MEMORANDUM

To: Christopher Lau, HECO Team
From: Eli Morris, Ken Walter and Fuong Nguyen, Applied Energy Group (AEG)
Date: November 1, 2021
RE: HECO IGP Supply Curve Inputs

In 2021, Hawaiian Electric Company (HECO) engaged AEG to develop energy efficiency supply curves for inclusion in its 2021 Integrated Grid Plan (IGP) using the results of the Hawaii statewide potential study AEG performed on behalf of the Hawaii Public Utility Commission. The supply curves are designed to allow Hawaiian Electric to consider energy efficiency as a resource on par with supply-side options. In addition to supply curve development, AEG assisted HECO with stakeholder engagement to gather input and buy-in on the methodology and key components of the supply curve development effort.

This memo describes the key aspects of the supply curve development support AEG provided to HECO, including stakeholder engagement, measure bundling methodology, and summary supply curve information.

Stakeholder Engagement

AEG worked with HECO to present information, solicit feedback and respond to questions from stakeholders throughout this the supply curve development process. A summary of stakeholder engagement activities is provided below:

- On September 7th, AEG presented the general supply curve methodology and bundling process to stakeholders during the HECO's IGP stakeholder meeting.
- On September 15th, AEG responded to questions from the Consumer Advocate regarding the Hawaii Statewide Market Potential Study (MPS) used as the basis for the supply curves, clarifying the development of the MPS business-as-usual potential case, achievable high case, and codes and standards in the model.[1] AEG's responses were incorporated into HECO's Reply to Party Comments and Commission Questions that was filed on September 21, 2021, in Docket No. 2018-0165.
    - Following this meeting, draft supply curves were uploaded to the IGP website for stakeholder review and comment.
- On September 23rd, AEG attended the Technical Working Group meeting to provide additional clarity and context regarding the supply curve bundling and definition of incremental potential as it would be applied in the IGP model.
    - AEG provided updated draft supply curves revising the incremental potential to eliminate re-purchases (described later in this document) and including exhibits responsive to stakeholder feedback.
- On October 18th, AEG provided responses to additional Information Requests (IRs) from Commission staff clarifying the definitions of potential used for the supply curves and their relationship to the potential

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[1] Division of Consumer Advocacy's Comments on the August IGP Update filed on September 10, 2021, in Docket No. 2018-0165 at 6.

levels in the Statewide MPS, as well as definitions for the peak period under consideration.[2] AEG noted at this time that the supply curve summary files would be updated to include peak MW impacts and costs in $/MW in addition to the energy-focused (MWh) summary information previously included.

  - Draft supply curves including MW impacts and $/MW were provided to HECO on October 29th, to be uploaded for stakeholder review and comment. Upon review by HECO, the hourly impacts were unitized to be used in conjunction with the cumulative peak impact by bundle and $/MW costs adjusted for cumulative measure impacts to better align with the available modeling input fields in its RESOLVE model.

Documents pertaining to stakeholder engagement and responses can be found here: https://www.hawaiianelectric.com/clean-energy-hawaii/integrated-grid-planning/stakeholder-engagement/key-stakeholder-documents

Energy Efficiency Supply Curve Development Methodology

There are two primary options for incorporating energy efficiency resources into integrated grid planning:

1. Use one of the achievable potential cases form the Statewide Market Potential Study, which has already been screened for cost-effectiveness. The expected amount of cost-effective and achievable potential would be decremented from the load forecast.
2. Perform the economic screening in the IGP, treating energy efficiency as an available resource that can be selected based on its cost and value. This option requires creating a new level of energy efficiency potential, referred to as "achievable technical," which has not been screened for cost-effectiveness.

The advantage of using option 1 is that it is simple to implement in the IGP as a decrement to the load forecast. However, the disadvantage of this option is that it requires a determination of avoided costs prior to running the IGP. Because of this, energy efficiency resource bundles are either in or out in every scenario, so the IGP model is not able to assess how the optimal level of energy efficiency may vary based on changes in other assumptions.

Option 2 allows the IGP to dynamically select cost-effective resources based on more granular cost groupings and competing resources. It also allows different IGP scenarios to select different bundles according to the needs under each scenario. The downside of using this option is that each bundle that competes in the IGP increases the run time of the model, so thought must be given to the optimal number of resource bundles, considering tradeoffs in data granularity and model performance.

Based on HECO's IGP objectives and considering stakeholder input, it was determined that Option 2 was the most appropriate way to consider energy efficiency within the IGP. The remainder of this methodology section describes the process AEG employed to develop supply curves that enable dynamic resource optimization within the IGP while accounting for limitations in the number of resources that could be modeled.

Developing Achievable Technical Potential

Achievable technical potential is a subset of technical potential, accounting for likely customer adoption of energy efficiency measures without consideration of cost-effectiveness. To develop the achievable technical potential for IGP modeling, AEG applied the customer participation rates from the "Future Achievable – High" case form the Statewide MPS, which account for market barriers, customer awareness and attitudes, program maturity, and other factors that may affect market penetration of energy efficiency measures.

