STATE OF HAWAII MARKET POTENTIAL STUDY

August 5, 2020

Report prepared for:
HAWAII PUBLIC UTILITIES COMMISSION

Energy Solutions Delivered.

This report was developed by

Applied Energy Group, Inc.
500 Ygnacio Valley Blvd., Suite 250
Walnut Creek, CA 94596

Project Director: I. Rohmund
Project Manager: K. Parmenter
Task Lead: K. Kolnowski

With support for demand-side rates analysis from

The Brattle Group
201 Mission Street, Suite 2800
San Francisco, CA 94105

Task Lead: A. Faruqui

in consultation with the Hawaii Public Utilities Commission

Chief of Policy and Research: D. Parsons
EE Program Manager: A. Norman

and the Energy Efficiency Manager team

Project Team Lead: T. Pope
PBF EM&V Lead: S. Schiller
Support Team: J. Fox
J. Mitchell-Jackson
M. Sutter

EXECUTIVE SUMMARY

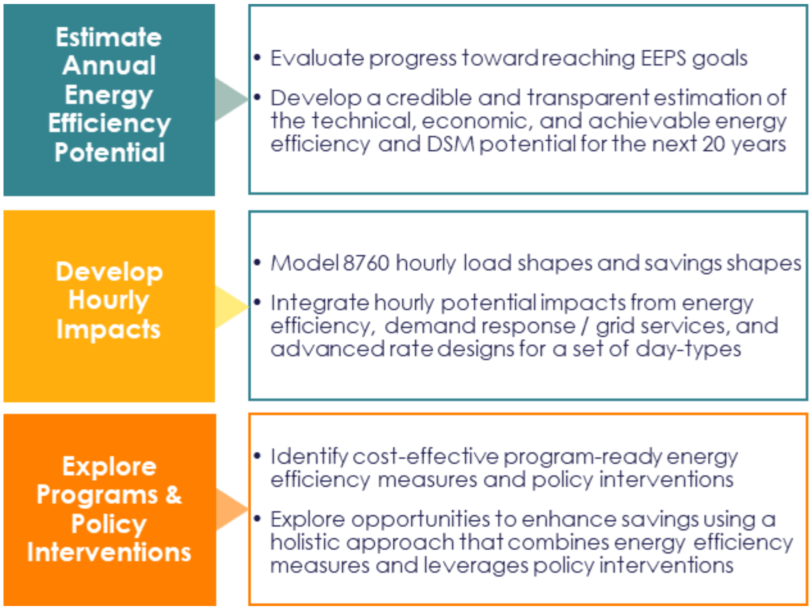
The Hawaii Public Utilities Commission (HPUC) contracted with Applied Energy Group (AEG) to perform a comprehensive market potential study (MPS) to assess the potential for future savings from energy efficiency programs and other interventions.

Goals of Study

The goals of the MPS are as follows:

- Evaluate the current status relative to the Energy Efficiency Portfolio Standard (EEPS) target and paths to continue to reach EEPS goals
- Quantify the landscape of energy efficiency and demand side management (DSM) over the next 20 years
- Provide a foundation to consider future programs and other interventions holistically

The figure to the right combines these primary goals with several secondary goals.



Estimate Annual Energy Efficiency Potential

- Evaluate progress toward reaching EEPS goals
- Develop a credible and transparent estimation of the technical, economic, and achievable energy efficiency and DSM potential for the next 20 years

Develop Hourly Impacts

- Model 8760 hourly load shapes and savings shapes
- Integrate hourly potential impacts from energy efficiency, demand response / grid services, and advanced rate designs for a set of day-types

Explore Programs & Policy Interventions

- Identify cost-effective program-ready energy efficiency measures and policy interventions
- Explore opportunities to enhance savings using a holistic approach that combines energy efficiency measures and leverages policy interventions

Background

The Hawaii MPS builds on and updates HPUC's 2014 Potential Study and 2019 EEPS Review Research, both of which were completed by AEG.[1,2] Using the resources from the previous studies as a starting point, AEG updated the analysis to reflect current circumstances and conditions. This report documents the MPS and provides estimates of the historic and future potential reductions in annual cumulative persistent energy savings for the time periods of 2009-2030 (EEPS horizon) and 2020-2040 (twenty-year forecast of energy efficiency potential). Additional outcomes include end-use load shapes and 8760 hourly models of potential impacts from energy efficiency, advanced rate designs, and demand response and grid services (DR/GS), as well as an assessment of policy and / or program interventions to optimize savings.

To gauge progress towards EEPS, the MPS needs to account for accomplishments since 2009 and forecasts of potential through 2030. The energy market looked very different in 2009 and much has changed since the 2014 Potential Study was completed:

- Hawaii has seen over a decade of federal and state codes and standards.
- New technologies have come on the market that impact how customers use and interact with energy (LEDs, connected devices, etc.).

---

[1] State of Hawaii Energy Efficiency Potential Study, Prepared for the Hawaii Public Utilities Commission, Prepared by Applied Energy Group (dba EnerNOC Utility Solutions Consulting), 2014.

[2] EEPS Review Research Report, Prepared for the Hawaii Public Utilities Commission, Prepared by Applied Energy Group, February 2019.

- Solar photovoltaic (PV) penetration has grown substantially.
- Energy efficiency programs have helped customers make their buildings more efficient.

Hawaii Considerations

To ensure the MPS addressed the appropriate set of issues and objectives relevant to Hawaii today, AEG worked with the HPUC, the Energy Efficiency Manager (EEM) and other stakeholders (collectively referred to as the MPS working group, or MPSWG) to define important aspects to consider for the Hawaii MPS. Figure ES-1 summarizes the key features to consider for the study as defined by the MPSWG. Some of the most important considerations for the MPS are Hawaii's unique market needs and the transforming landscape of energy efficiency, distributed energy resources (DERs), and policy that will define the State's energy future regarding the 2030 EEPS target, as well as beyond 2030.

Figure ES-1 Key Features of the Hawaii MPS

CUSTOMER SEGMENTATION

- By island
- Sector, housing / building type, income level for residential
- Presence of distributed energy resources (DERs) by tariff

TECHNOLOGIES & MEASURES

- Cast a wide net
- Include integrated demand-side management (iDSM), emerging technologies, electric vehicles (EVs) and DERs

CODES & STANDARDS (C&S)

- Building codes and appliance standards
- Include those "on the books"
- Consider additional C&S as sensitivity

NON-ENERGY BENEFITS (NEBS)

- Use the total resource cost (TRC) as the primary cost-effectiveness test
- Include NEBs that can be easily quantified

ANNUAL AND HOURLY ANALYSIS

- Technical, technical achievable, economic and economic achievable
- Estimate impacts of various DSM resources at the hourly level

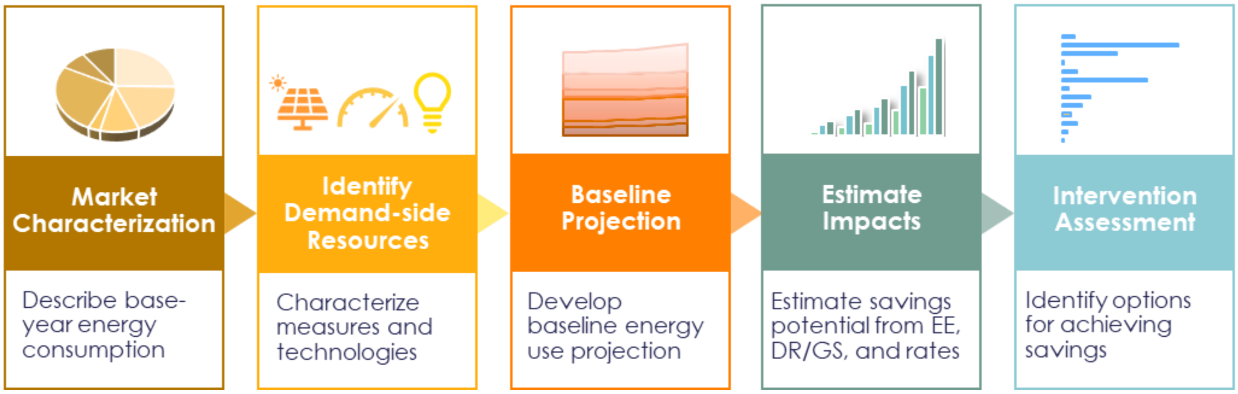
EXPANDED SET OF METRICS

- 1st year & cumulative persistent energy savings
- Load shapes and impact shapes by day-type
- Peak demand savings

Analysis Approach

To produce reliable and transparent estimates for the Hawaii MPS, AEG performed the five main steps shown in Figure ES-2.

Figure ES-2 Key Features of the Hawaii MPS



Market Characterization

Describe base-year energy consumption

Identify Demand-side Resources

Characterize measures and technologies

Baseline Projection

Develop baseline energy use projection

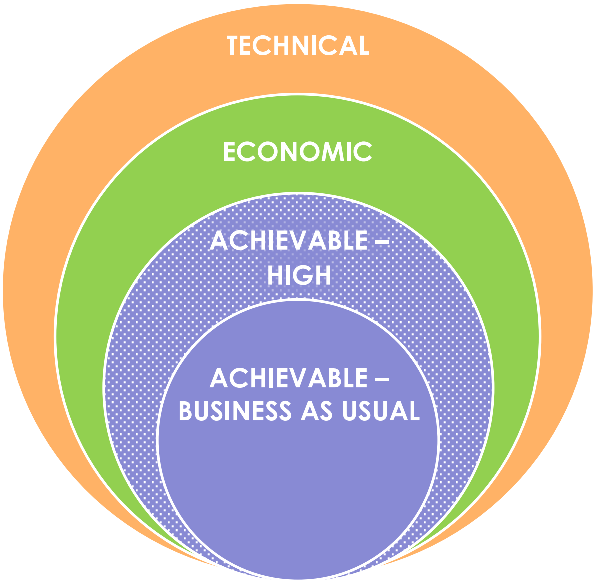
Estimate Impacts

Estimate savings potential from EE, DR/GS, and rates

Intervention Assessment

Identify options for achieving savings

During this process, AEG estimated four levels of energy efficiency potential at the measure level through 2030 to gauge progress towards EEPS, as well as through 2040 to provide a foundation for future program considerations:



- Technical potential: The theoretical upper limit of efficiency potential. It assumes that customers adopt all feasible measures regardless of their cost or customer preference.
- Economic potential: Subset of technical potential that includes only cost-effective measures based on total resource cost test (TRC). Customers are assumed to purchase the most cost-effective option applicable at any decision juncture.
- Achievable potential: Subset of economic potential that accounts for likely customer adoption of energy efficiency measures. It refines economic potential by applying customer participation rates that account for market barriers, customer awareness and attitudes, program maturity, and recent program history. There are two levels of achievable potential.
    - High: Assumes higher levels of participation where additional opportunity is identified as well as expanded programs, future (new) state and federal codes and standards, future market effects, and other future interventions.
    - Business as usual (BAU): Assumes gradual maturation of future interventions which are similar to those in the market today.

In addition to these four levels of potential, we also estimated technical achievable, a subset of technical potential that accounts for likely customer adoption of energy efficiency measures without consideration of costs. Technical achievable estimates are often calculated to support integrated resource planning (IRP). While IRP planning is not a consideration for this study, achievable technical potential is useful for understanding how much savings non cost-effective measures might provide, as is the case in the analysis of demand response and grid services (DR/GS)[3].

AEG first conducted the energy efficiency potential analysis at the annual level and then expanded the modelling to include 8760 hourly load analysis of energy efficiency, advanced rate designs, and DR/GS. The rate design analysis involved developing several time-varying rates for the residential and commercial classes in Hawaii and estimating potential impacts. These rates reflect the sales profiles of these two classes in Hawaii and were designed to recover the same revenue as the rates that are in place today. The DR/GS analysis built upon a recent DR Potential Study conducted by Navigant for HECO to estimate potential hourly impacts for five types of DR/GS options. AEG modelled the hourly impacts for each DSM resource as a separate, stand-alone category and then “stacked” the resources, accounting for interactions between the resources. The stacked impacts represent the overall technical achievable potential of integrated DSM (iDSM).

---

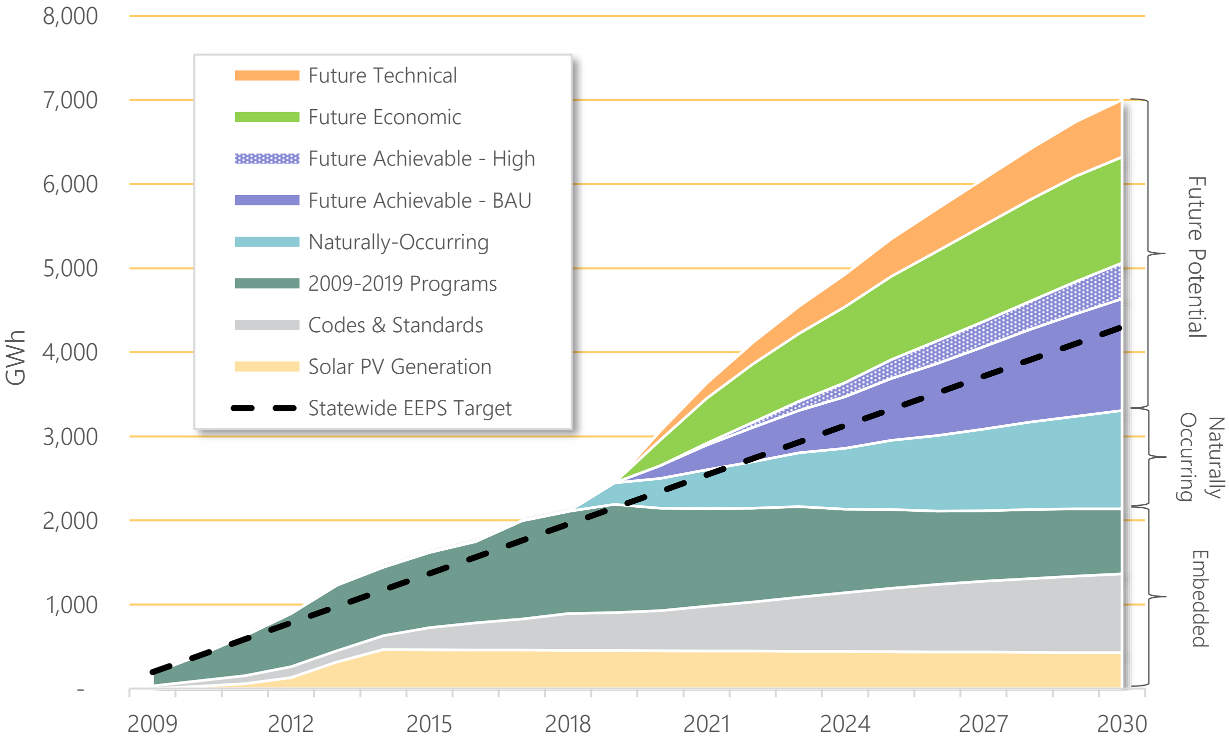
[3] In addition, programs typically consist of bundles of measures that may include both cost-effective and not cost-effective, as long as they are cost-effective when combined.

Lastly, AEG assessed potential impacts from programs and policy interventions. During this process, we reviewed the measure-level results to develop a list of the most impactful measures, characterized how each measure potentially meets a set of key metrics, defined four possible intervention options, and recommended how to categorize each measure into one of the four intervention options.

Key Findings

Figure ES-3 presents the cumulative persistent savings over the entire EEPS horizon of 2009 through 2030. The graph shows that the interim EEPS target was met through 2018 and the 2030 target is projected to be achievable under a business as usual (BAU) scenario. While Hawai'i Energy's portfolio has historically provided the majority of the EEPS savings, other entities also contribute to achieving the EEPS goals: Commission Regulated Entities[4] and Non-Regulated Entities.[5] Therefore, attainment of this goal will require continued contributions by all of these entities at a similar level as in recent years, which may necessitate additional efforts in the short-term to recover from the effects of the COVID-19 pandemic on "business as usual" for energy efficiency programs and the economy, in general.

Figure ES-3 Cumulative Persistent Energy Savings (GWh), 2009-2030, EEPS Perspective



These estimates reflect the change to the EISA standard that took place in late December 2019, which essentially removed the second tier of the standard[6]. The effect of this change was to shift savings that

---

[4] Commission Regulated Entity savings include savings from utility administered and third party administered energy efficiency programs. The bulk of these savings are anticipated to be provided by Hawai'i Energy and Kauai Island Utility Cooperative (KIUC).

[5] Non-Regulated Entity savings include savings from legislative mandates, non-profits, other coordinated programs, building codes, and federal, state, and local appliance standards.

[6] On December 27, 2019, the U.S. Department of Energy issued a final ruling stating that the efficiency standards for GSILs do not need to be amended; therefore, the backstop did not go into effect as originally planned. (Tier 2 of EISA called for a 45 lm/W minimum efficacy backstop for general service incandescent lamps (GSILs), which was subject to an effective date of January 1, 2020.) This means that potential

would have been attributed to appliance standards (Codes and Standards savings) to savings that could be achieved through programs and/or other interventions. Care should be taken when comparing these results with other potential studies completed in the same timeframe as the assumptions around EISA Tier 2 might be different than those used here.

Table ES-1 presents total cumulative persistent energy savings (cumulative savings[7]) potential estimates for the State of Hawaii for selected years through 2040. In 2020, achievable potential - BAU energy savings are 150 GWh or 1.5% of the baseline forecast. By 2040, cumulative persistent energy savings are 2,262 GWh or 20.6% of the baseline forecast for the achievable potential - BAU case.

Figure ES-4 and Figure ES-5 present the cumulative persistent energy savings and the baseline forecast as compared to each potential projection, respectively. Potential estimates in the later years flatten as ramp rates approach maturity and measure saturations reach maximum adoption. By 2040, cumulative savings for the achievable potential - high case are 3,089 GWh or 28.2% of the baseline forecast.

Table ES-1 Cumulate Savings Potential Summary (GWh), All Sectors, All Islands – Select Years

	2020	2025	2030	2040
Baseline Forecast (GWh)	9,790	9,982	10,132	10,955
Cumulative Savings (GWh)				
Achievable Potential - BAU	150	737	1,329	2,262
Achievable Potential - High	150	963	1,755	3,089
Economic Potential	455	1,951	3,014	4,125
Technical Potential	563	2,399	3,695	5,088
Energy Savings (% of Reference Baseline)				
Achievable Potential - BAU	1.5%	7.4%	13.1%	20.6%
Achievable Potential - High	1.5%	9.6%	17.3%	28.2%
Economic Potential	4.6%	19.5%	29.8%	37.7%
Technical Potential	5.7%	24.0%	36.5%	46.4%

---

savings from lightbulbs fall outside of codes and standards and a portion of those savings are available for future programs, while a portion is allocated to future naturally occurring savings.

[7] Throughout this report the labels “energy savings” and “cumulative savings” represent and are equivalent to cumulative persistent energy savings.

Figure ES-4 Statewide Cumulative Savings Potential Summary (GWh)

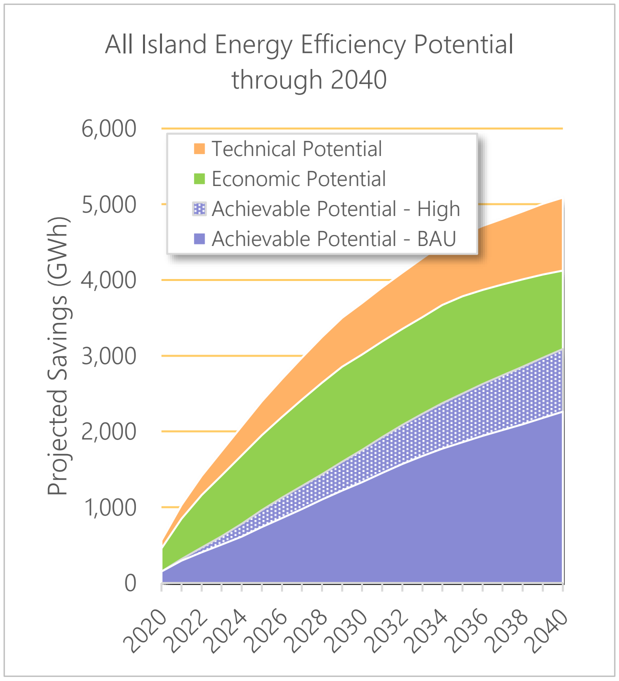


Figure ES-5 Statewide Baseline and Potential Forecasts (GWh)

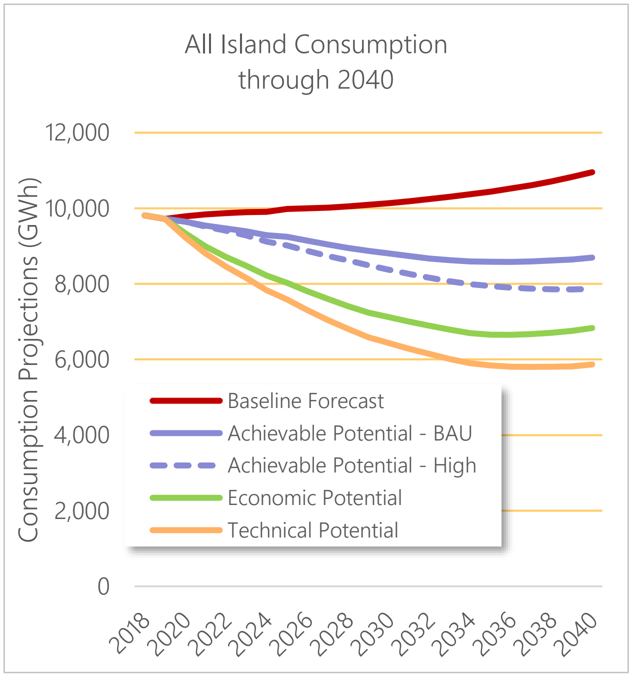


Figure ES-8 shows relative savings by island and military as percent of baseline and shows relative consistency among islands. Military achievable is lower due to barriers to adoption. Figure ES-7 shows that Oahu has the highest potential (Maui includes Molokai and Lanai). The energy savings potential by island correlates with the electricity consumption by island. The electricity consumption in Oahu is greatest because of significantly more homes and commercial building floor area for the base year of 2018.

Figure ES-6 Cumulative Savings Potential Summary by Island (% of Baseline)

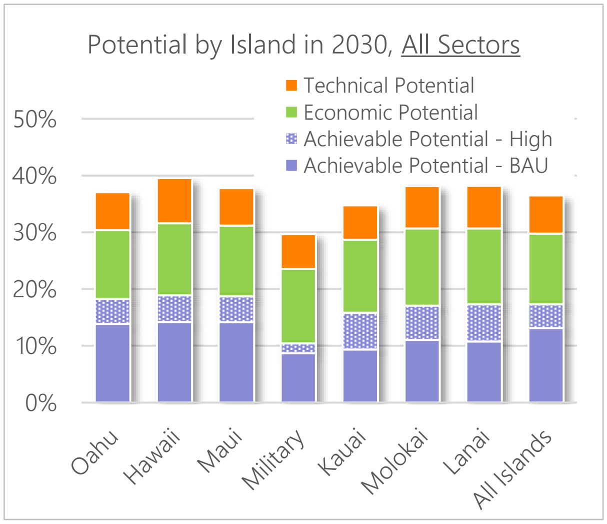


Figure ES-7 Achievable High Potential by Island and Military (GWh)

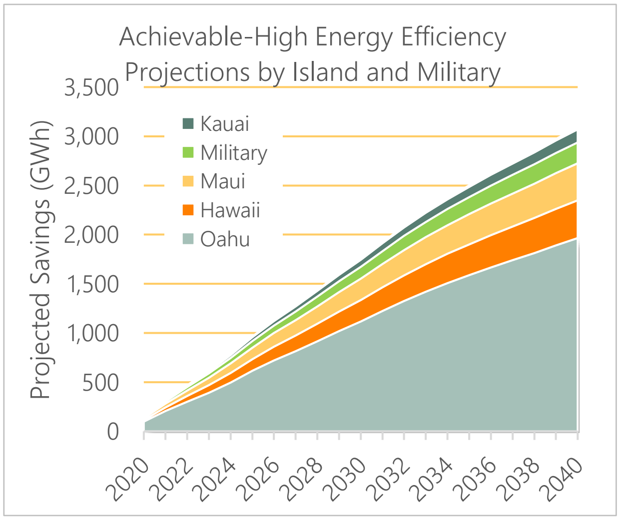


Figure ES-8 presents the cumulative savings potential by island in 2040. The end-use composition of the achievable potential savings are fairly consistent across the islands. Variation among end uses is small and is explained by the saturation of end-use technologies. That is, higher saturation of air conditioning results in higher potential for savings from cooling-related measures. Appendix A includes detailed results by island.

Figure ES-8 Cumulative Savings Potential Summary, by Island and for the Military (GWh)

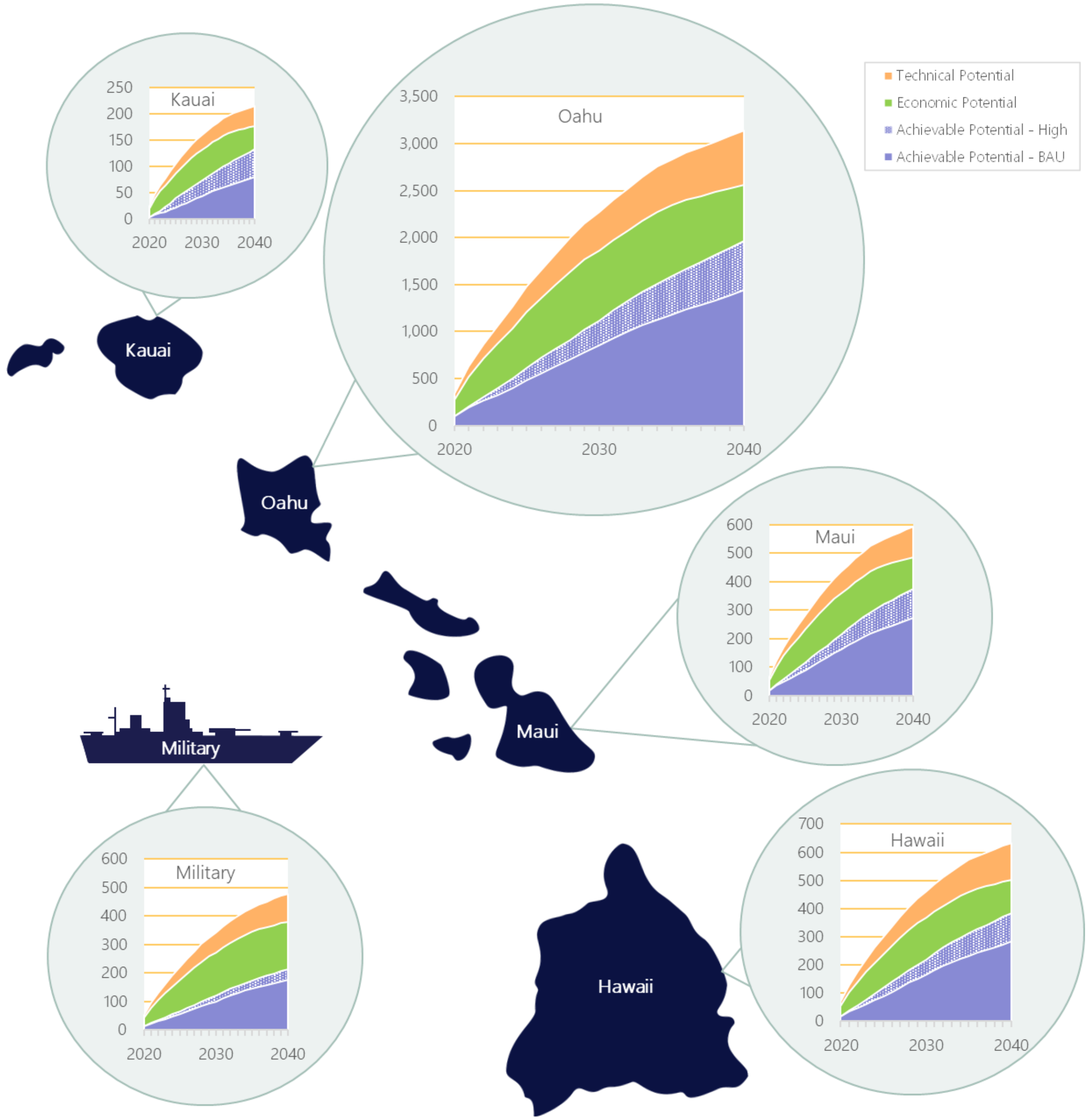


Figure ES-9 presents achievable potential - high by sector, showing that commercial sector savings projections are greater than those for the residential sector. This is consistent with trends in the industry as a result of impactful savings from a long list of appliance standards. These sector-level results include military facilities.

While absolute savings potential is higher for the commercial sector, savings as a percent of the baseline are higher in the residential sector as shown in Figure ES-10. This means that potential savings as a percent of overall usage could have a greater impact on customer bills in the residential sector.

The subsections below describe the sector-level and island-level results in more detail.

Figure ES-9 Achievable-High Potential Forecast by Sector (GWh)

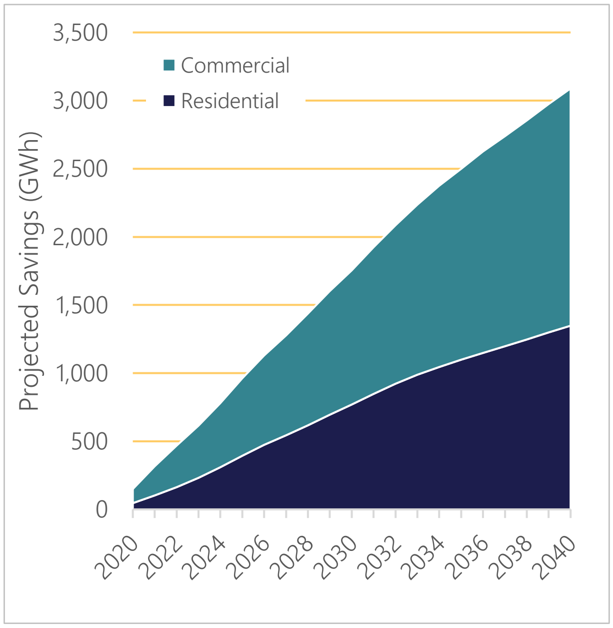
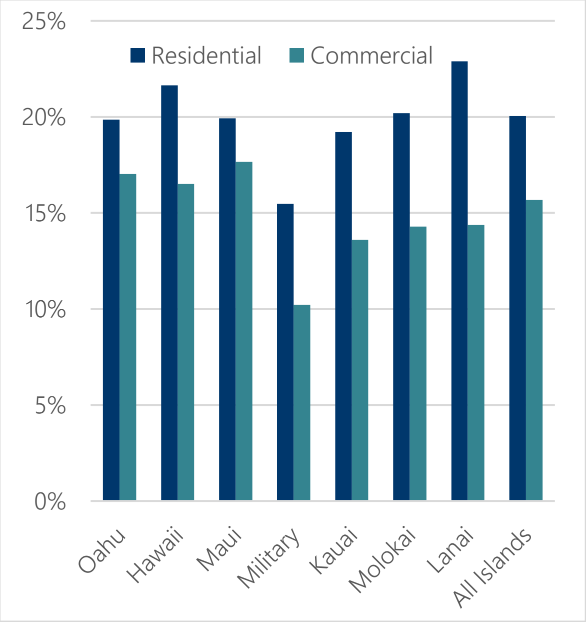


Figure ES-10 Achievable-High Potential by Sector in 2030 (% of Baseline)



The analysis found that a handful of residential and commercial measures account for the majority of savings in each sector. Figure ES-11 and Figure ES-12 show the projected savings for residential and commercial measures that contribute more than 50 GWh of cumulative persistent energy savings in 2030.

- Residential sector. The residential measure with greatest savings is solar water heaters, which pass the cost-effectiveness test throughout the study time horizon even though the federal tax credit is phased out. However, even with the tax credit, solar water heaters require a substantial investment, which limits adoption and achievable potential. The high growth in baseline cooling saturations through 2030 in regular-income homes[8] is driving the air conditioning potential. All but the most efficient ductless air conditioners pass the cost-effectiveness test. In addition, connected home control systems include connected thermostat savings, which are cost-effective in most applications.
- Commercial sector. Lighting end uses are represented in four of the top six commercial measures. A combination of high end-use intensity and popularity in programs is driving the lighting savings. The top measures include linear LED lamps (TLEDs) and LED fixtures plus controls.

---

[8] Low- and medium-income (LMI) homes have a much lower saturation of air conditioning so have much lower potential savings from this end use. Relatively speaking, the savings from lighting and water heating are higher in LMI compared to regular income.

Figure ES-11 Top Residential Measures, All Islands -Cumulative Savings in 2030 (GWh)

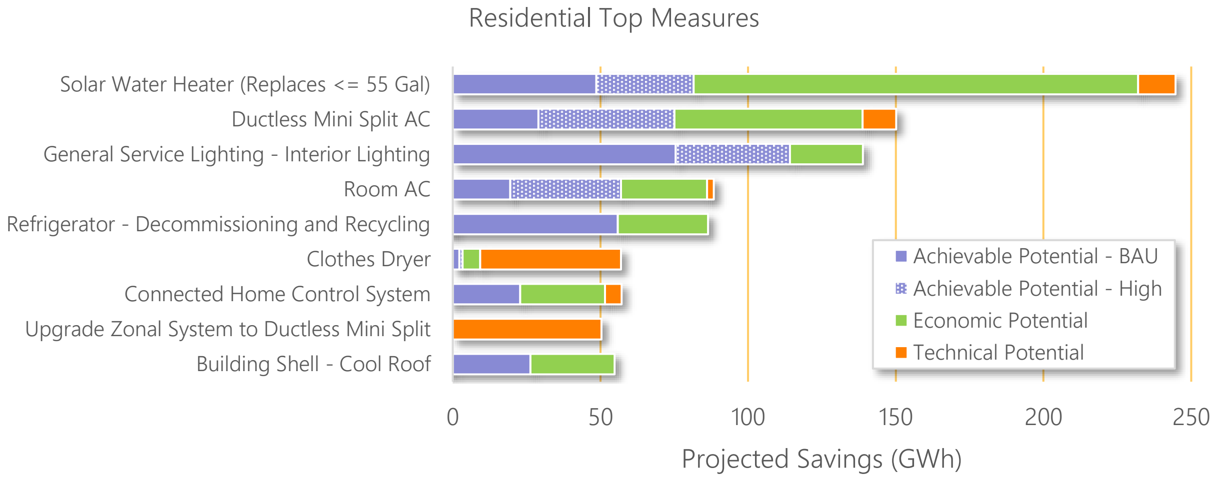
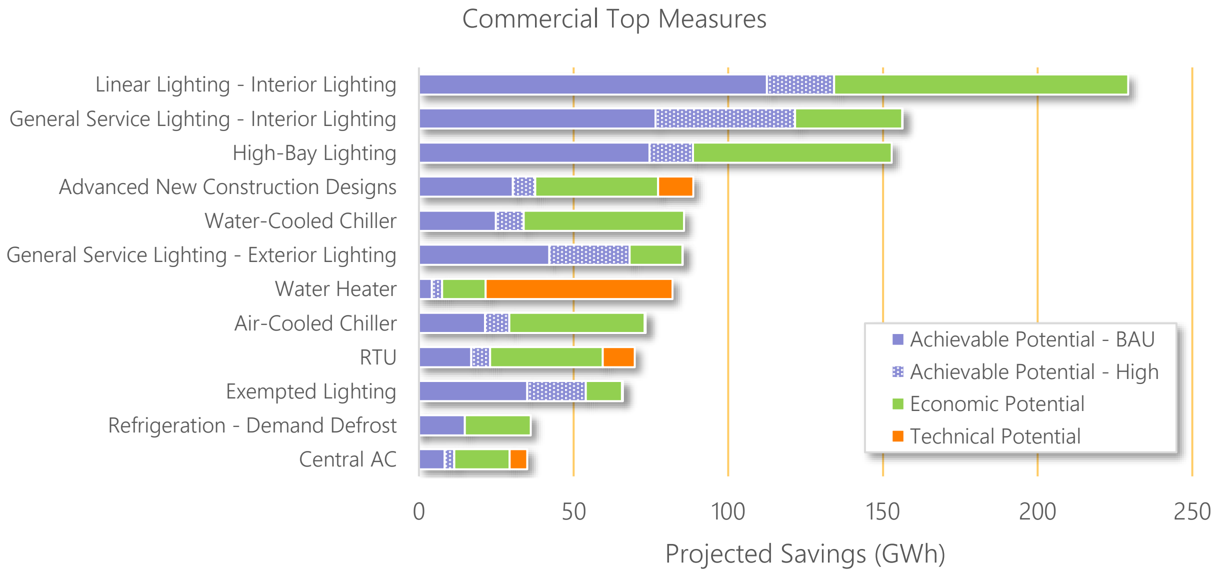


Figure ES-12 Top Commercial Measures, All Islands -Cumulative Savings in 2030 (GWh)

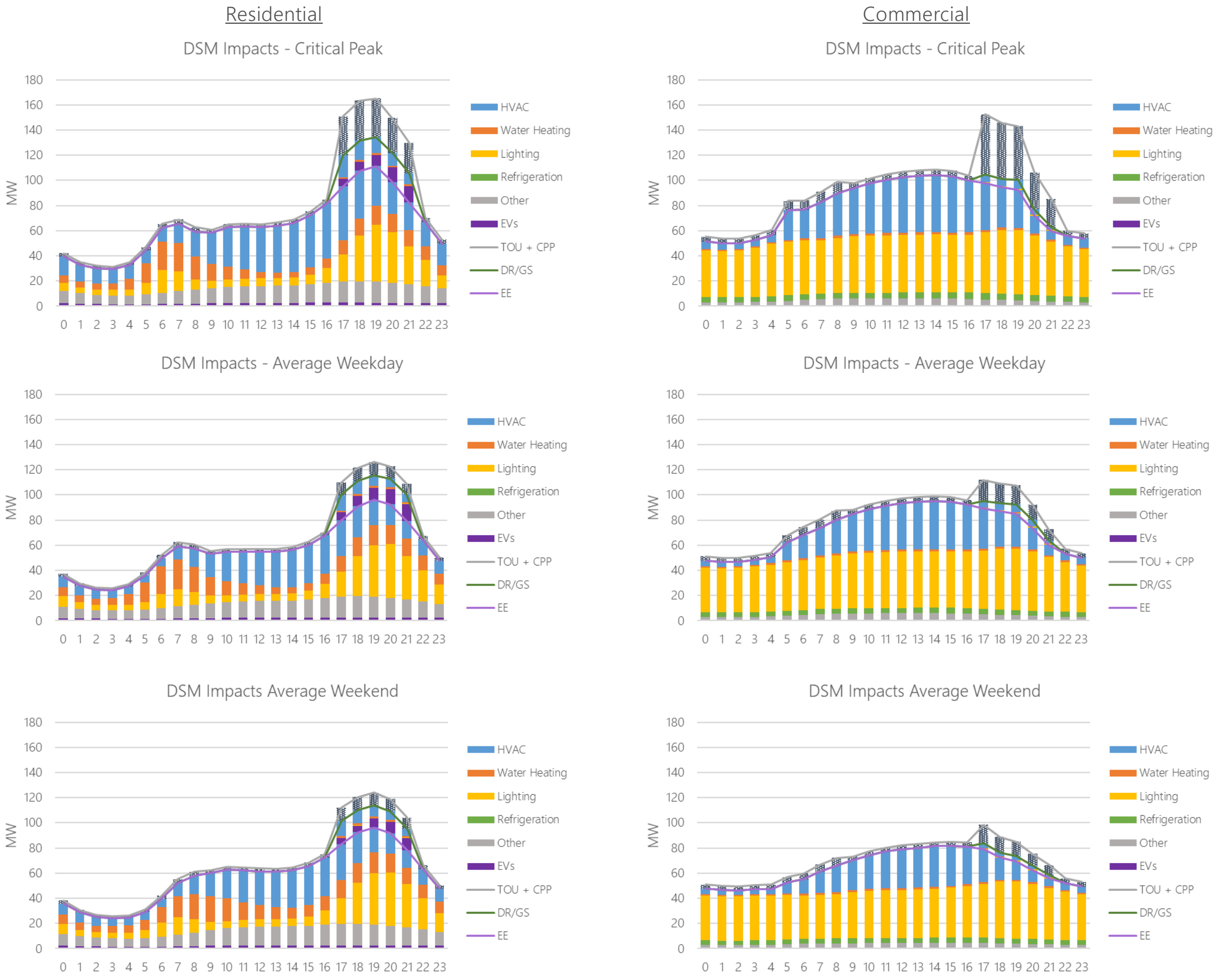


Results from AEG's 8760 hourly model show that integrating DSM resources can yield significantly greater energy savings than energy efficiency alone, helping Hawaii reach EEPS goals, while also addressing other grid needs, including peak load reductions. Figure ES-13 presents illustrative results from the hourly analysis. The graphs show stacked impacts for energy efficiency (EE), a Capacity - Decrease grid service option, and an opt-out time-of-use plus critical peak pricing (TOU+CPP) rate. The results are for Oahu in 2030 and are provided for the residential and commercial sectors for three day-types: critical peak day, average weekday, and average weekend. The EE impacts reflect the achievable - high potential, while the Capacity - Decrease impacts reflect the technical achievable potential assuming a level of customer acceptability consistent with the previous DR Potential Study conducted by Navigant for HECO.[9]

---

[9] Acceptability refers to the percentage customers that are willing to participate in a DR/GS option in exchange for financial incentives.

Figure ES-13 Hourly Stacked Impacts (EE, Capacity-Decrease, and Opt-Out TOU+CPP) by Day-Type and Sector: Oahu, 2030



Key Insights

Continuing with a business as usual approach to energy efficiency should be sufficient to meet the EEPS target by 2030. However, it is important to recognize that COVID-19 may be redefining what business as usual looks like in the future. Therefore, programs and policy interventions may have to adapt strategically to offset possible losses due to a post-COVID-19 energy efficiency landscape in order to secure enough cumulative savings by 2030. Fortunately, results from the "high" achievable potential scenario suggest that a substantial amount of additional cost-effective savings are available, beyond the BAU strategy, to help achieve the EEPS goal by 2030. In addition, the pandemic may offer new opportunities for securing energy savings such as increasing products offered through the online marketplace, tailoring messaging in home energy reports to help families spending more time at home, and mailing free kits to hard-to-reach homes and businesses.

Assessment of the integration of hourly impacts from energy efficiency, DR/GS, and rates sheds light on the highest impact measures and possible strategies for maximizing the achievable energy savings potential, as well as pursuing temporal-based impacts to reduce peak demand and provide other grid services. Figure ES-14 identifies four intervention options and the associated mapping of measures to the options. The intervention options are described as:

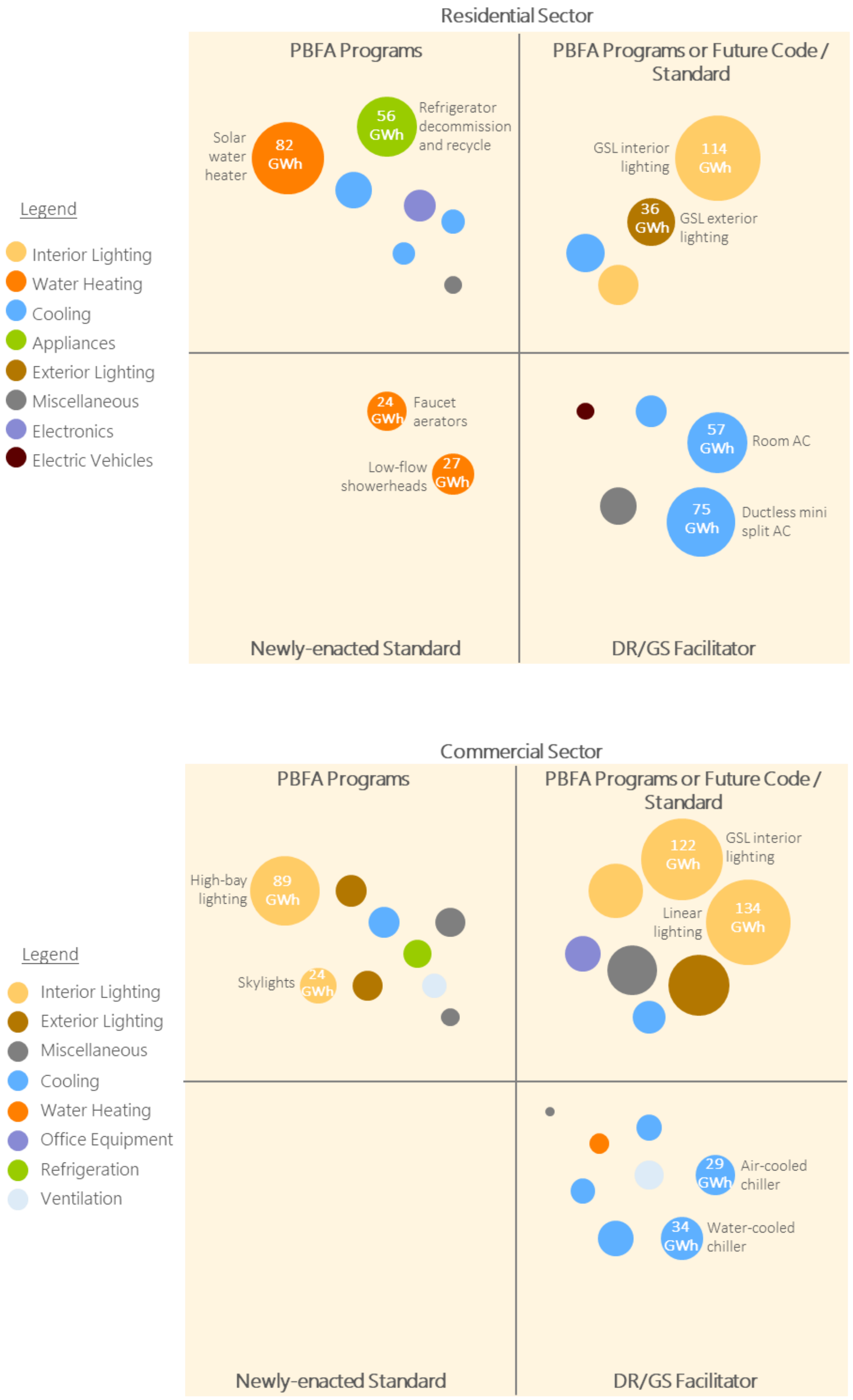
- PBFA Programs: Consider continuing to offer a mix of successful measures with high potential as well as promising new measures through the PFBA programs. The measures in this category with the highest potential are residential solar water heaters and commercial high-bay lighting.
- PBFA Programs or Future Code / Standard: Consider offering these measures through PBFA programs or by establishing future state codes and standards (or helping to lobby for new Federal standards)
- DR/GS Facilitator: Consider continued and further collaboration between Hawaiʻi Energy and HECO to promote "connected" equipment and measures that provide both energy efficiency and grid services.
- Newly-enacted Standard: These measures fall under a new standard that takes effect in 2021, transitioning away from a PBFA program. This is a unique situation, and required special modeling, so the savings are called out separately.

