



ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY

Hawaiian Electric Company Demand Response Roadmap Project

Roger Levy and Sila Kiliccote
Lawrence Berkeley National Laboratory

January 2013



DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor The Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or The Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or The Regents of the University of California.

Acknowledgments

The work described in this report was supported by the Hawaiian Electric Company, and by the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

The authors would like to thank the following individuals at the following companies for their time and guidance:

- Hawaiian Electric Company, Hawaii Electric Light Company, and Maui Electric Company:
 - Tom Aukai, Curt Beck, Jason Benn, Colton Ching, Teresa Clady, Conrad Copeland, Jose Dizon, Angie Eide, Jennifer Elfalan, Tim Ellis, Ken Fong, Ellsworth Fujii, Matt Goo, Alan Hee, Nohea Hirahara, Earle Ifuku, Darren Ishimura, Robert Kaneshiro, Mark Matsuura, Lynn McConnell, Pat Moore, Dora Nakafuji, Mark Nakasone, Ellen Nashiwa, Tom Overman, Carlos Perez, Robert Pytlarz, Leon Roose, Dan Sakamoto, Ross Sakuda, Scott Seu, Debby Shin, Erica Wingad, Jennifer Yoshimura, Peter Young, and Robert Yuenten.
- Hawaii Energy:
 - Michael Ching – Deputy Program Manager
 - Kyle Akagi – Business Programs Leader
 - Robert Vlacovsky – Program Engineer Lead
 - Jerome Keizer – Junior Engineer

The authors would also like to thank the Reliability Standard Working Group for their feedback on the presentation to them on July 12, 2012.

Table of Contents

Executive Summary	3
1. Introduction.....	7
2. Identify HECO Demand Response Objectives	17
3. Establish Current Deployment Issues	29
4. Rationalize the Opportunities and Vision.....	39
5. Developing a Roadmap Action Plan.....	45
Appendix A. Control Strategy Examination.....	54

Executive Summary

The objective of this project was to develop a “roadmap” to guide the Hawaiian Electric Company (HECO) demand response (DR) planning and implementation in support of the Hawaii Clean Energy Initiative (HCEI) 70% clean energy goal by 2030. Demand response is expected to provide approximately 200 MW of the clean energy goal. The specific objectives of this demand response roadmap project are:

- Evaluate the potential demand response needs of the HECO electricity grid,
- Outline potential demand response limitations, options, communication, and control technologies, and
- Identify research, education, policy, outreach needs, technology gaps, and best practices to guide HECO development activities.

Upfront, we established three major assumptions that guided our process and content development. Each of the following assumptions are further explained in the document:

1. *Time-differentiated efficiency is the highest priority and is a necessary foundation for the development of long-term, effective demand response initiatives.*
2. *Demand response options should be designed using technology, incentives, and operating features that can adapt to address a continuum of control and system response objectives that provide capability to capture a variety of values for the customer.*
3. *Demand response systems should be designed with capability to accommodate technological and operating uncertainties. This can best be accomplished with systems that functionally separate system control from communication and end-use control technologies*

The process to develop the DR roadmap included the following steps:

Step 1: Identify HECO demand response objectives – It is important to note that this step focuses on forward looking expected demand response objectives which includes but is not limited to capability intrinsic to existing HECO options. HECO’s prospective demand response objectives were determined based on interviews with key staff and executives at HECO, Hawaii Energy, the Hawaii Public Utilities Commission, the Consumer Advocates office, vendors, and through examination of numerous regulatory and planning documents.

Step 2: Establish current deployment status issues – Identifying the current deployment status establishes the baseline for determining the gap between HECO’s current and expected deployment requirements.

Step 3: Identify Technology Issues – Demand response technical capabilities, while principally driven by system objectives, involve considerations for differences between system and customer needs, market trends, and technical tradeoffs for addressing regulatory and other uncertainties.

Numerous vendors were contacted to update our own ongoing technology research and to identify potential HECO options.

Step 4: Identify Policy Issues – Legislative, regulatory, and HECO corporate policies can facilitate or limit demand response capability. While it may not be possible to change a particular policy, it is critical to identify potential options that impact the roadmap process.

Step 5: Rationalize the opportunities and vision - Rationalizing differences between HECO's prospective objectives and the existing deployment is both an objective and subjective process. We conducted expanded inquiries of experts within the Lawrence Berkeley National Laboratory as well as with other leading edge utilities, consultants, and vendors. Comparing our understanding of the HECO objectives with current and planned deployment activities helps identify areas of consistency, gaps, and potential conflicts, which then become active initiatives for the roadmap process.

Step 6: Develop the action plan – The action plan summarizes and establishes priorities for a variety of evaluation, market studies and research projects. To the degree feasible, we have organized all recommendations to reflect potential priorities, timing considerations, and interdependencies.

Key Observations:

- *Lack of price responsive options.* Price responsive demand accounts for approximately 42% of HCEI demand response objectives through 2030 split equally between time-of-use rates (TOU) and critical peak pricing (CPP).¹ HECO currently has TOU rate options with few participants. HECO has no comparable rate offerings that provide CPP. Contributing to this situation are system costs that may not provide sufficient inter-hour variation to support dynamic rate options with demand response capability. HECO tested advance metering necessary to support dynamic pricing however a proposed business case was withdrawn leaving metering infrastructure an open issue.² Based on a 2010 system potential study³ price response accounts for almost 80% of the HECO estimated system wide demand response potential⁴.
- *Load shaping objectives do not address intra-hour variability and load shifting capabilities of loads.* HECO demand response options and the 2010 demand response potential study⁵ do not address load shifting or energy efficiency objectives. Load shifting is typically dependent upon price driven control strategies, which becomes more complicated due to the corresponding need for residential advanced metering. However, load shifting should be a major consideration given the broad, flat nature of the HECO

¹ See Figure 8.

² Docket No. 2008-0303, Advanced Metering Infrastructure (AMI) Project, Application, filed December 1, 2008 was withdrawn. No formal explanation was available to explain the withdrawal.

³ See Figure 7.

⁴ Ibid.

⁵ Ibid.

system load and apparent contribution of residential water heating to the system peak. Load shifting can also address potential as-available renewable over generation issues, like what is already being experienced with MECO wind energy resources.

Regulation to manage intra-hour variability for intermittent wind resources is not currently being examined by HECO's FastDR or other demand response options. The FastDR Commercial and Industrial pilot is expected to test capability to provide a fast response bridge resource.⁶ The 2010 demand response potential study assumes regulation under the FastDR category for commercial and industrial loads, however regulation typically requires frequent operation of larger blocks of dedicated load with thermal or operating characteristics that allow up and down operation which is not necessarily consistent with more general interruptible or curtailable options.

- *Control strategy and dispatch criteria for current water heater and air conditioning demand response applications are still uncertain and not well documented.* Water heater load control has been a utility industry application since the late 1930's. Without exception, water heater control strategies turn units 100% off for durations that typically last 4-8 hours during system peak periods. Control strategies are almost universally designed to achieve reliability or peak reduction objectives, not economics. HECO dispatches water heaters to achieve both reliability and economic objectives. While HECO dispatch practices continue to evolve, water heaters appear to be subject to short cycling, which turns units off only for a percentage of time each hour, and short duration control periods that last three hours which may or may not be fully aligned with system peaks. Air conditioner dispatch records did not sufficiently reflect HECO's most current practices. Formal criteria need to be developed to guide system operators and govern when, for how long, and how often water heaters and air conditioners are controlled.
- *Clean Energy Initiative demand response targets for interruptible load appear to exceed the estimated HECO system potential.* HCEI demand response targets through 2030 provide specific price and interruptible demand response targets. HCEI interruptible targets through 2030 appear to exceed 2010 estimated HECO interruptible potential.
- *Energy efficiency and demand response efforts are not coordinated.* HECO has responsibility for demand response. The Hawaii Energy Efficiency Program has responsibility for energy efficiency programs. Demand response and energy efficiency initiatives from both organizations are not currently subject to any coordination or integration. Initiatives from both organizations address the same customers and same end-uses, often resulting in overlapping marketing, education, and incentive situations.

⁶ HECO is working with EPRI and a grid interactive energy thermal storage vendor for its examination of wind integration controls with residential electric resistance water heater end use

Recommendations

Our recommendations are grouped into two interrelated paths that address three key areas of focus. One path addresses demand response potential and associated policy issues. This path is divided into separate sets of interruptible and price responsive activities. The interruptible activities include efforts to better understand control strategy productivity, the need for end-use under frequency relay (UFR) capability, and potential targeting of demand response options to specific customers or loads. The price response activities examine the feasibility to provide dynamic rates (price responsiveness) and whether there is justification to support the required advanced metering infrastructure (for residential and small commercial customers) and other support systems. The interruptible and price response research present a logical hierarchical set of recommendations. The price response path also incorporates a “revise and revisit” circularity intended to accommodate some of the uncertainty and conflicting priorities introduced by conventional cost of service and rate design studies and the potential “public good” inherent in the HCEI objectives. The circularity reflected in the research plan provides an option to allow more creative public good issues to be brought into at least one part of the demand response discussion.

The second group of research recommendations is primarily focused on customer and system related technology issues, which typically require pilots or technical engineering evaluations. We have also attempted to define all pilots with narrow scopes and clear implementation objectives. The intent is to minimize associated costs and narrow the potential risks.

1. Introduction

The purpose of this project is to develop a demand response roadmap that can simultaneously address and integrate HECO, Hawaii Clean Energy Initiative (HCEI), regulatory, and customer objectives. A demand response roadmap provides a high level examination of the most critical technology, resource planning, environmental, operational, customer, and regulatory factors for achieving the demand response goals. A roadmap identifies gaps in technical capability and any conflicts between objectives that may influence or drive future HECO demand response capability. A roadmap is not an implementation action plan so it does not define specific programs, technologies, or develop detailed cost effectiveness scenarios; however it may recommend research or other projects that address these factors⁷. The specific goals of this demand response roadmap project are:

- Evaluate the potential demand response needs of the HECO electricity grid,
- Outline potential demand response limitations, options, communication, and control technologies, and
- Identify research, education, policy, outreach needs, technology gaps, and best practices to guide HECO development activities.

The emphasis in this demand response roadmap is on HECO. Our perspective throughout this project recognizes that HECO provides a unique island-based system without interconnections. While we expect some of the recommendations in this roadmap will also have application to Maui Electric Company, Ltd. (MECO) and Hawaii Electric Light Company, Inc. (HELCO), there are significant differences between the systems that must be considered. For example, issues related to understanding and determining demand response potential and technology options should have general application across systems. However, MECO has unprecedented levels of wind energy that already substantially impact their demand response opportunities and needs. MECO's recently initiated smart grid demonstration project also puts them on a technology path significantly ahead of both HECO and HELCO, which provides a unique test bed for examining many of the roadmap renewable integration options. Likewise, there are several key technology, policy, and operational experience issues specific just to the HECO demand response programs that are not relevant to MECO or HELCO.

Background

In 2005 Hawaiian Electric Company (HECO) initiated the residential and commercial and industrial (C/I) direct load control programs⁸. These demand response direct load control programs have two objectives: reduce costs by deferring new generation capacity additions and improve grid operating reliability by manually dispatching customer loads during system

⁷ Roadmap recommendations for research, demonstration, or other evaluation projects may provide a basis for developing what HECO refers to as a risk management action plan (Risk MAP).

⁸ EnergyScout Residential Direct Load Control (RDLC) and Commercial and Industrial Direct Load Control (CIDLC).

emergency events and with automatic load shedding for system frequency stabilization. In 2008 the Hawaii Clean Energy Initiative (HCEI) established a goal of achieving 70% clean energy by 2030. The HCEI goal will require the integration of significant renewable resources into the HECO electricity grid. Integrating renewable resources is expected to expand the objectives and may require substantial repositioning of HECO demand response capabilities. With the introduction of its 'Fast DR' pilot program in 2011⁹, HECO took the first steps to address renewable integration in their portfolio of demand response capabilities.

It is important to note that the HCEI goals introduce new requirements that go well beyond the scope and established experience of existing demand response applications. Research to examine how demand response can be most effectively deployed for renewable integration has only been underway for a few years, consequently, while best practices for traditional HECO peak load and reliability management applications are reasonably well understood, this is not yet the case for using demand response for renewable integration. Renewable integration substantially changes the dynamics of how traditional demand response programs are targeted, designed, and operated. What is clear is that the demand response renewable integration environment will require policy, technology, and operational options that can adapt to changing conditions.

Roadmap Assumptions

While demand response options have been employed by electric utilities for over 60 years, there is still no industry consensus regarding what constitutes an optimal system design or set of best practices. This is partially because demand response tries to address local issues and its value is driven by local markets that vary around the country. Development of the demand response roadmap will naturally reflect our experience as well as our implicit and explicit assumptions. In this section we identify three basic assumptions that guide our HECO roadmap development effort.

While storage water heater options began in the 1930's, most utility demand response and efficiency initiatives began as pilot programs initiated by PURPA¹⁰ in 1978. Successive legislative and regulatory actions at the federal and state levels have continued to expand and fund demand response and efficiency as separate, independent initiatives. Traditionally, demand response and efficiency are organized as utility managed initiatives, which are in many cases assigned to different organizational units. Each is usually comprised of a portfolio of many independent programs that are differentiated by their focus on a particular target market or technology. HECO reflects a similar environment with one distinct difference: energy efficiency

⁹ The FastDR pilot program was submitted in August 2010 and approved by the Hawaii PUC in November 2011

¹⁰ Public Utility Regulatory Act, adopted in 1978.

programs are managed by a completely different legislatively mandated non-utility organization.¹¹

Efficiency is the Foundation of Demand Response

The evolution of demand response from the original PURPA pilot programs contributed to two issues central to our roadmap assumptions. First, separating demand response and efficiency into separate independent organizations and program offerings can result in a lack of coordination that often adversely impacts both offerings. From the customer perspective,

Lawrence Berkeley National Laboratory (LBNL) research has shown that commissioning efforts to identify customer demand response options often identify significant efficiency and permanent load reduction or load shifting opportunities.^{12,13} When efficiency is not addressed first demand response cost effectiveness can be overstated or system needs may misidentify potential opportunities. As a result, our roadmap approach assumes that efficiency and demand response initiatives must be integrated and that efficiency should be the first priority.

Roadmap Assumption #1:

Time-differentiated efficiency is the highest priority and is a necessary foundation for the development of long-term, effective demand response initiatives.¹⁴

Demand Response is a Continuum of Options

Many of today's demand response options represent expanded versions of the pilots and demonstration projects commissioned to test and evaluate technical feasibility and cost effectiveness. Pilots use experimental designs to purposely isolate technical and other demand response features to facilitate evaluation. For pilots this approach deliberately creates boundaries or artificial distinctions between multiple programs that may focus on the same customers and same end-use but differ only in timing, incentives, control strategies, or control technologies being used. Program structures suitable for pilots are not necessarily suitable for large-scale operational programs. Because demand response tends to address uncertain environments, program designs need to provide capability to easily adapt to changing load shaping objectives or system conditions.

The roadmap perspective (Figure 1) views demand response as a continuum of options differentiated principally by system response requirements. Daily energy efficiency, on the far left of Figure 1, is considered the base foundation for demand response, which is also stated in our Roadmap Assumption #1. Moving from left to right, demand response characteristics reflect

¹¹ Hawaii Energy is a third-party administrator, created by legislation in 2006, that manages all Hawaii energy efficiency programs under a public benefits funded contract with the Public Utilities Commission.

¹² <http://drrc.lbl.gov/sites/drrc.lbl.gov/files/lbnl-187e.pdf>

¹³ <http://drrc.lbl.gov/sites/drrc.lbl.gov/files/lbnl-3348e.pdf>

¹⁴ Both energy efficiency and demand response should be implemented in a simultaneous and coordinated manner.

increasingly faster response time, shorter advance notice, and greater dependence on dynamic or real-time pricing incentives. The need for more advanced metering, communication, and automation requirements also increase as options move from left-to-right.