Differences from the Hawaii statewide potential study

Figure 1 (also included in the Statewide MPS report) illustrates the levels of potential assessed in the Statewide MPS. Striped layers show impacts that are contained in the baseline forecast and therefore not part of the

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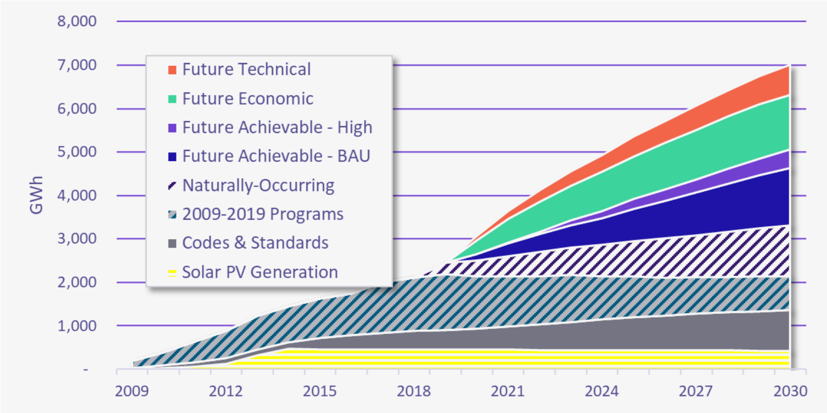
[2] HECO's Response to Commission's Information Requests filed on October 25, 2021, in Docket No. 2018-0165.

energy efficiency supply curves. These categories include naturally occurring efficiency, codes & standards impacts, and the lingering effects of past program achievement.

[3]



Because the achievable technical potential used to develop the IGP supply curves does not consider cost-effectiveness, it is not the same as any of the levels of potential shown in Figure 1. Rather, the amount of available achievable technical potential would fall between the "Future Technical" and "Future Achievable – High" potentials.

Measure Grouping

As discussed above, each resource modeled in the IGP model increases the required runtime. Therefore, it is important to design bundles around meaningful metrics to allow the IGP model to assess the relative cost and value of different levels of energy efficiency without having to consider a large number of distinct resources. Based on discussions with HECO regarding when energy efficiency provides the most value, AEG bundled the measures based on two factors: relative contributions during peak periods and cost-effectiveness (as determined in the Statewide MPS).

Peak Impacts

Each energy efficiency measure has an island-specific load shape, which was created during the potential study process. By taking the annual savings calculated from the potential study and distributing it across this shape, impacts in each hour of the year can be calculated for each measure shape.

For the first level of bundling, AEG considered the relative "peakiness" of each measure by comparing its impacts during HECO's peak hours to a flat shape. This calculation determined which measures would be considered peak-focused and which measures' impacts were mainly in non-peak hours. Where referenced in this document and related workbooks, peak impacts refer to impacts on the **average weekday evening peak hour** (between 6:00 PM and 8:00 PM) and are calculated as the average impacts during such hours.

Figure 2 shows the average impacts of all measures within each classification using Oahu as an example, based on cumulative potential in 2030. As expected, peak-focused measure impacts are strongly concentrated in the weekday evening hours, whereas "other" measure impacts are much flatter.

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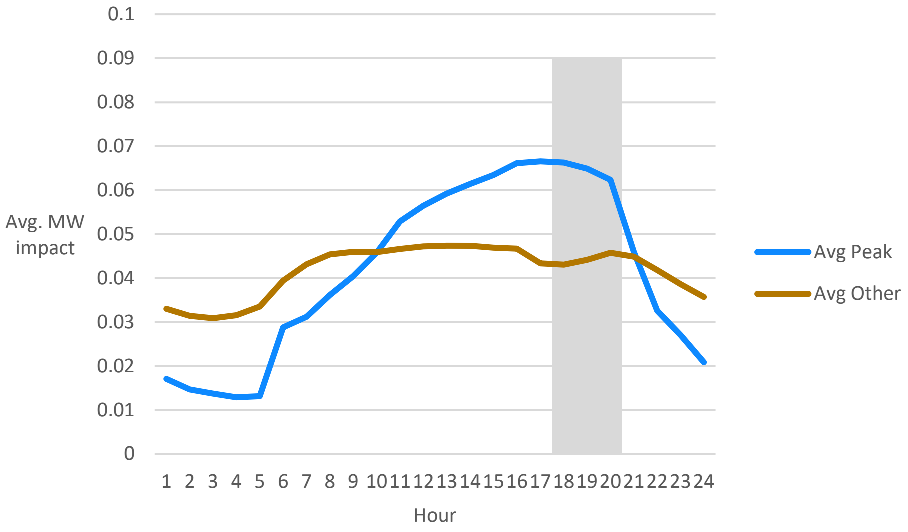
[3] See State of Hawaii Market Potential Study, Executive Summary page iv, Figure ES-3 (https://puc.hawaii.gov/wp-content/uploads/2021/02/Hawaii-2020-Market-Potential-Study-Final-Report.pdf)