Figure ES-14 provides AEG's recommended distribution of the most impactful measures considered in this analysis by intervention type for the residential and commercial sectors, respectively. The size of the bubbles is proportional to the cumulative achievable annual energy savings potential in 2030 for the given measure. [10] Overall, this subset of measures consists of 18 residential and 24 commercial measures. Other current and new program measures beyond these have the potential to provide additional savings to further exceed the EEPS 2030 target.

---

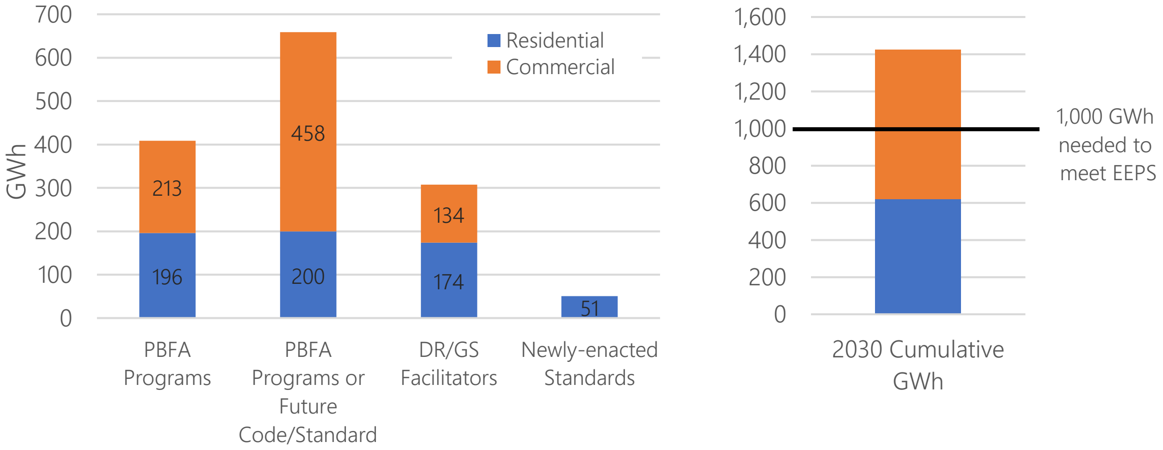
[10] The figure lists the top two measures and associated savings for each intervention type. Chapter 11 contains more detailed results.

Figure ES-14 2030 Cumulative Achievable Potential for High Impact Measures by Intervention Option



AEG's analysis shows that strategically pursuing the most impactful measures with programs and other policy interventions should allow the State of Hawaii to obtain the amount of cumulative persisting energy savings still needed to meet the overall EEPS target of 4,300 GWh in 2030. In fact, as can be seen in Figure ES-15, about 1,000 GWh of cumulative persisting energy savings are still needed and the potential savings from just the most impactful measures is about *40% higher* than needed to meet the target.

Figure ES-15 2030 Cumulative Savings for Most Impactful Measures



CONTENTS

LIST OF FIGURES

LIST OF TABLES

1

INTRODUCTION

In 2008, the State of Hawaii partnered with the United States Department of Energy to establish the Hawaii Clean Energy Initiative (HCEI), with a goal of meeting 70% of the State's energy needs through renewable energy and energy efficiency by 2030. The Hawaii State Legislature subsequently passed Act 155, Session Laws of Hawaii 2009 (Act 155), codified under § 269-96, Hawaii Revised Statutes (HRS), which established the State's energy efficiency goals into an Energy Efficiency Portfolio Standard (EEPS). As specified in HRS § 269-96, the statewide EEPS goal is 4,300 gigawatt-hours (GWh) of electricity savings by 2030.

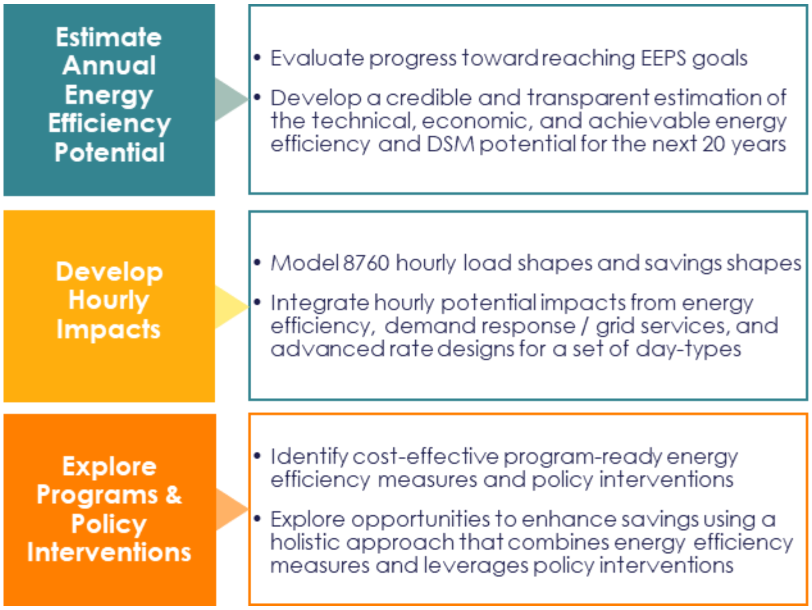
The Hawaii Public Utilities Commission (HPUC) contracted with Applied Energy Group (AEG) to perform a comprehensive market potential study (MPS) to assess the potential for future savings from energy efficiency and other interventions.

Goals of Study

The goals of the MPS are as follows:

- Evaluate the current status relative to the EEPS target and paths to continue to reach EEPS goals
- Quantify the landscape of energy efficiency and demand side management (DSM) over the next 20 years
- Provide a foundation to consider future programs and other interventions holistically

The figure to the right combines these primary goals with several secondary goals.



Estimate Annual Energy Efficiency Potential

- Evaluate progress toward reaching EEPS goals
- Develop a credible and transparent estimation of the technical, economic, and achievable energy efficiency and DSM potential for the next 20 years

Develop Hourly Impacts

- Model 8760 hourly load shapes and savings shapes
- Integrate hourly potential impacts from energy efficiency, demand response / grid services, and advanced rate designs for a set of day-types

Explore Programs & Policy Interventions

- Identify cost-effective program-ready energy efficiency measures and policy interventions
- Explore opportunities to enhance savings using a holistic approach that combines energy efficiency measures and leverages policy interventions

Background

The Hawaii MPS builds on and updates HPUC's 2014 Potential Study and 2019 EEPS Review Research, both of which were completed by AEG.[11,12] Using the resources from the previous studies as a starting point, AEG updated the analysis to reflect current circumstances and conditions. This report documents the MPS and provides estimates of the historic and potential reductions in annual cumulative persistent energy savings for the time periods of 2009-2030 (EEPS horizon) and 2020-2040 (twenty-year forecast of energy efficiency potential). Additional outcomes include end-use load shapes and 8760 hourly models of

---

[11] State of Hawaii Energy Efficiency Potential Study, Prepared for the Hawaii Public Utilities Commission, Prepared by Applied Energy Group (dba EnerNOC Utility Solutions Consulting), 2014.

[12] EEPS Review Research Report, Prepared for the Hawaii Public Utilities Commission, Prepared by Applied Energy Group, February 2019.

potential impacts from energy efficiency, advanced rate designs, and demand response and grid services (DR/GS), as well as an assessment of policy and / or program interventions to optimize savings.

To gauge progress towards EEPS, the MPS needs to account for accomplishments since 2009 and forecasts of potential through 2030 and beyond. The energy market looked very different in 2009 and much has changed since the 2014 Potential Study was completed:

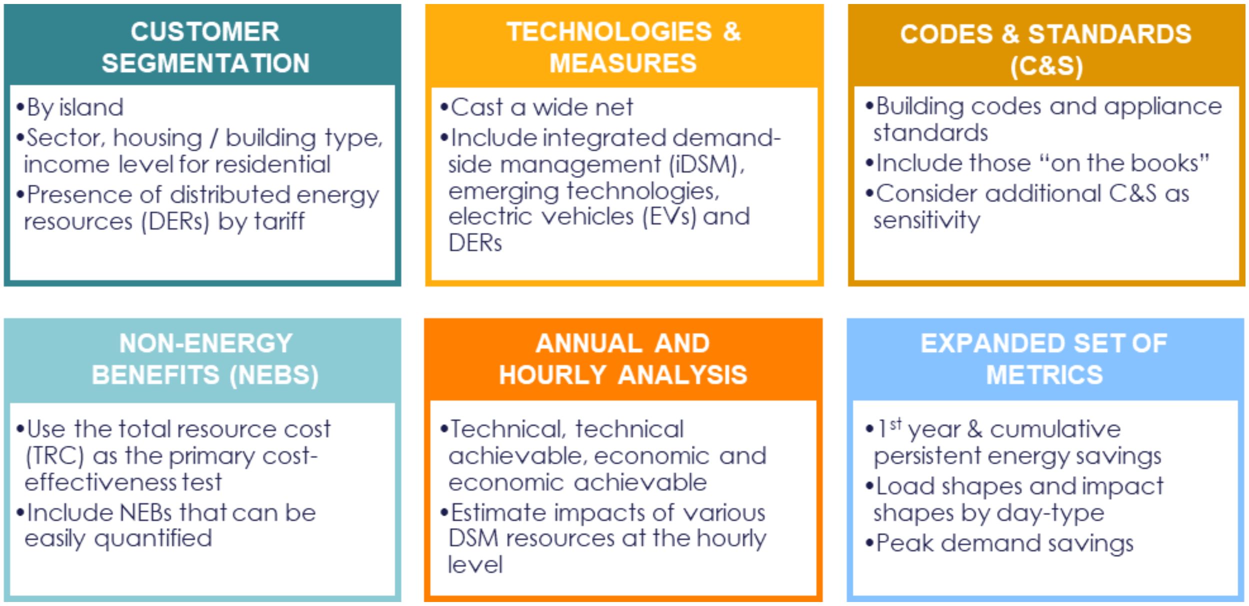
- Hawaii has seen over a decade of federal and state codes and standards.
- New technologies have come on the market that impact how customers use and interact with energy (LEDs, connected devices, etc.).
- Solar photovoltaic (PV) penetration has grown substantially.
- Energy efficiency programs have helped customers make their buildings more efficient.

Hawaii Considerations

To ensure the MPS addressed the appropriate set of issues and objectives relevant to Hawaii today, AEG worked with the HPUC, Energy Efficiency Manager (EEM) and other stakeholders (collectively referred to as the MPS working group, or MPSWG) to define important aspects to consider for the Hawaii MPS. Figure 1-1 summarizes the key features to consider for the study as defined by the MPSWG. The following bullet points describe these considerations in more detail.

Some of the most important considerations for the MPS are Hawaii's unique market needs and the transforming landscape of energy efficiency, distributed energy resources (DERs), and policy that will define the State's energy future regarding the 2030 EEPS target, as well as beyond 2030.

Figure 1-1 Key Features of the Hawaii MPS



CUSTOMER SEGMENTATION
- By island
- Sector, housing / building type, income level for residential
- Presence of distributed energy resources (DERs) by tariff

TECHNOLOGIES & MEASURES
- Cast a wide net
- Include integrated demand-side management (iDSM), emerging technologies, electric vehicles (EVs) and DERs

CODES & STANDARDS (C&S)
- Building codes and appliance standards
- Include those "on the books"
- Consider additional C&S as sensitivity

NON-ENERGY BENEFITS (NEBS)
- Use the total resource cost (TRC) as the primary cost-effectiveness test
- Include NEBs that can be easily quantified

ANNUAL AND HOURLY ANALYSIS
- Technical, technical achievable, economic and economic achievable
- Estimate impacts of various DSM resources at the hourly level

EXPANDED SET OF METRICS
- 1st year & cumulative persistent energy savings
- Load shapes and impact shapes by day-type
- Peak demand savings

- Customer segmentation: Used to explore and describe the variation in energy-use patterns and behavior among customers. Segments analyzed include the following:
  - Island – Oahu, Maui, Molokai, Lanai, Hawaii Island, and Kauai.
  - Sector – Residential and commercial, including military facilities.

  - Segment – Housing type, own vs. rent, new construction and existing homes, and regular income vs. lower income within residential; building type / activity and new construction vs. existing buildings within commercial.
  - Presence of distributed energy resources (DERs) – by type of tariff. This segmentation allow us to explore if and how customers with DERs are the same as or different than customers without DERs with respect to their energy-use behavior and their attitudes toward energy efficiency and other metrics of interest (e.g., desire to minimize their carbon footprint).
- List of technologies and measures: Developed by casting a wide net and includes traditional energy efficiency measures, behavioral measures, electric vehicles (EVs), DERs, and integrated DSM (iDSM).
- Appliance standards and building codes: The "reference case" reflects all codes and standards currently "on the books," which includes those approved but not yet in use. In addition, the study considers additional appliance standards and building codes as sensitivity cases to inform policy.
- Non-energy benefits (NEBs): Easily quantifiable NEBs are the focus for potential study modeling. The most straightforward example is water savings from high-efficiency clothes washers.
- Annual and hourly analysis: Characterization of energy use by end use for each customer segment on an annual and hourly basis and development of measure savings on an annual and hourly basis.
- Expanded set of metrics: Metrics include 1st year and cumulative persistent energy savings, load shapes and impact shapes by day-type, and peak demand reduction using hourly analysis to assess various peak periods.

Scope and Limitations

The MPS scope covers both annual and hourly estimates of energy efficiency potential for the residential and commercial sectors on each island, as well as for the military. The scope also includes estimates of the potential for energy savings and peak demand reductions from advanced rate designs and demand response / grid service (DR/GS) program interventions. Despite the broad scope of the study, there are a few limitations that are important to mention:

- AEG performed a full 8760 hourly analysis for all islands and the military, but this report only presents the hourly estimates for a set of three day-types, with focus on Oahu to manage document length. There is less seasonal variability in the State of Hawaii, which allows us to adequately represent the hourly variation with three day-types. In addition, we present mostly Oahu results because of Oahu's large share of the potential. The underlying data is available to look at load shapes for other day-types and islands more closely in future work.
- The primary market research AEG conducted as part of the 2019 Baseline Study[13] involved surveys of all islands served by Hawaiian Electric Industries (HEI). Therefore, surveys were not performed for customers of Kauai Island Utility Cooperative (KIUC). Therefore, to develop market characterization estimates for KIUC, AEG carried out a "baseline localization" exercise to translate market characterization results (market profiles) for HEI customers to be as representative as possible for KIUC customers. KIUC staff reviewed the resulting market profiles and provided adjustments so they better reflect their customer population.

---

[13] 2019 Hawaii Statewide Baseline Energy Use Study, Prepared by Applied Energy Group, Prepared for the Hawaii Public Utilities Commission, 2020.

- AEG's focus for the MPS was on energy efficiency; therefore, we did not perform a full DR potential study. Instead, the DR/GS analysis presented here leverages the DR Potential Study conducted by HECO in 2015 and updated in 2017.[14] Estimates of DR/DG potential reflect achievable technical potential, where likely adoption rates are applied to each DR/GS option regardless of cost-effectiveness. [15] Further analysis is recommended prior to implementing any of these options.
- The results presented in Advanced Rate Analysis are a function of the elasticities assumed in the analysis, which are borrowed from other studies. These parameters can vary widely across regions and customer types. To validate the analysis performed for this study, we recommend that scientific experiments (pilots) be carried out in Hawaii to generate state-specific elasticities for various time-varying rates. These experiments should test various combinations of rate designs (price signals), enabling technologies, and customer engagement/feedback strategies. We also recommend that market research (focus groups and conjoint analysis) be carried out to determine likely customer participation rates under alternative scenarios of deployment.

Report Contents

This report has three parts. The first part provides an overview of the analysis approach and presents the market characterization. The second part addresses energy efficiency potential from the perspective of the EEPS framework. The third part considers additional interventions that might complement the savings from EE-related interventions and hourly impacts. We describe each section below:

Part 1:

2. Analysis Approach Overview provides an overview of the analysis approach for conducting this market potential study.
3. Market Characterization describes how customers in Hawaii use electricity in the base year of the study, 2018. This is the starting point for the analysis.

Part 2:

4. Energy Efficiency Measures describes the scope of the measures included in the assessment of energy efficiency potential.
5. Baseline Forecasts describes several projections developed for this study prior to estimating future potential savings from energy efficiency.
6. Energy Efficiency Potential describes the twenty-year savings potential, on an annual basis through 2040.
7. Savings from EEPS Perspective presents estimates of energy savings over the entire EEPS horizon, from 2009 through 2030.

Part 3:

8. Potential from Advanced Rate Designs provides estimate of the potential impacts of advanced rate designs on energy consumption, peak demand and customer bills.

---

[14] Demand Response Potential Assessment for the Hawaiian Electric Companies. Draft Report. Prepared for Hawaiian Electric Company (HECO), Hawaii Electric and Light Company (HELCO), Maui Electric Company (MECO). Prepared by Navigant Consulting, Inc., Reference No: 181292, November 13, 2015

[15] The DR/GS analysis does not include an assessment of cost-effectiveness because the hourly avoided cost information that would be required for valuing time-of-day-based savings for DR/GS opportunities is not yet available. Hourly avoided cost information is expected to be available once HECO's Integrated Grid Planning process is complete.

9. Potential from Demand Response and Grid Services includes potential impacts from implementation of demand response / grid service (DR/GS) programs.
10. Integrating EE, DR/GS, and Rates combines the hourly impacts from energy efficiency measures, DR/GS, and advanced rates.
11. Intervention Concepts explores program and policy interventions that could yield more optimal savings by combining and leveraging energy efficiency, DR/GS, and demand-side rates and policy interventions such as developing new codes and standards.

Appendices provide details on various aspects of the study:

A. MPS Output contains detailed results from the MPS analysis, including results related to market characterization, baseline forecasts, progress towards reaching the EEPS target, and potential for savings through 2040.

B. Technology Saturation Data provides detailed technology saturation data for key residential and commercial end uses by market segment and island.

C. Measure List provides a summary listing of the measures included in the MPS.

D. Advanced Rate Designs Presentation describes the rate design analysis and results in more detail.

E. Supplemental Hourly Results contains more detailed results from the hourly impact analysis.

2

ANALYSIS APPROACH OVERVIEW

AEG used a bottom-up analysis approach for conducting the Hawaii MPS. Figure 2-1 illustrates the approach.

Figure 2-1 Overview of Analysis Approach

The following list summarizes each of the major analysis steps.

- Market characterization: Performed a market characterization to describe electricity use by technology and end-use for the residential and commercial sectors for the base year, 2018. Conducted separate analysis for the military. Data sources included 2018 HECO and KIUC billing and AMI[16] data, customer survey results from the 2019 Hawaii Statewide Baseline Energy Use Study,[17] survey results from HECO's 2019 Residential Appliance Saturation Survey (RASS), the Hawaiʻi Energy Program Year 2019 (PY19) Technical Reference Manual (TRM), and secondary resources such as the Energy Information Administration (EIA).
    - Residential sector: Segmented by island, housing type, home construction vintage, housing ownership, income level, and participation in net energy metered (NEM) program.
    - Commercial sector: Segmented by island, building type, and building vintage.
- Identify demand-side resources: Defined and characterized several hundred energy efficiency, integrated demand-side management, demand response, and behavioral measures to be applied to all sectors, segments, and end uses. AEG developed a resource list using Hawaiʻi Energy's current programs, measure lists from other studies, new/emerging technologies, and feedback from the MPS working group.
- Baseline projection: Developed several projections of electricity consumption by island, sector, segment, end-use, and technology for 2018 through 2040. Inputs included forecasts of electricity sales, distributed generation, and electric vehicles, appliance standards and building codes already known to be taking effect after 2018, and forecasts of naturally occurring efficiency in the general-service lighting and solar water heating technologies. Defined the baseline forecast to use as the metric against which future savings from programs and other interventions are measured.
- Estimate impacts: Estimated annual technical, economic, and achievable potential at the measure level through 2030 to gauge progress towards EEPS, as well as through 2040 to provide a foundation for future program considerations.
    - Expanded the analysis to model 8760 hourly impacts for energy efficiency measures, demand response and grid services (DR/GS), and advanced rate designs.
- Intervention assessment: To assess potential impacts from programs and policy interventions, AEG reviewed the measure-level results to develop a list of the most impactful measures, characterized how each measure potentially meets a set of key metrics, defined four possible intervention options, and recommended how to categorize each measure into one of the four intervention options.

The subsection below provides more detail on the LoadMAP model used for the analysis.

LoadMAP Model

For this analysis, AEG used AEG's Load Management Analysis and Planning tool (LoadMAP™) version 5.0 to develop both the baseline end-use projection and the estimates of potential. AEG developed LoadMAP in 2007 and has enhanced it over time, using it for the EPRI National Potential Study and numerous utility-specific forecasting and potential studies since. Built in Excel, the LoadMAP framework is both accessible and transparent and has the following key features.

---

[16] AMI refers to "Advanced Metering Infrastructure, also known as "smart meters."

[17] 2019 Hawaii Statewide Baseline Energy Use Study, Prepared by Applied Energy Group, Prepared for the Hawaii Public Utilities Commission, 2020.

- Embodies the basic principles of rigorous end-use models (such as EPRI's REEPS and COMMEND) but in a more simplified, accessible form.
- Includes stock-accounting algorithms that treat older, less efficient appliance/equipment stock separately from newer, more efficient equipment. Equipment is replaced according to the measure life and appliance vintage distributions defined by the user.
- Balances the competing needs of simplicity and robustness by incorporating important modeling details related to equipment saturations, efficiencies, vintage, and the like, where market data are available, and treats end uses separately to account for varying importance and availability of data resources.
- Isolates new construction from existing equipment and buildings and treats purchase decisions for new construction and existing buildings separately.
- Uses a simple logic for appliance and equipment decisions. Other models available for this purpose embody complex decision choice algorithms or diffusion assumptions, and the model parameters tend to be difficult to estimate or observe and sometimes produce anomalous results that require calibration or even overriding. The LoadMAP approach allows the user to drive the appliance and equipment choices year by year directly in the model. This flexible approach allows users to import the results from diffusion models or to input individual assumptions. The framework also facilitates sensitivity analysis.
- Can accommodate various levels of segmentation. Analysis can be performed at the sector level (e.g., total residential) or for customized segments within sectors (e.g., housing type or income level).
- Natively outputs model results in a detailed line-by-line summary file, allowing for review of input assumptions, cost-effectiveness results, and potential estimates at a granular level.

Consistent with the segmentation scheme and the market profiles in Chapters 3 and 5, the LoadMAP model provides projections of baseline energy use by island, sector, segment, end use, and technology for existing and new buildings. It also provides forecasts of total energy use and energy efficiency savings associated with the various types of potential. [18]

---

[18] The model computes energy projections for each type of potential for each end use as an intermediate calculation. Annual energy savings are calculated as the difference between the value in the baseline projection and the value in the potential projection (e.g., the technical potential projections).

3

MARKET CHARACTERIZATION

Market characterization describes how customers in Hawaii used electricity in the base year of the study, 2018. It is the starting point of the analysis and began with the implementation of the 2019 Hawaii Statewide Baseline Energy Use Study[19] and HECO's 2019 Residential Appliance Saturation Survey (RASS). The subsections below describe the approach for combining data from the two market research efforts with data from KIUC to characterize the Hawaii market.

Market Research

To estimate the savings potential from energy-efficient measures, it is necessary to understand how much energy is used today and what equipment is currently in service. The characterization began with primary market research to quantify electricity use in the residential and commercial sectors. Table 3-1 provides an overview of the market research data collection activities used to support the market characterization process. The market research consisted of a series of five surveys conducted with accounts served by Hawaiian Electric Industries (HEI); HECO conducted the RASS and AEG carried out the other four surveys on behalf of HPUC.

Table 3-1 Overview of Methodology

Sector	Definition	Data Collection Method	Market Research Lead	Completed Surveys/ Interviews
Residential	HEI Residential Accounts	Mail Survey	HECO	3,500
		Phone Audit	AEG for HPUC	403
Small and Medium Businesses	HEI Commercial Accounts < 1M kWh	Phone Audit Mail Online	AEG for HPUC	372 862
Large Customers	HEI Accounts > 1M kWh & largest military, government and Association of Apartment Owners (AOAO) accounts	Onsite and telephone interviews	AEG for HPUC	93

Residential Research Design

AEG organized the research design for the residential sector to take advantage of the fact that HECO was planning to conduct a RASS during 2019 and it was possible to coordinate the two survey efforts. Therefore, the residential baseline survey design included the following:

- Leveraging the 2019 HECO RASS as a secondary resource for the MPS. Since the HECO RASS sampled by island and energy use and had a relatively large sample size (several thousand respondents), it could provide the level of granularity required for almost any desired analysis required by the MPS.

---

[19] 2019 Hawaii Statewide Baseline Energy Use Study, Prepared by Applied Energy Group, Prepared for the Hawaii Public Utilities Commission, 2020.

- Conducting a phone audit (P/A) survey of residential customers. AEG designed these surveys to capture more detailed information from customers by having them complete a "guided walk-through audit" of their residence. Respondents walked through their home on a room-by-room basis and responded to questions about energy-using equipment in-place for each room. These longer, more detailed surveys made it possible to capture all (or at least most) of the relevant technical information required for the research plan and, in many cases, to capture nameplate information as well.

AEG and HECO coordinated the questionnaires for the RASS and the baseline P/A survey, but since the two surveys used fundamentally different methodologies (with the RASS completed mostly on paper), AEG analyzed the results of the two surveys separately for use in the MPS.

Nonresidential Research Design

To capture the technical information desired for the research, AEG implemented three different survey efforts within the nonresidential sector:

- A mail / online (M/O) survey with small and medium business (SMB) customers. The goal of this survey was to cover most of the desired survey content with sufficient granularity to provide a reasonable basis for exploring specific sub-populations of interest.
- A phone audit (P/A) survey among SMB customers to capture more detailed information from customers through a "guided walk-through audit" similar to the residential P/A described above. Respondents walked through their facility on a room-by-room or area-by-area basis and responded to questions about energy-using equipment in-place for each room or area. Again, these longer, more detailed surveys made it possible to capture all (or at least most) of the relevant technical information required for the research plan and, in many cases, to capture nameplate information as well.
- Onsite or telephone in-depth interviews (IDIs) with large customers. The large customer IDIs ranged from one hour in duration to several hours as needed to capture information for multiple buildings associated with a given site and unique sets of sometimes quite sophisticated equipment.

The research design treated the mail / online surveys of SMB customers as reasonable (if not completely comprehensive) surveys that could be used for most of the required inputs for the MPS, with the phone / audit (P/A) interviews treated as more accurate and more comprehensive versions of the M/O interviews. As a result, once the SMB surveys were completed, the team aggregated the two databases to create a single sample representing the SMB population.

KIUC Localization

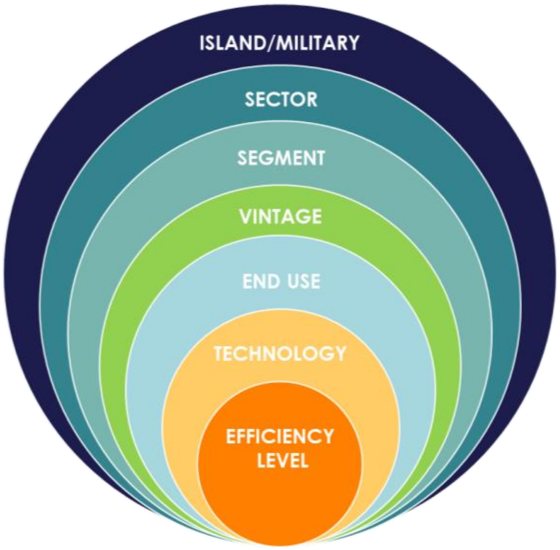
KIUC customers were not included in the core survey design for the 2019 Hawaii Statewide Baseline Energy Use Study. Therefore, to develop energy-use profiles for KIUC, AEG collected various types of data from KIUC (customer billing data and market research reports) and then used this Kauai-specific data to help extrapolate the market research results for the other Hawaiian islands to be as representative as possible of Kauai. KIUC provided feedback regarding the preliminary end-use profiles and AEG made some adjustments to appliance and equipment saturations, most notably air conditioning, in the final analysis.

Market Segmentation

The market characterization begins with the segmentation of the State of Hawaii's electricity footprint to quantify energy use by island/military, sector, segment, and other dimensions. Table 3-2 presents the segmentation scheme.

Table 3-2 Overview of MPS Analysis Segmentation Scheme

Segmentation Variable	Description
Island/Military	Oahu, Hawaii, Maui, Kauai, Molokai, Lanai, Military
Sector	Residential, commercial
Segment	Residential: single family, multifamily, home ownership, income level, participation in NEM program Commercial: building type
Vintage	Existing and new construction
End use	Cooling, lighting, water heating, etc. (as appropriate by sector)
Technology	Technologies such as lamp type, air conditioning equipment, etc.
Efficiency level	Baseline and higher-efficiency options as appropriate for each technology



High-level Market Characterization

After defining the market segmentation scheme, we performed a high-level characterization of electricity sales in the base year, 2018. We used detailed billing data and customer data from the primary market research to allocate energy use and customers to the various islands, sectors, and segments such that the total customer count and energy consumption matched the system totals from 2018 billing data. These high-level data were used to calibrate the base-year market profiles (described below)

In 2018, the State of Hawaii consumed a total of 9,810 GWh. As shown in Table 3-3 and Figure 3-1, Oahu accounted for 60.4% of that consumption, followed by the military (11.9%, which is treated like an island), Hawaii (11.3%), Maui island (11.3%), and the other islands. Table 3-4 presents the control totals by sector, including non-military residential, non-military commercial, and military (combination of residential and nonresidential military facilities). The non-military commercial sector comprises 53.1% of all consumption in the State of Hawaii, followed by the non-military residential sector (35.0%) and military sector (11.9%). Note that the residential and commercial sector discussions in the remainder of this report account for the military sector (i.e., residential military facilities and nonresidential military facilities are allocated to the residential and commercial sectors, respectively).

Table 3-3 Market Characterization by Island, 2018

Island	Electric Sales (GWh)	Generation (GWh)	Consumption (GWh)
Oahu	5,224 60.9%	703 56.7%	5,926 60.4%
Hawaii	957 11.2%	151 12.2%	1,108 11.3%
Maui	940 11.0%	171 13.8%	1,111 11.3%
Kauai	421 4.9%	20 1.6%	441 4.5%
Molokai	27 0.3%	4 0.3%	31 0.3%
Lanai	25 0.3%	1 0.1%	26 0.3%
Military	979 11.4%	189 15.2%	1,167 11.9%
Total	**8,571** 100.0%	**1,239** 100.0%	**9,810** 100.0%

Figure 3-1 Electricity Consumption by Island, 2018

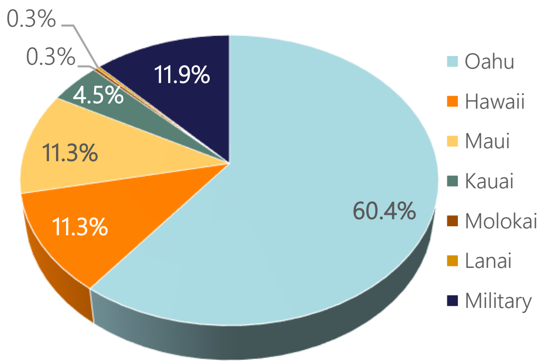
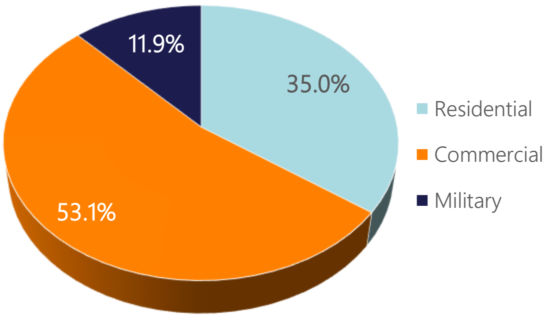


Table 3-4 All Islands Market Characteristics by Sector, 2018

Segment	Electric Sales (GWh)	Generation (GWh)	Consumption (GWh)
Non-Military Residential	2,665 35.0%	767 35.0%	3,432 35.0%
Non-Military Commercial	4,928 53.1%	283 53.1%	5,211 53.1%
Military	979 11.9%	189 11.9%	1,167 11.9%
Total	**8,571** 100.0%	**1,239** 100.0%	**9,810** 100.0%

Figure 3-2 All Islands Consumption by Sector, 2018



Market Profiles

The next step was to develop market profiles for each island, sector, customer segment, end use, and technology. A market profile includes the following elements:

- Market size is a representation of the number of customers in the segment. For the residential sector, the unit is the number of households. In the commercial sector, it is floor space measured in square feet.

- Saturations define the fraction of homes and square feet with the various technologies. (e.g., percent of homes with electric space heating).
- UEC (unit energy consumption) or EUI (energy-utilization index) describes the amount of energy consumed in the base year by a specific technology in homes or buildings that have the technology. UECs are expressed in kWh/household for the residential sector, and EUIs are expressed in kWh/square foot for the commercial sector.
- Annual energy intensity for the residential sector represents the average energy use for the technology across all homes in 2018. It is computed as the product of the saturation and the UEC and is defined in kWh/household terms. For the commercial sector, intensity, computed as the product of the saturation and the EUI, represents the average use for the technology across all floor space in the base year.
- Annual usage is the annual energy used by each end-use technology in the segment. It is the product of the market size and intensity and is quantified in GWh.

The subsections below summarize market characterization results for the residential and commercial sectors. Appendix A contains more detailed market characterization results, including market profiles for each individual market segment. Appendix B provides technology saturation data by sector and island for key end uses.

Residential

In 2018, there were 478,087 households in the State of Hawaii that consumed 3,476 GWh. Using the HECO RASS database and the residential survey from the Baseline Study, we segmented the residential sector into 11 segment that vary according to dwelling type, ownership status, and income. Income is classified into two groups: regular income and low- and moderate-income, which was defined using the 2019 Housing and Urban Development (HUD) threshold for household income by family size and island[20].

Table 3-5 shows that the average household consumption was 7,271 kWh. Of the eleven residential segments, the single-family, owner-occupied households have the highest consumption levels. Figure 3-3 shows that together, single-family, owner-occupied, regular income and the single-family, net energy metered accounted for 57% of total residential consumption. The net energy metered (NEM) households have the highest average household consumption, as presented in Figure 3-4; though NEM customers generate electricity at their homes to offset purchased electricity, they tend to consume considerably more energy overall, including for space cooling.

Across the islands, approximately 30% of customers fall into the low- and moderate-income (LMI) categories. They tend consume less energy per home than the regular income customers.

---

[20] The values used represent 80% of median income for a given household size and are identified below:

HH Size	Honolulu	Maui	Hawaii
1	$67,500	$54,700	$44,000
2	$77,150	$62,500	$50,250
3	$86,800	$70,300	$56,550
4	$96,400	$78,100	$62,800
5	$104,150	$84,350	$67,850
6	$111,850	$90,600	$72,850
7	$119,550	$96,850	$77,900
8	$127,250	$103,100	$82,900

Table 3-5 All Island Residential Market Characterization by Segment, 2018

Segment	Households	Electric Sales (GWh)	Generation (GWh)	Consumption (GWh)	Avg. Sales (kWh/HH)	Avg. Gen (kWh/HH)	Avg. Cons. (kWh/HH)
Single Family - Own - Regular Income	149,754	1,065	47	1,112	7,110	314	7,425
Single Family - Own - LMI	66,421	449	5	454	6,762	75	6,837
Single Family - Rent - Regular Income	15,211	109	5	114	7,155	311	7,466
Single Family - Rent - LMI	22,554	143	2	144	6,332	69	6,401
Single Family - Net-Energy Metered	68,737	187	682	869	2,722	9,919	12,641
Multifamily - Own - Regular Income	44,000	232	0	232	5,265	2	5,267
Multifamily - Own - LMI	19,629	91	0	91	4,655	0	4,655
Multifamily - Rent - Regular Income	18,926	95	0	95	5,010	3	5,013
Multifamily - Rent - LMI	32,066	145	0	145	4,528	0	4,528
Multifamily - Net-Energy Metered	3,911	13	22	35	3,287	5,591	8,878
Multifamily - Master Metered	36,876	179	7	185	4,843	185	5,027
Total	**478,087**	**2,707**	**769**	**3,476**	**5,662**	**1,609**	**7,271**

Figure 3-3 All Island Residential Consumption by Segment, 2018

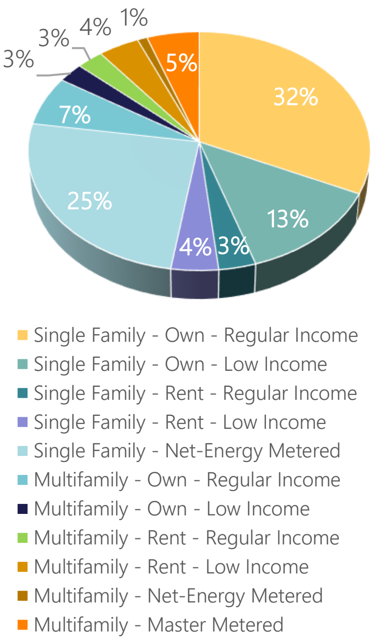


Figure 3-4 All Island Residential Consumption per Household (kWh/HH) by Segment, Sales, and Generation, 2018

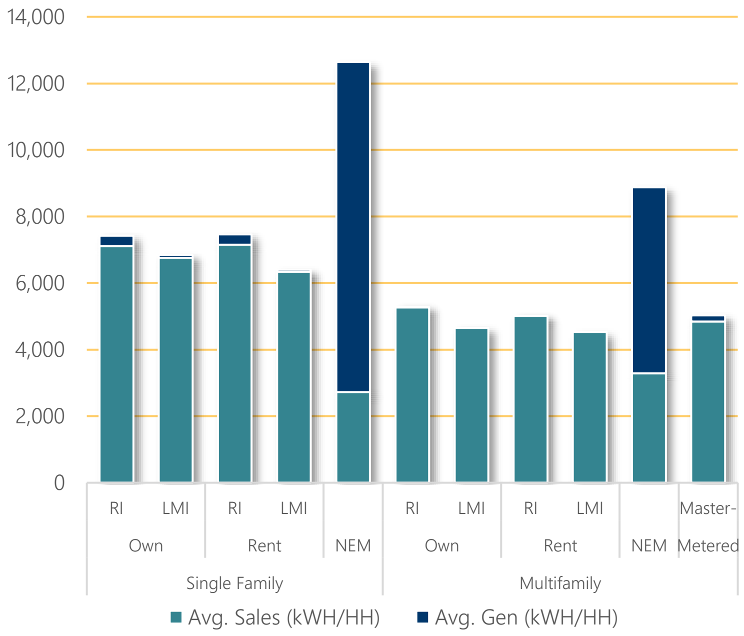


Figure 3-5 presents the average annual electricity consumption by end-use for all residential customers. Appliances and cooling equipment each account for approximately one-quarter of total usage. Appliances include refrigerators, stoves, clothes washers, clothes dryers, dishwashers, and microwaves. The remainder of the energy falls primarily into water heating, lighting, electronics and the miscellaneous category – which is comprised of furnace fans, pool pumps, and other "plug" loads (all other usage not covered by those listed, such as hair dryers, power tools, coffee makers, etc.).

End use composition has changed since 2013 when the last baseline study was performed:[21]

- Cooling and appliances are now the largest end uses in the average home.
- Efficient lighting represents more than 60% of lamps in the average home (41% of lamps are LEDs, compared with an average of only 1 LED per home in 2013).
- Increased adoption of solar water heating has lowered average water heating use per home.

Compared with regular-income customers, LMI in each segment have a lower saturation of air conditioning appliances. This reduces their energy consumption relative to non-LMI customers, but this is partially offset by less efficient appliances.

---

[21] Baseline Energy Appliance, Equipment and Building Characteristics Study Report, Prepared for the State of Hawaii Public Utilities Commission, Prepared by Evergreen Economics, Nov. 6, 2013, with errata Feb. 26, 2014.

Figure 3-5 All Island Residential Consumption by End Use, 2018

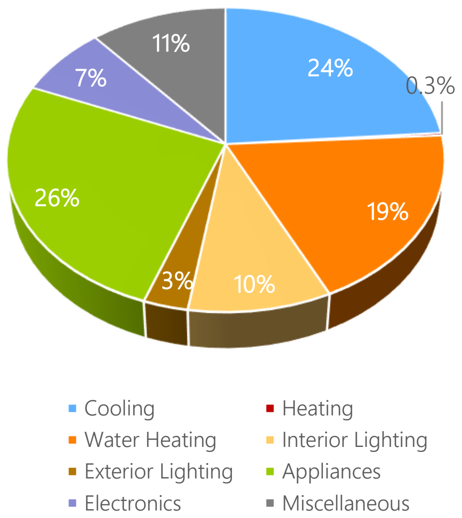
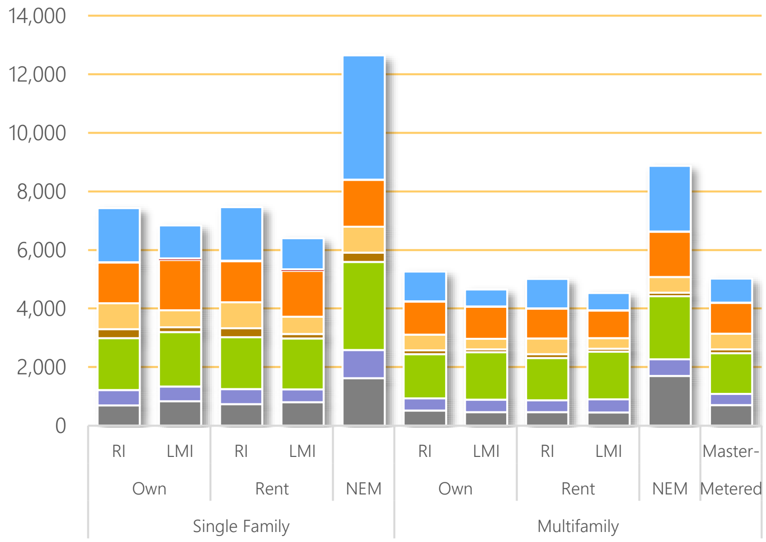


Figure 3-6 All Island Residential Consumption per Household (kWh/HH) by Segment and End Use, 2018



The average market profile for the residential sector is presented in Figure 3-6. The columns contain different components that describe customer usage by end use and technology, as previously described.

Table 3-6 Average Market Profile for All Island Residential, 2018

End Use	Technology	Saturation	UEC (kWh)	Intensity (kWh/HH)	Usage (GWh)
Cooling	Central AC	6%	4,763	263	126
Cooling	Room AC	32%	2,772	891	426
Cooling	Ductless Mini Split AC	16%	3,632	576	275
Heating	Electric Room Heat	4%	466	20	10
Water Heating	Water Heater (<= 55 Gal)	64%	1,796	1,142	546
Water Heating	Water Heater (> 55 Gal)	12%	1,870	225	108
Interior Lighting	General Service Lighting	100%	448	448	214
Interior Lighting	Linear Lighting	100%	144	144	69
Interior Lighting	Exempted Lighting	100%	106	106	51
Exterior Lighting	General Service Lighting	100%	219	219	104
Appliances	Refrigerator	99%	546	541	258
Appliances	Second Refrigerator	34%	783	266	127
Appliances	Freezer	28%	454	129	62
Appliances	Clothes Washer	86%	62	53	25
Appliances	Clothes Dryer	67%	769	514	246

End Use	Technology	Saturation	UEC (kWh)	Intensity (kWh/HH)	Usage (GWh)
Appliances	Dishwasher	36%	115	41	20
Appliances	Stove/Oven	80%	277	223	106
Appliances	Microwave	93%	124	115	55
Electronics	Personal Computers	55%	212	116	55
Electronics	Monitor	62%	34	21	10
Electronics	Laptops	110%	32	35	17
Electronics	Printer/Fax/Copier	74%	19	14	7
Electronics	TVs	123%	133	163	78
Electronics	Set-top Boxes/DVRs	127%	74	94	45
Electronics	Devices and Gadgets	100%	99	99	47
Miscellaneous	Electric Vehicle Charger	1%	3,651	48	23
Miscellaneous	Dehumidifier	5%	1,652	89	43
Miscellaneous	Air Purifier	9%	457	40	19
Miscellaneous	Fans	94%	32	30	14
Miscellaneous	Pool Pump	5%	2,056	96	46
Miscellaneous	Hot Tub/Spa	3%	845	23	11
Miscellaneous	Well Pump	5%	523	26	13
Miscellaneous	Miscellaneous	100%	460	460	220
Generation	Solar PV	18%	-8,995	-1,609	-769
Total				**5,662**	**2,707**

Energy market profiles each residential and commercial customer segment in each island are presented in Appendix B.

