Hawaiian Electric

Location-Based Distribution Forecasts

November 2021

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1 Introduction

1.1 OVERVIEW

This document describes the development of the location-based circuit level forecasts that will be used as part of the Distribution Planning Process and Integrated Grid Planning ("IGP") process. The Distribution Planning Process as described in the *Distribution Planning Methodology* document[1,2] was developed in collaboration with stakeholder and customer engagement through the Distribution Planning Working Group ("DPWG") and reviewed by the Technical Advisory Panel. The document was developed to identify the steps and tools used by the Company to analyze the distribution system and determine grid needs required to serve load growth and safely interconnect distributed energy resources ("DER") while maintaining power quality and reliability for all customers.

The Distribution Planning Process is comprised of four stages: forecast, analysis, solution options, and evaluation.

1. **Forecast Stage**: Develop circuit-level forecasts based on the corporate demand forecast.
2. **Analysis Stage**: Determine the adequacy of the distribution system.
3. **Solution Options Stage**: Identify the grid needs requirements.
4. **Evaluation Stage**: Evaluation of solutions.

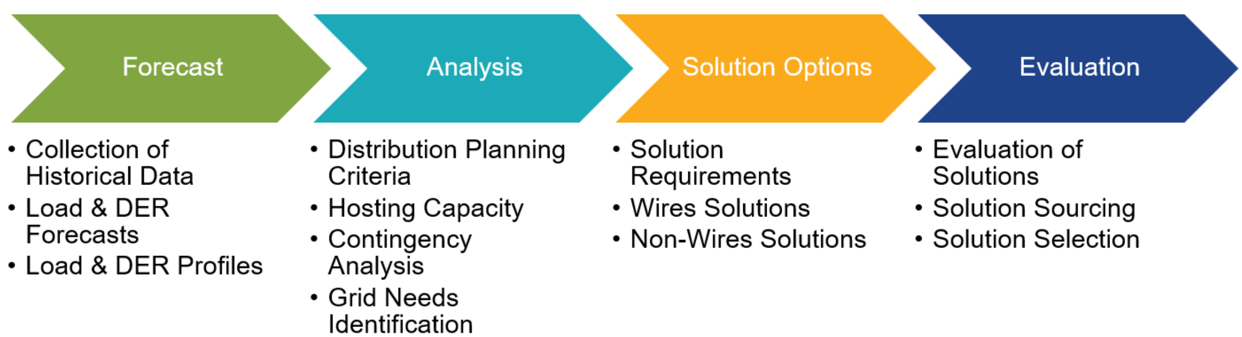

Figure 1: Stages of the Distribution Planning Process

The Distribution Planning Process is incorporated into the IGP process as it uses the corporate forecasts that include planned electrical demand and DER developed through IGP as an input

[1] *See* https://www.hawaiianelectric.com/documents/clean_energy_hawaii/integrated_grid_planning/stakeholder_engagement/working_groups/distribution_planning/20200602_dpwg_distribution_planning_methodology.pdf

[2] Concurrent to this filing, an update to the Distribution Planning Methodology was filed in the Grid Needs Assessment (Nov. 2021, Dkt. No. 2018-0165). References in this document are made to the document in footnote 1.

to the distribution planning analyses to identify distribution grid needs. These distribution grid needs are then used as an input into the IGP process which will select portfolios of solutions to address resource, transmission, and distribution needs. The figure below shows how the Distribution Planning Process (see orange box) is performed in parallel which then converges with other identified steps in the IGP Process.