Figure 2 Averaged Weekday Impacts by Measure Classification, Cumulative in 2030 (Peak vs Other, Oahu)



Cost-Effectiveness

The next consideration for bundling measures was the cost of savings. Through conversation with HECO, it was decided that although levelized cost of conserved energy ($/MWh), which annualizes costs across each measure's lifetime, is one means of understanding resource costs, grouping solely based on energy saved may not allow the model to efficiently target measures with higher benefits due to contributions to peak. Because the benefit-cost ratios (using the Total Resource Cost test perspective) from the Statewide MPS capture both energy and capacity benefits, these ratios represent a convenient metric for bundling measures considering both cost and value. Table 1 shows the ranges used for bundle classification, which serve to separate measures that are highly cost effective (A) from those which were potentially more sensitive to IGP scenarios (B and C), and finally isolate very non-cost-effective measures (D) to avoid them skewing the overall cost of the more attractive groups.

Table 1 Benefit-Cost Ratio Ranges Assigned to Bundle Groups

Bundle	Benefit-Cost Ratio Range
A	>1.2
B	1.0 - <1.2
C	0.8 - <1.0
D	< 0.8

It is important to note that because peak-focused measures gain extra value in terms of cost-effectiveness, many of the measures in group A could have absolute costs ($/MWh) that are *higher* than measures in group B or C. In those cases, the greater benefit of peak-focused resources offsets the costs in the MPS methodology. Depending on how the shape of bundles meets the IGP model's needs, it might choose lower absolute costs first, which could produce differences between the IGP model selections and the MPS. This flexibility is an expected feature of the chosen methodology.

Bundle Creation

Once all measures were assigned to appropriate bundles based on peakiness and cost-effectiveness, AEG developed supply curves for IGP modeling, described based on their cost, energy and demand impacts, and hourly shape. The process for developing each component is described below.

Bundle Costs

To compete energy efficiency resources against other resources in the IGP, the model is provided a levelized cost of conserved energy (LCOE) for each model based on the measure-level costs from the Statewide MPS, in $ per MWh. This is a Total Resource Cost **net** value which includes not only the installed cost of the measure, but net effects from non-energy impacts, O&M costs or savings, and possible avoided replacement costs, annualized over the life of the measure. Because non-energy impacts are netted out of the cost, it is possible for a measure to have a negative LCOE if the benefits are greater than the cost of the measure.

Each bundle's LCOE is calculated as the savings-weighted average of the LCOEs of the measures within the bundle. As noted above, it is possible for measure LCOEs to be negative, therefore it is possible that a bundle can have a net negative cost if savings within the bundle are dominated by one or more measures with negative LCOEs.

Bundle Energy and Demand Impacts

The energy impacts within each bundle are the sum of the various measures assigned to it. Measure bundling assignments are available in the IGP documentation linked above, and a summary of bundles by end use is provided in the analysis results section below.

The reported peak demand impact of each bundle is similarly the sum of the peak hour impacts of each measure. The potential of various measures that would apply to the same end use in the peak hour is already accounted for in the potential study itself, so no further adjustment is needed to account for overlap of measures.

Bundle Hourly Shapes

Each bundle's hourly shape emerges from summing the constituent measure impacts in each hour of the year. This aggregated hourly shape is what is provided to the IGP.

Analysis Results

Figure 3 below shows the incremental energy savings potential for each bundle over the forecast period. The sharp increase in savings in 2025 coincides with an increase in commercial linear lighting installations, due to equipment turnover in the potential study modeling. Note that these annual savings values do not include re-installation of measures of measures that were previously incentivized and may have expired. While these measures will need to be reacquired in later years, they will not increase the total cumulative potential, so those reacquisition savings are excluded from this perspective to be consistent with the IGP model.

In conversation with stakeholders, AEG acknowledged that there could be marginal additional savings at the time of re-acquisition, such as if technology standards have improved in the intervening years, however such savings would be difficult to quantify directly using the outputs of the Market Potential Study. The modeled potential without re-acquisitions is a conservative estimate, but in discussion with HECO and stakeholders we reached agreement that a conservative estimate was preferable to overstating possible potential for this resource planning process.

Figure 3 Incremental Annual Energy Savings Potential (Achievable Technical) by Measure Bundle (All Islands Combined)

