Analysis of Smart Grid Technologies –

Tools to Enable Renewable Energy in Hawaii

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ANALYSIS OF SMART GRID TECHNOLOGIES – TOOLS TO ENABLE RENEWABLE ENERGY IN HAWAII

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PREPARED FOR

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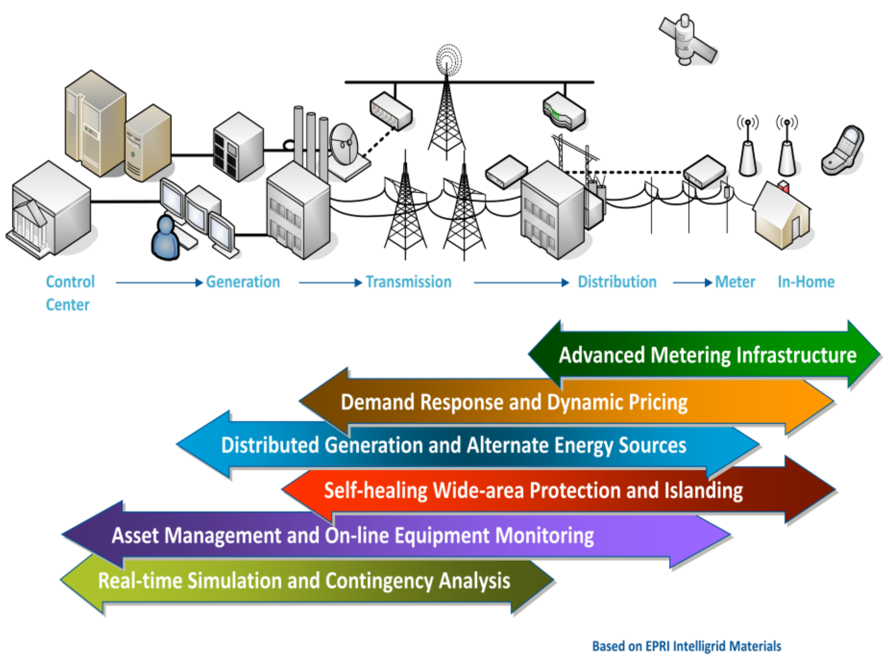
1.0 Executive Summary

Utilities are undergoing significant change to adapt to a landscape that is very different from the one that existed at the dawn of the existing electric power industry. Utilities are striving to accommodate new customer expectations, adapt to changing regulatory requirements, respond to weather and nature events, and invest in increasingly aged infrastructure. Against this background, utilities are also experiencing profound disruption in the generation mix. Throughout North America, natural gas has become a fuel of choice and worldwide, utilities are striving to integrate higher penetrations of renewable energy resources onto the grid. In Hawaii, a goal is to accommodate more renewable energy through various enabling technologies. All utilities are attempting to make this transition in part by implementing new solutions based on advances in technological innovation and the ability to integrate these new solutions together into a smarter grid.

Utilities have embraced the ability of the Smart Grid to enable a fundamental migration from a predominantly analogue industry based on time-proven but limited control systems into a two-way information rich, digital, highly integrated electric grid. While the term Smart Grid supports many different detailed definitions, each with a particular focus, the term has come to encompass a collection of enabling technologies and advanced applications that provide utilities with new tools and capabilities to operate the evolving electric grid more reliably. A commonly recognized view of the Smart Grid is provided in Figure 1-1.

Figure 1-1 High Level View of the Smart Grid



Smart Grid technologies include solutions that range from advanced control and operating solutions at generation facilities to smart meters and engagement solutions at customers' homes. Utilities are implementing a wide range of solutions on the transmission and distribution grid itself, including line sensors and monitors, substation automation, improved distribution management systems, distribution automation and control, and information and data analytic solutions. Each of these solutions has value that can be derived to operate the grid more efficiently, and with more flexibility to provide increased reliability. The importance of the term Smart Grid is the notion of combining these individual enabling technologies or advanced applications together into an integrated set of solutions that in aggregate will transform the grid.

Figure 1-1 also illustrates that the Smart Grid, in addition to being a collection of technologies and advanced applications, is also a layered effort to introduce more intelligent control and management of various aspects of the electricity grid. An important concept in understanding how utilities are implementing Smart Grid solutions is that generally, there is a sequenced approach to implementing the various solutions and Figure 1-1 illustrates that sequence.

From the perspective of generation resources, the Smart Grid technologies and applications create significant opportunities to enable increased operating flexibility that provides more reliability. Smart Grid allows utility operating practices related to reserves, generation plant management, curtailment, and optimum run decisions to be modified. The communications systems and customer engagement opportunities afforded by smart metering or demand response (DR) provide the opportunity to manage demand in ways that support the variable output of many renewable generation resources. The concept of *flexibility* and solutions that increase the flexibility of the grid relative to traditional generation capabilities are key components of the value that Smart Grid solutions enable and form the core of the discussion presented in this section of the HREGP report. Flexibility can be described as the capacity of a grid to rapidly modify generation or demand in response to evolving uncertain conditions.[1]

1.1 SCOPE OF WORK

This white paper explores the challenges of increasing the amount of renewable generation on the Hawaiian Island's grid to 1 GW and the role that Smart Grid technologies and solutions can play in enabling this fundamental shift in generation resource mix. The report discusses the current barriers to higher penetrations of renewable energy and how both traditional and non-traditional utility operations and policy are relevant. It further explores a selection of Smart Grid solutions that

[1] Beauvais, D.; et. al., "SMART GRID to Balance Renewable Energies - Contributing Distributed Energy Resources" Varennes Reseach Center, March 2012.

are relevant to meeting the technical, operational, business and policy requirements of transitioning to a more renewable rich resource mix.

1.2 REPORT ORGANIZATION

1.2.1 Introduction and Purpose

The goal of this report is to provide recommendations for the strategic deployment of the Smart Grid to enable an integrated portfolio of technologies and mechanisms that facilitate higher levels of energy efficiency and renewable energy deployment by providing increased electric system flexibility. While energy efficiency can be largely self-standing, flexible resources which provide necessary system flexibility/reliability functions are frequently enabled by the advanced monitoring, controls and information features of the Smart Grid. This report is part of the Hawaii Renewable Energy Grid Project (HREGP), which analyzes four enabling technologies (Smart Grid, alternative fuel vehicles, energy storage and undersea transmission cable) that will allow the integration of one gigawatt of intermittent renewable energy into the electric grid on the island of Oahu.

1.2.2 Grid Flexibility

Intermittent renewable generation increases the need to supply electric system flexibility/reliability functions with existing traditional and new emerging flexible resources. When flexibility/reliability functions are sold in energy markets they are called ancillary services. Hawaii's Reliability Standards Working Group (RSWG) recently worked with General Electric (GE) to define a set of "Hawaii-specific" ancillary services that could be used to protect reliability, incent renewable generation, and minimize production cost for each Hawaiian Island utility.[2]

Existing traditional and new emerging flexible resources will be enabled and enhanced with the advanced communications and control capability of the Smart Grid. Examples of emerging flexible resources that will be enabled by Smart Grid communications and control capability include fixed and mobile energy storage, new types of demand response, improved forecasting of renewable energy resources, and new methods of reserves management.

1.2.3 Energy Efficiency

Energy efficiency (EE) is a critical component of Hawaii's Clean Energy Initiative, and it is an important part of each of the island utilities' Integrated Resource Plans (IRPs). EE is typically considered the most cost effective means to meet future energy demand. EE reduces the need for new generation, thus reducing overall system cost. Many States have recognized this and have provided EE performance standards and other incentives to induce utilities and customers to adopt

[2] HNEI, "Report on Business Case in Hawaii for Storage Options," US Department of Energy, Office of Electricity Delivery and Energy Reliability, Honolulu, HI, October 2012.

it on a priority basis. Independent reports by both the Electric Power Research Institute and McKinsey and Company in 2009[3] indicated that energy efficiency presents a vast low-cost energy source nationwide for the U.S.

By increasing the ratio of renewable supply to grid load, EE reinforces the need for Smart Grid technologies to keep supply and demand in balance. EE also overlaps in some cases (capturing the same opportunities) with DR, and the result is a lean grid requiring increased flexible resources to be reliable.

Specific opportunities to strengthen energy efficiency policies and programs in Hawaii include minimizing free-ridership, promoting new energy efficiency technologies, enhancing customer experience with smart meters, smart appliances, and green button tools, strengthening appliance efficiency standards, strengthening state government-funded R&D initiatives, increasing stringency of building codes, adopting reward structures for utilities exceeding energy efficiency goals, and enhancing cost-benefit accounting to include new programs and technologies.

Black & Veatch recommends that the annual statewide measurement and verification reports, which currently address a number of energy efficiency programs, should be expanded to include cost-benefit accounting for demand response, and for communication, monitoring and control programs. This would enable capturing of additional savings, and ensure that co-benefits of EE measures do not go unrecognized.

1.2.4 Demand Response

Demand Response (DR) solutions and technologies come in many different variants depending on the load or appliances to be controlled, the control employed, and the initiating agent or methodology. DR can and should play an important role in the integration of the renewable energy resources. DR is becoming an increasingly valuable tool due to technological innovations and policy directives. It is both technically feasible and economically reasonable for consumers to respond to signals from a utility system operator, load-serving entity, Regional Transmission Operator (RTO)/Independent System Operator (ISO), or other DR provider for DR to provide reliability services to the bulk system. The key differences between DR for traditional peak shaving and DR for supporting renewable penetration are the amount of advance notice provided and the required response time. For peak shaving, which is typically based on day-ahead or hours-ahead forecasts, consumers can plan their response well in advance. Alternatively, the decision to call DR events for

[3] http://www.mckinsey.com/client_service/electric_power_and_natural_gas/latest_thinking/unlocking_energy_efficiency_in_the_us_economy
http://www.edisonfoundation.net/IEE/Documents/EPRI_SummaryAssessmentAchievableEEPotential0109.pdf

renewable generation variability occurs with limited advance notice and therefore requires faster reaction times by consumers in order to maintain grid stability.

DR programs vary in design and focus, some initiatives such as rate programs, which encourage consumers to shift load to off-peak periods when wind production is usually at its highest, could be used to avoid curtailment of variable generation or to minimize cycling of large base load power plants. However, DR is not one-size-fits-all and any DR program should include a portfolio of options designed to deliver necessary results, match customer "comfort zones" and maximize adoption rates. Utility requirements, business case justification, and program options vary greatly. Customer demographics, level of demand and participation of the commercial and industrial sector, and environmental conditions all impact how programs are designed to meet specific market dynamics. The program's opportunity to improve cost, reliability, and renewable generation penetration will impact program design, the underlying requirements and technologies used. DR therefore needs to be looked at as a set of solutions that are customized to meet particular utility needs. The availability of complementary or enabling Smart Grid technologies provides the opportunity to integrate the DR into broader holistic and sustainable grid reliability solutions. In addition, regulatory policies must accommodate the variety of viable DR options and support the goals of the DR programs.

1.2.5 The Smart Grid Enables Technologies That Provide Flexibility

The Smart Grid enables flexible technologies necessary for integration of intermittent renewable energy resources. Utilities require both fast acting power system solutions that respond to real-time situations and slower acting centralized analytical solutions that include forecasting and longer term resource management. The level of challenges will depend on the amount, size, location, and voltage levels of the interconnected resources; the capabilities of those resources for dispatch and communication (and similar Smart Grid capabilities); and the ability of the grid to accept generation at multiple distributed sites and to flow power as needed in the opposite direction to that initially designed. In preparing themselves for the increased penetration of renewable Distributed Generation (DG), utilities realize the need to investigate and apply Smart Grid solutions such as smart metering, smart communications solutions, distributed monitoring and control, and Distribution Management System (DMS) applications.

These Smart Grid solutions have far-reaching value beyond supporting a higher penetration of DG resources. The various enabling technologies are designed to meet a range of utility operational efficiencies, reliability improvements, and customer service enhancements. Solutions such as Distribution Management Systems (DMS), for example, are designed to provide a higher level of awareness of grid status and provide methods to control and respond in more real-time fashion. This provides value in identifying and responding to outage conditions, providing more efficient asset optimization, gathering substantially more data for downstream analytic tools, and initiating other new operational processes. Additionally, the value of such disparate smart grid solutions such as Advanced Metering Infrastructure (AMI) (i.e. Smart Metering), Distribution Management System

(DMS), Outage Management System (OMS) and System Control and Data Acquisition (SCADA) are increased through synergies by integrating the solutions together. By proactively embracing these changes, utilities can begin to shape the myriad of planning and operating approaches that maximize the potential long term benefits to the utility and its customers.

1.2.6 Barriers to Increased Penetration of Renewable Generation in Hawaii

A significant barrier to increasingly high penetrations of variable renewables is the lack of information about the relative merits (costs and benefits) of flexible resources. Similarly, the lack of information about the interaction between customer- based DR programs and renewable energy is a barrier. The solution to this information gap is the evaluation of actual field demonstrations that prove the solutions, their cost and benefits and the implementation methodologies and customer engagement options. As more demonstrations are conducted that leverage DR technologies and smart communications and control technologies, there will be an opportunity for the industry to identify cost-benefit tradeoffs so utilities can identify and rank DR alternatives which allow higher penetrations of intermittent renewables.

1.2.7 Solutions to Barriers to Increased Penetration of Renewables in Hawaii

In addition to the broader industry demonstration needs, Smart Grid technology demonstrations on the Oahu grid will be required to validate their effectiveness in reducing renewable curtailment or in reducing peak demand loads. The costs and benefits identified from these technology demonstrations will need to be analyzed and compared. In some cases, new cost recovery mechanisms will need to be approved by regulators or existing mechanisms adjusted to achieve implementation, and in some cases incentives will need to be provided to achieve commercialization. Also, process rule changes may be required and it may be necessary to provide education to inform customers, utilities and independent power producers.

Key technology demonstrations will be related to smart inverters, distribution system voltage controls, provision of automatic generation control (AGC) to enable regulation, frequency response, reserves management, and overall system integration. Information about the costs of individual technologies and mechanisms are required to develop priorities and an implementation plan. Once the information is available to establish the DR plan, the emphasis will switch to understanding and modifying cost recovery mechanisms, establishing appropriate incentives and identifying appropriate rule changes and education mechanisms.

1.2.8 Integration of Enabling Technologies

While the disparate Smart Grid solutions can be evaluated in isolation; a core concept of the Smart Grid is the integration of the various enabling technologies and advanced applications. Each individual solutions delivers defined benefits to utilities in supporting a safer, more reliable, more efficient and more flexible electric grid with a higher level of awareness and control. Integrating multiple technologies, especially enabling technologies and advanced applications, enhances the effectiveness of each individual technology, making the whole greater than the sum of the parts.. This synergistic relationship significantly increases the business benefit to utilities, customers and other stakeholders.

1.2.9 Proposed Implementation Roadmap

The proposed Smart Grid implementation roadmap included in this white paper follows a representative sequence of steps to address the barriers to achieving the goals of the Hawaii Clean Energy Initiative (HCEI) and integrate 1 GW of renewable generation capacity onto the Oahu grid:

- Demonstrate technologies' capabilities and effectiveness,
- Develop inter-utility coordination,
- Evaluate the costs and benefits,
- Determine cost allocation and recovery mechanism,
- Obtain regulatory approval,
- Establish incentives (customer, utility and other stakeholders),
- Identify and implement rule changes, and
- Provide necessary education mechanisms.

This sequence applies to all technologies and mechanisms used to achieve the electric system flexibility that is discussed in this report.

1.2.10 Summary of Overall Recommendations or Proposed Next Steps

The recommendations provided in this white paper are designed to leverage Smart Grid solutions that have value to the goal of enabling 1 GW of renewable generation onto the Oahu grid. These recommendations do not utilize the entire collection of available Smart Grid solutions. This road map, instead, focuses on those solutions that have demonstrated, or are reasonably anticipated to demonstrate, as a system the necessary attributes required by the Oahu grid to operate optimally. It is possible, furthermore, that advances in certain areas may deliver unanticipated benefits that will allow additional Smart Grid technologies and advanced applications to support even higher quantities of renewable energy.

The report includes the identification of the Smart Grid technologies and advanced applications as well as a recommendation for sequencing implementation that maximizes the operational impact and cost effectiveness. These solutions will require significant changes by the Hawaiian Electric Company (HECO), the utility operating the Oahu grid, including transitioning into entirely new processes, installing new and replacing outdated infrastructure, hiring and training employees, and balancing costs and benefits in a rapidly changing technological environment. HECO needs to perform a detailed strategy and business assessment to define these impacts and quantitative and qualitative benefits that would be attained from Smart Grid solutions. It should be noted that the recommendations do not take into account planned or potential initiatives that HECO may already have planned that might provide additional synergies or conflict with these recommendations.

2.0 Introduction and Purpose

The purpose of this report is to provide a strategic roadmap for the deployment of smart grid technologies to enable the achievement of twin goals related to renewable generation on the Hawaiian Islands' electric grids:

1. Meet Hawaii's clean energy goals of achieving 70 percent clean energy by 2030, 40 percent to be provided by renewable energy and 30 percent from energy efficiency, relative to 2008 levels.
2. Support the utilization of 1 GW of aggregate renewable energy generation capacity onto the Oahu grid.

This report is a work product of Black & Veatch under contract with the Hawaii Natural Energy Institute, as part of a larger effort in support of the Hawaii Clean Energy Initiative.

At the time of this writing, the State of Hawaii has achieved higher levels of renewable energy penetration in some parts of its electrical grids than the grids of any other state in the U.S. This means that the State of Hawaii is also by necessity leading the nation in developing solutions to address the challenges associated with high levels of renewable energy penetration in the electric power grid.

This report provides recommendations for the strategic deployment of Smart Grid solutions to enable an integrated portfolio of technologies and mechanisms that facilitate higher levels of energy efficiency and renewable energy deployment. While energy efficiency can be self-standing, additional flexibility in the electric gird which provides necessary system reliability functions can be enabled by Smart Grid features such as advanced monitoring, controls and information management.

A portfolio of technologies is required because each of these technologies has a different set of functionalities, delivered benefits and associated attributes and the various combinations provide synergistic capabilities at varying costs and capabilities. These attributes must work together to provide electric system reliability functions in an efficient, robust, integrated solution, customized to the unique island operating conditions of Hawaii.

The three greatest barriers to achieving high levels of renewable energy deployment are: 1) the typically high capital costs of renewable generation equipment and associated technologies necessary to achieve integration, 2) the intermittency of the renewable resources (predominantly sun, wind, and rainwater used for solar, wind and hydro generation respectively), and 3) the grid reliability impacts of this intermittent power generation. The following portfolio of smart grid technologies can address these barriers as they relate to the Oahu grid:

- Energy efficiency technologies provide low-cost energy services.

- Demand response technologies increase the system's ability to utilize renewable power at the time when it is available, or to schedule the delivery of generated electricity for the times when it is most needed.
- Monitoring capabilities provide real time status and alarming to provide indication of the grid situation, the availability of distributed generation resources, and inform the utility of problems.
- Control technologies provide means for utilities to react in real time to the changing situation or disturbance
- Information technologies provide analytic and forward looking tools to enable effective grid management.

These Smart Grid technology solutions can improve the Oahu electrical grid's flexibility/reliability functions, under the challenging frequency and voltage conditions that are potentially created by intermittent renewable energy generators.

Taken as a whole, this portfolio of technologies can dramatically improve the quality of service experienced by the electric power customer, while also achieving Hawaii's clean energy goals in the most cost-effective way.

2.1 BACKGROUND

The State of Hawaii has adopted aggressive goals to encourage a shift from the existing reliance on petroleum based energy supply toward an increased focus on renewable energy and energy efficiency. The Hawaii Clean Energy Initiative (HCEI) has a target of 70 percent clean energy by 2030 – 40 percent to be provided by renewable energy electricity and 30 percent from energy efficiency, relative to 2008 levels. That level of renewable energy penetration far exceeds current levels. In 2012, 11.3 percent of Hawaiian Electric Companies' electricity sales came from renewable sources[4], with the percentage on Oahu being 5.5% . This is comparatively high relative to many other US mainland electric utilities but low relative to Hawaiian goals. Achieving the state goals will require new technologies, modified utility operational processes and supportive public policy to enable a viable and efficient transition to the targeted clean energy penetration levels.

The aggressive clean energy goals coupled with the unique characteristics of an island-based grid means that Hawaii will continue to be at the forefront of efforts to identify, analyze and adopt policies to encourage the optimal use of enabling technologies. Hawaii does not have the luxury of participating in an integrated multi-utility grid with its inherent ability to provide mutual support and a robust ancillary services market that comes with these larger grids. Enabling smart grid technologies will include: energy efficient technologies, demand response programs, monitoring and control technologies, energy storage and information technologies.

[4] 2012 data was published in HECO's Consumer Lines, volume XXXII, No. 6, June 2013.

2.2 PURPOSE

The purpose of this section of the HREGP is to identify opportunities in expanding energy efficiency solutions and address opportunities and issues surrounding smart grid technologies that will support the integration of 1 GW of renewable energy onto the Oahu electric grid.

Smart grid technologies enable acceptance of renewable energy technology, optimize performance of energy efficient technologies and contribute to the reliability and efficiency of the grid. Specifically they enable increased customer engagement and support various forms of demand response. They also enable and optimize grid control and management, support energy storage and facilitate management of reserves.

2.3 EXISTING CONDITIONS

Hawaiian Electric Company and its subsidiaries serve 95 percent of Hawaii's 1.2 million residents. Hawaiian Electric Company (HECO) itself serves Oahu; a subsidiary, Hawaii Electric Light Company (HELCO), serves the Island of Hawaii; and another subsidiary Maui Electric Company (MECO), serves Maui, Lanai and Molokai. The island of Kauai is served by the Kauai Island Utility Cooperative (KIUC) and the islands of Niihau and Kahoolawe are not served by utilities. This white paper focuses on examples and opportunities related to the HECO utility companies, since they are so prominent and are essential to meeting the Hawaii goals, but the information and recommendations presented would be substantially applicable to most island electric grids.

The table below shows the current levels of renewable energy capacity installed.

Table 2-1 Levels of Renewable Generation Capacity on Each Island in 2012[5]

Island	Renewable Generation
Oahu	7.6%
Maui	20.8%
Hawaii	46.7%
Consolidated	13.9%

[5] HECO 2013 Annual IRP Report, http://www.hawaiianelectric.com/vcmcontent/IntegratedResource/IRP/PDF/IRP-2013-Report-Chapter-7.pdf

Table 2-22 Details of Current Generation on Each Island in 2012

	HAWAII ISLAND	MAUI	OAHU	KAUAI[6]
Electric Utility	HELCO	MECO	HECO	KIUC
Area (sq mi)	4,028	727	597	552
Population	185,079	144,444	953,207	66,921
Population Density (pop./sq mi)	46	199	1,598	121
Electric Customers	81,000	68,000	297,000	
Firm Generating Capacity[7]	287	262 (284.4 with Molokai and Lanai)	1,756	125.3
Central Solar (Installed MW)_	0.5	28	11	7.2
Distributed Solar (Installed MW)[8]	20	28	95	3
Wind (Installed MW)	31	72	99	0
Geothermal (Installed MW)	38	0	0	0
Biomass (Installed MW)	0	16	110	0
Waste-to-Energy (Installed MW)	0	0	73	0
Hydropower (Installed MW)	16.6	12.6	0	0
Total Existing Renewable Generating Capacity (MW)[9]	106.1	172.6	289	7
Total Potential Renewable Generating Capacity[10] (MW)	1,147	481	1,196	192
Percentage of Electricity Sales from Renewable Capacity (2012)[11] (%)	46.7	20.8	7.6	11.0
Existing Smart Grid Projects	Automated generation control program to respond to	Maui Smart Grid Project[13] DOE Smart PV Inverter	HECO East Oahu Switching Project[16]	Federal grant to install advanced metering

[6] http://website.kiuc.coop/content/energy-information-0
[7] http://hei.com/hei2011annualreport.pdf
[8] Personal communication with HNEI dated 24 June 2013.
[9] Additional data from PowerPoint presentation titled "Hawaiian Electric Companies (HECO, HELCO, MECO) IRP 2013: Existing System and Conditions. Lisa Gang, IRP Advisory Group Meeting #2.
[10] http://energy.hawaii.gov/wp-content/uploads/2011/09/Hawaii-Clean-Energy-Initiative-Scenario-Analysis-Summary_March2012.pdf
[11] http://energy.hawaii.gov/programs/securing-the-renewable-future

	changes in frequency in the grid. Smart Meter Education Program[12]	Project[14] Grid Modernization Projects[15] Maui County Load Management Assessment	Grid Modernizatio n Projects[17]	infrastructure [18]

It can be seen from the table above that the renewable energy and grid stability issue is different for each island. The islands have a wide range of load demand, potential renewable energy and currently installed renewable energy resources. Oahu has a stronger grid and lower renewable energy penetration but the most load and highest population density. Therefore there is significant potential for Oahu to expand renewable penetration while implementing smart grid technology in the process of working toward the state's renewable energy goals. In contrast, the Big Island has a much lower maximum demand and a low population density, and already has approximately 40 percent renewable energy installed, and cannot accept more intermittent renewable energy without significant grid upgrades and changes in operational methodologies and capabilities. Smart Grid deployments will need to be targeted and strategic on the Big Island, focusing on grid reliability.

An important conclusion from Table 2-1 is that the conditions and issues are different for each island and thus the smart grid technologies, prioritization and pace of implementation and grid flexibility and reliability challenges differ. For additional detail regarding each island's power generation resource mix, see the table provided in Appendix B. Hawaiian Electric Co. reported customers on Oahu, Maui and the Big Island installed 92.8 megawatts of photovoltaic generating capacity in 2012, which was more capacity installation than in the previous six years combined.[19]

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[13] http://www.mauismartgrid.com/maui-smart-grid-project-description/
[16] http://www.smartgrid.gov/project/hawaiian_electric_company_east_oahu_switching_project
[12] http://files.hawaii.gov/dbedt/annuals/2013/2013-essf.pdf
[14] http://files.hawaii.gov/dbedt/annuals/2013/2013-essf.pdf
[15] Ibid.
[17] Ibid.
[18] http://kiucrenewablesolutions.coop/renewable-technologies/smart-grid/
[19] http://www.mauismartgrid.com/heco-says-more-pv-was-installed-last-year-than-previous-six-combined/

For many years the state of Hawaii has planned and investigated an inter-island undersea transmission cable that will interconnect the electric systems on Oahu and neighbor island(s). This white paper assumes an end state that includes this transmission cable, but the content herein does not include discussion of the transmission interconnection.

In the context of existing conditions, it can be seen that each island has a different current state with unique generation needs, and each island has different constraints, within which next steps toward the state's renewable energy goals will take place.

The grid on each island will require different levels of flexibility, in order to adapt the existing resource mix to meet expected future demand. It is this paper's hypothesis that smart grid technologies can provide the needed flexibility.

3.0 Grid Flexibility

Wind and solar energy generation are variable and will impact the electric system's ability to maintain voltage and frequency. The higher the percentage of variable renewable energy and efficiency that exist, the more the electric system requires solutions that provide flexible response capabilities. The Grid Flexibility section is divided into three subsections. The first explains how electric utilities traditionally provide flexibility/reliability functions that allow them to respond to mismatches in supply and demand. The second identifies existing technologies and mechanisms (flexible resources) that utilities use to provide electric system flexibility/reliability functions. The third subsection identifies new flexible resources that utilities will use as they are technically and commercially available, and it also highlights that they will be enabled with advanced communications and control technologies of the future.

3.1 TRADITIONAL ELECTRIC SYSTEM FLEXIBILITY/RELIABILITY FUNCTIONS

Planners and operators are very familiar with variability and uncertainty as they are constantly balancing traditional demand and generation to maintain voltage and frequency. They adjust to demand and generation fluctuations, changes in transmission power flow, unexpected generation or large load outages and changing interconnection schedules with well-defined flexibility functions. System flexibility is defined by NERC as the ability of supply-side and demand-side resources to respond to such system changes and is accomplished with specific electric system flexibility functions[20].

