads.

***Task 3-* Create Technology Survey:** The project team will work together to summarize current demand response technologies with optional energy storage; communication methods, standards and protocols; goals of other demand response demos in the Pacific Northwest; and lessons learned and accomplishments of demand response demonstrations in the U.S. And Europe.

***Task 4-* Produce Guidebook for Consumer-Owned Utilities:** Create a guidebook for the consumer-owned utilities, with the Business Case and Technology Survey integrated. The guidebook will place all the technical and economic analyses, conclusions, and tools in one place, so utilities currently outside of the project can easily determine whether undertaking a pilot project is in line with their business goals and if so, move forward quickly and confidently.

***Task 5-* Develop Utility Marketing Materials:** The TAP will utilize its members with experience in marketing innovative, energy-saving programs to work with utilities to develop effective marketing programs and materials. One of the objectives in the project is to involve at least 1 commercial entity and at least 30 consumers in the pilot projects. These end-users need to actively participate within the project by installing "grid-responsive devices" in their buildings/houses, carry the risk of malfunctioning "new techniques", adjust their energy usage and, very important, give extensive feedback during and after the pilots about their experiences.

***Task 6-* Site Selection:** The participating utilities will carefully select the sites within their service areas to install the equipment and participate in the demonstration.

***Task 7-* Dispatch Optimization Support:** Provide technologies and support to vendors and utilities where needed to implement algorithms or analysis to support the efficient dispatch of available storage and validation/verification techniques. For dispatch optimization, models of the candidate devices are needed. The development of these models and testing of them is expected to start once the candidate devices are determined. Then testing the models can proceed along with development of dispatch algorithms. Finally, the project team will assist utilities with integration of the algorithms to the actual dispatch software.

***Task 8-* Technology Installations:** Once the program marketing proceeds, installations of control and communication equipment can begin. Installations are expected to continue over an extended length of time during the grant period.

***Task 9-* Dispatch Review Period:** A minimum 12 months of operation is planned for all installations, with up to 18 months for at least some of the installations. This is necessary to give a better view of the seasonality of the various storage capabilities and how these align with the balancing reserve requirements of BPA. This window of operational experience will be used as the basis for the evaluation.

***Task 10-* Interim Report:** This Interim Report will detail and document experience to date, success of marketing programs, anecdotal assessments of success, and challenges. Any needed course-corrections will be recommended in the Interim Report, which will also function as a vehicle for cross-utility information sharing.

***Task 11-* Balancing Services Contract Template:** Participating utilities will work with the project team and BPA to define the services they are capable of providing by operating the dispatchable loads and the general terms under which BPA would purchase these services. This template will be a model for other entities, such as wind project operators, to procure balancing services from the utilities after the conclusion of the project.

***Task 12-* Customer Satisfaction Survey:** The project team will assist the utilities to assess customer acceptance and satisfaction with programs. Key to the success of end-use programs is the acceptance and satisfaction of customers who have participated in the program, and an assessment of reasons non-participating customers chose not to participate.

***Task 13-* Project Evaluation:** The overall evaluation report will compare and contrast business models and utility successes in providing balancing services from controllable end-use loads. The evaluation will assess the verification and validation of end-use response, projected scalability and economic benefits, and assess customer acceptance to the range of marketing and technologies employed.

New Tasks per Modification No. 002, effective August 1, 2011

***Task 14-* More Rapid Data Analysis:** This Task will begin the analysis of data from the existing load control installations in August 2011, rather than October 2011. Several dozen controlled water heaters are providing fine grained (one minute to fifteen minute) data and have been for several months in the Eugene Water and Electric Board (EWEB) and Cowlitz County PUD service areas. Additionally, all six electric thermal storage furnaces have been installed in the Lower Valley Energy (LVE) service area, and are producing data, which should be analyzed. All four cold storage warehouses in the EnerNOC portion of the original project are also producing existing condition baseline data, which should be collected and organized, so it can be compared against the test period data, which is becoming available in July and August 2011.

***Task 15-* Additional Control Approaches:** This Task will develop at least two additional control algorithms for the Ecofys end use appliance controls. Ecofys will develop these two additional control strategies working with BPA staff in Power, Transmission, and Energy Efficiency (Demand Response and Planning) and the utilities participating in the Ecofys project. During the first year of program implementation (September 2010 to August 2011), Ecofys has become aware of new options, tradeoffs, and value streams which may be more interesting to BPA and regional utilities than those used in the original program deign and proposal.

***Task 16-* Commercial Building ETS Furnace Demonstration:** This Task will install and test Steffes model 9180 commercial building electric thermal storage (ETS) furnaces in two locations in the LVE service area: 1) a 10,000 square foot commercial building and 2) a 3.000 square foot commercial office building. No demonstration of the load control and energy storage capabilities and benefits of commercial building ETS heating systems have been performed in the western United States. This technology has great promise for BPA and regional utilities because it can store large quantities of light load hour energy and renewable (wind) energy compared to what water heaters and residential furnaces can store. Commercial building ETS may be economic, or we may learn that the installation and purchase costs outweigh the energy storage benefits of these larger ETS systems.