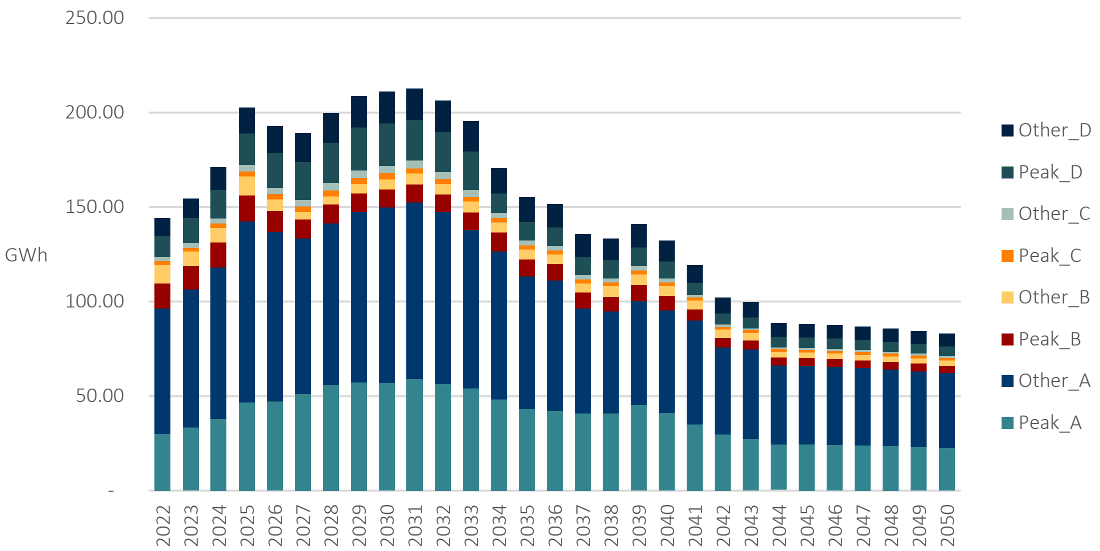


Table 2 and Figure 4 below show the cumulative energy savings by end use for each bundle. The savings here represent the total Achievable Technical Potential in 2045 from the MPS.[4]

The Peak bundles are dominated by the cooling end use. The Peak A bundle, which includes the most cost-effective measures from the potential study, is gets 77% of its savings from the cooling end use. The Other bundles are made up mainly of water heating, lighting, and appliance measures, which tend to have flatter or even morning-focused shapes.

Table 2 Technical Potential Energy Savings (GWh) by Measure Grouping and End Use (All Islands Combined)

	Peak				Other			
End Use	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**
Cooling	17.5	2.3	0.5	2.9	5.3	0.1	0.2	1.2
Ventilation	2.0	0.2	0.3	0.4	2.8	0.1	0.3	0.8
Water Heating	2.1	0.2	0.1	0.2	11.5	2.2	0.0	0.4
Interior Lighting	0.2	1.1	0.1	0.4	11.2	0.0	0.0	0.2
Exterior Lighting	0.1	0.1	0.0	0.0	1.0	0.0	0.0	0.3
Res Appliances	0.1	0.0	0.2	1.0	0.5	0.5	0.1	2.6
Com Refrigeration	0.2	0.0	0.0	0.2	1.9	0.0	0.2	1.0
Electronics	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Food Preparation	0.0	0.0	-	-	0.2	0.0	-	0.0
Miscellaneous	0.2	0.0	0.1	0.0	5.0	0.1	0.2	0.3
Total	**22.7**	**3.9**	**1.3**	**5.2**	**39.4**	**3.0**	**0.9**	**6.7**

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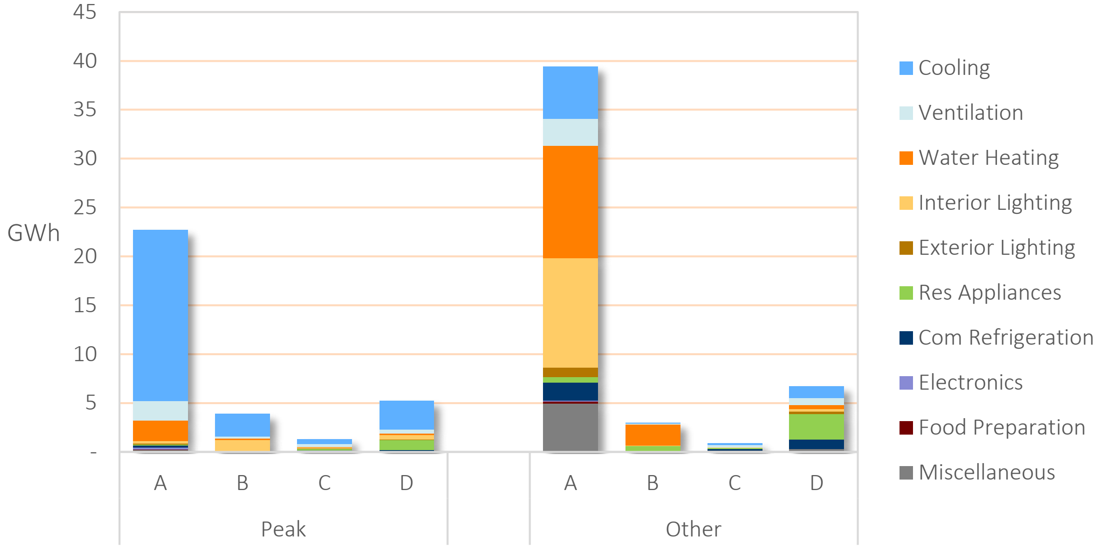
[4] The Statewide MPS study period only ran to 2045. Annual potential from 2046-2050 shown in some charts and provided for the IGP was calculated based on the year-over-year trend from 2040-2045. This is consistent with HECO's methodology for the IGP.