Table 3-1 presents the traditional electric system flexibility/reliability functions supplied by traditional generators. It identifies the flexibility/reliability functions and benefits that are required, grouping them into ten categories.

[20] North American Electric Reliability Corporation (NERC), "Potential Reliability Impacts of Emerging Flexible Resources," NERC, Princeton, NJ, November 2010.

Table 3-1 Flexibility/Reliability Functions[21]

RELIABILITY FUNCTION	RESPONSE TIME	BENEFIT
1) Inertial Response	Cycles to 1-2 seconds	• System stability
2) Primary Frequency Response	Cycles to 5-10 seconds	• System stability
3) Regulation (a FERC defined ancillary service)	10 seconds to several minutes	• Minute to minute frequency corrections
4) 4. Load following/ramping	Several minutes to a few hours	• Slower response resources are dispatched to follow system ramping requirements
5) Dispatchable Energy	Focuses on energy consumption at times of peak capacity requirements and minimum load	• Obtained from sub-hourly and hourly energy markets
6) Contingency Spinning Reserve	Must respond with 10 to 15 minutes	• Enough contingency spinning and non-spinning reserve must exist to deal with the largest failure that is anticipated
7) Contingency Non-spinning Reserve	Response not required immediately but required within 10 minutes	• Meets largest failure anticipated in conjunction with Spinning Reserve
8) Replacement or Supplemental Reserve	30 to 60 minutes	• Backup reserves
9) Variable Generation Tail Event Reserve	Ramps > 90 minutes	• Reserve for long duration wind events
10) Voltage Support	From short-term intermittent to long-term	• Maintain voltage control to specified criteria

3.2 TRADITIONAL SOURCES OF FLEXIBILITY

Traditionally, the existing technological solutions and mechanisms (flexible resources) listed below have provided the above electric system flexibility/reliability functions. However, advanced

[21] North American Electric Reliability Corporation (NERC), "Potential Reliability Impacts of Emerging Flexible Resources," NERC, Princeton, NJ, November 2010.

communication and control capabilities of the Smart grid technologies can enhance the ability of traditional technologies and mechanisms to maintain grid reliability through increased flexibility.

The following are technologies and mechanisms (flexible resources) that are currently used to accommodate variability in utility systems[22].

- Flexible Conventional Generation
- Demand Response
- Curtailment
- Sub-hourly Scheduling
- Consolidation of Balancing Areas
- Enabling Transmission (Transmission cannot provide flexibility by itself; however it provides access to additional sources of needed flexible resources.)
- Energy Storage (Pumped storage plants are an example of a bulk energy storage technology where all ten of the flexibility/reliability functions identified in Table 3-1 have been proven.)

These flexibility enabling resources are described in further detail in the following subsections.

3.2.1 Flexible Conventional Generation

Manufacturers are already developing conventional generation units that have higher ramp rates (fast changes in generating output) and cycling capabilities (large movements up and down in generating output), while managing the potential maintenance costs that result from this cycling. Transitioning these older generation facilities to more flexible units will provide grid operators with additional capabilities to meet rapid changes in generation needs due to renewable generation disturbances. A more flexible fleet of generators will also require transitioning the traditional base load units to ones which can operate at lower minimum levels and have an increased ability to cycle.

As an example, a large percentage of HELCO’s generation is not flexible. Many generators do not currently participate in load following or frequency management. These generators (run of river hydro (14MW), wind (33MW), and geothermal (30MW)), are operated as must-take generation with attendant reliability impacts. The impacts associated with this inflexible generation include a reduced ability to optimize costs and more difficulty in forecasting fuel requirements. Hence, the fuel supply barge schedule has to be changed when as-available energy exceeds forecasts, making fuel use unpredictable[23].

[22] North American Electric Reliability Corporation, "Flexibility Requirements and Metrics for Variable Generation: Implications for System Planning Studies," NERC, Princeton, NJ, August 2010.
[23] HELCO IRP Advisory group, HELCO System Operations, Hawaii Electric Light Company, Inc., August 2008.

As a result, HELCO has identified the need to maintain fast-starting units to provide offline reserves and the need to consider electric system flexibility functions through technology - fast start, ramping, cycling capabilities - for its future power generation additions. As part of these improvements, HECO has a project underway to retrofit eight of its fossil-fuel units to increase flexibility. The project will increase the utility's ability to accept more energy from variable renewable resources by reducing the combined minimum load of the units from about 330 MW to 170 MW. This retrofit will involve new equipment and equipment redesign, although specific changes are yet to be determined. The project is scheduled for completion by 2018.[24]

3.2.2 Demand Response

Like flexible conventional generation, demand response (DR) is another conventional flexibility resource. DR has been shown in some balancing areas (BAs), such as the grid managed by the Electric Reliability Council of Texas (ERCOT) in Texas, to be a flexible mechanism for operators to use with wind generation. ERCOT uses DR for minute-to-minute regulation and to supply contingency reserves. ERCOT demonstrated the ability to call on 1,200 MW of DR to restore system frequency during an incident in Texas in February 2008.[25] Effective DR can provide flexibility over short timeframes when an unpredictable change in intermittent renewable generation output occurs. A significant challenge in using DR to respond to intermittent renewable generation is that most DR programs are designed to operate only a limited number of times per year and thus are not necessarily matched to the high degree of variability of wind. DR is discussed more fully in Section 5.

3.2.3 Curtailment

Curtailment of intermittent renewable generation output may be necessary if the amount of energy available at a specific time is more than the grid can reliably accept. For less flexible island power systems with small balancing areas dominated by thermal generation, wind curtailments could occur even at relatively low variable generation penetrations. Recent wind integration studies[26] [27] [28] and operating experience demonstrate that at higher levels of penetration, wind generation may need to be curtailed during certain periods, unless suitable flexibility is designed into the bulk power system or measures are developed to store off peak wind power for use during higher demand periods. Wind generation can be designed to limit ramps and can be curtailed to provide

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[24] Western Governors' Association, "Meeting Renewable Energy Targets in the West at Least Cost: The Integration Challenge," Western Governors' Association, June 10, 2012.
[25] North American Electric Reliability Corporation, "Flexibility Requirements and Metrics for Variable Generation: Implications for System Planning Studies," NERC, Princeton, NJ, August 2010.
[26] S. Fink, et al, "Wind Energy Curtailment Studies, May 2008-May 2009,," NREL, Golden, CO., October 2009..
[27] North American Electric Reliability Corporation, "Flexibility Requirements and Metrics for Variable Generation: Implications for System Planning Studies," NERC, Princeton, NJ, August 2010.
[28] Kevin Porter, et al, *PJM Renewable Integration Study, Task Report: Review of Industry Practice and Experience in the Integration of Wind and Solar Generation,* Exeter Associates, Inc. and GE Energy, November 2012.

reserves, i.e. a source of increased flexibility. Wind procurement contracts may need to be modified to accommodate curtailment or to require features that facilitate curtailment and utility control.

3.2.4 Sub-hourly Scheduling

In many BAs, generation is scheduled on an hourly basis. Changes in load or generation occurring within the hour, must be met by generating units providing regulation and load following services. Scheduling generation on shorter time intervals can reduce the need for units to provide costly regulation services, freeing them up to support system flexibility requirements. If there are sufficient competitive resources in the market, sub-hourly energy markets can reduce costs by providing flexibility more cost effectively. These markets can provide economic incentives that reduce dispatch that is out of economic-merit order. Sub-hourly scheduling also reduces the period of uncertainty around wind generation schedules and allows wind plant owners to adjust schedules more frequently.

3.2.5 Consolidation of Balancing Areas

While each BA must continuously balance load and generation within its area, studies show that balancing area consolidation reduces ramping requirements for load, wind, and load with wind. If there is transmission capacity, increasing the size of a BA or collectively sharing the balancing obligation among BA's via dynamic transfers, formal energy imbalance markets or other means can provide flexibility to integrate variable energy resources (VER's). First, larger BAs provide access to more available generating resources and other sources of flexibility. Second, larger BAs can take advantage of the geographic diversity of wind resources. Results indicate the cost differential for operating independent balancing areas versus one consolidated BA increases significantly with significant wind penetration.

Currently, each Hawaiian island can be considered as a unique balancing area. Consolidation will play a role when an inter-island undersea transmission cable is in place. At that time, the interconnection of the separate grids will allow the consolidation of multiple island grids into a single BA with commensurate benefits. From a market structure and regulation standpoint, given that HECO controls the majority of the generation assets and load, especially on the islands that would be interconnected, HECO could act as the integrated BA authority.

3.2.6 Enabling Transmission

Transmission (internal within a system and external to other systems) by itself does not provide flexibility. However, transmission provides access to geographically dispersed renewable generation. Inclusion of a larger number of diverse locations of variable generation reduces the overall impact of changes in resource availability such as might result from changing cloud cover or gusts of wind. In order to include a wider array of sources, it is necessary to ensure adequate transmission between the diverse areas.

Island systems are substantially limited in their ability to use transmission to integrate diverse geographic resources. Weather conditions may not vary significantly enough to provide the diversity required. However, the island interconnection cable will introduce some transmission provided flexibility. Additionally, the strengthening of some aspects of the existing transmission gird may provide some opportunities to facilitate stronger connections between generation and load centers to minimize the impact of transmission system outages or curtailments.

3.2.7 Energy Storage

Energy storage is a technology that can be used to provide three different versions of electric system reliability functions as follows:

- Load shifting service: The storage system charges in periods of surplus and discharges during periods of scarcity,
- Shorter-term balancing service: Stored electricity is used to smooth variation of wind net load output thereby reducing the need for some spinning reserves, and
- Quick-acting instantaneous service: The storage systems provide immediate frequency and regulation products, and
- Pumped-hydro is an example of a proven traditional energy storage technique that is capable of providing any of the ten flexibility/reliability functions identified in Table 3-1[29]. Battery storage technologies are also a focus of significant development and investments to provide similar capabilities.

3.3 NEW EMERGING FLEXIBLE RESOURCES

Historically, at HECO and most other utilities, system load was highly predictable within each day and from day to day. Previous days' actual demand combined with near-term weather forecasting provided system load predictability. However, this has changed with increased intermittent distributed generation (DG), mainly from solar PV, which has currently reached 5-42 percent of retail sales, depending on the Hawaiian island. Since DG appears as volatile load reduction, it creates load variability for the bulk system. Thus, today, the load shows greater daytime variation, based on temperature, cloud cover, humidity and other factors that affect PV generation. Also, the production at larger utility-scale renewable generation sources varies significantly for the same reasons but is most often connected directly to the utility system as a discrete generation source and thus is easier to monitor.

Utility systems, including those in Hawaii, traditionally use flexible resources that are designed into the utility system to adjust to demand and generation fluctuations, changes in load, changes in transmission power flow and unexpected outages . Wind and PV generation vary more than conventional generation due to their reliance on a natural energy source. Seasonal variation, diurnal variation, and weather based events can cause extreme voltage ramps and other power

[29] North American Electric Reliability Corporation (NERC), "Potential Reliability Impacts of Emerging Flexible Resources," NERC, Princeton, NJ, November 2010.

quality issues. In addition, the integration of power from numerous intermittent DG sources rather than large traditional generation sources, pose control and stability challenges for local distribution system operators that lack more sophisticated controls.

New technologies, with increased flexibility will be required because operators must manage the additional variability and uncertainty that wind and PV introduce into the electric system. Intermittent renewable generation can reduce inertia and primary frequency response, cause large-scale changes in generation, and cause stability issues. It can affect power quality, voltage control and reactive power management at the local level. For island systems without interconnections, such as those in Hawaii, relatively small mismatches between demand and generation result in a significant change in frequency. For HELCO, a 2-3 MW drop in energy production results in a 0.1 Hz drop in frequency, which on most systems would be considered a significant variation but is something accepted on an island grid. Larger balancing authorities with large amounts of generation require much larger changes in output to result in a similar frequency drop.

As a result, additional flexibility will be required in the various time frames relevant to utility operations of milliseconds, seconds to minutes, minutes to hours, hours to days and beyond to many days to meet variability needs. This highlights the fact that additional flexibility will be necessary in Hawaii as compared to most utilities because smaller, isolated electric systems are more sensitive to variations in demand and generation than the larger and more integrated electric balancing areas that are found elsewhere in the U.S.

This need for increased flexibility will affect long-term transmission and resource adequacy planning and make it more costly to balance load and generation at all times. System reliability and stability and third-party contract provisions may take precedence over economic dispatch based decisions. Strategies for addressing this can be seen in the utilities' integrated resource plans (IRPs).

Sophisticated communications and controls available from the Smart Grid will help provide the new flexible resources needed to accommodate high amounts of energy produced by variable renewable energy resources. New and emerging resources have more integrated electronic features than existing technologies. New emerging flexible resources include the following:

Storage

- New bulk system central energy storage technologies, including flywheels, advanced batteries, Compressed Air Energy Storage (CAES), and others. These technologies are evaluated in another section of this HREGP report.
- Distributed stationary energy storage as demonstrated to date has not been economic on the mainland U.S. but may be economical in Hawaii considering the high cost of energy there.

- Distributed non-stationary energy storage (e.g. electric vehicles) is being assessed under a separate section of this HREGP report.

Demand Response

- New types of DR, including direct load control, scheduled load management, customer load response, and rate design.

Forecasting

- HECO has identified the benefits of improved forecasting and is working with industry forecasters to evaluate additional possibilities.

Ancillary Services-Reserves Management

- HECO will equip more existing conventional generators with automatic generation control (AGC) in the future. Hawaiian utilities have considered modest limits for ramp control of intermittent renewable generation and should use contingency reserves for extreme wind events.

Proof of technical and commercial viability combined with changes to reliability standards, tariff, rates,incentives and business rules will be necessary to adopt new technologies, which maximize electric system flexibility functions.

3.4 A “PROACTIVE APPROACH” IN HAWAII

A major effort is underway by the State of Hawaii to develop a proactive approach to achieve high levels of renewable generation. The Proactive Approach recommendation was developed in a multi-party process by the Reliability Standards Working Group (RSWG), involving utilities, state agencies, and clean energy groups. The PUC convened the RSWG in September 2011 at HECO's suggestion to deal with reliability concerns arising from increasing levels of renewable energy entering the Hawaii utility grids. At the PUC's direction, the RSWG formally concluded its work in January 2013 by submitting an array of recommendations and reports, which included the development of a recommendation for a Proactive Approach (the label attributed to the recommendations). The RSWG supports and recommends the Proactive Approach as the next evolutionary step in renewable DG interconnection, towards the clean energy grid of the future. The recommendations included a set of transparent reliability standards for the operation and planning of the utility grid.

When flexibility/reliability functions are sold in energy markets they are called ancillary services. Actual ancillary services employed are dependent on the characteristics of each and every power system. General Electric (GE) assisted the RSWG in defining a set of ancillary services that protect reliability, incent renewable generation, and minimize production costs.[30] They identified “Hawaii-specific” differences relative to more standardized definitions. The following are the Hawaii-specific RSWG recommendations regarding supply of ancillary services (flexibility/reliability functions).

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[30] HNEI, "Report on Business Case in Hawaii for Storage Options," US Department of Energy, Office of Electricity Delivery and Energy Reliability, Honolulu, HI, October 2012.

Smart Grid communication and control features will enable these flexibility/reliability functions, but in some cases will require additional demonstration, and cost justification before implementation.

- **Inertia -** The current and future combination of inertia and governor should be tracked and evaluated by the utilities to ensure all new generation fulfills frequency recovery needs and that needed response is provided at minimum cost. All power plants using rotating machines including those based on power electronics should be encouraged by utilities to provide maximum cost effective inertia to the power system. Emerging demand-response and storage technologies that provide sufficiently fast response to assist with arresting frequency decay should be encouraged to provide maximum cost effective inertia-like response to the power system. When the ability to provide adequate frequency recovery has been identified, utilities should endeavor to secure additional frequency recovery capability from new generating or storage plants or synthetic response from plants or storage systems where that is practicable. Engineering test procedures should be developed by utilities to perform field testing and measurement of synthetic or actual inertial capabilities for new or existing plants.
- **Frequency** - Frequency response should be specified in terms of droop. The time frame of the response should be defined. All generators (thermal, hydro, geothermal, wind, solar, etc.) should be required by utilities to be capable of frequency response to the extent economically feasible. Storage and demand response should be encouraged to provide frequency response capability to the extent that they are physically capable of doing so. Utility system operators should utilize the least cost frequency response resources, which may vary from hour to hour.
- **Automated Grid Controls (AGC) -** All generators (thermal, hydro, geothermal, wind, solar, etc.) should be required to be capable of responding to AGC commands. Each utility's AGC system should be modified to be able to utilize the full range of responsive resources (conventional generators, variable renewable generators, storage, and demand response) unless detailed studies demonstrate that this is not economically justified. Storage and demand response should be allowed to provide AGC response to the extent that they are physically capable. If the device or generator interface and response capabilities support the necessary AGC response (i.e.; AGC interface is provided, the response is predictable, and within the appropriate time frame) the device or generator should participate in frequency regulation as well as economic dispatch under AGC control. Utility system operators should utilize the least cost AGC resources which will likely change from hour to hour during conditions when frequency is within specified tolerances.
- **Spinning Reserves -** Utilities should require all generators (thermal, hydro, geothermal, wind, solar, etc.) to be designed with spinning reserve capability with the best response practicable. Storage and demand response should provide spinning reserve to the extent that they are physically and economically capable. System operators should utilize the least cost available resources for spinning reserves, which will likely change from hour to hour.
- **Contingency Reserves -** Utilities generally calculate the amount of spinning reserve required by defining the largest single contingency (i.e.; largest online generator). Larger units or installations, while less expensive per kW for the initial installer, will increase contingency reserve requirements and costs for the BA. Any added reserve cost should be considered when evaluating any new generation project. Utilities should consider the need for non-spinning and supplemental reserve in their routine generation planning. All

generators, storage and demand response should be able to provide non-spinning and supplemental reserve to the extent that they are physically and economically capable (i.e.; ability to come online quickly or operate in standby mode). Electric system operators should utilize the least cost replacement reserve resources, which will likely change from hour to hour. The total cost for providing replacement reserves is typically dominated by the standby cost rather than by the activation cost.

- **Reactive Power and Voltage Regulation -** All generators (thermal, hydro, geothermal, wind, solar, etc.) should be required by utilities to be capable of providing reactive power and controlling voltage in response to system operator commands. Storage should be encouraged to provide reactive power and voltage regulation. This may influence where storage is installed on the power system to make best use of the reactive power and voltage regulation capabilities. If storage must remain on line just to provide reactive power and voltage regulation, it should be compensated for doing so. Utilities should consider alternative sources of controllable reactive power to reduce operating cost where reactive power needs would otherwise require out-of-merit order or must-run operation.
- **Short Circuit -** Low short-circuit current problems due to increased penetration of renewable resources should be monitored and appropriate remedial action taken by utilities. As more generators that provide little or no short-circuit current are installed, problematic protection should be changed to a type that requires lower short-circuit current. Motor-starting or voltage flicker should be monitored at both the transmission and distribution levels for adverse impacts due to the increased penetration of renewables. When energy storage is considered for its many benefits, the short-circuit contribution of pumped hydro systems should be taken into consideration.
- **Planning -** HECO should evaluate and publicize excess energy expectations based on demand and generation forecasts for five to ten years into the future.
- **Compensation -**To provide and obtain these ancillary services in the most cost effective way, utilities should compensate independent power producers (IPPs) for direct and opportunity costs of resources providing increased inertia or frequency regulation, spinning reserve, and replacement reserve. Utilities should develop energy pricing tariffs that reflect the true marginal cost of energy, especially during curtailment periods and tariffs for both storage and demand response to encourage investment in technologies that reduce or eliminate power system minimum demand problems.

In addition, the following are recommendations RSWG made with respect to demand-side programs.

- The utilities should investigate and define options the use of demand response and energy storage to provide ancillary services that are technically possible and economically justified. They should investigate pricing programs and manual and automated demand response programs that will incentivize customers to change their consumption patterns in ways that are beneficial for stakeholders. Included in this investigation would be an analysis of the benefits of increasing demand during minimum load periods (i.e., examining the cost reductions that could be incurred and the impact on renewable energy purchases during the entire 24-hour day).
- Regulators should allow the utilities and other interested stakeholders to develop specific pricing and/or manual demand response programs, with expedited regulatory review and approval to get these programs in place as soon as possible. As the Commission reviews

new DR programs, it should consider the appropriate role of third party agents and aggregators (i.e. curtailment service providers) to deliver demand response programs effectively and efficiently.

- With regulatory approval utilities should ensure that demand response programs are considered in the Integrated Resource Planning process and direct the energy efficiency potential study contractor to perform specific load research data collection that will allow them to better estimate the demand response potential in Hawaii. State government should require that Hawaii Energy work with the utilities to identify those customers and loads that are most promising for demand response, and ensure that Hawaii Energy and the DR planners coordinate program plans and marketing to ensure that energy efficiency does not compromise promising DR opportunities (and vice versa).

3.5 SECTION SUMMARY

Intermittent renewable generation increases the need to supply electric system flexibility/reliability functions with existing traditional and new emerging flexible resources. When flexibility/reliability functions are sold in energy markets they are defined as ancillary services. Hawaii's RSWG worked with GE to define a set of "Hawaii-specific" ancillary services that could be used to protect reliability, incent renewable generation, and minimize production cost for each Hawaii island.[31]

Existing traditional and new emerging flexible resources will be enabled and enhanced with the advanced communications and control capability of the Smart Grid. Examples of emerging flexible resources that will be enabled by Smart Grid communications and control capability include fixed and mobile energy storage, new types of demand response, improved forecasting of renewable energy resources, and new methods of reserves management.

[31] HNEI, "Report on Business Case in Hawaii for Storage Options," US Department of Energy, Office of Electricity Delivery and Energy Reliability, Honolulu, HI, October 2012.

4.0 Energy Efficiency (EE)

The Hawaii Clean Energy Initiative includes a significant energy efficiency (EE) goal: 30 percent of forecasted 2030 energy use, equivalent to 4,300 GWh reduced by 2030[32]. For context, Hawaii's 2011 statewide energy efficiency program savings report indicates 130 GWh savings achieved that year. This single-year savings is just three percent of the 2030 goal, leaving much to be done to reach Hawaii's 2030 EE goal. Because the State of Hawaii has such high goals for renewable penetration and energy efficiency, all the Hawaii grids will require significant Smart Grid advances to manage the concurrent requirements of decreased load and increased penetration levels of intermittent renewable energy. The Energy Efficiency section of this report:

1. Identifies the value and advantages of EE;
2. Identifies existing end-use EE programs in Hawaii;
3. Identifies EE programs that improve the efficiency of the grid rather than the end use efficiency;
4. Explains how smart meters can improve end use and electric system efficiency;
5. Explains the effect of end use efficiency on electric system reliability and flexibility;
6. Identifies additional EE programs that can enhance the State's ability to meet its EE goals; and
7. Identifies the difference between EE and DR since they can compete for the same loads.

4.1 THE VALUE AND ADVANTAGES OF ENERGY EFFICIENCY

Energy efficiency is a critical component of Hawaii's Clean Energy Initiative, and it is an important part of each of the island utilities' Integrated Resource Plans (IRPs). EE is typically considered the most cost effective means to meet future energy demand. EE reduces the need for new generation,, thus reducing overall system cost. Many States have recognized this and have provided EE performance standards and other incentives to induce utilities and customers to adopt it on a priority basis. Independent reports by both the Electric Power Research Institute and McKinsey and Company in 2009[33] indicated that energy efficiency presents a vast low-cost energy source nationwide for the U.S. There is the potential, according to McKinsey, to reduce annual nationwide energy consumption significantly with an array of *Net-Present-Value-positive* energy efficiency measures, resulting in net cost savings to ratepayers. In addition to economic advantages, energy efficiency provides an air-quality-emission-free energy resource. Implementing energy efficiency strategies can result in significant reductions in greenhouse gas emissions, and it can serve as an important bridging technology toward long-term advanced low carbon technology scenarios.

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[32] Note: the HCEI roadmap, dated 2011, indicates 4,300 MWh reduced by 2030 (pg 4). The HI 70% scenario analysis indicates that the statewide EE goal is 4,300 GWh reduced by 2030 (pg 43). This is 3 orders of magnitude different. I assume the HCEI Roadmap contains a typo, and the actual goal is 4,300 GWh, not MWh.

[33] http://www.mckinsey.com/client_service/electric_power_and_natural_gas/latest_thinking/unlocking_energy_efficiency_in_the_us_economy
http://www.edisonfoundation.net/IEE/Documents/EPRI_SummaryAssessmentAchievableEEPotential0109.pdf

4.2 EXISTING ENERGY EFFICIENCY PROGRAMS IN HAWAII

Hawaii's 2011 Clean Energy Initiative Roadmap[34] contains a summary of statewide energy efficiency accomplishments to date, which include the following.

- Established quantitative 2030 energy efficiency savings goal.
- Decoupled HECO companies revenue stream from electricity usage.
- Established public benefits fund to help finance the retrofitting of the existing building stock.
- Deployed a State "Lead-By-Example" program.
- Transferred HECO building energy efficiency programs to public benefit fund (PBF) program administrator, and deployed monitoring and verification programs.
- Establish fully operable Kauai Island Utility Cooperative (KIUC) Public Benefit Fund (PBF) programs.
- Collected building stock data and identified needs.
- Adopt new, more efficient county building codes (IECC2006 for Maui, and Oahu and The Big Island).
- Conducted pilots of highly efficient new homes through Department of Defense and Department of Hawaiian Homelands.
- Conducted new construction efficiency savings potential analysis.
- Evaluated potential efficiencies from improving transmission/distribution infrastructure.
- Identified industrial and military electricity applications for future energy efficiency potential study.

For end-use energy efficiency in particular, Hawaii has established a public benefits fund for energy efficiency and demand-side management. This fund was established in 2006, and its size is generally calculated as a fraction of the utilities' annual revenues that the fund receives. For 2013, the fund is receiving two percent of the utilities' revenues including taxes. This funds The Hawaii Energy Conservation and Efficiency Program (Hawaii Energy), a program operated by SAIC, an independent third party contractor for the Hawaii Public Utilities Commission , with a Project Year 2013-14 budget of $33.6 million.

Hawaii Energy supports residential programs, business programs, and market focused programs such as workforce development, energy audit and benchmarking tools and support, and education programs such as "Energy Efficiency through Financial Literacy", and "Residential Home Rating Analysis".

Energy efficiency technologies promoted by these programs include: Clothes Washers, Refrigerators, Ceiling Fans, Water Heaters, Lighting, Lighting Controls/Sensors, Chillers, Heat Pumps, Central Air Conditioners, Heat Recovery, Windows, Motors, Processing and Manufacturing

[34] http://www.hawaiicleanenergyinitiative.org/storage/media/HCEI%20RoadMap_2011_40pgs.pdf

Equipment, Custom/Others pending approval, LED Exit Signs, Pool Pumps, Commercial Refrigeration Equipment, Food Service Equipment, LEDs, and Heat Pump Water Heaters.[35]

An overview of the latest results achieved by these energy efficiency programs can be seen in the statewide program measurement and verification reports, which are summarized below.[36]

Table 4-1 2011 Hawaiian Energy Efficiency Program Results

PROGRAM	DESCRIPTION	2011 VERIFIED SAVINGS [KWH]
Business, Energy, Efficiency, Measures (BEEM).	Provided prescriptive Incentives to business customers who purchased and installed energy efficiency measures. The program paid incentive rebates for lighting, air conditioning, water heating, water pumping, motors, building envelope improvements, energy awareness, measurement and control systems, and ENERGY STAR business equipment.	35,267,460
Custom, Business, Energy, Efficiency, Measures, (CBEEM).	Provided custom financial to commercial, institutional, governmental, and industrial sector customers based on their calculated energy savings.	22,115,468
Business Service and Maintenance (BESM)	Provided incentives and direct installation programs to business in addition to business design, audits, and commissioning.	2,057,135
Business Hard to Reach (BHTR).	Provided equipment grants to building owners, tenants and apartment/condo complexes.	1,675,686
Non-residential total		**61,115,749**
Residential Energy Efficiency Measures (REEM).	Provided prescriptive incentives to residential customers who purchased and installed energy efficiency measures. The program paid incentive rebates for prescriptive measures, including water heating, lighting, air conditioning, appliances, and awareness, measurement and control systems.	66,877,382
Residential Energy Services and Maintenance (RESM)	Provided incentives to homeowners for direct installations, design, energy audits, and system tune-ups.	91,481

[35] http://www.dsireusa.org/incentives/index.cfm?re=0&ee=0&spv=0&st=0&srp=1&state=HI
[36] http://www.hawaiienergy.com/media/assets/PY11VerificationMemoforHawaiiEnergy.pdf

Residential Hard to Reach (RHTR)	Provided equipment grants to landlords, tenants and apartment/condo complex owners.	2,021,151
Residential Total		**68,990,014**
Program Overall		**130,105,763**

The energy efficiency portfolio for PY12 yields an average life of 9.1 years across the overall portfolio and would result in lifetime program energy savings of $0.02 per kWh.[37] In 2011, the State invested 1.13 percent of annual utility revenues in electricity efficiency programs, and the State achieved savings of 1.15 percent of statewide retail electricity sales in 2010.[38]

For comparison, California (frequently perceived as a leader in EE) invested 3.35 percent of annual utility revenues in electricity efficiency programs in 2011, and achieved an average savings of 1.79 percent of statewide retail electricity sales in 2010. Much of the funding for energy efficiency in California is used to support natural gas savings, which are not included in our review of Hawaii's energy efficiency programs, and which are beyond the scope of this report.