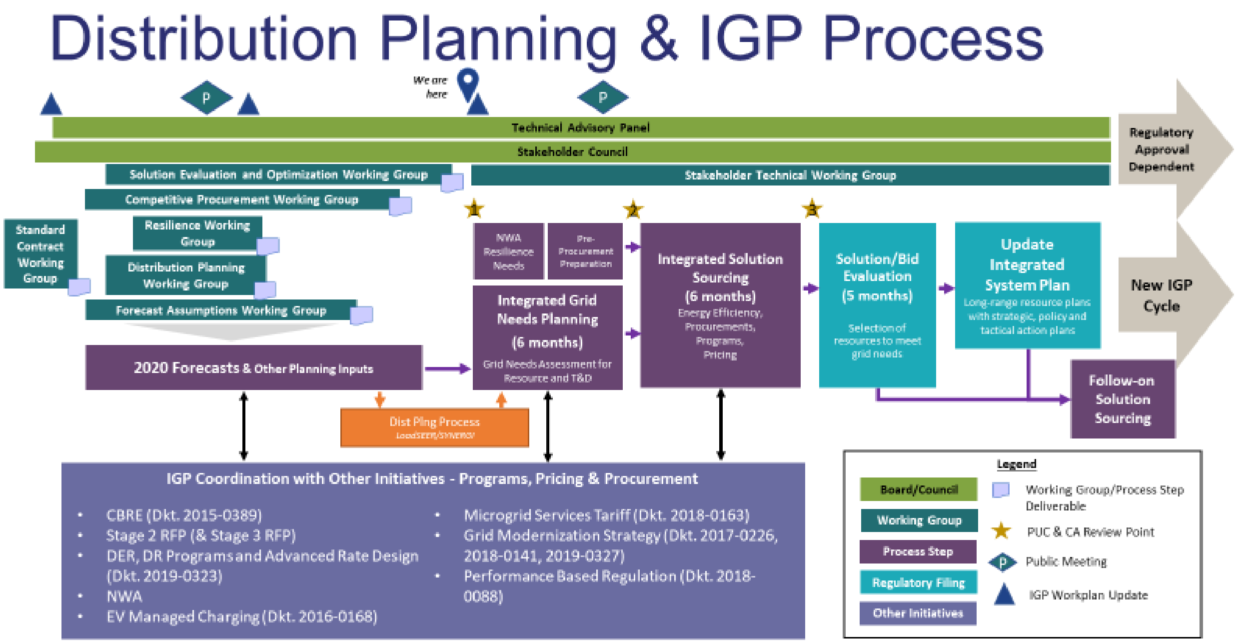

Figure 2: Distribution Planning Process and IGP Process[3]

This document focuses on describing the Forecast Stage of the Distribution Planning Process. Transformer and circuit location-based forecasts are the result.[4]

1.2 Use of Corporate Forecasts

As part of this analysis, location-based forecasts for the next ten years (year 2021 through 2030)[5] are derived from the corporate forecasts provided in the Hawaiian Electric Revision to Updated and Revised Inputs and Assumptions ("August Update") filed on August 19, 2021.[6]

[3] Hawaiian Electric, Presentation to IGP Stakeholder Technical Working Group, June 17, 2021.

[4] The forecasts are voluminous and therefore not provided in this report in table format. The files are available on the Company website in Excel workbooks. See Appendix A:.

[5] For this report, the Company elected to review the 10-year forecast as opposed to the 5-year forecast as provided in the *Distribution Planning Methodology*, pg. 19.

[6] *See* Hawaiian Electric Revision to Updated and Revised Inputs and Assumptions filed on August 19, 2021 in Docket No 2018-0165.

The corporate forecasts include specific layers for the underlying load growth, distributed energy resources ("DER"), energy efficiency ("EE"), and electric vehicles ("EV")[7]. These layers that are provided at the system level are disaggregated to create a total demand forecast for each circuit and transformer.

As discussed in the August Update, various forecast sensitivities and scenarios were developed to address forecasting uncertainty. As such, three of the scenarios were selected to provide a bookend approach in developing the location-based forecasts. In addition to a base forecast, the High Load Customer Technology Adoption Bookend and the Low Load Customer Technology Adoption Bookend were chosen to understand the impact of customer adoption of technologies that lead to higher loads and lower loads, respectively. The scenarios selected from the August Update are summarized in the following table.[8]

Table 1-1: Forecast Layer Mapping of Modeling Scenarios and Sensitivities

No.	Modeling Case	DER Forecast	EV Forecast	EE Forecast	TOU Load Shape
1	Base	Base Forecast	Base Forecast	Base Forecast	Managed EV Charging
2	High Load Customer Technology Adoption Bookend	Low Forecast	High Forecast	Low Forecast	Unmanaged EV Charging
3	Low Load Customer Technology Adoption Bookend	High Forecast	Low Forecast	High Forecast	Managed EV Charging

[7] This analysis uses the forecast for light duty electric vehicles but does not consider the forecast for eBus.