Figure 4 Achievable Technical Energy Savings (GWh) by Measure Grouping and End Use (All Islands Combined)



With this categorization and bundling complete, the hourly impacts for each bundle across the planning horizon and associated levelized costs were provided to HECO for input into the IGP. To further inform the planning process, the peak MW impact of each bundle was also noted (as calculated from the annual energy and load shape) and a value of $/MW was derived by multiplying the levelized cost of energy ($/MWh) by the annual savings (MWh) and dividing by the associated peak savings (MW).

Island Level Summary Results

Oahu Results

Figure 5 *Oahu Annual Energy Savings Potential (Achievable Technical) by Measure Bundle*

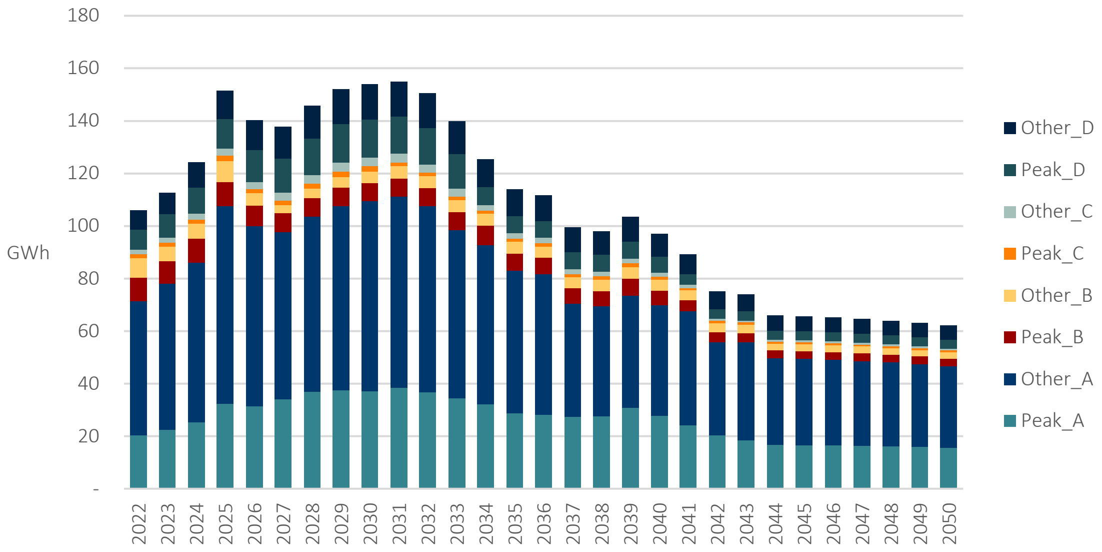
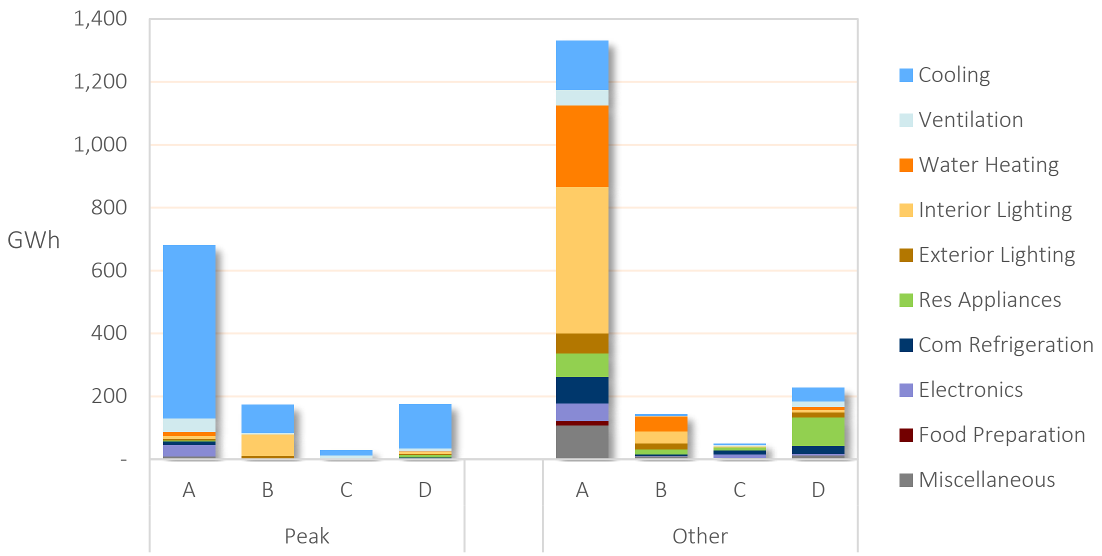


Figure 6 *Oahu Achievable Technical Energy Savings (GWh) by Measure Grouping and End Use*