Commercial

In 2018, commercial customers in the State of Hawaii consumed a total of 6,334 GWh (see Table 3-7). Figure 3-7 shows that the large retail and miscellaneous sectors each accounted for approximately 16% of the total electricity consumed, followed closely by large office (12%) and large resort (11%). Figure 3-8 presents average all island consumption per square foot of floor area. Grocery stores and restaurants have the highest average consumptions per square foot of all the commercial segments, primarily due to the large refrigeration loads (as shown in Figure 3-10).

Compared to the residential market, there is less installed solar PV serving commercial buildings. Market barriers include:

- Geography: low uptake/feasibility in downtown Oahu
- Segment: lower PV uptake in lodging and large resorts

Table 3-7 All Island Commercial Market Characterization by Segment, 2018

Segment	Floor Area (kSqFt)	Electric Sales (GWh)	Generation (GWh)	Consumption (GWh)	Avg. Sales (kWh/SqFt)	Avg. Gen. (kWh/SqFt)	Avg. Cons. (kWh/SqFt)
Large Office	59,869	762	12	774	12.7	0.2	12.9
Small Office	23,686	303	27	330	12.8	1.2	13.9
Large Retail	88,752	1,043	60	1,103	11.7	0.7	12.4
Small Retail	16,291	183	12	195	11.2	0.7	12.0
Restaurant	6,620	249	12	261	37.6	1.8	39.5
Grocery	5,953	335	41	376	56.3	6.9	63.2
Education	37,873	232	61	293	6.1	1.6	7.7
Healthcare	15,386	303	21	324	19.7	1.4	21.1
Lodging	33,387	435	4	439	13.0	0.1	13.1
Large Resort	47,120	647	26	674	13.7	0.6	14.3
Multifamily	43,283	215	8	223	5.0	0.2	5.2
Warehouse	39,729	209	100	310	5.3	2.5	7.8
Miscellaneous	76,103	947	85	1,032	12.4	1.1	13.6
Total	**494,052**	**5,864**	**470**	**6,334**	**11.9**	**1.0**	**12.8**

Figure 3-7 All Island Commercial Consumption by Segment, 2018

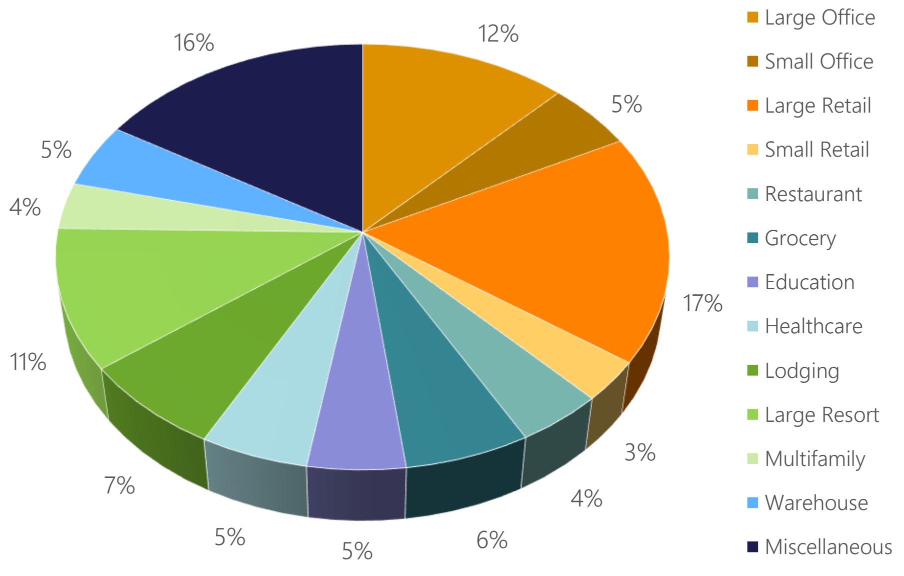


Figure 3-8 All Island Commercial Consumption per Floor Area (kWh/SqFt) by Segment, Sales, and Generation, 2018

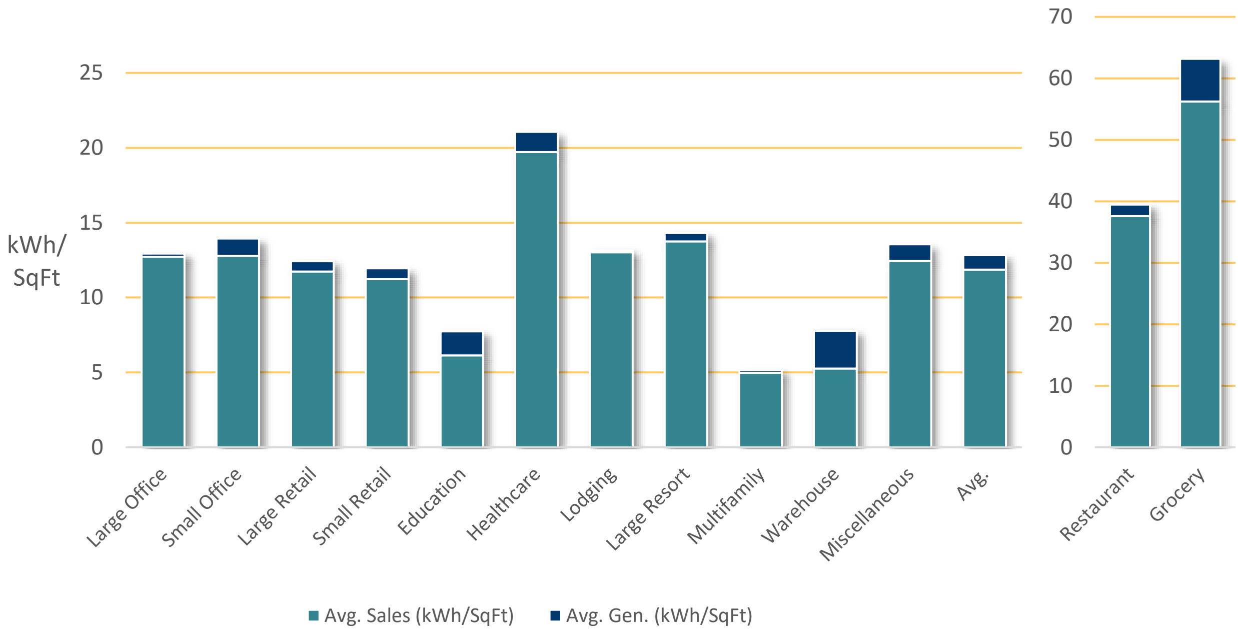


Figure 3-9 presents the average distribution of annual electricity consumption by end use across all commercial customers. Cooling and lighting account for the majority of total usage, at 35% and 25% respectively. Miscellaneous, ventilation, and refrigeration follow with the next largest consumption, at approximately 10% each. Substantial progress has been made in commercial sector lighting market since the 2013 baseline study was performed, which is reflected in energy efficiency program accomplishments in recent years.

Figure 3-9 All Island Commercial Consumption by End Use, 2018

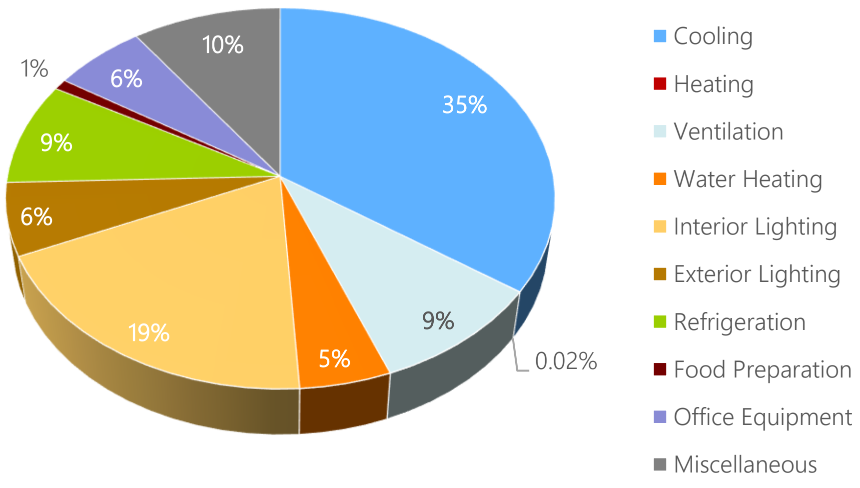
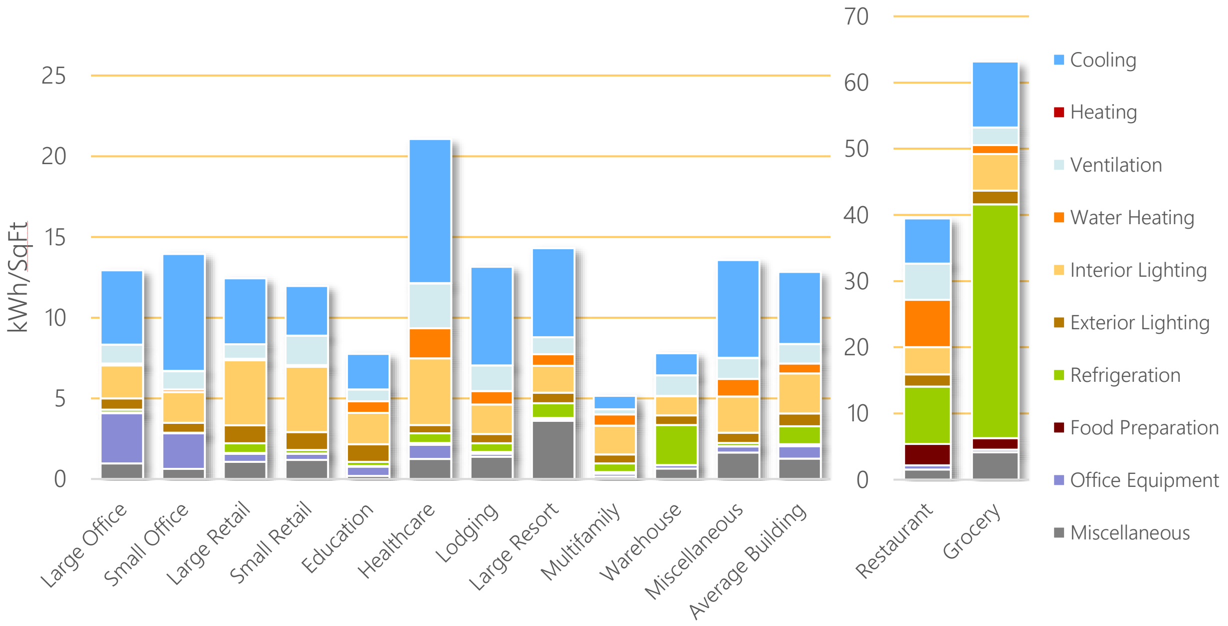


Figure 3-10 All Island Commercial Consumption per Floor Area (kWh/SqFt) by Segment and End Use, 2018



The average market profile for the commercial sector is presented in Table 3-8. The columns contain different components that describe customer usage by end use and technology, as previously described.

Table 3-8 Average Market Profile for All Island Commercial, 2018

End Use	Technology	Saturation	EUI (kWh/SqFt)	Intensity (kWh/SqFt)	Usage (GWh)
Cooling	Air-Cooled Chiller	24%	7.17	1.73	853
Cooling	Water-Cooled Chiller	21%	4.47	0.93	460
Cooling	RTU	11%	7.23	0.80	396
Cooling	Central AC	5%	5.71	0.31	152
Cooling	Room AC	6%	6.05	0.35	171
Cooling	Packaged Terminal AC	4%	7.62	0.34	168
Heating	Electric Room Heat	0%	2.14	0.00	1
Ventilation	Ventilation	100%	1.21	1.21	595
Water Heating	Water Heater	57%	1.09	0.62	307
Interior Lighting	General Service Lighting	100%	0.36	0.36	180
Interior Lighting	Exempted Lighting	100%	0.16	0.16	78
Interior Lighting	Linear Lighting	100%	1.34	1.34	663
Interior Lighting	High-Bay Lighting	100%	0.61	0.61	303
Exterior Lighting	General Service Lighting	100%	0.32	0.32	158
Exterior Lighting	Linear Lighting	100%	0.25	0.25	123

End Use	Technology	Saturation	EUI (kWh/SqFt)	Intensity (kWh/SqFt)	Usage (GWh)
Exterior Lighting	Area Lighting	100%	0.22	0.22	109
Refrigeration	Walk-in Refrigerator/Freezer	34%	1.50	0.52	254
Refrigeration	Reach-in Refrigerator/Freezer	22%	0.79	0.17	85
Refrigeration	Glass Door Display	10%	1.26	0.13	62
Refrigeration	Open Display Case	3%	0.96	0.02	12
Refrigeration	Icemaker	46%	0.46	0.21	105
Refrigeration	Vending Machine	53%	0.13	0.07	34
Food Preparation	Oven	26%	0.11	0.03	15
Food Preparation	Fryer	11%	0.17	0.02	9
Food Preparation	Dishwasher	12%	0.11	0.01	7
Food Preparation	Hot Food Container	17%	0.06	0.01	5
Food Preparation	Steamer	12%	0.12	0.01	7
Food Preparation	Electric Griddle	16%	0.17	0.03	14
Office Equipment	Desktop Computer	47%	0.87	0.41	203
Office Equipment	Laptop	30%	0.10	0.03	15
Office Equipment	Monitor	48%	0.17	0.08	40
Office Equipment	Server	19%	0.62	0.11	57
Office Equipment	Printer/Copier/Fax	44%	0.27	0.12	59
Office Equipment	POS Terminal	24%	0.11	0.03	13
Miscellaneous	Non-HVAC Motors	65%	0.38	0.25	123
Miscellaneous	Pool Pump	43%	0.10	0.04	22
Miscellaneous	Pool Heater	24%	0.05	0.01	6
Miscellaneous	Clothes Washer	23%	0.03	0.01	3
Miscellaneous	Clothes Dryer	5%	0.21	0.01	5
Miscellaneous	Electric Vehicle Charger	5%	0.19	0.01	5
Miscellaneous	Miscellaneous	100%	0.93	0.93	457
Generation	Solar PV	27%	-3.52	-0.95	-470
Total				**11.87**	**5,864**

End Use Load Shapes

AEG developed a model to estimate the 8760 hourly load on each island at the end-use level in 2018. The key inputs to the model were AEG's annual 2018 estimates of energy use at the end-use and technology level (described above) and unitized end-use load shapes from the following sources:

- EnergyPlus Simulations:[22] Hourly, physics-based, end-use simulations for residential and commercial building prototypes. We used these simulation models with normal weather data (typical meteorological year, TMY) from weather stations on each island to shape weather-sensitive loads for Hawaii. AEG developed the single family residential prototypes in BEopt™ with EnergyPlus v8.8 as the simulation engine using Hawaii-specific data on housing characteristics and end uses.[23] Other simulations were from the U.S. Department of Energy's OpenEI dataset using models developed for IECC Zone 1A (Hawaii's climate zone).[24]
- California Energy Commission (CEC) Load Shape Study:[25] Hourly end-use shapes for residential and commercial buildings in California. We used the CEC load shapes for non-weather sensitive loads and selected data for a southern California climate zone to approximate Hawaii's latitude as closely as possible.

Hourly data for solar PV simulations was derived from NREL's PVWatts® Calculator.[26] AEG then used the following steps to develop end-use load shapes:

- Developed a mapping between the residential and commercial market profiles and the appropriate load shapes for each segment, end-use, and technology.
- Developed a load profile for each segment consisting of a set of unitized end-use/technology load shapes.
- Multiplied the unitized load shapes from EnergyPlus (weather sensitive loads) and CEC (non-weather sensitive loads) by the corresponding end-use/technology intensity from the market profiles.

In unitized load shapes, the sum of the 8760 values for the year equals 1, which allows those fractions to be multiplied by the annual energy values to create a load shape with units of energy per hour.

Figure 3-11 through Figure 3-13 on the next page provide examples of hourly load shapes resulting from the analysis. These examples show data for the island of Oahu on the system peak day in 2018, which occurred in October. Figure 3-11 includes sales load shapes for the commercial and residential sectors, the military, and the island as whole. The dashed line represents consumption for the island as a whole, without subtracting distributed generation (DG). Figure 3-12 and Figure 3-13 show end-use profiles for the residential and commercial sectors, respectively.

For comparison, Table 3-9 shows the estimated peak load (MW) on the island system peak day for each island. Since each island peaks at a different time, peaks should not be summed across islands.

Table 3-9 Island-Level Peak Estimates

Island	Island Peak (MW)	Month of Island Peak
Oahu	1,237.0	October
Hawaii	190.4	December
Maui	199.1	October
Molokai	5.8	November
Lanai	5.8	November
Kauai	80.8	October

---

[22] EnergyPlus is an open-source whole-building energy modeling engine. Source: Department of Energy, Energy Efficiency & Renewable Energy, https://www.energy.gov/eere/buildings/downloads/energyplus-0.

[23] National Renewable Energy Laboratory. Building Energy Optimization (BEopt) Software. Version 2.8.0.0. U.S. Department of Energy. January 2018. Available at: https://beopt.nrel.gov/.

[24] Commercial and Residential Hourly Load Profiles for all TMY3 Locations in the United States, OpenEI Datasets, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, last website update: Oct/Nov 2014, <https://openei.org/doe-opendata/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states>.

[25] The California Energy Commission provided the HPUC with a set of 8760 hourly loads for 2018. The load shapes were developed with data from 12 forecast zones in California, https://ww2.energy.ca.gov/2019publications/CEC-500-2019-046/CEC-500-2019-046.pdf.

[26] PVWatts Calculator, https://pvwatts.nrel.gov/.

Figure 3-11 Oahu Sector-Level Load During Island Peak, 2018

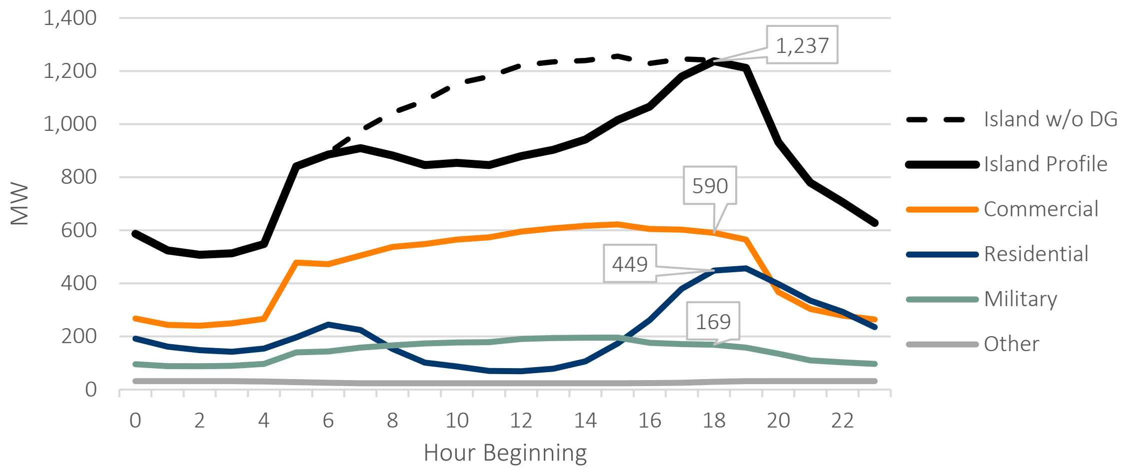


Figure 3-12 Oahu Residential Load During Island Peak by End Use, 2018[27]

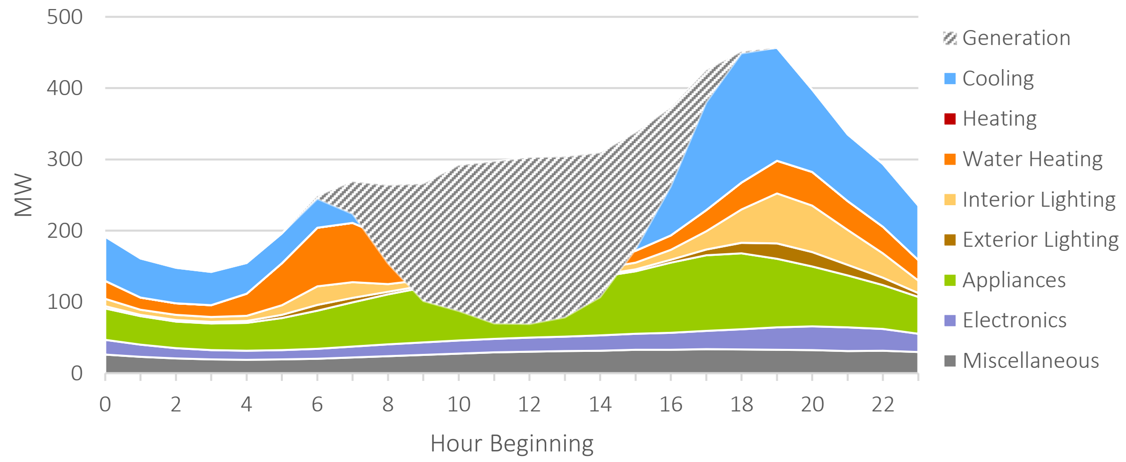
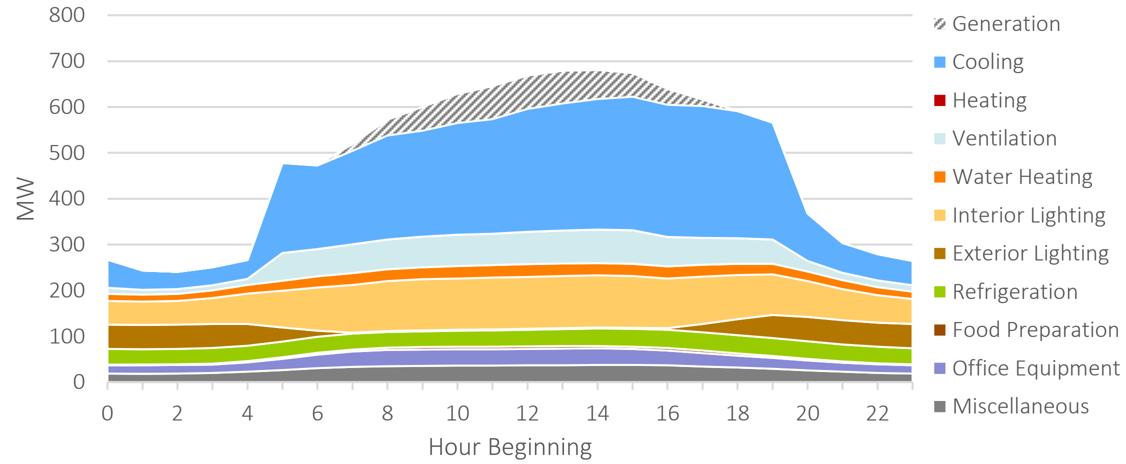


Figure 3-13 Oahu Commercial Load During Island Peak by End Use, 2018



---

[27] The "Generation" areas in both charts do not suggest that only those end uses from the top down (largely cooling) are affected.

The residential peak day shape exhibits the expected "duck" curve for consumption and sales due to the high penetration of solar PV systems. However, sales still peak in the evening based on household occupancy patterns.

- Water heating and lighting are in use while occupants are home (morning and night).
- This outweighs the cooling required during the traditional afternoon peak.
- Appliances behave mainly as a "base load" but their high end-use share results in a noticeable peak impact.

Commercial load peaks during the early afternoon. Lower PV penetration does not substantially change the shape. Cooling and ventilation are the main drivers of the peak, followed by interior lighting. Building types have different occupancy schedules resulting in the "blockiness" exhibited in the commercial end-use profiles. Lights for an office might turn off around 5 pm, but a restaurant, retail store, or resort may stay illuminated late into the evening.

4

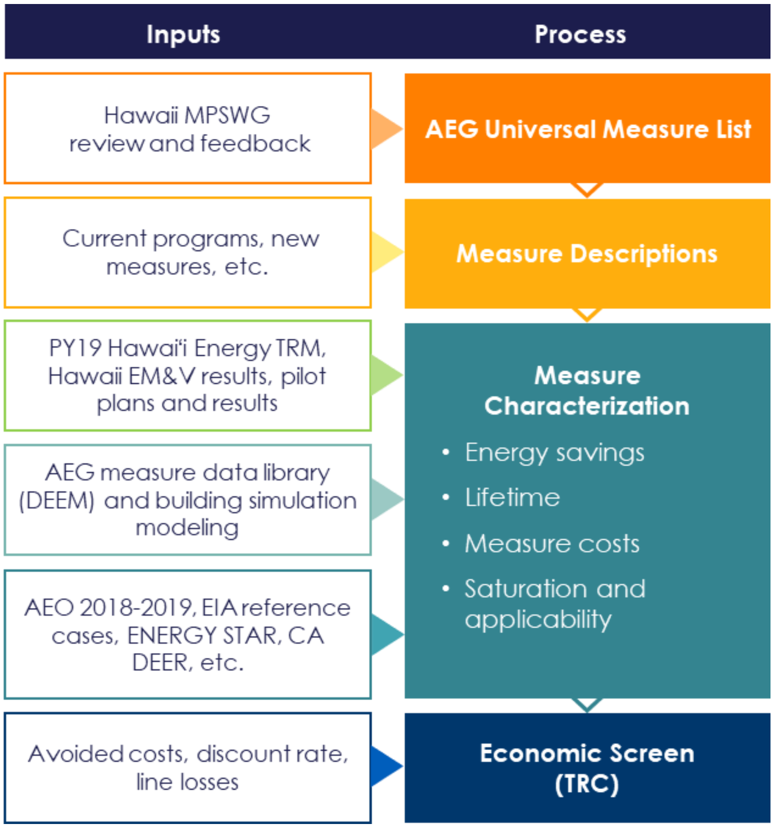
ENERGY EFFICIENCY MEASURES

AEG considered hundreds of measures in the energy efficiency potential analysis. The subsections below summarize the approach used to assess the savings, costs, and other attributes of energy efficiency measures and describe the scope of the measures included in the study.

Approach for Measure Assessment

Figure 4-1 outlines the approach for energy efficiency measure assessment. The approach involved identifying the list of measures to include in the analysis, determining their applicability to each island, market sector and segment, fully characterizing each measure, and performing economic screening for cost-effectiveness.

Figure 4-1 Approach for Measure Assessment



AEG began by compiling a robust list of measures for each customer sector. When compiling the list and describing the measures, we drew upon input from the Hawaii MPS working group (MPSWG), program experience in Hawaii, AEG's measure databases and building simulation models, and secondary sources. We identified new and emerging technologies for inclusion in the list through a detailed screening process that assessed the feasibility of measures. AEG engineers, through the AEG Database of Energy Efficiency Measures (DEEM), constantly monitor for new and emerging measures by following trends in energy-efficient technologies that are available on the market, as well as those expected to be on market in the coming years.

For all measures, we assembled measure characterization information from the PY19 Hawai'i Energy TRM and other sources to reflect energy savings, measure lifetimes, and incremental measure costs. We included non-energy impacts if they could be both quantified and monetized (e.g., water savings from high efficiency clothes washers). These characteristics form the basis for determining measure-level savings as well as for measure-level cost-effectiveness analysis. For the cost-effectiveness analysis, we used this measure characterization information along with avoided cost data from the Hawaii PY19 TRM and KIUC in the economic screen to determine economically feasible measures. The economic screen used the total resource cost (TRC) test. The total savings, costs, and monetized non-energy benefits are calculated for each year of the study and depend on the base year saturation of the measure, the applicability of the measure, and the savings as a percentage of the relevant energy end uses. Table 4-1 lists the information provided for each measure during the measure characterization process.

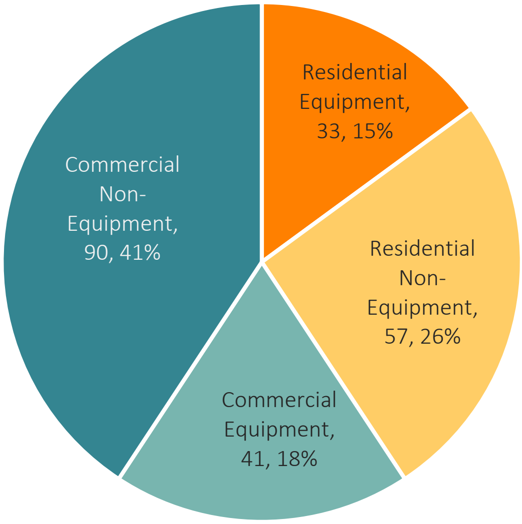
Table 4-1 Measure Characterization Information

Measure Identifiers
Island: Relevant island for which this measure applies. Includes data for Oahu, Hawaii, Maui, Kauai, Molokai, and Lanai as well as for the Military (Military is covered for all islands except Kauai).
Sector: Relevant market sector for which this measure applies.
Segment: Relevant market segment, building type, or facility type.
Vintage: New or existing construction application.
End Use: Category of end-use equipment to which measure savings apply.
Measure Name: Name of measure analyzed.
Measure ID: Identification code unique to every measure in the MPS. Indicates the island, sector, measure type (Equipment or Non-Equipment), and unique reference number.
Measure Characteristics
Efficient Option Definition: Specification of a measure's baseline condition in the final year of analysis.
Efficient Option Definition: Specification of a measure's efficient condition in the final year of analysis.
Base-Year Saturation: Percentage of units (homes, building, equipment, etc.) that have already installed or received the measure.
Applicability: Percentage of units (homes, buildings, equipment, etc.) that can receive the measure. Accounts for technical limitations of installing the measure. The available market is Applicability minus Base Year Saturation.
Assigned Participation Rate: Name of participation rate applied to a specific measure. Participation rate taxonomy considers measure type (i.e., lost opportunity, retrofit), years to technical maturity, and representative measure category (used to estimate achievability)
Assigned Load Shape: Name of 8,760 load shape used for modeling hourly impacts and island-coincident peak impacts for a specific measure.
Line Loss: Electric system delivery losses, expressed as % of consumption at the customer site.
Measure Data
Measure Life (Yrs.): Expected lifetime of a measure.
Unit Energy Savings (Annual kWh): First-year kWh savings at the customer meter.
Unit Island-Coincident Peak Savings (kW): First-year island-coincident peak reduction at the customer meter.
Unit Incremental Cost (2018$): Includes incremental equipment and labor costs.
Non-Energy Impacts (2018$): Annual non-energy impacts present in a measure, positive implies a benefit.
Unit of Measure: All measures are modeled in units consistent with their primary data sources. For example, General Service LEDs are reported per lamp installed, so the unit energy and peak savings, costs, non-energy impacts, and cumulative purchases are all reported per lamp.

Scope of Measures

This universal list of measures covers all major types of end-use equipment, as well as devices and actions to reduce energy consumption. If considered today, some of these measures would not pass the economic screens initially but may pass in future years as a result of lower projected equipment costs or higher avoided cost benefits. The selected measures are categorized into two types according to the LoadMAP modeling taxonomy: equipment measures and non-equipment measures. In all, the final measure list included 74 equipment measures (not counting the multiple efficiency levels for most measures) and 147 non-equipment measures. Figure 4-2 shows the breakdown by sector and measure type.

Figure 4-2 Distribution of Measures in Final Measure List



- Equipment measures are efficient energy consuming pieces of equipment that save energy by providing the same service with a lower energy requirement than a standard unit. An example is an ENERGY STAR® refrigerator that replaces a standard-efficiency refrigerator. For equipment measures, many efficiency levels may be available for a given technology, ranging from the baseline unit (often determined by code or standard) up to the most efficient product commercially available. For instance, in the case of central air conditioners, this list begins with the current federal standard SEER 14 unit and spans a broad spectrum up to a maximum efficiency of a SEER 24 unit. These measures are applied on a stock-turnover basis, and in general, are referred to as lost opportunity measures since once a purchase decision is made, there will not be another opportunity to improve the efficiency of that equipment item until the lifetime expires again.
- Non-equipment measures save energy by reducing the need for delivered energy, but typically do not involve replacement or purchase of major end-use equipment (such as a refrigerator or air conditioner) so they can be implemented at any time. An example would be a Wi-Fi-enabled thermostat that is pre-set to run heating and cooling systems only when people are home. Non-equipment measures can apply to more than one end use. For instance, the addition of wall insulation will affect the energy use of both space heating and cooling equipment. Non-equipment measures typically fall into one of the following categories:
    - Building shell (windows, insulation, roofing material)
    - Equipment controls (thermostat, integrated lighting fixture controls)
    - Whole-building design (advanced new construction, passive solar lighting)
    - Displacement measures (destratification fans to reduce use of central air conditioners)
    - Retro-commissioning
    - Home and business behavioral programs
    - Energy management programs

Appendix C contains the measure list.

5

BASELINE FORECASTS

Prior to estimating future potential savings from energy efficiency, AEG developed several projections of annual electricity use for 2018 through 2040. These projections led to the development of baseline forecasts used to quantify the likely consumption in the future in absence of any energy efficiency programs or policy interventions. The baseline forecasts are the metric against which we measure future savings from programs and other interventions.

Baseline Forecast Development

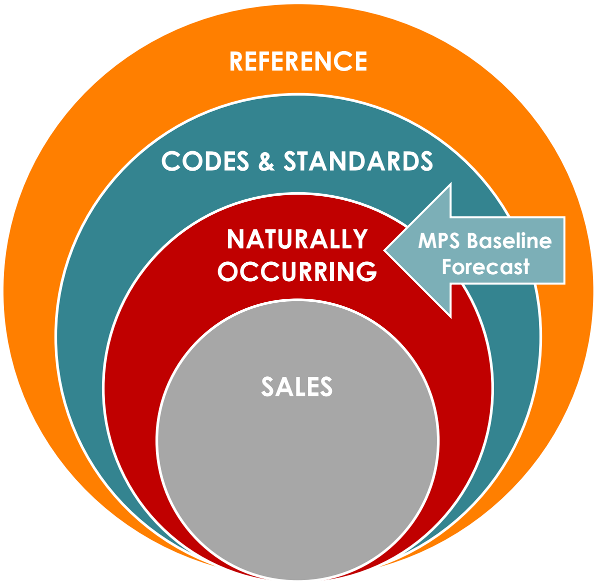
AEG developed projections of electricity use by island, sector, segment, end use, and technology for 2018 through 2040. Inputs to the baseline projection included the following:

- Base-year market profiles
- Forecasts of electricity sales, distributed generation, and electric vehicles
- Appliance standards and building codes already known to be taking effect after 2018
- Forecasts of naturally occurring efficiency. This is particularly important for general-service lighting and solar water heating technologies where there is momentum outside of programs.

The savings from past programs are embedded in the base-year market profiles and the electricity use projections assume that these past programs cease to exist in the future. Thus, the potential analysis captures all possible savings from future programs and policy interventions.

The projections consisted of four different scenarios of electricity use, which each scenario progressively lowering the baseline:

- Reference baseline: Forecast of consumption prior to any future interventions
- Codes and standards: Includes savings that occur from an upgrade from the minimum level of efficiency available in the absence of codes and standards to what is required by a code or standard currently "on the books" (i.e., is expected to take effect during the forecast period)
- Naturally occurring efficiency: Includes savings that occur when customers choose to install an energy-efficiency measure outside of programs. For this analysis, AEG accounted for naturally occurring efficiency in the lighting and water heating end uses.



- Sales: Forecast of electricity sales as opposed to consumption; this projection removes generation from customer-sited distributed energy resources, such as rooftop solar PV systems

AEG used the naturally occurring projection as the baseline forecast for the potential analysis. Therefore, the baseline forecast includes the relatively certain impacts of codes and standards and naturally occurring efficiency that will unfold over the study timeframe.

The subsections below summarize the baseline forecast results for the State of Hawaii and by customer sector and end use. Appendix A contains more detailed baseline forecast results, including forecasts by island and for the military.

State-Level Baseline Forecast

Figure 5-1 presents the four electricity use scenario projections (including generation) for the State of Hawaii. The contribution of each scenario to reducing the electricity use from the reference case is shaded in the figure. For example, the light teal-colored shaded area represents the *reduction* to the reference case electricity use projection due to savings from codes and standards, while the pink shaded area represents the *additional reduction* to the electricity use projection due to naturally occurring savings. As previously mentioned, the naturally occurring baseline, which includes generation, is utilized as the baseline forecast for the potential analysis.

Figure 5-1 All Island State-Level Electricity Use Projections (including Generation)

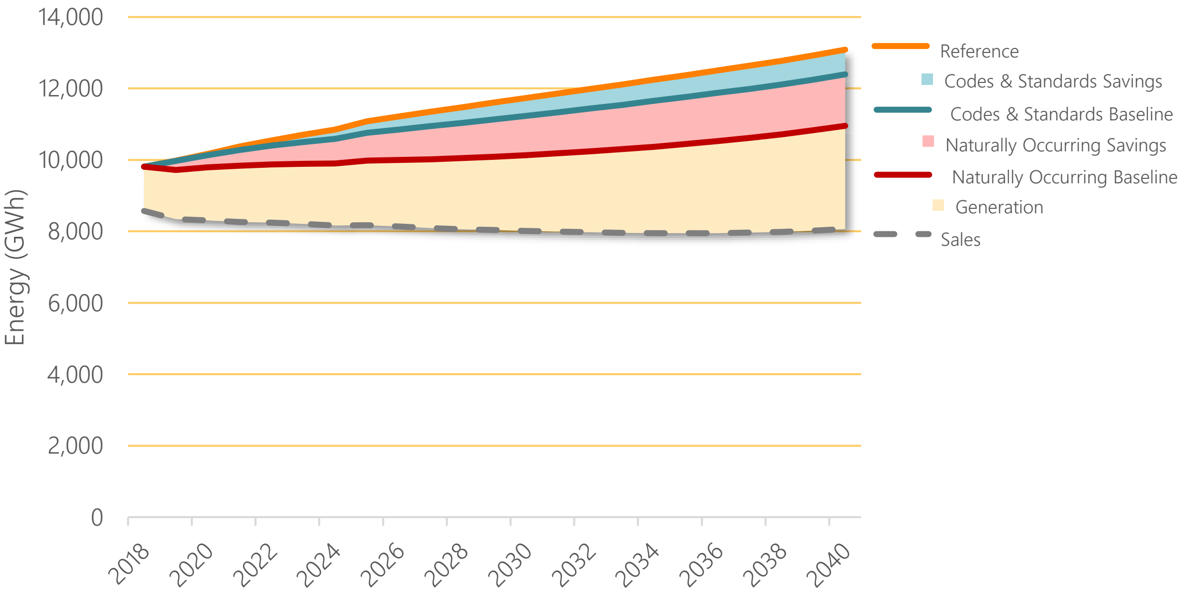
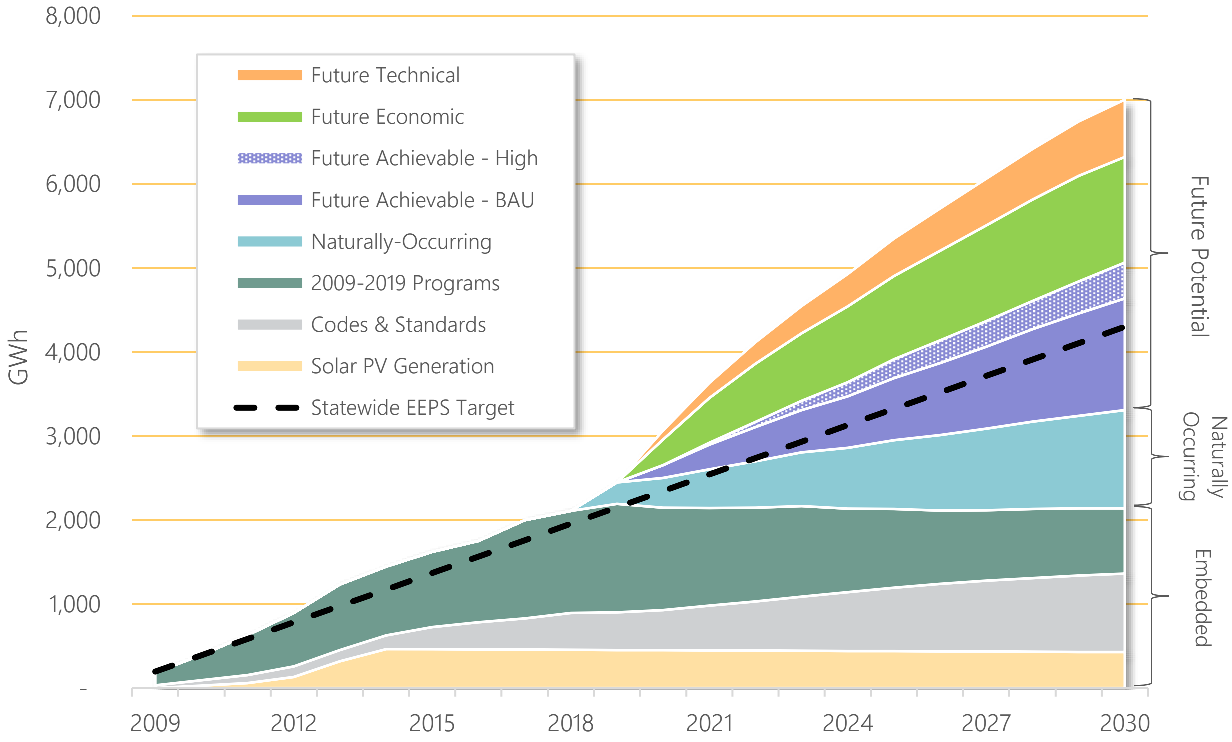


Table 5-1 presents electricity use data for select years of the naturally occurring forecast, which is utilized as the baseline to estimate potential savings. The military and non-military segments are broken out into residential and commercial sectors. Non-military accounts for 89% of total projected baseline electricity use in 2040 (11% for military). The residential sector (military and non-military combined) accounts for

42% of total projected baseline electricity use in 2040Figure ES-3 Cumulative Persistent Energy Savings (GWh), 2009-2030, EEPS Perspective



These estimates reflect the change to the EISA standard that took place in late December 2019, which essentially removed the second tier of the standard. The effect of this change was to shift savings that would have been attributed to appliance standards (Codes and Standards savings) to savings that could be achieved through programs and/or other interventions. Care should be taken when comparing these results with other potential studies completed in the same timeframe as the assumptions around EISA Tier 2 might be different than those used here.

Table ES-1 presents total cumulative persistent energy savings (cumulative savings) potential estimates for the State of Hawaii for selected years through 2040. In 2020, achievable potential - BAU energy savings are 150 GWh or 1.5% of the baseline forecast. By 2040, cumulative persistent energy savings are 2,262 GWh or 20.6% of the baseline forecast for the achievable potential - BAU case.

Figure ES-4 and Figure ES-5 present the cumulative persistent energy savings and the baseline forecast as compared to each potential projection, respectively. Potential estimates in the later years flatten as ramp rates approach maturity and measure saturations reach maximum adoption. By 2040, cumulative savings for the achievable potential - high case are 3,089 GWh or 28.2% of the baseline forecast.

(58% for commercial sector).

Table 5-1 All Island State-Level Baseline Forecast (Naturally Occurring), by Sector (GWh)

Segment	Sector	2018	2020	2021	2022	2030	2040	% Change ('18-'40)	Avg. Growth
Non-Military	Residential	3,432	3,441	3,465	3,493	3,791	4,528	31.9%	1.5%
	Commercial	5,211	5,189	5,211	5,220	5,185	5,238	0.5%	0.0%
	Subtotal	*8,643*	*8,629*	*8,676*	*8,713*	*8,976*	*9,766*	*13.0%*	*0.6%*
Military	Residential	44	44	45	45	49	59	32.9%	1.5%
	Commercial	1,123	1,116	1,116	1,114	1,106	1,130	0.6%	0.0%
	Subtotal	*1,167*	*1,161*	*1,161*	*1,160*	*1,156*	*1,189*	*1.8%*	*0.1%*
Total		**9,810**	**9,790**	**9,837**	**9,873**	**10,132**	**10,955**	**11.7%**	**0.5%**

Residential Baseline Forecast

Figure 5-2 and Table 5-2 present the residential electricity baseline forecast at the end use level. Overall, total residential consumption increases by 31.9% from 2018 to 2040, or an average of 1.5% per year. Water heating and electronics usage remains relatively flat while the electric vehicles end use experiences very high average annual growth of 15.6% and cooling experiences steady growth of 1.5% per year on average.