California has implemented several EE measures of note, which are not currently being implemented in Hawaii, but which may be worth considering in Hawaii, as they have achieved great success and recognition in the EE professional community. These include the following, as noted by the American Council for and Energy Efficient Economy (ACEEE):[39]

- Reward structures for successful energy efficiency programs: incentive earnings accrue only if the Investor Owned Utility (IOU) energy efficiency portfolio of programs achieves a minimum percentage of the CPUC's goals. Utilities receive higher net benefits if they meet or exceed savings goals.
- Building codes: California's energy code is considered to be the most aggressive and best enforced energy code in the United States, and has been a powerful vehicle for advancing energy-efficiency standards for building equipment. Many specifications are performance-based, offering flexibility for designers. The most recent code, effective January 1, 2010 is mandatory statewide and exceeds 2009 International Energy conservation Code (IECC) standards for residential buildings and meets or exceeds American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE)/Illumination Engineering Society of North America (IESNA) 90.1-2007 for commercial buildings. For comparison, Hawaii's current building codes are compliant with 2006 IECC with Amendments. According to ACEEE, Hawaii has not yet adopted IECC 2009, but adoption with amendments appears to be in progress as of May 2012.

[37] Hawaii Energy's Program Year 2012 Annual Plan
[38] http://aceee.org/files/pdf/fact-sheet/2012-spending-and-savings-tables.pdf
[39] http://aceee.org/sector/state-policy/california

- Appliance efficiency standards: Presently, California has adopted standards for ten products that are not covered by federal standards. Of particular note are the state's precedent-setting efficiency standards for incandescent light bulbs, metal halide lamp fixtures, and televisions.
- Energy efficiency financing programs: California offers eligible customers 0% financing for qualifying energy-efficient improvements.

4.3 TRANSMISSION AND DISTRIBUTION EFFICIENCY, VOLTAGE CONSERVATION AND VOLTAGE/VAR OPTIMIZATION

In addition to end-use efficiency, another type of EE involves increasing the efficiency of the power delivery system itself. Because Section 4 is focused on end-use efficiency, we will simply note here that there are additional types of efficiency discussed elsewhere in this report. Please see Section 6 for a discussion of how the Smart Grid will allow more effective control of distribution system voltage and allow improvement of electric system efficiency. Utilities are implementing conservation voltage reduction (CVR) programs and volt/VAr optimization (VVO) programs, sometimes as part of wider ranging Advanced Distribution Management System (ADMS) initiatives, to decrease system losses. These programs have the potential to reduce demand by 1.5-2.1%, and to reduce energy by 1.3-2.0%.[40] Full implementation these programs will provide additional system flexibility, more control of local voltage, and greater penetration of distributed renewable energy, and provide overall efficiency improvements.

It is worth noting here that, while CVR programs tend to produce overall system efficiency improvements, there are cases where this rule does not apply. In particular for large industrial complexes with older motors, recent literature indicates significant value in implementing solutions that are designed to optimize for power factor rather than CVR.[41]

4.4 SMART METERING INCREASES CUSTOMER DRIVEN EFFICIENCY

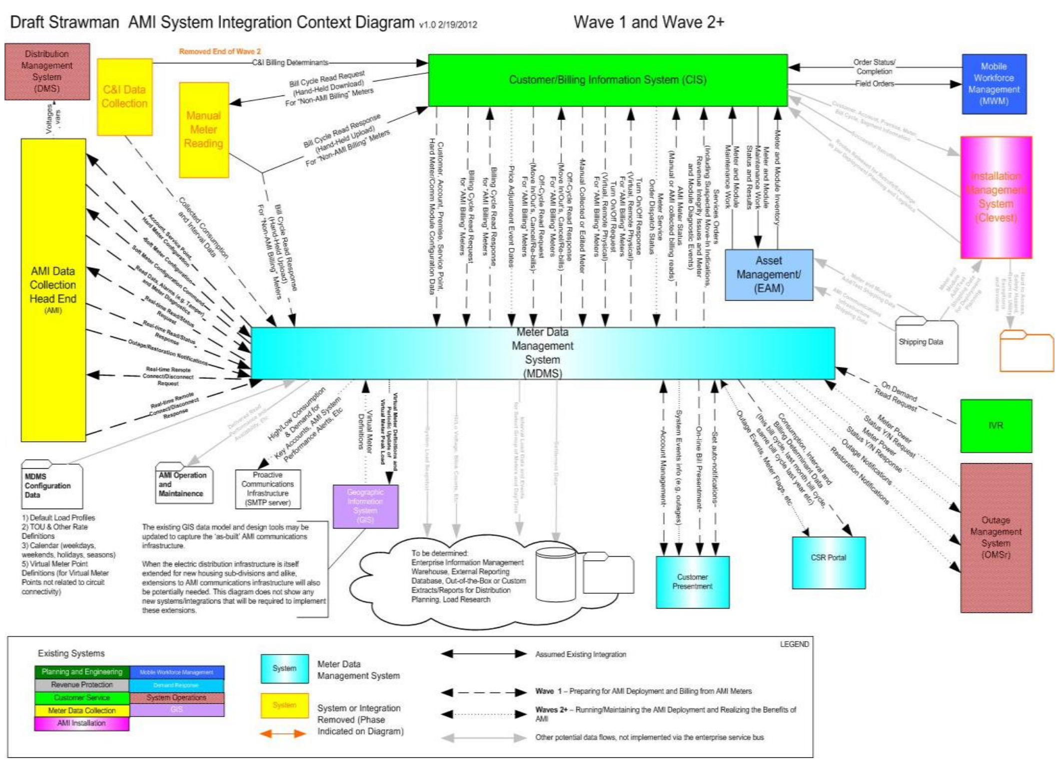
Smart metering solutions, which will be discussed in depth in Section 6, are a Smart Grid feature that can enable electric system flexibility. However, they are also discussed here since they have great potential for raising consumer awareness and for driving energy efficiency. Smart meters can provide energy efficiency value due to the education effect they have on energy consumers. Traditional monthly billing provides baseline information but is generally confusing to customers and makes it challenging for consumers to reduce their day-to-day energy usage since they cannot see the impact of individual actions. Rather, consumers require a feedback loop with a shorter delay to understand the implications of their usage patterns and create energy-saving behavioral changes. The European Smart Metering Industry Group (ESMIG) recently noted that "unless people know how much energy they are consuming, when they are consuming it, and how much it costs, it will be almost impossible for them to conserve energy or shift consumption in any significant

[40] http://cialab.ee.washington.edu/nwess/2012/talks/uluski.pdf
[41] Ibid.

way."[42] Smart meters provide an effective avenue to address this gap and enable energy savings through better awareness of energy consumption.

However, smart metering by itself does not result in smart consumers. Captured data must be coupled with end-user services and devices to allow for interpretation of results. Data must be presented in a clear, attractive, and timely manner in order to affect consumer behavior. The tool for aggregating, managing and presenting the metering and associated data collected from AMI systems is the MDMS (Meter Data Management System). This application provides a platform on which the business rules and processes are applied to the collected data. The resultant processed information is then made available to other internal utility applications and users, and is structured for easy customer access. Figure 4-1 provides an example of a MDMS implementation architecture and data flows that illustrates the Smart Grid capabilities of an MDMS.

Figure 4-1 MDMS Implementation Architecture



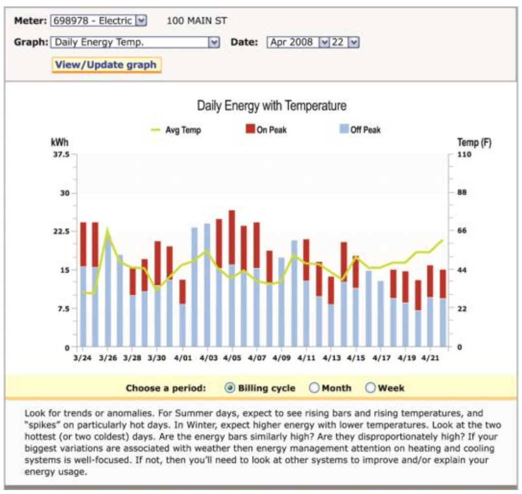
The most basic feedback channels for this information are energy reporting via online portals or smart phone applications and indirect feedback via more informative billing statements which track individual progress and may also show comparisons to similar homes. More advanced feedback involves real-time data through in-home energy displays and the introduction of smart

[42] ESMIG, "Position Paper on Smart Metering in the Energy Efficiency Directive," January 2012

products with automated controls which can react to utility signals, price changes, and consumer preferences.

For customers that have internet access , consumer web portals have become very popular because they are relatively inexpensive, requiring no new specialized hardware (such as an in-home display) and utilizing the metering data (commonly 15 minute or hourly) already available from the smart metering system. Figure 4-2 provides an example of a commercially available customer energy usage presentation application. Mobile applications, which can be viewed as an extension of web portals, are also gaining traction since they can be accessed from anywhere and since increasing percentages of consumers have access to the requisite mobile devices, such as smart phones and tablets. While not all customers have Internet access at home or possess smart phones, the overall percentage of access to these tools is increasing to the point where utilities must focus on these customer engagement paths to reach the bulk of customers.

Figure 4-2 Customer Energy Use Data Presentment



A noteworthy point highlighted by a number of studies show that savings tend to increase when multiple methods are combined. This effect should be expected to grow as future consumers have more options and ways of receiving timely information. Simple and low-cost consumption feedback systems could be widespread within the next decade, leading to some amount of energy savings purely through behavioral changes.

The following figures show the range of energy conservation which can result from increasing consumer awareness through smart metering data.

- Real-time displays: 3-12% (8.7% average)
- Web portals: 0-8% (5.1% average)
- Monthly information & feedback: 2-9% (5.9% average)

These data are based on a global study of over 450,000 residential energy consumers comprising 100 different utility projects.[43]

Energy savings effects due to education and increased awareness may fit best under Hawaii's existing energy efficiency program structure, in the category of transformation programs - activities include education, training and other similar transformational activities that may not result in immediate quantifiable energy savings, but are likely to contribute to energy savings over time.

4.5 GREEN BUTTON INITIATIVES PRESENT NEW OPPORTUNITIES TO INCREASE CUSTOMER-DRIVEN EFFICIENCY

In addition to smart metering, there is an information technology initiative underway nationwide in the U.S. that seeks to promote new methods for consumers to monitor and interact with their energy use. This "Green Button" initiative is a response to a 2011 White House call to action, requesting that the electricity industry provide electricity customers with easy access to their energy usage data in a consumer-friendly and computer-friendly format via a "Green Button" on electric utilities' websites. Green Button is a common technical standard, which enables software programmers and developers to work with energy usage data, providing customers with apps and games to make informed energy decisions, to set energy reduction goals, to compete with one another, and to track and share their progress toward these goals through social media.[44]

4.6 ENERGY EFFICIENCY CREATES THE NEED FOR ADDITIONAL SYSTEM FLEXIBILITY

Increases in EE bring reduction in load. As a result, the extant renewables therefore become a higher percentage of generation. This requires additional system flexibility. To maintain reliability, utilities are increasingly applying smart technologies such as Distribution Automation (DA) and Demand Response (DR,), as well as flexibility mechanisms that provide electric system reliability. These mechanisms are further discussed in Section 5.

The grid stability issue related to renewables is a function of both the overall quantity of energy and also of the timing of energy delivery. While EE may represent the lowest cost and lowest impact activities, the overall grid stability must be kept in mind. Black & Veatch recommends that steps taken toward the State's EE and RE goals should be performed in sequence, without sacrificing grid reliability on the path to low energy consumption and a high penetration renewable energy. Black & Veatch recommends an approach that balances EE and RE, in order to maximize system flexibility and reliability, as laid out in the following Sections of this report.

[43] Jessica Stromback, Christophe Dramacque, Mazin Yassin; "The potential of smart meter enabled programs to increase energy and systems efficiency: a mass pilot comparison," VassaETT, 2011
[44] http://www.greenbuttondata.org/greenabout.html

4.7 OPPORTUNITIES TO ENHANCE HAWAII'S ENERGY EFFICIENCY PROGRAMS, AS IDENTIFIED TO DATE IN STATE PLANNING DOCUMENTS

This section reviews opportunities that have already been identified in Hawaii's planning documents, for enhancing existing Hawaiian Energy Efficiency programs to meet State goals and objectives:

The opportunities listed below represent lessons learned, reflections, and strategies taken from the Hawaii Energy Annual Plan 2012[45]. EE programs should:

- Minimize free-ridership and eliminate underperforming incentive offerings,
- Focus incentives on high and persistent savings measures,
- Ensure hard-to-reach consumers are served well on all islands,
- Maximize direct customer benefit from each Public Benefits Fee (PBF) dollar collected,
- Make customers aware that Program incentives offer a great return on their PBF investment,
- Focus attention and budget on cultural behavior and other transformational energy changes,
- Use technology to increase consumer awareness of their own real-time energy use,
- Make energy conservation and efficiency the go-to first choice for every energy consumer,
- Use all available data to target best opportunities, identify outliers and track performance,
- Constantly review, modify and diversify portfolio offerings to ensure maximum performance,
- Explore best practices and new outside-the-box opportunities to keep strong momentum,
- Educate a broader base of customers/decision-makers about energy conservation and efficiency,
- Provide critical leadership in EEPS, IRP, HCEI and other clean energy efforts,
- Give decision-makers better tools to monitor and understand their own energy performance, and
- Reach deeper into consumer energy planning, operations, maintenance and energy use tracking.

[45] http://www.hawaiienergy.com/media/assets/HawaiiEnergyPY2012AnnualPlan7.19.2012.pdf

Black & Veatch recommends the following strategies to reach these goals.

Table 4-2 Strategy Recommendations to Meet Energy Efficiency Goals

GOAL	STRATEGY
Minimize free ridership	Free riders are defined as participating customers who would have bought a program-sponsored product without the utility program intervention. For California EE program measurement and verification (M&V), the “net-to-gross ratio” is defined as the percentage of non-free rider participants (i.e., the number of participants who purchased the product because of the program and its promised benefits) divided by total program participants (i.e., the number of people receiving a rebate). Hawaii’s M&V methodology in the Hawaii Energy Efficiency Program Technical Resource Manual (TRM19) includes a version of this net-to-gross ratio – the “realization rate”. The realization rate could be calculated in more precise detail based on updated surveys and field research.
Maximize benefit for each dollar collected	Enhance cost/benefit calculation methodologies to include demand response measures and enhanced monitoring and control measures, in particular, those described in Section 6 of this report.
Increase customer awareness	Increase deployment of advanced metering. Take advantage of nationwide “Green-Button” initiatives to encourage customers to make informed energy decisions[46]
Best practices and out-of-the-box opportunities to keep strong momentum	Promote new and emerging EE technologies such as seawater air conditioning district cooling systems, solar air conditioning, heat pump water heating, ice storage, and the use of rejected heat from combined heat and power (CHP) systems. Increase stringency and enforcement of building codes and appliance efficiency standards Adopt reward structures for utilities exceeding energy efficiency goals Create energy efficiency financing programs, in order to increase accessibility of EE to the broader public. Continue to expand the high penetration of solar water heating already present on the islands.

[46] http://www.greenbuttondata.org/greenabout.html

4.8 OPPORTUNITIES TO ENHANCE HAWAII'S ENERGY EFFICIENCY PROGRAMS, AS IDENTIFIED BY THIRD PARTIES

In the energy efficiency cost/benefit literature, there are several broad categories of typical EE measures which states implement in order to accelerate adoption of EE technologies and practices statewide. The American Council for an Energy Efficient Economy's EE scorecard[47] summarizes a representative sample of these measures. Scoring categories, and Hawaii's scores for each category, are provided in the table below.

Table 4-3 ACEEE 2012 Energy Efficiency Scorecard for the State of Hawaii

SCORING CONTENT AREA	POINTS AWARDED TO HAWAII	POSSIBLE POINTS	PERCENT OF POSSIBLE POINTS ACHIEVED,%
Utility & Public Benefits Programs and Policies	12.5	20	63
Transportation Policies	3	9	33
Building Energy Codes	4	7	57
Combined Heat and Power	0.5	5	10
State Government Initiatives	2	7	29
Appliance Efficiency Standards	0	2	0
Total Score	22	50	44

Hawaii ranks 18th of the 50 U.S. states, in ACEEE's 2012 Energy Efficiency Scorecard. Hawaii has demonstrated leadership in Building and Energy Codes, and in Utility & Public Benefits Programs and Policies, according to this scorecard. This scorecard also indicates that Hawaii has room for improvement in several areas. The areas with the greatest room for improvement are, in order of potential improvement by ACEEE standards: appliance efficiency standards, combined heat and power, state government initiatives, and transportation policies.

Because the focus of this report is electricity only, Black & Veatch recommends prioritizing the two electricity measures in this list: appliance efficiency standards and state government initiatives. Recommendations in each of these areas are provided below.

[47] http://www.aceee.org/sites/default/files/publications/researchreports/e12c.pdf

4.8.1 Appliance efficiency standards

The following recommendations apply to appliance efficiency standards.

- Adopt appliance efficiency standards for televisions and battery chargers, following California's "best practice" example.[48]
- Adopt efficiency standards for incandescent lamps that are more stringent than the federal standards, following Nevada's "best practice" example.[49]
- Adopt efficiency standards for toilets, urinals, faucet aerators, showerheads, commercial pre-rinse spray valves, following the "best practice" example of California, Georgia, and Texas. These measures produce water savings as well as energy savings associated with the production, heating, treatment, pumping, and disposal of water and wastewater.

4.8.2 State government initiatives

The following recommendations apply to appliance efficiency standards.

- Existing "lead by example" programs to improve the energy efficiency of state agencies, state-owned buildings and fleets are widely recognized to be high-achieving. Activities include promoting and executing energy savings performance contracts throughout the state, developing a pilot sustainable community with net-zero-energy homes, benchmarking, retro-commissioning, and LEED certifying a number of state buildings.
- Opportunities remain to enhance state-funded research, development, and demonstration programs for energy efficiency technologies and practices.
- The state building code has been updated to IECC 2006 for most islands. This could be further updated to IECC 2009, as has been done on Kauai.

4.9 THE INTERACTION BETWEEN ENERGY EFFICIENCY & DEMAND RESPONSE

EE and DR programs can target the same loads. Therefore it is useful to understand the difference between the two. EE seeks to provide a sustained reduction in the amount of energy consumed by an appliance or load device through the application of technology improvements or operating

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[48] Source: ACEEE 2012 State Energy Efficiency Scorecard, p. 86. Accessed online, June 2013 at the following URL: http://www.aceee.org/sites/default/files/publications/researchreports/e12c.pdf
Excerpt: "California, scoring the maximum 2 points, continues to take the lead on appliance efficiency standards, most recently adopting the first-ever standards for televisions as well as standards for battery chargers. Not only has California adopted the greatest number of appliance and equipment standards, many other states' standards are based on Califronia's, such as the television standards passed in Connecticut in 2011."

[49] Source: ACEEE 2012 State Energy Efficiency Scorecard, p. 86. Accessed online June 2013 at the following URL: http://www.aceee.org/sites/default/files/publications/researchreports/e12c.pdf
Excerpt: "In our 2011 Estate Energy Efficiency Scorecard, Nevada earned credit for adopting standards for general service incandescent lamps that are more stringent than existing federal standards. However, those standards are not yet being enforced and it is uncertain when they will begin to be enforced, so we have deducted those points indefinitely."

measures. This baseline energy use reduction lowers base load and can reduce plant cycling and the use of peaker plant units. It is common for utilities to capture and quantify both energy efficiency (kWh) and peak demand reduction (kW) benefits for each EE measure, in their EE program measurement and verification reports. Demand response is discussed further in Section 5.

4.10 SECTION SUMMARY

Energy efficiency is a critical component of Hawaii's Clean Energy Initiative, and it is an important part of each of the island utilities' Integrated Resource Plans (IRPs). EE is typically considered the most cost effective means to meet future energy demand. EE reduces the need for new generation,, thus reducing overall system cost. Many states have recognized this and have provided EE performance standards and other incentives to induce utilities and customers to adopt it on a priority basis. Independent reports by both the Electric Power Research Institute and McKinsey and Company in 2009[50] indicated that energy efficiency presents a vast low-cost energy source nationwide for the U.S.

By increasing the ratio of renewable supply to grid load, EE reinforces the need for Smart Grid technologies to keep supply and demand in balance. EE also overlaps in some cases with DR, and the result is a lean, reliable grid.

Specific opportunities to strengthen energy efficiency policies and programs in Hawaii include minimizing free-ridership, promoting new energy efficiency technologies, enhancing customer experience with smart meters, smart appliances, and green button tools, strengthening appliance efficiency standards, strengthening state government-funded R&D initiatives, increasing the stringency of building codes, adopting reward structures for utilities exceeding energy efficiency goals, and enhancing cost-benefit accounting to include new programs and technologies.

Black & Veatch recommends that the annual statewide measurement and verification reports, which currently address a number of energy efficiency programs, should be expanded to include cost-benefit accounting for demand response, and for communication, monitoring and control programs. This would enable capturing of additional savings, and ensure that co-benefits of EE measures do not go unrecognized.

[50] http://www.mckinsey.com/client_service/electric_power_and_natural_gas/latest_thinking/unlocking_energy_efficiency_in_the_us_economy
http://www.edisonfoundation.net/IEE/Documents/EPRI_SummaryAssessmentAchievableEEPotential0109.pdf

5.0 Demand Response

Section 3 identified Demand Response (DR) as a flexible resource that can provide reliability functions necessary to integrate larger amounts of intermittent renewables into a grid. This section presents DR technologies in more detail, focusing on customer programs and engagement strategies which can optimize the use of renewable energy and help meet Hawaii's energy objectives. Existing and emerging DR programs and mechanisms will be reviewed as well as potential barriers to adoption and possible solutions to overcome those barriers.

While DR programs have typically been economically justified by avoiding the high cost of building additional peaking generating capacity, they are equally relevant for integrating intermittent renewable generation. DR technologies that meet established performance criteria can provide power system balancing needs raised by the presence of renewable generation. By adjusting the timing of demand to enable renewable energy to be delivered and consumed during optimal hours, DR programs can address the intermittency of renewable energy generation.

5.1 WHAT IS DEMAND RESPONSE, WHAT ARE THE TYPES OF DEMAND RESPONSE

Demand Response has been effectively used in the electric power industry for decades to induce lower electricity use during critical time periods such as times of system peaks, high wholesale market prices, limited power supply, or when system reliability is otherwise jeopardized. By their nature these critical periods are intermittent and random. In addition, DR programs are most effective in regions with large cooling loads or large amounts of electric heating (space and water). However, advances in communications and controls technologies are expanding the ability of all types of consumers to respond both to system operator directives and to price signals, making DR applicable in almost any region.

DR is not a single technology. Rather, DR is any technology that controls the rate of electricity consumption rather than the rate of generation and thus, there are numerous existing DR technologies. The Federal Energy Regulatory Commission (FERC) defines demand response as "a reduction in the consumption of electric energy by customers from their expected consumption in response to an increase in the price of electric energy or to incentive payments designed to induce lower consumption of electric energy."[51] While DR traditionally referred to programs which reduced system peaks, FERC considers DR to include "consumer actions that can change any part of the load profile of a utility or region, not just the period of peak usage." FERC goes on to recognize DR as including devices that can manage demand as needed (by, for example, responding

[51] FERC, "Wholesale Competition in Regions with Organized Electric Markets," Order No. 719, FERC Stats. & Regs.

automatically to near real-time signals) to provide grid services such as regulation and reserves, and changing consumption for the "smart integration" of variable generation resources.

All demand response technologies and programs fall into two broad families – dispatchable and non-dispatchable load. Dispatchable load provides utility system operators with direct control of devices or with specific actions which a customer has agreed to take upon request. Because it can be consistently relied upon, dispatchable load is also known as "load as a resource." Non-dispatchable load, on the other hand, encourages demand reductions or demand shifts indirectly by adjusting the price of electricity. Non-dispatchable load, also known as 'price responsive demand,' includes dynamic pricing programs such as Time-of-Use (TOU), Critical Peak Pricing (CPP), and Real-Time Pricing (these programs are defined in detail below). While non-dispatchable programs can be very effective if designed properly, the impact is generally more variable since customers choose whether or not to participate at any given time based solely on their level of price comfort.

The following are types of DR programs and mechanisms:

- Direct Load Control (DLC), including control of individual appliances such as water heaters, air conditioners, and smart appliances (Dispatchable Load).
- Load aggregation and management by third party suppliers (Dispatchable Load).
- Loading Shifting & Scheduled Load Management (Dispatchable Load).
- Rate Design Programs (RDP) – Price-based, including real-time incentives for utility control of load (Non-Dispatchable Load).
- Loading Shaping (Dispatchable Load).

5.1.1 Direct Load Control

Direct Load Control (DLC), or load shedding, is the most basic form of dispatchable load and has been in use for several decades to shut off devices during peak events. The most common solutions utilize load control devices which are designed to control up to a 30 Amp load per device using a relay switch. The devices are wired directly into the power supply for the targeted appliances and are reached using a variety of communication mechanisms, including power-line based systems, dedicated radio networks, and cellular systems. Available from a wide variety of vendors, DLC switches have proven to be a versatile and reliable method for demand response since they can connect to common home loads and can be used to respond to DR signals from a utility, to local home energy management system settings, or to utility pricing signals. The combination of enabling technology with pricing signals has been shown to produce the greatest impact on customer loads.

The most commonly controlled loads are electric water heaters and pool pumps since these appliances can be controlled with little to no end consumer impact/awareness. In addition to responding to basic on/off signals, most DLC devices today have been designed to provide appliance cycling over a requested period of time, mimicking the natural on/off cycle but with shorter "on" durations. This makes DLC also effective for air conditioning control since compressors can be cycled on and off, minimizing the increase in room temperature to which the consumer would be sensitive, while still providing a decrease in overall load.

One of the most successful DLC programs in the world has been the "On Call® Savings Program" run by Florida Power & Light (FPL). Serving a population on a peninsula, much of which is concentrated in the southern end, FPL's sensitivity to grid reliability is similar in nature to Hawaii's in that there are limited ways for power to be transmitted into some portions of the territory. The On Call® program attracts both residential and commercial customers and guarantees savings by providing participants with monthly credits, regardless of whether control events are called, which typically only occur 3-4 times per year. With more than 780,000 customers enrolled, the program reliably controls ~1,000 MW of power on a regular basis and can provide as much as 2,000 MW of dispatchable load in emergency situations. While providing a large reliability and emergency resource to the utility, the energy saved by the program is estimated to have deferred construction of three medium sized power plants since the program's inception.[52]

The advent of the Home Area Network (HAN) has enabled a new generation of DLC, which creates small local networks to communicateamong in-home devices. Spurred largely by Advanced Metering Infrastructure (AMI) deployments, HAN's typically utilize a low-power radio frequency (RF) link to connect a gateway (which could potentially be the smart meters) to in-home appliances. A fully deployed Home Area Network (HAN) can include multiple end-points, including DLC devices connected directly to large appliances, thermostats to manage heating and cooling systems, and in-home displays (IHD) to provide near real-time energy usage information.