Maui Results

Figure 7 *Maui Annual Energy Savings Potential (Achievable Technical) by Measure Bundle*

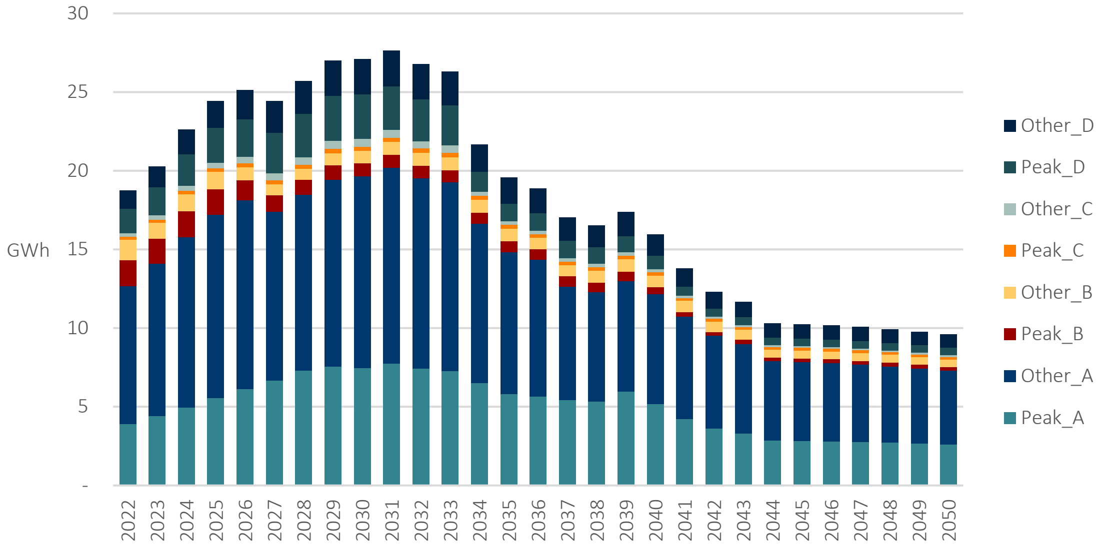
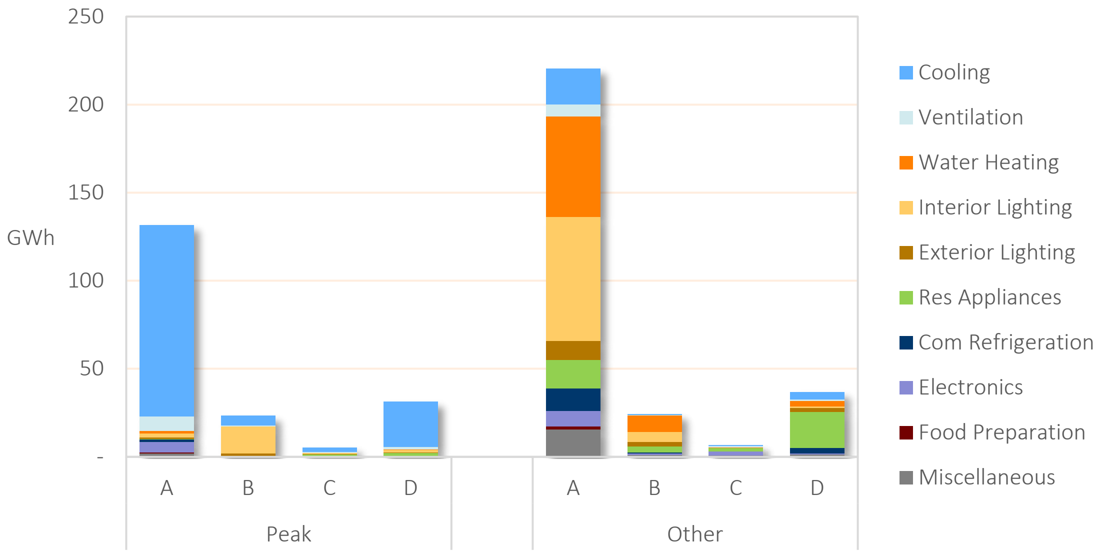


Figure 8 *Maui Achievable Technical Energy Savings (GWh) by Measure Grouping and End Use*



Hawaii Results

Figure 9 *Hawaii Annual Energy Savings Potential (Achievable Technical) by Measure Bundle*