Figure 5-2 All Island Residential Baseline Forecast (Naturally Occurring), by End Use

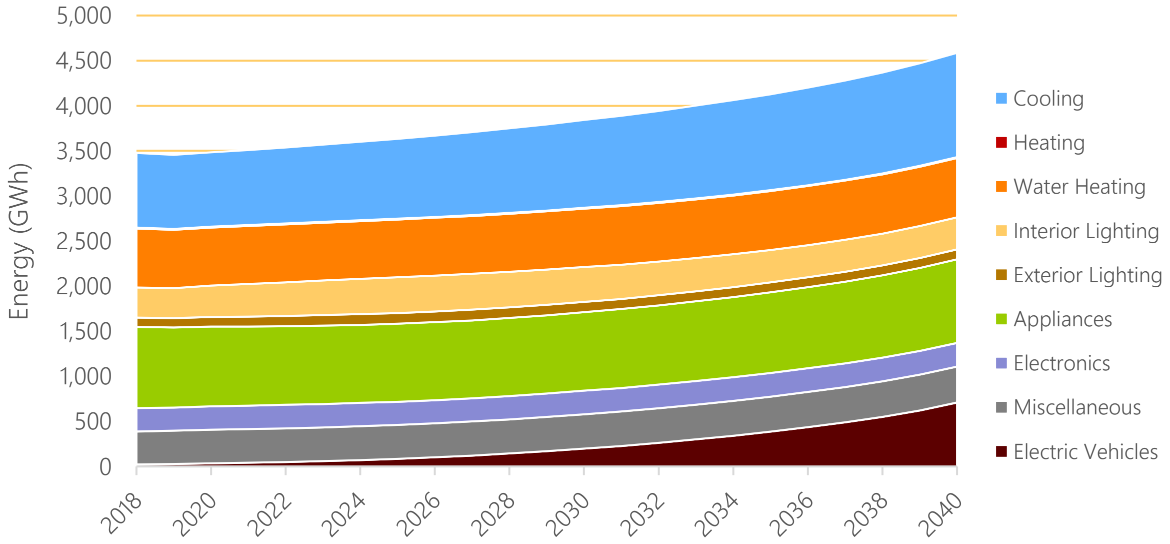


Table 5-2 All Islands Residential Baseline Forecast (Naturally Occurring), by End-Use (GWh)

Segment	2018	2020	2021	2022	2030	2040	% Change ('18-'40)	Avg. Growth
Cooling	827	826	834	844	973	1,156	39.7%	1.5%
Heating	10	10	10	10	10	10	5.2%	0.2%
Water Heating	654	646	644	643	646	657	0.6%	0.0%
Interior Lighting	334	346	360	373	386	356	6.7%	0.3%
Exterior Lighting	104	108	111	114	115	110	5.2%	0.2%
Appliances	900	882	876	871	872	928	3.2%	0.1%
Electronics	259	262	261	260	260	261	0.6%	0.0%
Miscellaneous	365	373	373	374	381	400	9.4%	0.4%
Electric Vehicles	23	34	41	49	198	708	3010.9%	15.6%
Total	**3,476**	**3,485**	**3,510**	**3,538**	**3,840**	**4,586**	**31.9%**	**1.5%**

Commercial Baseline Forecast

Figure 5-3 and Table 5-3 present the commercial electricity baseline forecast at the end use level. Overall, total commercial consumption increases by a modest 0.5% from 2018 to 2040, with annual average growth staying flat over the period. Cooling, water heating, and refrigeration experience a decline in consumption while food preparation and lighting each experience average annual growth of 0.8%.

Figure 5-3 All Island Commercial Baseline Forecast (Naturally Occurring), by End Use

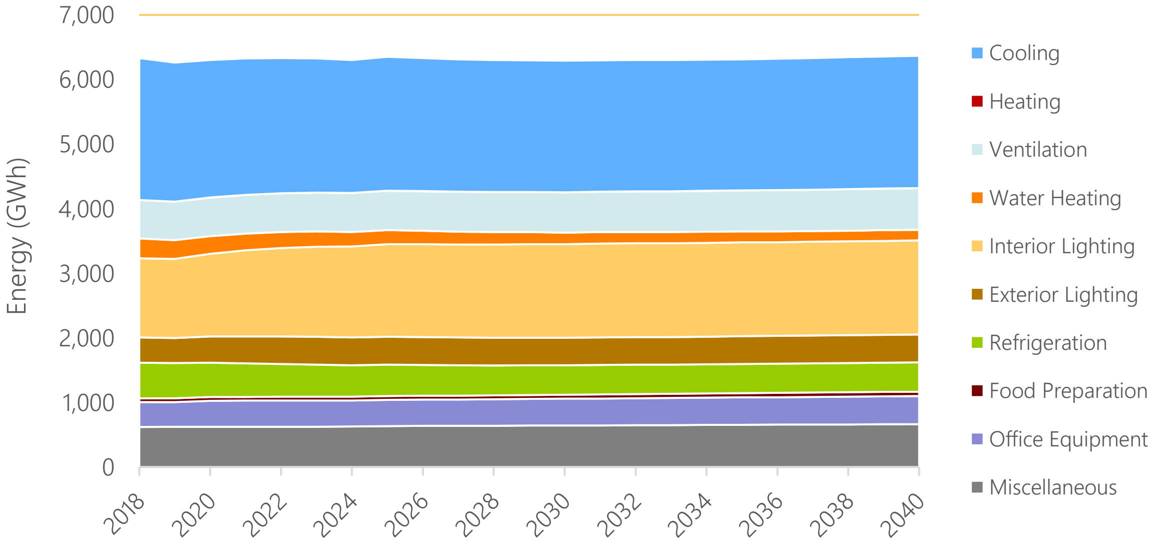


Table 5-3 All Islands Commercial Baseline Forecast (Naturally Occurring), by End-Use (GWh)

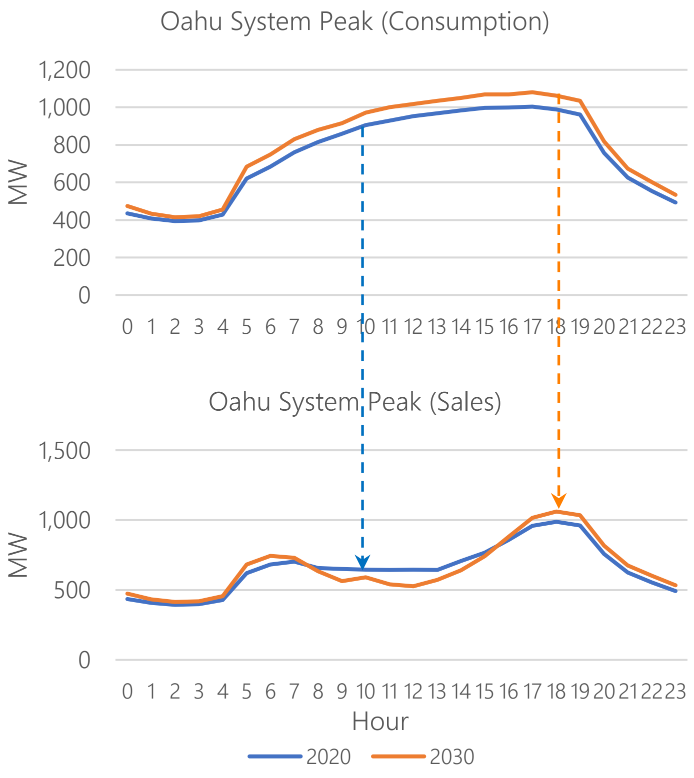
Segment	2018	2020	2021	2022	2030	2040	% Change ('18-'40)	Avg. Growth
Cooling	2,200	2,131	2,111	2,094	2,036	2,048	-6.9%	-0.3%
Heating	1	1	1	1	1	1	8.7%	0.4%
Ventilation	595	597	598	599	623	646	8.5%	0.4%
Water Heating	307	275	262	249	183	164	-46.5%	-2.8%
Interior Lighting	1,225	1,280	1,332	1,370	1,444	1,454	18.7%	0.8%
Exterior Lighting	390	404	417	425	427	431	10.6%	0.5%
Refrigeration	553	532	520	508	456	456	-17.4%	-0.9%
Food Preparation	57	57	57	57	64	68	19.5%	0.8%
Office Equipment	385	405	405	406	415	432	12.2%	0.5%
Miscellaneous	621	623	624	625	643	666	7.2%	0.3%
Total	**6,334**	**6,305**	**6,327**	**6,334**	**6,291**	**6,368**	**0.5%**	**0.0%**

Hourly Baseline Forecast

AEG used the hourly model developed for the base year, 2018 (see Chapter 3, End Use Load Shapes), coupled with the annual baseline forecast described above to project hourly loads through 2030. The projection aligns with HECO assumptions regarding load growth and customer-sited PV. It also includes future codes & standards "on the books" and known market transformation. We modelled equipment consumption and hourly generation profiles simultaneously, allowing us to shift between consumption and sales.

Figure 5-4 shows a comparison of the hourly forecasts (consumption and sales) for the Oahu system peak day in 2020 versus 2030. Consumption increases from 2020 to 2030, but the 2030 sales load shape shows a deeper dip during the midday hours due to the expected growth in customer-sited PV. (Note that Hour = 0 represents the hour from midnight to 1 am.)

Figure 5-4 Oahu Hourly System Peak Forecast, 2020 vs. 2030



6

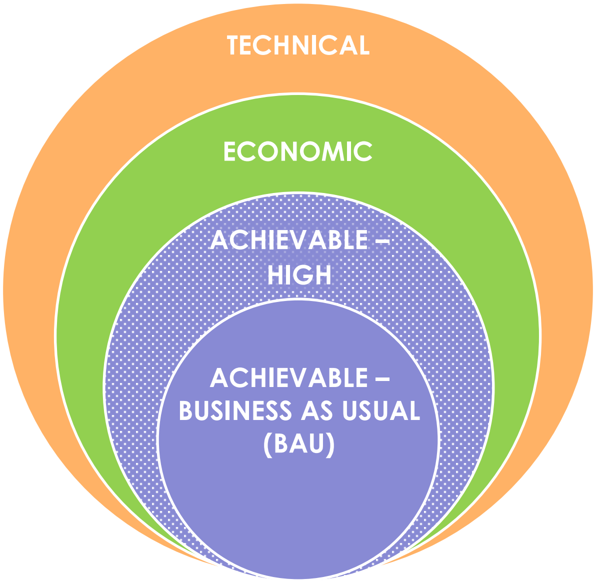
ENERGY EFFICIENCY POTENTIAL

AEG estimated four levels of energy efficiency savings potential through 2040. The subsections below define the levels of potential and present summaries of the twenty-year potential results at the state, sector, and island levels. Chapter 7 provides additional summary-level results for the EEPS timeframe through 2030. Appendix A contains detailed results from the energy efficiency potential analysis.

Levels of Potential

AEG developed the Hawaii MPS savings estimates for four types of potential: technical potential, economic potential, achievable potential – high, and achievable potential – business as usual (BAU).

- Technical potential: The theoretical upper limit of efficiency potential. It assumes that customers adopt all feasible measures regardless of their cost or customer preference:
    - At the time of existing equipment failure, customers replace their equipment with the most efficient option available; retrofit measures are phased in over a number of years to align with the stock turnover of related equipment units rather than modeled as immediately available all at once.
    - In new construction, customers and developers choose the most efficient option (e.g., installation of high-efficiency windows).
    - Customers also adopt every other available measure, where applicable (e.g., air conditioner maintenance in all existing buildings with central and room air conditioning).

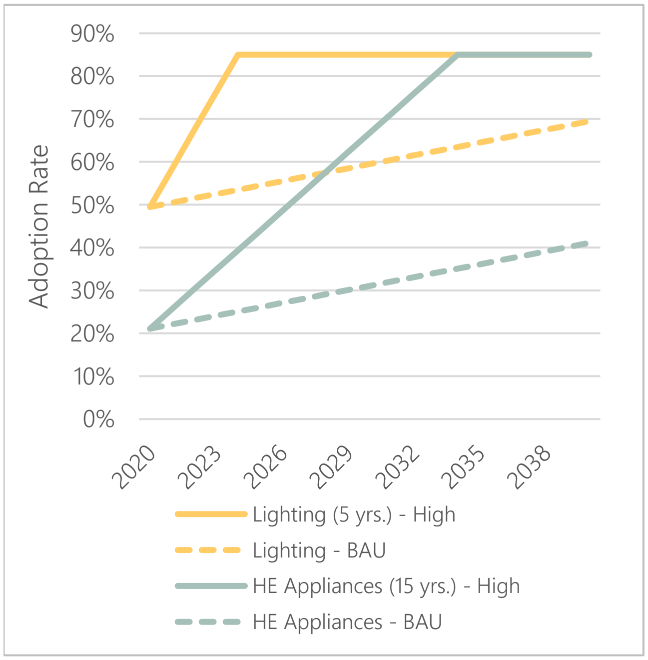


- Economic potential: Subset of technical potential that includes only cost-effective measures based on total resource cost test (TRC) using current avoided cost forecasts from HECO and KIUC. The costs are the incremental cost of the measure relative to the relevant baseline condition plus any utility costs that are incurred by the program to deliver and implement the measure. Non-energy impacts may be included if they can be both quantified and monetized. If the benefits outweigh the costs (that is, if the TRC ratio is greater than 1.0), the measure is included in the economic potential. Customers are assumed to purchase the most cost-effective option applicable at any decision juncture.
- Achievable potential: Subset of economic potential that accounts for likely customer adoption of energy efficiency measures. It refines economic potential by applying customer participation rates that account for market barriers, customer awareness and attitudes, program maturity, and recent program history. More specifically, achievable potential maintains current levels of participation for mature programs, but uses higher levels of participation where additional opportunity is identified. It also includes new measures, using market adoption rates based on secondary research. The bullet

points below describe two levels of achievable potential. Figure 6-1 shows examples of adoption rates for the two types of achievable potential.

- High: Assumes adoption ramps up linearly to a maximum limit of 85% market adoption, which is consistent with previous potential studies as well as with planning guidance in other regions of the country. Assumes program and market adoption from a variety of sources:
  - Expanded programs
  - Future (new) state and federal codes and standards
  - Future market effects
  - Other future interventions
- BAU: Assumes gradual maturation of future interventions which are similar to those in the market today.

Figure 6-1 Achievability Example: Adoption Rates for Residential Lighting and Appliances



AEG developed these four types of potential estimates at the measure level and provided results as annual savings impacts over the twenty-year projection horizon.

In addition to these four levels of potential, we also estimated technical achievable, a subset of technical potential that accounts for likely customer adoption of energy efficiency measures without consideration of costs. Technical achievable estimates are often calculated to support integrated resource planning (IRP). While IRP planning is not a consideration for this study, achievable technical potential is useful for understanding how much savings non cost-effective measures might provide, as is the case in the analysis of demand response and grid services (DR/GS) below[28].

Energy Efficiency Potential Results

State-Level Potential

Table 6-1 presents total cumulative persistent energy savings [29]potential estimates for the State of Hawaii. In 2020, achievable potential - BAU energy savings are 150 GWh or 1.5% of the baseline forecast. By 2040, cumulative energy savings are 2,262 GWh or 20.6% of the baseline forecast for the achievable potential - BAU case.

Figure 6-2 and Figure 6-3 present the cumulative energy savings and the baseline forecast as compared to each potential projection, respectively. Potential estimates in the later years flatten as ramp rates

---

[28] In addition, programs typically consist of bundles of measures that may include both cost-effective and not cost-effective, as long as they are cost-effective when combined.

[29] Throughout this report the labels "energy savings" and "cumulative savings" represent and are equivalent to cumulative persistent energy savings.

approach maturity and measure saturations reach maximum adoption. By 2040, cumulative energy savings for the achievable potential - high case are 3,089 GWh or 28.2% of the baseline forecast.

These estimates reflect the change to the EISA standard that took place in late December 2019, which essentially removed the second tier of the standard[30]. The effect of this change was to remove savings that would have been attributed to appliance standards (Codes and Standards savings) and increase savings that might be achieve through programs and/or other interventions. This increased the amount of Future Achievable savings (both BAU and High). Care should be taken when comparing these results with other potential studies completed in the same timeframe as the assumptions around EISA Tier 2 might be different than those used here.

Table 6-1 Energy Savings Potential Summary (GWh), All Sectors, All Islands – Select Years

	2020	2021	2022	2025	2030	2040
Baseline Forecast (GWh)	9,790	9,837	9,873	9,982	10,132	10,955
Cumulative Savings (GWh)						
Achievable Potential - BAU	150	295	406	737	1,329	2,262
Achievable Potential - High	150	316	468	963	1,755	3,089
Economic Potential	455	849	1,161	1,951	3,014	4,125
Technical Potential	563	1,031	1,415	2,399	3,695	5,088
Energy Savings (% of Baseline Consumption)						
Achievable Potential - BAU	1.5%	3.0%	4.1%	7.4%	13.1%	20.6%
Achievable Potential - High	1.5%	3.2%	4.7%	9.6%	17.3%	28.2%
Economic Potential	4.6%	8.6%	11.8%	19.5%	29.8%	37.7%
Technical Potential	5.7%	10.5%	14.3%	24.0%	36.5%	46.4%

---

[30] On December 27, 2019, the U.S. Department of Energy issued a final ruling stating that the efficiency standards for GSILs do not need to be amended; therefore, the backstop did not go into effect as originally planned. (Tier 2 of EISA called for a 45 lm/W minimum efficacy backstop for general service incandescent lamps (GSILs), which was subject to an effective date of January 1, 2020.) This means that potential savings from lightbulbs fall outside of codes and standards and a portion of those savings are available for future programs, while a portion is allocated to future naturally occurring savings.

Figure 6-2 Statewide Cumulative Energy Savings Potential Summary (GWh)

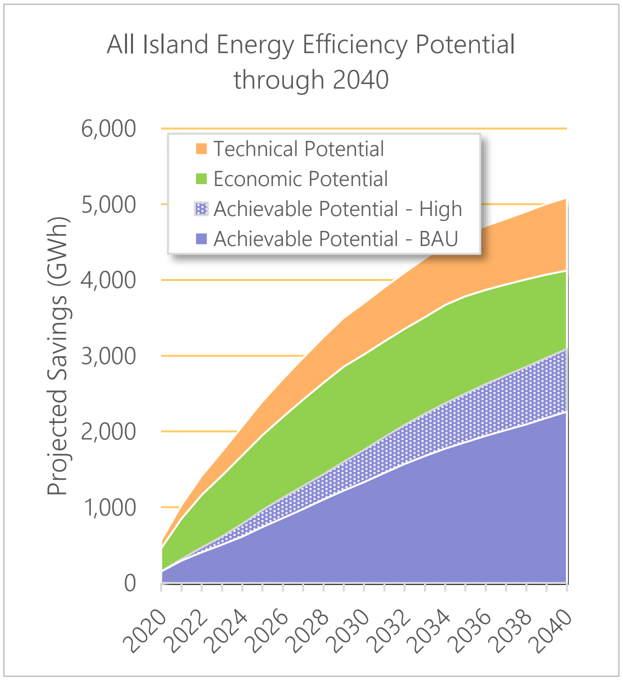


Figure 6-3 Statewide Baseline and Potential Forecasts (GWh)

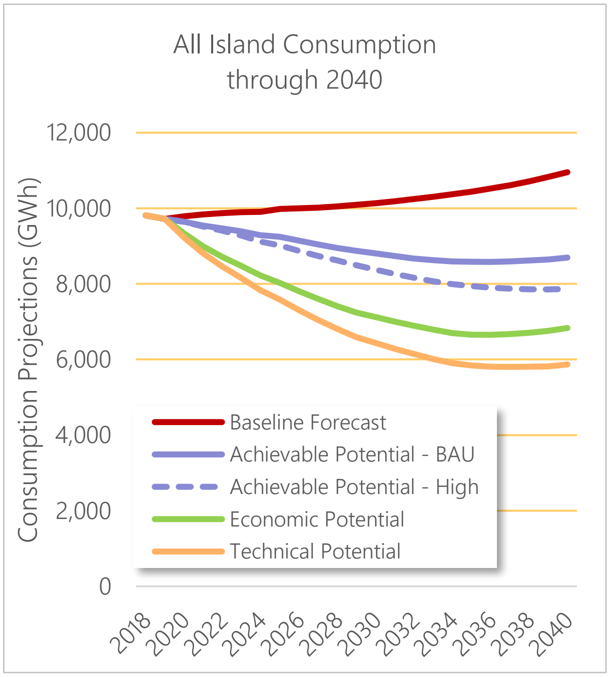


Figure 6-4 shows that Oahu represents the significant majority of the achievable potential - high of the Hawaiian islands and the military sector. (Potential savings for Lanai and Molokai are not visible on the graph because of their relatively small values.) Figure 6-5 presents achievable potential - high by sector, showing that commercial sector savings projections are greater than those for the residential sector. These sector-level results include military facilities. The subsections below describe the sector-level and island-level results in more detail.

Figure 6-4 Achievable-High Potential by Island and Military (GWh)

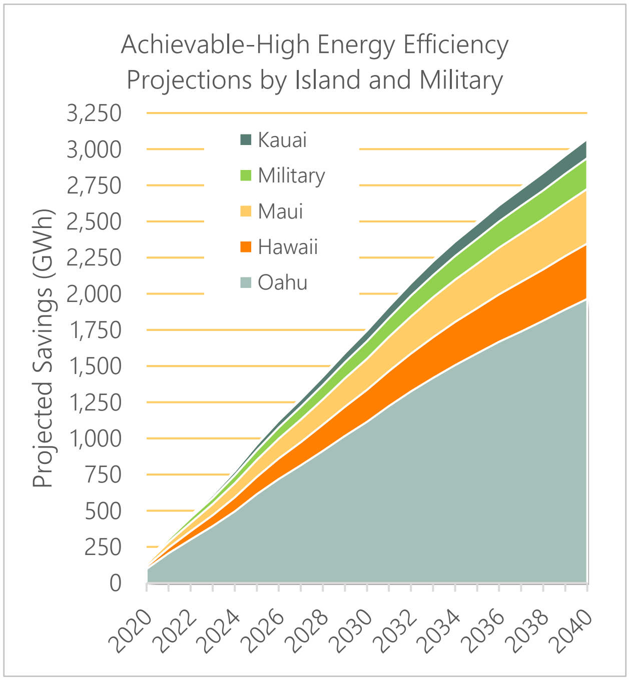
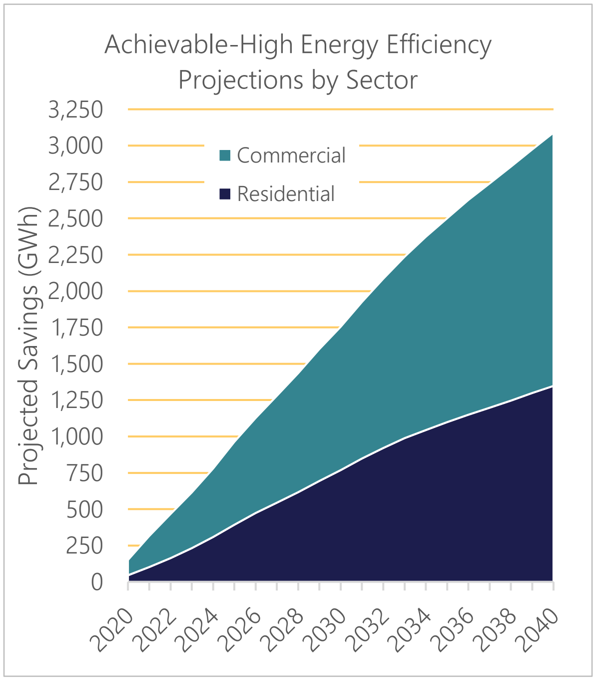


Figure 6-5 Achievable-High Potential by Sector (GWh)



Residential Potential

Table 6-2 presents total residential sector energy savings potential savings estimates for the State of Hawaii, including military residences. In 2020, achievable potential - BAU energy savings are 46 GWh or 1.3% of the baseline forecast. By 2040, cumulative energy savings are 938 GWh or 20.5% of the baseline forecast for the achievable potential - BAU case.

Figure 6-6 and Figure 6-7, respectively, present the cumulative residential sector energy savings and the residential sector baseline forecast as compared to each potential projection. By 2040, the achievable potential – BAU forecast flattens potential estimates to approximately early 2020s levels. The cumulative energy savings for the achievable potential - high case are 1,348 GWh or 29.4% of the baseline forecast.

Table 6-2 All Island Residential EE Potential Summary (GWh)

	2020	2021	2022	2025	2030	2040
Baseline Forecast (GWh)	3,485	3,510	3,538	3,632	3,840	4,586
Cumulative Savings (GWh)						
Achievable Potential - BAU	46	93	138	280	549	938
Achievable Potential - High	46	102	164	393	770	1,348
Economic Potential	171	319	459	814	1,284	1,674
Technical Potential	235	416	591	1,038	1,617	2,146
Energy Savings (% of Baseline Consumption)						
Achievable Potential - BAU	1.3%	2.7%	3.9%	7.7%	14.3%	20.5%
Achievable Potential - High	1.3%	2.9%	4.6%	10.8%	20.0%	29.4%
Economic Potential	4.9%	9.1%	13.0%	22.4%	33.4%	36.5%
Technical Potential	6.7%	11.9%	16.7%	28.6%	42.1%	46.8%

Figure 6-6 Residential Cumulative Energy Savings Potential Summary (GWh)

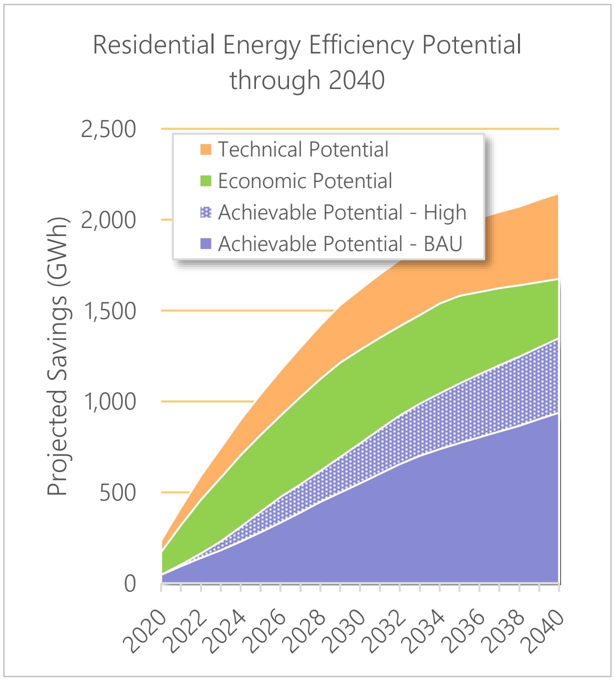


Figure 6-7 Residential Baseline and Potential Forecasts (GWh)

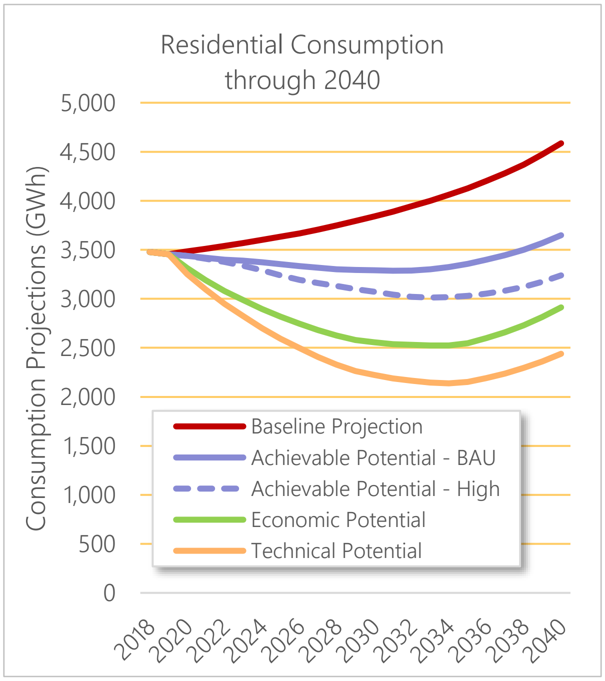
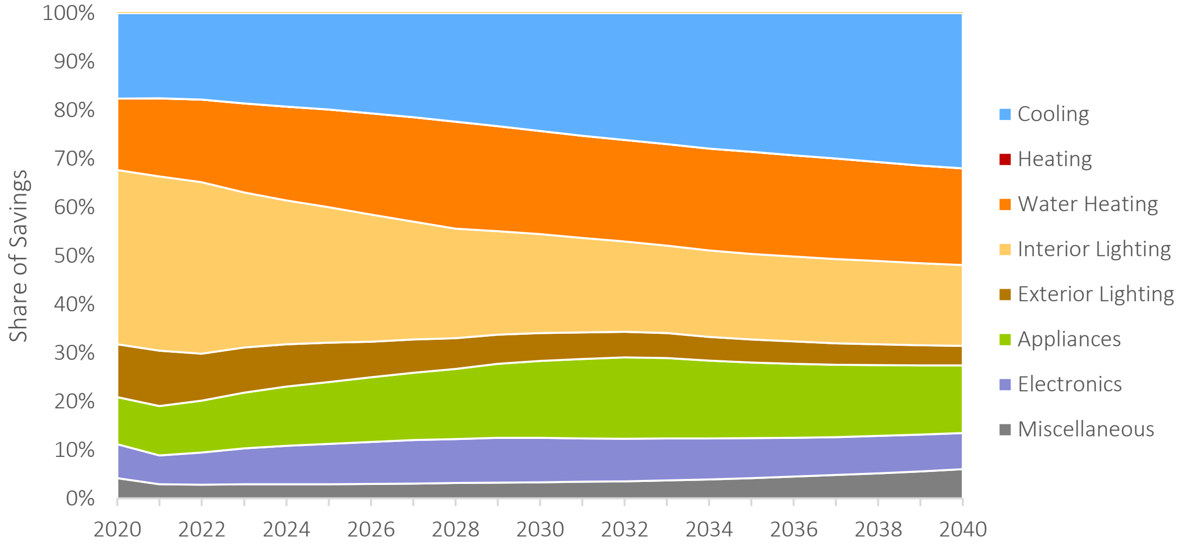


Figure 6-8 shows that cooling, water heating, and lighting measures account for most of the savings over the twenty-year period. Looking at trends, the share of energy savings for cooling, appliances, and water heating measures increases while the share of energy savings from lighting measures decreases from 2020 to 2040. This reflects the projected growth in penetration of air conditioners in residential homes, and the natural market adoption of efficient lighting.

Figure 6-8 All Island Residential Achievable Potential – High, % of Total Savings



Commercial Potential

Table 6-3 presents total commercial sector energy savings potential estimates for the State of Hawaii, including military facilities. In 2020, achievable potential - BAU energy savings are 104 GWh or 1.7% of the baseline forecast. By 2040, cumulative energy savings are 1,324 GWh or 20.8% of the baseline forecast for the achievable potential - BAU case.

Table 6-3 All Island Commercial EE Potential Summary (GWh)

	2020	2021	2022	2025	2030	2040
Baseline Forecast (GWh)	6,305	6,327	6,334	6,350	6,291	6,368
Cumulative Savings (GWh)						
Achievable Potential - BAU	104	202	268	457	780	1,324
Achievable Potential - High	104	214	304	570	986	1,741
Economic Potential	283	530	702	1,137	1,730	2,450
Technical Potential	328	615	825	1,361	2,078	2,942
Energy Savings (% of Baseline Consumption)						
Achievable Potential - BAU	1.7%	3.2%	4.2%	7.2%	12.4%	20.8%
Achievable Potential - High	1.7%	3.4%	4.8%	9.0%	15.7%	27.3%
Economic Potential	4.5%	8.4%	11.1%	17.9%	27.5%	38.5%
Technical Potential	5.2%	9.7%	13.0%	21.4%	33.0%	46.2%

Figure 6-9 and Figure 6-10 present the cumulative commercial sector energy savings potential and the commercial sector baseline forecast as compared to each potential projection. Unlike the residential sector, the commercial sector baseline forecast is relatively flat from 2020 to 2040. Therefore, the commercial sector potential savings forecasts do not flatten as seen with the residential sector potential savings forecasts. By 2040, the cumulative energy savings for the achievable potential - high case are 1,741 GWh or 27.3% of the baseline forecast.

Figure 6-9 Commercial Cumulative Energy Savings Potential Summary (GWh)

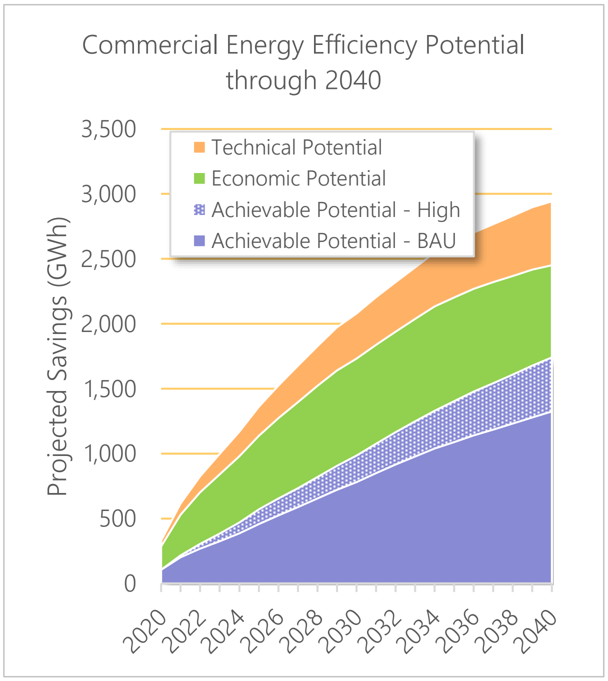


Figure 6-10 Commercial Baseline and Potential Forecasts (GWh)

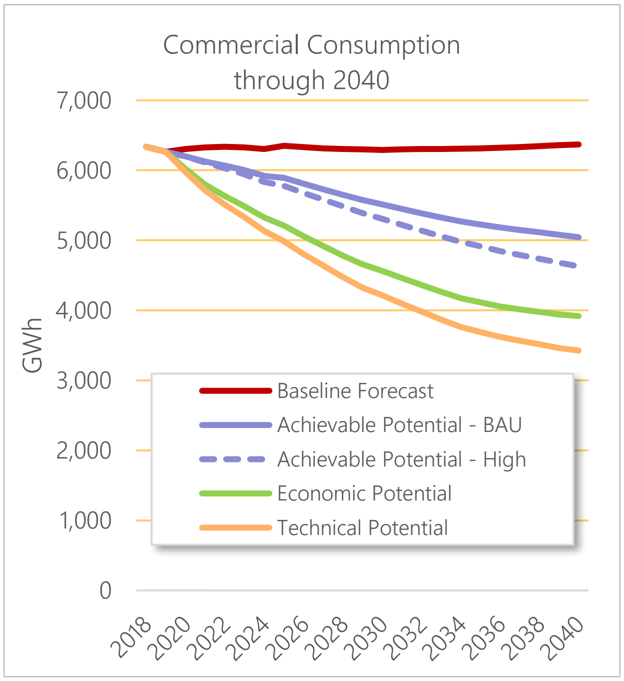
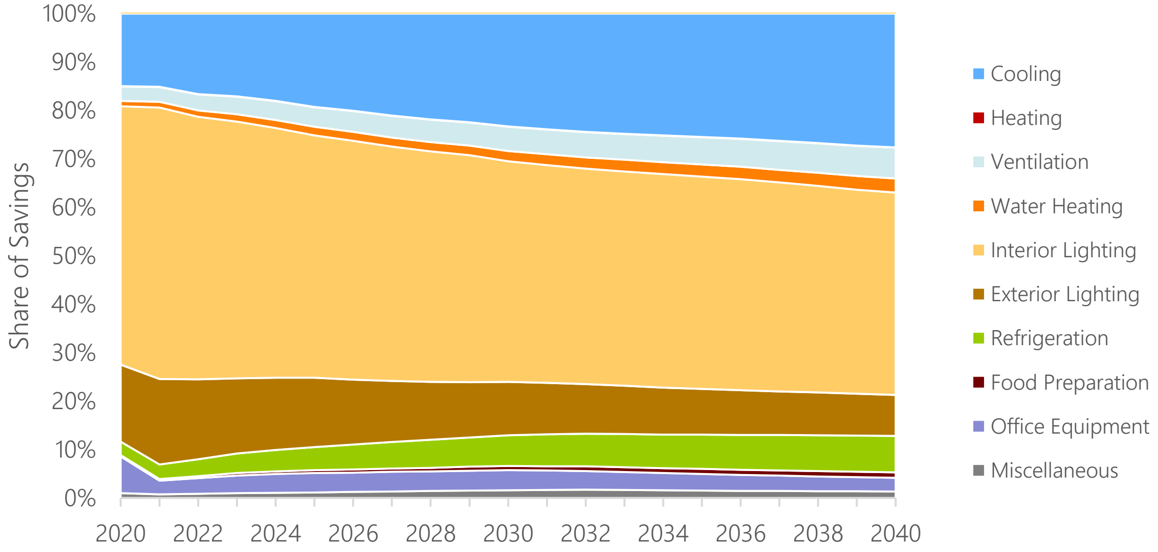


Figure 6-11 shows that a substantial share of the savings over the twenty-year period comes from lighting and cooling measures. Looking at trends, the share of energy savings for cooling, refrigeration, and ventilation measures increases while the share of energy savings from lighting measures decreases from 2020 to 2040. These trends reflect increasing opportunities to improve cooling efficiency and decreasing opportunities to improve lighting efficiency due to natural market adoption of efficient lighting.

Figure 6-11 All Island Commercial Achievable Potential – High, % of Total Savings



Potential by Island

Table 6-4 presents the cumulative energy savings potential by Island in 2040. In 2040, cumulative energy savings for the achievable potential - BAU case are 2,262 GWh. Oahu accounts for the majority (64%) of the total cumulative energy savings potential for the State of Hawaii, followed by Hawaii (13%), Maui (12%), the military (8%), and Kauai (3%). Molokai and Lanai account for less than 0.5% of cumulative energy savings potential.

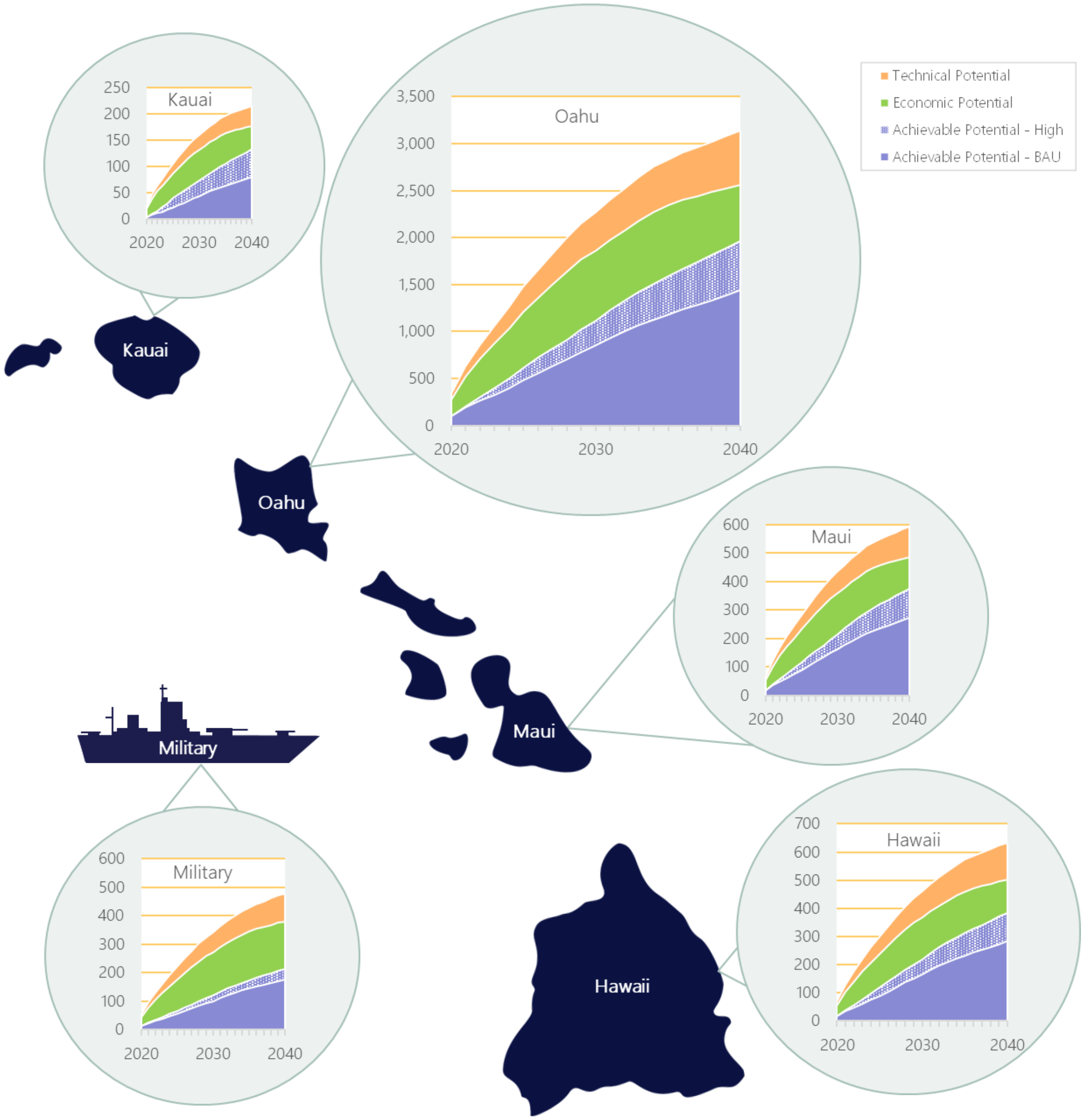
Table 6-4 Energy Savings Potential Summary (GWh), All Sectors, By Island and for the Military – 2040

All Sectors, Year 2040	Oahu	Hawaii	Maui	Kauai	Molokai	Lanai	Military	All Islands
Achievable Potential - BAU	1,439	284	272	79	6	6	177	2,262
Achievable Potential - High	1,965	384	377	132	9	9	213	3,089
Economic Potential	2,559	501	485	176	13	12	379	4,125
Technical Potential	3,138	633	593	214	16	15	478	5,088

Figure 6-12 presents the cumulative energy savings potential by Island in 2040. The figure does not present Molokai or Lanai potential because of the relatively small savings potential compared to the other islands.

The energy savings potential by island correlates with the electricity consumption by island. Refer to the Table 3-3 and Figure 3-1 (previously presented) for the distribution of consumption by island in the base year, 2018. The electricity consumption in Oahu is greatest because of significantly more homes and commercial buildings.

Figure 6-12 Cumulative Energy Savings Potential Summary, by Island and for the Military (GWh)



7

SAVINGS FROM EEPS PERSPECTIVE

The statewide Energy Efficiency Portfolio Standard (EEPS) goal is 4,300 gigawatt-hours (GWh) of cumulative electricity savings between 2009 and 2030. The subsections below present results from AEG's analysis of the State of Hawaii's progress toward meeting that goal.

EEPS Perspective, 2009-2030

The Hawaii State Legislature passed Act 155, Session Laws of Hawaii 2009 (Act 155), codified under § 269-96, Hawaii Revised Statutes (HRS), which established the State's energy efficiency goals into an Energy Efficiency Portfolio Standard (EEPS). As specified in HRS § 269-96, the statewide EEPS target is 4,300 gigawatt-hours (GWh) of electricity savings in 2030. Several types of savings count toward the target:

- Embedded savings:
    - Solar PV generation[31]
    - Codes and standards
    - 2009-2019 programs
- Future naturally occurring savings
- Future potential savings:
    - Achievable - BAU
    - Achievable - High
    - Economic
    - Technical

Table 7-1 Incremental and Cumulative Energy Savings Potential Compared to Target (GWh) – 2030

Savings Type	Incremental Savings (GWh), 2030	Cumulative Savings (GWh), 2030
2009 Base Case	**0**	**0**
Solar PV Generation	427	427
Codes and Standards	936	1,363
2009-2019 Programs	776	2,139
Naturally Occurring	1,169	3,308
Total Embedded and Naturally Occurring	*3,308*	
Future Achievable - BAU	1,329	4,637
Future Achievable - High	426	5,063
Future Economic	1,259	6,322
Future Technical	681	7,003
Total Future Potential (Technical)	*3,695*	
Statewide EEPS Target		**4,300**

Table 7-1 compares the 2030 values of incremental savings and cumulative savings for each savings type with the EEPS target of 4,300 GWh of cumulative savings. For a given savings type, the incremental savings represent the additional savings, above and beyond the prior savings type, that contribute to the overall cumulative savings in 2030. For example, we show solar PV as the first tier of savings (427 GWh in 2030). Codes and standards is the next tier (incremental savings over solar PV are 936 GWh, while the cumulative savings for the codes and standards forecast in 2030 are 1,363 GWh). The future technical potential savings category is the final tier. It has an incremental savings of 681 GWh over the economic potential in 2030 but represents an overall cumulative savings of 7,003 GWh relative to the 2009 baseline.