[8] *See* Hawaiian Electric Revision to Updated and Revised Inputs and Assumptions filed on August 19, 2021 in Docket No 2018-0165. Table 6-3.

2 Deriving Location-Based Forecasts

This section describes the steps used to derive the location-based forecasts:

1. Compile a base load shape for each circuit.
2. Add specific DER and load growth adjustments.
3. Determine corporate forecast layer amounts to be allocated.
4. Perform location-based allocation.

First, a base load shape is compiled using a historical load shape for each circuit and serves as the base for creating the location-based forecasts. The raw data is reviewed to remove anomalous data that is not representative of normal feeder conditions such as loss of load due to planned maintenance or system interruptions on the feeders.

In step 2, known future load growth and DER in specific areas, such as service requests and CBRE phase 1 projects, are added to the circuits where the growth is anticipated. Within the LoadSEER software this is known as "adjustments". In step 3, the corporate forecast layers are adjusted, if necessary, to determine the total forecast amounts for each layer that will be allocated amongst each circuit.

Steps 2 and 3 determine the total amount of load that will be allocated to each circuit in step 4 to create the location-based forecasts. The process is different for O'ahu and the neighbor islands. As mentioned in the August Update, LoadSEER is currently being used to develop location-based forecasts for O'ahu. Step 2 and step 3 prepare the load for input into LoadSEER and step 4 is completed using the LoadSEER program. Since LoadSEER modeling is not yet available for Maui County and Hawai'i Island[9], a different method is used to perform steps 2 through 4.

In summary, the location-based allocation in step 4 is performed using one of the following methods for the respective islands:

1. Forecast allocation in LoadSEER (O'ahu)
2. Forecast allocation based on existing loads (Hawai'i Island and Maui County)

The steps are summarized in the figure below.

[9] The implementation of LoadSEER for the neighbor islands is targeted for middle of 2022 as reported in Exhibit 2 of Hawaiian Electric Companies' Quarterly DER Technical Report filed on September 30, 2021 in Docket No. 2019-0323.

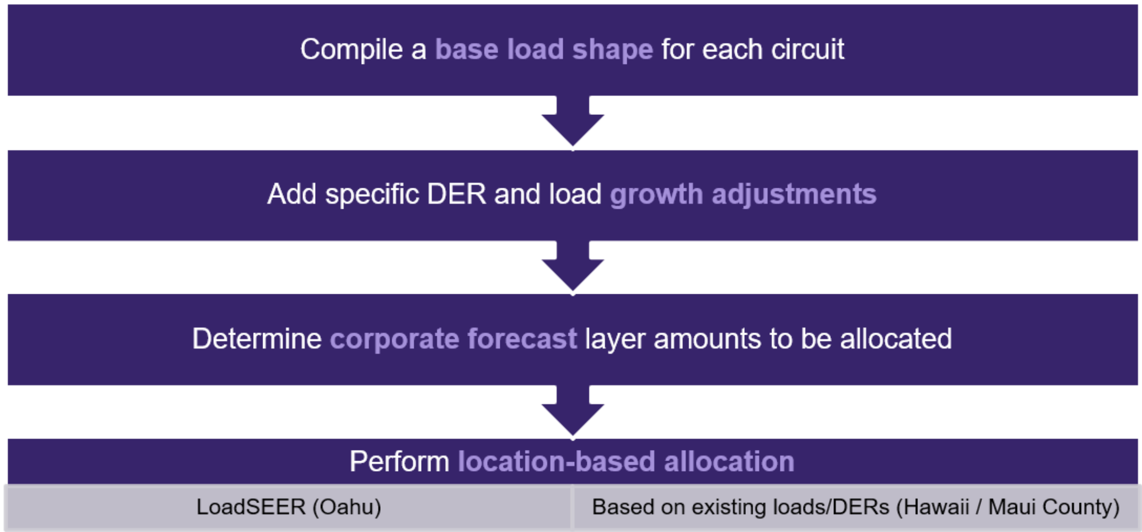

Figure 3: Steps to Derive Location-Based Forecasts

Consistent with the *Distribution Planning Methodology*, the resulting location-based forecasts will be provided in the following format:[10]