***Task 17-* Wireless Pneumatic Thermostats Demonstration:** This Task will demonstrate the potential significant benefits of using low cost retrofit wireless thermostats to control pneumatic commercial and public building HVAC systems. Over 75% of PNW commercial and public building HVAC systems are pneumatically controlled. There is no low cost option to control these systems. Typically, they must be retrofit to direct digital control systems (DDC systems), which is very costly, disruptive to tenants and occupants, and usually involves costly mitigation of hazardous materials (asbestos, etc.) as walls and ceilings are opened. In 2009-2010, Cypress Envirosystems developed and patented new technology, which allows existing pneumatic HVAC systems to be put under control by simply adding a retrofit wireless module to the existing zone thermostats, at a low cost, and without the need for a licensed electrician. This opens up significant energy efficiency and demand response opportunities – the 75% of commercial and public building HVAC loads which cannot be economically load controlled in the past, can now economically and efficiently contribute to utility demand response programs and goals. No demonstration or testing of the Cypress technology has occurred outside of California. This technology also has the potential of providing significant energy efficiency benefits. This Task will provide BPA and regional utilities direct experience with the installation and testing of this new technology.

***Task 18-* Customize Demand Response Business Case:** This Task will enhance the existing Business Case tool developed under the original Ecofys project and customize it for each of ten utilities. The existing Business Case tool is an economic model for a generic utility to use in evaluating the business case for deploying one or thousands of the Steffes technologies for water and space heat. It became apparent while evaluating the applicability of the tool, that each utility had to customize several inputs and assumptions, and the technology in turn might be operated differently based on these changing assumptions. This Task will customize the Business Case for each of ten utilities, add an Excel Solver tool to assist utilities in making optimized decisions, include other end use control devices (e.g., Carina controllers and C&I measures), add the value of infrastructure deferral, evaluate different BPA and utility dispatch options, and add probabilistic forecasts for future values of selected inputs and assumptions (e.g., future BPA demand charges). This will have great value for local utilities, and greatly increased value for BPA.

***Task 19-* Carina Water Heater Controller Demonstration (Existing Tanks):** This Task will deploy and demonstrate the capabilities of Carina Technologies electric water heater controls in the service territories of two or three BPA Power customer utilities. Up to 100 water heaters would be controlled, with the goal of demonstrating the capability of the Carina controllers for demand reduction, load shaping, and the provision of balancing services. Other water heater control pilot projects are underway in BPA territory, but none with the Carina WISE (Water Heater Information Solution for Energy) technology. The Carina technology represents a lower price point and installation cost than the Steffes control systems (which require mixing valves and plumbing), and can be added on most major manufacturers water heaters. (Steffes controls can only be installed on certain makes and models of water heaters).

In order to demonstrate and quantify the various operational goals and value streams, the Carina-controlled water heaters would be controlled according to optimized dispatch algorithms that may increase or decrease the water heater load every 10 minutes. An 11-month demonstration period is planned. Through the demonstration period, several control modes will be tested, including the same controls signals used for the Steffes water heater controls. This will inform BPA, host utilities, and other regional utilities of the potential value of the Carina technology. Efforts will also be made to aggregate the Carina technology with other technologies in the Ecofys project. No tests of Carina controllers have been made west of the TVA service area in Tennessee. All demonstrations of Carina controllers have been for peak clipping only. BPA will be the first utility or research organization to test this promising technology for wind integration.

Task 20- **Additional Steffes Water Heater Controllers:** This Task will produce a more robust sample size of Steffes-controlled water heaters. This has been requested by Power and Transmission planners and analysts so that BPA decision-making on energy storage, capacity, Demand Response, and wind integration options can be made more confidently. Cowlitz County PUD is presently deploying 40 Steffes interactive water heater controls on 105 gallon Marathon water heaters. The PUD is willing to install an additional 30 Steffes-controlled new water heaters, on a combination of 50 and 105 gallon tanks. This would be a very valuable enhancement to the original and presently funded Ecofys project.

Task 21- **Additional Cold Storage Warehouse Demonstration and Reprogramming of Controls at Existing Warehouses:** This Task will test a larger scale DR project at a cold storage warehouse. This should show that the economics of controlling cold storage warehouse loads is improved with the sale of the facility. That is one of the topics to be addressed with this Task. Also, this Task will explore how both demand response and energy efficiency objectives can be achieved through the same measures and actions. Sno-Temp, a participant in the existing cold storage warehouse demand response Ecofys project in Albany, OR, is willing to work with BPA, EnerNOC, and EWEB, to implement a similar, but larger scale test at its Eugene, OR, warehouse. EnerNOC would include this as an addition to its existing Ecofys project load control portfolio. This would have value to other cold storage warehouse owners and operators in the region, the utilities serving those loads, as well as to BPA, EWEB, and Sno-Temp. In addition, EnerNOC is willing to test the EWEB warehouse using Open Automated Demand Response (ADR) communications and dispatch technology. This is a major breakthrough because EnerNOC has previously insisted on using its own proprietary technology. BPA wants Open ADR protocols to be used in its DR pilots. This decision will also integrate the Sno-Temp demonstration with the other BPA EE-funded EWEB C&I demand response tests. In addition, this Task will reprogram the controls at the four existing participating cold storage warehouses to reduce the maximum size of DEC requests from 200 kW to 50 kW. This responds to the results of the initial control period tests performed by EnerNOC and the four warehouses.

Task 22- **Carina Water Heater Controller Demonstration (New Tanks):** This test will demonstrate how Carina controllers can be added to new tanks and then installed in consumer homes, rather than retrofit existing tanks. This could further reduce costs and make this technology more economic and cost effective for BPA and regional utilities. No test of this action has been done anywhere in the USA.