---

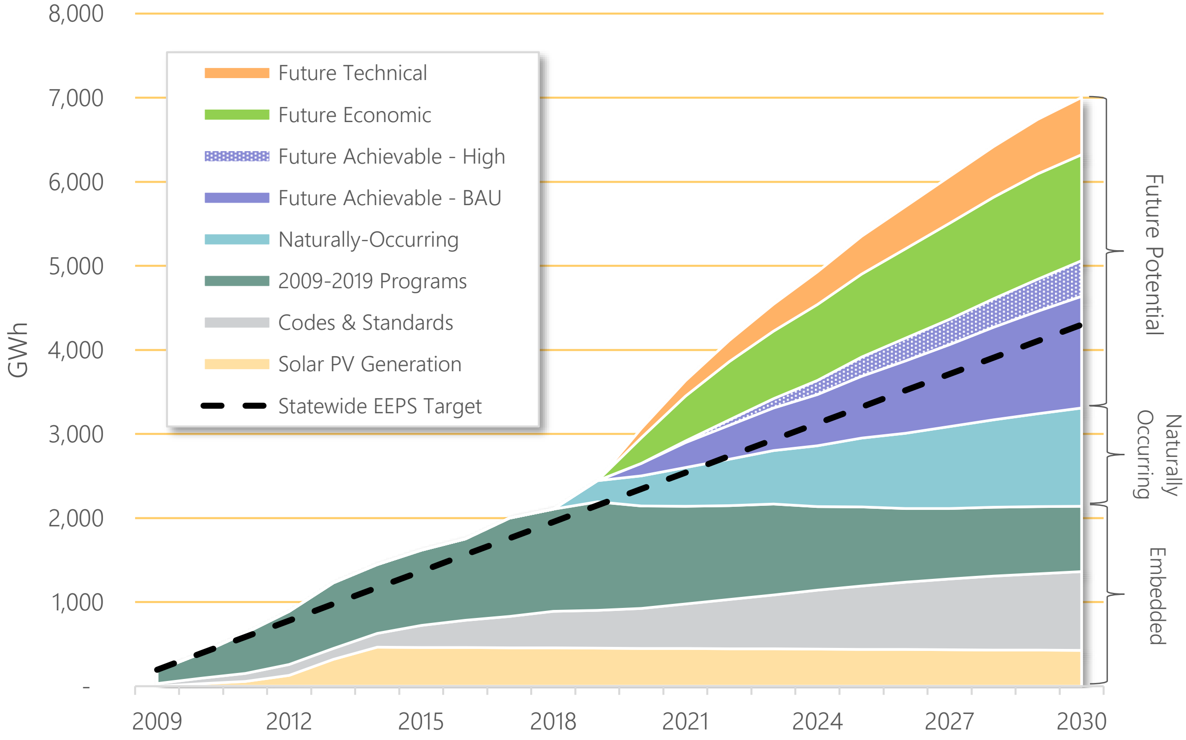
[31] Pursuant to HRS 269-91, solar PV savings from installations after 2014 count towards the Renewable Portfolio Standard.

AEG's approach for the Hawaii MPS defines the baseline from which to estimate savings potential as the naturally occurring savings projection. Therefore, relative to the naturally occurring baseline forecast, the future potential cumulative savings in 2030 range from 1,329 for the achievable potential - BAU case to 3,695 GWh for the technical potential case (see also Table 6-1). The remaining amount of cumulative savings needed to reach the EEPS 2030 target is about 1,000 GWh (4,300 – 3,308 GWh).

Figure 7-1 presents the cumulative persistent savings over the entire EEPS horizon of 2009 through 2030. The graph shows that the interim EEPS target was met through 2018 and the 2030 target is projected to be reached under the achievable potential - BAU scenario. While Hawai'i Energy's portfolio has historically provided the majority of the EEPS savings, other entities also contribute to achieving the EEPS goals: Commission Regulated Entities[32] and Non-Regulated Entities.[33] So, attainment of this goal will require continued contributions by all of these entities at a similar level as in recent years.

It is important to recognize that COVID-19 may be redefining what business as usual looks like in the future. Therefore, programs and policy interventions may have to adapt strategically to offset possible losses due to a post-COVID-19 energy efficiency landscape in order to secure enough cumulative savings by 2030. Fortunately, results from the "high" achievable potential scenario suggest that a substantial amount of additional cost-effective savings are available, beyond the BAU strategy, to help achieve the EEPS goal by 2030.

Figure 7-1 Cumulative Persistent Energy Savings (GWh), 2009-2030, EEPS Perspective



---

[32] Commission Regulated Entity savings include savings from utility administered and third party administered energy efficiency programs. The bulk of these savings are anticipated to be provided by Hawai'i Energy and Kauai Island Utility Cooperative (KIUC).

[33] Non-Regulated Entity savings include savings from legislative mandates, non-profits, other coordinated programs, building codes, and federal, state, and local appliance standards.

Comparison with 2019 Legislative Report

To support the 2019 Legislature Report on Hawaii's Energy Efficiency Portfolio Standards,[34] AEG conducted a partial update of the 2014 Potential Study.[35] The updated potential analysis provided estimates of the savings from state and federal codes and standards for the historical period, 2013-2017. It also estimated 1st year (or incremental) savings, as well as cumulative persisting savings, for the forecast period (2018-2030). However, the update was done prior to the 2019 Baseline Study, so did not have the advantage of current customer end-use information or up-to-date sales and consumption data. The savings from the updated potential study, as provided in the 2019 Legislature Report, also had a key difference in assumptions for codes and standards because of the timing of the analysis:

- The analysis for the 2019 Legislative Report showed that savings from codes and standards increased substantially in 2015 as a result of EISA Tier 1.[36] In 2020, these codes and standards savings were projected to increase dramatically again as a result of EISA Tier 2.[37] Therefore, the achievable potential - BAU program savings were forecasted to level off after 2020 as a result of reduced savings from lighting, with the expectation that EISA Tier 2 would go into effect and a substantial portion of the savings would be attributed to codes and standards instead of programs.
- However, on December 27, 2019, the U.S. Department of Energy issued a final ruling stating that the efficiency standards for general service incandescent lamps (GSILs) do not need to be amended; therefore, the backstop did not go into effect as originally planned.[38] This means that potential savings from lightbulbs fall outside of codes and standards and a portion of those savings are available for future programs, while a portion is allocated to future naturally occurring savings. This rollback of the EISA Phase 2 backstop is reflected in the 2019 MPS presented here.
- The analysis for the 2019 Legislative Report was focused only on Oahu and scaled the results upward to represent the state as a whole. This analysis missed nuances among the islands and the military.
- Finally, the analysis for the 2019 Legislative Report relied primarily on measures included in the previous 2014 study. As described in Section 5, a comprehensive review of measures was conducted for this study.For example, new residential measures included ductless mini split AC, connected control systems, and cool roofs. New or refined commercial measures included enhanced fixed controls and linear and high-bay lighting, interior skylights, and demand-controlled ventilation.

The results of the updated potential study that were published in the 2019 Legislature Report indicated that Hawai'i Energy would continue to provide the bulk of the energy savings in the Second EEPS Performance Period (2015-2020), but that codes and standards would provide an increasingly significant contribution toward EEPS savings. Those preliminary potential study results also indicated a possible gap in meeting the EEPS target of 4,300 GWh in 2030 under the BAU scenario. However, the analysis also indicated that the available, untapped, economic energy efficiency resource in Hawaii exceeded the EEPS goal of a cumulative 4,300 GWh in 2030, suggesting that the EEPS goal would be achievable, but would requires strategic adaptation, possible increases in energy efficiency program budgets, and continued

---

[34] Report to the 2019 Legislature on Hawaii's Energy Efficiency Portfolio Standards, Issued pursuant to Section 269-96, Hawaii Revised Statures, State of Hawaii Public Utilities Commission, December 2018.

[35] State of Hawaii Energy Efficiency Potential Study, Prepared for the Hawaii Public Utilities Commission, Prepared by Applied Energy Group (dba EnerNOC Utility Solutions Consulting), 2014.

[36] Tier 1 of the Energy Independence and Security Act of 2007 (EISA) went into effect in January 2012. Between 2012 and 2014, it phased in energy-efficient screw-based lightbulbs to replace traditional 40-100W incandescent bulbs. The law mandated that the new bulbs use at least 27% less energy than the traditional bulbs.

[37] Tier 2 of EISA called for a 45 lm/W minimum efficacy backstop for general service incandescent lamps (GSILs), which was subject to an effective date of January 1, 2020.

[38] U.S. Department of Energy, 2019-12-27 *Energy Conservation Program: Energy Conservation Standards for General Service Incandescent Lamps; Final Determination*, https://www.regulations.gov/document?D=EERE-2019-BT-STD-0022-0120.

innovation in program design. In the 2019 MPS presented here, which is based on more recent and comprehensive data for the state of Hawaii, we project that the EEPS target can be met under a BAU approach.

Future Potential Impacts, 2030

The following subsections provide more detail—at the state, sector, and island levels—for the future potential impacts using the naturally occurring baseline as the reference forecast for the savings. However, it is important to remember that embedded impacts and future naturally occurring savings also count towards reaching the EEPS target.

State-Level Results

Table 7-2 summarizes the subset of cumulative savings potential in the final year of the EEPS horizon (2030) for the category of "future potential." These cumulative values exclude embedded savings and naturally occurring savings and represent savings potential from programs and other interventions. In 2030, the achievable potential - BAU is 1,329 GWh in cumulative savings, while the achievable potential - high is 1,755 GWh.

Table 7-2 Future Energy Savings Potential Summary (GWh), All Sectors, All Islands – 2030

Cumulative Savings (GWh)	2030
Achievable Potential - BAU	1,329
Achievable Potential - High	1,755
Economic Potential	3,014
Technical Potential	3,695

Residential Results

Figure 7-2 shows the four levels of potential for the top 20 measures for the residential sector in 2030, the final year for EEPS. The measure with greatest savings is the solar water heater measures. Solar water heaters pass the cost-effectiveness test throughout the study time horizon even though the federal tax credit is phased out. This results in a high economic potential. However, even with the tax credit, solar water heaters require a substantial investment, which limits adoption and achievable potential. The high growth in baseline cooling saturations through 2030 are driving the air conditioning potential. All but the most efficient ductless air conditioners pass the cost-effectiveness test. In addition, connected home control systems include connected thermostat savings, which are cost-effective in most applications.

Commercial Results

Figure 7-3 shows the four levels of potential for the top 20 measures for the commercial sector in 2030. Lighting end uses are represented in four of the top six measures. A combination of high end-use intensity and popularity in programs is driving the lighting savings. The top measure includes linear LED lamps (TLEDs) and LED fixtures plus controls. Water heating is not cost-effective due to lower hot water demand in many commercial segments. Building energy management systems are expensive to install and do not tend to be cost-effective based on energy benefits alone.

Figure 7-2 All Island Residential Energy Efficiency Potential by Top Measures, 2030

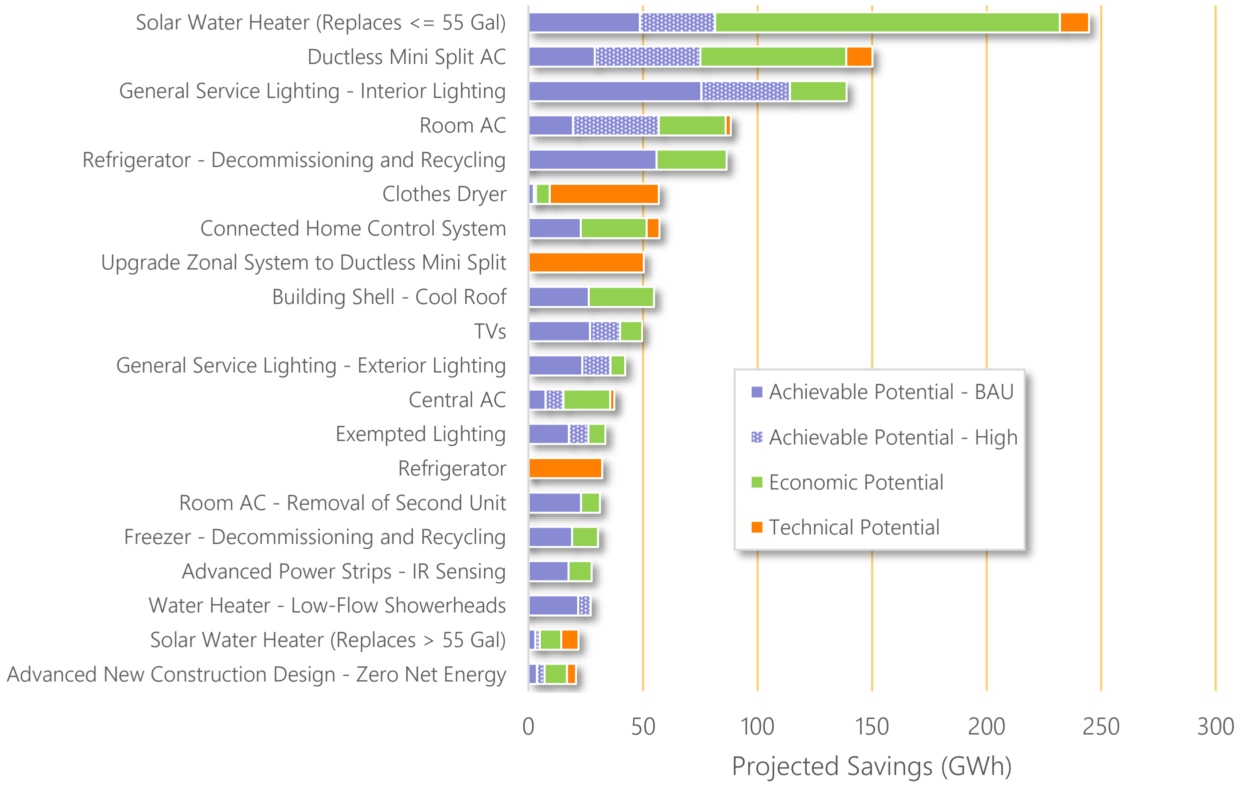
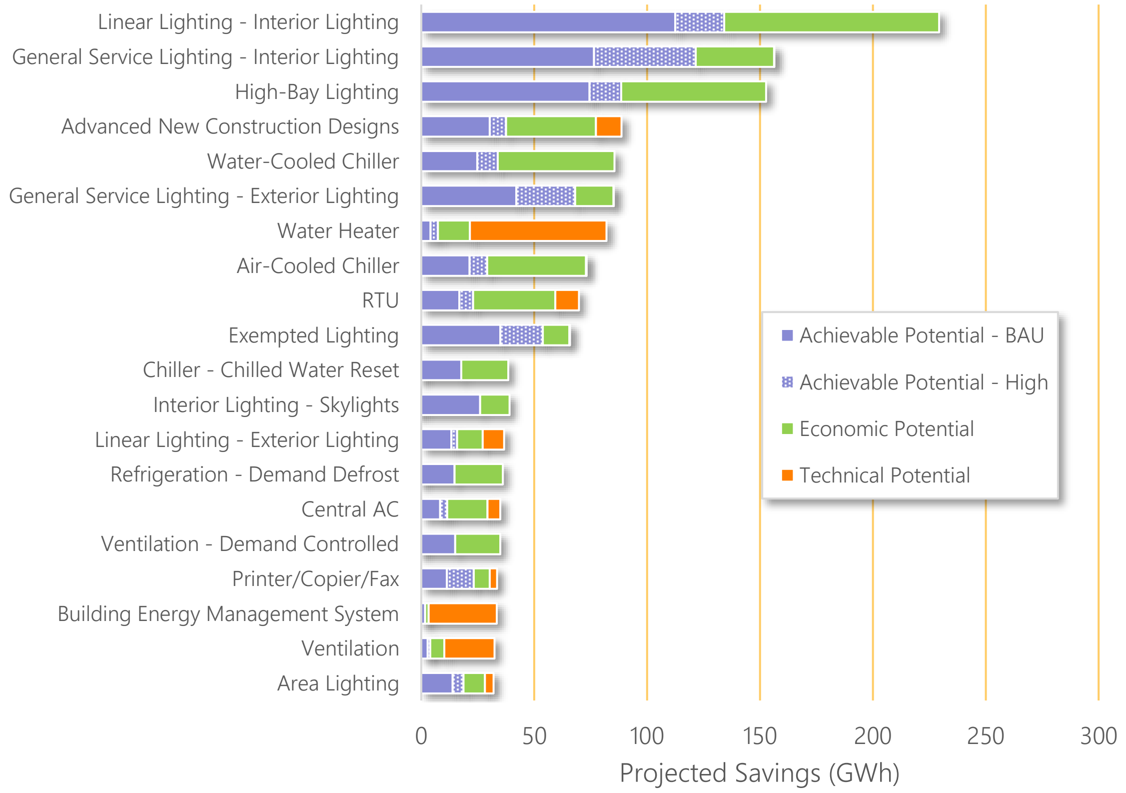


Figure 7-3 All Island Commercial Energy Efficiency Potential by Top Measures, 2030



Island-Level Results

Table 7-3 summarizes the subset of cumulative savings potential in the final year of the EEPS horizon (2030) for the category of "future potential." Again, these cumulative values exclude embedded savings and naturally occurring savings and represent savings potential from programs and other interventions. For each island, the magnitude of the savings correlates to the amount of electricity consumption the island (or military). The cumulative potential savings in 2030 are highest in Oahu, followed by Hawaii, Maui, the military, Kauai, and then Molokai and Lanai.

Table 7-3 Future Energy Savings Potential Summary (GWh), All Sectors, By Island – 2030

Cumulative Savings (GWh) All Sectors, 2030	Oahu	Hawaii	Maui	Kauai	Molokai	Lanai	Military	All Islands
Achievable Potential - BAU	851	166	163	43	3	3	100	1,329
Achievable Potential - High	1,116	220	216	72	5	5	121	1,755
Economic Potential	1,865	369	359	131	10	9	272	3,014
Technical Potential	2,274	462	435	159	12	11	343	3,695

Figure 7-4 shows the energy savings potential for each island and the military as a percentage of baseline consumption for the given island in 2030. Figure 7-5 shows the share of statewide achievable - high potential by island in 2030.

Figure 7-4 Energy Savings Potential in 2030, by Island (% of Baseline Consumption)

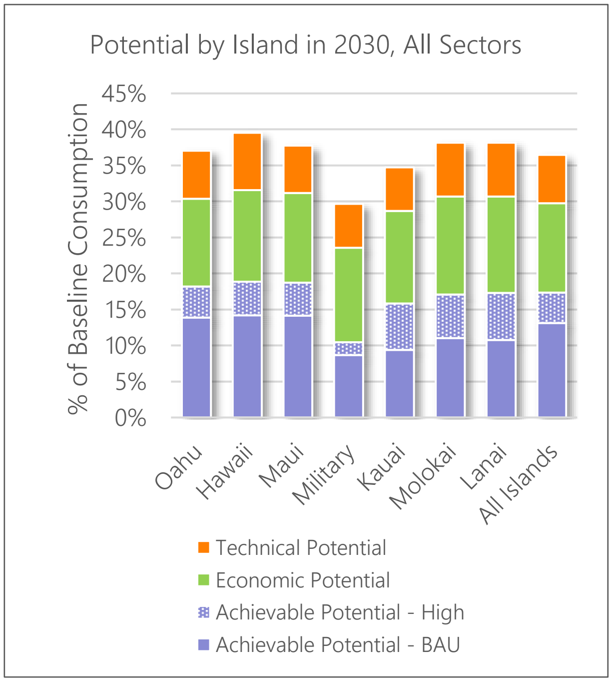
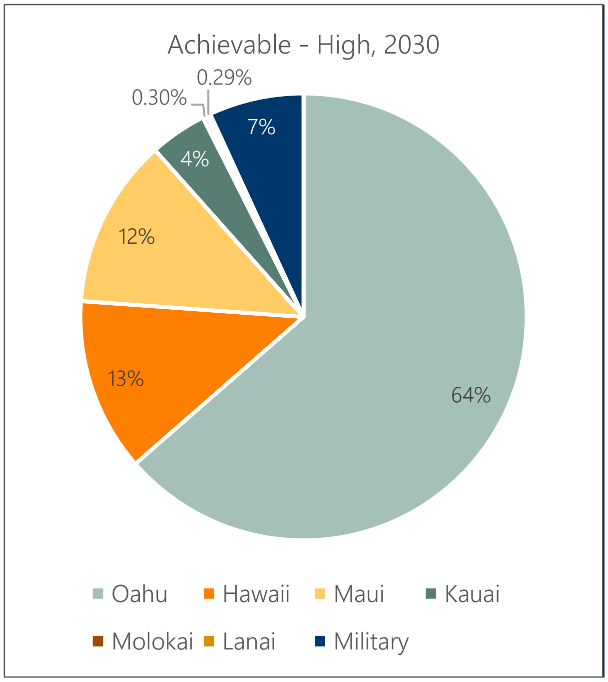


Figure 7-5 Share of Achievable - High Potential by Island in 2030 (Total = 1,755 GWh)



The achievable - BAU percentages range from 8.7% of baseline consumption (military) to 14.2% (island of Hawaii). Similarly, the achievable - high percentages range from 10.4% of baseline consumption (military) to 18.9% (island of Hawaii). The military percentages for both types of achievable potential are lower than for the islands because of the uniqueness of how the military uses energy and procures equipment. To capture this uniqueness, the potential modeling differed from the civilian sector in three ways:

- Incremental measure costs are 25% higher
- Early-year achievability is lower by 25%.
- Communication-based controls measures were removed due to energy security concerns.

The Kauai achievable potential values (9.4% of baseline consumption for BAU and 15.8% for high case) are also a bit lower than the other islands, primarily because of lower program participation rates in recent years and lower penetration of air conditioning.

In terms of the total statewide achievable - high potential in 2030, Figure 7-5 shows that Oahu accounts for the largest share (64%), followed by Hawaii (13%), Maui (12%), the military (7%), and Kauai (4%). Molokai and Lanai each account for less than one percent.

8

POTENTIAL FROM ADVANCED RATE DESIGNS

The core MPS work described thus far has quantified the role of new technologies in enhancing energy efficiency in the State of Hawaii. This work is conditional on the existing rate designs staying in place. These are traditional in nature, since advanced meters are not in place today. The existing rate designs recover revenue mostly through a flat volumetric charge that does not vary by time of day. By contrast, modern rate designs feature time variation in recovering energy costs. That time variation sometimes comes in the form of simple time-of-use rates and sometimes in the form of dynamic pricing rates. They also feature demand charges for recovering capacity costs associated with generation, transmission and distribution. Sometimes generation and transmission costs may be collected in time-varying energy charges, but it is rare in modern rate designs to include distribution costs in energy charges.

With the State of Hawaii's intention to become 100% renewable by 2045, it has begun to modernize the grid to enable such a future. The new grid will integrate supply-side and demand-side resources, allow for two-way flow of power, and have smart meters. As the power system in Hawaii becomes dominated by renewable energy resources, the wholesale price of power will become more intermittent. Load flexibility will be required to maximize economic efficiency.

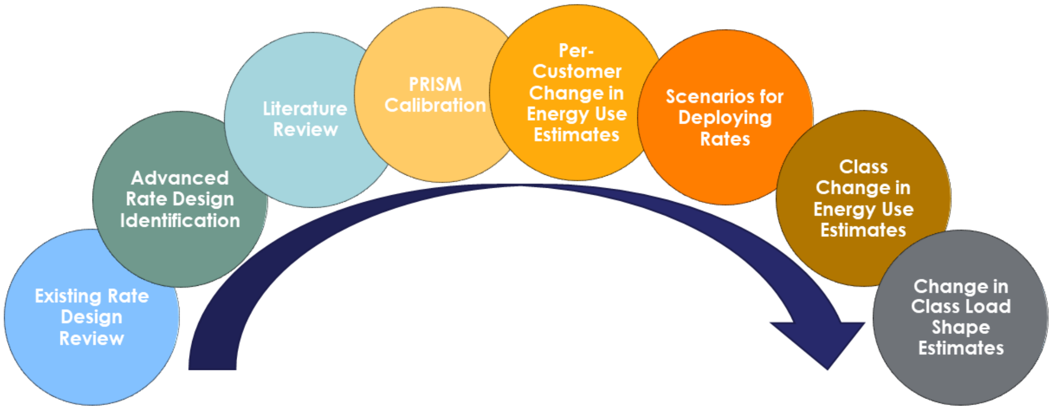
Studies have shown that customers in other states accept and respond to modern pricing designs that vary by time of day and by type of day. In the future, that will become commonplace since customer homes will be equipped with digital technologies, smart meters, and smart phones, which will act as dynamic energy management systems.

This section describes an analysis that estimated the potential impacts of advanced rate designs on energy consumption and peak demand in Hawaii, with consideration for different deployment scenarios (opt-in, opt-out, and mandatory).

Approach

AEG engaged with The Brattle Group to conduct the advanced rate design study through an eight-step process, as shown in Figure 8-1.

Figure 8-1 Process to Estimate the Potential Impact of Advanced Rate Designs in Hawaii



Advanced Rate Design Results

The following subsections summarize the results for each of the analysis steps. For more detail, see Appendix D.

Review of Existing Rate Designs

Table 8-1 through Table 8-4 show the existing rate designs in Hawaii for residential and commercial customers.

Table 8-1 Residential Rates Offered by HECO, HELCO, and MECO

Schedule	Rate Design	Description
R	Tiered fixed volumetric	Standard residential rate
TOU-R	TOU + Tiered fixed volumetric	Pilot TOU rate; closed to new participants since 2016
Residential TOU EV	TOU + Tiered fixed volumetric	Pilot TOU EV rate; closed to new participants since 2016
TOU-RI	TOU	Interim TOU rate; also applies to customers with EVs (required to have separate meter); capped at 5,000 customers

Table 8-2 Residential Rates Offered by KIUC

Schedule	Rate Design	Description
D	Fixed volumetric	Standard residential rate
TOU-S	TOU	Capped at 300 customers

Table 8-3 Commercial Rates Offered by HECO, HELCO, and MECO

Schedule	Rate Design	Description
G	Flat volumetric	General Service Non-Demand
J	Demand + flat volumetric	General Service Demand
TOU-G	TOU	Small Commercial Time-of-Use
TOU-J	Demand + TOU	Commercial Time-of-Use Service
TOU-P	Demand + TOU	Large Commercial Time-of-Use Service
EV-F / EV-U	TOU	Commercial Public Electric Vehicle Charging Pilots
E-Bus-J / E-Bus-P	Demand + TOU	Commercial Electric Bus Charging Facility Service Pilot

Table 8-4 Commercial Rates Offered by KIUC

Schedule	Rate Design	Description
G	Fixed volumetric	General Light and Power Service
J	Demand + flat volumetric	General Light and Power Service
L / P	Demand + tiered fixed volumetric	Large Power Primary (L) / Secondary (P) Service

Identification of Advanced Rate Designs

For both classes of customers, we designed the following three rates:

- Three-period time-of-use (TOU) rates
- Three-period TOU rates with demand charges
- Three-period TOU rates with critical-peak pricing (CPP) rates

The advanced rate designs are revenue neutral with respect to the existing rates. Figure 8-2 shows the residential and commercial average annual load shapes.

Figure 8-2 Hawaii Residential and Commercial Average Annual Load Shapes

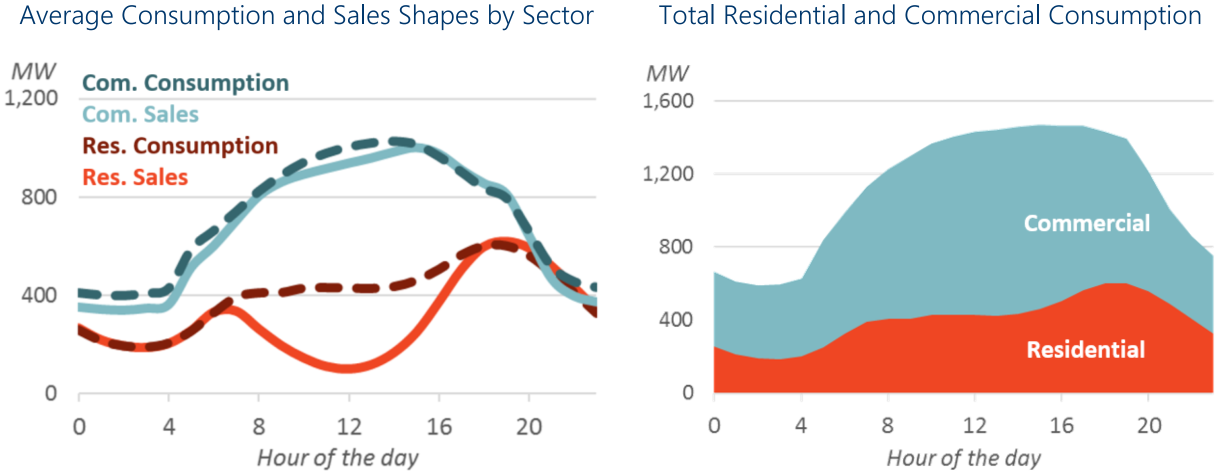
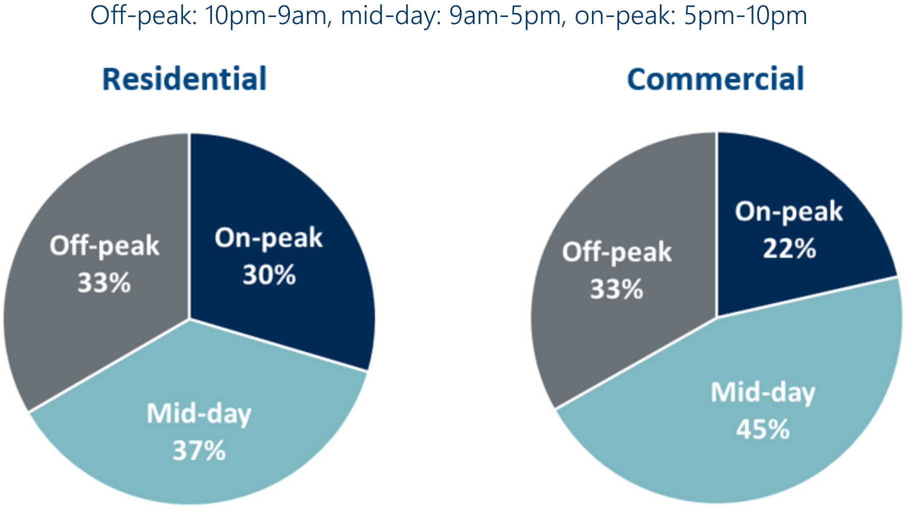


Figure 8-3 shows the definitions of the pricing periods, which differ by class.

Figure 8-3 Average Consumption by TOU Period



Source: Residential and commercial class consumption profiles for 2018 provided by AEG. Note: Period definition based on HECO's TOU period definition for residential and commercial customers (same period definition for both classes).

The prices by time period and demand charges also vary by class. Table 8-5 and Table 8-6 show the rates by customer class.

Table 8-5 Revenue Neutral Rate Proposals for the Residential Class

	Non-Fuel Energy Charges					Other Charges	
	TOU			Demand	CPP	Fixed Charge	Fuel + Other Charge
	On-peak	Mid-day	Off-peak	On-peak	On-peak		
	5-10pm	9am-5pm	10pm-9am	5-10pm	5-10pm*	n.a.	All hours
Rate Design	¢/kWh	¢/kWh	¢/kWh	$/kW	¢/kWh	$/mo	¢/kWh
Existing Flat Vol.	11.83	11.83	11.83	n.a.	n.a.	11.50	18.42
Existing TOU	24.68	-4.48	15.85	n.a.	n.a.	11.50	18.42
TOU	25.00	1.00	5.00	n.a.	n.a.	11.50	18.42
TOU + Demand	19.85	1.00	5.00	6.33	n.a.	11.50	18.42
TOU + CPP	19.85	1.00	5.00	n.a.	174.28	11.50	18.42

Notes: *Only applies during the top 10 highest sales days of the year. During the on-peak period of those critical 10 days, the TOU on-peak charge gets replaced by the CPP on-peak charge. "Existing TOU" rate based on HECO Schedule TOU-RI and "Existing Flat Vol." rate based on HECO Schedule R. The non-fuel energy charges of the "Existing Flat Vol." rate are tiered: 10.6812¢/kWh for the first 350 kWh, 11.8347¢/kWh for the next 850 kWh, and 13.7121¢/kWh for all kWh over 1,200 kWh. Monthly fixed charge of $11.50 based on HECO's Schedule TOU-RI and Schedule R fixed charge for single-phase service. Fuel charge of $0.18/kWh estimated based on the difference between the average residential all-in electricity price and the fixed and non-fuel energy charges. The demand and CPP charges collect 20% of the total revenue collected from on-peak hours in the "TOU" rate.

Table 8-6 Revenue Neutral Rate Proposals for the Commercial Class

	Non-Fuel Energy Charges					Other Charges	
	TOU			Demand	CPP	Fixed Charge	Fuel + Other Charge
	On-peak	Mid-day	Off-peak	On-peak	On-peak		
	5-10pm	9am-5pm	10pm-9am	5-10pm	5-10pm	n.a.	All hours
Rate Design	¢/kWh	¢/kWh	¢/kWh	$/kW	¢/kWh	$/mo	¢/kWh
Existing Flat Vol.	9.60	9.60	9.60	n.a.	n.a.	35.00	18.42
Existing Demand	5.32	5.32	5.32	13.00	n.a.	66.00	18.42
Existing TOU	14.60	6.60	11.60	n.a.	n.a.	35.00	18.42
TOU	30.00	1.00	8.50	n.a.	n.a.	35.00	18.42
TOU + Demand	18.00	1.00	8.50	11.42	n.a.	35.00	18.42
TOU + CPP	24.00	1.00	8.50	n.a.	210.45	35.00	18.42

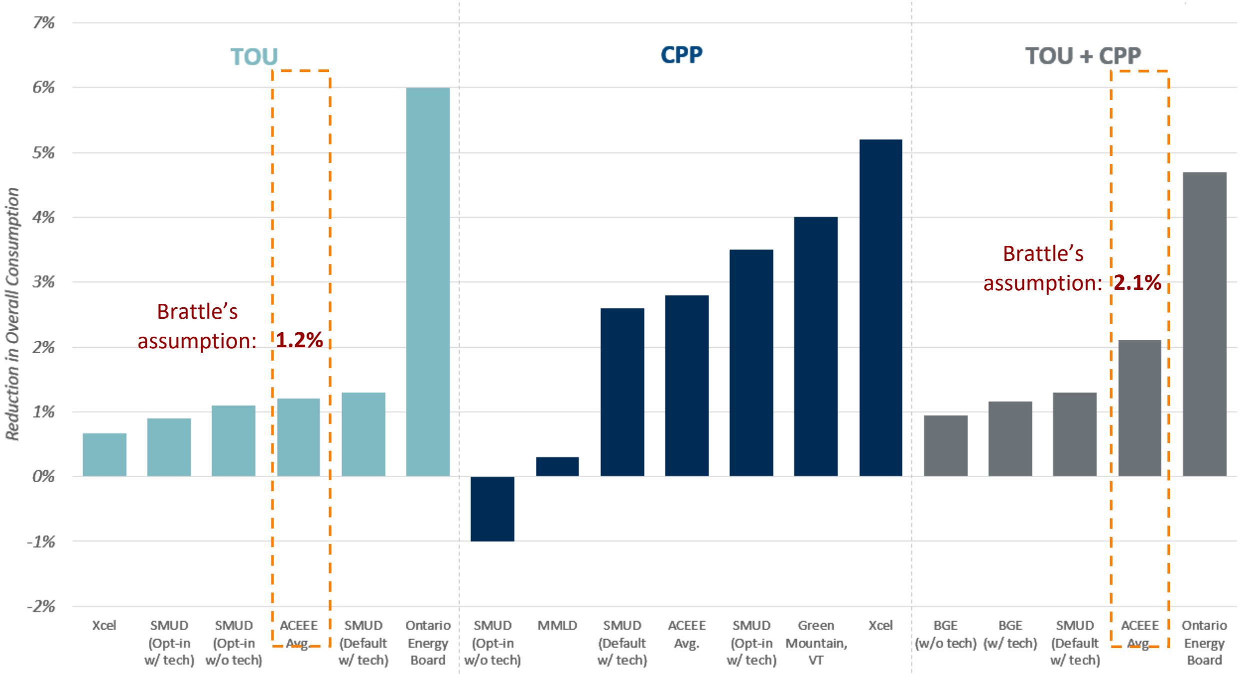
Notes: "Existing Flat Vol." based on HECO Schedule G, "Existing Demand" based on HECO Schedule J, and "Existing TOU" rate based on Schedule TOU-G for HECO. CPP on-peak charge is in addition to the TOU charge during that period. Monthly fixed charges based on HECO's Schedule J charge for single-phase service. Assumed same fuel charge as for the residential class. The demand and CPP charges collect 40% and 20%, respectively, of the total revenue collected from on-peak hours in the "TOU" rate.

Literature Review

It is important to emphasize that no other place in the mainland is like Hawaii, which has its unique climate, sociodemographic and economic characteristics.

Figure 8-4 shows findings from our review of a wide range of TOU, demand, and CPP pilot studies investigating the reduction in overall consumption from rate designs. There are no Hawaii-specific studies available on the topic.

Figure 8-4 Comparison Across Studies of Reduction in Overall Consumption for Residential Customers



Source: Brendon Baatz, "Rate Design Matters: The Intersection of Residential Rate Design and Energy Efficiency", American Council for an Energy-Efficient Economy (ACEEE), March 2017.

Based on our review, we estimated the average customer's change in overall consumption in response to the new rate structures to be as follows:

- Three-Period TOU rate: 1.2% reduction in overall consumption
- Three-Period TOU with a demand charge: 1.2% reduction in overall consumption
- Three-period TOU rate with CPP charge: 2.1% reduction in overall consumption

We also reviewed elasticity of substitution data from several residential rate design pilots (see Figure 8-5).[39] We based our elasticity parameters on the results from a study in California, given the similarity in climate to Hawaii compared to other regions in the US. We tested two elasticities values—the averages from the two mild climate zones in California (Zone 1 and Zone 2) and from the two hot climates zones (Zone 3 and Zone 4)—to capture the likely range of customer price response in Hawaii:

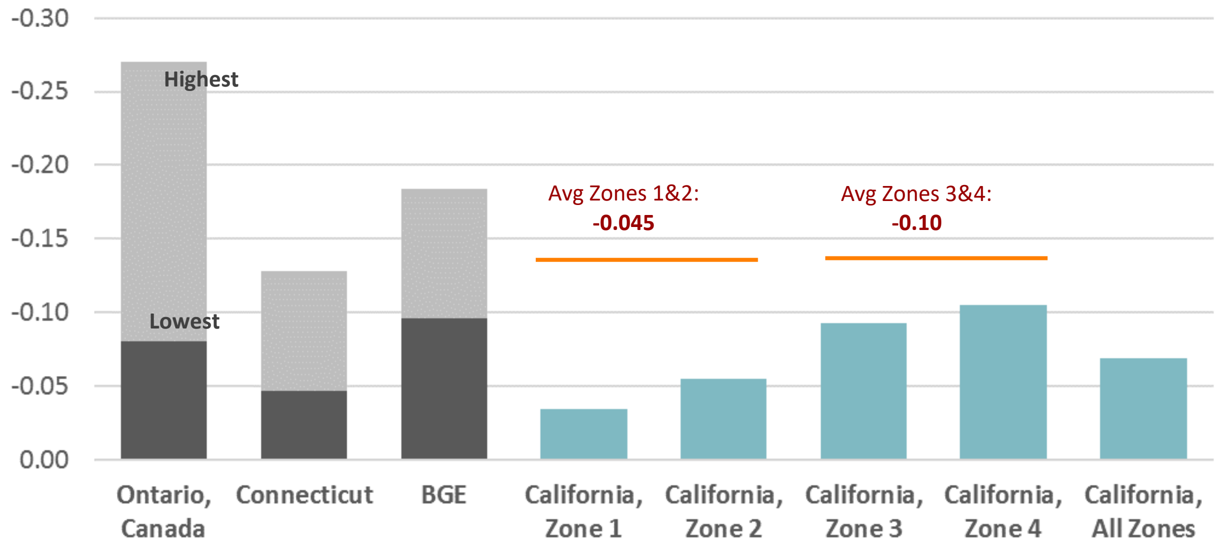
- Average of Zones 1&2: -0.045
- Average of Zones 3&4: -0.10

---

[39] The elasticity of substitution measures a customer's willingness to shift consumption across periods in response to the price differences across those periods.

Given the lack of information available about the possible range of customer elasticities for the commercial class, we used the same elasticities of substitution as for the residential analysis.

Figure 8-5 Comparison of Elasticities of Substitution Across Residential Rate Design Pilots



Source: Brendon Baatz, "Rate Design Matters: The Intersection of Residential Rate Design and Energy Efficiency", American Council for an Energy-Efficient Economy (ACEEE), March 2017.

Calibration of PRISM

We calibrated Brattle's PRISM model to Hawaii customer consumption data and class revenue requirements. Next, we populated it with customer response parameters derived from studies carried out in the mainland for the residential class.

The inputs to PRISM were:

- Average customer 8760 hour consumption profile
- Proposed new rates
- Change in total energy consumption (based on literature review)
- Elasticities of substitution (based on literature review)

PRISM grew out of California's Statewide Pricing Pilot in 2004. Subsequently, it has been used to predict impacts for a variety of time-varying rate designs in pilots in Connecticut, Florida and Maryland.

Based on those inputs, PRISM outputs the change in energy consumption for each TOU period.

Per-Customer Change in Energy Use

We used PRISM to estimate, on a per-customer basis, the percentage change in consumption by time period for each of the rate designs by time period by class.

Residential Class

We obtained the following results for the residential class:

- Three-period TOU rate: Using Hawaii-specific residential consumption shapes and customer elasticities of substitution between -0.045 and -0.010, we estimated that residential customers would on average reduce consumption during the on-peak period by 3.3%-5.8%, from 2,390 kWh/yr to

2,250-2,310 kWh/yr under a TOU rate design, assuming an on-peak/off-peak price ratio of 2. Overall energy consumption would be reduced by an average of 1.2%, from 8,070 kWh/yr to 7,970 kWh/yr.

- Three-period TOU rate with a demand charge: The change in overall and on-peak consumption by switching to a TOU rate with a demand charge (assuming revenue neutrality) would be expected to be similar to that of the simple TOU rate on average. In addition, we would also expect customers to reduce their peak demand by 3.3%-5.8%, from 1.8 kW to 1.70-1.75 kW.
- Three-period TOU rate with CPP charge: Under a revenue neutral TOU+C PP rate, we estimate that on-peak consumption would decrease by 4.0%-6.3% on average, from 2,390 kWh/yr to 2,240-2,290 kWh/yr. In addition, consumption during the on-peak hours of the critical peak days would be reduced by 10%-20%, from 72 kWh/yr to 58-64 kWh/yr.

Commercial Class

We obtained the following results for the commercial class:

- Three-period TOU rate: Using Hawaii-specific commercial consumption shapes and customer elasticities of substitution between -0.045 and -0.010, we estimated that commercial customers would reduce consumption during the on-peak period by 4.0%-7.3% under a TOU rate structure, from 11,500 kWh/yr to 10,640-11,030 kWh/yr, assuming an on-peak/off-peak ratio of 2. Overall energy consumption would be reduced by an average of 1.2%, from 53,620 kWh/yr to 52,980 kWh/yr.
- Three-period TOU rate with a demand charge: The change in overall and on-peak consumption by switching to a TOU rate with a demand charge (assuming revenue neutrality) would be expected to be similar to that of the simple TOU rate. However, we would also expect peak demand to reduce by 4.0%-7.4%, from 11.2 kW to 10.2-10.7 kW.
- Three-period TOU rate with CPP charge: Under a revenue neutral TOU+CPP rate, we estimate that on-peak consumption would decrease by 4.5%-7.6%, from 11,500 kWh/yr to 10,630-10,990 kWh/yr. In addition, consumption during the on-peak hours of the critical peak days would reduce by 11%-22%, from 377 kWh/yr to 294-334 kWh/yr.

Scenarios for Deploying New Rates

Drawing upon the literature, we estimated the following customer participation rates for each of three scenarios (see Table 8-7):

- Opt-in: 20% of the class population. Most TOU deployments today are opt-in in character. OGE in Oklahoma has achieved 20% with its Smart Hours program, Salt River Project in Arizona has achieved 29% and Arizona Public Service has achieved 57%. This assume that rates are nicely communicated to customers, appropriate customer service is made available to customers, and supportive web portals have been created.
- Opt-out: 80% of the class population. The percentage may be even higher, based on recent deployments in SMUD (it started moving its residential customers to default TOU deployment last year and has reported opt-out percentages of just a few percentage point) and earlier deployments in Ontario, Canada where 90% of customers are on default TOU rates.

Table 8-7 Rate of Adoption Under Three Scenarios

Scenario	Rate of Adoption
Opt-in	20%
Opt-out	80%
Mandatory	100%

- Mandatory: 100% of the class population. Fort Collins in Colorado moved all its customers to TOU rates last year. In many jurisdictions, TOU rates are mandatory for commercial customers.

Class Change in Energy Use

We estimated the percent change in class energy use by pricing period as the product of the per-customer impact times the percentage of customers participating in the rate under the three scenarios enumerated above. The following subsections summarize the results by customer class.

Residential Class

Under the assumptions laid out here, we estimated that residential consumption during on-peak hours could be reduced on average by the following amounts:

- Opt-in: 0.7%-1.3%, from 1,030 GWh/yr to 1,015-1,025 GWh/yr
- Opt-out: 2.6%-5.0%, from 1,030 GWh/yr to 980-1,005 GWh/yr
- Mandatory: 3.3%-6.3%, from 1,030 GWh/yr to 965-995 GWh/yr

We estimated that total residential consumption could be reduced on average by the following amounts:

- Opt-in: 0.2%-0.4%, from 3,480 GWh/yr to 3,465-3,470 GWh/yr
- Opt-out: 1.0%-1.7%, from 3,480 GWh/yr to 3,420-3,3445 GWh/yr
- Mandatory: 1.2%-2.1%, from 3,480 GWh/yr to 3,405-3,440 GWh/yr.