Figure 1. Demand Response Continuum

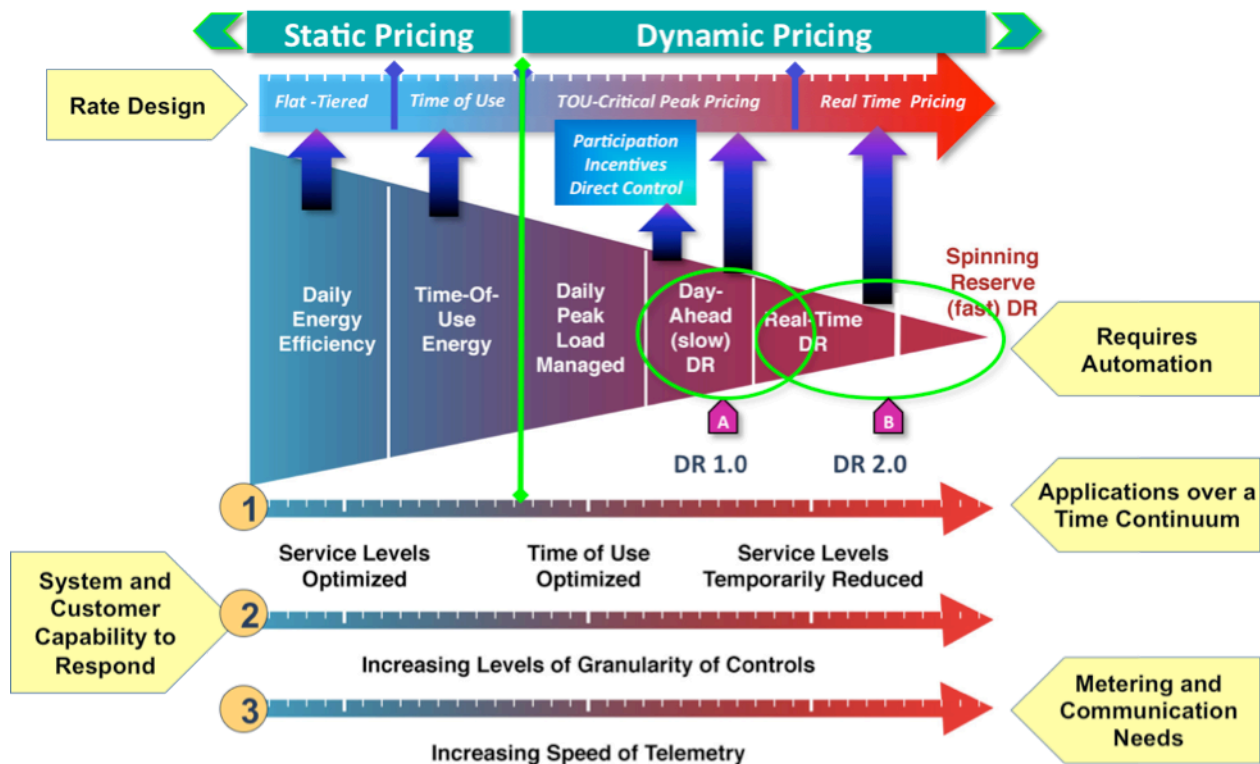


Figure 1 illustrates a continuum of demand response initiatives and the interrelationship between technology and policy. Specifically, pricing or rate structures implicitly dictate metering and communication requirements and both (rate policy and technology implementation) in turn explicitly facilitate demand response capabilities. Advanced metering and communications without dynamic rates limits demand response to only those options supported by static pricing. Conversely a policy to pursue dynamic rates cannot proceed without advanced metering and improved communication capability.

Figure 1 also defines the potential technology approach and application space that utilities should consider to build in flexibility and capability to address uncertain future system conditions. For example, implementing communications and control equipment compatible with real-time demand response offerings (Figure 1, labeled DR 2.0)¹⁵ will generally support all day-ahead,

¹⁵ Technology to support traditional direct control assumes participation rather than performance payments. Even when configured to provide day-of, fast response capabilities direct control technology packages may not necessarily provide communication acknowledgment or the metering to support performance confirmation.

daily peak load managed and other options in the left portion of Figure 1, however this choice comes at a cost. While forward looking technology investments would provide HECO and its customers with flexibility to more easily adapt and shift between options as business conditions and individual lifestyles change, the roadmap has to consider the prudence of all investment costs. Utility and customer costs to change equipment can also be a practical and cost effectiveness barrier to maintaining demand response options. As a result, the roadmap options must also consider the tradeoff between current and potential future technology capability. If system decisions can be structured to broadly define demand response as a continuum of offerings they can provide a hedge against uncertainty (changing system load and resource requirements) and build in flexibility that might allow the utility and customers to shift between options with minimal cost impacts. The demand response roadmap must make provision to address the uncertain outcomes HECO faces as it implements increasing levels of renewable resources.

Figure 1 also has implications for defining potential target customers and end-uses. For example, real-time demand response (far right area of the graphic) will require costs to provide advanced metering, pricing, telemetry, and control equipment. Those costs and the real-time response requirements may be more compatible with large commercial, industrial or aggregated loads and not with individual residential loads. In essence, moving from the less to more sophisticated and more real-time options potentially requires some segmentation or dedication of overall system potential to specific demand response alternatives.

The demand response continuum depicted in Figure 1 is a conceptual basis for our review of the HECO requirements.

Roadmap Assumption #2:

Demand response options should be designed using technology, incentives, and operating features that can adapt to address a continuum of control and system response objectives that provide capability to capture a variety of values for the customer.

Demand Response Should be Designed to Address Uncertainty

Public Utilities Regulatory Policy Act (PURPA) and the subsequent federal and state legislation that created the demand response initiatives implicitly assumed the utility is the primary provider of demand response and efficiency initiatives. This ‘utility centric’ approach was consistent with existing electric operations and system designs characterized by exclusive utility control over centralized generation, transmission, distribution, and customer service options. Demand response systems developed under this model also justified investments that assumed long-term cost recovery expectations similar to treatments applied to other traditional utility assets.

The ‘utility centric’ approach depends on the utility to decide what programs are offered; to provide, install, and maintain any control equipment; determine when, how, and how often that

control equipment is operated, and; to evaluate program effectiveness. This approach promotes what is often described as a vertically integrated program structure that is often locked into a single communication option and fixed incentive, operating, and control technology requirement. The need to provide for long-term cost recovery further encourages design and engineering approaches that lock demand response into systems with limited capability to address changing electric system operating needs. In other word the historical approach to demand response limits flexibility.

This approach is increasingly difficult to support with today's rapidly changing technology development, changing customer needs, or the dynamics and uncertainties in the energy market. New customer energy management and control technologies that offer cost and performance improvements are often difficult or impossible to accommodate (e.g. technical and operating incompatibilities) in existing utility demand response systems without disrupting or changing the program designs or replacing the physical equipment on both the utility and customer sides of the meter. Frequent equipment or program changes are disruptive to system operations and customer acceptance and generally have negative cost effectiveness implications.

HECO's demand response environment is characterized by uncertainty on the utility side of the meter due to the addition of renewable resources, a potential expanding market for electric vehicles, and evolving environmental regulations. There is additional uncertainty on the customer side of the meter due to rapidly changing electronics, the development of smart appliances, and greater dependence on the Internet. Planning or committing to system and or equipment changes in this environment has to address the risk of premature obsolescence, the creation of stranded assets, and reduced system functionality. Designing systems consistent with industry standards may also no longer offer sufficient risk mitigation. The standards process can no longer keep pace with the rapid change in communication, energy management, control technology, and customer appliances.

LBNL research has shown that uncertainty on both the utility and customer sides of the meter can be addressed by segmenting demand response system designs into three major components: (1) utility control system or demand response management system, (2) physical communications with bridge clients, and (3) customer controls.¹⁶ These three components are integrated and linked using existing communication standards and data models. Data models standardize the data translation and transfer of information between each component. Using data models to link these system components allows changes to occur within each component independently without disrupting the rest of the system. For example, changes in utility operating strategies or incentives get translated into price and event signals and transparently passed to the communication components. The communication system sees a common data format and the customer sees a new price or event signal, however there is no need to change out any equipment. Customers may or may not have to change how they respond to new price or event signals (control strategies). Under this segmented design utilities could support multiple

¹⁶ <http://drrc.lbl.gov/sites/drrc.lbl.gov/files/lbnl-63665.pdf>

communication options. Bridge clients can translate price or event signals to accommodate different communication options and allow the utility or customer to implement multiple devices within a premise or within a single demand response option, each potentially with different communication attributes. Elements of this approach are already included in the HECO FastDR pilot plan. This modular approach also:

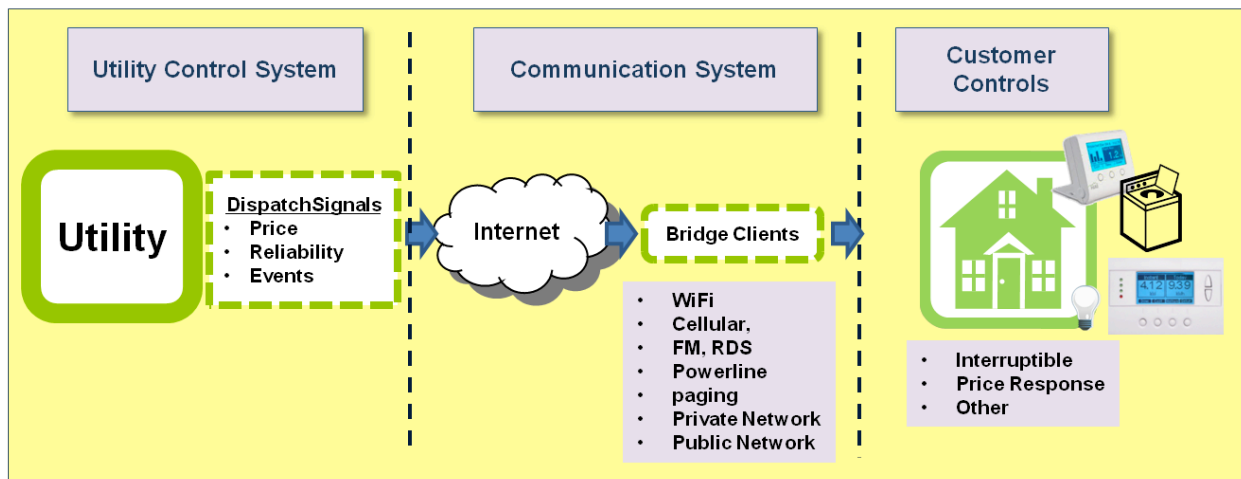
- Allows multiple communication options to coexist within the same system,
- Provides capability to adapt to new emerging communication and control options,
- Reduces the likelihood of premature technology obsolescence by providing capability to simultaneously operate and transition between legacy and other replacement options, and
- Provides capability to move customers between options within the continuum described in Figure 1.

While our roadmap approach does not exclude the potential need for specialized demand response systems, we generally view system requirements in a modular framework described in Roadmap Assumption #3.

Roadmap Assumption #3:

Demand response systems should be designed with capability to accommodate technological and operating uncertainties. This can best be accomplished with systems that functionally separate system control from communication and end-use control technologies (Figure 2).

Figure 2. Demand Response Modular Design Approach



Defining the Framework for Demand Response Roadmap

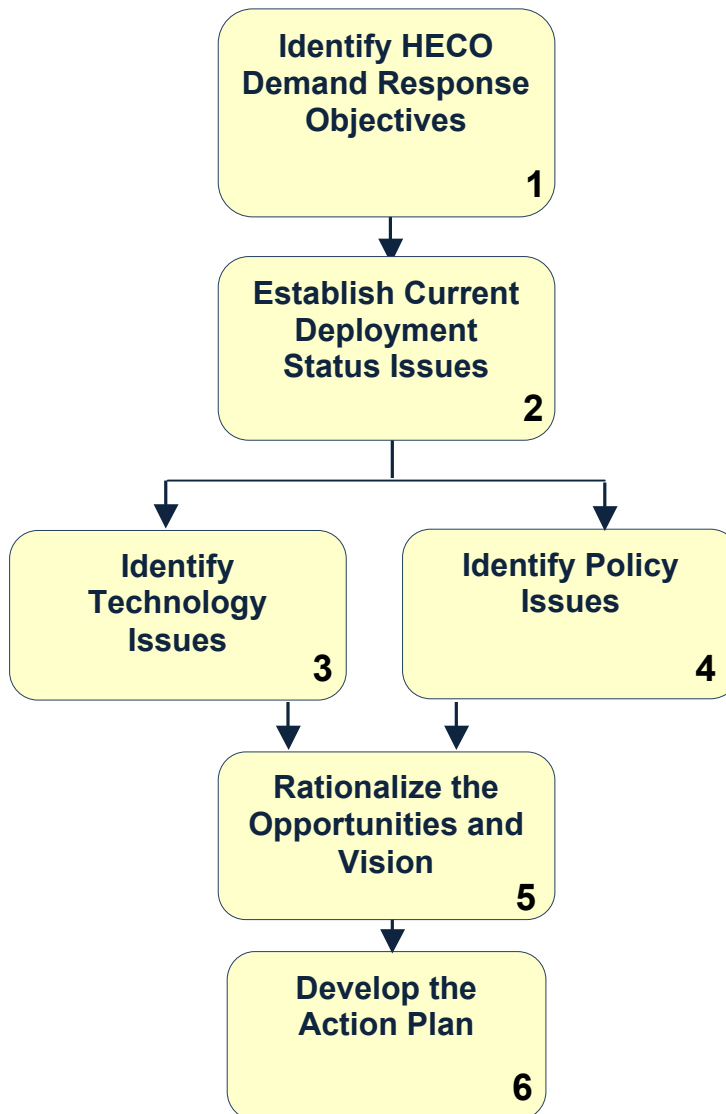
We defined a six-step process (Figure 3) to guide development of the HECO demand response roadmap.

- Step 1: Identify HECO demand response objectives – It is important to note that this step focuses on forward looking expected demand response objectives which includes but is not limited to capability intrinsic to existing HECO options. HECO’s prospective demand response objectives were determined based on interviews with key staff and executives at HECO, Hawaii Energy, the Hawaii Public Utilities Commission, the Consumer Advocates office, vendors, and through examination of numerous regulatory and planning documents. Some objectives are explicitly stated in corporate planning or legislative and regulatory mandates. Other objectives were extrapolated based on our industry experience or interpretation of the changing HECO environment.

For example, demand response is expected to provide HECO with capability to facilitate the integration of renewable resources. Objectives define the demand response goals, expectations, and capabilities the roadmap must address.

- Step 2: Establish current deployment status issues – Existing operating practices, recent system studies, active regulatory filings, and ongoing research and implementation activities were reviewed to provide a picture of where the existing HECO environment matches up with the objectives identified in Step 1. While the capability and status of existing demand response applications are relatively easy to determine, many deployment issues are subjective, uncertain, and in many cases outside HECO control. Identifying the current deployment status establishes the baseline for determining the gap between HECO’s current and expected deployment requirements.

Figure 3. Demand Response Roadmap Development Steps



- Step 3: Identify Technology Issues – Demand response technical capabilities, while principally driven by system objectives, involve considerations for differences between system and customer needs, market trends, and technical tradeoffs for addressing regulatory and other uncertainties. Numerous vendors were contacted to update our own ongoing technology research and to identify potential HECO options.
- Step 4: Identify Policy Issues – Legislative, regulatory, and HECO corporate policies can facilitate or limit demand response capability. While it may not be possible to change a particular policy, it is critical to identify potential options that impact the roadmap process. Like the approach described in Step 5, we expanded our efforts with selected

inquires to other experts both within and outside the Lawrence Berkeley National Laboratory.