The DLC devices used in HAN solutions provide the same general functionality described above to control large home loads. The newer types of devices enabled by HAN solutions include programmable communicating thermostats (PCT), smart plugs, and smart appliances. PCT's, also known as smart thermostats, are compatible with a wide variety of residential heating and cooling systems. Using built-in wireless chips, they can receive temperature set point and schedule changes initiated by the utility or by the user either from inside the home directly or remotely via web portals or smart phones. PCT programs have been a common focus of DR pilots the past several years since they utilize a device which is already common in many U.S. homes and since temporarily adjusting the set point of a thermostat during a DR event reduces the load but still allows the air conditioning system to cycle on/off, minimizing consumer awareness of the event. However, PCT programs have limited applicability for Hawaii's utilities since most homes in Hawaii do not have central air conditioning. Window air conditioning units are more common. Smart plugs are similar in functionality to DLC switches but plug directly into standard wall outlets, allowing them to turn almost any plug-in load into a controllable one, including window air conditioning

[52] http://www.fpl.com/residential/energy_saving/programs/oncall.shtml, Florida Power & Light Company, ©1996-2013

units. Smart appliances, on the other hand, integrate the necessary communications hardware into traditional home appliances such as washers, dryers, and water heaters. Major appliance vendors such as GE have solutions, but options are limited and prices are high compared to standard appliances in a market which is extremely cost competitive. Further limiting penetration is that there is no real incentive for consumers to purchase such appliances save individuals' own desires to do their part for the environment and grid reliability. Smart plugs may offer the best path to penetration since they are low cost and provide customers with easy entry, but, even in this case, there remains little tangible benefit for today's consumer.

5.1.2 Third-Party Aggregation

Third party aggregators bundle load for collective power purchasing and bundle DR for selling purposes back to utilities or grid operators. Electric load aggregation is the process by which large energy consumers band together to secure more competitive prices than they might otherwise receive working individually. Similarly, with DR aggregation a third party company pools together the dispatchable load from multiple commercial and industrial customers to provide what is essentially a standby virtual power plant. Through contracts with grid operators, third party aggregators guarantee specific amounts of dispatchable load by using software systems to remotely and automatically enact agreed upon energy reduction plans within specified response times, often through direct load control mechanisms.

While most utilities have both residential and commercial facing DR programs, third-party DR aggregation programs apply almost exclusively to commercial and industrial energy consumers since they represent much greater consumption. Whereas a residential demand response program may require hundreds or thousands of participants to provide any meaningful quantity of dispatchable load, industrial customers offer huge opportunities for DR because they are able to contribute extremely large amounts of load reduction. For example, a single brewery in Boston, MA provides independent system operator ISO-New England with 350 kW ofcurtailable load and a group of five shopping centers in Arizona provides Salt River Project (SRP) with ~1.5 MW in total on-demand reduction.[53] It would take approximately 75 and 330 residential consumers, respectively, on water heater load control to equal these levels of dispatchable load.[54] Third-party DR providers offer commercial and industrial (C&I) customers a win-win proposition by designing energy curtailment plans which reduce non-essential energy use during critical periods of electric supply-demand imbalance while minimizing the impact on day-to-day operations. In return, these customers get paid for the energy saved or shifted in time. And, just like residential DR program participants, they also often get paid year-round just for being on call. On the other end, utilities and grid operators are provided with virtual power plants from which they can draw when necessary and do so without the burden of managing an in-house DR program since third-party providers often support the entire delivery process: from marketing and customer recruitment to

[53] EnerNoc, Inc.: www.enernoc.com/our-resources/case-studies
[54] Calculations are rounded down and assume a standard 4500W heating element

measurement and verification.[55] A key factor, however, is that a critical mass of large industrial scale loads is required in order to make third-party aggregation commercially viable. Therefore, Hawaii may not be a suitable choice for aggregators or have sufficient industrial load to support multiple aggregators. However, there may be opportunities for solutions targeted at commercial loads, such as office buildings and retail stores, rather than industrial loads found in other regions.

Looking beyond commercial and industrial loads, there are discussions in the Smart Grid industry about offering similar third-party programs to residential consumers. The concept has been put forward that DR aggregation could be offered to the masses by large retailers (e.g. electronics stores and home improvement chains) who would act as middlemen between consumers and utilities and grid operators selling the cumulative load savings back to the grid.[56] Like C&I aggregators, retailers would make direct payments to participants, making the benefits more visible than are electric utility bill credits. While this business model is far from becoming a reality, it suggests a potential path for how significant residential contributions can be achieved while providing a tangible consumer benefit for products such as smart appliances. Given Hawaii's relatively low number of large industrial and commercial loads, this model may have broader application in Hawaii than the traditional third party aggregation model.

5.1.3 Load Shifting and Scheduled Load Management

The goal of most DR programs is only to reduce system peaks during critical situations. Events are thus initiated sparingly, perhaps only several times per year, to address these emergency situations, and overall energy consumption is not necessarily reduced. For example, temporarily turning off a water heater with direct load control will defer energy consumption but most of the saved energy will inevitably be needed to return the water to the desired temperature. This type of DR is known as load shifting and is very effective at moving demand away from system peaks.

Scheduled load management takes this concept of moving demand from one part of the day to another and applies a regular schedule to it, providing permanent changes in demand profiles. Examples of shifting methods include thermal energy storage (TES) solutions such as residential electric heat storage and commercial ice storage. Residential electric heat storage switches around the typical winter heating cycle - instead of consuming power during the cold late night and early morning hours, heat storage systems heat up thermal bricks during the day and then release that heat overnight to maintain a desirable building temperature. Conversely, commercial ice storage moves cooling loads from the day to the night. Using roof top refrigeration units, ice is built up over night and is then used to cool buildings during the day. As the name implies, ice storage solutions are currently limited to commercial and industrial settings such as office facilities, retail complexes

[55] EnerNoc, Inc: www.enernoc.com/for-utilities/program-implementation
[56] www.smartgridnews.com/artman/publish/Technologies_Demand_Response/The-demand-response-Catch-22-and-how-to-fix-it-5574

or hotels; TES, on the other hand, is a viable residential option, although it has limited applicability in the warm climate of the Hawaiian Islands.

Scheduled load management solutions should be considered as one method for adapting demand to the inherent but often predicable intermittency of renewable energy resources. These forms of DR fit well into the renewable energy equation since they can be used to schedule large, predictable loads when renewable resources are plentiful. TES, for example, can be used very effectively in the winter months in combination with solar PV since the sun rises and falls on a very reliable schedule. Likewise, commercial ice storage complements off peak wind generation very well. By shifting air conditioning load from on-peak to off-peak periods, ice storage could be designed to consume off-peak wind generation during periods when it is often curtailed today.

5.1.4 Rate Design Programs

Another time-tested method for shifting demand is the use of dynamic rate programs which are designed to encourage customers to shift consumption away from peaks and other periods when the grid is stressed. While they fall into the category of non-dispatchable demand response since the utility has no direct control over loads, well-structured rate design programs can very successfully change customer usage patterns, thereby lowering distribution and supply costs and increasing grid reliability. The overarching principal is to raise the price of electricity when demand is higher than desired and to make the price more attractive when supply is greater than demand. In essence, dynamic pricing mechanisms can better reflect the cost of supplying electricity than the normal flat rate pricing model, since the supply chain costs are themselves dynamic.

There have been a lot of creative rate models developed and there is much debate over which ones are most effective, but there are four main types which have been implemented at scale or at a minimum, widely piloted: time-of-use (TOU), real-time pricing (RTP), critical peak pricing (CPP), and critical peak time rebate (CPR). All four of these design types have been repeatedly shown to be effective at changing customer usage patterns. The following descriptions are far from exhaustive, but rather, are intended to provide basic design information for each of these four key types.

TOU plans assign different rates to different parts of the day, utilizing two or more rates. The most basic TOU plans simply split each day into on-peak and off-peak rate periods. More complex TOU plans have intermediate tiers, known as shoulder, mid-peak, or partial peak rates (or other similarly descriptive names), with the day split into three or four periods and some programs breaking up the day even further. Mid-day TOU rates are typically the highest, especially in the summer when the goal is to reduce cooling loads. Also, since weekday work and school patterns often cause peaks in the morning and late afternoon hours, TOU plans tend to focus on weekdays, assigning lower rates to weekends and holidays. Finally, some TOU programs utilize year-round schedules while others may have seasonal calendars (e.g. summer vs. winter). Regardless of design details, the goal of TOU programs is to get consumers to defer household activities such as laundry and dishwashing to off-peak periods with the tangible benefit of a lower electricity bill. TOU plans are popular because they are easy to understand and have a regular schedule on which consumers can rely, thus allowing the use of simple timer controls to shift load. TOU programs do not directly add flexibility to address the intermittent aspects of renewable generation but in as much as they can shift demand to periods where there may be high amounts of wind generation, they could provide realizable benefits.

RTP programs adjust the price of electricity on an on-going basis. Prices may change daily, hourly, every fifteen minutes, or even minute by minute in extreme cases. More than other pricing designs, these programs are intended to reflect the real fluctuations in electricity costs and the changes in the supply-demand balance. While RTP programs are simple to understand conceptually, they can be the most challenging for consumers to manage since they must continuously remain informed of electricity rates in order to appropriately adjust their usage. Consequently, RTP programs are more susceptible to customer burnout and are more complex to implement since they require a mechanism to keep customers informed of rates on a timely basis. RTP also generally requires a mature competitive marketplace to produce a market price. In Hawaii, this does not currently exist and may not be practical given the construction and dynamics of the energy marketplace.

CPP rate programs are the pricing equivalent of DLC since events occur infrequently and these programs are designed to reduce load only during critical system peaks (for example on exceptionally hot summer days). These programs offer an off-peak rate which is lower than the standard flat rate in exchange for extremely high peak rates during critical hours. For example, an off-peak rate may be less than $0.10/kWh while the critical peak rate may be more than five times higher at $.50/kWh. However, like many DLC programs, the number of events is usually capped at several times per year in order to not put unreasonable burden on participants. Finally, customers are typically informed of peak days one day in advance so communication mechanisms such as email or text notifications must be put in place.

CPR rate plans are among the newest rate designs and have the same narrow focus on critical peak periods as CPP plans. However, rather than penalizing customers for high usage during system peaks, CPR encourages energy savings by rewarding customers for the amount of energy consumption they reduce during critical periods. As with CPP events, customers are typically informed of peak days one day in advance, requiring communication mechanisms to be in place, and the number of events is usually capped at several times per year. The key difference for customers is that CPR programs have no downside since not taking action during peak events simply results in customers receiving their standard flat rate with no additional savings. These programs are, however, susceptible to free rider issues in that customers could get rebates for taking actions that they would have taken anyway.

Some utility programs have utilized a combination of these primary types. For instance, TOU plans can be combined with either CPP or CPR events to encourage additional savings during peak system periods. There have been at least one hundred well documented dynamic pricing pilots with each one demonstrating that dynamic pricing can be very effective at shifting demand. While individual program results can vary widely, the following figures provide a good comparison of the four key pricing program types and illustrate the magnitude of peak savings which can be achieved through dynamic pricing programs:[57]

- TOU – 5% peak reduction
- RTP – 12% peak reduction
- CPR – 12% peak reduction
- CPP – 16% peak reduction

These figures are based on an exhaustive study by VaasaETT, an energy think tank organization, which examined the results of dozens of pilots conducted around the world. The study compared load reduction percentages during peak rate hours to those in standard rate periods, and in total included 158,000 participants across 340 sample groups, with over half of the sample groups coming from U.S.-based pilots.

While the figures clearly show peak load reduction in all cases, it is important to note that although TOU programs show the lowest reductions, they, along with RTP programs, have the advantage of providing daily reductions as opposed to CPP and CPR, which only produce reductions during critical period events. The relative impact on total consumption and consumer bills could be quite different between the two groups and the peak reduction figures for TOU and RTP are not indicative of total energy saved. Furthermore, the results seen in the pilots have been largely independent of time of year, challenging the belief that impacts will be greatest in the winter in cold climates and greatest in the summer in warm climates.[58] In the U.S., the deregulated retail energy provider (REP) setting in Texas should be considered a future source of consumer behavior data since consumers there can pick from more than 250 real programs, not pilots: While studies are still on-going, the programs, governed by ERCOT (the Energy Reliability Council of Texas), should provide a wealth of information on what type of programs are most attractive to customers.

A recurring theme is that variable pricing is only effective if mechanisms are provided which give consumers time to react - text messages, emails, in-home displays or other communication methods are needed to make consumers aware of rates (communications mechanisms are described in further detail in section 5.5). This is a major advantage for TOU programs since the repeating schedules do not need to be continuously communicated. In addition, studies have shown significant differences when pricing programs are combined with automation, such as appliances which are price/signal responsive. For example, a 2010-2011 pilot conducted by Oklahoma Gas &

[57] Jessica Stromback, Christophe Dramacque, Mazin Yassin; "The potential of smart meter enabled programs to increase energy and systems efficiency: a mass pilot comparison," VassaETT, 2011
[58] Ibid.

Electric (OG&E) showed that the peak reduction percentage roughly doubled when TOU pricing was combined with smart thermostats.[59]

Along with other load shifting demand response solutions, variable rate design programs should be investigated for adjusting demand patterns to better accommodate the integration of renewable energy resources.

5.1.5 Load Shaping

Load Shaping is the newest technique with the fewest commercially viable technology options. However, it is worthy of discussion because of its potentially large benefits for renewable energy integration. Load shaping is the fine tuning of system load curves by utilities. Using advanced sensors and software controls, supply and demand are dynamically balanced in real-time by making adjustments to energy usage as conditions change (e.g. weather changes). Demand is thus kept in check by quickly responding to fluctuations in supply, such as those caused by variable energy resources. This next generation of DR, "Demand Response 2.0," is the Smart Grid counterpart of static load following - the practice of bringing on additional generation to meet moment-to-moment demand in the system, and/or keeping generating facilities informed of load requirements to ensure that generators are producing neither too little nor too much energy to supply the utility's customers.[60] However, load shaping occurs on a much more dynamic level. Using load following generation, supply is constantly chasing demand. With load shaping, utilities can continuously adjust demand to accommodate supply based on multiple variables, making it ideal for dampening the supply peaks and valleys of such renewables as wind and solar. So, although load shaping does not reduce overall consumption, it is very relevant for Hawaii where improving the conditions for intermittent renewables integration is important.

Load shedding and load shifting are proven demand management techniques with many available technology and vendor options. Meanwhile, real-time load shaping is a relatively new concept and its complexities require smart meters and advanced software and analytics to tie together weather conditions, energy supplies, grid conditions, power quality, and dispatchable loads to make real-time DR decisions. Because of this need for real-time data processing and an interconnected network of intelligent electronic devices (IED's), load shaping is in actuality an operational feature of an advanced Distribution Management System (DMS), covered in section 6. However, since it targets demand adjustments, load shaping is also covered here for completeness. While the technical requirements and complexities raise the barrier to entry, load shaping could play a valuable role in maintaining system reliability and should become increasingly relevant as

[59] OG&E, Mike Farrell, "2010 Demand Response Study Interim Results & Lessons Learned," DistribuTech 2011
[60] EnergyVortex.com, Energy Dictionary

renewables reach higher levels of penetration, thereby making up a larger percentage of total power.[61]

5.2 DEMAND RESPONSE FOR FLEXIBILITY

Balancing the influx of new uncontrollable energy requires dispatchable resources on the system to ensure reliability. The electrical grid will need the ability to rapidly respond to a wide range of load and renewable energy production conditions. Flexible capacity can be provided from traditional generating resources or from demand responsive loads. To date, however, demand response development and the growth of variable generation capacity have largely proceeded in parallel but without much consideration of better connecting the two. The North American Electrical Reliability Corporation (NERC) and others have identified DR as an additional source of electric system flexibility that could aid in integrating variable generation. Effective DR programs can provide essential flexibility over relatively short timeframes when an unpredictable change in renewable generation output occurs. DR has been shown in some balancing areas to be a flexible tool for operators to use with wind generation. For example, in 2008, ERCOT, which operates the electric grid in Texas, used DR to restore system frequency and thereby demonstrated the effectiveness of using DR to enhance system flexibility.

At high penetrations of solar and wind energy, Hawaii's grids will need to carry higher levels of operating reserves to account for the variability of these renewable resources. This provides a good opportunity for Hawaii's electric utilities to look at DR technologies as reserves to cover a portion of the operating reserves requirement. DR solutions may be more cost effective, as well as more environmentally friendly, than traditional reserve resources. While DR programs have been used to provide planning reserve margins, operators are beginning to realize the potential for dispatchable load DR programs to be used as operating reserves.

Integrated with a DMS, which should be responsible for managing all generation and reserve types, DR becomes a valuable component of the total supply and demand equation. Response (i.e. ramp rates) can be quicker than some generation sources for the more responsive loads. The response can be automated as well, and different loads can be set to trip at different frequencies, thus providing a frequency droop curve that simulates generator governor response. Also, DR acts as a contingency reserve by always being ready, but with events happening infrequently and actual deployment being relatively short in duration, compared to building a new generating resource. In addition, system operators are now using DR more frequently to provide ancillary services, such as contingency reserves and supplemental reserves. While it should be noted that the use of DR for ancillary services is a recent development and represents only a small amount of demand response, it is indicative of the potential of DR to address electric grid reliability issues.

[61] Smart Grid News, "Smart Grid Demand Response: Why today's leaders are at risk as DR 2.0 emerges," April 27, 2010

Overall usage of DR as a resource increased from 30 GW to 43 GW between 2010 and 2011 for all NERC regions combined. However, some regions consider DR for supplying reserves and some do not. ERCOT, for example, currently obtains half of its responsive (spinning) reserves (1,150 MW of the 2,300 MW total) through a Demand Response product called Loads-Acting-As-Resources (LAARs). The program's customers have under-frequency relays set to 59.7 Hz so that their participating loads automatically trip off-line during under-frequency events. During emergency conditions, these loads will also disconnect upon receiving instructions from ERCOT. ERCOT also has an Emergency Interruptible Load Service (EILS), a separate program of loads that will separate from the system during emergency conditions upon receiving instructions from ERCOT. Hawaii's utilities should consider DR that supplies reserves similar to ERCOT. However, due to the ongoing variability of renewable resources, it is important to target loads which can be frequently interrupted with little to no customer impact to minimize participant burnout.

5.3 HAWAII'S EXISTING DEMAND RESPONSE PROGRAMS

This section summarizes residential and commercial DR programs currently in place in Hawaii and the most recent program developments.

The Hawaii Energy Conservation and Efficiency Program (Hawaii Energy) is a program operated by SAIC, an independent third party contractor for the Hawaii Public Utilities Commission. The program includes four programs for the C&I sector and three for residential customers.[62] While this program is well organized and very well tracked (see section 4 for specific results), its focus is exclusively on energy efficiency and does not include any documented DR features.

There are, however, meaningful DR pilot programs in progress on the islands by the Hawaiian Electric Company, which provides approximately 95 percent of electric power in the state through its three grid operators, HECO (OAHU), MECO (Maui) and HELCO (Big Island of Hawaii). Through HECO, MECO, & HELCO, the program strategy is to identify residential, commercial and industrial customers who are able to reduce electricity use to help maintain grid reliability and increase the presence of renewable energy. The DR plan is being implemented in phases through a combination of pilot programs; research, development, and demonstration projects; and market studies.[63]

For residential customers, the program, marketed as "EnergyScout," offers traditional DLC (direct load control) for water heaters and air conditioning (AC). This program is an effective starting point given that a significant portion of residential loads can come from water heaters. Currently in the pilot stage, the program is fully subscribed but is looking to expand in 2013. Approximately 34,000 customers have been outfitted with water heater controls, providing operators with approximately 15 MW of controllable peak demand. In addition, controls on the AC units of

[62] http://www.hawaiienergy.com/media/assets/PY11VerificationMemoforHawaiiEnergy.pdf
[63] http://dr.heco.com/

approximately 4000 participants represent another approximately 2.5 MW, for a total of approximately 17.5 MW of controllable load.

HECO's pilot DR program offerings for commercial and industrial customers are more varied, which is typical given the greater cost/benefit which comes from C&I DR (see section 5.1.2 regarding the relative impacts of C&I DR). HECO currently offers three C&I programs - "AutoDR," "Semi AutoDR," and "Energy Scout for Business," - and is awaiting approval of a fourth program, C&I Dynamic Pricing (CIDP) Pilot Program.

Customers enrolled in AutoDR, also known as Automatic Fast DR, and Semi AutoDR, or Manual Fast DR, are engaged to proactively reduce their electrical consumption and are rewarded with financial incentives in return. For customers who qualify, Hawaiian Electric Company places automatic (AutoDR) or semi-automatic (Semi AutoDR) controllers on non-essential equipment. The key element is that the loads must respond in 10 minutes or less. These programs are extremely new and thus there are no published results, but several major customers have enrolled. Launched in February 2012, the first AutoDR customer, an office complex in Honolulu, started in the fall of 2012. When combined with a customer side EMS (energy management system), power consumption can be automatically and temporarily reduced using Automatic Fast DR. For example, the EMS could temporarily adjust building AC temperatures when triggered by a utility signal. While Fast DR requires some automation; customers always maintain complete control and can opt out of having their demand impacted at any time. Semi-AutoDR is very similar to the AutoDR program but relies on manual controls. Under the programs, in addition to incentives paid during DR events, businesses automatically receive a bill credit of $3,000/year for every 50 KW of power they are willing and able to turn off within 10 minutes of being signaled.

The EnergyScout for Business program is the commercial version of the EnergyScout residential DLC pilot. With approximately 43 customers enrolled, the program is providing approximately 18.2 MW of controllable load, eclipsing the 17.5 MW provided by the approximately 38,000 involved on the residential side. Like its residential counterpart, EnergyScout for Business is fully subscribed and newly interested customers are being moved to the new AutoDR programs.

The application for the C&I Dynamic Pricing (CIDP) Pilot Program was submitted to the Hawaii Public Utilities Commission on December 29, 2011. If approved, the CIDP Pilot Program could start as early as 2013. The proposed rate design program is intended to evaluate dynamic pricing options offered to participating commercial and industrial customers for a two-year period. As described in 5.1.4 above, dynamic pricing allows customers to respond to the changing cost of electricity by adjusting their demand, especially during periods of limited supply. The proposed program would reduce the demand charge for program participants in return for their lowered energy use at certain times (and sometimes on short notice).

As the Hawaiian electric companies move toward a grid composed of higher levels of intermittent renewable generation, these programs can provide an additional resource to reduce electricity demand until additional generating units are brought online.

5.4 OPPORTUNITIES TO ENHANCE HAWAII'S DEMAND RESPONSE PROGRAMS

The DR programs described in section 5.3 are very promising and indicate that with expanded participation the overall grid reliability impacts could be substantial. It is also clear that the curtailment benefits resulting from the commercial and industrial programs have a far greater incremental impact per customer than those of residential programs. Hawaii's existing DR programs should be evaluated for cost effectiveness to determine how best to prioritize future investments and resources. In parallel, load research data collection and market assessments are needed to allow utilities to better estimate the demand response potential in Hawaii and understand the overall role which DR can play. A good example of such research is the "DSM Market Potential Assessment" commissioned by Kauai Island Utility Cooperative (KIUC). Being fairly new, none of the assessment's recommendations have been implemented, but this study provides a good picture of the magnitude of peak-demand savings which DR, combined with other demand side initiatives, could provide as well as estimated costs.[64]

For DR to play a larger role, however, barriers in the regulatory environment must be reduced and business conditions must be favorable for all parties involved. Two specific areas which should be addressed are the pace of the regulatory process and the role of third party aggregators.

Speeding up the regulatory process will provide a quicker first hand understanding of DR benefits and challenges. Utilities need to be able to further develop and test a range of value propositions to assess customer interest in direct load control and in pricing event strategies to support renewable generation. For example, the C&I Dynamic Pricing (CIDP) Pilot Program which was submitted to the Hawaii Public Utilities Commission (HPUC) on December 29, 2011 remains in the approval cycle. Expedited regulatory review and approval is needed to get such programs in place as soon as possible. In addition, improving the regulatory process could allow expansion of successful programs such as those already being piloted.

As described in section 5.1.2 and as is clear even with the limited sample size of the existing HECO DR pilots, C&I-focused DR programs can be extremely effective at providing grid scale benefits. Regulators and utilities, therefore, should look for opportunities to expand these programs and to introduce similar ones. In parallel, regulators also need to consider the appropriate role of third

64 http://kauai.coopwebbuilder.com/sites/kauai.coopwebbuilder.com/files/kauai_dsmpotential_20120620.pdf

party aggregators in delivering demand response programs to allow DR to compete on equal footing with supply-side options. While Hawaii may lack the volume of large industrial scale loads needed to support a traditional third-party aggregator market, policies and alternative technology solutions better suited for commercial loads, which are more common in Hawaii, should be pursued.

The Demand Side Options Subgroup of the HPUC's Reliability Standards Working Group (RSWG) has made similar recommendations, including ensuring that DR programs are considered in the integrated resource planning process.[65] DR technology is widely available with proven, positive impacts, but regulators must act on recommendations in order to see progress.

5.4.1 Measurement and Verification of Demand Response

Since DR is still relatively new as a resource, stakeholders need to measure its performance in order to gauge its benefits and impacts on reliability. Evaluating the performance of DR resources begins with and depends on the measurement and verification (M&V) methodologies for determining demand reduction quantities. For example, the methodology used to calculate and estimate the baseline can impact measuring performance. There are various baseline methodologies and some are more appropriate than others depending on the type of DR resource, the frequency and duration of events, and the timing of notification, as well as other factors. These differences have often made comparisons difficult since programs may not be compared in an "apples to apples" manner.

From a practical perspective, data quality is critical regardless of the M&V methodology used. Smart Meter AMI systems in combination with Meter Data Management Systems (MDMS) offer the potential to use reliable 15-minute interval data to support M&V activities while also providing a robust and valid baseline. While 60-minute interval data is standard for residential smart metering, 15-minute data is standard for C&I metering and could be applied selectively on residential DR participants. By processing metering data after events occur, an MDMS can provide detailed DR event results. DMS, on the other hand, should be used for M&V analysis during events (e.g. tracking real-time participation) since it has a view of potential resources. DMS, MDMS, and AMI systems are discussed in more detail in section 6.

New standards for measurement and verification of results for DR programs are under development to simplify comparisons and assessments. In recent years, NERC, which has been at the forefront of developing performance evaluation criteria, has been developing a more systematic and uniform approach to collecting and quantifying DR performance. In addition to specifying a consistent and timely basis for counting and validating DR contributions, a major accomplishment

[65] Reliability Standards Working Group, Hawaii PUC Docket No. 2011-0206, "Demand Response as a Flexible Operation Resource," RSWG Demand Side Options Subgroup

thus far has been the establishment of the Demand Response Availability Data System (DADS). While it is still in the early stages, the goal of DADS is to collect DR enrollment and event information to measure its actual performance. As the database becomes more populated, DADS will be able to provide the industry with a more reliable basis for projecting DR contributions.[66]

Lawrence Berkley National Laboratory (LBNL) has been another key source of M&V methodology research. LBNL is seeking to develop lower-cost, standardized M&V methods that are acceptable to system operators and load aggregators.[67] LBNL recently evaluated existing M&V processes for both settlement and impact estimation.[68] Settlement is the process used to calculate the reductions achieved by individual program or market participants, and to determine the corresponding payments or penalties owed to or from each participant. Settlement has major financial impacts since inaccurate processes can result in over- or under-payments, affecting program costs and participation levels. Impact estimation M&V is used to determine projected program-level demand reductions. Impact estimation is immediately applicable to Hawaii since these methods are used to both valuate existing programs as well as to forecast impacts in planning processes. As part of their research, LBNL outlined the complex inter-relationships between M&V methods, DR program design & rules, program operating conditions, load characteristics, and participant types: "DR performance evaluation methods and results affect and are affected by many aspects of program planning, design, and operations."[69] For example, the M&V method used affects both M&V results and accuracy, but different participant types have different load characteristics, which in turn affect M&V accuracy. Thus, program design and M&V method are tightly intertwined. The key is that M&V cannot be an afterthought - it must be part of the initial DR program design.