Commercial Class

Under the modeled assumptions, we estimate that commercial consumption during on-peak hours could be reduced on average by the following amounts:

- Opt-in: 0.8%-1.5%, from 1,350 GWh/yr to 1,330-1,340 GWh/yr
- Opt-out: 3.2%-6.1%, from 1,350 GWh/yr to 1,270-1,305 GWh/yr
- Mandatory: 4.0%-7.6%, from 1,350 GWh/yr to 1,245-1,295 GWh/yr.

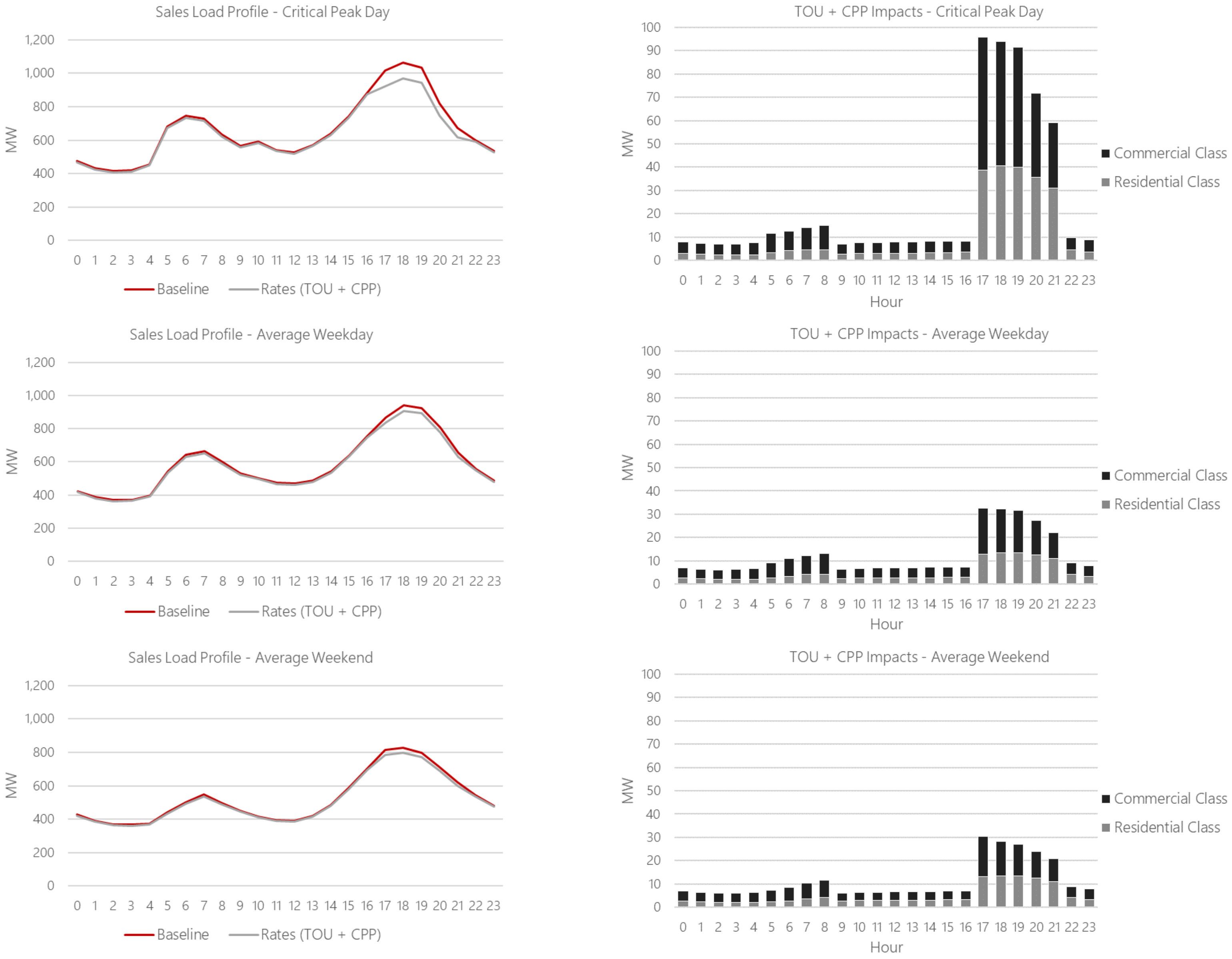
We estimate that total commercial consumption could be reduced on average by the following amounts:

- Opt-in: 0.2%-0.4%, from 6,295 GWh/yr to 6,270-6,280 GWh/yr
- Opt-out: 1.0%-1.7%, from 6,295 GWh/yr to 6,190-6,235 GWh/yr
- Mandatory: 1.2%-2.1%, from 6,295 GWh/yr to 6,165-6,220 GWh/yr.

Hourly Impacts

Taking the percent change in class energy use and multiplying it into the class energy use (expressed in kWh) and class peak demand (expressed in kW) we obtained changes in the sales and consumption load shapes. Figure 8-6 shows examples of the estimated hourly impacts in 2030 for the TOU+CPP rate in Oahu under the opt-out scenario (80% rate of adoption) using an elasticity of substitution of -0.045. The figure shows results for three day-types: critical peak day, average weekday, and average weekend. Because of the rate design, the impacts are significantly higher for the critical peak day during the on-peak period than for the other day-types and time periods. The highest single hour impact is estimated to be 96 MW (39 MW for residential and 57 MW for commercial) and occurs during 5-6 pm on the critical peak day. The average impact during the five-hour peak period is 82 average MW (aMW).

Figure 8-6 Hourly Impacts from Opt-Out TOU+CPP Rate by Day-Type: Oahu, 2030



9

POTENTIAL FROM DEMAND RESPONSE AND GRID SERVICES

In addition to reaching EEPS goals, the State of Hawaii has other priorities for addressing grid concerns, such as shedding peak loads, shifting loads, and supporting frequency regulation and grid resiliency. This chapter includes potential impacts from implementation of demand response / grid service (DR/GS) programs.

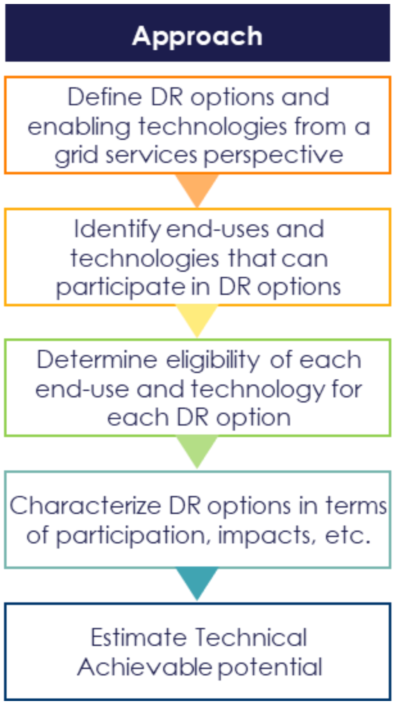
Purpose

The purpose of this task is to estimate the potential impacts from several types of demand response and grid services on energy consumption and peak demand in Hawaii. The focus is on “smart” and “connected” end-use technologies and measures that can communicate with the grid and respond to DR/GS events. Distributed batteries were not a part of this assessment.

Approach

Figure 9-1 summarizes AEG’s approach for estimating the potential from demand response and grid services. AEG’s DR/GS analysis leveraged HECO’s DR Potential Study[40] as a starting point, making some key enhancements based on EE results from the MPS, as noted below, and incorporating detailed end-use load. The subsections below describe key aspects of the analysis.

Figure 9-1 DR/GS Analysis Approach



DR Options and Grid Services Modeled

AEG modeled five different grid services:

- Traditional Capacity: Traditional DR designed to shed load during high peak times. It is characterized by day-ahead or day-of notification and longer event hours.
- Non-spin Auto Response or 10 Minute Reserves: Traditional DR that can shed load in response to emergency or contingency events. 10-minute response time and 30-minute minimum event durations are typical.
- Load Shift: DR designed to shift load to off-peak hours. Thermal or battery storage and EVs are good candidates. It is characterized by day-of notification and longer event hours.
- Fast Frequency Response: Automated response of resource to change in frequency by control. It is referred to as a shimmy-load following type of grid service.

---

[40] AEG revised some information to make the analysis more current. AEG and HECO have acknowledged that AEG’s estimates may be different than what HECO has now for its Forecasting and DR groups.

- Regulation Reserves: Automated response that can increase or decrease load in a consistent manner. It is referred to as a shimmy-regulation type of grid service.

Enabling Technologies and Eligible End Uses

There are three main types of enabling technologies for grid services. The bullet points below describe these technologies and provide examples of eligible end uses and end use technologies. AEG mapped end uses and end use technologies to these enabling technologies and to the grid services for which they would be eligible.

- Direct Load Control (DLC) requires one-way communication and allows a program administrator to remotely control the customer's equipment on short notice. Wired DLC switches can be used on various end use equipment such as central AC systems, water heaters, and pool pumps. Plug-in DLC switches can be used on equipment like zonal AC systems.
- Automated Demand Response (ADR) requires two-way communication and allows customers to participate in DR programs when they enable their automated systems to send and receive signals from the utility. Connected thermostats, connected EV chargers, connected home control systems, energy management systems, and grid-tied batteries used with solar PV can be used with ADR.
- Manual Switching allows the customer to control loads manually in response to a notification. While manual control is an option, AEG's analysis focused on end-use technologies with the capability of being automatically controlled.

Factors that Affect Participation and Impacts

Three factors affecting participation and impacts were considered in the analysis:

- Acceptability refers to the percentage customers that are willing to participate in an option in exchange for financial incentives. AEG utilized two acceptability scenarios to represent low and high levels of customer acceptability.
    - Low: AEG utilized acceptability assumptions from the Navigant study to develop a "Low" case. The prior study varied acceptability over a 24-hour period, with commercial-customer willingness to participate dropping into the single-digit percentages during some time periods.
    - High: To develop a "High" bookend on the analysis, AEG developed a scenario where the minimum acceptability for an eligible load was constrained to 20%. This represents the most successful scenario we have seen for similar demand response programs in other jurisdictions.
- Controllability refers to the percentage of load for a given end-use that can be enabled with the capability for load sheds/shifts. To develop estimates of controllability, AEG utilized technical achievable results from the EE potential analysis, tracking the adoption of potentially controllable technologies throughout the forecast. For example, smart thermostats installed for their EE benefits might one day be controllable within a DR/GS program. The adoption of this EE technology formed the basis for the controllability for the smart thermostat DR/GS measure.
    - Participation rate (DR option) = Acceptability * Controllability
- Sheddability refers to the fraction of participating load that can be increased or decreased during a DR event. We used data from the HECO DR Potential Study.

The DR/GS analysis considers Technical Achievable potential instead of Economic Achievable potential since the hourly avoided cost information that would be required for valuing time-of-day based savings for DR/GS opportunities is not yet available. Hourly avoided cost information is expected to be available once HECO's Integrated Grid Planning process is complete.

  - DR potential = Load * Participation rate * Sheddability

AEG applied these factors to estimate the technical achievable potential.

Time Periods and Day-Types

Because of the temporal nature of demand response and grid services, the analysis must be done at an hourly level. AEG applied results from the hourly analysis described in Chapter 3 and key findings from the Advanced Rate Design described in Chapter 8 to inform the end-use load profiles, time periods, and day-types used in the hourly impact analysis (see Figure 9-2 for illustration):

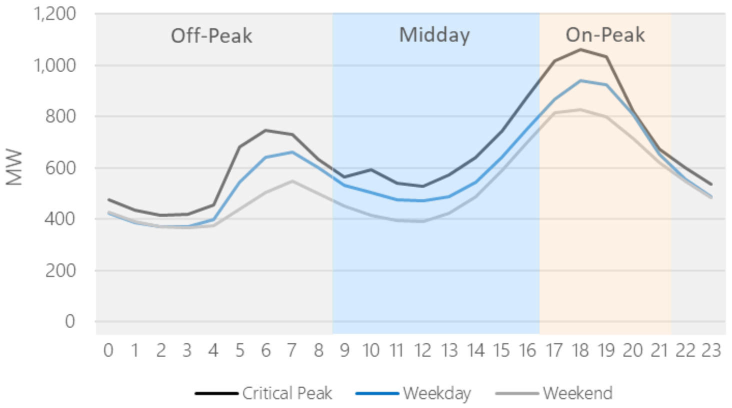
Time Periods

- Critical Peak: 5 – 10 PM on 10 critical peak days
- On-Peak: 5 – 10 PM
- Off-Peak: 10 PM – 9 AM
- Midday: 9 AM – 5 PM

Day-Types

- Critical peak day – defined as 10 days per year with the highest load
- Average weekday
- Average weekend

Figure 9-2 Sales Load Profile: Day-Types and Time Periods



There is less seasonal variability in the State of Hawaii, which allows us to adequately represent the hourly variation with these three day-types. Since AEG performed the analysis at the 8760 hourly level, other day-types of interest could be explored in the future.[41]

Key Results

The subsections below first present summary-level results of DR/GS impacts by type of grid service and then present more detailed results for one specific type of grid service: "Capacity – Decrease."

By Grid Service Type

AEG modeled five types of grid services:

- Capacity – Decrease
- Capacity – Increase
- Non-Spin Auto Response – Decrease[42]
- Fast Frequency Response – Decrease
- Regulation Reserves – Decrease

It is important to note that the impacts from different types of grid services are not stackable. This is because generally the same end-use equipment would be called for each type of grid service event, and the same equipment cannot be called for more than one type of event at the same time. (However, there is a possibility to assign different types of equipment to different types of grid services.)

Figure 9-3 shows examples of hourly impacts for each of the five types of services. These impacts represent the technical achievable potential in 2030 on a critical peak day for the island of Oahu using the low

---

[41] Due to the unpredictability of renewables, we modeled grid services for every hour of the year. The actual service performance will depend on real-time requirements of the grid.

[42] HECO notified the AEG team that the non-spin auto response grid service is currently obsolete.

acceptability scenario. The results are for the residential and commercial sectors combined. The Capacity - Decrease service yields the highest load reductions during the on-peak period, with most of the reduction coming from HVAC equipment. HVAC equipment dominates the potential impacts for the Capacity – Increase service as well, showing a high potential for increasing loads during the midday period. Potential impacts for Non-Spin Auto Response and Regulation Reserves come primarily from HVAC during daytime hours and electric vehicles during the evening, while water heating and electric vehicles account for most of the impacts for the Fast Frequency Response service.

Figure 9-3 Hourly DR/GS Impacts on Critical Peak Day: Oahu, All Sectors, Technical Achievable, 2030

Capacity - Decrease

The remainder of the report focuses on the Capacity - Decrease grid service because it has the potential to yield the highest peak demand reductions relative to the other grid services. It is designed specifically to shed load between 5 and 10 pm. Table 9-1 shows the average MW (aMW) impacts by time period and island in 2030.[43] The results are presented for both acceptability scenarios (low and high) and represent

---

[43] Impact estimates are provided for each island and the military separately; however, Oahu and Military were modeled together when estimating peak.

the combined impacts from the residential and commercial sectors. The impacts are relative to the hourly baseline *consumption* forecast in 2030. To estimate the average impacts, AEG averaged the hourly impacts for each hour in a given time period across the year (e.g., average impact over the 5-hour peak period for the 10 critical days). Since Capacity - Decrease is designed to reduce demand during peak hours, there are no impacts during the midday and off-peak time periods. On an absolute savings scale, Oahu has the highest peak demand impacts, with the potential ranging from 38-62 average MW (aMW) on the critical peak day, depending on acceptability scenario. On a savings percentage basis, the impacts for Oahu and Maui are about 4% relative to the baseline for the low acceptability scenario and about 7% for the high acceptability scenario. Percentage impacts for the other islands are about 3% for the low acceptability case and 5-6% for the high case. The Island of Hawaii's percentage savings are lower than Oahu and Maui's because Hawaii has a lower EV penetration in the forecast and because of climate differences. Kauai's percentage savings are lower than Oahu and Maui's because of lower HVAC saturation in Kauai. Note that the military has zero impacts for all time periods; this is because all measures with communication-based controls were removed when modeling military facilities due to energy security concerns.

Table 9-1 Average Capacity-Decrease Impacts by Time Period and Island: All Sectors, 2030

Critical Peak			
Island	**Consumption Baseline (aMW)**	**Impact (aMW)**	
		Low	**High**
Oahu	934.0	38.0	62.1
Hawaii	187.3	5.6	10.9
Maui	179.4	7.1	12.1
Molokai	5.1	0.2	0.3
Lanai	4.4	0.1	0.2
Kauai	70.7	1.9	3.4
Military	155.3	-	-

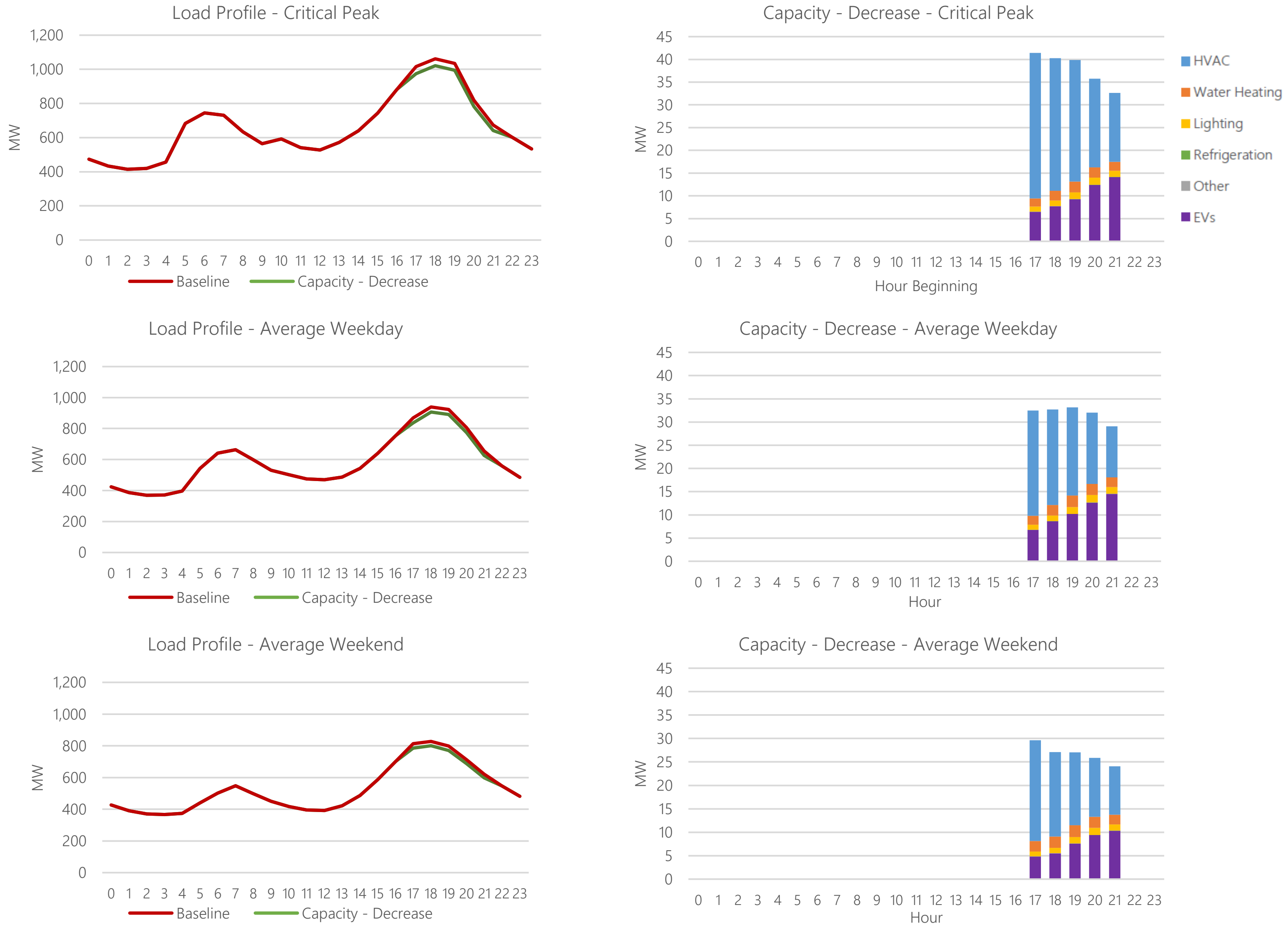
Midday			
Island	**Consumption Baseline (aMW)**	**Impact (aMW)**	
		Low	**High**
Oahu	886.5	-	-
Hawaii	165.3	-	-
Maui	163.9	-	-
Molokai	4.3	-	-
Lanai	4.3	-	-
Kauai	62.0	-	-
Military	173.8	-	-

On-Peak			
Island	**Consumption Baseline (aMW)**	**Impact (aMW)**	
		Low	**High**
Oahu	829.0	30.3	48.8
Hawaii	168.0	4.4	8.8
Maui	161.5	5.8	9.8
Molokai	4.5	0.1	0.2
Lanai	4.0	0.1	0.2
Kauai	63.5	1.5	2.8
Military	139.2	-	-

Off-Peak			
Island	**Consumption Baseline (aMW)**	**Impact (aMW)**	
		Low	**High**
Oahu	506.5	-	-
Hawaii	93.9	-	-
Maui	94.0	-	-
Molokai	2.6	-	-
Lanai	2.2	-	-
Kauai	39.8	-	-
Military	97.9	-	-

Figure 9-4 shows example load profiles and impact shapes for the Capacity - Decrease scenario by day-type (critical peak day, average weekday, and average weekend). The data represents results for Oahu in 2030 under the low acceptability scenario and for the residential and commercial sectors combined. As expected, the impacts are highest on the critical peak day, followed by the weekday and then weekend. In the hour of 5-6 pm on the critical peak day, the potential impact exceeds 40 MW, with 32 MW of that due to HVAC equipment.

Figure 9-4 Hourly Capacity-Decrease Impacts by Day-Type: Oahu, All Sectors, Technical Achievable, 2030



10

INTEGRATING EE, DR/GS, AND RATES

Integrating demand-side management resources is known to increase the effectiveness of energy efficiency and DR/GS efforts over conducting energy efficiency and DR/GS programs separately. With integrated DSM (iDSM), energy efficiency programs can focus on improving the energy efficiency of end-use equipment that has the capability of being controlled to respond to demand response or other grid service events. There is an important synergy because many EE measures contribute to peak demand reductions, while the DR/GS events often yield additional energy savings over EE alone. This chapter describes the integration of energy efficiency measures, DR/GS, and advanced rate designs to optimize energy savings and meet other grid objectives. It begins by presenting hourly energy efficiency impacts and then layers on impact results from advanced rates (specifically, opt-out TOU+CPP), and then DR/GS (specifically, Capacity – Decrease impacts).

Hourly Energy Efficiency Potential

To model the hourly energy efficiency potential, AEG shaped the annual energy efficiency potential results, hourly, using the unitized end-use load shapes discussed in Chapter 3. For example, for a given market segment and a given year of the forecast, the corresponding 8760 lighting load shape was used to create the savings load shape for each lighting energy efficiency measure. This approach assumes that end-use load shapes represent savings load shapes from end-use measures reasonably well[44]. Then, we overlaid the hourly projections of energy efficiency impacts for a given year on top of the hourly baseline projections creating a modified system load profile after future EE adoption.

Table 10-1 (on the following page) shows the average MW (aMW) and percent (%) impacts by time period and island (plus military) in 2030. The results represent the combined impacts from the residential and commercial sectors. The impacts are relative to the hourly baseline *consumption* forecast in 2030. To estimate the average impacts, AEG averaged the hourly impacts for each hour in a given time period across the year (e.g., average impact over the 5-hour peak period for the 10 critical days). The percent impacts are of similar magnitude across the islands where customer accounts are served by HEI. Kauai has slightly lower impacts primarily because of lower program participation rates in recent years and lower penetration of air conditioning, as also noted in Chapter 7. Impacts for the military are lower than the islands due to uniqueness of how the military uses energy and procures equipment.

---

[44] That is, we can use the end-use shape for lighting to represent the savings shape from more efficient lamps because the savings are proportionate in each hour. This is a reasonable assumption for many measures, with the exception of load-shape changing measures such as variable speed pool pumps.

Table 10-1 *Average Energy Efficiency Impacts by Time Period and Island: All Sectors, 2030*

Critical Peak			
Island	**Consumption Baseline (aMW)**	**Impact (aMW)**	**Impact (%)**
Oahu	934.0	182.4	20%
Hawaii	187.3	39.3	21%
Maui	179.4	36.8	21%
Molokai	5.1	1.0	20%
Lanai	4.4	0.9	20%
Kauai	70.7	12.8	18%
Military	155.3	16.9	11%

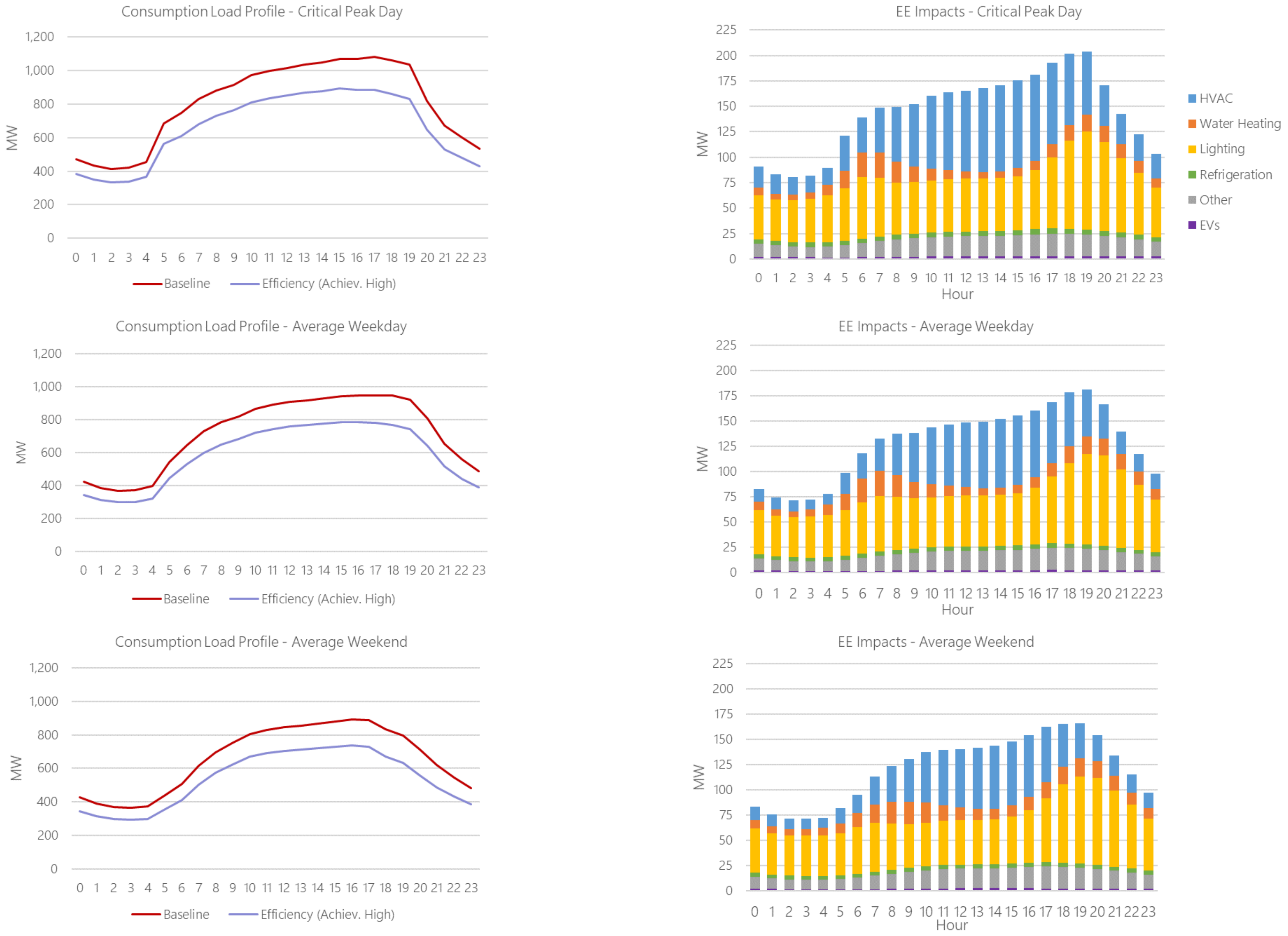
Midday			
Island	**Consumption Baseline (aMW)**	**Impact (aMW)**	**Impact (%)**
Oahu	886.5	147.4	17%
Hawaii	165.3	27.5	17%
Maui	163.9	27.9	17%
Molokai	4.3	0.6	15%
Lanai	4.3	0.7	15%
Kauai	62.0	8.7	14%
Military	173.8	17.1	10%

On-Peak			
Island	**Consumption Baseline (aMW)**	**Impact (aMW)**	**Impact (%)**
Oahu	829.0	163.4	20%
Hawaii	168.0	35.2	21%
Maui	161.5	33.0	20%
Molokai	4.5	0.9	20%
Lanai	4.0	0.8	19%
Kauai	63.5	11.4	18%
Military	139.2	15.1	11%

Off-Peak			
Island	**Consumption Baseline (aMW)**	**Impact (aMW)**	**Impact (%)**
Oahu	506.5	96.3	19%
Hawaii	93.9	18.8	20%
Maui	94.0	18.4	20%
Molokai	2.6	0.5	18%
Lanai	2.2	0.4	19%
Kauai	39.8	6.5	16%
Military	97.9	10.7	11%

Figure 10-1 shows example load profiles and hourly energy efficiency impacts for three day-types: critical peak day, average weekday, and average weekend. The data represents the achievable - high potential for Oahu in 2030. Impacts for the residential and commercial sectors are combined. As expected, overall hourly impacts (MW) are highest on critical peak days, followed by weekdays and then weekends. Lighting provides the greatest savings potential during on-peak and off-peak hours, followed by HVAC, "other" various end uses, water heating, refrigeration, and then EVs. HVAC offers the greatest savings potential during midday hours.

Figure 10-1 Hourly Energy Efficiency Impacts by Day-Type: Oahu, All Sectors, Achievable–High, 2030



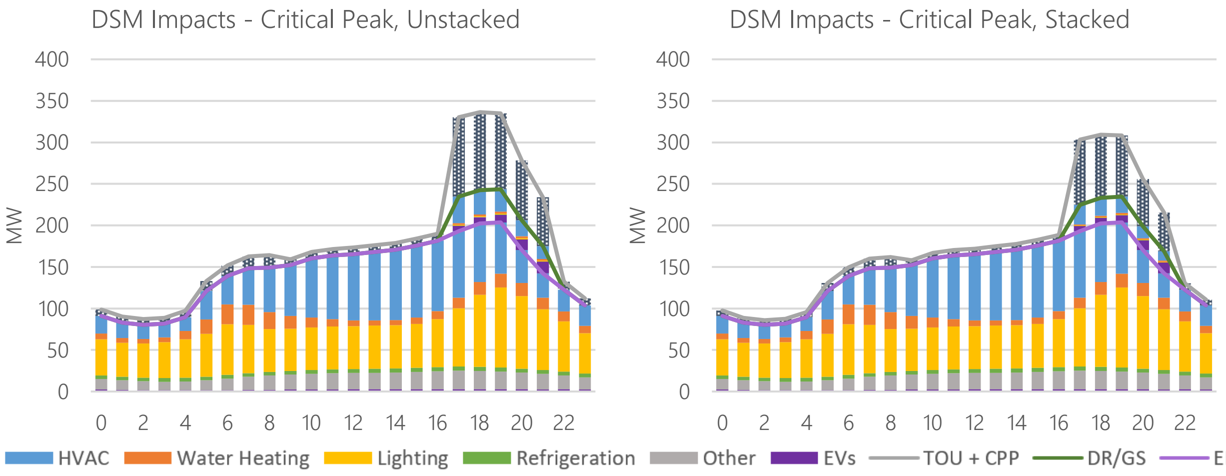
Estimation of Resource Class Interactions

AEG combined the hourly EE results with the results for the TOU+CPP rate concept (Chapter 8) and DR/GS options (Chapter 9) to estimate the hourly potential of the combined impacts. We modelled two scenarios:

- Unstacked impacts: Unstacked impacts represent the simple addition of hourly EE, TOU rates, and hourly DR/GS impacts with no consideration of a "loading order" for the three types of DSM resources. As such, they overstate the potential since impacts from advanced rates and DR/GS are proportional to the amount of load that can be decreased during an event—the higher the original load (i.e., the less efficient), the greater the potential for higher load impacts when the load is curtailed due to the rate and DR/GS event. Unstacked impacts are useful for comparing the three types of DSM resources relative to the same baseline, but should not be added to approximate a combined impact.
- Stacked impacts: Analysis of stacked impacts takes a "loading order" of DSM actions into account. That is, the impacts are modelled with the assumption that the energy efficiency measures have already been implemented prior to establishing the TOU rate, and that both the EE measures and TOU rate are in place prior to the DR/GS events. As a result, the impacts from the advanced rates are estimated relative to a more efficient baseline (lower loads) than the original baseline and therefore yield lower rate impacts compared with the unstacked case. Similarly, the DR/GS impacts are estimated relative to an even lower baseline since they are layered on top of both the EE and advanced rate analysis. The stacked impacts reflect a more accurate estimate of the true potential of layering EE and DR/GS and should be used when considering the integrated effects of multiple DSM resources.

Figure 10-2 compares unstacked versus stacked results for the three classes of DSM resources. The results are for Oahu on a critical peak day in 2030. The EE impacts reflect the achievable - high potential, while the Capacity - Decrease impacts reflect the technical achievable[45] potential for the low acceptability scenario. The rate shown is opt-out TOU+CPP. For visual clarity, impacts for the rate appear on the top of the load shape with the black and white cross pattern and the gray line, even though rates are actually *second* in the loading order. In this scenario, the maximum hourly impact is 309 MW (6 pm) for the stacked case, compared with 336 MW (6 pm) for the unstacked case; this illustrates the point that using unstacked savings would be overstating impacts (by about 9% for that particular hour).

Figure 10-2 Unstacked vs. Stacked EE, TOU+CPP, and Capacity-Decrease Impacts for Critical Peak Day: Oahu, All Sectors, 2030



---

[45] See Chapter 9 for the explanation for using Technical Achievable potential for DR/GS.

Hourly Potential of EE, Rates, and DR/GS

Figure 10-3 presents the stacked results for Oahu in 2030 by sector and day-type. Once again, the DR/GS option shown in the figure is Capacity - Decrease. The EE impacts reflect the achievable - high potential, while the Capacity - Decrease impacts reflect the technical achievable potential for the low acceptability scenario from the Navigant study. The rate shown is opt-out TOU+CPP, which assumes that 80% of customers will choose to remain on the rate (instead of opting out).

Table 10-2 Additional Savings Potential from iDSM: Oahu, All Sectors, Critical Peak Day, 2030

DSM Type	On-Peak Impact (aMW)	On-Peak Impact (% of Baseline)
Energy Efficiency	182.4	20%
TOU+CPP	66.4	7%
Capacity-Decrease	29.6	3%
All DSM Classes	**278.4**	**30%**

The figure shows that integrating EE with advanced rates and DR/GS has the potential to increase the savings significantly over EE alone. This benefit of iDSM is especially apparent on the critical peak day during the on-peak period (see Table 10-2), where impacts for EE alone are 182 average MW[46] (aMW) compared with 278 aMW for integration of all three DSM classes—a more than 50% increase in potential savings.

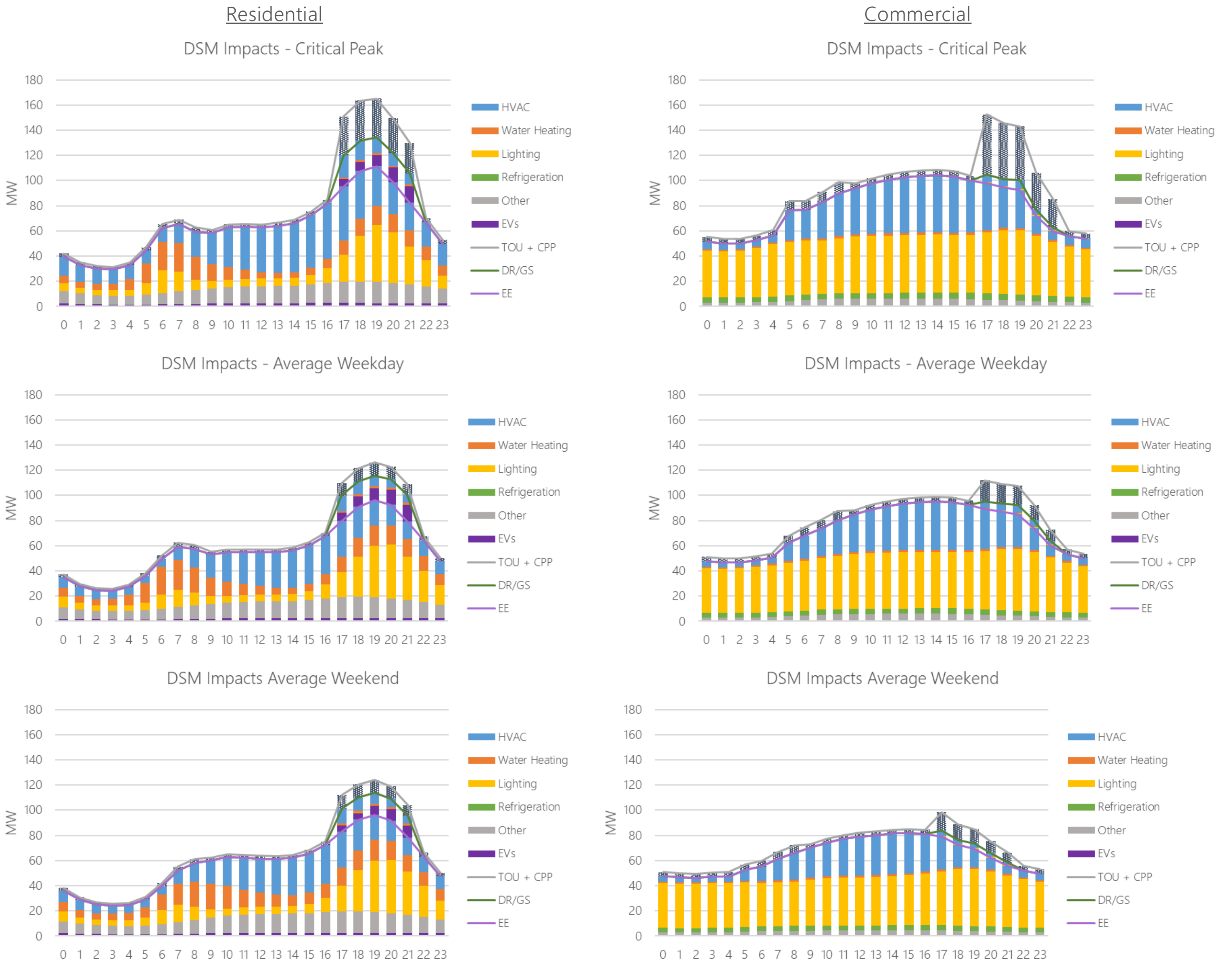
Figure 10-3 also allows a side-by-side comparison of potential residential and commercial impacts. Peak demand impacts are higher for the residential sector for all day-types, but overall energy savings are higher for the commercial sector. In addition, the commercial sector has greater impacts from rates, while the residential sector has greater impacts from the Capacity - Decrease DR/GS option.

Using the low acceptability scenario for DR/GS impacts and the opt-out rate of 80% for TOU-CPP rate represents a conservative estimate of the potential impacts on the system. Appendix E contains additional findings from the hourly analysis, including supplemental results for other DR/GS options and for the high acceptability scenario.

---

[46] Average MW or aMW is the average of the MW during a period time, in this case during the on-peak period.

Figure 10-3 Hourly Stacked Impacts (EE, Capacity-Decrease, and Opt-Out TOU+CPP) by Day-Type and Sector: Oahu, 2030



11

INTERVENTION CONCEPTS

This chapter explores program and policy interventions to optimize the savings potential for the most impactful measures identified during the study.

Purpose

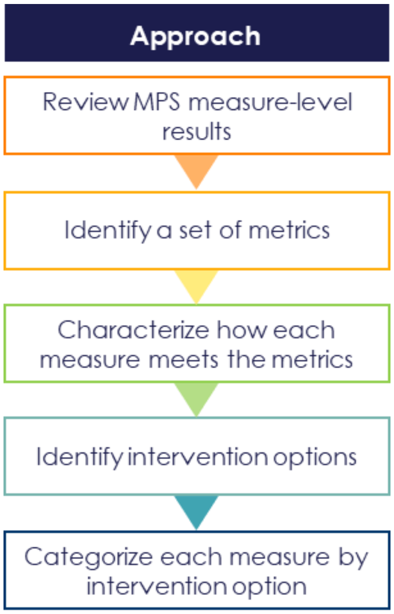
With all the annual and hourly modeling of potential impacts completed, AEG took a step back to reflect on the key findings. Our desire was to provide guidance to the HPUC regarding how it might move forward to do the following:

- Achieve EEPS goals: The highest priority in the context of this study was to provide an estimate of the energy efficiency potential by 2030 (and beyond) and to recommend ways to help reach the EEPS goals.
- Achieve other objectives in parallel: The State of Hawaii has other important goals to consider, including adding more renewables to the grid, enhancing grid services, increasing water use efficiency, and addressing customer equity by reaching hard-to-reach markets, to name a few.
- Manage cost: By identifying cost-effective energy efficiency measures with high achievable potential, as well as exploring cost-effective (at least in a qualitative sense) program and policy interventions to pursue those measures.

We frame our analysis as development of "intervention concepts."

Analysis Approach

Figure 11-1 Intervention Concepts Analysis Approach



The analysis approach for the intervention concepts task involved five main steps (see Figure 11-1). The bullet points below describe each step:

- Review MPS measure-level results: Reviewed MPS measure-level results from the annual analysis and identified measures that are most impactful with respect to cumulative savings by 2030. We considered the two levels of achievable potential (BAU and High) in this review.
- Identify a set of metrics: Considered metrics related to the main objectives of this study, and other metrics of importance for the State of Hawaii:
    - Impact toward EEPS goal
    - Load reduction potential by time-of-day (on-peak, off-peak and midday, as defined during the advanced rate design)
    - Contribution to renewable energy goals
    - Water savings
- Characterize how each measure meets the metrics: Looked at quantitative and qualitative valuations of the metrics for each measure:

  - Cumulative energy savings (GWh) by 2030 for the two levels of achievable potential
  - Qualitative assessment of load reduction potential (High, Medium, Low) by time-of-day
  - Does the measure contribute to renewable energy goals (Yes, No)
  - Does the measure contribute to water savings (Yes, No)
- **Identify intervention options:** Selected four types of possible intervention options:
  - **Public Benefits Fee Administrator (PBFA) programs:** Energy-efficiency measures either included, or recommended for consideration, in PBFA program.
  - **PBFA Programs or Future Code/Standard:** Energy efficiency measures that could continue to be implemented through PBFA programs but could also become a new code or standard at the state and/or federal levels, as inspired by EISA, CA Title 20, CA Title 24, etc.
  - **DR/GS Facilitator:** Energy efficiency measures for equipment that has the potential to be automatically controlled, facilitating future DR/GS programs.
  - **Newly-enacted Standard:** These measures fall under a new standard that takes effect in 2021, transitioning away from a PBFA program. This is a unique situation, and required special modeling, so the savings are called out separately.
- **Categorize each measure by intervention option:** Assessed which measures were best suited for each type of intervention approach.

Findings and Recommendations

Figure 11-2 and Figure 11-3 show the cumulative savings by 2030 for the subset of measures we determined to be most impactful. The savings are grouped into the four types of intervention options. The second category—PBFA Programs or Future Code/Standard—has the highest savings potential, with 666 GWh of cumulative savings potential by 2030. Collectively, the top measures across all categories have a savings potential of 1,434 GWh by 2030. As Figure 11-3 shows, this compares favorably with the amount of cumulative energy savings still needed between 2020 and 2030 (~1,000 GWh) to meet the overall EEPS target of 4,300 GWh between 2009 and 2030. Therefore, these interventions are expected to exceed the EEPS requirement in 2030 by more than 40%.

In estimating the potential by intervention type, AEG used achievable - high potential for the "PBFA Programs or Future Code/Standard" category.

When identifying what should be considered as the most impactful measures, we looked at the top 20 measures for each sector (in terms of energy savings potential) as well as a few other measures that show promise to have higher potential when bundled with other measures and/or implemented through a code or standard or GS/DR delivery approach.