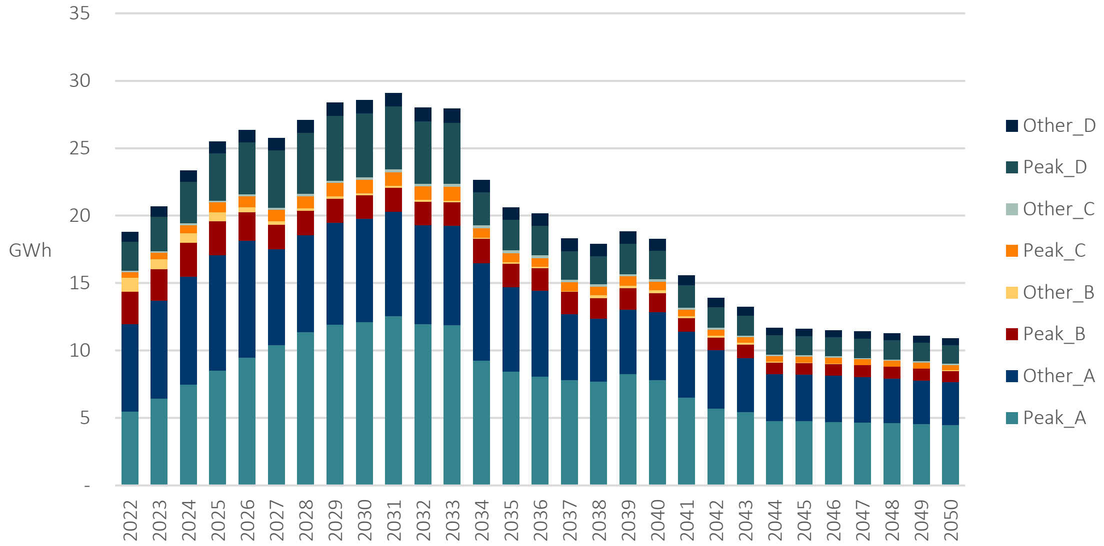
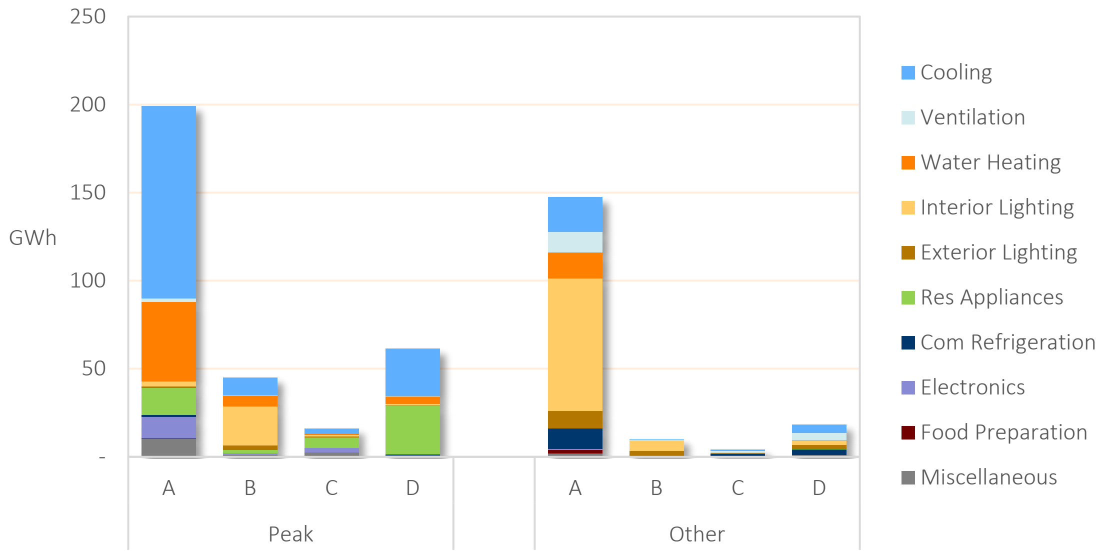


Figure 10 *Hawaii Achievable Technical Energy Savings (GWh) by Measure Grouping and End Use*



Lanai Results

Figure 11 *Lanai Annual Energy Savings Potential (Achievable Technical) by Measure Bundle*