To account for both load characteristics and program design, we recommend the consideration of several factors when designing and assessing DR M&V methods:[70]

- Weather sensitivity of loads,
- Seasonal sensitivity of loads,
- Customer type – design should be based on observable load characteristics and broad revenue class, rather than reported business category or customer segment,
- Variability of loads, especially for those which are highly variable,
- Effect of notification timing (e.g. day ahead notification),
- Gaming opportunities - measures should be taken to limit baseline manipulation by participants, and
- Baseline assessment methods employed

[66] http://www.nerc.com/files/DADS_Report_Final_Revised.pdf
[67] http://emp.lbl.gov/projects/measurement-and-verification-protocols-demand-response-programs
[68] Goldberg, M, and Agnew, K., "Measurement and Verification for Demand Response," LBNL, 2013
[69] Goldberg, M, and Agnew, K., "Measurement and Verification for Demand Response," LBNL, 2013
[70] Ibid.

Overall, this is a very simplified explanation of the work by LBNL and others. The key point is that existing and future DR programs should carefully review M&V methodologies to use the most appropriate ones with respect to the specific conditions in Hawaii and to ensure industry best practices are being applied.

5.4.2 Evaluating the cost-effectiveness of DR Programs

Cost-effectiveness is critical to DR program approval, program funding, and getting businesses to participate. So, DR performance measurements must utilize M&V to calculate the savings from load reductions and then compare that to the cost of implementation to understand whether or not the benefits of the program outweigh its costs. As described above, the determination of cost effectiveness is very much affected by the type of M&V method used.[71]

LBNL also provides a key source of guidance for evaluating DR program cost effectiveness. In a recently published work for the National Forum on the National Action Plan on Demand Response, LBNL provided a framework which should be used to evaluate the cost effectiveness of DR programs, detailing what key costs and benefits need to be accounted for in evaluations.[72] The basis of the LBNL framework is the California Standard Practice Manual which has become the industry standard for evaluating energy efficiency programs. The Manual defines five cost effectiveness tests and how to apply them. The five tests cover societal costs & benefits, total resource costs & benefits, program administrator costs & benefits, participant costs & benefits, and the impact on utility rates. The LBNL DR framework adapts the successful EE cost effectiveness framework with key modification to account for the unique considerations of DR. The DR framework outlines eleven program cost categories and twelve program benefit categories which should be accounted for when evaluating cost effectiveness. While support for renewable energy is not listed as a specific benefit of DR, a number of the benefits do have direct relevance such as improved electrical system reliability, avoided ancillary service costs, and avoided environmental compliance costs.[73]

As stated previously, DR programs which focus on commercial & industrial customers are likely to provide the largest incremental benefits. However, rather than high-level calculations and anecdotal assumptions, the cost effectiveness of Hawaii's existing DR programs and programs under consideration should be critically evaluated using the latest cost-effectiveness methodologies to determine next steps, to screen opportunities, and to prioritize future initiatives.

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[71] Ibid.

[72] Woolf, T, Malone, E, Schwartz, L, and Shenot, J. "A Framework for Evaluating the Cost-effectiveness of Demand Response," 2013

[73] Ibid.

5.5 CUSTOMER INTERACTIONS, COMMUNICATION TECHNIQUES AND ADVANCEMENTS IN LOAD CONTROL

Getting consumers to actively participate can sometimes be the biggest challenge for Demand Response. While DLC devices currently provide a reliable method to connect utilities with individual load sources, it is also important to connect with consumers themselves to engage them in the energy process. At the same time, consumers do not want to be inundated with DR-related messages; DR must be used at a level which does not seem burdensome. For example, DR could be initiated so often that people would drop out of the programs. In addition to being balanced with other Smart Grid reliability technologies, therefore, DR programs and communication strategies must be designed to yield long-term consumer participation and engagement.

Various methods have been used over the years to provide DR event notifications to program participants and to provide updated rate information for rate-based DR programs. Tools for communicating DR-related information have evolved from voice messaging, to emailing and text messaging, and most recently to utility-specific devices such as In-Home Displays (IHD). IHD's provide customers with information on their energy usage and pricing and may also provide messaging capability for utilities to send alerts and notices. There are a significant number of IHD options on the market with varying levels of functionality, from simple text displays to full color touch screens with real-time graphs. While they are potentially an effective means of communication, however, they are also relatively costly and utilities are thus trending away from dedicated devices in favor of web portals and mobile applications.

In addition to being more cost efficient, web and mobile applications better suit today's consumer. The traditional relationship between utilities and consumers has been very static, with contact often limited to connecting and disconnecting service and bill paying. However, the modern consumer has changed significantly. Spurred by the proliferation of the internet, smart phones and applications such as Facebook and Twitter, today's consumers live in a world of real-time information and instant gratification and are beginning to expect this type of interaction from everyone with whom they do business. Survey findings point to a growing segment of consumers who are interested in technology solutions to monitor and manage their usage, with approximately one-third of consumers interested in seeing their personal usage in real-time using a mobile application.[74] As a result, the electric industry is seeing a wave of efforts to increase customer access and standardize the format of energy usage information.

This movement has fostered the rapid development of new applications to increase consumer engagement and awareness. One of the latest and most widely supported examples is the "Green Button." The Green Button Initiative is a White House backed voluntary effort by utilities to provide

[74] Accenture, "Revealing the Values of the New Energy Consumer: Accenture end-consumer observatory on electricity management," 2011

retail electricity customers with easily accessible and up-to-date data on their electricity usage. With the Green Button, consumers throughout the country will be able to securely access their own energy usage information in a user-friendly, easy-to-understand format. The goal is to provide consumers with an easy way to make more informed energy decisions. For example, consumers could use Green Button applications to optimize the size and cost-effectiveness of solar panels modules for their home or verify that energy-efficiency investments are performing as expected. Consumers can even use innovative applications to compete against Facebook friends to save energy and lower their carbon emissions.[75] Since its launch in January 2012, 34 utilities have implemented or committed to participate, and at least 48 technology companies have already released or committed to providing Green Button solutions including Web and smartphone applications and services.[76] Green Button aside, there are a multitude of utility-specific web portals and smart phone applications on the market with a wide variety of capabilities and functionality. While some applications provide the same basic usage and pricing information as IHD's, others allow customers to respond to utility messages and events, opt-out of a demand response event, or view their savings from participating in an event. Some applications even support device configuration and control (e.g. smart thermostat programming). Another great product to come out of the movement away from solution specific hardware devices such as IHD's is the USB plug-in dongle. Similar in size to a USB memory stick, these inexpensive devices plug into a home computer and communicate directly with smart meters equipped with ZigBee® Smart Energy wireless capability. Using built-in software, the simple USB devices allow homeowners to see their energy consumption information in real time, on their own home computer.

Beyond consumer engagement techniques, an area of development for DR technology is the method used to communicate to in-home devices. Current Smart Grid implementations most commonly utilize smart meters via AMI networks to connect to the devices in the home. However, strong opportunities exist to connect utilities to the HAN without depending on an AMI system or Smart Meters. According to Internet World Stats, 82.6 percent of Hawaii's population was connected to the Internet as of June 2010, compared to a national average of 78.1% (as of June 2012).[77,78] Consequently, there is a lot of interest in moving from Smart Meter-based ZigBee HAN solutions to internet-based WiFi solutions, driven by the fact that WiFi is common in homes and ZigBee is arguably a niche home automation solution. Rather than using the meter as an entry point, IP gateway solutions typically consist of a device connected to the consumer's broadband Internet or with an imbedded cellular modem. In these cases, the HAN gateway can still connect to the Smart Meter via ZigBee (or other commonly supported communication method), but the meter does not serve as the gateway into the home or as the HAN controller. In this configuration, the Smart Meter

[75] http://www.greenbuttondata.org/greenabout.html
[76] http://www.greenbuttondata.org/greenadopt.html
[77] Internet World Stats, www.internetworldstats.com
[78] At the time of writing, the most recent state-level statistics were from June 2010; national-level numbers were updated June 2012.

simply provides energy usage information to the HAN. All other data, including that for control of DR devices, travels directly to the HAN via the internet connection. This type of solution could apply to any of the DR methods outlined in section 5.1. In fact, while there has been a general decrease in the popularity of application specific hardware such as IHD's, interest in Programmable Controllable Thermostats (PCT)'s (and other DLC devices) remains popular since customers already need thermostats and appliances in their homes.

Finally, a tremendous amount of growth is being seen in the area of electric battery storage. Since it supports grid reliability in general, with DR being just one of the instances where it may be called upon, energy storage will be discussed in further detail in section 6.3.5 but is mentioned here for completeness. Energy storage does not directly reduce load but is viewed nonetheless as a key component in the renewables equation since it shifts demand patterns to better align with the generation patterns of variable resources such as PV solar and wind. Energy storage can also buffer against rapid changes in load or supply. Although energy storage is still relatively expensive compared to traditional DR methods and currently exists at low penetration levels, the combination of a significant number of energy storage providers and rapidly evolving battery technologies will lead to inevitable decreases in solution costs. Storage solutions should therefore be monitored closely when developing a comprehensive strategy for increasing renewable energy penetration.

5.6 SECTION SUMMARY

Demand Response penetration is increasing significantly due to technology innovations and policy directives. These advances have made it both technically feasible and economically reasonable for consumers to respond to signals from a utility system operator, load-serving entity, RTO/ISO, or other DR provider to make the grid more reliable. There is a key difference between DR for traditional peak shaving and DR for supporting renewable penetration. For peak shaving, based on day-ahead or hours-ahead forecasts, the decision to call DR events is made either via pricing signals or other utility signals; but for DR to respond to renewable generation variability, it needs to be faster acting and is therefore more akin to DR for reliability. This distinction increases the importance of integrating DR systems with technologies such as AMI, advanced DMS, and Distribution Automation (DA). Linked by an interconnected network of intelligent devices and utilizing real-time data processing, utilities can take advantage of the synergies between these various technologies to optimize the role of DR.

As outlined in this section, DR technologies come in many different flavors and DR can and should play an important role in the integration of the renewable energy resources. For example, such programs as time-of-use rates, which shift load to off-peak periods when wind production is usually at its highest, could be used to avoid curtailment of variable generation or minimize cycling of large base load power plants. DR is not one size fits all, however, and any demand response program should include a portfolio of options designed for customer "comfort zones" to maximize adoption rates. DR, furthermore, needs to be balanced and integrated with other Smart Grid technologies to provide holistic and sustainable grid reliability solutions, and regulatory policies must accommodate the variety of viable options.

6.0 The Smart Grid Monitoring, Communications and Control Technologies

This section identifies and assess existing and emerging monitoring and control technologies that can assist in the integration of renewable energy into the grid.

Intermittent Distributed Generation (DG) can cause voltage and frequency irregularities, imbalances in reactive power, transient voltage variations, and harmonic distortions to power quality. As we continue to move from a world of centralized power generation and resource management to one of decentralized intermittent energy resources, flexibility to address the resultant impacts on the grid will be critical. Smart Grid technology provides system operators with real-time continuous awareness of electrical generation, storage, transmission, distribution, and loads; this information is essential in order to maximize the integration of renewable resources onto the grid.

According to the Energy Information Administration's (EIA) latest figures, as of the end of 2012, there were nine states where wind is generating at least 10 percent of electricity, with Iowa and South Dakota at well over 20 percent, and two others on the verge of breaking 10 percent.[79] Wind energy has also become the leading source of new generating capacity in the U.S., accounting for over 55 percent of new capacity in 2012.[80] While this trend is positive in many respects, without proper planning and technology upgrades, the end result could be grid instability.

Take the case of California, for example, which rather than having a capacity problem is on the verge of having a flexibility problem.[81] The state has very successfully ramped up renewable generation is on pace to exceed its 2020 goal of 33 percent of sales from renewable and overall has a capacity surplus. However, the rapid increase in renewable energy resources *could* cause significant reliability issues to the grid as a whole since such a great portion of the supply mix is intermittent, fluctuating with weather patterns. To date, California has not had problems but reliability is a significant issue of debate and the CPUC, California utilities and other stakeholders are voicing concern and paying attention to the risk. To prevent problems and keep pace with the changing energy supply mix, California's utilities have had to undertake major Smart Grid infrastructure initiatives and will need to continue to do so to maintain reliability.

Germany provides another valuable case study since their high penetration of wind energy is already causing notable grid instability. The German government is targeting 35 percent of its electricity to come from renewable resources by 2020, with an even more ambitious goal of 80

[79] U.S. Energy Information Administration, Annual Electric Generator Report
[80] http://www.onlinetes.com/wind-power-generation-awea-united-states-31813.aspx
[81] Rebecca Smith, Wall Street Journal, "California Girds for Electricity Woes," 2013

percent by 2050. Certainly, no traditional grid can handle this level of variable power supply without significant reliability upgrades. Stakeholders are beginning to recognize the opportunity afforded by Smart Grid technology to automate electricity distribution by tying together electricity generation and consumers through additional sensors, instrumentation and control systems, and communication and data infrastructure.[82] Two valuable lessons learned by Germany which are relevant to Hawaii's renewable energy discussion are 1) the importance of establishing an extensive communication network parallel to existing and planned energy grids, and 2) ensuring that new distributed generation resources (e.g. wind or PV) are approved as grid compatible before they can feed energy into the grid. As discussed further in this section, advanced communication networks are necessary to exchange information between various systems and devices and trigger appropriate response mechanisms to maintain grid reliability. On the administrative side, Germany requires DG owners to provide proof of compatibility before resources can go on line and utilizes accredited third-party certification organizations to review design documentation.

6.1 HOW DOES THE SMART GRID ENABLE

The deployment of Smart Grid technologies has surged to become one of the most significant areas of utility capital investment. Related projects include transmission upgrades, substation automation, distribution automation, information technology and smart metering. Rather than being a single definable end-state, the Smart Grid represents a family of technologies and programs that increase reliability and provide flexibility functions. The Smart Grid vision is to remove barriers between transmission and distribution operations, improve communications, and enhance back office systems to create an integrated network that provides diagnosis and resolution of problems and enables real-time information exchange throughout the utility and with its customers. Smart Grid technologies provide communications and automated control of devices associated with electrical generation, storage, transmission, distribution and loads. The result is an integrated network which provides utilities with visibility and control to improve the efficiency, reliability, and quality of the electrical energy provided.

Smart Grid technology is evolving, even as utilities are implementing their initial demonstrations or projects. And it will continue to evolve as utilities reach higher levels of implementation. This is likely to be a continuous evolution with more new technologies and higher levels of integration occurring at each level of implementation with an increasing number of vendors entering the market. Another important factor to note is that there is no one-size-fits-all Smart Grid solution – the terms "smart" and "Smart Grid" have different meanings around the world depending on local electric system conditions and starting points. Many utilities around the globe view the first step in implementing a smarter grid as the installation of smart meters to enhance utility operations and to provide customers with an accurate picture of when and how power is being consumed. Future

[82] Dieter Rosenwirth and Kai Strubbe, Renewable Energy World, "Integrating Variable Renewables as Germany Expands Its Grid," 2013

steps will involve use of real-time information about incoming loads, as well as automated systems which monitor and adjust system parameters to allow for more stable introduction of intermittent sources of power. A significant milestone will be achieved when utilities have visibility of all generation sources and loads and are able to operate or cause operations that maintain a reliable system.

There are a number of technology solutions which fall under the Smart Grid umbrella as follows.

- Smart Inverters
- Substation monitoring and control
- Voltage Management
    - Voltage monitoring & analytics
    - Integrated volt/VAr optimization (VVO)
    - Conservation voltage reduction (CVR)
    - Static VAr (SVAR) technology & distributed static VAr compensation (DSVC)
- Remote monitoring and control of distribution line devices
    - Capacitor banks
    - Reclosers
- Low voltage and low frequency ride-through
- Ramp rate control
- Automatic load tap changing (LTC)
- Automated curtailment based on integrated forecasting
- Energy storage
- Distributed energy resource management systems (DERMS)
- Distribution management systems (DMS)
- Smart metering
- Smart appliances
- Energy & building management systems (EMS & BMS)
- Outage management and restoration

This list is not all-inclusive but underscores the variety of technologies which are part of the Smart Grid. A summary of the potential of each of the above Smart Grid solutions follows. To illustrate industry best practices and put these solutions into more tangible terms, we also describe several examples of renewable resource related Smart Grid initiatives currently being undertaken by leading utilities in the U.S.

<u>Smart Inverters</u>

As distributed generation and disruptive loads continue to increase in prevalence on the distribution grid, more granular and regular voltage regulation and VAr compensation will be required to maintain power quality throughout the distribution network. Most DG resources produce direct current (DC). To be integrated into the distribution network, this DC power is converted to alternating current (AC) power by inverters. Traditional inverters convert DG power from DC to AC current with a power factor near unity (meaning the device does not require reactive power support from the grid) to limit the effect of DG power on the voltage profile of the power traveling through the distribution grid. However, this equipment is installed and calibrated using model-based calculations rather than any real-time or empirical data. These devices as calibrated were sufficient for maintaining voltage and power factor within limits when they were a small component of the power generation pool, but were by no means optimized on a system basis.

Voltage conservation and volt/VAr optimization (VVO) are Smart Grid features which can be used to mitigate voltage fluctuations caused by intermittent renewables and thus maintain the desired voltage profile. A localized controller can activate and resolve a local voltage imbalance, but it would do so without an understanding of what was happening elsewhere in the system with the consequence of creating suboptimal conditions. Smart Grid technologies allow big picture intelligence to be applied to such situations. With built-in volt/VAr capabilities, smart inverters and transformers can ensure DC power from renewable resources is "clean" of harmonics and smart inverters of the future may provide many other "smart" advances as well. For example, smart inverters have the potential to allow PV generation to provide voltage support and improve response to under and over frequency events, but even newer inverter designs are anticipated to provide even greater potential to reduce the impact of PV solar on the distribution grid. Recent EPRI reports estimate the cost of smart inverters at $0.80-1.00/Watt-of alternating current capacity (Wac).[83] This is compared to typical market inverter prices around $0.20/Wac at the time of writing of this report. As there is significant active development in this area, it is likely that the cost effectiveness of static inverters will improve with time and field experience.

Voltage Management

Current generation capacitor banks, load tap changers, and voltage regulators were not designed to react on a minute-by-minute basis, as may be required to keep up with constant VER (variable energy resource) fluctuations. A new generation of power electronics-based voltage control and reactive power compensation devices will be required to adjust voltages and reactive power compensation multiple times per minute on highly variable feeders.

In addition to ensuring stable voltage conditions, protection systems are necessary to isolate DG in the event of faults. DG can impact the ability of the normal protection devices such as fuses, reclosers, and sectionalizer to function optimally by introducing normal and fault current flows in

[83] EPRI 2011. "Estimating the Costs and Benefits of the Smart Grid: A Preliminary Estimate of the Investment Requirements and the Resultant Benefits of a Fully Functioning Smart Grid" accessed online at the following URL on May 7, 2013:
http://ipu.msu.edu/programs/MIGrid2011/presentations/pdfs/Reference%20Material%20-%20Estimating%20the%20Costs%20and%20Benefits%20of%20the%20Smart%20Grid.pdf

different directions on the distribution grid. Utilities can leverage new low-cost remote monitoring devices to detect reverse power flow, abnormal operating conditions and DG status.

Distributed Energy Resource Management Systems

System planners and operators are very familiar with variability and uncertainty as they are constantly balancing traditional demand and generation fluctuations to maintain voltage and frequency. Non-traditional generation sources such as wind and PV, however introduce additional uncertainty and variability which operators must manage. The variability of wind and PV generation requires special attention since conditions can change in the short term, from minute to minute based solely on wind speed or changing cloud cover, or from day to day, based on weather conditions.

For years SCADA (supervisory control and data acquisition) has provided control & monitoring at the substation level but Smart Grid technology now extends intelligence into the field, at individual devices. Existing industry standards, however, define advanced functions at the individual device level, not at the aggregated feeder level which is necessary for enterprise-level integration. Connecting all of the remote devices together in a coordinated fashion requires a strong communications backbone and advanced software technology. Without advanced communication and control, utilities cannot efficiently integrate all the pieces to make them work together as a holistic system.

While Distribution Management Systems are discussed below in section 6.3.2 and provide many Smart Grid advantages, the current generation of DMS does not specifically support integration of distributed energy resources (DER). DER includes not only generation sources but battery storage and similar devices. In general, DER support is limited to monitoring the output of "utility scale" DG (i.e. greater than one megawatt), missing the smaller intermittent renewable generation resources which will be prevalent in residential settings. Consequently, the Electric Power Research Institute (EPRI) has been "exploring various ways in which the DMS can utilize these distributed resources more effectively."[84]

The conceptualized solution for managing all of the many diverse DER devices in a system is a Distributed Energy Resources Management System (DERMS). A DERMS is an enterprise application which would provide the central control necessary to handle all of the smart DER devices throughout a distribution system by monitoring and managing the status and capabilities of each device and feeding that information into a DMS and other applications in a more useful form. Rather than having the DMS make sense of the individual device data, the DERMS could aggregate the information of individual devices, "transforming their settings and effects so that they become

[84] Brian Seal, Robert Uluski, "Integrating Smart Distributed Energy Resources with Distribution Management Systems," Electric Power Research Institute (EPRI), September 2012

attributes at the circuit, feeder, or segment level."[85] DERMS will thus improve the ability of operators to optimize the dispatch of distributed resources, DR, energy storage, and other Smart Grid features.

For example, consider the existing standard functions of smart inverters, such as volt/VAr capability. With proper control and management, smart inverters and solid-state transformers could act as gatekeepers for DG resources by disconnecting the grid segment that is experiencing the fault from the local DG allowing it to island from the grid. This would allow the DG supported island to continue to produce power for the loads on the customer side of that distribution secondary transformer. Moreover, if the volt/VAr settings on a distribution circuit vary from one device to another, as they most certainly will in a diverse system, then managing voltage behavior becomes very complex. Without a DERMS, the complexities of such management fall directly to other applications such as DMS, which are not currently built for such tasks. In reality, DERMS functionality may or may not be dedicated software. DERMS functionality could be integrated as a module into a DMS or deployed as a standalone application to work alongside a DMS. In either case, significant commercial development is still required, but DERMS concepts should nonetheless be considered in today's resource planning discussions.

The following list compiled by EPRI represents services which a DERMS can provide related to intermittent renewable generation:[86]

- Identify installed capability
- Report resource status
- Forecast supply capacity
- Connect / disconnect DER from the Grid
- Provide volt/VAr regulation support
- Provide phase balancing
- Coordinate DER with circuit reconfigurations to ensure continued optimum operation
- Provide maximum capacitive VAr support to maintain grid voltage
- Provide support for conservation voltage reduction (CVR) Mode to allow utilities to optimize grid voltage to minimize energy requirements

<u>Outage Management & Restoration</u>

A related set of Smart Grid features which can directly facilitate higher levels of renewable energy deployment is outage management & restoration. Outage management systems (OMS) or the outage management module of Distribution Management Systems (DMS) and Fault Location

[85] Ibid.
[86] Ibid.

Isolation and Service Restoration (FLISR) solutions are used to monitor, assess, and logically recover (automatically, when possible) from traditional power outages, such as those caused by storm damage. While these features alone make them very cost effective, OMS and/or FLISR can also help manage DG interconnection using the same self-healing and proactive principles which are used to reconfigure a system during a traditional outage, restoring power to customers served by un-faulted sections of a feeder.

While DEMRS, and even DMS technology itself, is still in its infancy, the development and implementation of such systems and their combination with existing Smart Grid solutions such as OMS and FLISR will undoubtedly help overall system reliability and help optimize conditions for increased penetration of intermittent renewable generation.

<u>SVAR & DSVC</u>

Static VAr (SVAR) compensation devices are common at the transmission level as an essential means to balance reactive power by dynamically producing reactive power in real-time. At the distribution level, however, SVAR technology is still in development with a few pilot demonstrations. Combined with smart capacitor banks and inverters, smaller installations of distributed static VAr compensation (DSVC) can provide considerable increases in power quality and facilitate far greater injections of intermittent renewable power.

Some examples of how utilities are beginning to use Smart Grid technology to enable higher penetrations of renewables are as follows.

- Arizona Public Service Company (APS) serves one million customers in Arizona. It is the second fastest growing electric utility in the country and has integrated about 6 GW of solar generation into its system. APS's Smart Grid initiatives, and more specifically its distribution infrastructure upgrades, have made it one of the most reliable utilities in the U.S. APS has also implemented self-isolating and self-healing technologies on two of its main distribution lines in Flagstaff, AZ using an S&C Electric 900 MHz radio system. Additionally, the utility has integrated more than 200 MW of consumer-owned photovoltaic (PV) systems into its distribution grid, one of the largest portfolios of PV capacity in North America. The company's Flagstaff micro-grid project will incorporate an additional 1.5 MW of PV capacity, solar hot water heaters and micro-wind turbines, as well as a 1.5 MWh lithium-ion battery storage system designed to complement the utility's 500-kW Doney Park PV farm.

- Pacific Gas & Electric (PG&E) plans to install a voltage/VAr optimization (VVO) system between 2013 and 2017. This system would mitigate the voltage variations caused by distributed energy resources and maintain the desired voltage profile.. PG&E also plans to expand the use of CVR from peak load only to full-time application. In addition, automatic load tap changing is being implemented on transformers at PG&E to increase control, drive operational efficiency, and enable improved fault detection by allowing PG&E to adjust the transformer high-side tap to maintain low side voltage within a desired band.

- To address rising penetration levels of distributed energy resources, San Diego Gas & Electric (SDG&E) is rolling out an advanced weather prediction and visualization system in 2013, followed by a distributed energy resource management system (DERMS) to be finished in 2016. These two systems will improve SDG&E's ability to predict the output of intermittent generation sources and optimize the dispatch of distributed resources, demand response, and EV charging.

- As part of their "Circuit of the Future" initiative, Southern California Edison (SCE) is piloting distribution level rapid voltage support technologies to lower the impact of increasingly large concentrations of VER on individual circuits. The utility plans to install a small number of DSVC units in a small group of substations that have a high penetration of distributed PV generation. Static VAr compensators are typically placed near high-variant voltage sources or at transmission substations to compensate for rapid shifts in voltage and automatically adjust the reactive power supply. This pilot project will attempt to cost-effectively regulate rapid voltage shifts that accompany distribution circuits with high PV penetration when solar radiation intensity shifts rapidly (e.g. from passing clouds). The project will run from 2012-2014.

- Tennessee Valley Authority (TVA) is piloting a newly developed technology by Smart Wire Grid, Inc. which clamps onto transmission lines to control the flow of power, turning ordinary transmission lines into "smart wires." The Smart Wire devices are powered using line current and do not require communications among devices since they are designed to autonomously switch on at pre-specified current levels. With such tools, system operators can limit the current flow on the line to maintain quality and reliability.

6.2 HAWAII'S EXISTING SMART GRID, COMMUNICATIONS AND CONTROL PROGRAMS

Smart Grid implementation is in the infancy stages in Hawaii. Smart meter solutions have been piloted but have not found support for full-scale implementation. At the end of 2012, FERC reported that only 0.2 percent of the state's approximately 485,000 total meters met FERC's current definition of AMI smart meters, with only 0.1 percent of residential services connected to a smart meter.[87,88] This penetration level is clearly very low, especially when compared to the 2012 national average of 23 percent. This is an area of significant opportunity which should be investigated to enable the State to meet its aggressive renewable energy goals.