- Step 5: Rationalize the opportunities and vision - Rationalizing differences between HECO's prospective objectives and the existing deployment is both an objective and subjective process. Technical features and capabilities of existing load control equipment (e.g. communication speed and latency) can be objectively established. However many intermittent resource issues are not yet fully understood, consequently determining the policy, technical, and operating needs become much more subjective. To further expand on our own experience and interpretation of the information obtained in Steps 1 and 2, we conducted expanded inquiries of experts within the Lawrence Berkeley National Laboratory as well as with other leading edge utilities, consultants, and vendors. Comparing our understanding of the HECO objectives with current and planned deployment activities helps identify areas of consistency, gaps, and potential conflicts, which then become active initiatives for the roadmap process.
- Step 6: Develop the action plan – The action plan summarizes and establishes priorities for a variety of evaluation, market studies and research projects. To the degree feasible, we have organized all recommendations to reflect potential priorities, timing considerations, and interdependencies.

The sections that follow consolidate the six-step roadmap process into four chapters. Chapter 2 matches Step 1 in the roadmap approach. It summarizes and examines the HECO demand response objectives, comparing them against a broad template of possible objectives. Chapter 3 reviews a range of deployment issues. Chapter 4 consolidates Steps 3-5 of the roadmap and also integrates observations from Chapters 2 and 3. The individual steps in the roadmap process are well suited to documenting the categorical factors influencing demand response, however rationalizing the opportunities and vision require these factors to be integrated into meaningful proposals. Finally, Chapter 5 provides a set of potential planning, evaluation, and research projects as well organizational issues for HECO consideration.

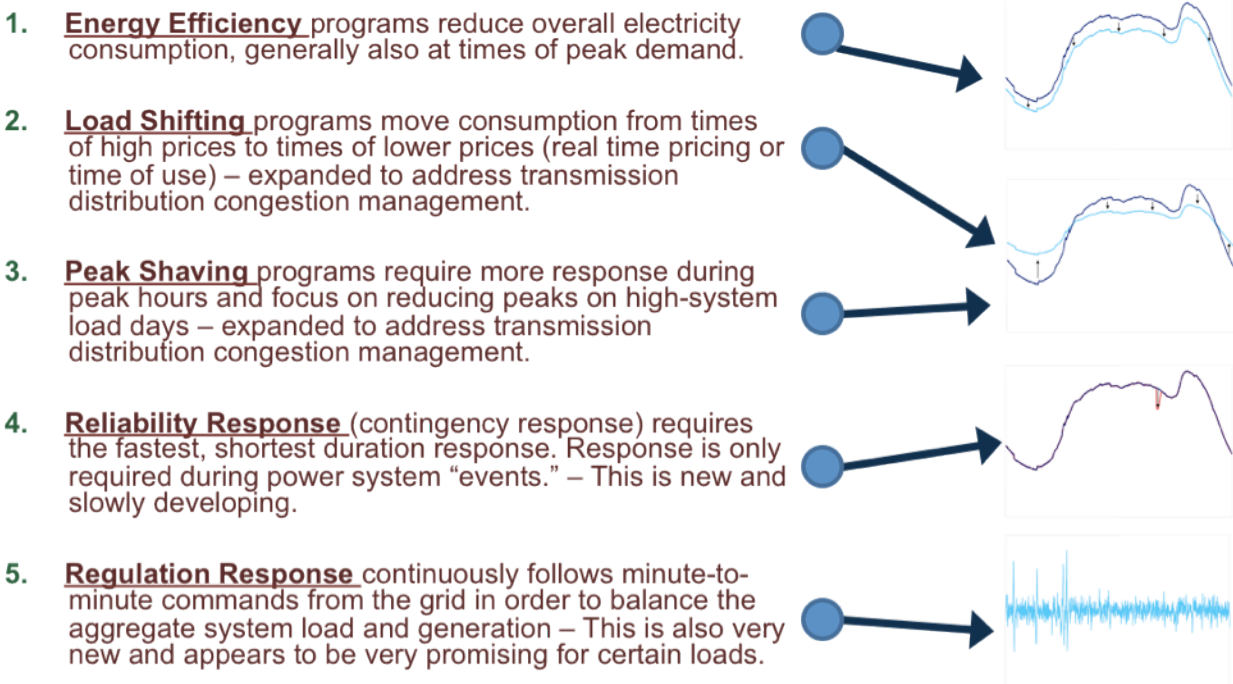
2. Identify HECO Demand Response Objectives

HECO has developed a portfolio of residential and commercial/industrial demand response options that employ incentives, technologies, and operating practices designed to achieve a range of six different load shaping objectives. Table 1 identifies each of the HECO options with a snapshot of key attributes and objectives. Our review of the HECO demand response objectives focuses on two key issues: (1) does the mix of load shaping objectives provide flexibility to address existing and anticipated system conditions, and; (2) do these objectives position HECO to capture the capabilities and system potential for demand response?

The Mix of Demand Response Load Shaping Objectives

Demand response applications are typically designed to achieve one or more of the five basic load shaping objectives described in Figure 4. There are alternative demand response classification schemes, however Figure 4 covers the basic range of industry implementations. These objectives vary in their focus on energy and capacity. Like HECO actual utility demand response implementations can incorporate these objectives with widely differing control technologies, notification options, control periods, event frequency, and response time features. While there are no formal standards, industry-wide utility demand response applications tend to incorporate similar approaches and attributes relative to each particular objective.

Figure 4. Demand Response Objectives¹⁷



¹⁷ Adapted from: Demand Response Spinning Reserve Demonstration Project, Consortium for Electric Reliability Technology, LBNL, Joseph Eto presentation October 19, 2009

Table 1. HECO Demand Response Program Attributes

	Residential Direct Load Control (RDLC)	Commercial and Industrial Direct Load Control (CIDLC) [2]	Small Business Direct Load Control SBDLC [2]	Fast Demand Response (FastDR)	Commercial and Industrial Dynamic Pricing Pilot Program (CIDP)
A. Objectives					
1. Emergency Peak Reduction	●	●	●	●	●
2. Capacity Deferral	●	●	●		●
3. Economic Dispatch	Proposed		Proposed	●	●
4. Non-spin reserves				●	●
5. Under Frequency	●	●	●		
6. Bridge Resource for Intermittent load	Proposed		Proposed	●	●
B. Target Customers	Residential	Large Commercial and Industrial	Small Commercial and Industrial • Demand >3< 300kW	Large Commercial and Industrial	Large Commercial and Industrial
C. Participation	<ul style="list-style-type: none"> • 34,200 WH, 15.0MW • 4,100 AC, 2.7MW 	<ul style="list-style-type: none"> • 42 customers • 18.2 MW 	<ul style="list-style-type: none"> • 161 customers • 1MW 	<ul style="list-style-type: none"> • 6MW semi automated • 1MW automated 	<ul style="list-style-type: none"> • 20 customers minimum • 2MW goal • Pending PUC approval
D. Participation Conditions	<ul style="list-style-type: none"> • Electric water heating >30 gallons • Central air conditioning • Load control receiver or PCT 	<ul style="list-style-type: none"> • Large C/I with non-critical or generator backed loads that can be controlled by HECO [1] • Under Frequency optional • Min 50kW controlled 	<ul style="list-style-type: none"> • Electric water heating min 4.5kW/unit or • Central air conditioning min 3-tons and • Other controllable loads >5kW 	<ul style="list-style-type: none"> • Min 50kW controlled • 10min or less response • Max 2 hr. duration 	<ul style="list-style-type: none"> • Min 50kW controlled or • 15% of annual demand • 10min, 1-hr day-ahead • Duration option dependent 1-6 hrs.
E. Availability	<ul style="list-style-type: none"> • 24 hrs/day, 365 days/yr. • No notification • No limits 	<ul style="list-style-type: none"> • 24 hrs/day, 365 days/yr. • 1-hour advance notice • Unlimited duration • 300 hrs/yr. 	<ul style="list-style-type: none"> • 24 hrs/day, 365 days/yr. • 1-hour advance notice • Unlimited duration • 300 hrs/yr. 	<ul style="list-style-type: none"> • Weekdays 0700-2100, • no holidays • 80 max hrs/yr. 	Complex schedule based on notice, duration, events
F. Technology	One-way Paging Load Control Receiver	One-way Paging Load Control Receiver	One-way Paging Load Control Receiver	<ul style="list-style-type: none"> • Two-way Internet • AutoDR / Aggregator 	<ul style="list-style-type: none"> • Two-way Internet • AutoDR/ Aggregator

[1] EPA rules to limit generator response to 15 hours/year and new permitting costs projected to reduce customer participation in this option.

[2] May not reflect all updates from Docket 2012-0118 expansion request filed with the Public Utilities Commission of Hawaii on May 17, 2012.

Demand response applications can also be classified as either price responsive (non-dispatchable) or interruptible (dispatchable). Price responsive demand requires a time varying dynamic rate where some element of the rate is communicated to the customer based on system peak load or reliability conditions. Price responsive demand also requires advanced metering to provide interval data and enhanced billing system capability. Under a price responsive application the utility communicates a price signal and the customer determines how and when to respond. Typically, price responsive incentives charge customers for their actual usage during any pricing period or event. The customer has the choice to modify their usage to avoid high prices, take advantage of low prices, or pay through an event regardless of cost to accommodate varying lifestyle or business conditions.

Interruptible demand response applications require a communication link between the customer and utility that operates control switches or other control points attached to one or more specific customer loads. Under an interruptible application, the utility determines how and when the customer load will be controlled, which may or may not be preceded by some form of notification. Interruptible incentives also tend to specify firm service levels to assure a fixed or more certain demand response and the use of baselines to compute penalties or reduced incentives for failure to comply.

Emphasizing Interruptible Applications

Table 1 lists six different HECO load shaping objectives. These objectives generally map to only two of the five objectives identified in Figure 4. HECO's Emergency Peak Reduction (1), Capacity Deferral (2), Economic (3), and Bridge Resource for Intermittent Load (6) objectives are generally equivalent to the Figure 4 Peak Shaving objective. All of these HECO objectives focus on shaping load to either reduce existing system fuel costs or to defer future capacity additions. Peak Shaving is the most common demand response objective within the industry and like HECO, utilities typically target residential water heaters and air conditioners using some form of direct control. HECO's Non-Spin objective is equivalent to the Figure 4 Reliability Response objective.

HECO's RDLC and CIDLC options incorporate three features that relax constraints and provide much greater flexibility and potential load shaping value than what is common to other industry applications, specifically:

- Elimination of Seasonal and Event Constraints: Almost all residential load control options have restrictions that limit operations to specific seasons, defined peak hours, and a fixed number of events and cumulative hours per year. The HECO RDLC and CIDLC options eliminate seasonal and peak hour constraints. This approach provides HECO with enhanced operating flexibility which should substantially improve the option resource value. These expanded features also better address the lack of significant differences between the seasonal system load profiles and need for year-round demand response capability.

- Small Business Direct Load Control: The SBDLC direct control options for small business commercial customers are not commonly offered by other utilities. Providing options to address the commercial and industrial sector provides HECO with a demand response balance not common to most utilities.
- Under Frequency Response: HECO load control receivers provide remotely configurable capability to autonomously monitor and shed load when frequency dips below pre-set levels. While under frequency response is not considered a demand response option, this option may provide HECO with additional system benefits at a small incremental technology cost. Based on our examination, HECO is very likely the only utility in the US to offer frequency response integrated into device level control switches (load control receivers).

The Fast Demand Response (FastDR) and Commercial and Industrial Dynamic Pricing Pilot Program (CIDPP) are both relatively new pilot interruptible options¹⁸ with similar operating characteristics. Both options have been designed to provide non-spinning reserves and to provide a bridge resource to address intermittent wind and avoid the need for acquiring or operating quick ramping conventional fuel-powered generation resources. The utility industry has raised expectations for using demand response to provide ramping services, however most options are still in the research stage. HECO is well positioned to contribute to the results and experience from these two pilots will establish how effectively these options will address renewable intermittency.

At the time of this report, the CIDPP had not yet been approved by the Hawaii Public Utilities Commission (HPUC). The CIDPP employs a matrix of demand charge and energy surcharge options differentiated by wind versus capacity, advance notice, and duration options. Although HECO labels the CIDPP a dynamic pricing option, prices in each option are fixed and are technically dispatched as incentive proxies for a firm service interruptible action. For the purposes of this roadmap project we classify the CIDPP as a dispatchable reliability based option.

Observation: A Lack of Price Responsive Options

Existing HECO options do not address two of the five demand response objectives listed in Figure 4: (1) Energy Efficiency and (2) Load Shifting. Both of these objectives are critically dependent upon rate or price-based incentives that can motivate customer technology investments and more permanent behavior change. Both objectives also address foundational energy usage issues that can materially impact the potential and effectiveness of all other demand response options. If effective, Energy Efficiency and Load Shifting change the baseline demand during the system peak potentially reducing the need for more active peak load reduction. This is consistent with our *Roadmap Assumption #1* that emphasizes efficiency first. Both of these

¹⁸ FastDR was approved by the Hawaii PUC and is undergoing implementation. CIDPP is still awaiting a Hawaii PUC decision.

objectives can also be accomplished, in most cases, with customer provided investment in more efficient end-uses, timers, and energy management systems avoiding the need for active utility involvement or investment.

Energy Efficiency demand response actions, which are also referred to as permanent demand response, lowers the demand curve permanently by using rates and incentives to encourage customers to replace older less efficient end-uses with more efficient units. Active controls to manage customer end-use run times are not usually required to accomplish this objective. Load shifting is also dependent upon rates and incentives to encourage customers to move load from peak to off-peak periods. Load shifting options are often preferable to interruptible options because they have less adverse impact on sales¹⁹ (kWh) and tend to better preserve customer service levels. Both of these objectives also create different load impacts than traditional interruptible or curtailable²⁰ demand response options. Efficiency and load shifting objectives emphasize economic impacts over large blocks of hours in contrast to reliability oriented interruptible and curtailable options that tend to emphasize control over much shorter 1-6 hour durations (e.g. RDLC, SBDLC, and CIDLC) or options designed to provide even shorter-term spin and bridging options (e.g. FastDR and CIDPP). Efficiency and load shifting objectives can also require a focus on selected target customers and specific loads that either have significant energy efficiency potential or thermal storage capability (e.g. refrigeration, water heaters, pumping, and building envelope). The HECO peak day load profile depicted in Figure 5 clearly indicates that residential usage is the major contributor to the system peak. Figure 6 identifies electric water heating as a key target for load shifting.

¹⁹ Reduced kWh sales under decoupling may not adversely impact utility earnings; however rates may have to increase to maintain the revenue requirement.

²⁰ Interruptible refers to loads that are directly controlled by a utility installed switch – typically targeted to residential and small commercial/industrial customers (e.g. HECO EnergyScout). Curtailable refers to customer controlled loads, which may vary from one event to another – typically targeted to large commercial/industrial customers.