- Demand Forecast
- Demand Forecast by Load Type

The resulting location-based forecasts are discussed further in Section 3 and available on the Company website (see Appendix A: for a description of the files provided).

The following procedures described in this section are repeated for each scenario and its corresponding sensitivity layers:

- Base
- High Load Customer Technology Adoption Bookend
- Low Load Customer Technology Adoption Bookend

[10] Hawaiian Electric, *Distribution Planning Methodology*, June 2020 at 19.

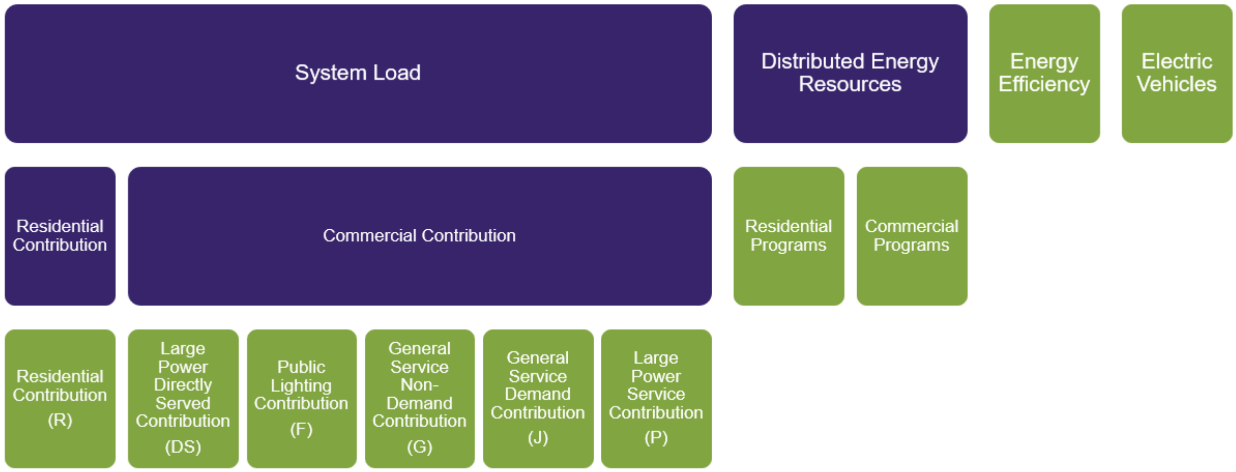

Figure 4: Illustration of forecast allocation by layers (top row indicates disaggregated layers)

2.1 BASE LOAD SHAPE

The base load shape is created using historical load data and serves as the basis for creating the location-based forecasts. Historical load data for the prior calendar year is compiled for each circuit in hourly ("8760") format.[11] For this process, historical load data from the year 2020 was compiled.[12] This data is compiled primarily using raw data sources such as distribution supervisory control and data acquisition ("SCADA") devices that measure load at the distribution transformer or circuit level.

Since the raw data contains measured data for all hours of the year, the raw data is reviewed to remove anomalous data that is not representative of normal feeder conditions such as loss of load due to planned maintenance or system interruptions on that feeder or conversely, extra load on the feeder due to transferred load from an adjacent feeder. In addition to these types of events, there may also be missing or bad data due to a loss of communication with the SCADA devices.