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[87] Federal Energy Regulation Commission Staff Report, David Kathan, et.al; 2012 Assessment of Demand Response and Advanced Metering, December 2012

[88] Previously reported figures were as high as 2% but were comprised of AMR/1-way technology meters.

On the island of Maui, a project is in progress to test the feasibility of home-based Smart Grid technologies. The primary focus of the project is the deployment of a smart meter network in the "Maui Meadows" neighborhood in South Kihei.[89] In addition to allowing both customers and the Maui Electric Company (MECO) to monitor home electricity usage more precisely in real time, the project is expected to foster increased integration of renewable energy resources. In cooperation with multiple project partners, the initiative is being managed by HNEI and MECO and is funded by the U.S. Department of Energy (DOE) through the American Recovery and Reinvestment Act (ARRA). The AMI network was installed in 2012, laying the communication system foundation for a Smart Grid. Smart meters were installed at the homes of volunteer customers who can track their energy consumption on-line through a personalized energy website. Program participants may also choose to have optional in-home devices installed as part of the project. The in-home device options include in-home displays (IHD), smart thermostats (PCT), and smart water heater control switches. The project is currently in the data collection phase. Surveys and home visits are being conducted periodically to gather feedback from program participants. After a minimum of one year data collection, a report is due to the DOE evaluating the technologies and impacts on energy usage. The project will be used to support decision making on future smart grid initiatives in Hawaii.

Another promising initiative is occurring in eastern Oahu and Waikiki, where HECO is starting development of a self-healing grid. In partnership with Siemens Corporation, the East Oahu Transmission Project (EOTP) is intended to increase electricity reliability in East Oahu by automating HECO's 46 kV sub-transmission system using self-healing technologies to modernize existing energy distribution infrastructure. The first completed phase included installation of new transformers and the second phase aims to automate high-load distribution circuits.[90] In parallel, the East Oahu Switching Project (EOSP) aims to provide automated maintenance switching, fault isolation, and restoration capabilities managed through HECO's control center. This project includes the installation of intelligent substation controllers, automated switches, and automated reclosers to quickly isolate and restore power. The broader impact for HECO is to provide a working model for how to satisfy Hawaii's growing energy needs without expensive construction and expansion in Hawaii's delicate environment.[91]

Efforts such as these ones by HECO and MECO will be critical in improving the grid landscape for renewable energy penetration.

6.3 OPPORTUNITIES TO ENHANCE HAWAII'S SMART GRID PROGRAMS

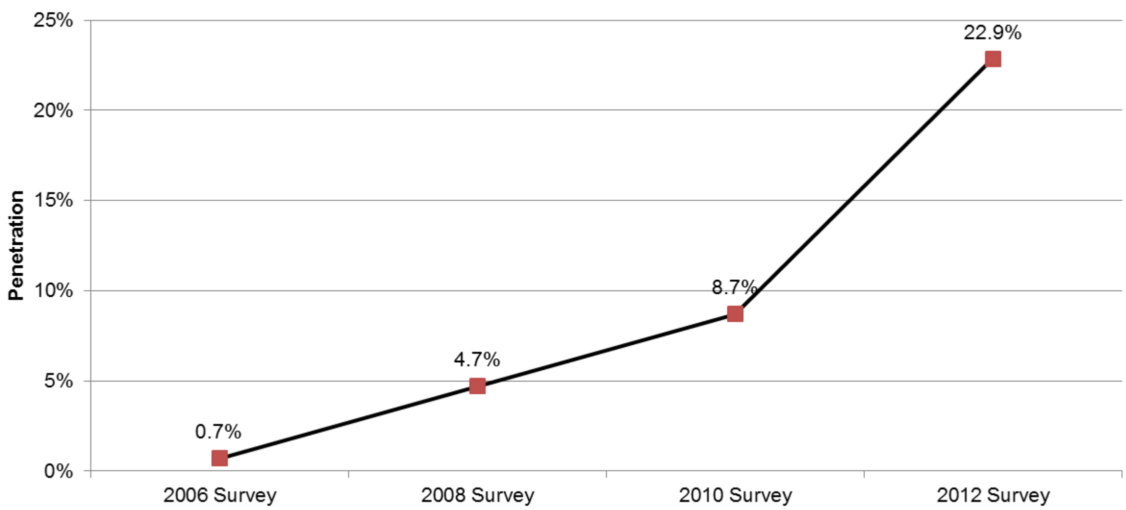
Available Smart Grid solutions cover a range of applications. Utilities must evaluate which mixture of solutions would be optimum for voltage and frequency management under varying scenarios of

[89] http://www.mauismartgrid.com/
[90] http://w3.usa.siemens.com/smartgrid/us/en/webinars/leadthecharge/Documents/Heco_CaseStudy.pdf
[91] Ibid.

intermittent renewables penetration. Hawaii's utilities will gain advantage by including Smart Grid considerations in their renewable energy integration efforts and resource planning processes. Smart Grid implementations are improving the efficiency and reliability of the grid and allowing direct two-way communication with customers, enabling local voltage control and the ability to turn on or off resources and load at the source to assist in managing system events. By integrating Smart Grid efforts and renewable energy efforts, Hawaii's utilities will be able to make better technology decisions, maximizing the value of future investments while reducing the risk of one effort outpacing the other.

6.3.1 Smart Metering as an enabler

Many utilities have identified smart meters as the first step toward a Smart Grid, connecting them to their customers by integrating the delivery and consumption of electricity using two-way wireless communications. Figure 6-1 below illustrates the growth in smart metering penetration between 2006 and 2012 across the U.S.[92]



Source: Federal Energy Regulatory Commission - 2012 Assessment of Demand Response and Advanced Metering; Staff Report; December 2012

Figure 6-1 Estimated Advanced Metering Penetration Nationwide

Although there are differing definitions, the following are generally the minimum characteristics of a Smart Metering AMI system.

- At least hourly reading frequency, with most new systems supporting 15 minute increments
- At least daily retrieval of readings
- Scheduled remote reading
- Possibility for real-time display
- Voltage profile and exception reporting

[92] Federal Energy Regulation Commission Staff Report, David Kathan, et.al; 2012 Assessment of Demand Response and Advanced Metering, December 2012

- Internal disconnect switch on single phase meters
- 2-way fixed network communication
- Ability to receive and execute on-demand commands (e.g. for demand response)

While their primary purpose is tracking the usage of individual power consumers, modern solid state meters provide a wealth of information which can be remotely harvested by modern metering systems such as AMI networks. Utilizing advanced electronics, smart meters provide valuable sensors distributed throughout a service territory. These sensors are capable of monitoring voltage, current, power quality such as voltage sags and swells, tamper and theft activity, and service outages. Deploying AMI can therefore significantly improve utility knowledge of circuit-specific conditions, reducing operating costs and improving reliability. In addition, AMI systems provide a communications network which can be utilized for much more than just automating the meter reading process and harvesting smart meter data.

In addition to the operational benefits of smart meters, there are also a host of consumer benefits such as those described in section 4.4. A good example relevant to the integration of distributed generation is use of net metering. Net metering is the measurement of energy flow in both directions, into a meter from the grid, and out of the meter, as would occur when an individual is producing more energy than they are consuming, thus putting energy back onto the grid. With analytics, the advanced meter data can be used to identify customers who may have installed PV generation but who have not registered with the utility as such and are therefore not being net metered.

6.3.1.1 Smart Meters and Planning

With integrated advanced electronics, the always-on sensing capability of smart meters makes them ideal for identifying unbalanced and overloaded circuits, conditions which are increasingly caused by high PV/DG penetration. Using GIS (geographic information system) and distribution planning and modeling tools, meter data can be overlaid onto geospatial models and single-line diagrams in order to identify visually areas of 'clustering' where grid challenges exist.

Also, new planning and modeling tools consider not only steady-state loading during normal conditions (that experienced under routine and long-term) but also more complicated modeling of intermittent renewable generation fluctuations or cold-load pick-up conditions of DR events where customer loads may radically change over a very short duration (for example, at the end of a DR event where controlled loads simultaneously turn on). While these conditions may seem radical or extreme today, they will become increasingly "normal" as renewable energy resources grow as a percentage of total supply capacity and smart meter data can provide a valuable means to plan for them.

6.3.1.2 Smart Meters and Voltage Control

Voltage regulation is a core function of all electric utilities. Most electric equipment is designed to operate at a consistent voltage, with excessive fluctuations causing wear and tear, leading to premature equipment failure and unhappy customers. Thus, industry standards require utilities to maintain acceptable voltage (120 volts +/- 5 percent) at the service entrance of all customers served under all possible operating conditions.

Increased intermittent renewables will make the job of maintaining consistent voltage significantly more challenging. Traditional grids were designed to transport power in one direction, away from the substation, with voltage controlled at the distribution level and declining as the current traveled farther from the substation. Renewable energy resources, however, increase "the voltage at the point of interconnection" and also fluctuate as the energy sources (i.e. wind or solar) fluctuate.[93] For grid scale renewable energy resources utilities must implement solutions which incorporate low voltage and low frequency ride through that allow the renewable resource to remain connected during short system disturbances, and can take advantage of regulating capacity if available. Dealing with voltage fluctuations caused by residential renewable energy sources, especially solar, is a much larger issue for utilities due to the higher number of local renewable sources and the proximity to customers.

Electric meters provide the ability to measure actual voltage at individual customer locations. By being connected to an intelligent communications network, smart meters enable a continuous feedback loop for measurement and verification of local voltage, allowing voltage regulator and capacitor bank operations to be optimized around voltage management. Smart meters are also capable of logging voltage levels, sending "report by exception" voltage alarms, and with analytics and event-management solutions, these new telemetry sources can be used to maintain system voltages for all customers closer to the nominal 120-volt service level. For example, voltage analysis using advanced analytics on smart meter voltage data can be used to address proactively poor voltage quality issues caused by malfunctioning equipment.

AMI voltage data can also improve CVR (conservation voltage reduction) solutions. CVR intentionally lowers the voltage on distribution feeders to a minimum while ensuring it is still acceptable at the end of line (above the lower limit requirements). By lowering voltage to the lowest acceptable voltage level, electric utilities reduce overall demand and reduce energy consumption without any adverse impacts on customers. While CVR is not new, emerging technologies better enable utilities to optimize the voltage towards the lower end of the spec range (114 volts), while still complying with customer equipment performance requirements.

[93] Sandia National Laboratories, "Solar Energy Grid Integration Systems (SEGIS) Program Concept Paper," DOE EERE/SNL, October 2007.

Finally, smart meter voltage data can play a critical role in VVO (volt/VAr optimization). Traditional feeder voltage regulators and switched capacitor banks are operated as completely independent (stand-alone) devices, with no direct coordination between the individual controllers. This can be problematic since changes in one device could cause an opposite reaction in another, negating the intended system operator's goals. The coordinated control of voltage and reactive power via modern software systems is needed to determine and execute volt/VAr control actions that are truly optimal. Stand-alone VVO solutions added a level of intelligence and central coordination, but the advent of the Smart Grid has spawned "Smart VVO." By integrating smart meter data feeds and other telemetry sources in near real-time, advanced VVO systems can now determine the optimal set of control actions for voltage regulating and VAr control devices. VVO strategies should be deployed in order to make the grid more energy efficient. Although energy savings will differ by circuit based on various types of loads, the benefits are clear, as is the role which AMI data can play. Implementation of advanced VVO techniques are not necessarily needed system-wide in the near future, but could very much justify their costs on feeders with high VER concentrations where voltage & VAr fluctuations occur frequently.

6.3.1.3 Smart Meters and Reactive Power Management

While the implementation of more capacitor banks can reduce line losses when functioning properly, malfunctioning timers and blown fuses reduce the effectiveness of these devices, often unbeknownst to grid operators. Technology vendors have developed solutions which can directly monitor and even control regulating devices such as capacitor banks but these solutions typically require dedicated telemetry systems. However, in recent years, AMI system vendors have started to integrate these types of monitoring and control solutions directly into AMI systems, further increasing the value of AMI beyond simply reading meters. In addition, reactive power measurements recorded by smart meters can be used indirectly to verify that power management assets are functioning properly and achieving the intended benefits in supporting system voltage.

Smart meters can also help grid operators more strategically deploy the assets used in the management of reactive power. Using smart analytics, AMI meter data can be used to identify customer loads which generate the most reactive power flow and those circuits which may benefit from grid assets such as capacitor banks (devices that insert capacitance onto the electric grid and provide voltage support), resulting in better prioritization of limited utility resources.

6.3.2 Control systems as an enabler

Historically distribution operations have been characterized by:

- The manual operations of devices by field personnel,
- Local operation of devices by control panels configured largely to operate independently of one another,
- Operational processes based on past practices and a fixed circuit topology,
- Operating parameters based on calculations and approximations focused on peak loading, and

- Data spread across multiple databases using various storage media including computer-based storage as well as hard copy.

While these approaches have served the electric utility industry well for over a century, there are inherent limitations, which more efficient, automated, software-based control systems are well suited to address.

Monitoring and control is required for load devices, DG devices, distribution system devices, transmission system devices and generation devices, often using separate systems. An Advanced Operating System (AOS) can integrate all of these communications and controls. A major component of an AOS is the development of Distribution Management Systems (DMS), which allow utilities to take advantage of the unprecedented data and technologic advances that make up the Smart Grid. Performing long-term generation planning, substation and distribution system upgrade design and routine load flow analysis requires insight into all available DG resources. This in turn requires that these sources provide real-time information that can be fed into the new generation of DMS power flow applications for both planning and system operations. This provides the information that utilities need to plan and operate the grid safely and reliably. Figure 6-2 illustrates how DMS solutions are integrated into the broader utility operational and control landscape.

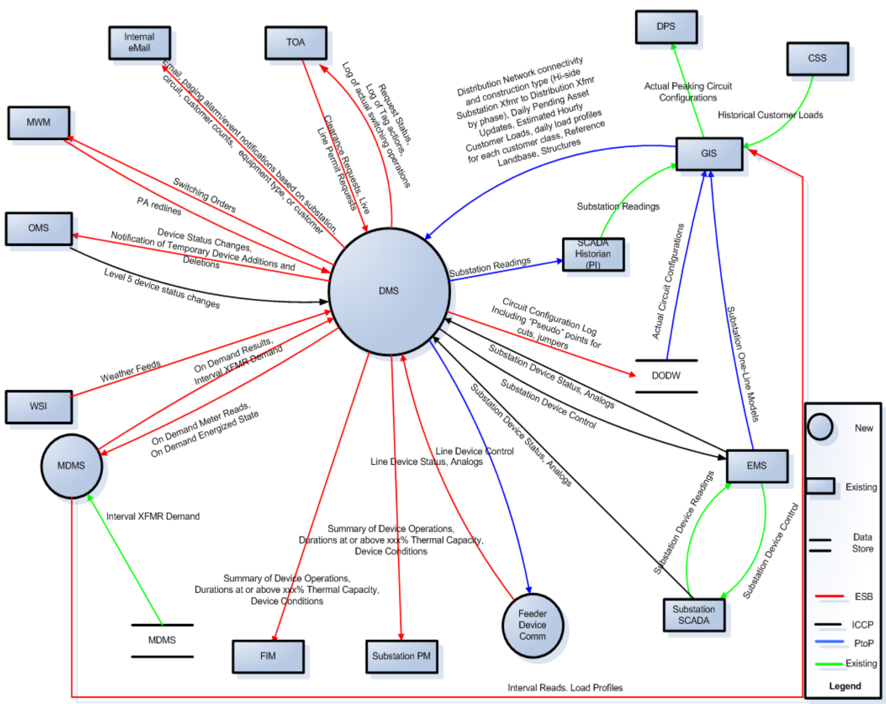


Figure 6-2 DMS Example Integration Scenario

The heart of a DMS is the data model of the distribution system, which requires both operational and static data. Operational data deals with changes to connectivity and equipment settings. This typically includes device status changes, such as a switch status changing from open to close or the position of a capacitor bank being connected or disconnected. Static data, on the other hand, does not describes the distribution system over an extended time frame. The static data includes information from the GIS for the distribution connectivity model, system configurations and land base to represent the distribution lines, as well as substation internal connectivity model. Protective relay settings and system impedance data are required along with component and facilities ratings, equipment impedance and ratings, and device settings from reclosers, capacitors and regulator controls. Furthermore, the DMS requires customer information including customer count, load data and load schedules--data which are readily available through AMI systems. Finally, when combined with actual data from AMI-enabled smart meters and data from SCADA devices, the DMS data model, using static and operational data, provides a platform from which to perform real-time power flow calculations and analysis that represent current conditions on the system. These calculations can enable advance functions like voltage and VAr control, fault identification and service restoration.

Another key example of Smart Grid control software is a Demand Response Management System. As discussed in section 5.4.1, it is critical to measure and track the effectiveness of DR programs accurately. Despite these current DR capabilities, today we are still primarily in the realm of "ManualDR," where operators trigger events manually or utilize basic scheduling software. DRMS software offers a path to "AutoDR" and is used to:

- Manage the overall Demand Response (DR) program,
- Manage customer enrollment and registration,
- Support device provisioning,
- Monitor (& quantify) available DR resources and interruptible demand,
- Forecast DR resources and interruptible demand,
- Initiate load control/DR events –> Command & Control,
- Track event participation and actual demand reduction –> Validate & Verify, and
- Manage DR-related devices.

DRMS solutions are especially useful for residential programs with large enrollment numbers, where the administrative aspects of program management alone can be a major challenge.

In parallel, the OpenADR Alliance industry group has led the development of standards for AutoDR to move the industry away from proprietary solutions. Focused on commercial and industrial loads, the goal of OpenADR is to provide standardized processes and protocols to automate the response of commercial and industrial buildings to utility signals. For example, price signals and reliability signals could feed directly into customer-side EMS/BMS to execute pre-programmed responses. With a DRMS on the utility side, the entire DR process is thereby automated from event initiation to event participation to M&V and settlement.

A real-world example of an advanced control system initiative is the Sacramento Municipal Utility District (SMUD), which expects to implement an Advanced Operating System (AOS) in its service territory. SMUD is installing automated equipment on select distribution lines and building a wireless communication network to support the AOS. The system will tie together traditional separate solutions including CVR, VVO, and Automatic Sectionalizing and Restoration. Furthermore, SMUD is proposing a DMS with combined functionalities of OMS, and SCADA/EMS that leverages GIS capabilities and integrates into other SMUD operational technologies. The system will enable operators to view and control the distribution system and optimize Smart Grid resources with real-time analytics for an efficient and reliable grid. Hawaii's utilities need to strongly consider similar solutions as part of the planning process in order to help meet the aggressive renewable energy goals set by the State.

6.3.3 Communication systems as an enabler

No single communications system is capable of communicating with all the load devices, generation devices, and distribution and transmission system devices. Nevertheless, a key enabler for effectively integrating, monitoring and managing renewable energy resources on the grid lies with the utility's ability to ingest, route, process and act upon the increased levels of instrumentation data from DG sources and the grid as a whole. Smart Grid technology can tie together new and existing communications systems in a coherent and effective manner. With the increasing deployment of information technology (IT) solutions such as enterprise service buses (ESBs) and stream processing tools, the time between "sensory" and "actionable" information can be dramatically compressed, thereby reducing the time between grid stimulus and effective utility response. For example, when combined with advanced analytical software solutions, Smart Grid communications systems can intelligently connect energy storage systems with the grid, leading to an "interconnected and orchestrated fleet of communicating batteries"[94] which would enable increased levels of renewable energy penetration while providing stable power quality.

Up to now, most customer-side renewable energy systems have not generated sufficient energy to put electricity back onto the grid. Monitoring these small and dispersed systems was generally therefore not necessary. For wholesale DG systems, this type of monitoring is already typically present and relied upon by utility operators.[95] However, many utilities now feel that visibility into smaller systems, particularly those larger than 250 kW, is needed as well and will allow them to factor small DG resources into their transmission capacity margin calculations. In the future, with a Smart Grid dependent upon new standard communication protocols, it will be more feasible to create visibility and control for these many customer-side systems and all of the larger systems.

[94] http://www.forbes.com/sites/peterdetwiler/2013/02/26/one-companys-approach-to-innovation-in-electricity-storage-focus-on-the-software/

[95] Currently, telemetering requirements are imposed only on DG systems 1 MW or larger. Smaller units do not have this requirement since at lower penetrations the expectation was that the impacts would be minimal, the cost to collect the data would be relatively high, and processing of this additional data may not be necessary. This assumption should be revisited as penetration increases or the operational requirements for DG change. For example, California utilities have recently proposed telemetering requirements for certain wholesale DG systems smaller than 1 MW that will export power to be aggregated and scheduled into CAISO's market. As of this writing, the CPUC has not yet evaluated those proposals.

Europeans have already started implementing new communications and control features and strategies.

In addition to the existing lack of monitoring and control of customer-side energy resources, reliable means of forecasting the near-term output from renewable resource systems is only now emerging. Forecasting of DG, and PV in particular, is necessary for better integration and optimization of these resources. For example, forecasting moving cloud cover and other weather changes will allow for improved control and function of the distribution system. And, when combined with advanced communication and control technologies, better forecasting will allow grid operators to maximize the use of available renewable resources or otherwise control distributed generation as necessary.

Understandably, utilities want to run multiple applications over their communications networks to maximize the value of their investments and simplify operations. For example, AMI networks provide significant foundational platforms for communication with intelligent devices, enabling initiatives such as large-scale Demand Response programs. Smart Grid communications systems can also address utility concerns with the cost of communication and control of devices, such as smart inverters, by eliminating the need for dedicated infrastructure. With Smart Grid technologies, utilities can leverage the same communication & control features used for automated substations and also integrate them with SCADA. Utilities should therefore evaluate the cost of implementing promising device options which integrate well with Smart Grid communications strategies.

6.3.4 Enabling DR

As discussed in Section 5 above, Demand Response solutions provide a host of benefits to increasing renewable energy penetration. Sophisticated software, enhanced communications techniques, and load control features and devices are required to enable DR on any significant scale. Smart Grid technology provides a foundation with appropriate functionality to allow utility control and encourage customer response to utility supplied signals and information.

However, DR is not needed everywhere in a service territory. As was recommended by RSWG, Hawaii's utilities should work "to identify those customers and loads that are most promising for demand response."[96] Smart meters identify how much energy is consumed, where it is consumed, and when it is consumed. Using this smart meter data, utilities can take advantage of "targeted DR," prioritizing where DR investments are required. For example, customers can be targeted on individual substations, or even individual feeders, which are more susceptible to variability due to the higher levels of renewable energy resources. In addition to helping determine where to best target deployment of DR devices, an analytics platform can use smart meter information to identify

[96] Reliability Standards Working Group, Hawaii PUC Docket No. 2011-0206, "Demand Response as a Flexible Operation Resource," RSWG Demand Side Options Subgroup

and prioritize load curtailment requirements for active DR programs. Also, smart meter data can enable customer segmentation and surgical load curtailment, which can exclude critical facilities such as hospitals, nursing homes, and police and fire stations from DR events.

BGE (Baltimore Gas & Electric) has already used their AMI data to perform these exact types of analytics for targeted demand response. Armed with smart meter data, BGE has used advanced analytics to help proactively identify "the right customers to target for BGE's peak rewards program."[97] Already seeing clear benefits, BGE is continuing to refine their algorithms and to expand the scope of their smart meter data analytics efforts. Hawaii's utilities should look at programs such as BGE's as models of how smart grid data can enable programs which have direct benefits to renewable energy integration.

6.3.5 Enabling Energy Storage

Energy Storage (ES) is a technology that can provide electric system reliability functions. Smart Grid communications and control functions can enable this technology. While energy storage does not directly control usage (as DR) nor reduce overall consumption (as EE), it has a lot of potential benefits for integrating renewable generation by working as part of the Smart Grid to smooth out the supply curve (as opposed to demand curve).

Different storage technologies have different characteristics (such as storage duration and cost) that make them more or less suited for particular applications. Below are some potential energy storage solutions:

- Short Duration (flywheel, ultra-capacitor),
- Medium Duration (batteries), and
- Long Duration (pumped hydro storage, compressed air storage).

Rather than shifting *demand* via DR, energy storage with Smart Grid control capabilities provides a method to shift *supply*, particularly in conjunction with renewable generation. For example, residential demand typically spikes in the early mornings and early evenings and is low during the middle of the day when solar energy would be at its peak. Through Smart Grid control capabilities, solar energy would be stored during the day and then be available in the evening when consumers return to their homes.

Energy storage devices do not necessarily need to be co-located with renewable generation. They could be widely distributed across the grid. With Smart Grid controls, distributed energy storage devices may meet multiple needs in different applications at various scales—from large centralized storage devices at substations, to community energy storage devices on distribution feeders, to small devices at individual homes (see **Error! Reference source not found.** overlaid with Smart rid controls).

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[97] http://www.smartgridnews.com/artman/publish/Technologies_Demand_Response_News/Smart-Grid-Demand-Response-Today-s-Leaders-at-Risk-as-DR-2-0-Emerges-2252.html

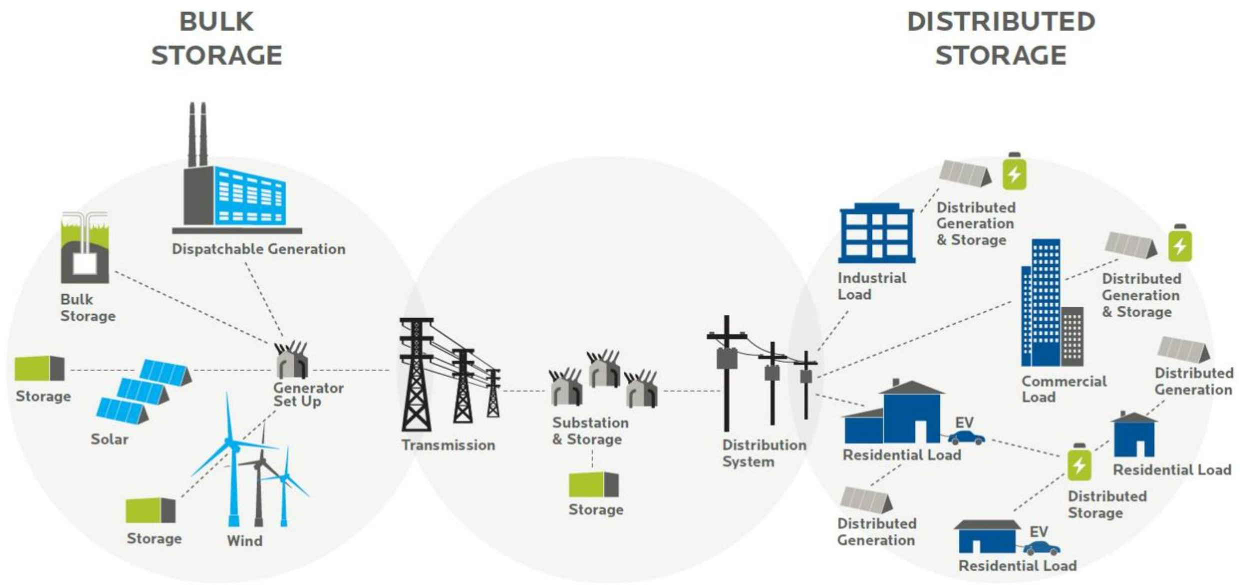

Figure 6-3 Potential Applications of Energy Storage

With two levers at their disposable - DR to shift demand and Energy Storage to shift supply - grid operators have two powerful and complementary methods to tailor the supply-demand balance, providing better conditions for increasing renewable energy penetration. Energy storage can likely meet all needs for regulation, spinning reserve and other ancillary services required for variable renewable generation; however, it is costly. The relative economics of these ES and DR options should be analyzed in relation to other approaches to integrating renewables while still maintaining power quality (such as voltage and VAr control technologies, smart inverters, forecasting, automated substations, etc.) under various grid scenarios. Effectively integrating energy storage as a flexibility tool will require Smart Grid technologies to ensure that storage is used optimally.

A specific storage method with strong potential for Hawaii is commercial ice storage, specifically for large hotels. Commercial ice storage shifts cooling loads from the day to the night. Using roof top refrigeration units, ice is built up over night and is then used to cool buildings during the day. Thus, ice storage is very complementary to wind generation since wind energy typically peaks during off-peak periods, periods during which wind is often curtailed. In regions with high concentrations of large hotels (or other significant commercial buildings), cooling through ice storage could significantly improve the use of renewable energy and help improve grid reliability.