Figure 5. HECO System Peak Day Load Profile (October 27, 2003)²¹

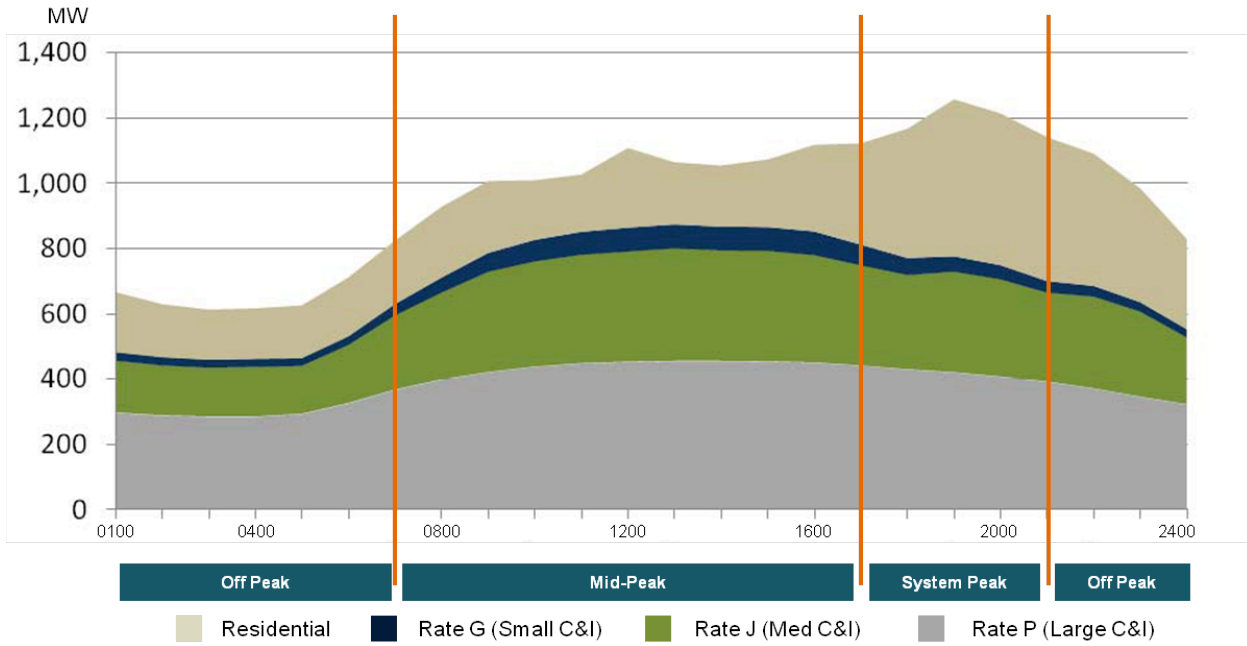
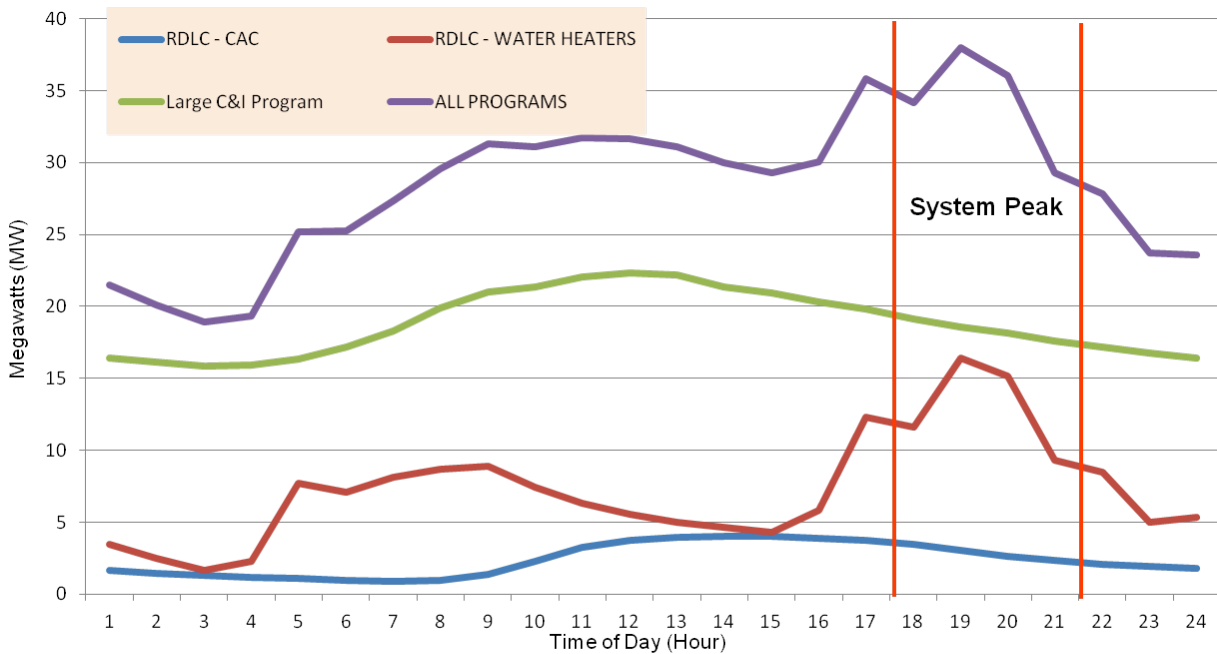


Figure 6. HECO Demand Response Participant Load Profiles (October Peak Day 2011)²²



Source: HECO Demand Response PUC Briefing, November 28, 2011, Slide #26

²¹ Assessment of Demand Response Potential for HECO, HELCO, and MECO. Final Report, Global Energy Partners, LLC, May 2010, Figure 2-1, page 2-3.

²² HECO Demand Response Hawaii PUC briefing, November 28, 2011, Slide #26.

Although HECO experiences similar summer and winter peak to off-peak load shape differentials, existing residential, general service, and large power time-of-use rates do not appear to provide sufficient cost variation or energy based rate incentives to either attract a large enough customer base or to incent pre-cooling or shifting from peak to off-peak periods. The existing HECO resource mix may not provide sufficient cost variation²³ to justify energy based rate incentives sufficient to encourage load shifting however, contractual provisions tied to renewable resource additions may create an opportunity for other incentives. For example, demand response may have economic advantages when incentives are based on the marginal cost of the next expected resource, especially when siting, environmental, as well as capital and fuel costs are considered. Incentive rates to encourage efficiency and load shifting without an adequate cost of service or deferred cost basis may not be a feasible mid to long-term solution if they create temporary subsidies that would eventually need to be recovered in base rates.

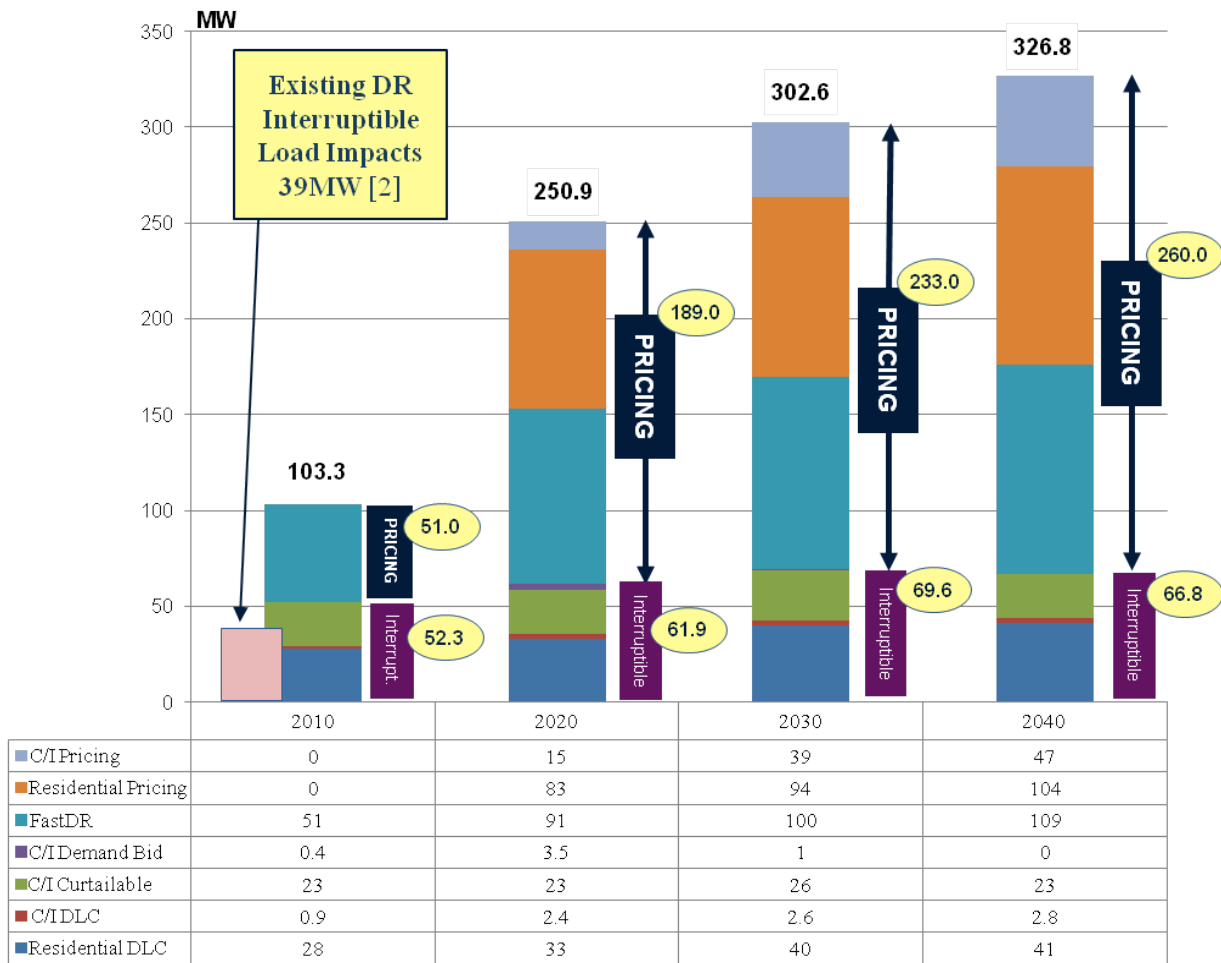
According to a report commissioned in 2010, price responsive options comprise a significant proportion of the HECO 30 year projected demand response potential²⁴ (Figure 7). Projections depicted in Figure 7 anticipate that price responsive demand could make up approximately 80% of the total system potential by 2040. According to Table 1, existing HECO demand response initiatives account for 39 MW of interruptible load and no price responsive load.²⁵

²³ Average rates show little variation over a 24 hour period since the marginal costs of generating units on Oahu differ little from each other throughout the day and peaking units make up a small fraction of total output. Internal correspondence between HECO and LBNL project management, March 16, 2012.

²⁴ Assessment of Demand Response Potential for HECO, HELCO, and MECO. Final Report, Global Energy Partners, LLC, May 2010, Tables ES-4 and ES-5.

²⁵ The CIDP Pilot Program has not yet been approved by the Hawaii PUC.

Figure 7. HECO Projected Demand Response Potential by Program and Year²⁶



A potential difficulty arises when the HECO demand response potential is compared to the target objectives outlined in the Clean Energy Initiative Agreement signed in 2008 (Figure 8)²⁷.

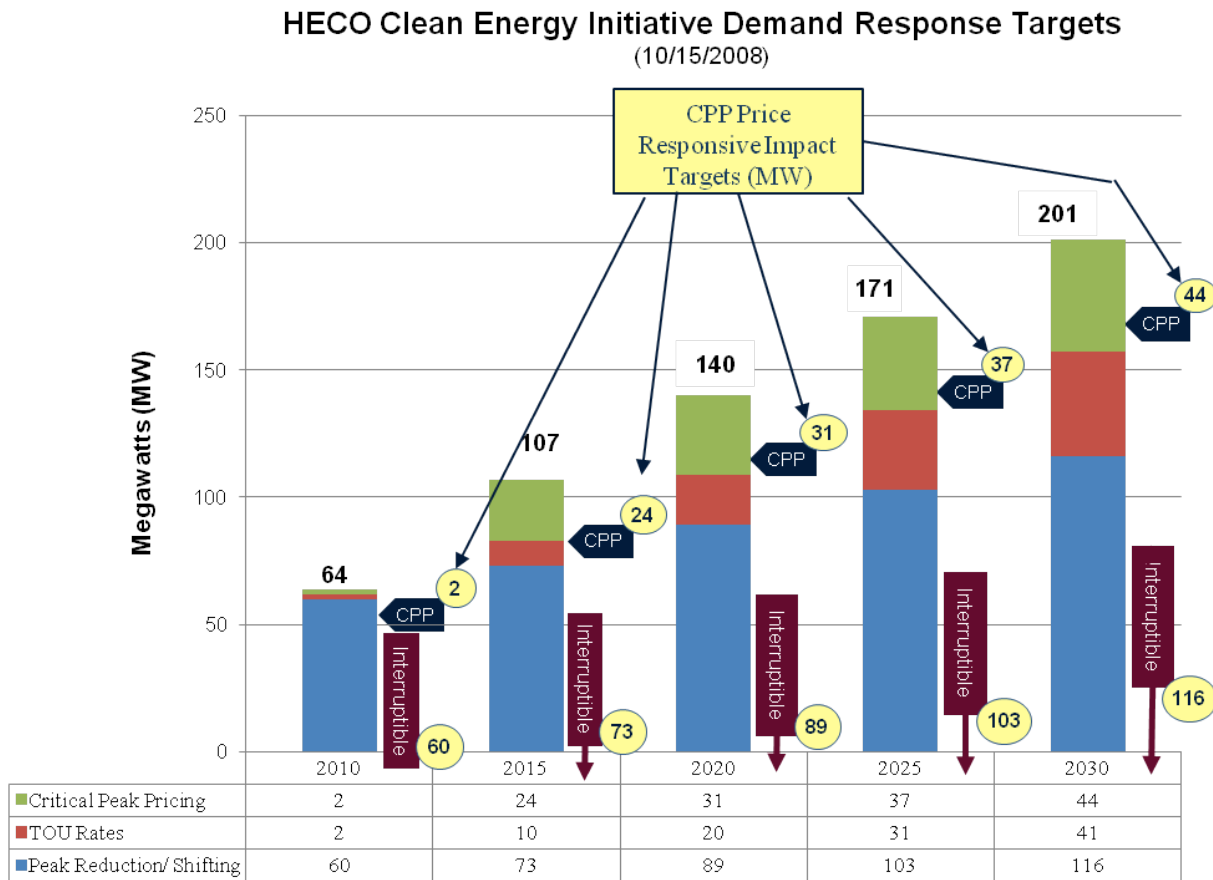
Figure 8 lists potential demand response implementation targets for 2010 to 2030 for three different options: Time of use rates (TOU), Critical Peak Pricing (CPP), and Peak Reduction. For comparative purposes, Peak Reduction estimates in Figure 8 are assumed equivalent to the interruptible and/or direct control options listed in Figure 7. Comparing Figure 8 with Figure 7, interruptible targets exceed the estimated interruptible potential throughout the 2010 to 2040 time horizon.

²⁶ Estimates in Figure 7 reflect the most conservative “realistic achievable potential (RAP)” included in the 2010 report (Assessment of Demand Response Potential for HECO, HELCO, and MECO. Final Report, Global Energy Partners, LLC, May 2010, sum of Tables ES-4 and ES-5).

²⁷ Cumulative Target Goals (MW by year-end) for HECO, Amendment No. 1, Energy Agreement Among the State of Hawaii, Division of Consumer Advocacy of the Department of Commerce & Consumer Affairs, and Hawaii Electric Company, October 2008.

The 2010 study that derived the Figure 7 estimates classified CPP as a dynamic rate option, which is consistent with the CPP classification in Figure 8. While the 2010 to 2040 potential for price responsive demand in Figure 7 exceeds aggregate potential Figure 8 targets, the cost variation necessary to support the development of viable dynamic rate options is still somewhat uncertain [see footnote #24]. The 2010 demand response potential study did not consider TOU rates dynamic, consequently they are not included in Figure 8 although the ability to achieve this target will be dependent upon similar metering and rate design issues.

Figure 8. Potential Demand Response Implementation Targets by Year.²⁸



What Figure 7 and Figure 8 identify is the possibility that HECO demand response potential may not be sufficient to meet HCEI expectations. Price responsive demand is a major area of concern. While Figure 7 identifies price responsiveness as the most significant portion of HECO demand response potential, there are two significant issues that need to be resolved: (1) hourly peak to off-peak cost differentials may not be sufficient to motivate or justify customer response and; (2) price response requires advanced metering supported by a positive business case.

²⁸ Ibid.

Unresolved differences between what is expected and what can be achieved may require more creative technical and policy considerations.

Observation: Objectives to Address Renewable Integration

The 2010 HECO demand response potential study provides a range of assumptions and detailed estimates for each operating company by initiative over a 30-year time horizon consistent with a broad range of conventional load shaping objectives. However, there are two key objectives material to the HECO renewable integration that are not addressed, specifically (1) load shifting and (2) regulation up and down. Both of these objectives imply a capability to use some form of storage that can be used to; (1) move or shift several hours of energy use from one time period to another to reduce system peak load and absorb excess off-peak renewable (wind) generation or; (2) to provide 10-20 minutes of short-term ramping that can provide more economic transitions to conventionally fueled generation when renewable resources become unavailable.