Figure 11-2 2030 Cumulative Savings by Intervention Type

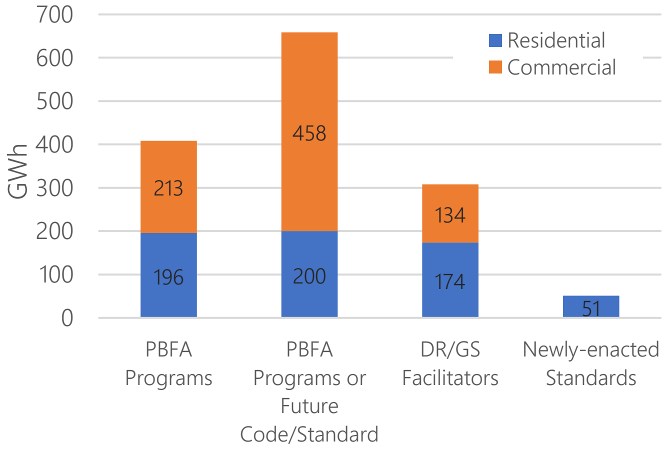


Figure 11-3 Contribution by Sector to Achievable Potential

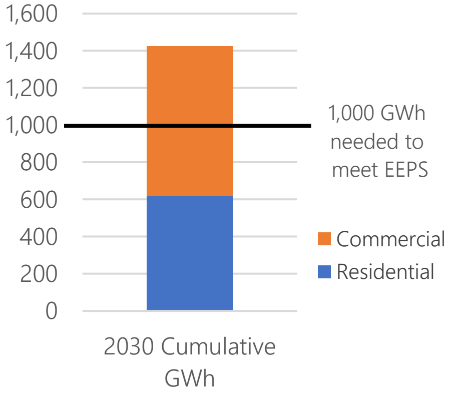


Figure 11-4 and Figure 11-5 show AEG's recommended distribution of the most impactful measures considered in this analysis by intervention type for the residential and commercial sectors, respectively. In all, 18 residential and 24 commercial measures rose to the top. The size of the bubbles is proportional to the cumulative achievable energy savings potential by 2030 for the given measure. The colors indicate the end use applicable to the measure. In addition, the measures are color-coded and listed in order of decreasing potential savings (GWh) alongside each of the four quadrants of intervention types. The figures also show the savings for the top two measures for each intervention type directly on the bubble chart. Below are summary recommendations:

- PBFA Programs: Continue to offer a mix of successful measures with high potential as well as promising new measures through the PFBA programs. The measures in this category with the highest potential are residential solar water heaters, refrigerator decommissioning and recycling, and removal of second AC unit. The solar water heater measure assumes the federal tax credit is phased out and the state tax credit continues; any new changes in the solar tax credits could influence the savings for this measure.
    - One possible new concept is to bundle the planting of shade trees with delivery of another measure (e.g., when a new AC system is installed). We have found planting shade trees has high customer satisfaction in other programs, but siting of the trees would be an important consideration due to the high penetration of rooftop PV in Hawaii homes.
- PBFA Programs or Future Code / Standard: These measures could continue to be offered through PBFA programs or new codes or standards. Consider pursuing state standards for exempted lighting and the printer/copier/fax measures. Consider making the commercial linear lighting, residential cool roof, and commercial guest room controls measures part of the energy code as has been done in California. For general service lighting, promote new Federal standards.

The recommendation to pursue new codes and standards is consistent with work that has already begun in Hawaii. For example, the State of Hawaii recently adopted International Energy Conservation Code (IECC) 2015 with amendments, as well several new state appliances standards that will take effect on January 1, 2021.

- DR/GS Facilitator: Consider continued and further collaboration between Hawai'i Energy and HECO to promote "connected" equipment and measures that provide both energy efficiency and grid services. Focus on HVAC equipment, but also electric vehicle chargers, grid-tied water heaters, connected home control systems, and building energy management systems. For example, a program element could focus on "smart" connected HVAC solutions for residential and small/medium businesses. Technologies could include connected room AC, connected mini-splits, and smart thermostats coupled with efficient central AC and heat pump systems. The "smart" aspect could be a requirement for the program, or the program could allow for a second tier of incentives for smart systems to offset the higher costs.

This would build on some of the new programs and pilots that Hawai'i Energy and HECO have been working together on, such as the smart thermostat offering, grid integrated water heater pilot, and exploration into leveraging energy management systems for energy efficiency and demand response.

- Newly-enacted Standard: Faucet aerators and low-flow showerheads have been included in PBFA programs in the past. However, a new state standard takes effect on January 1, 2021.[47] Because of the timing of this analysis, the future savings from these measures are attributed to "newly-enacted standards". Consider continuing to help support the transition of these measures as they become standards.

One of the priorities for the State of Hawaii beyond energy efficiency is to advance efficiency in the water-energy nexus. The new state standards for water-saving appliances contribute to this objective, as do additional activities outlined in Hawai'i Energy's triennial plan.

---

[47] Hawaii House Bill 556 (Prior Session Legislation), A Bill for an Act, Relating to Energy Efficiency, Passed 7/1/2019, Act 141 6/26/2019, access text here: <https://legiscan.com/HI/text/HB556/id/2003415/Hawaii-2019-HB556-Amended.html>.

Figure 11-4 Illustration of How High Impact Measures are Distributed Among Possible Intervention Approaches: Residential Sector

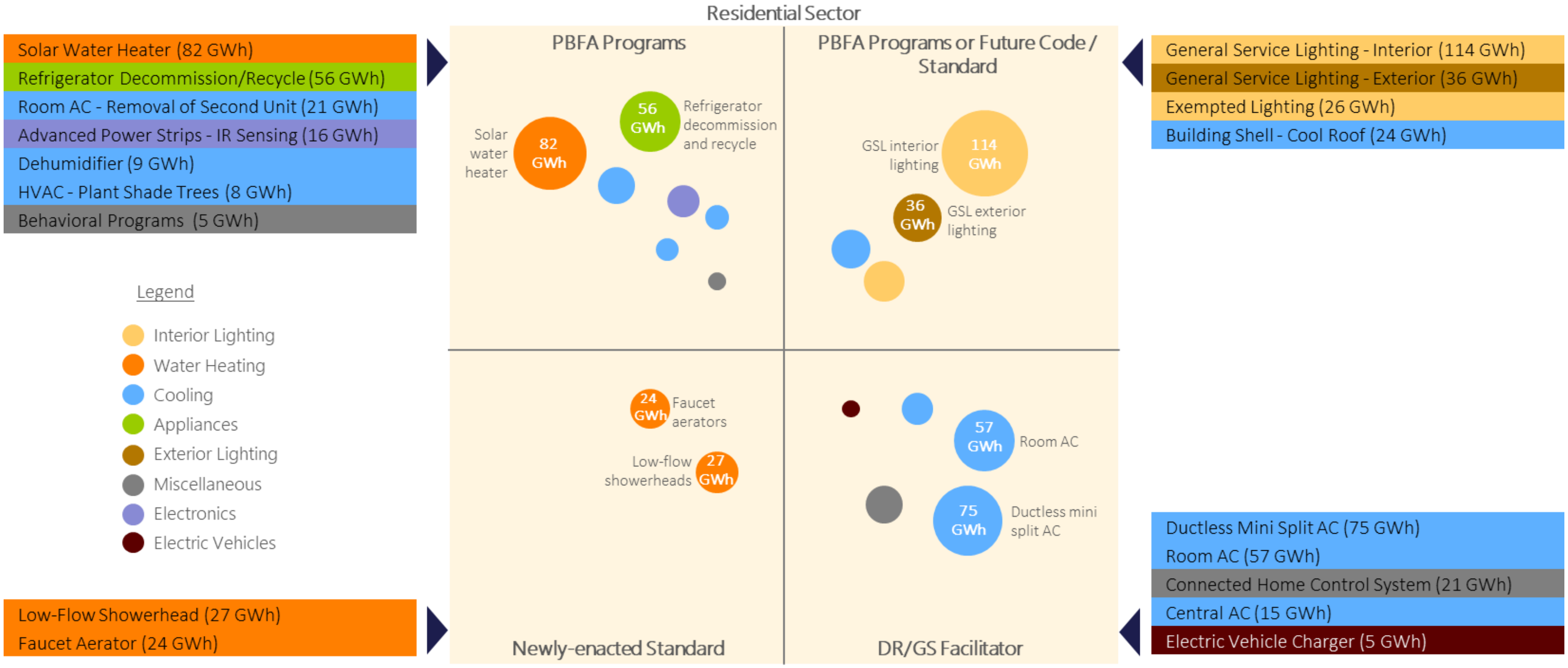
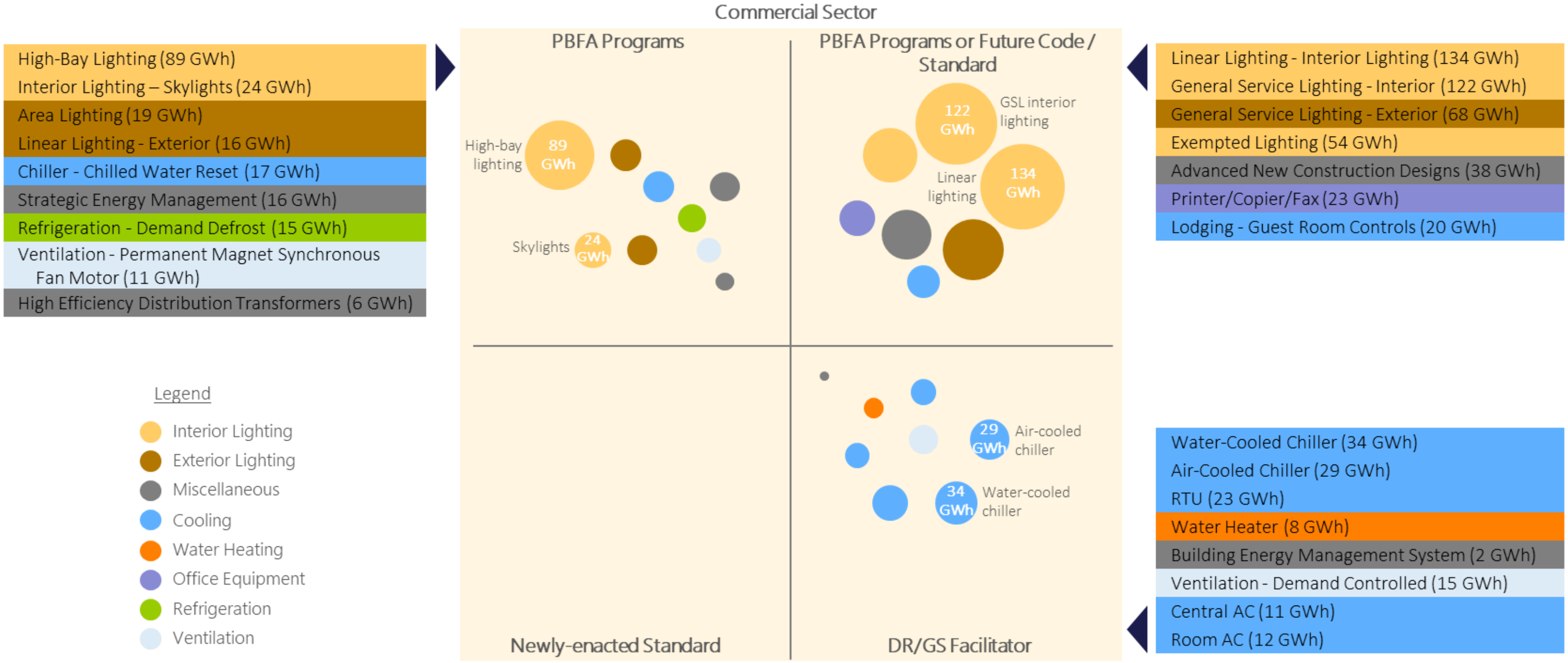


Figure 11-5 Illustration of How High Impact Measures are Distributed Among Possible Intervention Approaches: Commercial Sector



A

MPS OUTPUT

The Excel file, Appendix A Hawaii 2020 MPS Final Annual Results.xlsx, contains summary results as well as island-level results by sector.

Appendix A Hawaii
2020 MPS Final Annu

B

TECHNOLOGY SATURATION DATA

The subsections below present detailed technology saturation data for key residential and commercial end uses by market segment and island.

Residential

The residential data was developed using results from the 2019 Baseline Study,[48] 2019 HECO RASS, and input from KIUC. Table B-1 provides definitions for the residential market segment acronyms used throughout this appendix.

Table B-1 Definitions of Residential Market Segment Acronyms

Acronym	Definition
SF RI	Single family, regular income
SF LMI	Single family, low-moderate income
SF NEM	Single family, net energy metered
MF RI	Multifamily, regular income
MF LMI	Multifamily, low-moderate income
MF NEM	Multifamily, net energy metered
MF MM	Multifamily, master metered

Space Cooling

Table B-2 and Figure B-1 provide residential space cooling saturation by air conditioning (AC) technology, market segment, and island. The results for Lanai and Molokai are combined with Maui results and presented as Maui County. Overall, the market segment with the highest saturation of AC systems is single family homes with NEM on Oahu, with 100% AC saturation. On the island of Hawaii, single family homes with regular income have the highest AC saturation (68% of homes), with most systems being room AC (37% of homes), followed by ductless mini split AC (23%), and central AC (7%). On Kauai, single family and multifamily homes with NEM have the highest AC penetration (44% of homes), with at least half of those homes with AC having room AC systems. In Maui County, single family homes with NEM have an AC penetration of 85% (41% room AC, 26% ductless mini split, and 18% central AC). Across all islands, multifamily homes with low-moderate income are least likely to have AC systems (19-21% AC penetration, depending on the island); single family homes with low-moderate income are the next least likely market segment to have AC systems (27-37% AC penetration, depending on the island).

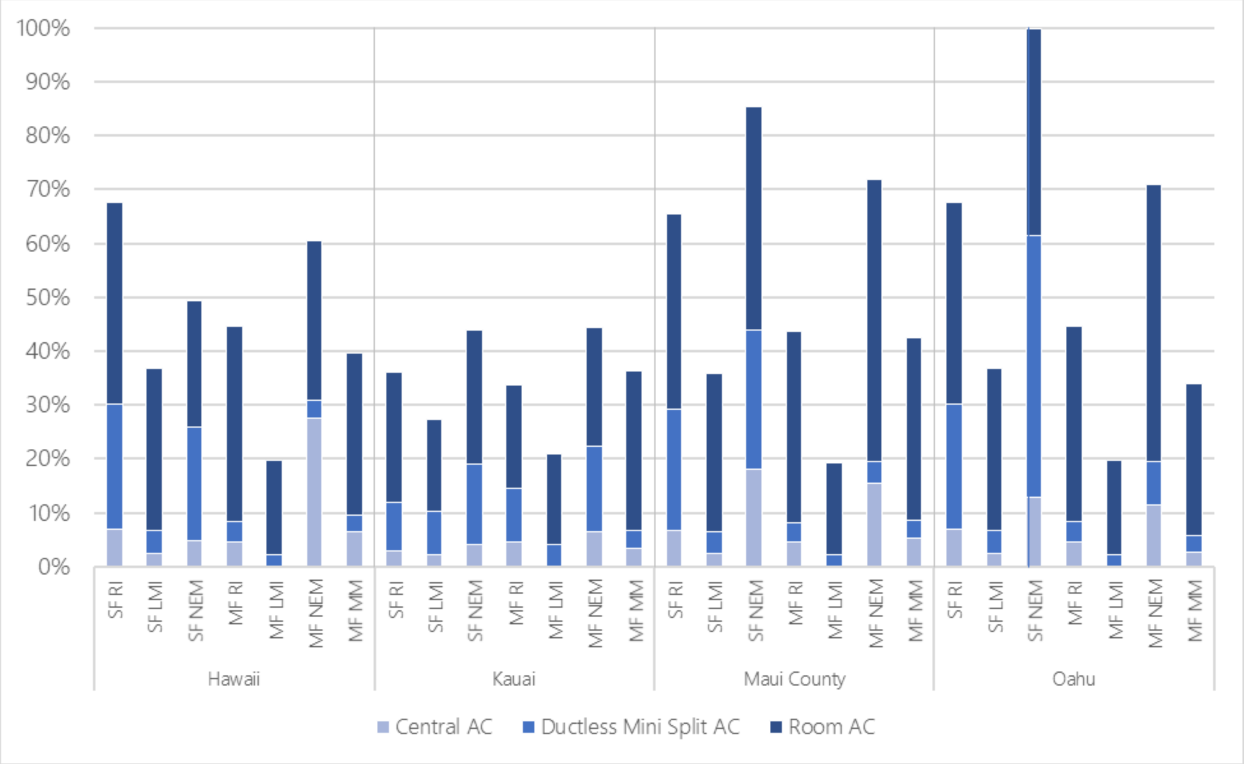
---

[48] 2019 Hawaii Statewide Baseline Energy Use Study, Prepared by Applied Energy Group, Prepared for the Hawaii Public Utilities Commission, 2020.

Table B-2 Residential Space Cooling Technology Saturation by Island and Market Segment

Technology	Saturation within each Residential Market Segment						
Hawaii	**SF RI**	**SF LMI**	**SF NEM**	**MF RI**	**MF LMI**	**MF NEM**	**MF MM**
Central AC	7%	2%	5%	5%	0%	28%	6%
Ductless Mini Split AC	23%	4%	21%	4%	2%	3%	3%
Room AC	37%	30%	23%	36%	18%	30%	30%
Hawaii Total	**68%**	**37%**	**49%**	**45%**	**20%**	**61%**	**40%**
Kauai	**SF RI**	**SF LMI**	**SF NEM**	**MF RI**	**MF LMI**	**MF NEM**	**MF MM**
Central AC	3%	2%	4%	5%	0%	6%	3%
Ductless Mini Split AC	9%	8%	15%	10%	4%	16%	3%
Room AC	24%	17%	25%	19%	17%	22%	30%
Kauai Total	**36%**	**27%**	**44%**	**34%**	**21%**	**44%**	**36%**
Maui County	**SF RI**	**SF LMI**	**SF NEM**	**MF RI**	**MF LMI**	**MF NEM**	**MF MM**
Central AC	7%	2%	18%	5%	0%	16%	5%
Ductless Mini Split AC	22%	4%	26%	4%	2%	4%	3%
Room AC	36%	29%	41%	36%	17%	52%	34%
Maui Total	**65%**	**36%**	**85%**	**44%**	**19%**	**72%**	**43%**
Oahu	**SF RI**	**SF LMI**	**SF NEM**	**MF RI**	**MF LMI**	**MF NEM**	**MF MM**
Central AC	7%	2%	13%	5%	0%	11%	3%
Ductless Mini Split AC	23%	4%	48%	4%	2%	8%	3%
Room AC	37%	30%	38%	36%	18%	51%	28%
Oahu Total	**68%**	**37%**	**100%**	**45%**	**20%**	**71%**	**34%**

Figure B-1 Residential Space Cooling Technology Saturation by Island and Market Segment



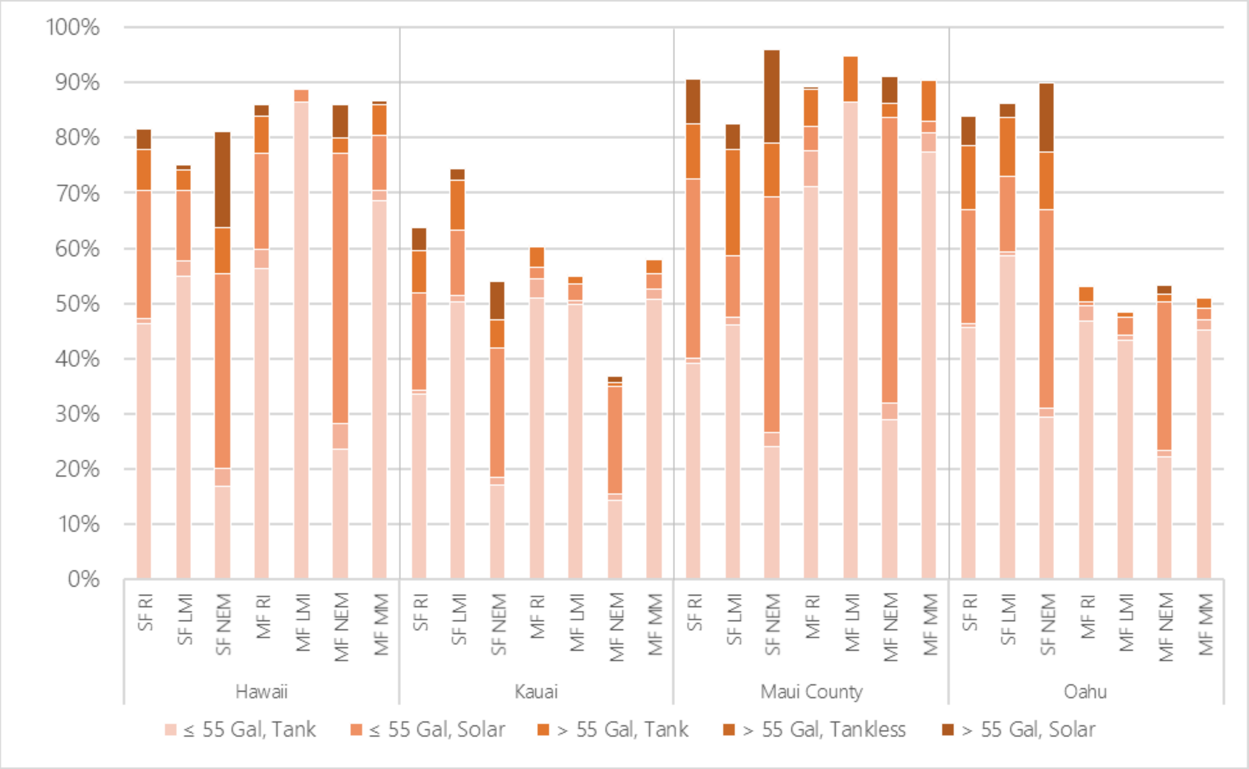
Water Heating

Table B-3 and Figure B-2 provide residential electric water heating saturation by technology, market segment, and island. In both single family and multifamily homes with NEM, solar water heaters with electric resistance back-up and ≤ 55 gallon storage tanks have the highest saturation on every island, ranging from a saturation of 20% in multifamily NEM homes on Kauai to 52% in multifamily NEM homes in Maui County. In all other market segments, electric water heaters with storage tanks of ≤ 55 gallons have the highest saturation on every island, ranging from 34% in regular income homes on Kauai to 87% in low-moderate income homes on the island of Hawaii and Maui County. The saturation of tankless electric water heaters is much lower across the islands, with zero percent saturation in some segments up to a high of 7% in multifamily homes with regular income in Maui County.

Table B-3 Residential Electric Water Heating Technology Saturation by Island and Market Segment

Technology	Saturation within each Residential Market Segment						
Hawaii	**SF RI**	**SF LMI**	**SF NEM**	**MF RI**	**MF LMI**	**MF NEM**	**MF MM**
≤ 55 Gal, Tank	46%	55%	17%	56%	87%	24%	69%
≤ 55 Gal, Tankless	1%	3%	3%	3%	0%	5%	2%
≤ 55 Gal, Solar	23%	13%	35%	17%	2%	49%	10%
> 55 Gal, Tank	7%	4%	8%	7%	0%	3%	6%
> 55 Gal, Solar	4%	1%	17%	2%	0%	6%	1%
Kauai	**SF RI**	**SF LMI**	**SF NEM**	**MF RI**	**MF LMI**	**MF NEM**	**MF MM**
≤ 55 Gal, Tank	34%	50%	17%	51%	50%	14%	51%
≤ 55 Gal, Tankless	1%	1%	1%	3%	1%	1%	2%
≤ 55 Gal, Solar	17%	12%	24%	2%	3%	20%	3%
> 55 Gal, Tank	8%	9%	5%	4%	1%	1%	3%
> 55 Gal, Solar	4%	2%	7%	0%	0%	1%	0%
Maui County	**SF RI**	**SF LMI**	**SF NEM**	**MF RI**	**MF LMI**	**MF NEM**	**MF MM**
≤ 55 Gal, Tank	39%	46%	24%	71%	87%	29%	78%
≤ 55 Gal, Tankless	1%	1%	3%	7%	0%	3%	3%
≤ 55 Gal, Solar	32%	11%	43%	4%	0%	52%	2%
> 55 Gal, Tank	10%	19%	10%	7%	8%	3%	7%
> 55 Gal, Solar	8%	5%	17%	0%	0%	5%	0%
Oahu	**SF RI**	**SF LMI**	**SF NEM**	**MF RI**	**MF LMI**	**MF NEM**	**MF MM**
≤ 55 Gal, Tank	46%	59%	30%	47%	43%	22%	45%
≤ 55 Gal, Tankless	1%	1%	2%	3%	1%	1%	2%
≤ 55 Gal, Solar	21%	14%	36%	1%	3%	27%	2%
> 55 Gal, Tank	12%	11%	10%	3%	1%	1%	2%
> 55 Gal, Solar	5%	2%	13%	0%	0%	2%	0%

Figure B-2 Residential Electric Water Heating Technology Saturation by Island and Market Segment



Lighting

Table B-4 and Figure B-3 provide counts of lamps for residential sector interior lighting by general technology type, specific lamp type, and market segment. The data are for the State of Hawaii as a whole and were obtained from the residential phone audits described in Chapter 3 and in the 2019 Baseline Study report. For single family homes, the results were only compiled for two home types: low-moderate income homes and all other single family homes. Therefore, the results in the table for single family homes with regular income are the same as for single family homes with NEM. Similarly, for multifamily homes, the results were only compiled for two home types: low-moderate income homes and all other multifamily homes. Therefore, the results in the table for multifamily homes with regular income are the same as for multifamily homes with NEM and for master-metered multifamily homes.

The total number of lamps for interior lighting ranges from 14 lamps in multifamily homes with low-moderate income to 46 lamps in single family homes with regular income or NEM. The most prevalent type of lighting technology is the general service screw-in category, representing 72-81% of total lamps, depending on the market segment. Within the general service screw-in category, LEDs are the most common lamp type in all segments except for multifamily homes with low-moderate income; they represent between 27% (MF LMI) to 52% (SF RI and SF NEM) of all general service screw-in lamps. LEDs also represent a notable share of linear lamps (12% to 31%, depending on segment) and exempted lamps (27% to 33%, depending on segment).

Table B-4 Residential Interior Lighting: Counts of Lamps by Technology and Market Segment

Interior Lighting, Statewide Average		Lamp Count within each Residential Market Segment						
Technology	Lamp Type	SF RI	SF LMI	SF NEM	MF RI	MF LMI	MF NEM	MF MM
General Service Screw-in	Incandescent	1.93	1.50	1.93	1.60	1.25	1.60	1.60
	EISA-Compliant (Halogen)	5.80	4.51	5.80	4.80	3.76	4.80	4.80
	CFL	8.67	5.57	8.67	4.92	2.42	4.92	4.92
	LED	18.09	10.44	18.09	10.51	2.81	10.51	10.51
	Subtotal	***34.50***	***22.03***	***34.50***	***21.83***	***10.24***	***21.83***	***21.83***
Linear Lighting	T12	3.74	2.57	3.74	1.29	1.94	1.29	1.29
	T8	0.68	0.47	0.68	0.24	0.35	0.24	0.24
	Super T8	0.34	0.23	0.34	0.12	0.18	0.12	0.12
	T5	0.56	0.38	0.56	0.19	0.29	0.19	0.19
	LED	1.74	1.63	1.74	0.82	0.36	0.82	0.82
	Subtotal	***7.06***	***5.28***	***7.06***	***2.66***	***3.12***	***2.66***	***2.66***
Exempted Lighting	Incandescent	2.26	0.84	2.26	1.02	0.10	1.02	1.02
	Infrared Halogen	0.45	0.35	0.45	0.37	0.29	0.37	0.37
	CFL	0.67	0.43	0.67	0.38	0.19	0.38	0.38
	LED	1.39	0.80	1.39	0.81	0.22	0.81	0.81
	Subtotal	***4.77***	***2.42***	***4.77***	***2.57***	***0.79***	***2.57***	***2.57***
Total Interior Lamps		**46.33**	**29.72**	**46.33**	**27.07**	**14.15**	**27.07**	**27.07**

Figure B-3 Residential Interior Lighting: Counts of Lamps by Technology and Market Segment

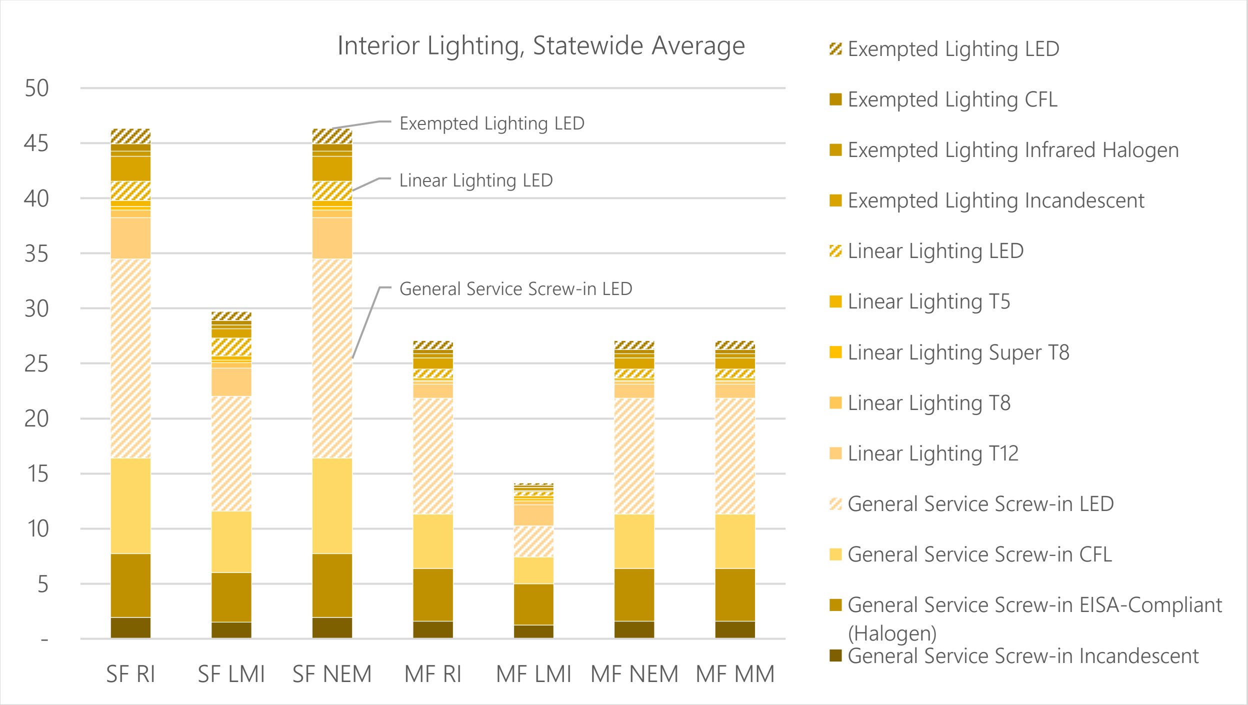


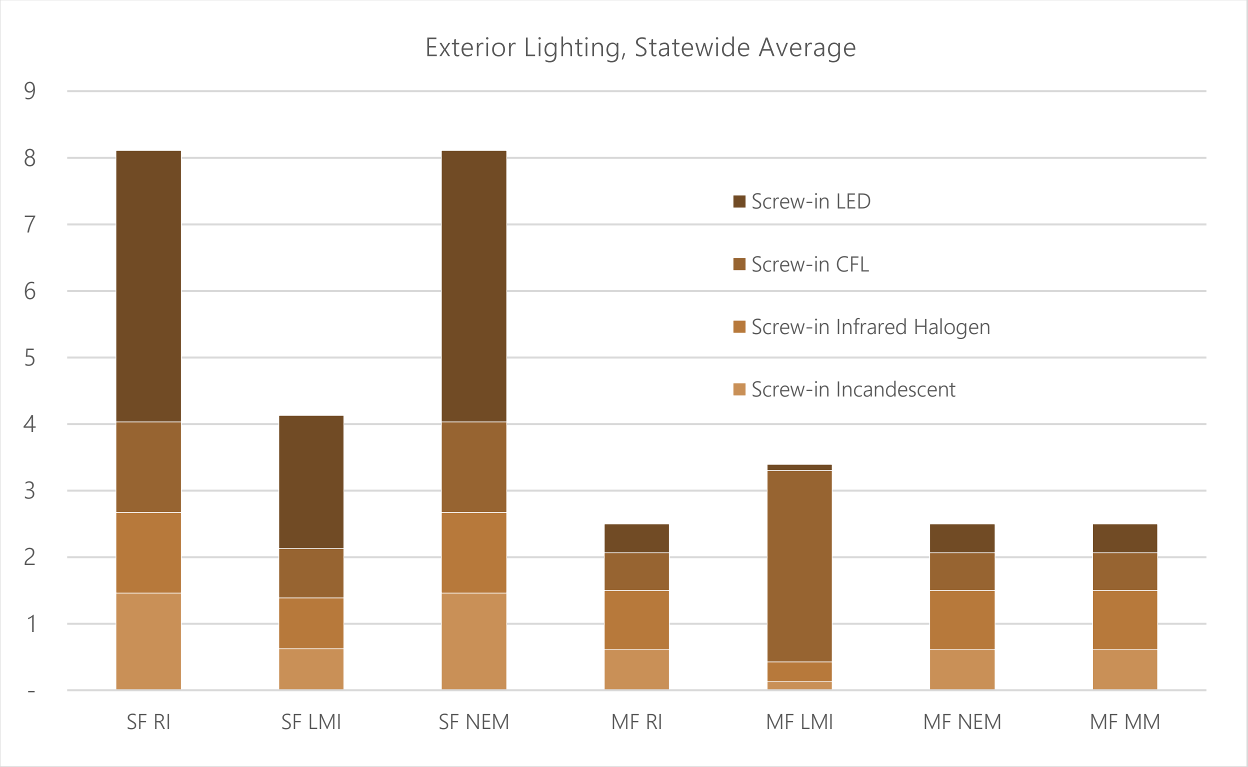
Table B-5 and Figure B-4 provide counts of lamps for exterior lighting by general technology type, specific lamp type, and market segment. As for interior lighting, the data are for the State of Hawaii as a whole and were obtained from the residential phone audits described in Chapter 3 and in the 2019 Baseline Study report. In addition, for single family homes, the results were only compiled for two home types: low-moderate income homes and all other single-family homes. Therefore, the results in the table for single family homes with regular income are the same as for single family homes with NEM. Similarly, for multifamily homes, the results were only compiled for two home types: low-moderate income homes and all other multifamily homes. Therefore, the results in the table for multifamily homes with regular income are the same as for multifamily homes with NEM and for master-metered multifamily homes.

The total number of exterior lamps in the average home ranges from 2.5 in multifamily homes (regular income, NEM, and master-metered) to eight in single family homes (regular income and NEM). In all single family homes, LEDs are the most prevalent lamp type, ranging from two-of-four total exterior lamps for low-moderate income homes to four-of-eight total exterior lamps for regular income and NEM homes.

Table B-5 Residential Exterior Lighting: Counts of Lamps by Technology and Market Segment

Exterior Lighting, Statewide Average		Lamp Count within each Residential Market Segment						
Technology	Lamp Type	SF RI	SF LMI	SF NEM	MF RI	MF LMI	MF NEM	MF MM
Screw-in	Incandescent	1.46	0.63	1.46	0.61	0.13	0.61	0.61
	Infrared Halogen	1.21	0.76	1.21	0.89	0.30	0.89	0.89
	CFL	1.36	0.74	1.36	0.57	2.88	0.57	0.57
	LED	4.07	2.00	4.07	0.43	0.09	0.43	0.43
Total Exterior Lamps		**8.11**	**4.13**	**8.11**	**2.50**	**3.39**	**2.50**	**2.50**

Figure B-4 Residential Exterior Lighting: Counts of Lamps by Technology and Market Segment



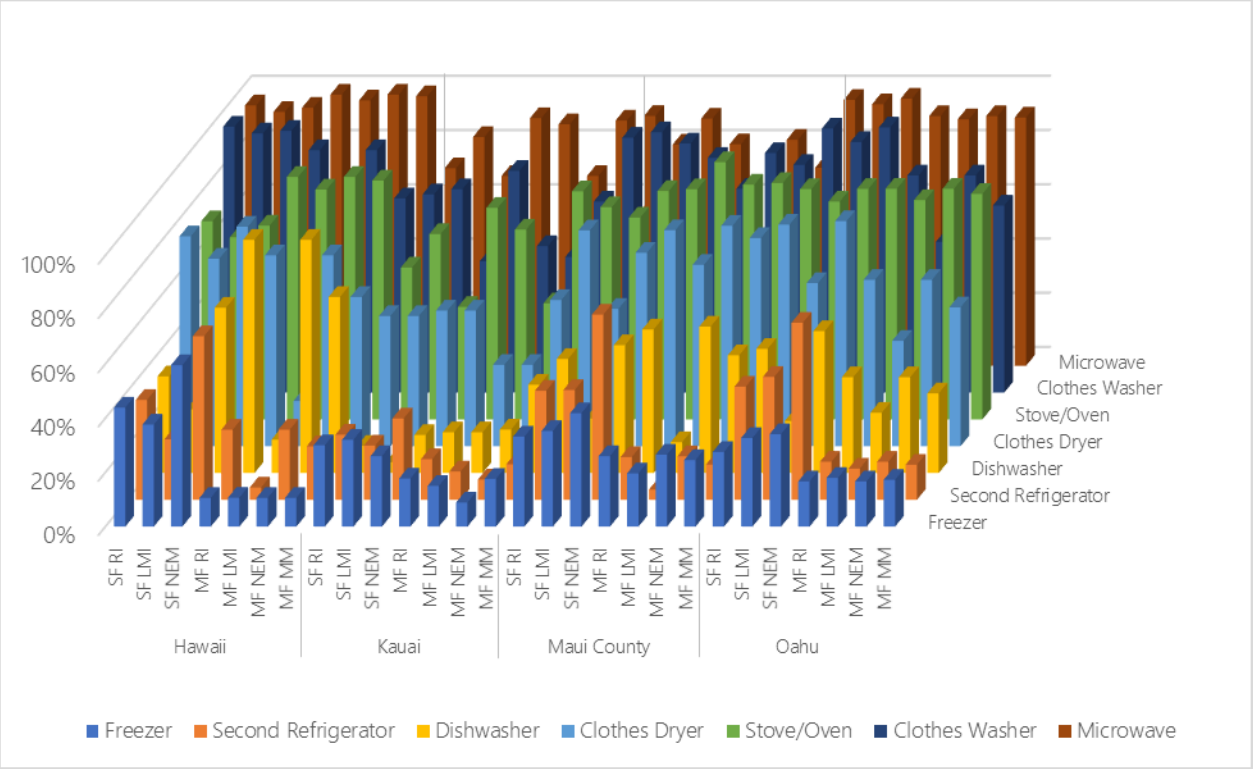
Appliances

Table B-6 and Figure B-5 show the saturation of electric appliances in the residential sector by market segment and island. Microwave ovens have the highest saturation across the segments and islands (44% to 100%, depending on home type and island). Stand-alone freezers have the lowest saturation (9% to 60%, depending on home type and island). In general, homes on Kauai have lower saturations of electric appliances than homes on the other islands.

Table B-6 Residential Electric Appliance Saturation by Island and Market Segment

Technology	Saturation within each Residential Market Segment						
Hawaii	**SF RI**	**SF LMI**	**SF NEM**	**MF RI**	**MF LMI**	**MF NEM**	**MF MM**
Freezer	44%	38%	60%	11%	11%	11%	11%
Second Refrigerator	37%	22%	60%	26%	5%	26%	20%
Dishwasher	36%	23%	61%	86%	12%	86%	65%
Clothes Dryer	77%	69%	81%	70%	17%	70%	55%
Stove/Oven	73%	67%	71%	89%	85%	89%	88%
Clothes Washer	98%	96%	97%	89%	27%	89%	72%
Microwave	96%	94%	95%	100%	98%	100%	99%
Kauai	**SF RI**	**SF LMI**	**SF NEM**	**MF RI**	**MF LMI**	**MF NEM**	**MF MM**
Freezer	30%	32%	26%	18%	15%	9%	18%
Second Refrigerator	24%	20%	30%	15%	10%	7%	13%
Dishwasher	10%	4%	14%	15%	15%	16%	33%
Clothes Dryer	48%	48%	50%	50%	30%	30%	54%
Stove/Oven	56%	68%	41%	78%	70%	43%	84%
Clothes Washer	73%	75%	48%	82%	54%	50%	70%
Microwave	73%	84%	70%	91%	89%	70%	90%
Maui County	**SF RI**	**SF LMI**	**SF NEM**	**MF RI**	**MF LMI**	**MF NEM**	**MF MM**
Freezer	33%	35%	42%	26%	20%	27%	25%
Second Refrigerator	40%	41%	68%	16%	4%	16%	13%
Dishwasher	42%	20%	47%	53%	11%	54%	43%
Clothes Dryer	80%	51%	71%	80%	67%	81%	77%
Stove/Oven	78%	74%	84%	85%	95%	87%	87%
Clothes Washer	94%	96%	92%	87%	75%	88%	84%
Microwave	92%	82%	91%	82%	44%	83%	73%
Oahu	**SF RI**	**SF LMI**	**SF NEM**	**MF RI**	**MF LMI**	**MF NEM**	**MF MM**
Freezer	28%	33%	34%	17%	18%	17%	17%
Second Refrigerator	42%	45%	65%	14%	12%	14%	13%
Dishwasher	46%	19%	52%	35%	22%	35%	29%
Clothes Dryer	82%	60%	83%	61%	39%	61%	51%
Stove/Oven	85%	80%	85%	85%	81%	85%	83%
Clothes Washer	97%	92%	98%	80%	56%	80%	69%
Microwave	98%	96%	99%	92%	91%	92%	92%

Figure B-5 Residential Electric Appliance Saturation by Island and Market Segment



Commercial

The commercial data was developed using results from the 2019 Baseline Study and input from KIUC.

Space Cooling

Table B-7 and Figure B-6 provide commercial sector space cooling saturation by technology, market segment, and location. AEG derived the results for Oahu, Hawaii, and Maui County from the 2019 Baseline Study. As per the research design of that study, the focus was on obtaining market segment-level results for the group of islands served by HEI as a whole; there were not enough sample points to develop accurate results by both market segment and by island. The market saturation data for Kauai was derived using input on the space cooling market from KIUC.

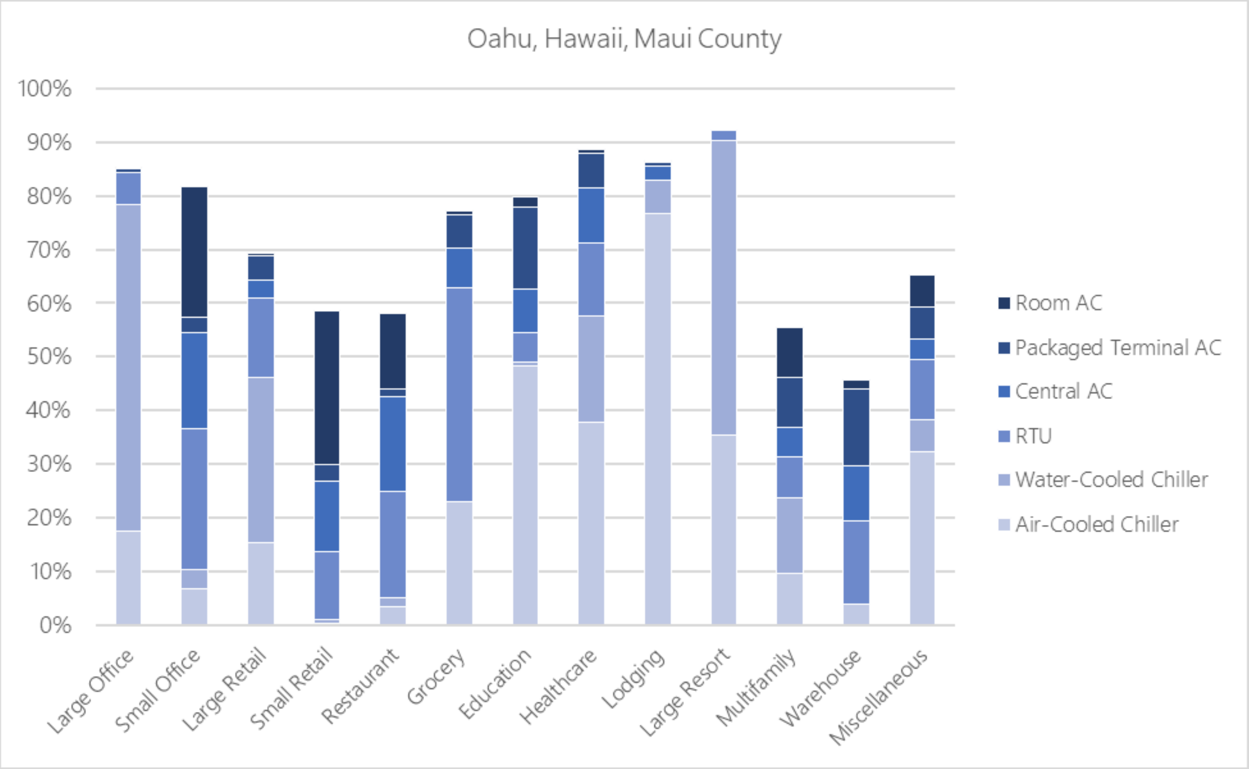
For Oahu, Hawaii, and Maui County as a whole, the market segment with the highest saturation of space cooling equipment is the large resort segment, with 92% saturation. Healthcare (89%), lodging (86%), and large offices (85%) also have high saturation of space cooling equipment. The market segment with the lowest saturation is the warehouse segment (46%). Small retail and small offices are more likely to have room AC units, while large resorts, lodging, and large offices are more likely to have chillers. RTUs and central AC systems are most common in grocery stores, small offices, and restaurants, while packaged terminal AC systems are more common in education and warehouses than in other segments.