6.3.6 Enabling Generation and Storage and Reserves Management

Smart Grid technologies can enable the management of generation, energy storage and reserves in an effective way that can limit the challenges with intermittent renewable integration. Recent wind turbine technology improvements, specifically from GE, are moving towards “smart” (what GE is calling "brilliant") turbines. These turbines communicate with each other and such other devices as energy storage to maintain grid power quality.[98]

As an additional mitigation technique, conventional generation not already equipped with automatic generation control (AGC) can be modified to include AGC and appropriate SCADA communications to integrate with the greater Smart Grid. Intermittent generation can also be equipped with AGC capabilities that communicate with the Smart Grid. And in general, AGC operations can be modified to enhance the integration of intermittent resources; HELCO has already modified AGC control for intermittent generation including allowing a greater range of frequencies as compared to conventional generation technologies.[99]

The use and management of reserves can be modified with the Smart Grid to enhance intermittent renewables integration. It is considered good practice to use contingency reserves for extreme wind events causing extended ramps.[100] Such reserves will receive signals from the AOS. If contracts require, wind farms can be equipped with features that allow modest limits for ramp rate control and AGC can be provided for down-regulation. Communication is required between the AOS, the wind generators and the wind meteorological stations involved in wind forecasting – Smart Grid technology will be the enabler for this communication.

Using the Smart Grid to dynamically calculate regulation reserves and load following reserves can mitigate net load variations and can help to reduce overall reserve requirements. Reserve sharing between electric systems will average-out fluctuations. Reserves sharing will be enabled when the undersea transmission cable comes on-line and through Smart Grid communication and control capabilities.

6.3.7 Enabling Forecasting and Curtailment

Improved forecasting, including ramp forecasts, helps grid operators monitor system conditions, schedule or de-commit fuel supplies and power plants in anticipation of changes or ramps in wind and solar generation, and prepare for extreme high and low events. Some studies show that forecasts can reduce costs by decreasing fuel consumption.[101] For less flexible power systems with small balancing areas dominated by thermal generation such as Hawaii, curtailments of generation may be required, even at low variable generation penetrations.

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[98] http://www.renewableenergyworld.com/rea/news/article/2013/04/ges-new-brilliant-wind-turbine-put-to-the-test

[99] HELCO IRP Advisory Group Oriented Session, "HELCO Systems Operations," August 22, 2008.

[100] Kevin Porter, et. al; PJM Renewable Integration Study, Task Report: Review of Industry Practice and Experience in the Integration of Wind and Solar Generation; Prepared by Exeter Associates, Inc. and GE Energy.

[101] Kevin Porter, et al; PJM Renewable Integration Study, Task Report: Review of Industry Practices and Experience, in the Integration of Wind and Solar Generation, Prepared by Exeter Associates, Inc. and GE Energy.

Demonstrations are occurring to better understand the technology and cost tradeoffs necessary to optimize forecast precision. While better precision is always desired, there are limitations on what can be achieved[102]. Overall, there is a point of diminishing returns on forecasting precision that needs to be identified. Key barriers to better forecasting are deficiencies in forecast tools; time required to implement, process and collect data; more need to incorporate VER into day-ahead dispatch and lack of real time dispatch schedule updates.

Curtailment of VER output may be necessary if the amount available at a specific time is more than the grid can reliably deliver while maintaining stability. Recent wind integration studies and operating experience demonstrate that at higher levels of penetration, wind generation may need to be curtailed during certain periods, unless suitable flexibility is designed into the bulk power system. HELCO has already implemented curtailment to reduce variability and excess generation[103].

From a technology standpoint, wind generation can be designed with equipment to limit or flatten ramps and wind generation can be curtailed to provide reserves, thereby improving flexibility. And smart inverters may provide curtailment capabilities for solar PV facilities as well. These features may require additional communications and utility control via the Smart Grid to maximize their benefit. To optimize the use of renewable energy resources and minimize curtailment, forecasting tools need to be combined with Smart Grid technologies, including advanced DMS, AMI, and DRMS. Using these combined systems, electric grid operators will have the tools to monitor both energy supply and energy demand and react in real -time with appropriate system responses. Emerging wind turbine technologies such as the "brilliant" GE turbines mentioned above may also aid in limiting or flattening ramps. There is a demonstration project on Lanai where a 1.2 MW solar PV system is equipped with a Satcon inverter that has a remote utility control system. This control system, in conjunction with a 12 to 24 hour solar resource forecast enables MECO to predict the solar PV generation and effectively integrate it into the grid.[104]

6.3.8 How microgrids help

A microgrid is a technical solution that may have the ability to assist renewable integration at the local or distribution level. Microgrids typically integrate storage and generation into a seamless system that integrates renewables into reliable local grid solutions. On an island with no interconnections, several microgrids integrated into a total island grid may provide increased system reliability as compared to one central grid solution.

[102] Bri-Mathias Hodge, Anthony Florita, Kristen Orwig, Debra Lew, and Michael Milligan, "A Comparison of Wind Power and Load Forecasting Error Distributions," National Renewable Energy Laboratory, Presented at the 2012 World Renewable Energy Forum, Denver, July 2012.
[103] HELCO IRP Advisory Group Oriented Session, "HELCO Systems Operations," August 22, 2008.
[104] Bower, W; et al, Solar Energy Grid Integration Systems: Final Report of the Florida Solar Energy Center Team, SAND2012-1395, March 2012.

SMUD defines a microgrid as a smart grid concept that is an "Integrated energy system consisting of interconnected loads and distributed energy resources which as an integrated system can operate in parallel with the grid or in an intentional island mode. Microgrids can vary in scope, size, and ownership."[105] The CEC says, "Microgrids are basically self-contained electrical ecosystems. Power is produced, transmitted, consumed, monitored, and managed all on a local scale. In many cases, they can be integrated into larger, central grids, but their defining characteristic is that they can operate independently if disconnected from the whole." This single point of common coupling with the macrogrid can be disconnected.

The microgrid can then function autonomously. Microgrid generation resources can include several distributed generators, including fuel cells, wind, solar, or other energy sources. The multiple dispersed generation sources and ability to isolate the microgrid from a larger network can provide highly reliable electric power." As SMUD demonstrates, smart grid features need to be included in modern microgrids to allow monitoring, operation, and automated connection or disconnection from the macrogrid, to optimize storage, if included, and to eliminate the potential for unsafe islanding (operating unsafely after disconnection from the macrogrid). Interoperability with demand response may also be included. Renewable resources connected to the microgrid may include real time forecasting for optimum automated operation.

Microgrids are also used by campuses, military bases, communities or other loads to integrate distributed renewables and increase their reliability above and beyond a grid only connection. The military is very interested in microgrids to allow military bases, including those in Hawaii, to operate independently when there is a grid outage due to equipment failures, weather events or terrorism. A microgrid allows itself to seamlessly and automatically operate as an island when there is a grid outage. A key component is the electronic switch that provides this capability. It monitors grid voltage and automatically disconnects the microgrid from the grid when a grid outage occurs. In addition, a microgrid will likely have a controller to optimize operation of the distributed generation and the storage as well as the fossil fuel fired DG if provided. A battery, an internal combustion engine and a wind turbine integrated with a load comprise a simple microgrid when integrated with the controller and electronic switching.

The growing frequency of extreme weather events increases the appeal of the reliability benefits attached to a microgrid. For this reason university campuses are also interested. The University of California, San Diego has a well-recognized microgrid that has operated independently for months while San Onofre Nuclear outages decreased grid reliability. The University of Santa Clara has

[105] Mark Rawson, "Microgrid and Smart Grid Activities at SMUD," Sacramento Municipal Utilities District, Presented at the 2010 MicroGrid Symposium, July 2010. http://der.lbl.gov/sites/der.lbl.gov/files/vancouver_rawson.pdf

adopted renewable energy and pursued microgrid development as a result of continued outages which prevented operation of schools in New Orleans after Hurricane Katrina. Universities in Hawaii could be interested.

SDG&E is developing a microgrid at Borrego Springs in the high desert, looking to tap excellent solar energy resources owned by its customers to help sustain operations at a remote utility substation.

The State of Hawaii is involved in federal microgrid demonstration projects and has a number of private microgrid projects, including the one described in the following excerpt.

> *A separate project from this SEGIS effort, but with particular relevance, involves a PV generation site on the Hawaiian island of Lana'i, where a moderate PV plant (1.2MW) is integrated into a small diesel engine-generator grid (4MW). The 1.2 megawatt (MW) installation is the first solar photovoltaic power plant to be controlled remotely by a utility, Maui Electric Company, Ltd. (MECO). MECO has to manage the grid remotely from the island of Maui, thirty miles and an ocean channel away, by ramping up and down different generation sources. They also have to be able to handle intermittent power output from the PV plant due to cloud cover during the day and lack of solar power at night. Given a 12-24 hour weather forecast and knowledge of expected solar irradiance levels at all times during the day, MECO is able to predict when the solar plant is available to generate power and when spinning reserve diesel generators need to be used to meet demand. Satcon developed a remote utility-control system embedded in the inverters to be used at Lana'i. With this advanced system control technology, the PV plant is seamlessly integrated into the utility grid, with the inverter serving as the central control point. The intelligence contained in the inverter means that MECO can dynamically switch from solar to diesel energy sources and back, thus supplying uninterrupted power to the island. Additionally, MECO can use the inverter to generate reactive power from the PV plant, stabilizing the grid when it comes under stress. The penetration of 30 percent Solar PV coupled with the small grid highlights many of the same concerns of large scale integration into the larger utility grid.*
>
> *This project was undertaken at the request of the PV Integrator (SunPower), the PV plant owner (Lana'i Sustainability Research – a division of Castle and Cooke), the DOE, and the local utility (MECO, HECO), to incorporate inverter control features that would enable the high PV penetration, address and control intermittency, give the utility control over the plant from a remote control center (on the island of Maui), and upgrade overall grid performance. Incorporating these inverter and PV plant control features, integrated with the utility SCADA system on*

the Lanaʻi grid, required detailed software development, extensive simulation work, and laboratory and field testing, which ultimately enabled the site owner to meet the requirements of the Power Purchase Agreement with MECO, the local grid operator.

While this Lanaʻi project is separate from the SEGIS effort and has distinct differences, it did provide an opportunity to provide concept checks on SEGIS and to work on high-penetration at 30 percent of the grid load during peak solar hours, but also 10 percent of the annual electrical energy demand, which today is all produced from diesel fuel.

6.4 SECTION SUMMARY

In preparing themselves for the increased penetration of renewable DGs, utilities need to investigate and apply smart grid solutions such as smart metering, smart communications solutions, distributed monitoring and control, and DMS applications. The Smart Grid enables electrical system flexibility to meet the challenges of integrating intermittent renewable energy resources. The level of challenges will depend on the amount, size, location, and voltage levels of the interconnected resources; the capabilities of those resources for dispatch and communication (and similar Smart Grid capabilities); and the ability of the grid to accept generation at multiple distributed sites and flow power as needed in the opposite direction as initially designed. In addition, these solutions have far-reaching value beyond supporting DG. Smart Grid technology provides system operators with real-time awareness of electrical generation, storage, transmission, distribution, and loads, resulting in improved system performance and reliability. The development and implementation of such technologies and their combination will enable real-time information exchange throughout the utility and with its customers. Therefore, while Smart Grid solutions should be considered necessary for providing flexibility functions to optimize the use of renewable energy resources, the greater impact is an integrated electrical grid which provides utilities with visibility and control to improve the efficiency, reliability, and quality of the electrical energy provided.

7.0 Barriers to Adoption of Smart Grid Technologies in Hawaii

This section discusses the following barriers to the adoption and deployment of the technologies and programs which are valuable in facilitating the increased penetration of renewables:

- Lack of technical and commercial readiness
  - Technologies must demonstrate technical viability and economic viability, their performance must be properly valued by regulators, and costs must be properly allocated.
  - Business rules, regulatory rules, and contracts must be adapted to deal with these implications. An example is a technology to limit ramping of wind turbines which would supply a flexibility/reliability function that would be paid for by utilities after appropriate business rules and contracts are put in place.
- Lack of utility preparedness,
- Cost
  - Implementation costs
  - Incentive levels
  - Critical mass to support third party participation
- Unrecognized benefits of technology or enabling solution to the utility, ratepayers, and State
- Cost recovery
- Lack of customer awareness
- Lack of customer's access to their own energy information
- Policy, regulatory, statutory barriers
- Permitting requirements/procedures

7.1 BARRIERS

7.1.1 Lack of technical and commercial readiness

Energy efficiency and some demand response programs are well understood, and performance and cost data is well documented. A mature smart grid does not exist at scale in any utility system. However, pilots and demonstrations are being implemented globally. Most utilities begin smart grid implementation with smart meter implementation and they are working hard to utilize the data and communications available. However, full implementation of smart meter capability does not yet exist either. Additional demonstrations are necessary to understand the implementation of all smart meter features.

7.1.2 Lack of Utility Preparedness

Smart Grid solutions are only one category of investments and initiatives that utilities are undertaking in today's rapidly changing utility environment. The Smart Grid solutions discussed herein must compete with other projects and investments underway at the HECO Companies. And it is not just a matter of sufficient financial inducements or capabilities, but the ability of a utility, or any organization, to withstand significant amounts of change. The enabling technologies and advanced applications require new employee skills, redefined job classifications, modified organizational structures, new operating processes – in general a fundamental transformation of how HECO operates the electric grid.

The grids of the HECO Companies also have very different current configurations and level of technology advancement that must be assessed. The amount of distribution automation, substation automation, advanced applications, GIS capabilities, and other foundational systems varies significantly across the island. Therefore the starting point to a smarter grid and the enablement of increased grid flexibility is island specific.

7.1.3 Cost

Costs are well understood for existing EE technologies. This is also partially true for commercial DR, but the role of large aggregators will be dependent on the level of incentives offered because of the high cost of establishing operations in Hawaii, relative to the size and number of customers with large, dispatchable loads. Costs for new advanced DR programs that depend on smart grid communication and control features are not completely understood. Additionally, a method to allocate costs based on actual achievable benefits is required. The costs and benefits of smart grids and nearly all smart grid features necessary to enable system flexibility are still being defined. Comprehensive studies which measure costs and benefits of various flexibilities and enabling smart grid features are necessary for each unique electric system.

7.1.4 Cost Recovery

Cost recovery is an issue that needs to be addressed differently for different technologies. For energy storage new tariffs and other rule changes that allow benefits to be monetized are only now beginning to be considered. Interconnection costs for wholesale DG systems are often an issue because of rules for allocation of costs to the DG owner versus the utility. There are also issues of cross subsidies and tariff structure for net metered systems. And in the future, requirements for smart grid features will need to be allocated between the utility and the owners of the generation. Finally, there are also issues with respect to rate structures and the availability of price signals that modify consumer behavior, especially for customer-driven DR programs. High existing rates and customer resistance to assuming the burden of higher rates may limit the costs that can be allocated to the ratepayer

7.1.5 Lack of customer awareness

Well-designed behavior based EE and DR programs require informed and educated customers with adequate awareness, education, and access to data. The lack of a feedback process and ability of customers to connect actions and results are a significant problem with some EE and DR programs. Customers must be able to understand the impact of such programs on their lives and homes; concern over how such programs will affect them results in a portion of customers deciding not to participate. Conversely, obtaining information on how programs positively impact them, either financially or through contribution to societal benefits have been shown to further stimulate customer responsiveness.

7.1.6 Customer's lack of access to their own energy information

Customers require information to make informed decisions that can contribute to utility objectives. A mechanism to get more usable information to the customer is the smart meter. In home displays or web pages, programmable appliances, thermostats, and power strips will assist with displaying or automatically using energy information. Rate structures also need to be modified to deliver proper price signals, especially to enable functionality of smart meters and smart appliances.

7.1.7 Policy, Regulatory, Statutory barriers

Policy, regulatory, statutory, and contractual or arbitrary business rules are all barriers. New contracts may be required to modify behavior and designs. Codes and standards are needed to require smart inverters and customers may need to be paid for supplying benefits to the electric system. Regulatory changes will be necessary to allow new types of reserves, monetizing of benefits, and modification of reliability standards, and to address methods of benefit calculation, customer privacy protection and other factors that impact how we design and operate electric systems with new automated communication and control technologies. Larger DG projects need policy mechanisms to ensure they are located to provide utility distribution system benefits. Regulatory actions are also required to allow or cause widespread smart grid implementation.

7.1.8 Permitting requirements/procedures

Permitting requirements are of more significance to utility-scale projects than net metered DG. Mechanisms should be put in place to identify preferred locations for siting utility scale projects in areas of minimal environmental impact while achieving maximum beneficial impact to the utility system. Similarly procedures should be put in place for larger DG projects to ensure they are located strategically to provide distribution system benefits.

7.2 SECTION SUMMARY

The biggest barriers to attaining high penetrations of energy from variable renewables are lack of information that informs utilities about the costs and benefits of options to provide reliability functions and lack of information to enable customer-based DR programs. As more demonstrations are conducted for DR technologies and smart communications and control technologies that enable various flexibilities, there will be a need for comprehensive studies that identify cost-benefit tradeoffs so utilities can identify and rank alternatives which allow higher penetrations of intermittent renewables to be achieved on each Hawaiian island.

Another barrier exists with respect to the rule changes to UL 1741 and IEEE 1547 safety standards that will be necessary to implement smart inverters and the business case development for regulatory actions necessary to achieve full Smart Grid implementation.

8.0 Solutions to Barriers to Adoption of Smart Grid Technologies Increased Penetration of Renewables in Hawaii

This section addresses the barriers identified in Section 7 and presents solutions designed to overcome these barriers. Recommended focus areas include policy, customer engagement and technology readiness assessment.

8.1 INCENTIVES, TAX CREDITS AND REBATES THAT CHANGE PERCEIVED COST

Beyond existing federal, state and utility incentives for renewable energy projects and energy efficiency, Hawaii utilities should evaluate the potential for using different types of incentives that would place new DG in locations on the grid that maximize system benefits.

8.2 MODIFICATION OF COST RECOVERY MECHANISMS

Hawaii utilities should investigate options that would allow utility ownership of DG.
Hawaii utilities should investigate alternatives for evaluating benefits and costs of DG. The goal is to get DG placed in locations that help utilities achieve specific beneficial objectives. Much of the benefit ascribed to DG is not currently realized since utilities have yet to adopt planning processes designed to achieve real documented savings realizable from strategically sited DG.

8.3 MECHANISMS THAT IMPROVE TECHNICAL AND COMMERCIAL READINESS

Utilities around the country are performing demonstrations focused on improving technical readiness. These demonstrations prove feasibility and provide technical information necessary for changes to standards, rules and regulations. However, very few of these demonstrations are focused on defining implementation costs and the next steps necessary to move from technical success to commercial scale implementation. Also, the results of these demonstrations will need to be analyzed to apply the results to Hawaii's electric systems. Hawaii's utilities should define and implement demonstration programs that provide insight into the following attributes of the Oahu grid., .

- **Inertia -** All demonstrations of new technology should include consideration of inertia or synthetic inertia. Providing inertia-like response from technologies which have inverters has not previously been a priority. The demonstrations need to consider the cost of providing these ancillary services, the mechanisms to pay for these services and the rule changes necessary to require them in all future installations.
- **Frequency -** Similarly, frequency response must be considered in technology demonstrations and the Smart Grid features need to be included to achieve this frequency response automatically.

- **AGC -** AGC and associated Smart Grid communications and control will need to be demonstrated on all generators, storage and demand response.
- **Spinning Reserves -** Demonstrations will be required to provide command and control functionality into variable generation that will provide spinning reserve functionality.
- **Contingency Reserves -** Demonstration of new types or combinations of contingency reserves will be useful to improve grid flexibility.
- **Reactive Power and Voltage Regulation -** Smart inverter technology should be investigated through demonstration to determine its usefulness for different system sizes. Smart grid technology will be necessary to manage information from the large number of DG inverters anticipated. It may not be necessary to require all sizes of projects to be included, but the need for more flexibility on the Hawaii Island electric systems means a greater need for smart inverter capability. Smart Grid technology, which manages and controls voltage on distribution systems, will need to be demonstrated.
- **Short Circuit -** Smart Grid features that provide the recommended short circuit functionality will need to be demonstrated. These features can be coupled with advanced protection schemes that leverage the status data available from remote devices as well as a communications system to provide real-time information on fault conditions and locations.
- **Planning -** Planning should seek to use probabilistic techniques to establish priorities for technology implementation and geographic implementation that minimizes costs. New techniques for integrating transmission and distribution planning may need to be demonstrated.
- **Compensation -** Mechanisms to compensate developers of flexible resource projects will need to be developed once the technology demonstrations are completed, as part of the early commercialization process.

8.4 EDUCATION TO IMPROVE CUSTOMER AWARENESS

As mentioned previously, barriers to efficiency and renewable energy can be overcome by providing information and enabling customers to make informed energy decisions. Progress toward the State's goals can also be accelerated through enhanced marketing efforts, to improve accessibility of existing EE, DR, RE and Smart Grid incentive programs.

Particular tools and technologies that can support customer education are smart meters, energy data visualization tools including web portals, and "green button" enabled programs. These technologies are discussed in Section 4.

8.5 RULE CHANGES

Business rules will need to be created and possible regulatory changes will be necessary to allow ancillary services defined by RSWG to be bought and sold in Hawaii.

Wind procurement contracts may need to be modified to accommodate curtailment or to require generation facility features that facilitate curtailment and utility control.

To better manage generation reserves, HECO will need to equip more of its existing conventional generators with automatic generation controls. Hawaiian utilities should consider modest limits for ramp control of VERs and should use contingency reserves for extreme wind events.

Two other barriers exist with respect to the regulatory rule changes (UL 1741 and IEEE 1547 safety standards) necessary to implement smart inverters and the business case development necessary to justify full Smart Grid implementation in Hawaii.

8.6 SECTION SUMMARY

HECO needs to demonstrate the usefulness of smart grid technologies to provide grid flexibility. The costs and benefits identified from these technology demonstrations will need to be analyzed and compared to each other. In some cases, cost recovery mechanisms will need to be adjusted to achieve implementation and in some cases incentives will need to be identified to achieve commercialization. Also, in some cases rule changes may be required and it may be necessary to provide education to improve awareness of customers, utilities and independent power producers.

Key technology demonstrations will be related to smart inverters, distribution system voltage control, provision of AGC to enable regulation, frequency response, reserves management, and overall system integration. Today, the greatest unknowns preventing the development of a set of implementation priorities are the costs for individual technologies and mechanisms and the information necessary to compare those costs. Once the information is available to establish priorities, the emphasis will switch to understanding and modifying cost recovery mechanisms, establishing appropriate incentives and identifying appropriate rule changes and education mechanisms.

A typical or representative sequence of barrier removal which applies to all technologies and mechanisms used to achieve electric system flexibility are the following.

- Conduct technological demonstration
- Evaluate and assess costs
- Determine cost recovery
- Establish incentives
- Identify and implement rule changes

- Provide necessary education mechanisms

9.0 Integration of Enabling Technologies

9.1 HOW MANY FLEXIBLE RESOURCES DO WE NEED?

This white paper identifies flexible resources that can help to integrate VERs. The implementation of storage options, interconnection of islands via the undersea cable and electric vehicle impacts are covered elsewhere. The discussion here relates primarily to EE, DR and the communications and control technologies required to implement EE, DR and other flexible resources. Since Smart grid and renewable energy integration demonstrations are still underway throughout the country, and Hawaii utilities have very unique utility systems with limited existing flexibility, it is unclear at this time which portfolio of flexibility technologies and mechanisms will work best, at least cost in Hawaii; but it is possible to generate an initial sequence of implementation that can serve as a starting point for future planning discussions and further investigations. This portfolio of flexible technologies and mechanisms will evolve over time and the sequence of implementation can change as new and additional Hawaii-specific information becomes available.

9.2 HOW DO WE SELECT THEM AND WILL THEY BE READY IN TIME?

While items can be eliminated or reprioritized in the future based on the results of demonstrations and economic analyses, it is acknowledged that most Smart Grid capability will be justified by reliability criteria, and economic savings potential achieved from energy efficiency, not on the criteria of DER integration. However, once that smart grid capability exists, it will be useful for DER integration (to enable the flexibility/reliability functions of new technologies and mechanisms).

9.3 A STRAW MAN ORDER OF GRID FLEXIBILITY OPTIONS

An implementation sequence is suggested below based on current knowledge about technology status and relative implementation costs. Items not particularly relevant to Hawaii, such as increased interconnection and expanded balancing areas are not included. This straw man sequence can serve as a starting point for planning discussions and further investigations:

- Use conventional fossil generation for regulation and contingency with Smart Grid enablers,
- Implement community and residential energy storage with Smart Grid enablers,
- Implement Smart Grid to improve distribution system operation and voltage/VAr control at the substations,
- Implement Smart Grid and smart inverters to allow voltage/VAr control along the distribution grid and at the DG,
- Implement Smart Grid with DR and smart appliance control,
- Integrate advanced forecasting and curtailment with smart inverter implementation and DR with Smart Grid enablers,
- Implement utility-scale energy storage with smart grid enablers, and

Deploy AMI to enable smart meter data gathering and provide a Smart Grid communication platform., and

- Utilize energy efficiency programs aggressively throughout this sequence

If the benefits and costs of any technologies are not quantifiable, or indicate reprioritization, based on demonstrations or other means, items in this sequence can be moved up or down in priority.. The first step would be getting experts to develop a consensus of the order of implementation and to develop a process for moving items on this list up or down in priority. Modeling can be conducted at appropriate times to assist in re-prioritizing the list.

In our straw man list above, reducing conventional fossil generation, adding pumped hydro storage and construction of the undersea cable are the likely bookends in terms of lead-time, cost, and curtailment mitigation effectiveness. Other options should be modeled/compared and their relative positions adjusted as sufficient data becomes available. At current penetrations, it is still cost effective to provide reserves with conventional resources/technologies. It is hypothesized that at scenarios with very high penetrations, storage and the undersea cable will be required. It is further hypothesized that implementation of other items listed above can progressively delay the need for storage and the undersea cable by pushing the time they are needed to higher and higher penetrations. It is not known if other techniques can totally eliminate the need for storage and the undersea cable; that will need to be determined by future studies of new techniques as they are developed.

10.0 Proposed Implementation Roadmap

10.1 WHAT ARE THE STEPS TO MAKE THESE FLEXIBILITIES AVAILABLE

The generalized steps required to assess the potential impact and implications of any particular Smart Grid enabling technology would follow an implementation roadmap:

- Demonstrate technologies' capabilities and effectiveness,
- Develop inter utility coordination process,
- Evaluate the technologies' costs and benefits,
- Determine cost allocation and recovery mechanism,
- Obtain regulatory approvals,
- Establish incentives (customer, utility and other stakeholders),
- Identify and implement rule changes,
- Implement deployment planning,
- Integrate solution into grid, and
- Provide necessary education mechanisms (e.g. utility, rate-payers, energy resources).

This sequence applies, with necessary modification, to all technologies and mechanisms used to achieve the electric system flexibility that is discussed in this report.

In addition to the assessment of the individual technologies, it is critical to understand and validate the synergies that result from the integration of the different Smart Grid solutions into a more holistic solution set. The integration and interaction of the individual solutions result in improved information, status and control capabilities across the utility and marketplace. The roadmap therefore must take into account how technologies interact and identify which are foundational to others. While there is flexibility in how solutions are implemented, there is a natural progression to some of the technologies and advanced applications.

In general, those enabling technologies and mechanisms that are the easiest to implement, have the lowest initial cost and are the most mature and proven will be implemented first and others will follow. The variation on this order occurs when alternative sequencing is necessitated by the interaction of multiple technologies or dependencies therein. The key is to identify the end state desired and to establish a sequence of intermediate states (See Figure 10-1) that provide for an orderly progression from the current state to the envisioned end state. The progress and benefits of this migration must be validated and adjustments made accordingly. By taking the approach of breaking the entire list of solutions into segments, it also allows HECO, customers, regulators and other stakeholders to be in a better position to understand, absorb and respond to the significant impacts of some of the Smart Grid technologies and advanced applications, and other enabling mechanisms.