- Load Shifting

Load shifting uses price or rate incentives, timers, or automated controls to pre-cool, pre-heat, or reschedule energy use from one time period to another. Off-peak pre-heating for domestic and commercial water heating using oversized storage tanks is one of the oldest demand response applications. It has historically been used to use lower priced off-peak rates to pre-heat and store hot water and shift the entire water heating cycle out of system peak periods. The same approach could be adapted to use excess off-peak wind energy, avoid curtailments of wind, and reduce the need to acquire and engage expensive peaking unit or to throttle back less efficient base load. Based on the load curves in Figures 5 and 6, load shifting may a potential option for addressing HECO residential water heating. A potential constraint to this application is the Act 155²⁹ which we address in Chapter 4.

Municipal water and some commercial pumping loads with proper storage capability may also have load shifting capability.

- Regulation

“Power systems with large amounts of variable generation (both wind and solar), which can increase or decrease output unexpectedly, may raise the importance of both upward and downward reserves. “³⁰The same customer loads targeted for load shifting can also have non-spin operating reserve application and for short-term regulation up (decrease usage) and regulation down (increase usage) in response to intermittent wind generation. The 2010 HECO demand response potential report assumed this load shaping capability under the FastDR category. While the speed of response (latency) may be similar to FastDR, regulation will generally require different contractual relationships and more dedicated control as the loads are expected to be instructed through the Automatic Generation Control.

²⁹ Act 155 2009 (HB1464, CD1) Part VII, Solar Water Heater System, Section 13.

³⁰ Operating Reserves and Variable Generation, NREL/TP-5500-51978, August 2011, p.1

The value of these objectives to the electricity grid has to be translated into value for the customers before customers are asked to participate in these types of interactions with the electricity grid.

Summary Observations

HECO has created a broad portfolio of demand response applications targeted to each of its major customer segments. HECO's small business commercial, in particular, target a market segment underserved by the utility industry. The features of these programs also provide operating flexibility not often found in most other utility applications. Eliminating seasonal and event/duration limitations, common to almost all other utility applications elsewhere, provides HECO with valuable operating flexibility. With the FastDR and proposed CIDPP pilot projects, HECO is in a position to examine state-of-the-art options in communication and customer control features critical to demand response for renewable integration. HECO has also assembled detailed projections to estimate system wide potential for demand response across a range of typical load shaping objectives.

Notwithstanding these positive attributes, there are several areas that warrant additional examination, specifically:

- Clean Energy Initiative demand response targets for interruptible load appear to exceed the estimated HECO system potential.
- Clean Energy Initiative targets for price-responsive demand may not be supported by the underlying cost structure of Oahu generating units (see footnote #24). Price response accounts for approximately 20% of the Clean Energy Initiative targets and almost 80% of the HECO estimated system wide demand response potential.
- HECO demand response options and the 2010 demand response potential study (see Figure 7) do not address load shifting or energy efficiency objectives. Load shifting is typically dependent upon price driven control strategies, which becomes more complicated due to the corresponding need for residential advanced metering. However, load shifting should be a major consideration given the broad, flat nature of the HECO system load and apparent contribution of residential water heating to the system peak. Load shifting can also address potential over generation issues, like what is already being experienced with MECO wind energy resources.
- Efficiency objectives refer primarily to organizational coordination and integration of kWh reduction measures with demand response, which is not a control strategy issue. Coordination and integration issues can occur even when efficiency and demand response programs are managed by a single organization. Separating efficiency and demand response between the Hawaii Energy Efficiency Program and HECO accentuates this issue which is addressed in more detail in the next chapter.
- Regulation to manage intra-hour variability for intermittent wind resources is currently in very early stages of being addressed by the HECO FastDR pilot and is still only in

planning stages for the remaining demand response options.³¹ The 2010 demand response potential study assumes regulation under the FastDR category, however regulation typically requires frequent operation of larger blocks of dedicated load with thermal or operating characteristics that allow up and down operation which is not necessarily consistent with more general interruptible or curtailable options.

Each of these areas will be addressed further in the chapters that follow as well as our recommended action plan.

³¹ While HECO is participating with EPRI in several industry projects examining the potential of demand response to address intra-hour variability, the effectiveness and economics of those approaches have not yet been determined.

3. Establish Current Deployment Issues

This chapter examines two deployment issues that impact the operational effectiveness and scope of existing HECO demand response initiatives. Our examination of “operational” features focuses on the effectiveness of control strategies to reduce load and satisfy HECO’s stated reliability, economic, and under frequency objectives. HECO’s demand response objectives and the control strategies to accomplish those objectives are critical elements of the roadmap process. Control strategies impact customer recruitment and participation which in turn establish or jeopardize application potential. Control strategies can also determine the basic application structure, communication, and control technology requirements. Therefore, HECO’s control strategies need to be examined as part of the roadmap process and revised to address several potential design and effectiveness issues.

Our examination of “scope” examines the coordination and integration of initiatives between HECO and Hawaii Energy, which is critical to achieving the coordination and integration of efficiency with demand response. Again, based on our review, there are many opportunities for coordinating and integrating initiatives that should be beneficial to both organizations.

Demand Response Control Strategies for Water Heaters and Air Conditioners

Voluntary direct load control programs like those offered by HECO (EnergyScout) interrupt customer service. Control strategies that are too frequent or too severe can increase inconvenience and discomfort and cause customers to discontinue participation. Control strategies that are not properly designed can produce insufficient load impacts that do not support load shaping objectives or regulatory cost effectiveness criteria. Under certain conditions, poorly designed control strategies can actually accentuate peak load problems. Control strategies have to balance system load impacts with customer service needs.

Utilities began deploying water heater load control applications in the late 1930’s. Air conditioner direct control applications began in the late 1970’s. Both applications were designed to reduce system peak loads and improve system reliability. These direct control options are also occasionally used to reduce transmission congestion and pilot studies have demonstrated potential to provide short-term spinning reserve capability.³² For basic reliability purposes, the objective of a water heater or air conditioner load control strategy is to reduce kW system load sufficient to restore reserve margins to pre-determined safe levels. This is accomplished by turning off or restricting the diversified or average run-time of targeted end-uses through a block of peak hours. Control is often continued over several hours following the peak period to prevent a rebound or snapback of load. Water heaters and air conditioners have specific operating characteristics which directly determine how the control strategies need to be

³² Demand Response Spinning Reserve Demonstration, Phase 2 Findings from the summer of 2008, Lawrence Berkeley National Laboratory and Oak Ridge National Laboratory for the California Energy Commission, April 2009.

structured. Table 2 lists key water heater and air conditioner characteristics and the typical utility load control strategies that are deployed today.

Table 2. Water Heater and Air Conditioner Control Strategies

Target End Use Load	Operating Characteristics that Drive Control Strategy Design	Typical Demand Response Control Strategies
Electric Water Heaters	<ul style="list-style-type: none"> • Upper and lower elements operate independently. • Lower elements cycle on and off to maintain stored hot water within a thermostatically controlled dead band • Upper elements generally come on only when hot water demand exceeds supply. 	<p>Option 1: Turn WH off through the entire peak period for varying durations.³³</p> <p>Option 2: Use time clocks to control WH operation, restricting heating to off-peak time periods.³⁴</p> <p>Option 3: Use price or event signal with thermostatic control to raise or lower WH temperature within a pre-set comfort/safety band.</p>
Electric Air Conditioners	<ul style="list-style-type: none"> • Unless a compressors is undersized for a facility, it will cycle on and off to maintain temperature within a dead band of the thermostat setting • Undersized compressors may run continuously during peak temperature hours. 	<p>Option 1: Limit compressor run time to a fixed number of minutes or percent during each hour.</p> <p>Option 2: Use an adaptive controller that remembers a historical duty cycle and when activated, limits run time to a percentage of that duty cycle.</p> <p>Option 3: Use price or event signal with thermostatic control to raise or lower WH temperature within a pre-set comfort/safety band.</p>

For water heaters, control strategies to address economic and reliability objectives generally differ only in how often they are dispatched. Control strategies to accomplish both objectives typically defer water heater operation over four to eight hour or longer blocks of time depending upon the duration of the system peak. Reliability events are targeted to address a limited number of system peak conditions, while economic events are usually targeted to more frequent and sometimes daily events.

³³ To avoid customer service problems, participation in various duration options often requires certain minimum sized storage tanks.

³⁴ Water heater control with time clocks is no longer a common practice, with the exception of a few cooperative and rural utilities. Historically, time clocks were not remotely controlled which resulted in time synchronization problems each time there was a power outage or other interruption.

In almost all applications that we are familiar with, control strategies turn off all power to the water heater for the duration of the control period. Diversified water heater load is generally low (e.g. less than 0.5 kW) since the lower heating element cycles itself on and off to maintain stored water temperature. Cycling or reducing power less than 100% during the control period would effectively just synchronize average water heater load, reduce diversity and create large potential snapbacks or rebounds³⁵ that could exceed any load reduction.³⁶ Water heater storage capability, if properly sized, is usually capable of supplying customer needs during the restricted operating periods. Some utilities condition customer participation, incentives and control strategies based on water heater storage capacity³⁷ – the larger the storage capacity the longer the potential hours of control. Water heater demand response options are not usually deployed to separately address both reliability and economic objectives. In many cases these objectives are technically identical. For example, preheating water in lower cost off-peak hours and not allowing water heaters to run during higher cost peak hours, can simultaneously achieve economic and peak load reduction objectives.

Peak period control strategies to address economic objectives are not commonly associated with air conditioner control. Unlike water heater control, air conditioner control strategies are much more likely to adversely impact customer comfort. As a result utility demand response applications almost universally associate target reliability objectives with restrictions that limit operation to a fixed number of events and hours per season. Peak period direct control to achieve economic objectives would require more frequent operation, often at times when diversified air conditioner load is particularly low and less likely to provide benefits that offset potential adverse customer reactions. There are two exceptions. Recent field trials using distributed control (customer not utility controlled) with programmable communicating thermostats (PCTs) that optimize cooling to each customer facility and lifestyle have demonstrated capability to achieve economic as well as reliability objectives.³⁸ At least one utility pilot has also successfully used direct control technology options with PCTs to facilitate pre-cooling that shifts load to hours preceding the peak period.

HECO's use of under frequency control integrated into the water heater and air conditioner load control receiver is a unique application. We were not able to identify any other utility using this approach. While this application has potential value to the HECO system, more information is needed to confirm operating impacts.

The preceding overview provides a context for our observations regarding the HECO control strategies, specifically:

³⁵ Heating elements can average > 4kW

³⁶ Prior studies have shown that water heater rebounding load can exceed the demand reduction by a factor of three or more.

³⁷ <http://www.pieg.com/PDFs/Controlled%20Water%20Heating%20Service%20Schedule%20CWH.09.pdf>

³⁸ <http://gigaom.com/cleantech/ecofactor-finally-a-smart-way-to-control-thermostats/>

- Water Heater Reliability Control Strategies – Short Cycle Control Problem.

HECO water heater control strategies turn off all power (100%) to the unit through the duration of the control cycle. With one exception, all 2010 reported control cycles for reliability events (Appendix A, Table 1) lasted less than 30 minutes. While a short period of control may reduce water heater load during the time span defining the control cycle³⁹ it will also synchronize water heater run times, eliminate the diversity among individual units, and could produce a much higher and problematic rebounding load in the 30-60 minute period that follows control.⁴⁰ Dispatching water heaters in sub-groups will reduce the effective peak load impacts, will require an extended duration control period, and will most likely not fully address the snapback problem.

- Water Heater Economic Control Strategies – Short Cycle Control Problem

Economic events (Appendix A, Table 2) during 2010 occurred only during three (1800 to 2000) of the five (1700 to 2100) system peak hours. The duration of control, with few exceptions, also lasts less than 30 minutes each hour. Starting with the August events, there are multiple dates where water heaters were tuned off for 22 minutes each hour between the 1800 to 2000 system peak hours. A 22-minute off-time during each hour of the control period is equivalent to a cycling strategy. Cycling strategies are not considered an effective way to control water heaters, for the same reasons noted in the preceding paragraph.

- Water Heater Control – Customer Installed Timer Issues

The KEMA report⁴¹ noted that approximately 20% of the water heaters enrolled in the RDLC-WH program included customer installed timers⁴² which impacted the load shape inputs used to estimate program impacts. KEMA identified significant load differences between water heaters with and without timers, however it did not discuss specific interactions between timers and HECO load control receivers. We are not aware of any other utility water heater load control programs that allow units with customer installed timers. Timers wired into the power circuit behind the utility load control receiver will shut down and lose their time synchronization with each utility control event. Loss of

³⁹ For example for the February 28, 2010 reliability event that ran from 1929.04 to 19.54.57, average load across all controlled water heaters was estimated to be .48kW/unit, which when multiplied by the avoided capacity and fuel cost yield an estimate of expected benefits. What is not addressed is the capacity and fuel cost incurred from the rebounding or snapback load, which for water heaters could be greater substantially greater than the benefits.

⁴⁰ Docket No. 2007-0341, Review of Demand Side Management Reports and Requests for Program Modification, 2011 Energy Scout Impact Evaluation report, KEMA, Inc., March 31, 2011. Concern with “snapback” or rebounding load was also identified as an issue in the KEMA impact evaluation, however no specifics were provided regarding the individual control strategies or the magnitude of the problem.

⁴¹ Ibid.

⁴² Ibid #25., page 2-3, Section 2.2.1

synchronization can adversely impact water heater load profiles, load impacts, and customer service.

- Air Conditioner Control

Appendix A, Table 5 provides a listing of the RDLC-CAC test events conducted during 2010. According to HECO, the objective in 2010 was to test and begin calibrating the system. No information was available to provide any insight into actual operating practices. The KEMA report did indicate that all control strategies are based on 50% off from the baseline duty cycle created by a learning algorithm feature in the load control receiver and that “snapback” or rebounding load following the control period needs to be addressed.

- Economic Control Strategy – Dispatch Criteria

We recognize that the reliability (Appendix A, Table 1 and Table 3) and economic (Table 2) dispatch history for 2010 may reflect experimentation, testing, and system calibration efforts not necessarily representative of the most current practice. However, the dispatch history and current program documentation do not evidence a clearly defined dispatch criteria. Reliability criteria for other utility demand response applications often trigger dispatch when system reserve margins fall below a predetermined threshold. Economic criteria often reflect system lambda, the incremental peaking unit capacity and fuel cost, or some other objective criteria. HECO demand response operations are not currently restricted to fixed hours of the day, which provides capability to match control events to the most productive opportunities. HECO’s system load data for 2011 include several instances when the system peak and near-peak loads occur during late morning and early afternoon hours well outside the historical peak period.

- Dispatch criteria should be designed to address extended system peak loading situations if warranted by reliability and economics criteria.
- Dispatch also needs to be balanced against customer concerns for both the duration and cumulative frequency of events.
- Finally, dispatch criteria need to address ‘how much’ demand response is necessary during any given event to address the expected range of reliability and economic need or value to the system. This factor in particular is critical to determining recruitment, system operation, and potential consequences of several key policy issues.

- Under Frequency Control – Unconfirmed Benefits

HECO water heater and air conditioner load control receivers include embedded sensors and that can be remotely set to provide under frequency response (UFR) by immediately turning off power to the controlled device when system frequency falls below a set point. Appendix A, Table 4 and Table 5, list the dates, durations, and expected average loads under control during 2010 for both residential and commercial and industrial customer

applications. Given no other information, we assume the low reported average load (kW) in Appendix A, Table 2 represents water heater loads and that air conditioner load is not included. No monitoring or other information was available to verify or determine if UFR using water heater and air condition load is effective in stabilizing system frequency.