For O'ahu, the historical load data is analyzed in SCADA Scrubber. As described in the *Distribution Planning Methodology*, SCADA Scrubber[13] is a tool available in LoadSEER that analyzes hourly data for trends then normalizes periods where there are system interruptions or planned maintenance. Once the data is processed using SCADA Scrubber, the resulting "cleaned" shape is considered the normal feeder load and used in the subsequent processes. The following figure shows an example of a circuit shape being "cleaned". The red line plot in

[11] An 8760-hour profile represents all 365 days of the year at a 1-hour resolution.

[12] Data for year 2020 was used to calculate the historical circuit peaks. For circuits where this data was unavailable, data for the most recent historical year was used or the circuit peak was estimated based on a similar circuit.

[13] Hawaiian Electric, *Distribution Planning Methodology,* June 2020 at 8-9.

the upper chart is the original SCADA data that contains anomalous portions. The blue plot is the resulting "cleaned" data where the anomalous sections were removed using SCADA Scrubber.

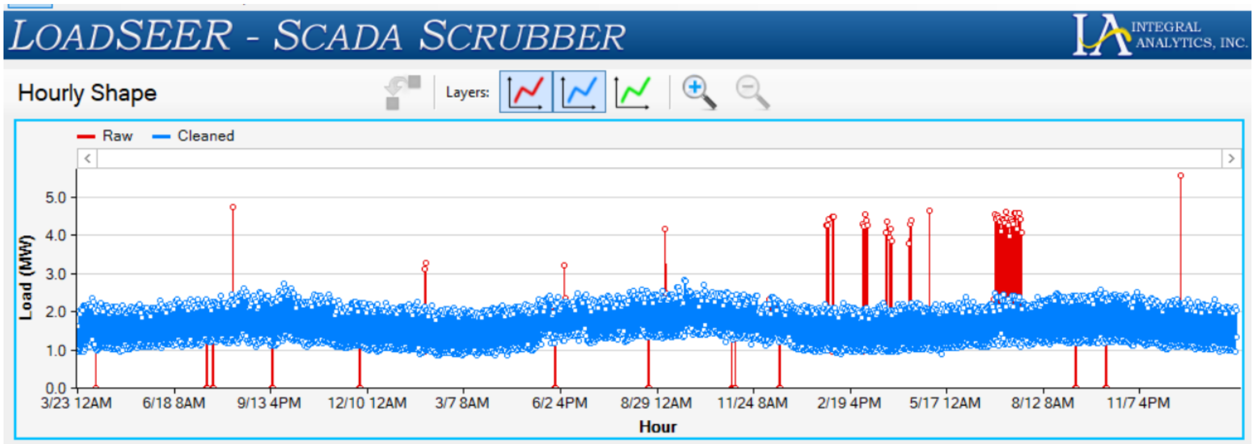

Figure 5: Hourly data for a Sample Circuit Processed in SCADA Scrubber (Red-Raw Data, Blue-Clean Data)

For Hawai'i Island and Maui County, the 2020 SCADA data was analyzed manually to determine the circuit peak loads. Anomalous periods of data are excluded when determining the peak load. The following figure shows example SCADA data for the single phase feeder readings in megawatts ("MW") showing an anomalous peak. In general, the anomalous peaks are verified against actual operations on the day that it occurred (i.e., planned maintenance, system interruptions, etc.). This peak was excluded when determining the circuit peak load to use for the base load shape for this circuit, similar to the way SCADA Scrubber cleans the SCADA data.