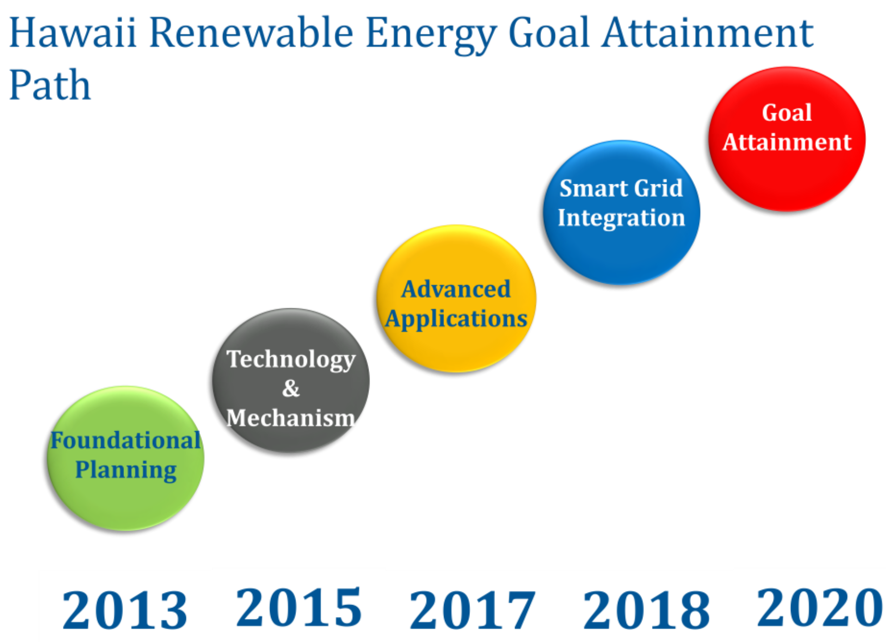

Figure 10-1 Strategic Plan Path Forward

The underlying solutions and mechanisms that comprise the straw man sequence above will undoubtedly change as demonstrations are successfully completed and implementation costs defined. An important consideration will be how much Smart Grid implementation is justified for curtailment and reliability purposes on the existing grid and how those costs will be allocated to developers and owners of the generation resources and ultimately rate-payers. At the moment, it appears that the option with the greatest lead-time and cost is the undersea transmission cable. Other options will be available sooner at lower cost and should be demonstrated and evaluated to adjust the straw man sequence.

The list below captures the Smart Grid technologies and advanced applications as well as other mechanisms that are recommended for evaluation to enable the levels of renewable energy desired in the Hawaiian Islands.

Smart Grid Enabling Technologies:

- Demand Response programs can combine proven load control programs for commercial and residential customers with more advanced load shaping solutions.
- Load shifting solutions such as Ice Storage solutions can better match energy requirements with off peak wind generation resources.
- Installation of AGC on existing conventional generation fleet can provide enhanced low power operation and improved ramping control.

- Distribution automation solutions can provide better monitoring and control of the distribution grid.
- Enhanced SCADA capabilities can provide more precise information on status of grid operating conditions and power flows.
- Smart Meter solutions can leverage AMI technology and MDMS applications b y collecting and making available meter and customer quality of service information.
- Static VAr (SVAR) technology & distributed static VAr compensation (DSVC) solutions can provide faster acting response to voltage disturbances
- Smart inverter technology on the renewable generation resources can improve grid stability.
- Advanced power electronics based distribution line voltage regulation can provide finer system status resolution and faster response capabilities.
- Island wide communications networks can support the collection of distributed data and control capabilities; multiple networks will be required to support the wide variation of service requirements.
- Microgrid integrated technology solutions can isolate problems and locally stabilze the grid.

Smart Grid Advanced Applications:

- ADMS solution in the HECO control centers (initially separate solutions on each island but eventually coordinated solutions when balancing areas are combined)
- The ADMS must be integrated into the existing HECO EMS solutions to ensure seamless and complete grid management.
- The ADMS brings curtailment mitigation, renewable energy and load forecasting, real-time load flow management and analytic and planning capabilities.
- FLISR implementation can improve grid reliability and resiliency and increase the availability of distributed resources.
- VVO application can respond to voltage fluctuations due to a more distributed generation profile on the distribution grid utilizing smart meter voltage data, DA information, SCADA information and analytic tools.
- DERMS module can integrates DER into the ADMS control paradigm.
- Foundational technologies and solutions can support HECO’s migration from the current grid operations to a DMS

Programs

- Customer Engagement solutions can provide a mechanism to provide information and notification to customers based on their desired configuration.
- AMI data can provide the basis for M&V analysis of EE solutions
- Enhanced rate programs can encourage load shifting to better match energy consumption with renewable resource generation

Regulatory and Policy Initiatives or Changes can:

- Allow demand response and demand shaping solutions to substitute for traditional reserve requirements,
- Determine fair cost allocation formulas that promote optimal adoption of Smart Grid solutions and
- Encourage the utilization of the State's priority Smart Grid solutions into HECO's plans.

The following Figure 10-2 presents a sequenced picture of these recommendations that support Hawaii meeting its HCEI goals.

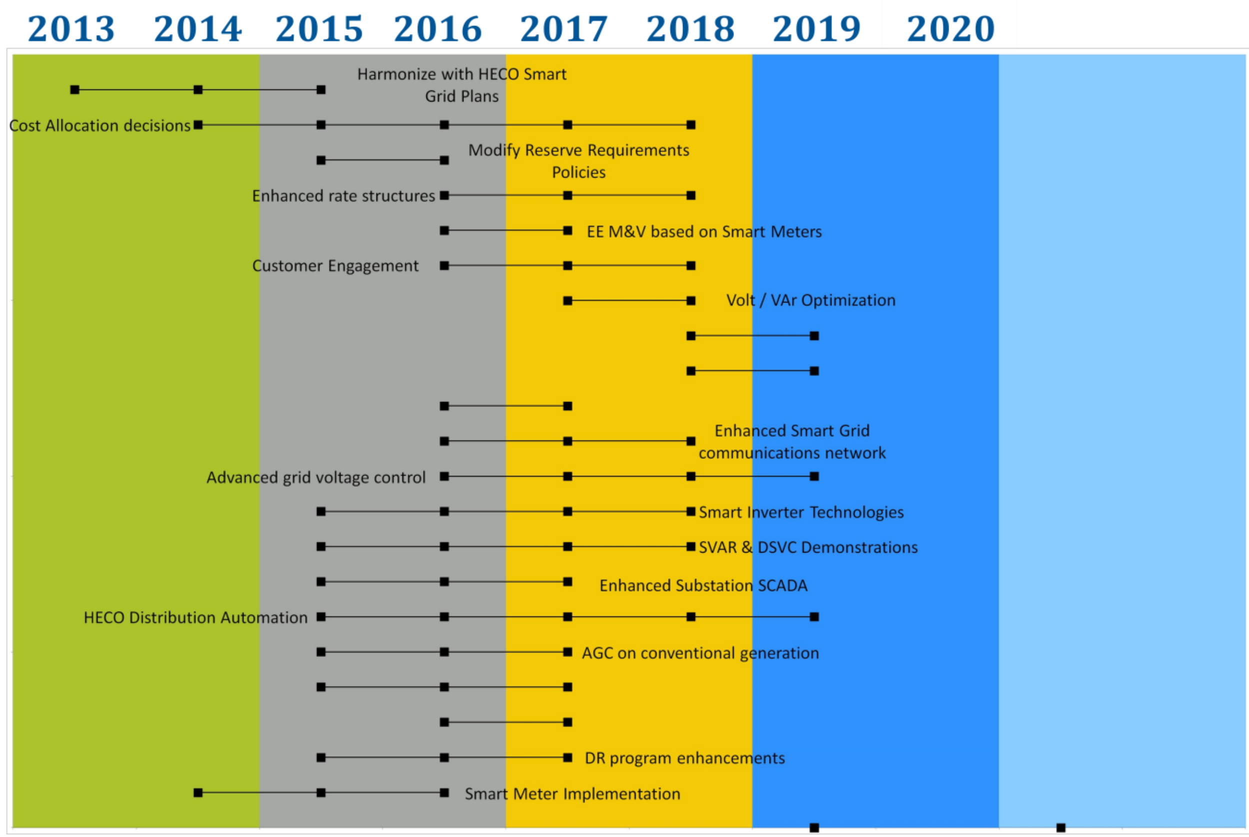

Figure 10-2 Recommended Smart Grid Solution and Enabling Mechanisms Sequencing

The above figure also illustrates the important sequencing and interdependencies of many of the technology solutions; the actual start dates and length of implementation can vary depending on regulatory rules and requirements, State policy initiatives, financial incentives and stakeholder effort,.

10.2 SOLUTION COSTS

Accurately estimating the costs, benefits and synergies of the recommendations included in this report are vital to prioritizing Smart Grid investments and to designing a detailed implementation strategy. Implementation details, and thus solution costs, are utility specific and have many dependencies. These dependencies include:

- The existing technology configuration in the utility – and in Hawaii, each HECO operating company'sconfiguration is different,
- Organizational design and change management capability of the utility, particularly regarding the ability and willingness to modify its current approach to innovation, job descriptions, and work practices,
- IT policies and standards related to the implementation and management of advanced applications, and
- The level of field force automation in existence at HECO that supports improved communications to and support of field workers and activities or planned that would integrate with the proposed technologies.

One of the first tasks identified in this white paper is to work closely with HECO to determine that relevant technology initiatives are underway or planned that would impact the value or implementation ability of the proposed solutions. This is also a critical component of understanding what unique conditions could exist that would impact costs and benefits of the proposed solutions.

While the quantification of detailed implementation costs and specific benefits of the various recommendations is outside the scope of this paper, a high-level understanding of some solution costs can be developed using industry standard costs and estimates.

Based on prior industry experience, order-of-magnitude estimates for some of the Smart Grid technologies identified herein are provided in Table 10-1 below:

Table 10-1 Smart Grid Solution Reference Cost Estimates

Smart Grid Technology	Cost Estimate
Smart Meter mass deployment	$100M
DMS initial implementation, including foundational systems work	$20M
MDMS implementation	$8M
DMS advanced applications	$10M
Distribution Automation	$50M

Costs associated with Substation SCADA, Distribution Automation and other technologies are difficult to estimate with any accuracy without taking into account unique conditions, design criteria and plans of HECO. The existing level of automation of the electric grid on the islands varies significantly with Maui and Hawaii having significantly more existing field automation than Oahu. Oahu however has more experience with the complexities of advanced applications and will be more prepared to implement these solutions without substantial changes in organization and resources.

The Smart Grid technologies and advanced applications identified herein also have many system reliability, operational, power quality and customer services benefits beyond those related to renewable energy support and penetration. These benefits range from such well defined and proven technologies as smart metering and distribution automation to those still being validated, such as VVO and DMS. It is not appropriate to estimate the benefits to HECO and the State of Hawaii without looking at specific HECO conditions and opportunities.

A recent study generated by GE for Hawaii's RSWG provides cost per kilowatt for a wide array of resource types.[106] In the overall spectrum of energy resource costs, the extremes are represented by energy storage and traditional generation. Storage enables energy to be consumed at a different time than it was generated. Since storage does not create energy, its cost is above and beyond the cost to generate the energy which is stored, resulting in one of the highest cost options. At the opposite end of the spectrum are traditional generation resources, which can provide low cost alternatives by operating existing resources more flexibly. Such flexibility could be changing the speed of ramping, or reducing the minimum operating load or similar operational changes. Depending on the existing generation type, age, original design, etc. such changes can potentially have a very minor initial cost and a very small change in O&M cost. Or, the costs may be larger but still relatively low compared to other approaches to adding system flexibility.

10.3 SECTION SUMMARY

The individual Smart Grid solutions do not operate in isolation but work cooperatively to create a more reliable and flexible electricity grid. These benefits and synergies are obtained by integrating the solutions together to share information and leverage capabilities. The relative sequencing of the solutions is important as the benefits envisioned will not materialize if required foundational solutions or necessary precursors are not implemented in advance. Given the length of time required to fully implement many of the recommended solutions, it is recommended that the actual demonstration activities, regulatory and financial analysis and project planning be performed in parallel even if actual project implementation may be sequenced. Given the uncertainties involved with many of the advanced technologies, it is essential that appropriate project integration and schedule risk be addressed. The recommendations as to roadmap content and schedule are provided based on our best current understanding of the challenges and barriers to be overcome as well as our assessment of the benefits, complexity and readiness or the various Smart Grid initiatives. The assumptions underlying these recommendations must be validated and where changes are necessary, modifications of the roadmap will be required.

[106] General Electric, "Ancillary Services Definitions and Capability study," Part 1, Tasks 1-2 Final Report, December 2012.

11.0 Summary of Overall Recommendations or Proposed Next Steps

Based on the assessment of existing and emerging technologies and programs, the barriers to their adoption, and possible solutions to overcome those barriers, this report provides recommendations that will help Hawaii realize the benefits of these technologies and programs to integrate high levels of as-available energy into the Hawaiian Islands' electric grids. The recommendations include:

- Identification of Smart Grid solutions that can enable renewable generation increases
- Changes to policies, regulations, programs and initiatives that support renewable generation
- A prioritization of technologies and programs having the greatest potential to help integrate large amounts of renewable energy into the grid, and
- A high-level road map for implementation of the recommendations.

The next steps required to promote these recommendations include the review of the recommendations in the broader context of research and recommendations undertaken on associated work efforts. A wider prioritization must be performed to identify the highest potential impacts and while Smart Grid solutions provide real enabling benefits, they must compete with other technologies and programs not covered in this report.

It is critical that the recommendations contained herein be shared with HECO and a dialogue developed to identify which Smart Grid technologies and advanced applications may already be part of technology roadmaps underway or envisioned at the HECO Companies and which are not being considered. For those solutions that already form part of HECO's Smart Grid roadmap and plans, the value to increased penetration of renewables can be derived and used to generate additional support for HECO's plans. Where there are gaps between what HECO is investigating and what is recommended herein, it will be necessary to bridge that difference. The coordination of the recommended Smart Grid technologies with HECO's current initiatives is a critical factor in implementation success and given the time required to integrate these technology opportunities, the timeline provided in this report for eventual implementation of these solutions will very likely lengthen.

12.0 Conclusion

This report presents the barriers and challenges to reaching the energy efficiency and renewable penetration goals of the Hawaii Clean Energy Initiative and the specifically goal of adding 1 GW or renewable generation capacity to the Oahu grid. The need for mechanisms to provide increased flexibility and enhanced reliability of the electric grid are presented as well as the benefits that these options provide. The potential of Smart Grid technologies and advanced applications to enable the desired renewable energy levels has been discussed along with a characterization of the commercial maturity and availability of the various solutions.

Many of the Smart Grid technologies presented have reached a level of technical maturity but have not attained a similar level of commercial maturity, at least as they relate to the costs and benefits associated with using the solutions for the purpose of supporting renewable generation. There is a need to work with HECO to build a broader business justification and benefit analysis for the Smart Grid solutions identified.

Some of the technologies require further demonstration of their effectiveness or robustness and it's important to keep in mind that technology is rapidly changing. Additionally, no utility has implemented the full range of Smart Grid solutions envisioned herein and consequently there is no real world example demonstrating an optimal mix of technologies on any particular grid. The complexity and organizational impact of integrating all the enabling technologies cannot be stressed enough. In addition to the technical issues of the solutions, therefore, the ability of HECO to implement the significant changes required and the ability and willingness of HECO's customers to pay for it must be determined.

Appendix A. Glossary of Abbreviations and Terms

AC - air conditioner

ACCEE - American council for an Energy Efficient Economy

AMI - Advanced Metering Infrastructure

Automatic Generator Control(AGC) - AGC systems control generators to increase or decrease electrical output to match changes in load. Changes in load are typically not predicted or scheduled and must be followed by generation reserve capacity that is online and grid-synchronized[107].

Ancillary Services - Broadly, ancillary services are the regulation and reserves utilities supply to reliably balance generation and load. However, ancillary services are controversial because they are defined and used differently in each regional market. They are dependent on the characteristics of the system. In fact, no one had heard of ancillary services before 1995 when FERC defined them to enable new electricity markets following utility deregulation. FERC defined ancillary services as those "necessary to support the transmission of electric power from seller to purchaser given the obligations of control areas and transmitting utilities within those control areas to maintain reliable operations of the interconnected transmission system". Others describe ancillary services as the functions performed by the equipment and people that generate, control, transmit, and distribute electricity to support the basic services of generating capacity, energy supply, and power delivery.[108] In 2012, HNEI sponsored, with support and guidance from the Hawaii RSWG, a study by General Electric to provide a standardized set of ancillary services, along with their associated definitions, to reflect the operation needs of the Hawaii system.[109]

AC - Alternating current

ACEEE – American Council for Energy Efficient Economy

AOS - Advanced Operating System

AMI – Advanced Metering Infrastructure

APS - Arizona Public Service

ARRA – American Recovery and Reinvestment Act

ASHRAE – American Society of Heating, Refrigeration, and Air Conditioning Engineers

AZ - Arizona

BA - Balancing Area

BAPV - Building Applied Photovoltaics

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[107] North American Electric Reliability Corporation (NERC), "Potential Reliability Impacts of Emerging Flexible Resources," NERC, Princeton, NJ, November 2010

[108] Eric Hirst and Brendan Kirby, "Electric-power Ancillary Services," Oak Ridge National Laboratory (ORNL/CON-426), Oak Ridge, Tennessee, February 1996.

[109] HNEI, "Report on Business Case in Hawaii for Storage Options," US Department of Energy, Office of Electricity Delivery and Energy Reliability, Honolulu, HI, October 2012.

BEEM - Business, Energy Efficiency, Measures

BESM -Business Service and Maintenance

BGE - Baltimore Gas & Electric

BHTR - Business Hard to Reach

BMS - Building Management Systems

CAES - Compressed Air Energy Storage

CA-ISO – California Independent System Operator, the independent system operator for the CA electric grid

Capacitor – an energy storage device used on electric distribution systems that provides voltage support to the grid by injecting reactive power during voltage fluctuations

CBEEM - Customer, Business Energy Efficiency Measures

CHP - Combined Heat and Power

CIDP - Commercial & Industrial Dynamic Pricing Program

CPP - Critical Peak Pricing

CPR - Critical Peak Time Rebate

CPUC - California Public Utility Commission

CVR - Conservation Voltage Reduction or Regulation

C &I – Commercial and Industrial

DA -Distribution Automation

DADS -Demand Response Availability Data System

DC - Direct Current

DG - Distributed generation

DMS -Distribution management system

Distributed Generation(DG) - What constitutes distributed generation is not perfectly defined in the industry; however, it is generally understood to consist of electric power resources connected to the distribution system and frequently limited in size, for example not larger than 20MW.

Demand Response (DR) - Systems that react to signals from utilities or third parties designed to shed load under predefined conditions, for specific periods of time and in response to either pricing or reliability disruptions

Demand Response 2.0 - Next generation demand response

DER - Distributed Energy Resource

DERMS - Distributed Energy Resource Management System, Provides an integrated management application for distributed energy resources on the distribution grid. It may be a stand-alone application or a module in a DMS solution.

DLC - Direct Load Control

DOE – Department of Energy

DSM - Demand Side Management

DMS - Distribution Management Systems

DSVC - Distributed Static VAr Compensation

EE - Energy efficiency

EEPS - Energy Efficiency Portfolio Standard

EOSP -East Oahu Switching Project

EOTP – East Oahu Transmission Project

EIA - Energy Information Administration

EILS - Emergency Interruptible Load Service

EMS - Energy Management System

EPRI - Electric Power Research Institute

ES -Energy Storage

ESMIG - European Smart Metering Industry Group

ESB -Enterprise service buses

EV - Electric vehicle

ERCOT - Electricity Reliability Council of Texas

FERC -Federal Energy Regulatory Commission

Flexibility/ Reliability Functions - Traditionally utility system operators have obtained most of the system flexibility and stability support from the performance capabilities of and specific services provide by traditional generators. When these flexibility/reliability functions are provided within a regional market, they may be designated as ancillary services.[110]

Flexible Resources - Sources of system flexibility, examples of newly emerging sources of system flexibility are DR, energy storage and electric vehicles.[111]

FLISR - Fault Location Isolation and Service Restoration, a module in the new evolution of DMS solutions

FPL - Florida Power & Light

GIS -Geographic Information System

GW - Gigawatt

HAN - Home Area Network

HCEI - Hawaii Clean Energy Initiative

HECO - Hawaiian Electric Company

HELCO - Hawaii Electric Light Company

HNEI - Hawaii Natural Energy Institute, School of Ocean and Earth Science and Technology, University of Hawaii.

ICE - Internal Combustion Engine

Ice Storage – A load shifting solution that makes ice during off peak periods and uses the stored cooling capability for air conditioning during peak electricity usage periods.

IED -Intelligent Electronic Devices_

IECC - International Energy Conservation Code

IESNA – Illumination Engineering Society of North America

IEEE - Institute of Electrical and Electronics Engineers

IED – Intelligent Electronic Device

IHD - In-Home Display

IOU - Investor Owned Utility

IPP - Independent Power Producer

[110] North American Electric Reliability Corporation (NERC), "Potential Reliability Impacts of Emerging Flexible Resources," NERC, Princeton, NJ, November 2010
[111] North American Electric Reliability Corporation (NERC), "Potential Reliability Impacts of Emerging Flexible Resources," NERC, Princeton, NJ, November 2010

IRP - Integrated Resource Plan

ISO -Independent System Operator

IT - Information technology

KIUC -Kauai Island Utility Cooperative

KW - Kilowatt

LAARs - Loads-Acting-As Resources

LBNL -Lawrence Berkeley National Laboratory

LED -Light Emitting Diode

LTC - automatic Load Tap Changing transformer

Market Transformation - The term market transformation is the strategic process of intervening in a market to create lasting change in market behavior by removing identified barriers or exploiting opportunities to accelerate the adoption of all cost-effective energy efficiency as a matter of standard practice (ACEEE).[112]

MECO -Maui Electric Company

MW -Megawatt

M&V - Measurement and verification

MDMS – Meter Data Management System

NERC - North American Electric Reliability Council

NPV – Net Present Value

Net Present Value Positive for energy efficiency – If the expected annual energy savings over the life of a project, discounted back in time by an appropriate discount rate, is greater than the initial energy investment, the NPV of the project will be positive.

OG&E - Oklahoma Gas and Electric

OpenADR – industry standard making organization for Auto Demand Response

OMS - Outage management system

PBF - Public Benefit Fund

PCT - Programmable Communicating Thermostat

[112] American Council for an Energy Efficiency Economy (http://aceee.org/portal/market-transformation)

PJM - Pennsylvania, New Jersey, Maryland energy market

PEV - Plug-in Electric Vehicle

PG&E - Pacific Gas & Electric

PHEV – Plug-in Hybrid Electric Vehicle

PUC - Public Utility Commission

PV - Photovoltaic

Ramping - large changes in electricity generation, for example solar or wind generation

Recloser – also known as an autorecloser, is a circuit breaker which can automatically close the breaker after it has opened due to a fault; used to interrupt momentary faults on overhead distribution lines.

REEM - Residential Energy Efficiency Measures

Regulator – a device used in substations or on the distribution grid that provides voltage regulation capability by adjusting taps on an internal transformer to change the transformer ratio between high and low sides of the regulator.

Regulation - Refers to continuous response of reserves under Automatic Generation Control (AGC) that are deployed to correct minute-to-minute deviations in system frequency or to return system frequency to the desired range following system disturbance. Regulation is a FERC defined service, most frequently obtained from energy markets.

Reliability Standards Working Group (RSWG) - In 2010, the Hawaii Public Utilities Commission indicated its intent to establish a RSWG; that group began working together in July 2011. Since that time the RSWG has been meeting and working diligently to produce policy and technical recommendations that will facilitate the increased use of renewable energy in the islands without compromising grid reliability. As of mid-December 2012, the RSWG members had made a significant amount of progress towards developing a shared, sophisticated technical understanding of the relevant issues and developing specific work products that can help the state's utilities, generators, and other stakeholders operate the grid with high reliability and high levels of renewable generation.

REP – Retail Energy Provider, term used in Texas

RF -Radio Frequency

RESM - Residential Energy Services and Maintenance

RHTR - Residential Hard to Reach

RTO - Regional Transmission Operator

RTP -Real Time Pricing

SCE - Southern California Edison

SDG&E - San Diego Gas & Electric

SCADA -System Control & Data Acquisition

SEGIS - Solar Energy Grid Integration System

SMUD - Sacramento Municipal Utility District

SRP - Salt River Project

Smart Grid - a term referring to the collection of enabling technologies and advanced applications that are based on digital technologies and provide a two-way flow of information to better monitor and manage the electric grid.

System Flexibility - System Flexibility is defined as the ability of supply-side and demand-side resources to respond to system changes and uncertainties.[113]

SVAR -Static VAr technology

TES - Thermal Energy Storage

TOU - Time of use

TRM - Technical Resource Manual

TVA - Tennessee Valley Authority

UL - Underwriters Laboratories

USB - Universal Serial Bus

VaasaETT – an energy think-tank and consultancy focusing on issues relating to customer behavior and psychology in energy and utilities markets.

Variable Energy Resource (VER) - Renewable energy generation resources such as wind and PV use weather-dependent fuel, the availability of which can vary over time. VERs are generators that vary output as the local renewable energy resource increases or decreases.

VAr - volt-ampere reactive; also written as "Var," "VAR," or "var."

VVO - Volt/VAr optimization

WiFi - a wireless local area network (LAN) open standard technology based on the IEEE 802.11 standard

[113] North American Electric Reliability Corporation (NERC), "Potential Reliability Impacts of Emerging Flexible Resources," NERC, Princeton, NJ, November 2010

ZigBee - ZigBee is a wireless open standard technology for low-cost, low-power wireless networks. The ZigBee standard operates on the IEEE 802.15.4 physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz.

Appendix B. Power Generation Resource Mixes

	ISLAND OF HAWAII	ISLAND OF MAUI	ISLAND OF OAHU	ISLAND OF KAUAI
Utility Name	HELCO	MECO	HECO	KIUC
Firm Capacity	287 MW	262MW	1,756 MW	125 MW
Units	Puna Geothermal Ventures (27 MW off-peak, 30 MW on-peak)(No droop response, off AGC) Three steam units: Hill 5 14 MW, Puna 15 MW, and Hill 6 20 MW (AGC) 35.5MW One combined cycle unit: HEP 28.5 MW (AGC)Two small steam units (Shipman 3&4, 7.5 MW each) operated 2 shifts (AGC) The second train of HEP (in this configuration, produces up to 60 MW) (AGC) Three simple cycle gas turbines (CT3, CT4, CT5 20 MW each) (AGC) Peaking/emergency units 14 small diesels (nine 2.5 MW, four 1 MW, one 2 MW) (off AGC, remote start) Two simple cycle gas turbines (CT1 11 MW, CT2 14 MW) (AGC)	Kahului Power Plant 4 steam units 35.9 MW Hana Substation 2 DG Diesel Engines 1.94 MW Maalaea Power plant 15 Diesel Units 2 Dual train Combined Cycle Units 208.4 MW IPP Puunene Mill 3 steam turbines, firm baseload 12 MW	Honolulu oil 113 Waiau oil 499 Kahe oil 651 CIP oil 113 IPPs H-Power waste to energy 73 MW Kalaeloa Partners oil 208 MW AES-Hawaii coal 180 MW	Port Allen Diesel D1 & D2: 4 MW Port Allen Steam Turbine S1: 10 MW Port Allen D3-5: 8.2 MW Port Allen Combustion Turbine GT1: 19.2 MW Port Allen Combustion Turbine GT2: 23.7 MW Port Allen Diesel D6 & D7: 15.7 MW Port Allen Diesel D8 & D9: 15.7 MW Kapaia Steam Injected Gas Turbine: 27.5 MW Waihi Hydro: 0.5 MW