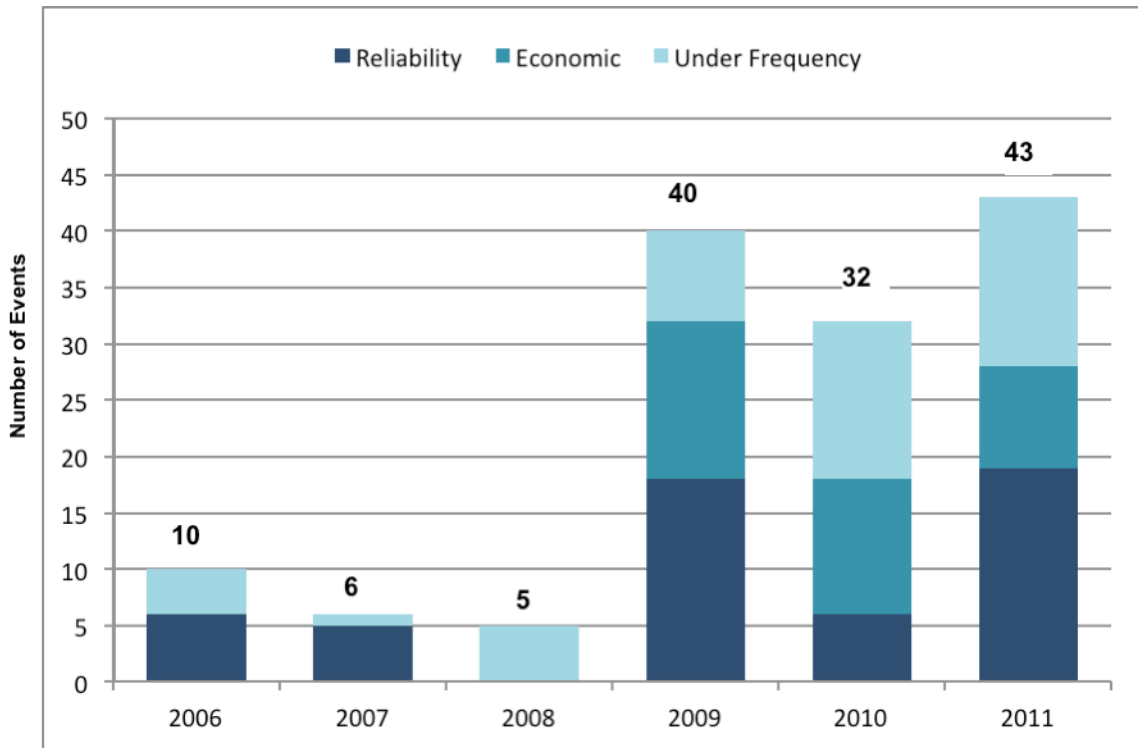
As mentioned earlier, we are not aware of and could not confirm any other utility UFR applications linked to water heaters and air conditioners. The HECO application may be a very innovative and cost effective use of existing technology, however several key issues need to be resolved, specifically:

- Load and frequency impacts need to be monitored at a sufficient level of detail to better understand both the positive and potential negative effects of UFR control of water heaters and air conditioners on system frequency.⁴³ Appendix A, Table 4 and Table 5 indicate that many of the recorded events in 2010 occurred at times when little air conditioner load would be expected (30% before 9:30am and 50% more before 2:00pm) or when water heater load is marginal. Additional monitoring and evaluation should help determine the resource value of UFR control of water heaters and air conditions.
- Potential technical issues that can contribute to adverse customer impacts from UFR control of air conditioners also need to be resolved. For example, a 2010 KEMA EnergyScout process evaluation⁴⁴ noted that UFR events have been reported to trigger circuit breaker faults which prevented air conditioner units from automatically returning to service following an interruption.
- The potential value of UFR control of water heaters and air conditioners also needs to consider how cumulative and potentially overlapping impacts of economic and reliability dispatched events could affect long-term customer participation and system operation. Figure 9 documents the cumulative UFR and HECO dispatched reliability and economic events between 2006 and 2011. Our expectation is that the number of events and likely potential conflicts will continue to increase as dispatchable events expand to address renewable integration. This raises the possibility that UFR events could eventually overlap with dispatched economic and reliability events, which could lead to customer as well as system operating issues.

⁴³ Ibid #25, p 4-65. KEMA raised the same concern.

⁴⁴ Process Evaluation of Hawaiian Electric Company's EnergyScout™ Program, Final Report, KEMA, November 15, 2010.

Figure 9. HECO Cumulative Residential Demand Response Events ⁴⁵



Coordinating and Integrating Energy Efficiency and Demand Response

One of the fundamental assumptions in our approach to a HECO demand response roadmap is the need to coordinate and integrate efficiency with demand response initiatives (Roadmap Assumption #1). Energy efficiency refers to using less energy to provide the same or improved level of service. For efficiency, time of use is not necessarily a critical factor. In contrast, demand response seeks to change how and when customers use energy, when there is a problem with the electricity grid, therefore time of use is critical. While both initiatives focus on customer behavior and the same energy consuming devices customer education, incentives, and program objectives are not necessarily compatible.

We reviewed the Hawaii Energy program documentation and 2011 annual plan⁴⁶ and then examined how customer and end-use targets matched up with HECO’s existing demand response programs and plans. Table 8 summarizes our comments relative to thirteen Hawaii Energy initiatives.

⁴⁵ Events compiled from HECO Demand Response PUC briefing, November 28, 2011, slide #39.

⁴⁶ Hawaii Energy, Conservation and Efficiency Programs, Annual Plan Program Year 2011, July 5, 2011.

Table 8. Example Hawaii Energy-HECO Coordination and Integration Opportunities

Hawaii Energy Initiatives		HECO Opportunities
Initiative #	Description	
1.2.13	Turn-Key Programs - Air conditioning and refrigeration tune-ups, central plan metering, small business direct measures	Integration to facilitate and promote identification and recruitment for demand response initiatives
2.3.1	Community presentations, efforts with organizations, retailers, other establishments, etc.	Joint messaging to encourage demand response and renewables.
2.3.2	Marketing, advertising, and public relations to promote trade ally, access to information, and efficiency	Joint messaging, coordination of resources
2.4.1	High efficiency AC, window AC, High efficiency pool pumps	Integration to facilitate participation and installation of demand response controllers
2.4.3	Solar System Tune Up	Reconsider options to the installation of remote timers and consider use of demand response controllers on WH resistance backup.
2.4.4	Landlord / Tenant Measures	<ul style="list-style-type: none"> • Coordination to facilitate participation and installation of demand response controllers • Consideration for financing DR automation and small business energy management capability
2.4.5	Residential financing, Peer Comparison to encourage behavior change	
2.5.1	<ul style="list-style-type: none"> • High efficiency chillers • Waste water, compressed air process • Small business submetering 	Demand response audits, building commissioning, participation and installation of demand response capability.
2.5.2	Target cost per kWh request for proposals – develop cost effective projects for high use businesses	<ul style="list-style-type: none"> • Expand to include demand response commissioning, EMS, automation, etc. • Consideration for expanded water storage applications in DR regulation options.
2.5.3	Building engineer challenge and cooling tower optimization	
2.5.4	Small Business direct lighting retrofits	Expand to identify automated lighting and related energy management controls opportunities.
3.1	Government Strategy and Implementation	Opportunity to examine, pursue building and appliance standards, enhanced regulation
3.2	Education & Training Institution Support	Joint promotion of efficiency and demand response

We believe there is a substantial opportunity to coordinate and integrate Hawaii Energy initiatives with the HECO demand response initiatives. The notations under the Table 8 column labeled “HECO Opportunities” fall into four categories that were also identified in a resource guide to the National Action Plan for Energy Efficiency⁴⁷, specifically:

- 1) Combining program offerings: Combining compatible efficiency and demand response incentives, marketing, and other services under the same program will leverage the resources of both organizations and avoid potential conflicting or

⁴⁷ Coordination of Energy Efficiency and Demand Response, Lawrence Berkeley National Laboratory, January 2010.

- duplicative activities. For example, Hawaii Energy initiatives 1.2.13, 2.4.1, and 2.4.4 create opportunities to link incentives, purchasing of more efficient appliances, and collaboration with local service providers to help promote HECO demand response initiatives.
- 2) Coordinated marketing and education: Initiatives may remain distinct, however the marketing and education are closely coordinated so the customer receives a unified set of options that have been screened to assure compatibility.
 - 3) Market driven services: Initiatives, incentives, and policy are closely coordinated and packaged for delivery by community, business and other organizations. Combining HECO and Hawaii Energy initiatives potentially creates greater value and interest to the service providers, which should be expected to increase their effectiveness.
 - 4) Building and appliance standards: Building codes and efficiency standards can incorporate preferred features reducing long-term costs to the consumer while also improving implementation. There are several Hawaii Energy initiatives that might warrant either legislative action or development of a potential building or appliance standard. For example, Hawaii Energy initiative 2.4.3 is targeted to correct timer problems with solar system backup electric resistance water heaters. An alternative should consider replacing timers with HECO load control receivers, which would provide a positive approach for keeping backup heating out of the peak and potentially add value to the HECO demand response application. Public policy considerations may offset cost differentials between timers and load control receivers even with low expected load impact benefits.

Summary Observations

- It is not clear whether dispatch criteria have been addressed to guide start, end-time, duration, or system reliability or economic parameters to govern economic and reliability demand response events.
- Consistent with the first observation, it is also not clear whether minimum magnitude (how much) or threshold targets for demand response events have been established necessary to achieve positive economic as well as reliability benefits.
- Control strategy impacts for economic, reliability, and UFR events need to be confirmed with more accurate load research and evaluation.
- As demand response operations expand to address renewable integration the number of control actions individual customers experience will almost certainly increase raising the potential for adverse customer response
- Demand response water heater participation requirements should be examined to determine if customer installed timers are compatible with program operating requirements.

- There appear to be a range of opportunities to coordinate and integrate HECO and Hawaii Energy initiatives, which have potential to achieve marketing, customer education, financial, and implementation benefits.

4. Rationalize the Opportunities and Vision

The first stage of the roadmap process identified HECO's objectives. The second stage looked at what we labeled deployment practices or how control strategies and operation of the existing demand response applications align not only with HECO system objectives but also with our perspective and understanding of effective industry practices. This chapter looks at the technology architecture⁴⁸ (infrastructure) and basic operating capability used to support existing, anticipated, and evolving demand response applications and control strategies.

The demand response environment is evolving rapidly due to advances in communication and microprocessor based control technologies. Smart grid, widespread implementation of advanced metering and rapidly expanding development of wind, solar, and clean energy initiatives have introduced many changes and created uncertainties that complicate utility demand response technology planning. Some of the major areas of uncertainty include:

- **Uncertain renewable environment and impacts** - Implementation of solar, wind, electric vehicles, and storage introduce a variety of local system reliability, load, dispatch, and other impacts. While there are expectations that demand response can be used to mitigate many of these impacts, much of the industry work to-date is limited to what is still considered early stage research.
- **Lack of industry standards** – In response to smart grid efforts which began about five years ago, NIST⁴⁹ initiated a massive effort to develop hundreds of standards focused on all aspects of system operation. Demand response, metering, data models to support pricing, and appliance related controls were among the targets. Unfortunately, standards take time and development occurs in a dynamic continually changing environment which extends that time. To-date few demand response standards have been adopted. HECO is employing OpenADR 1.0 in its FastDR program. The full standard, OpenADR 2.0 and its three profiles will be available towards the end of 2012 and will include a certification process to achieve interoperability.
- **Lack of best practices for DR renewable integration** – Technically demand response has capability to support renewable integration, however to-date most efforts are in early stage research.
- **Adoption of control devices/systems seems to be reactionary than strategic** – With few exceptions, utility demand response capability evolves as a patchwork of applications and control technology. To-date there has been little systematic planning to provide a structure that can integrate multiple communication options, a mix of

⁴⁸ Technology architecture includes the mix of internal HECO systems for monitoring and managing demand response activities, the communication capability for connecting with customers, and the mix of control technologies deployed by HECO and the customer to manage response to price, reliability and event signals.

⁴⁹ National Institute of Standards and Technology

utility and customer-owned automation and control, and flexibility to address the range of inter-hour variability necessary to address system emergency and renewable intermittent resource requirements.

- **Shifting from utility to customer control** – The emergence of price response is dramatically shifting control system/device ownership and development of control strategies from the utility to the customer. Numerous industry pilots, particularly during the last ten years, have shown that customer control produces greater load and energy impacts, is more equitable, and is less likely to cause discomfort, inconvenience and dropouts. A consequence of this shift is that it introduces open market competitive suppliers for control devices and automation, which in turn increases uncertainty regarding compatibility and reliability.
- **Privacy concerns** – Advanced metering and price response, which are foundations of advanced demand response, require data collection and activities at time intervals that raise public concerns for privacy.
- **Uncertain control strategies and lack of guidance to the customers** – Utility direct control of customer end-uses is at best a compromise approach. Diverse usage patterns assure that any control strategy will over control some and under control others. Designing strategies with technologies that allow customers to mitigate potential adverse consequences is not yet guided by industry best practices.

Our review of the technology architecture focuses on the broad capabilities necessary to respond to a wide range of industry uncertainties without disrupting or jeopardizing HECO’s capability to support expected demand response objectives. Unfortunately, while many Smart Grid investment and demonstration projects are currently not completed, most of the money is being spent on smart meters and some of the projects concentrate on regional or local issues that are not similar to HECO’s issues. Therefore, it is almost impossible to draw conclusions from these experiences for HECO.

In this section, we propose a technology evaluation framework that is developed by LBNL as a by-product of OpenADR development effort. Then, we investigate technology ownership issues from a DR sustainability perspective. Finally we outline the need to match technology to the objective it is achieving for HECO and the value it is creating for the customers; as well as suggesting that once a technology is identified, regulatory support may be needed to deliver it to its “tipping point”.

HECO has already proposed a dynamic rate option, a review of alternative control technology options⁵⁰, and is examining an entirely new communication and system structure with its FastDR pilot. These initiatives include forward-looking characteristics with the potential to expand HECO demand response capability, however their future status and relation to HCEI objectives

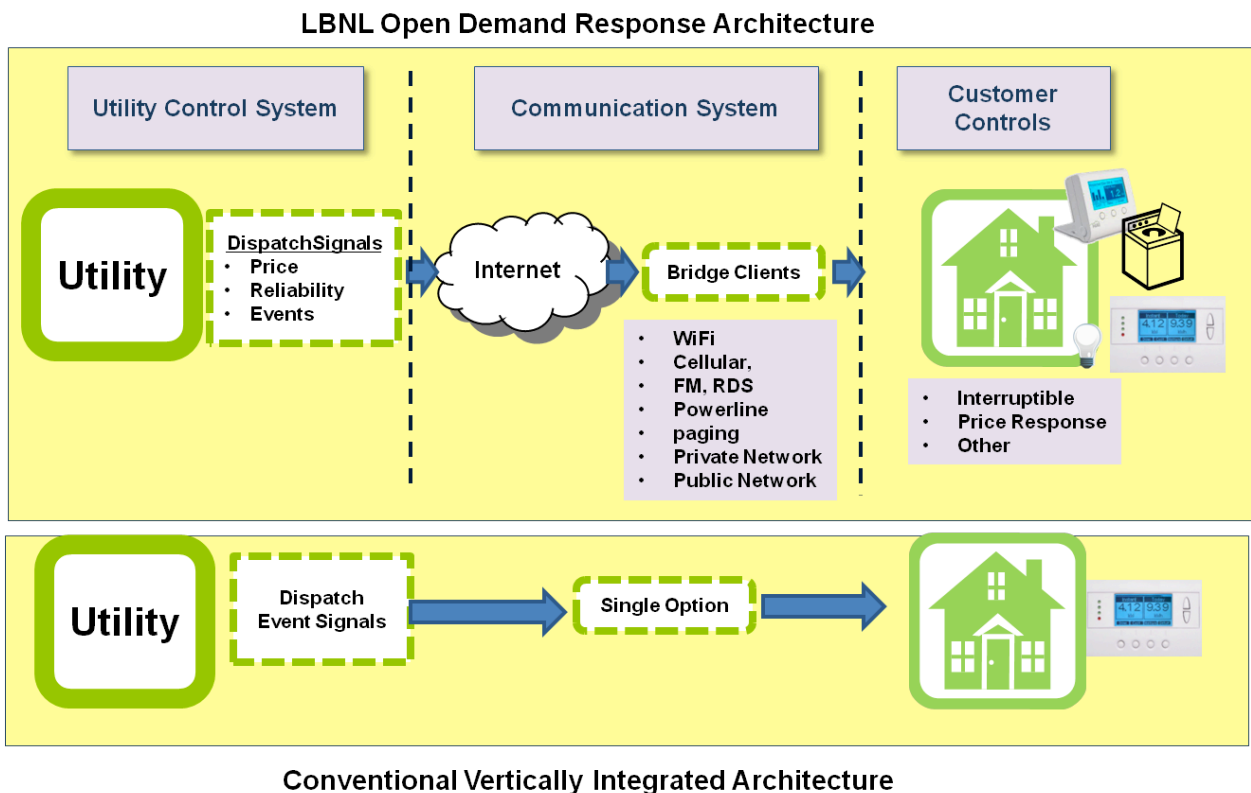
⁵⁰ The CIDP (see Table 1) proposal is still awaiting final review by the Hawaii PUC. HECO has also proposed field examinations of programmable communicating thermostats (PCTs) and home energy management systems (HEMS) as an expansion to its residential EnergyScout program.

have not yet been firmly established. We propose the technology framework below to benchmark existing technology deployments with past and future technology deployments.