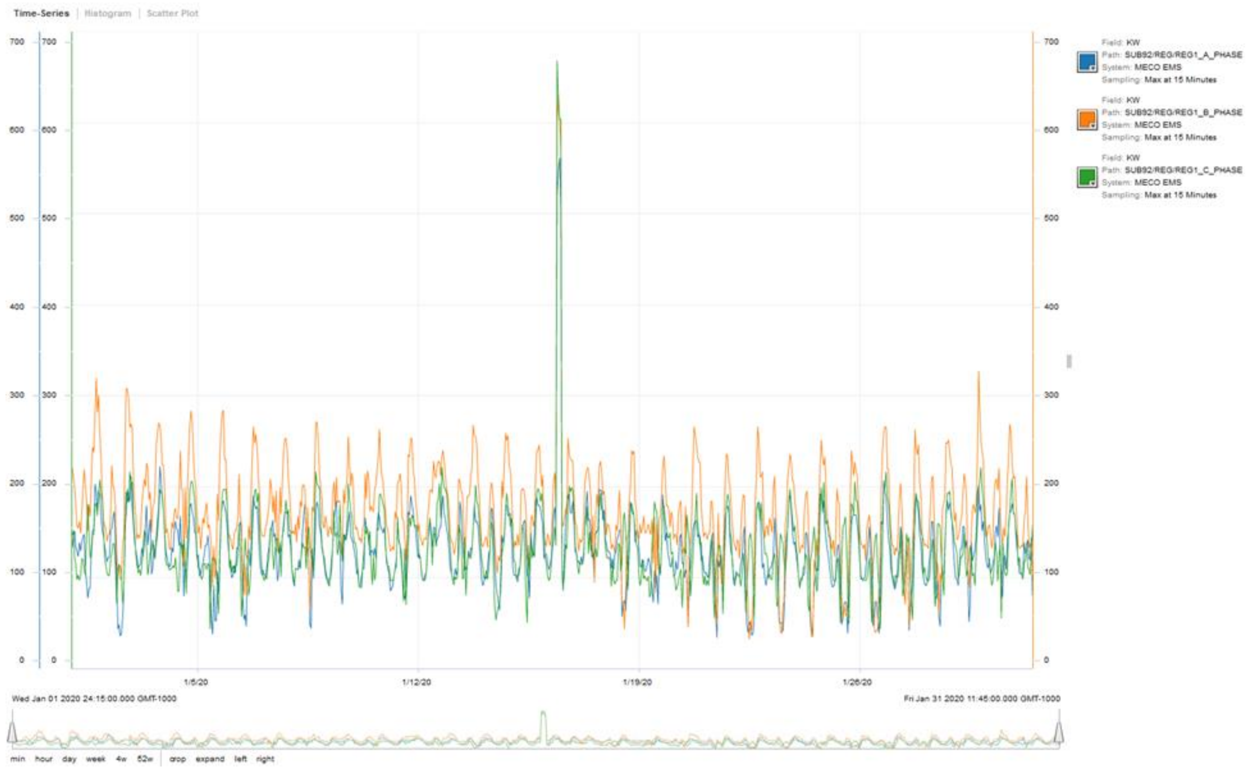

Figure 6: Sample SCADA Data with an Anomalous Peak

2.2 LOAD GROWTH ADJUSTMENTS

The Company receives service requests, or new load requests, from residential and commercial developers such as new subdivisions, condominiums, or shopping centers throughout the year as part of the normal Distribution Planning process. Typically when these requests are received, the developer provides an estimated peak load and an approximate in-service date.

Since service requests are for anticipated new loads in specific areas, the capacities of nearby feeders are evaluated and the service is assigned to a feeder based on location and available feeder capacity. This process is also described in the *Distribution Planning Methodology*.[14] The total load anticipated due to service requests are summed by feeder.

<u>O'ahu (Preparation for Allocation in LoadSEER)</u>

In LoadSEER, these service requests are added to the forecast as map adjustments. Map adjustments in LoadSEER can be either load or generation adjustments to the forecast where the location is known and can be added directly to the map tool in LoadSEER. The following is

[14] Hawaiian Electric, *Distribution Planning Methodology,* June 2020 at 9.

a screenshot of the map tool in the LoadSEER program. Since the service locations and the specified demand amounts are provided by customers on the service requests, the new service can be added at their specific locations.