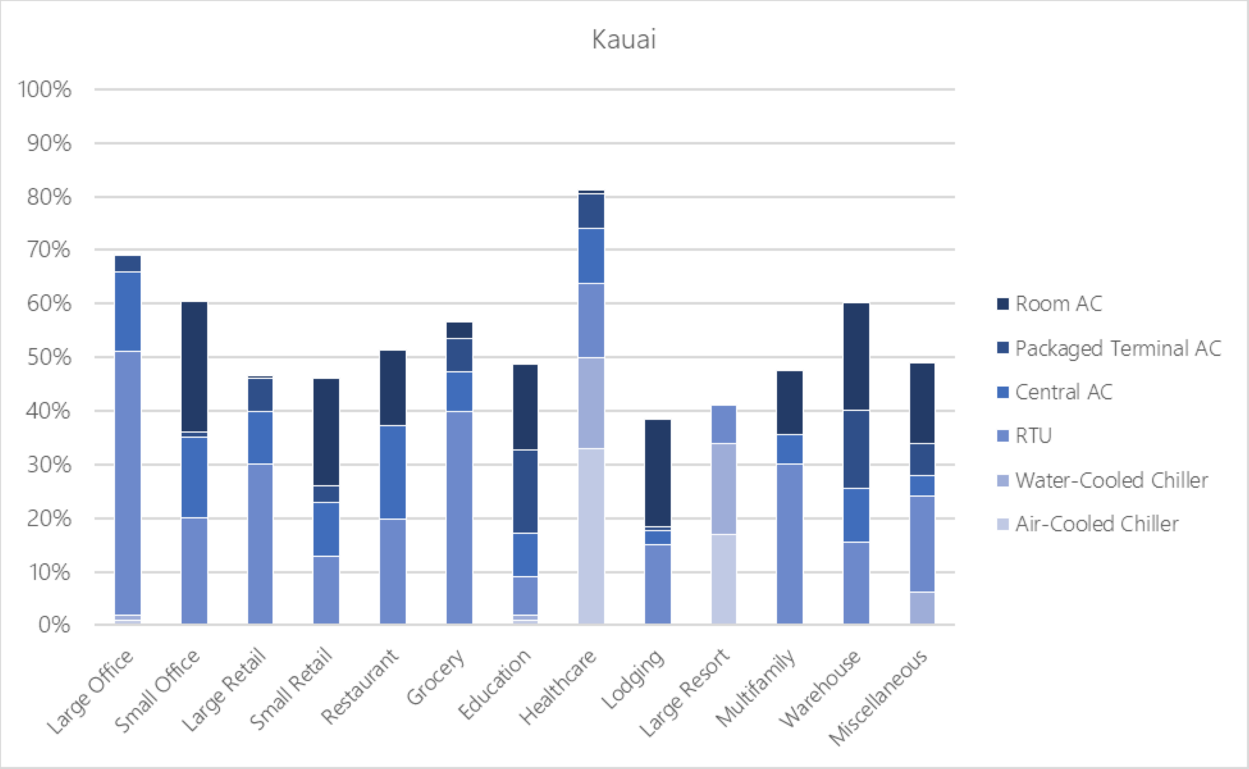
In Kauai, the market segment with the highest saturation of space cooling equipment is healthcare, with 81% saturation. Large offices (69%), small offices (60%), and warehouses (60%) also have relatively high saturation of space cooling equipment. The market segment with the lowest saturation is lodging (38%). Small offices, small retail, lodging, and warehouses are more likely to have room AC units, while healthcare and large resorts are more likely to have chillers. RTUs and central AC systems are most common in large offices, grocery stores, large retail, restaurants, and multifamily buildings, while packaged terminal AC systems are more common in education and warehouses than in other segments. Overall, the saturation of space cooling systems (especially chillers) is lower in Kauai than found for the average accounts served by HEI.

Table B-7 Commercial Space Cooling Technology Saturation by Location and Market Segment

Technology	Saturation within each Commercial Market Segment												
Oahu, Hawaii, Maui County	**Large Office**	**Small Office**	**Large Retail**	**Small Retail**	**Rest-aurant**	**Gro-cery**	**Educa-tion**	**Health-care**	**Lodging**	**Large Resort**	**Multi-family**	**Ware-house**	**Miscel-laneous**
Air-Cooled Chiller	17.5%	6.8%	15.3%	0.2%	3.4%	22.9%	48.3%	37.7%	76.8%	35.5%	9.6%	4.0%	32.2%
Water-Cooled Chiller	60.8%	3.4%	30.9%	0.8%	1.8%	0.0%	0.7%	19.8%	6.1%	54.9%	14.2%	0.0%	6.1%
RTU	6.1%	26.4%	14.8%	12.7%	19.7%	39.9%	5.4%	13.7%	0.0%	2.0%	7.6%	15.5%	11.2%
Central AC	0.0%	17.9%	3.4%	13.1%	17.6%	7.4%	8.1%	10.4%	2.6%	0.0%	5.5%	10.1%	3.9%
Packaged Terminal AC	0.7%	2.7%	4.5%	3.2%	1.6%	6.3%	15.5%	6.4%	0.8%	0.0%	9.3%	14.5%	6.0%
Room AC	0.1%	24.4%	0.5%	28.5%	14.0%	0.7%	1.7%	0.7%	0.1%	0.0%	9.3%	1.6%	6.0%
Oahu, Hawaii, Maui County Total	**85.1%**	**81.7%**	**69.4%**	**58.5%**	**58.1%**	**77.2%**	**79.7%**	**88.7%**	**86.4%**	**92.3%**	**55.5%**	**45.7%**	**65.3%**
Kauai	**Large Office**	**Small Office**	**Large Retail**	**Small Retail**	**Rest-aurant**	**Gro-cery**	**Educa-tion**	**Health-care**	**Lodging**	**Large Resort**	**Multi-family**	**Ware-house**	**Miscel-laneous**
Air-Cooled Chiller	1.0%	0.0%	0.0%	0.2%	0.0%	0.0%	1.0%	33.0%	0.0%	17.0%	0.0%	0.0%	0.0%
Water-Cooled Chiller	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	17.0%	0.0%	17.0%	0.0%	0.0%	6.1%
RTU	49.0%	20.0%	30.0%	12.7%	19.7%	39.9%	7.0%	13.7%	15.0%	7.0%	30.0%	15.5%	18.0%
Central AC	15.0%	15.0%	10.0%	10.0%	17.6%	7.4%	8.1%	10.4%	2.6%	0.0%	5.5%	10.1%	3.9%
Packaged Terminal AC	3.0%	1.0%	6.0%	3.2%	0.0%	6.3%	15.5%	6.4%	0.8%	0.0%	0.0%	14.5%	6.0%
Room AC	0.1%	24.4%	0.5%	20.0%	14.0%	3.0%	16.0%	0.7%	20.0%	0.0%	12.0%	20.0%	15.0%
Kauai Total	**69.1%**	**60.4%**	**46.5%**	**46.1%**	**51.4%**	**56.6%**	**48.6%**	**81.1%**	**38.4%**	**41.0%**	**47.5%**	**60.1%**	**48.9%**

Figure B-6 Commercial Space Cooling Technology Saturation by Location and Market Segment





Lighting

Table B-8 and Figure B-7 provide counts of lamps per 1,000 square feet (sq ft) for commercial sector interior lighting by general technology type, specific lamp type, and market segment. The data are for the State of Hawaii as a whole and were obtained from the nonresidential phone audits described in Chapter 3 and in the 2019 Baseline Study report. The total number of lamps for interior lighting ranges from almost 6 lamps (per 1,000 sq ft) in warehouses to 27 lamps (per 1,000 sq ft) in lodging. For all market segments except lodging, large resort, and multifamily, the most prevalent type of lighting technology is the linear lighting category, with an average of 4 to 14 lamps (per 1,000 sq ft) depending on market segment. Within the linear lighting category, linear LEDs account for a notable share in some market segments, ranging from a low of 15% of linear lighting in the large resort segment to a high of 70% in the miscellaneous segment. The next most common lighting technology for most market segments is general service lighting (it is the most common technology for lodging, large resort, and multifamily). Within the general service lighting category, LEDs account for a relatively small portion of lamps in some segments (e.g., 8% in the grocery segment) and a very high share in other segments (82% in large retail). Exempted lighting and high-bay lighting technologies represent relatively small shares of the lighting in most commercial buildings. Overall, LEDs account for between 24% (large office) and 68% (large retail) of the total number of interior lamps across all lighting technologies.

Table B-9 and Figure B-8 provide counts of lamps (per 1,000 sq ft) for commercial sector exterior lighting by general technology type, specific lamp type, and market segment. The total number of lamps for exterior lighting ranges from almost 2 lamps (per 1,000 sq ft) in healthcare to 6 lamps (per 1,000 sq ft) in grocery stores. For large offices, education, healthcare, and warehouses, linear lighting accounts for the largest number of exterior lamps; for the remaining market segments, general service lighting accounts for the largest share. In all segments, there is less than one lamp (per 1,000 sq ft) on average for exterior area lighting. Overall, LEDs account for between 22% (large office) and 60% (lodging) of the total number of exterior lamps across all lighting technologies.

Table B-8 Commercial Interior Lighting: Counts of Lamps (per 1,000 sq ft) by Technology and Market Segment

Technology	Lamp Type	Large Office	Small Office	Large Retail	Small Retail	Rest-aurant	Gro-cery	Edu-cation	Health-care	Lodg-ing	Large Resort	Multi-family	Ware-house	Miscel-laneous
General Service Lighting	Incandescent	0.07	0.27	0.13	0.55	0.91	1.10	0.05	1.11	0.41	1.08	1.02	0.13	0.39
	90W Halogen PAR-38	0.45	0.18	0.15	0.68	0.72	0.04	0.03	0.13	0.05	2.31	0.32	0.09	0.25
	CFL	2.37	0.43	1.30	2.58	0.97	0.35	0.89	0.57	2.59	2.68	7.72	0.45	1.11
	LED	0.63	2.10	7.41	3.20	3.98	0.13	0.30	1.50	12.96	4.20	6.18	0.29	1.61
	Subtotal	***3.52***	***2.98***	***9.00***	***7.02***	***6.58***	***1.63***	***1.27***	***3.31***	***16.02***	***10.27***	***15.23***	***0.96***	***3.36***
Exempted Lighting	Incandescent	0.11	0.40	0.20	0.83	1.37	1.66	0.07	1.67	0.62	1.62	1.53	0.20	0.59
	90W Halogen PAR-38	0.11	0.04	0.04	0.17	0.18	0.01	0.01	0.03	0.01	0.58	0.08	0.02	0.06
	CFL	0.26	0.05	0.14	0.29	0.11	0.04	0.10	0.06	0.29	0.30	0.86	0.05	0.12
	LED	0.07	0.23	0.82	0.36	0.44	0.01	0.03	0.17	1.44	0.47	0.69	0.03	0.18
	Subtotal	***0.55***	***0.73***	***1.21***	***1.64***	***2.10***	***1.72***	***0.21***	***1.93***	***2.36***	***2.96***	***3.15***	***0.30***	***0.95***
High-Bay Lighting	Metal Halides	0.01	0.02	0.28	0.14	0.11	0.13	0.06	0.00	0.08	0.10	0.03	0.00	0.17
	High Pressure Sodium	0.00	0.02	0.02	0.01	-	-	0.01	0.01	-	-	-	0.00	0.06
	T5	0.06	0.07	0.05	0.06	0.05	0.06	0.05	0.03	0.06	0.07	0.06	0.16	0.02
	T8	0.25	0.14	0.16	0.12	0.07	0.25	0.22	0.04	0.11	0.16	0.09	0.51	0.09
	LED	0.09	0.24	0.12	0.20	0.44	0.05	0.80	0.19	0.11	0.03	0.16	0.10	0.28
	Subtotal	***0.40***	***0.49***	***0.62***	***0.53***	***0.68***	***0.49***	***1.15***	***0.27***	***0.35***	***0.37***	***0.33***	***0.77***	***0.64***
Linear Lighting	T12	2.53	3.45	1.53	3.07	2.69	2.23	3.30	2.01	2.09	-	1.55	0.98	1.57
	T8	4.68	2.68	3.02	2.29	1.34	4.69	4.19	0.76	2.01	3.02	1.65	0.51	1.74
	Super T8	2.04	0.17	-	0.29	0.21	0.41	0.25	0.20	0.57	0.66	0.01	0.19	0.09
	T5	1.05	1.30	0.93	1.09	0.97	1.11	1.02	0.56	1.16	1.38	1.05	0.16	0.47
	LED	3.72	4.31	8.59	5.19	3.01	4.90	3.23	5.40	2.62	0.90	4.20	1.87	9.04
	Subtotal	***14.03***	***11.91***	***14.07***	***11.94***	***8.22***	***13.34***	***11.99***	***8.94***	***8.45***	***5.97***	***8.47***	***3.71***	***12.92***
Total Interior Lamps (per 1,000 sq ft)		**18.50**	**16.11**	**24.90**	**21.12**	**17.58**	**17.18**	**14.61**	**14.44**	**27.17**	**19.57**	**27.17**	**5.74**	**17.87**

Figure B-7 Commercial Interior Lighting: Counts of Lamps (per 1,000 sq ft) by Technology and Market Segment

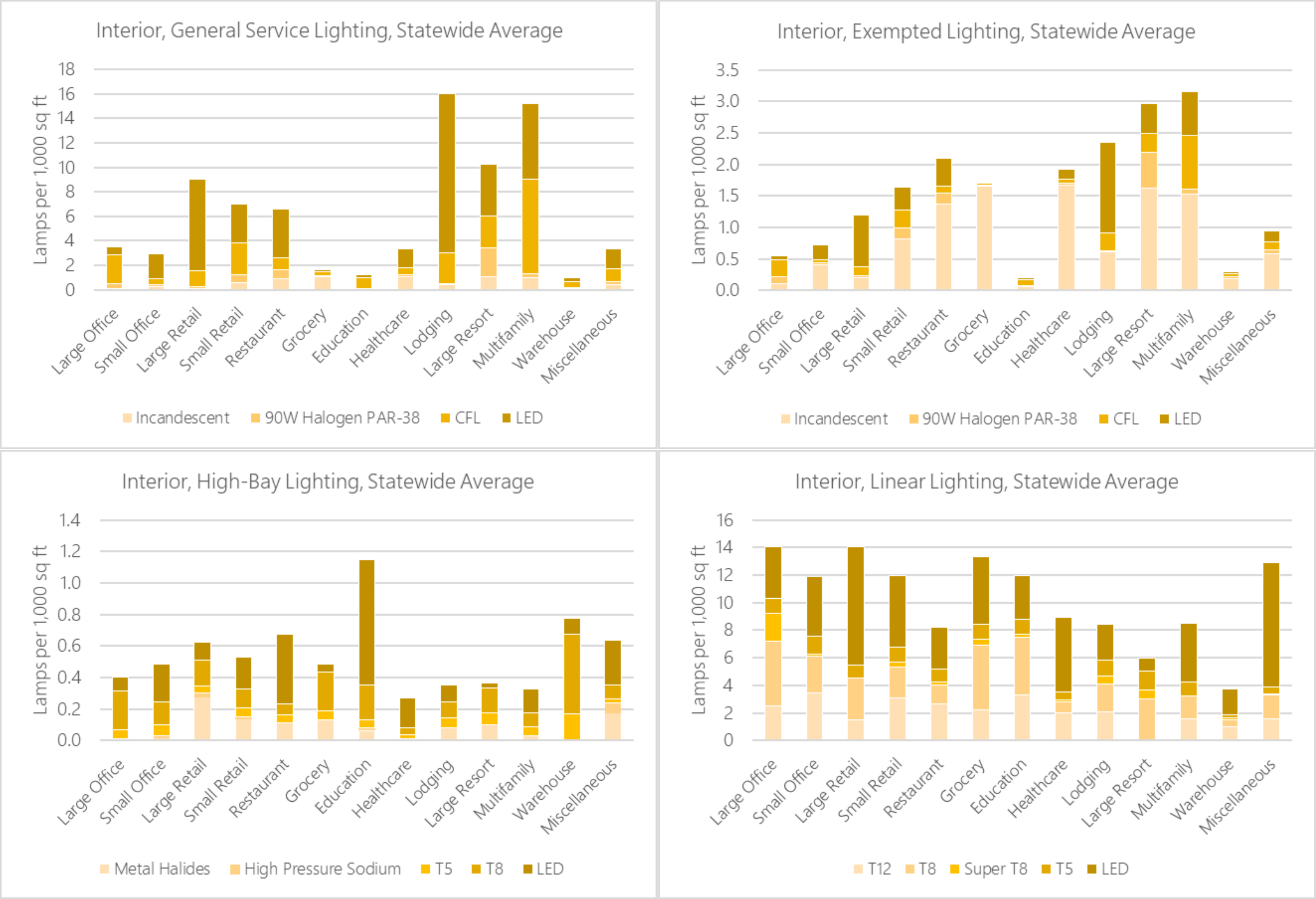
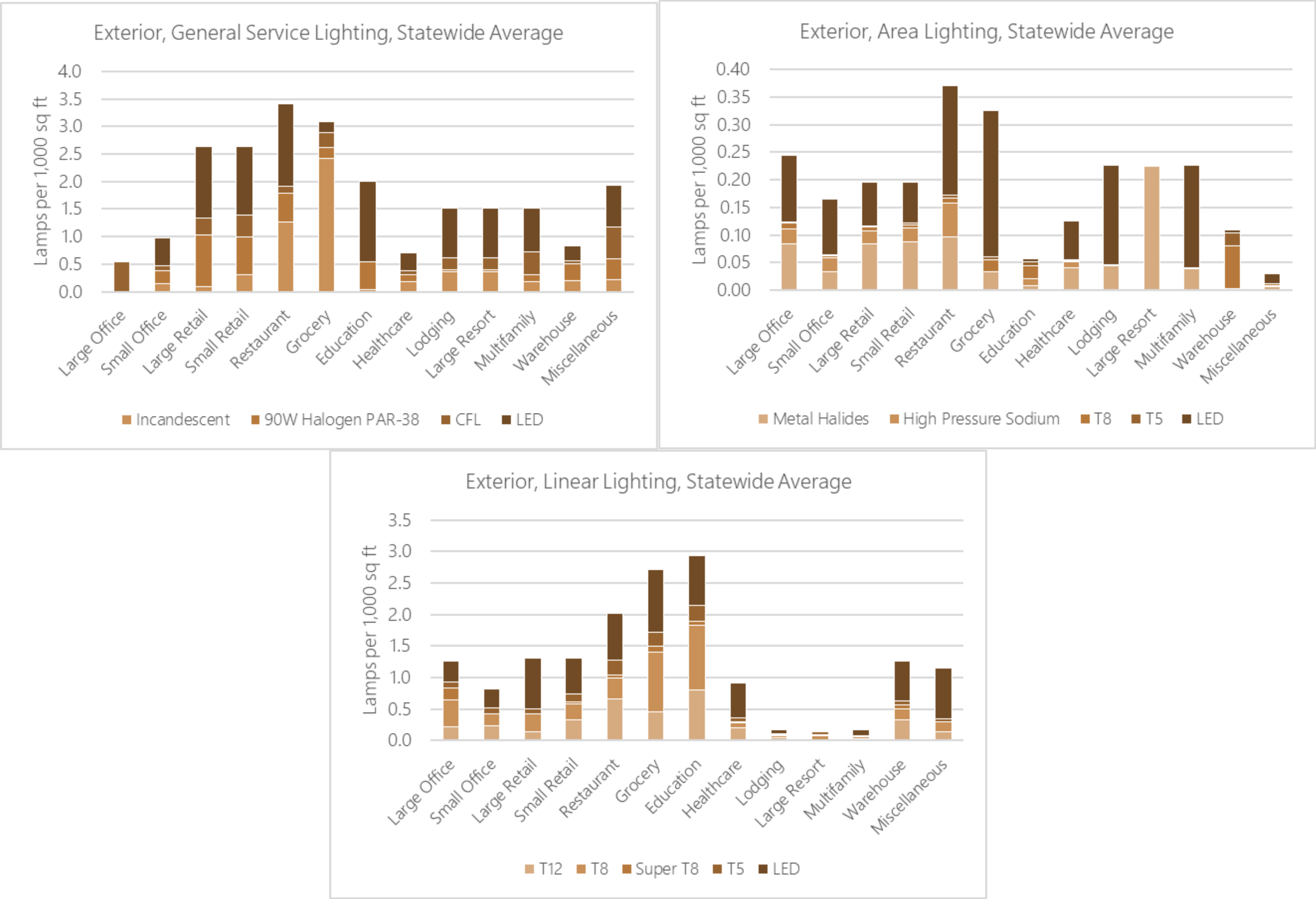


Table B-9 Commercial Exterior Lighting: Counts of Lamps (per 1,000 sq ft) by Technology and Market Segment

Technology	Lamp Type	Large Office	Small Office	Large Retail	Small Retail	Restaurant	Grocery	Education	Healthcare	Lodging	Large Resort	Multifamily	Warehouse	Miscellaneous
General Service Lighting	Incandescent	-	0.14	0.09	0.30	1.27	2.43	0.03	0.18	0.36	0.36	0.19	0.20	0.21
	90W Halogen PAR-38	-	0.23	0.94	0.69	0.52	0.20	0.51	0.12	0.03	0.03	0.11	0.30	0.39
	CFL	0.54	0.10	0.31	0.40	0.13	0.26	0.01	0.07	0.22	0.22	0.41	0.06	0.58
	LED	-	0.50	1.28	1.23	1.51	0.20	1.46	0.32	0.91	0.91	0.80	0.28	0.75
	Subtotal	***0.54***	***0.97***	***2.63***	***2.63***	***3.42***	***3.08***	***2.01***	***0.70***	***1.51***	***1.51***	***1.51***	***0.83***	***1.93***
Area Lighting	Metal Halides	0.08	0.03	0.08	0.09	0.10	0.03	0.01	0.04	0.04	0.23	0.04	0.00	0.01
	High Pressure Sodium	0.03	0.02	0.02	0.03	0.06	-	0.01	0.01	-	-	-	0.00	0.00
	T8	0.01	0.00	0.01	0.01	0.01	0.02	0.02	0.00	0.00	0.00	0.00	0.08	0.00
	T5	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.00
	LED	0.12	0.10	0.08	0.07	0.20	0.27	0.01	0.07	0.18	-	0.19	0.01	0.02
	Subtotal	***0.24***	***0.17***	***0.20***	***0.20***	***0.37***	***0.33***	***0.06***	***0.13***	***0.23***	***0.23***	***0.23***	***0.11***	***0.03***
Linear Lighting	T12	0.23	0.24	0.14	0.34	0.66	0.45	0.81	0.20	0.04	-	0.03	0.33	0.14
	T8	0.42	0.18	0.28	0.25	0.33	0.96	1.02	0.08	0.04	0.08	0.03	0.17	0.16
	Super T8	0.18	0.01	-	0.03	0.05	0.08	0.06	0.02	0.01	0.02	0.00	0.06	0.01
	T5	0.09	0.09	0.09	0.12	0.24	0.23	0.25	0.06	0.02	0.04	0.02	0.06	0.04
	LED	0.33	0.29	0.80	0.57	0.74	1.00	0.79	0.55	0.05	0.02	0.08	0.64	0.81
	Subtotal	***1.26***	***0.81***	***1.31***	***1.31***	***2.02***	***2.72***	***2.94***	***0.91***	***0.17***	***0.16***	***0.17***	***1.26***	***1.16***
Total Exterior Lamps (per 1,000 sq ft)		**2.04**	**1.95**	**4.13**	**4.13**	**5.81**	**6.12**	**5.00**	**1.73**	**1.91**	**1.90**	**1.91**	**2.20**	**3.11**

Figure B-8 Commercial Exterior Lighting: Counts of Lamps (per 1,000 sq ft) by Technology and Market Segment



C

MEASURE LIST

The Excel file, Appendix C Hawaii 2020 MPS EE Measure List.xlsx identifies all the measures that were included in this study.

Appendix C Hawaii
2020 MPS EE Measur

D

ADVANCED RATE DESIGNS PRESENTATION

Presentation on Estimating the Potential Impact of Advanced Rate Designs in Hawaii.

HI Advanced Rate Design.pdf

E

SUPPLEMENTAL HOURLY RESULTS

The subsections below provide additional results from the hourly impact analysis.

Impacts for DR/GS: High Acceptability

By Grid Service Type

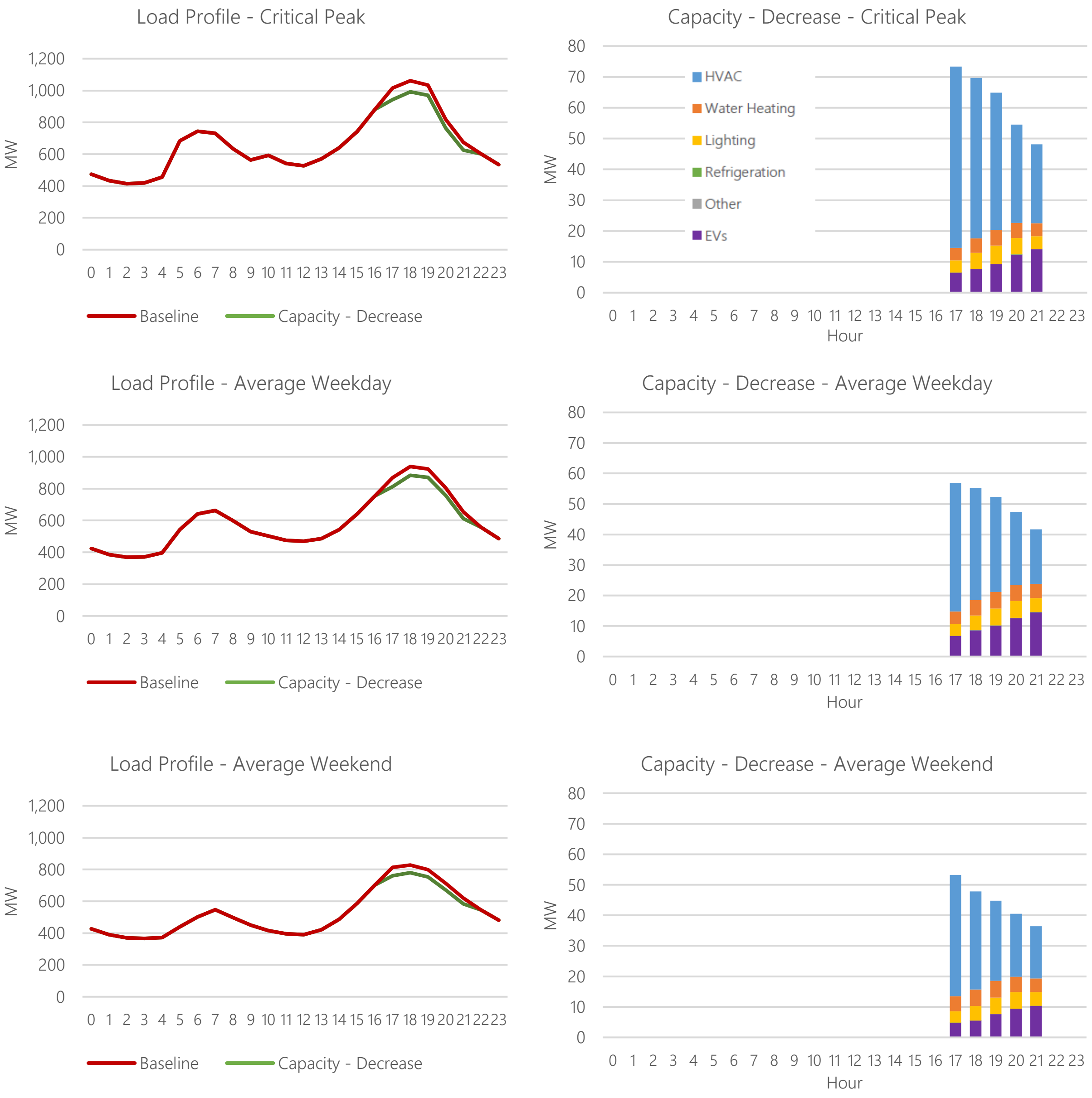
Figure E-1 shows examples of hourly impacts for each of the five types of services. These impacts represent the technical achievable potential in 2030 on a critical peak day for the island of Oahu using the high acceptability scenario (20%). The results are for the residential and commercial sectors combined.

Figure E-1 Hourly DR/GS Impacts on Critical Peak Day: Oahu, All Sectors, Technical Achievable, 2030, High Acceptability

Capacity - Decrease

Figure E-2 shows example load profiles and impact shapes for the Capacity - Decrease scenario by day-type (critical peak day, average weekday, and average weekend). The data represents results for Oahu in 2030 under the high acceptability scenario (20%) and for the residential and commercial sectors combined.

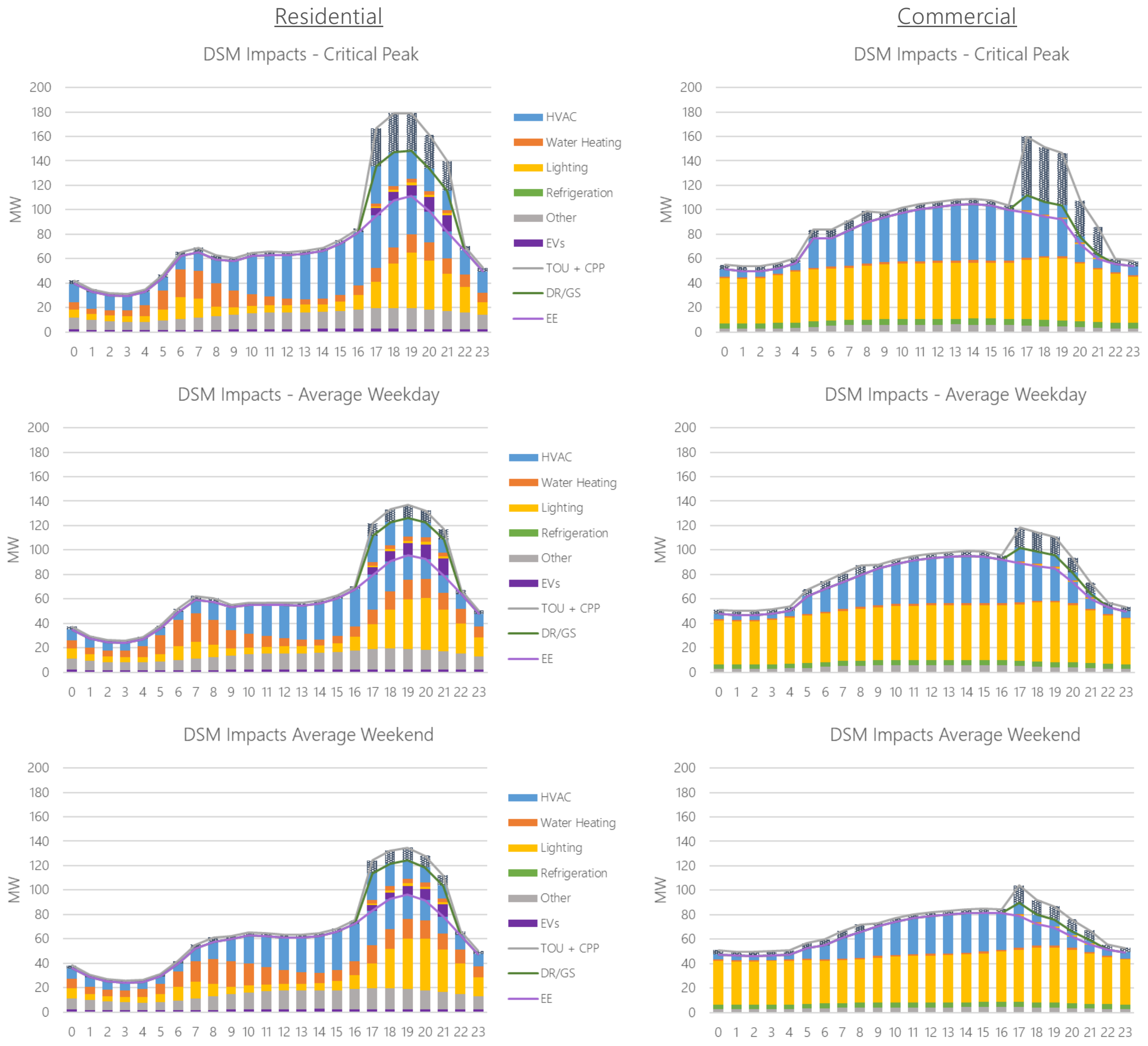
Figure E-2 Hourly Capacity-Decrease Impacts by Day-Type: Oahu, All Sectors, Technical Achievable, 2030, High Acceptability



Integrated DSM Impacts: High Acceptability for DR/GS

Figure E-3 presents the stacked results for Oahu in 2030 by sector and day-type. The DR/GS option shown in the figure is Capacity - Decrease. The EE impacts reflect the achievable - high potential, while the Capacity - Decrease impacts reflect the technical achievable potential for the high acceptability scenario (20%).

Figure E-3 Hourly Stacked Impacts (EE, Capacity-Decrease, and Opt-Out TOU+CPP) by Day-Type and Sector: Oahu, 2030, High Acceptability



Detailed Island Level Results

Table E-1 through Table E-4 show the average MW (aMW) impacts by time period and island in 2030.[49] Unstacked and stacked results are presented for both acceptability scenarios (low and high). The data represent the combined impacts from the residential and commercial sectors. The impacts are relative to the hourly baseline *consumption* forecast in 2030. To estimate the average impacts, AEG averaged the hourly impacts for each hour in a given time period across the year (e.g., average impact over the 5-hour peak period for the 10 critical days).

Unstacked DSM Impacts: Low Acceptability for DR/GS

Table E-1 Average Impacts by DSM Class, Time Period, and Island: All Sectors, 2030, Unstacked, Low Acceptability

Island	Baseline Load (aMW)	Impacts (aMW)						
		Achievable - High	TOU + CPP	Capacity - Decrease	Capacity - Increase	Non-Spin Auto Response	Fast Frequency Response	Regulation Reserves
Critical Peak								
Oahu	934.0	182.4	82.4	38.0	0.0	14.4	24.0	15.1
Hawaii	187.3	39.3	16.4	5.6	0.0	1.2	2.5	0.5
Maui	179.4	36.8	15.7	7.1	0.0	2.2	4.3	2.2
Molokai	5.1	1.0	0.4	0.2	0.0	0.1	0.1	0.1
Lanai	4.4	0.9	0.4	0.1	0.0	0.0	0.1	0.0
Kauai	70.7	12.8	6.2	1.9	0.0	0.6	1.2	0.4
Military	155.3	16.9	14.3	0.0	0.0	0.0	0.0	0.0
On-Peak								
Oahu	829.0	163.4	28.3	30.3	0.0	13.5	23.7	14.5
Hawaii	168.0	35.2	5.7	4.4	0.0	1.1	2.4	0.5
Maui	161.5	33.0	5.5	5.8	0.0	2.1	4.1	2.1
Molokai	4.5	0.9	0.2	0.1	0.0	0.1	0.1	0.1
Lanai	4.0	0.8	0.1	0.1	0.0	0.0	0.1	0.0
Kauai	63.5	11.4	2.2	1.5	0.0	0.6	1.1	0.4
Military	139.2	15.1	5.0	0.0	0.0	0.0	0.0	0.0
Midday								
Oahu	886.5	147.4	6.9	0.0	-17.6	8.7	13.9	6.1
Hawaii	165.3	27.5	1.3	0.0	-2.8	1.1	1.9	0.4
Maui	163.9	27.9	1.3	0.0	-3.1	1.4	2.5	0.9
Molokai	4.3	0.6	0.0	0.0	-0.1	0.0	0.1	0.0
Lanai	4.3	0.7	0.0	0.0	-0.1	0.0	0.1	0.0
Kauai	62.0	8.7	0.5	0.0	-0.9	0.4	0.8	0.2
Military	173.8	17.1	1.3	0.0	0.0	0.0	0.0	0.0
Off-Peak								
Oahu	506.5	96.3	8.5	0.0	0.0	11.3	19.3	12.4
Hawaii	93.9	18.8	1.6	0.0	0.0	0.8	1.8	0.4
Maui	94.0	18.4	1.6	0.0	0.0	1.8	3.3	1.8
Molokai	2.6	0.5	0.0	0.0	0.0	0.0	0.1	0.0
Lanai	2.2	0.4	0.0	0.0	0.0	0.0	0.1	0.0
Kauai	39.8	6.5	0.7	0.0	0.0	0.5	0.9	0.3
Military	97.9	10.7	1.8	0.0	0.0	0.0	0.0	0.0

---

[49] Impact estimates are provided for each island and the military separately; however, Oahu and Military were modeled together when estimating peak.

Stacked DSM Impacts: Low Acceptability for DR/GS

Table E-2 Average Impacts by DSM Class, Time Period, and Island: All Sectors, 2030, Stacked, Low Acceptability

Island	Baseline Load (aMW)	Impacts (aMW)						
		Achievable - High	TOU + CPP	Capacity - Decrease	Capacity - Increase	Non-Spin Auto Response	Fast Frequency Response	Regulation Reserves
Critical Peak								
Oahu	934.0	182.4	66.4	29.6	0.0	12.4	20.3	13.7
Hawaii	187.3	39.3	13.0	4.1	0.0	0.9	1.8	0.4
Maui	179.4	36.8	12.5	5.4	0.0	1.9	3.4	1.9
Molokai	5.1	1.0	0.4	0.1	0.0	0.1	0.1	0.1
Lanai	4.4	0.9	0.3	0.1	0.0	0.0	0.1	0.0
Kauai	70.7	12.8	5.1	1.4	0.0	0.5	1.0	0.4
Military	155.3	16.9	12.8	0.0	0.0	0.0	0.0	0.0
On-Peak								
Oahu	829.0	163.4	22.7	24.8	0.0	11.9	20.4	13.3
Hawaii	168.0	35.2	4.5	3.4	0.0	0.9	1.8	0.4
Maui	161.5	33.0	4.4	4.6	0.0	1.8	3.4	1.9
Molokai	4.5	0.9	0.1	0.1	0.0	0.0	0.1	0.0
Lanai	4.0	0.8	0.1	0.1	0.0	0.0	0.1	0.0
Kauai	63.5	11.4	1.8	1.2	0.0	0.5	0.9	0.4
Military	139.2	15.1	4.4	0.0	0.0	0.0	0.0	0.0
Midday								
Oahu	886.5	147.4	5.7	0.0	-14.6	7.5	11.8	5.5
Hawaii	165.3	27.5	1.1	0.0	-2.3	0.9	1.6	0.3
Maui	163.9	27.9	1.1	0.0	-2.6	1.2	2.1	0.8
Molokai	4.3	0.6	0.0	0.0	-0.1	0.0	0.1	0.0
Lanai	4.3	0.7	0.0	0.0	-0.1	0.0	0.0	0.0
Kauai	62.0	8.7	0.4	0.0	-0.8	0.4	0.7	0.2
Military	173.8	17.1	1.1	0.0	0.0	0.0	0.0	0.0
Off-Peak								
Oahu	506.5	96.3	6.9	0.0	0.0	9.9	16.8	11.4
Hawaii	93.9	18.8	1.2	0.0	0.0	0.7	1.4	0.3
Maui	94.0	18.4	1.2	0.0	0.0	1.5	2.8	1.6
Molokai	2.6	0.5	0.0	0.0	0.0	0.0	0.1	0.0
Lanai	2.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Kauai	39.8	6.5	0.6	0.0	0.0	0.4	0.7	0.3
Military	97.9	10.7	1.6	0.0	0.0	0.0	0.0	0.0

Unstacked DSM Impacts: High Acceptability for DR/GS

Table E-3 Average Impacts by DSM Class, Time Period, and Island: All Sectors, 2030, Unstacked, High Acceptability

Island	Baseline Load (aMW)	Impacts (aMW)						
		Achievable - High	TOU + CPP	Capacity - Decrease	Capacity - Increase	Non-Spin Auto Response	Fast Frequency Response	Regulation Reserves
Critical Peak								
Oahu	934.0	182.4	82.4	62.1	0.0	16.9	24.0	21.8
Hawaii	187.3	39.3	16.4	10.9	0.0	1.6	2.5	1.7
Maui	179.4	36.8	15.7	12.1	0.0	2.6	4.3	3.2
Molokai	5.1	1.0	0.4	0.3	0.0	0.1	0.1	0.1
Lanai	4.4	0.9	0.4	0.2	0.0	0.1	0.1	0.1
Kauai	70.7	12.8	6.2	3.4	0.0	0.8	1.2	0.9
Military	155.3	16.9	14.3	0.0	0.0	0.0	0.0	0.0
On-Peak								
Oahu	829.0	163.4	28.3	48.8	0.0	15.6	23.7	20.3
Hawaii	168.0	35.2	5.7	8.8	0.0	1.5	2.4	1.5
Maui	161.5	33.0	5.5	9.8	0.0	2.5	4.1	3.1
Molokai	4.5	0.9	0.2	0.2	0.0	0.1	0.1	0.1
Lanai	4.0	0.8	0.1	0.2	0.0	0.0	0.1	0.1
Kauai	63.5	11.4	2.2	2.8	0.0	0.7	1.1	0.8
Military	139.2	15.1	5.0	0.0	0.0	0.0	0.0	0.0
Midday								
Oahu	886.5	147.4	6.9	0.0	-24.4	13.9	13.9	15.4
Hawaii	165.3	27.5	1.3	0.0	-4.0	2.0	1.9	2.0
Maui	163.9	27.9	1.3	0.0	-4.5	2.3	2.5	2.5
Molokai	4.3	0.6	0.0	0.0	-0.1	0.1	0.1	0.1
Lanai	4.3	0.7	0.0	0.0	-0.1	0.1	0.1	0.1
Kauai	62.0	8.7	0.5	0.0	-1.2	0.7	0.8	0.8
Military	173.8	17.1	1.3	0.0	0.0	0.0	0.0	0.0
Off-Peak								
Oahu	506.5	96.3	8.5	0.0	0.0	12.0	19.3	15.5
Hawaii	93.9	18.8	1.6	0.0	0.0	0.9	1.8	0.9
Maui	94.0	18.4	1.6	0.0	0.0	1.9	3.3	2.3
Molokai	2.6	0.5	0.0	0.0	0.0	0.0	0.1	0.1
Lanai	2.2	0.4	0.0	0.0	0.0	0.0	0.1	0.0
Kauai	39.8	6.5	0.7	0.0	0.0	0.5	0.9	0.5
Military	97.9	10.7	1.8	0.0	0.0	0.0	0.0	0.0

Stacked DSM Impacts: High Acceptability for DR/GS

Table E-4 Average Impacts by DSM Class, Time Period, and Island: All Sectors, 2030, Stacked, High Acceptability

Island	Baseline Load (aMW)	Impacts (aMW)						
		Achievable - High	TOU + CPP	Capacity - Decrease	Capacity - Increase	Non-Spin Auto Response	Fast Frequency Response	Regulation Reserves
Critical Peak								
Oahu	934.0	182.4	66.4	46.5	0.0	14.4	20.3	18.9
Hawaii	187.3	39.3	13.0	7.7	0.0	1.3	1.8	1.3
Maui	179.4	36.8	12.5	8.9	0.0	2.2	3.4	2.7
Molokai	5.1	1.0	0.4	0.2	0.0	0.1	0.1	0.1
Lanai	4.4	0.9	0.3	0.2	0.0	0.0	0.1	0.0
Kauai	70.7	12.8	5.1	2.4	0.0	0.6	1.0	0.7
Military	155.3	16.9	12.8	0.0	0.0	0.0	0.0	0.0
On-Peak								
Oahu	829.0	163.4	22.7	38.4	0.0	13.6	20.4	18.0
Hawaii	168.0	35.2	4.5	6.5	0.0	1.2	1.8	1.2
Maui	161.5	33.0	4.4	7.6	0.0	2.1	3.4	2.7
Molokai	4.5	0.9	0.1	0.2	0.0	0.1	0.1	0.1
Lanai	4.0	0.8	0.1	0.1	0.0	0.0	0.1	0.0
Kauai	63.5	11.4	1.8	2.1	0.0	0.6	0.9	0.7
Military	139.2	15.1	4.4	0.0	0.0	0.0	0.0	0.0
Midday								
Oahu	886.5	147.4	5.7	0.0	-19.7	12.0	11.8	13.5
Hawaii	165.3	27.5	1.1	0.0	-3.2	1.7	1.6	1.7
Maui	163.9	27.9	1.1	0.0	-3.6	1.9	2.1	2.1
Molokai	4.3	0.6	0.0	0.0	-0.1	0.1	0.1	0.1
Lanai	4.3	0.7	0.0	0.0	-0.1	0.1	0.0	0.1
Kauai	62.0	8.7	0.4	0.0	-1.0	0.6	0.7	0.7
Military	173.8	17.1	1.1	0.0	0.0	0.0	0.0	0.0
Off-Peak								
Oahu	506.5	96.3	6.9	0.0	0.0	10.5	16.8	13.9
Hawaii	93.9	18.8	1.2	0.0	0.0	0.8	1.4	0.7
Maui	94.0	18.4	1.2	0.0	0.0	1.6	2.8	2.0
Molokai	2.6	0.5	0.0	0.0	0.0	0.0	0.1	0.1
Lanai	2.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Kauai	39.8	6.5	0.6	0.0	0.0	0.4	0.7	0.5
Military	97.9	10.7	1.6	0.0	0.0	0.0	0.0	0.0

Applied Energy Group, Inc.
500 Ygnacio Valley Road, Suite 250
Walnut Creek, CA 94596

P: 510.982.3525