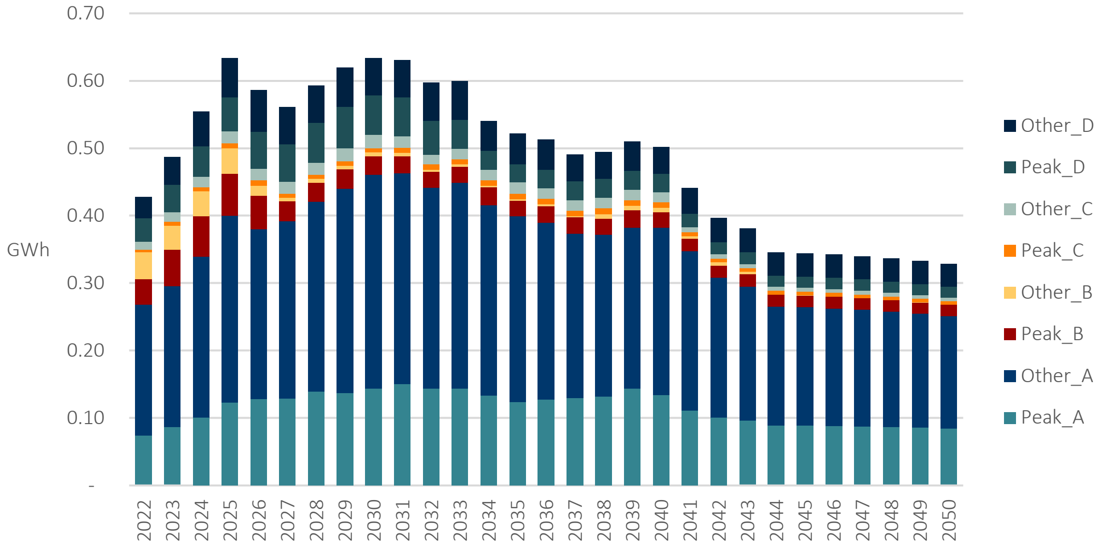
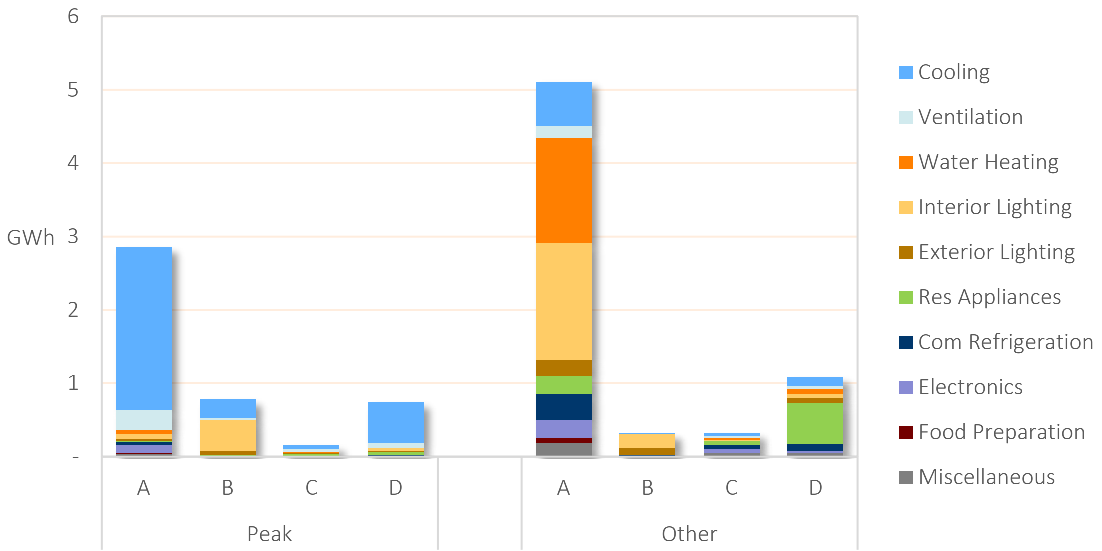


Figure 12 *Lanai Achievable Technical Energy Savings (GWh) by Measure Grouping and End Use*



Molokai Results

Figure 13 *Molokai Annual Energy Savings Potential (Achievable Technical) by Measure Bundle*

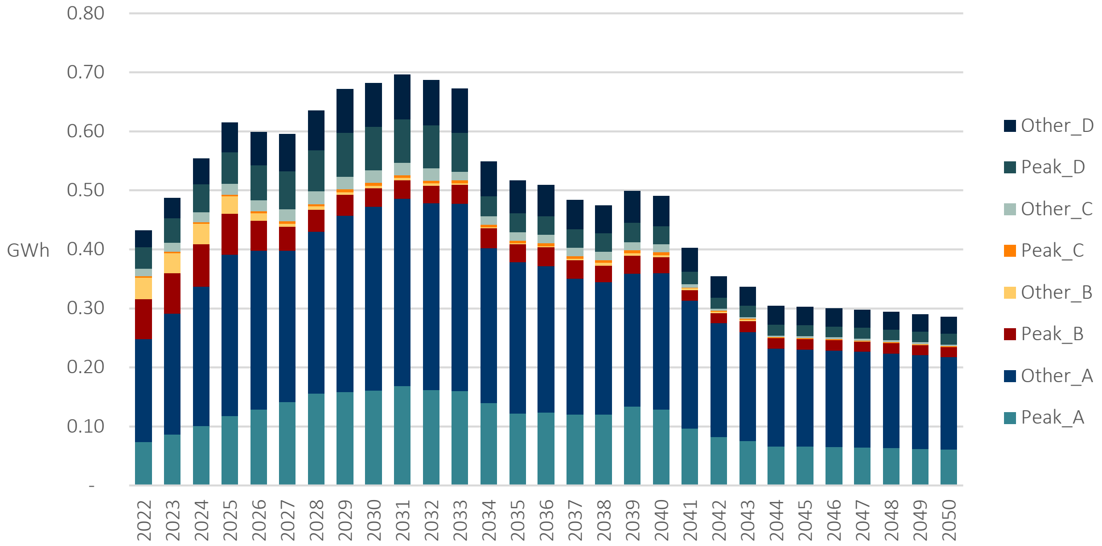


Figure 14 *Molokai Achievable Technical Energy Savings (GWh) by Measure Grouping and End Use*