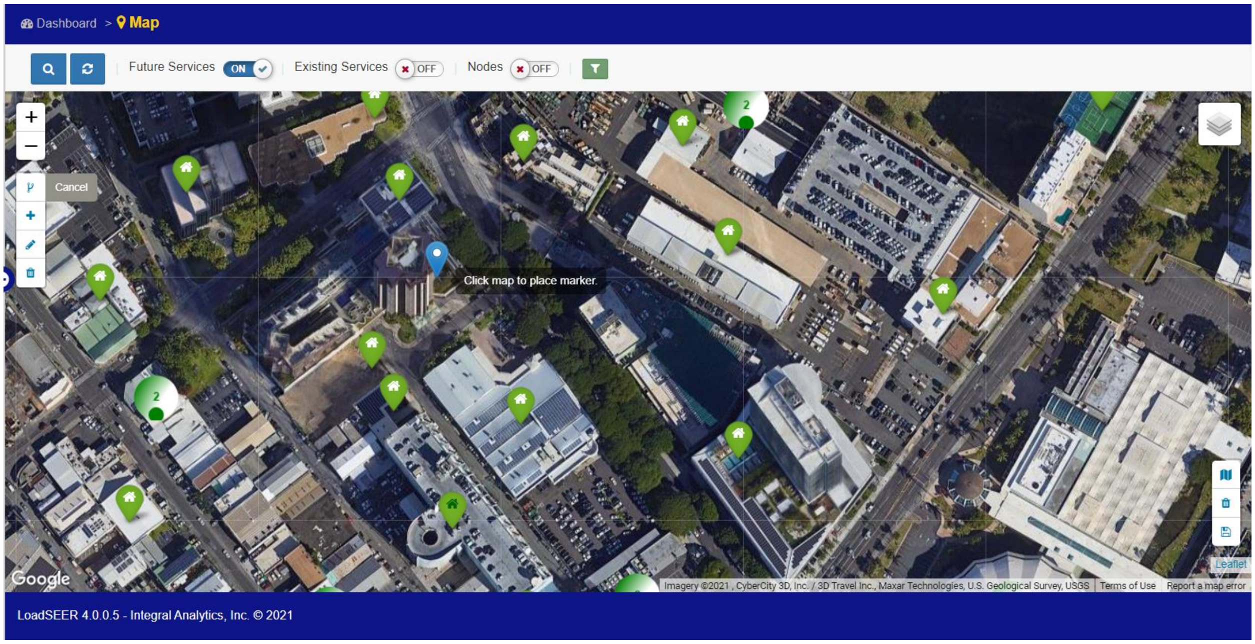

Figure 7: LoadSEER Map

These service requests are assigned to a nearby distribution feeder with available capacity and are then "locked" into the final forecast as a separate growth category, in addition to the forecast layers that will be described in the following sections.

These totals are shown as New Service Requests.

<u>Hawai'i Island and Maui County (Preparation for Allocation Based on Existing Load)</u>

Since the service requests are for anticipated loads in specific areas, the service requests received are summed by circuit to create a total service request amount (MW). This amount will be assigned to specific circuits where the future load growth is anticipated. For the purposes of this analysis, if an estimated in-service date was not provided by the customer, it is assumed that the loads will be in-service in the year 2025 timeframe. The year 2025 was chosen as an estimate using the middle of the study period.

The service request totals are combined with the underlying load from the corporate forecast (see Section 2.3.1) to create the forecasted load growth (see Section 2.4.2.2.).

2.3 CORPORATE FORECAST

As described in the August Update, modeling scenarios and sensitivities were developed to test different customer behaviors and changes in policy by incorporating a range of corporate forecasts. The scenarios and sensitivities provide a range of possible futures based on different levels of technology adoption rates. The corporate forecasts are created at the system level and are built with layers that include the underlying load, DER, EV, and EE components.

The August Update provided the corporate forecast layers as a load on an hourly basis (8760) for years 2021 through 2050.[15] These 8760 profiles are used to determine the amount of load for each layer that will be allocated as explained in Section 0. The process to determine the corporate forecast amounts to be allocated for each layer are described in the following sections.

2.3.1 Underlying Load

<u>O‘ahu (Preparation for Allocation in LoadSEER)</u>

Starting with the Underlying Load Forecast 8760[16] from the August Update, the monthly peak is extracted for each year from 2021 through 2030. The extracted monthly peak for each year will be used to create the LoadSEER input files that relate the Corporate level forecast to the circuit level spatial allocation. The figure below shows one month of hourly data from the August Update Workbook 3. In this example, the peak value 1,094 MW is extracted for the month of January.