Establishing a Framework for Technology Benchmarking

HECO’s technology approach is compared against a model of open demand response architecture developed at LBNL which incorporates the design assumptions noted at the beginning of this report and a physical structure generally depicted in Figure 2 and presented again below in Figure 10 as the “LBNL Open Demand Response Architecture”. The LBNL architecture evolved through the development of OpenADR and it is based on research, pilots, and commercial development efforts in multiple utility environments, with legacy as well as advanced communication and control technology. The architecture has also contributed to development of the first NIST national demand response standard.

Figure 10. Comparing Demand Response Architectures



In the conventional vertically integrated architecture depicted in Figure 10, the utility typically develops a specific DR application that is designed to incentivize a single communication option with a single control technology. For HECO, the EnergyScout system uses a paging communication technology which is being phased out on Hawaii. Until HECO acquired the

licenses to operate the system themselves, third-party service provider plans to phase out paging technically rendered their load control system obsolete.

Load control technologies become obsolete (e.g. HECO example) due to technology improvements, such as when load control receivers changed from analog to digital communications or when control devices lose compatibility with advancing end-use design features. The utility ends up with a stranded asset, additional expense to purchase a replacement system, and the customer experiences both a new cost and the disruption necessary to change out the old and install the new technology.

Demand response applications or programs can also become obsolete if the utility changes program incentives, operating or participation requirements. Again, under a conventional vertically integrated architecture, the utility and customer experience new costs and disruption.

The LBNL open architecture divides the conventional demand response approach into three separate but integrated components. The “utility control system” include capability to dispatch price reliability and event signals, however all signaling is guided by a standard data model. If prices or event parameters change, the format of the signal remains the same, just the metrics change. Within this architecture communication system components are designed to use the same data model. As long as the communication components use this model, the resulting system becomes communication agnostic, essentially allowing the utility use any and many communication options simultaneously. This approach allows a utility to operate a legacy system in parallel with a new system, providing a more controlled and less expensive transition from one system to another. Transition periods can also be extended on multi-year periods to avoid premature obsolescence and economic write-offs that might otherwise increase customer rates. This approach also allows multiple systems with potentially different capabilities to operate side-by-side.

The utility can publish a variety of price, reliability and event signals using the same infrastructure. While these signals are well defined and open, they are also now transport or communication system independent.

At the receiving end, customer controls and automated systems are also designed to recognize the same data model. Prices or the parameters of an event signal may change, however the format of the signal remains the same. Bridge clients or programs that convert or map price, reliability, and event signals from one communication media to another facilitate the ability to simultaneously operate and maintain varieties of customer systems. Using bridge clients, a customer could have an EnergyScout water heater controller operating with a paging signal and at the same time be using a PCT receiving the same price, reliability or event signals over broadband. Logic in the customer device can also determine whether the customer end-use or commercial process responds to a utility control strategy or customer programmed control strategy.

In essence, changes can occur independently within each of the three components that characterize the LBNL architecture without material impact on the overall system. When the customer receives these signals through a variety of transports, different systems respond based on how they communicate with the grid. The key take away is that over time, the utility signaling systems may change; the communication infrastructure may also change; and the customer loads will certainly change. Segmenting the system design and using a standard data model to link each segment reduces the risk from technology and application changes and also reduces the potential risk of stranded assets on both the utility and customer side of the meter.

Technology Ownership Models

The second major issue with technology is its ownership. There are two basic models each with their own set of issues:

- Customer owned and maintained systems – Examples include programmable communicating thermostats (PCTs) for residential customers and facility energy management systems (EMS) for commercial and industrial customers. For either example, customers are expected to pay for and maintain their own equipment. Because the customer owns and operates the equipment, they have a self interest in properly maintaining its operation. Commercially available PCTs and EMS now come designed with capability for the customer to program automated controlling actions in response to utility price, reliability and event signals. Financial incentives and rebates like those offered under Energy Star can encourage customer ownership. Building and appliance standards that address retrofit, sale, transfer or other events can also facilitate long-term transition to customer owned controls. Customer ownership reduces the traditional utility cost share of demand response applications which can substantially improve overall cost effectiveness. While industry trends and public policy is now encouraging customer owned automation to support demand response, it is also likely that existing utility direct applications will continue to have value and customer appeal. There is no reason that both options cannot coexist.
- Utility owned and maintained systems – Examples include the load control receivers installed on water heaters and air conditioners like those supporting the HECO EnergyScout program. Under this model the customer has no or little control over how devices are operated (e.g. control strategies) and little interest or capability for maintaining proper operation. The utility has full responsibility for operating and maintaining the system, but in almost all implementations (e.g. EnergyScout) the utility has little customer feedback and limited capability to understand when the system is or is not working properly. If the utility does not maintain the system or if control strategies become too disruptive frustrated customers either disconnect the device or opt-out from the program all together.

Matching appropriate technology with customer value

Technology deployments should address clear problems with well-captured value. One of the problems technology is trying to address may be reliability, in which case the value to customers may be fewer blackouts and brown outs and a more reliable electric grid. Industry research consistently shows that there are customer segments that value reliability more than others. Another problem may be price volatility in which case the customer may receive an incentive payment commensurate with the displaced price for participating in demand response.

Technologies that augment energy efficiency values with demand response values or vice-versa are critical to achieve HECI's goals. HECO and Hawaii Energy collaboration can assist the customers to clearly identify value streams from daily efficient operations and demand response applications.

Observation Summary

The HECO FastDR pilot already incorporates the LBNL Open Demand Response Architecture. HECO should consider the development of small pilots using bridge clients to examine and better understand the potential costs, benefits, and operating issues that this architecture may provide as a foundation for their demand response roadmap. Pilots should consider examination of various ownership models, control strategy options, and signaling/response options to test demand response across timescales expected with renewable integration.

5. Developing a Roadmap Action Plan

The Roadmap Action Plan lays out a logical process to identify research, education, policy, outreach needs, technology gaps, and best practices to guide HECO demand response development activities. The collective end goal of all recommendations is to provide HECO with a flexible demand response framework that has the capability to address uncertainty, easily adapt to evolving requirements, and support options for achieving a range of objectives. Our development of the proposed roadmap produced two separate but closely interrelated research paths both of which are depicted in Figure 11.

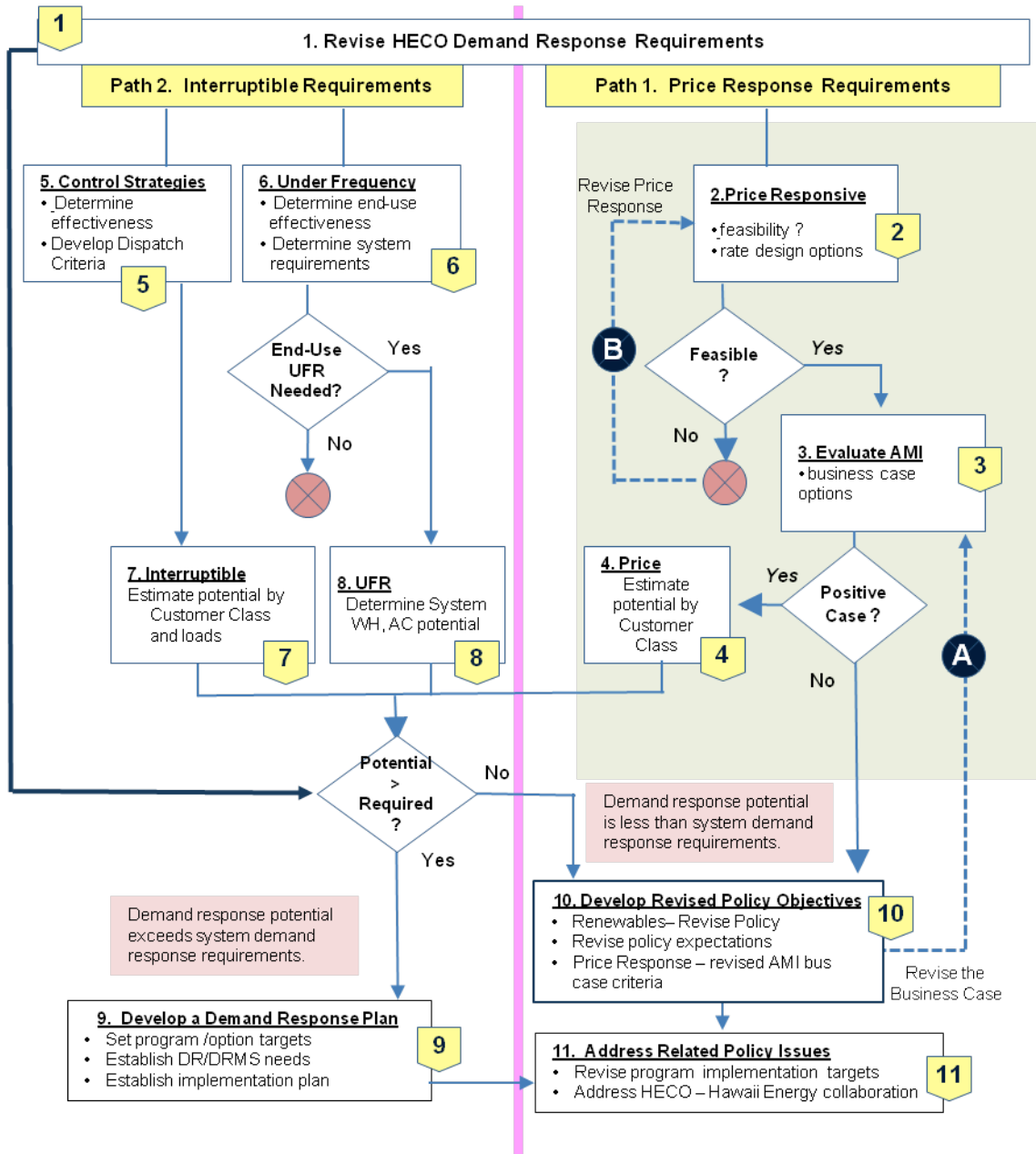
Figure 11 is divided into two paths, one focused on issues related to interruptible capability and the other price response capability. The markers in Figure 11 labeled with numbers 1-11 represent individual research or evaluation studies, some with multiple parts and objectives. We did not assume that the roadmap should just start with the HCEI objectives but rather that it was imperative to start with research to refine HECO's actual demand response potential. While the 2010 demand response potential report⁵¹ was exceptionally detailed, it did not address the need to provide inter-hour variability or load shifting, both of which are critical renewable integration objectives. There is also a need to refine estimates at a greater level of detail, in some cases at the customer and end-use levels. The 2010 report also assumed that "price responsive demand" is feasible. Price responsiveness is a critical expectation that wraps in other significant cost elements like advanced metering, which may or may not be supported. The logic flow in Figure 11 suggests a process for resolving these critical issues.

Our review of objectives in Chapter 1 raised the possibility that HECO's potential demand response resources may not be sufficient to meet the HCEI expectations. The research recommendations in Figure 11 are intended to also resolve this issue. If demand response cannot provide resources capable of facilitating HCEI renewable integration then other resources need to be procured. In a worst case scenario HCEI objectives may need to be revised. What is unique about the logic flow and research recommendations in Figure 11 is the circularity we've incorporated in the logic flow of the price responsive path. The shaded block that highlights reports labeled 2-3-4 and the decision blocks labeled "A" and "B" represents a *research-review-decision process* to address uncertainties that often arise when traditional cost-of-service or cost effectiveness evaluations come into conflict with public policy goals. For example, if HECO cost of service issues can be resolved, price response will then be dependent on a positive advanced metering business case (Report Block #3). The circularity in "A" is intended to provide options for considering and factoring in the often difficult to quantify value of HCEI "public good" environmental and other values that might not be captured in traditional advanced

⁵¹ See Figure 7.

metering business cases. Similar circularity is also represented in the decision block labeled “B” to address first level cost of service issues.

Figure 11. Determine HECO Demand Response Potential / Policy Implications



The second path provides a list of recommendations for a series of short, focused pilots and other projects to evaluate and confirm technical capabilities and to refine operational issues identified in preceding chapters. Recommendations for pilots are meant to be narrow in scope and linked to implementation.

Resolving HECO Demand Response Potential

Figure 11 identifies nine studies, split into two paths that are intended to develop revised estimates of HECO demand response potential and validate HECO capability to successfully address HCEI demand response objectives. Projects are identified in Figure 11 by reference to markers labeled 1-11.

Project #1. Revise HECO Demand Response Requirements

Objective: The overall objective of this project is to prioritize and develop expected minimum demand response requirements by load shaping objective, specifically:

- a. Confirm and resolve the HCEI interruptible and price responsive objectives depicted in Figure 8 and whether they are mandatory or advisory.
- b. Establish priorities for load shifting and regulation to address inter-hour variability for intermittent renewables and estimate minimum levels of demand response necessary to address expected renewable implementation targets.

The HCEI agreement (see footnote #17) identified clean energy initiative demand response implementation objectives with specific megawatt price response and interruptible levels specified for the years 2010 to 2030. As stated the HCEI objectives appear to exceed HECO 2010 estimated interruptible potential. In addition HCEI price responsive objectives include time of use rates (TOU) which is not generally considered a demand response initiative. The HCEI targets need to be confirmed and put into context to determine whether they should be interpreted as HECO targets. If the HCEI objectives are not targets then HECO demand response will be determined solely by revised estimates of potential and system economics.

Load shifting and regulation provide capability to directly address renewable integration which is the primary objective of the demand response roadmap. Field monitoring of existing wind and solar resources for HECO and MECO, simulations, and other industry resources should be used to estimate the expected minimum ranges of load shifting and regulation that might be necessary to address HCEI renewable implementation goals.

Estimates from both of these efforts will be compared with the equivalent available capability in the HECO customer population in that feeds into Project #9.

Project #2. Establish Capability to Support Price Responsive Demand Response

Objective: Identify whether the HECO expected cost of service can support dispatchable dynamic pricing options and price responsive demand.

HECO costs of service need to be evaluated to determine if there is sufficient cost variation to support development of effective dispatchable dynamic rates and price responsive demand options. The effectiveness of potential rate options will likely require modeling based on results from other industry studies. Cost of service should examine a

range of capital deferral, energy cost, and reliability options as well as the financial impacts and potential value of price responsive demand to address renewable over/under generation.

Price responsive demand expands the potential customer base and load available to meet changing load shaping objectives, provides improved customer choice, and provides both the utility and customers with flexibility to adapt to changing conditions. Table 9 summarizes some of the most significant advantages of price responsive versus interruptible or direct load control.

Table 9. Price Responsive versus Conventional Interruptible or Direct Control

Demand Response Attributes	Conventional Interruptible or Direct Load Control	Price Response
Program Structure	DR remains a utility program	DR becomes a default condition of service
Equipment Costs	Utility provides, limited suppliers, high cost	Customer provides, many suppliers, customized, low cost
Who participates – DR Market	<ul style="list-style-type: none"> Limited participation Requires a specific, targeted end-use 	<ul style="list-style-type: none"> All customers eligible All load can participate
Expected Load Impacts	<ul style="list-style-type: none"> Depends on control strategy effectiveness Dependent upon targeted end-uses 	<ul style="list-style-type: none"> Depends upon customer value function Pilots show greater impacts than DLC
Compatibility with efficiency, solar, load shifting objectives	<ul style="list-style-type: none"> Incentives not compatible Central control not compatible with objectives 	Fully compatible with all objectives.
Incentives / Equity	<ul style="list-style-type: none"> Fixed participation incentives over/under estimate payments for all customers. No way to validate load contributions. 	<ul style="list-style-type: none"> Incentives based on actual customer metered usage
Customer Acceptance, Customer Choice	<ul style="list-style-type: none"> Customer comfort dependent upon utility control strategy Choice is accept or don't participate 	<ul style="list-style-type: none"> Customer determines control Customer determines when and how to control There are no dropouts.

If price responsive demand is deemed not feasible based on conventional costing practices, additional scenarios represented by the path labeled “**B**” might be considered to examine the impacts of “difficult to quantify” environmental, public good, and related community or regulatory values. This alternative examination would require collaboration with several consumer, regulatory, and other outside groups.

Project #3. Establish Capability to Support Price Responsive Demand Response

Objective: Evaluate and develop a business case to support the implementation of the advanced metering infrastructure (AMI) necessary to support implementation of dynamic rates and price responsive demand options.

This effort assumes that results from Project #2 support the development of dynamic pricing and price responsive demand options. The business case should consider the costs and benefits of full system wide implementation to facilitate lower costs as well as a capability to address the entire HECO customer base. Models for AMI business cases are available from numerous industry sources, including a “Toolbox” through the Mid Atlantic Demand Response Initiative that includes materials from several states. Experience from the MECO and Kauai Smart Grid implementations may provide current, relevant information for calibrating potential renewable, outage management, and system operational benefits. The AMI business case needs to include the capital and operating costs for meters, meter data management, other related information technology capabilities for outage management, as well as upgrades to the customer information and complex billing systems.

If the AMI business case is not positive, the same alternative approach recommended in Project #2 should be considered. AMI business cases on their own include many “difficult to quantify” benefits that are typically excluded from consideration. Given the significance of price responsive demand to the load shifting and renewable integration effort, path “A” is suggested as an alternative approach for considering the full range of “difficult to quantify” environmental, public good, and related community or regulatory values. As with Project #2, this alternative examination would require collaboration with several consumer, regulatory, and other outside groups.

Project #4. Estimate System Wide Price Responsive Demand Potential

Objective: Develop detailed estimates of price response demand potential by customer class, segment within class, and by load shaping objective.

The purpose of this evaluation is to develop detailed estimates of price responsive demand potential expected within the HECO customer population. Estimates should be at a level of detail that supports market segmentation, customer, and load targeting and the development of specific load shaping applications. Figure 12 provides a matrix of example commercial and industrial end-uses generally compatible with load shifting and regulation applications. The result of this refined evaluation will be matched against HECO, HCEI, and other demand response requirements to determine how the potential aligns with system requirements. It will also be used as input to help develop system wide application development, marketing and customer outreach, and system dispatch criteria.

Figure 12. Demand Response Load Shifting and Regulation End Uses

End Use	Type	Modulate	On/Off	Maximum Response Time
HVAC	Chiller Systems	Set point Adjustment		15 min.
	Package Unit	Set point Adjustment	Disable Compressors	5 min.
Lighting	Dimmable	Reduce Level		5 min.
	On/Off		Bi-Level Off	5 min.
Refrig/Frozen Warehouse		Set point Adjustment		15 min.
Data Centers		<ul style="list-style-type: none"> • Set point Adjustment • Reduce CPU Processing 		15 min.
Agricultural Pumping			Turn Off selected pumps	5 min.
Wastewater Treatment			Turn Off selected pumps	5 min.

Project #5. Determine Control Strategy Effectiveness and Develop Dispatch Criteria

Objective: The overall objective of this project is to resolve control strategy uncertainties and to develop objective criteria to guide system dispatch operations.

Dispatch logs (Appendix A) used to develop this report documented HECO water heater and air conditioner economic and reliability control strategies for 2010. While that information may or may not reflect the most current practices, all control strategies should be reviewed to make certain they are accomplishing diversified positive energy and capacity impacts. Interval data recorders for a load research sample provide the best data for evaluating energy, capacity and rebound or snapback impacts. Evaluation needs to establish specific criteria to identify the most productive opportunities for dispatch, optimum durations, and how best to manage system load rebound or snapback. This information forms the basis for the development of system dispatch criteria both to guide system operators and eventually to provide the input for expert system algorithms. This information also provides inputs to Project #7, which will be used to determine system wide demand response potential.

Project #6. Evaluate and Determine the Need for and Effectiveness of End-Use UFR

Objective: Confirm the benefits and need for under frequency response control relays (UFR) for water heaters and air conditioners.

Implementation of UFRs for water heaters and air conditioners is an application somewhat unique to HECO demand response applications. High resolution metering needs to be considered to monitor the very short cycle 2-4 minute interruptions resulting from automated UFR response to system frequency events. Monitoring needs to establish the collective contribution end-use UFR operations contribute to restoring system frequency and whether that capability may be better provided by conventional resources or by targeting much larger commercial and industrial loads. Determining the effectiveness of end-use UFR is necessary for four additional reasons: (1) existing EnergyScout paging-based load control receivers may not be compatible with future system needs and embedded UFR capability may not be available from other vendors; (2) trends in load control that favor a move to programmable communicating thermostats (PCTs) and other customer owned automation equipment do not currently support UFR and may not technically be capable of supporting UFR; (3) there is concern that UFR response may overlap economic and reliability control periods, which could create adverse customer impacts, and; (4) operational issues that may prevent automatic end-use resumption of service need to be resolved.

Project #7. Estimate System Wide Demand Response Interruptible Potential

Objective: Develop detailed estimates of interruptible demand response demand potential by customer class, segment within class, and by load shaping objective.

The purpose of this project is similar to the description provided for Project #4.

Project #8. Estimate System wide UFR Water Heater and Air Conditioner Potential

Objective: Estimate the minimum load impact threshold necessary to support water heater and air conditioner UFR implementation.

This project extends the results from Project #6 to determine the minimum aggregate load impacts and load availability necessary to support a continued or extended implementation of water heater and air conditioner UFR capability. The estimates from this evaluation should focus on the population of HECO water heaters and air conditioners, not necessarily existing installed load control receivers. If some percentage of the aggregate system population of water heaters and air conditioners has the time-differentiated potential to support effective UFR, alternatives to load control receivers, such as appliance standards, need to be considered.

Project #9. Develop A Demand Response Implementation Plan

Objective: Develop a demand response plan that combines the prioritized load shaping objectives, revised control strategies, dispatch criteria and estimates of interruptible, price response, and UFR potential into a comprehensive demand response plan.

This project pulls together all prior results into a comprehensive demand response implementation plan. The plan will include long-term implementation targets necessary

to achieve minimum required system potential, specifications for a demand response management system, and the development of interruptible and price response applications.

Water heater and air conditioner UFR capability if needed may pursue two separate paths. One path may seek alternative vendor resources that can continue to supply relays integrated in load control receivers. The other path may seek policy support to pursue UFR as a mandated appliance standard with long-term objectives to target all HECO air conditioner and water heater loads.

Project #10. Develop Revised Policy Objectives

Objective: Determine potential options for revising legislated, regulatory and other mandates that appear to be inconsistent with the HECO estimated potential.

Reexamination of water heater and air conditioner load control strategies could substantially result in downward revision of system economic and reliability demand response potential. HECO system costs may lack sufficient variation to support dynamic rates and/or it may not be possible to develop a positive AMI business case – the result being a lack of support for the development price responsive demand options. Either of these situations could leave HECO with a shortfall of demand response potential and without capability to satisfy mandated demand response or renewable integration objectives.

This project will document shortfall situations and examine alternatives including: (1) revising cost and benefit parameters to enhance the capability to support price responsive demand options, (2) recommendations for revising existing mandates to bring them in line with HECO estimated potential, or (3) consider alternative regulatory or policy options that might include building and appliance standards and mandatory conditions of service that boost demand response potential beyond what is feasible with voluntary options.

Project #11. Address Related Policy Issues

Objective: Address policy issues in two areas: (1) develop alternatives for coordinating and integrating HECO and Hawaii Energy initiatives and, (2) consider other policy options for enhancing demand response opportunities and renewable integration capability.

Coordinating and integrating HECO and Hawaii Energy demand response related activities has the potential to leverage marketing and financial resources to improve the effectiveness of each organizations initiatives. Organizational and legislative mandates need to be examined to identify potential legal and other barriers to collaboration. Working relationship, oversight, reporting requirements and an initial set of target objectives need to be established.

Results from the previous projects will identify potential opportunities for reducing uncertainties, risk, and enhancing renewable integration capabilities. Some of the same options identified in Project #10 such as building and appliance standards, mandatory or opt-out rate/demand response options need to be identified. Examples specifically related to issues identified earlier in this report include:

- Legislated mandates for solar water heaters – Solar water heaters require electric resistance backup water heaters. Hawaii Energy initiative 2.4.3 (Table 8) indicates that backup resistance electric water heaters are equipped with timers to prevent on-peak operation. Unfortunately, timers lose synchronization each time there is a power interruption. Timers are not compatible with water heater load control applications. Legislation or policy should consider replacing timers with HECO load control receivers.
- HECO system peak is significantly driven by electric resistance water heater load. The HECO system peak is also characterized by relatively flat, long duration which can often result in peak loads early in the afternoon outside the traditionally defined hours of 1700-2100. Long duration peak load conditions are typically not compatible with traditional water heater load control. However, there is a long history of using oversized electric resistance water heating for off-peak storage to reduce system peak. Oversized electric resistance water heating initially appears to be inconsistent with HCEI objectives. However with thermostatic controls this approach would provide capability to address over/under generation and regulation to facilitate wind and other renewable integration.

Acknowledgments

The work described in this report was supported by the Hawaiian Electric Company, and by the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

Appendix A. Control Strategy Examination

Table 1. HECO Water Heater Direct Control – Reliability Dispatch History 2010⁵²

Month	Day	Event Type	Time Dispatched	Time Restored	Duration (min)	Average Load (kW)
2	28	Reliability	19.29.04	19.54.57	25.53	0.48
4	23	Reliability	20.30.11	20.51.43	21.32	0.44
8	11	Reliability	10.13.05	10.26.49	13.44	0.22
8	16	Reliability	19.37.10	20.07.4	30.30	0.48
12	9	Reliability	7.00.00	8.03.00	60.03	0.24
12	9	Reliability	8.17.00	8.34.00	17.00	0.25
12	19	Reliability	8.53.00	9.10.00	17.00	0.25
12	19	Reliability	9.51.00	10.11.00	20.00	0.26
12	19	Reliability	10.31.00	10.50.00	19.00	0.22
12	24	Reliability	14.34.06	15.00.00	25.54	0.14
12	26	Reliability	18.08.47	18.25.42	16.55	0.34
12	27	Reliability	9.57.53	10.23.59	26.03	0.26
12	28	Reliability	14.41.36	14.47.30	5.05	0.14

Table 2. HECO Water Heater Direct Control – Economic Dispatch History 2010⁵³

Month	Day	Event Type	Time Dispatched	Time Restored	Duration (min)	Average Load (kW)
2	6	Economic	18.36.40	18.40.47	4.07	0.34
2	7	Economic	18.43.45	20.16.36	92.41	0.34
2	8	Economic	18.45.35	19.21.53	36.18	0.34
2	11	Economic	18.46.00	19.21.29	35.29	0.34
2	12	Economic	19.46.55	20.31.18	44.23	0.48
8	3	Economic	18.00.00	18.22.00	22.00	0.34
8	3	Economic	19.00.00	19.22.00	22.00	0.48
8	3	Economic	20.00.00	20.22.00	22.00	0.44
8	4	Economic	18.00.00	18.22.00	22.00	0.34
8	4	Economic	19.00.00	19.22.00	22.00	0.48
8	4	Economic	20.00.00	20.22.00	22.00	0.44
8	6	Economic	18.00.00	18.22.00	22.00	0.34
8	6	Economic	19.00.00	19.22.00	22.00	0.48
8	6	Economic	20.00.00	20.22.00	22.00	0.44
8	15	Economic	19.35.04	20.30.30	55.26	0.48
8	19	Economic	18.00.00	18.22.00	22.00	0.34
8	19	Economic	19.00.00	19.22.00	22.00	0.48
8	19	Economic	20.00.00	20.22.00	22.00	0.44
9	17	Economic	18.00.00	18.22.00	22.00	0.34
9	17	Economic	19.00.00	19.22.00	22.00	0.48
9	17	Economic	20.00.00	20.22.00	22.00	0.44

⁵² Ibid #25, Table 2-3.

⁵³ Ibid #25, Table 2-5.

10	17	Economic	18.26.41	19.25.00	58.19	0.34
10	17	Economic	19.33.08	19.59.33	26.25	0.48

Table 3. HECO Air Conditioner Direct Control –Dispatch History 2010⁵⁴

Month	Day		Start Time	Duration (min)	HECO Estimated Load Shed
7	13	test	14.00	15	3.4
7	14	test	14.00	30	4.2
7	15	test	14.00	60	4.5
7	16	test	13.15	90	5.1
8	10	test	13.00	120	3.5
8	20	test	13.00	120	4.4
8	26	test	13.00	120	4.8
9	16	test	13.00	120	4.0
9	23	test	13.00	120	4.3
9	30	test	13.00	120	4.5
10	7	test	13.00	120	4.8
10	15	test	13.00	120	4.0
10	22	test	13.00	120	4.3
10	23	test	13.00	180	4.8
10	24	test	13.00	120	4.9

Table 4. HECO Residential UFR Dispatch History 2010⁵⁵

Month	Day	Event Type	Time Dispatched	Time Restored	Duration (min)
2	26	Under Frequency	14.28	14.31	3.00
2	28	Under Frequency	18.36	18.38	2.00
3	19	Under Frequency	6.40	6.42	2.00
8	23	Under Frequency	13.46	13.50	4.00
9	1	Under Frequency	11.17	11.21	4.00
9	10	Under Frequency	20.29	20.34	5.00
9	13	Under Frequency	12.02	12.06	4.00
10	15	Under Frequency	13.40	13.42	2.00
10	30	Under Frequency	12.37	12.37	0.00
11	11	Under Frequency	13.56	14.00	4.00
12	10	Under Frequency	10.34	10.34	0.00
12	11	Under Frequency	0.19	0.22	3.00
12	25	Under Frequency	1.43	1.45	2.00
12	26	Under Frequency	9.11	9.13	2.00

⁵⁴ Ibid #25. Table 2-5.

⁵⁵ Ibid #25. Table 2-4.

Table 5. Commercial and Industrial Under Frequency Control⁵⁶

Month	Day	Event Type	Start Time	End Time	Duration (min)
8	17	Dispatch	13.00.00	13.15.00	0.15.00
8	23	UF	13.47.36	13.50.41	0.03.05
9	10	UF	20.29.22	20.34.06	0.04.44
10	26	Dispatch	12.56.00	13.16.00	0.20.00
12	11	UF	00.19.06	00.22.36	0.03.30
12	25	UF	1.43.11	01.45.26	0.02.15

⁵⁶ Ibid #25, Table 4-1.