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[15] Revised Input and Assumption workbooks for the August Update are available on the Company's website: https://www.hawaiianelectric.com/clean-energy-hawaii/integrated-grid-planning/stakeholder-engagement/key-stakeholder-documents..

[16] *See*: https://www.hawaiianelectric.com/documents/clean_energy_hawaii/integrated_grid_planning/Revised%202021-08-18%20Draft%20Oahu%20Inputs%20Workbook%203.xlsx.

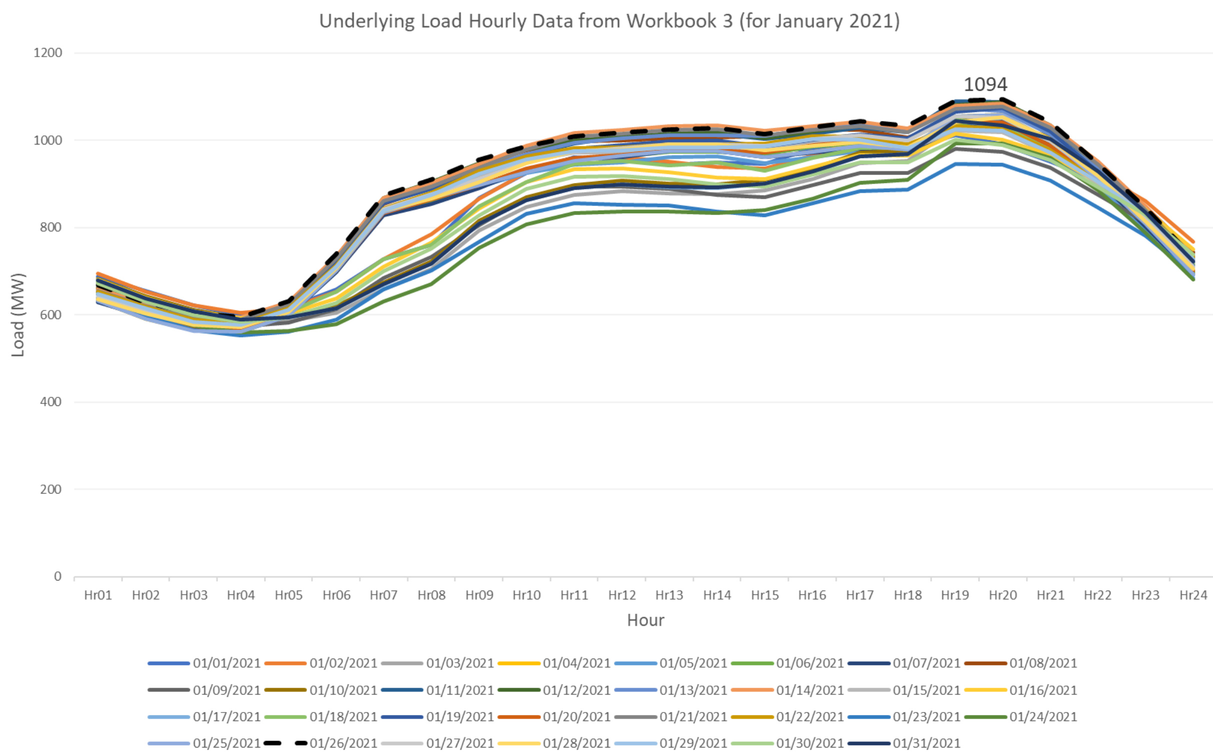

Figure 8: Underlying Load Hourly Data from Workbook 3 (for January 2021)

Once the monthly peaks for the entire forecast period are determined, the monthly incremental change is calculated. For the underlying load forecast, the monthly incremental total is then split into customer rate classes based on historical load data and allocated to the distribution circuits based on their respective totals. The following figure shows the customer rate classes created through the disaggregation of the system load.

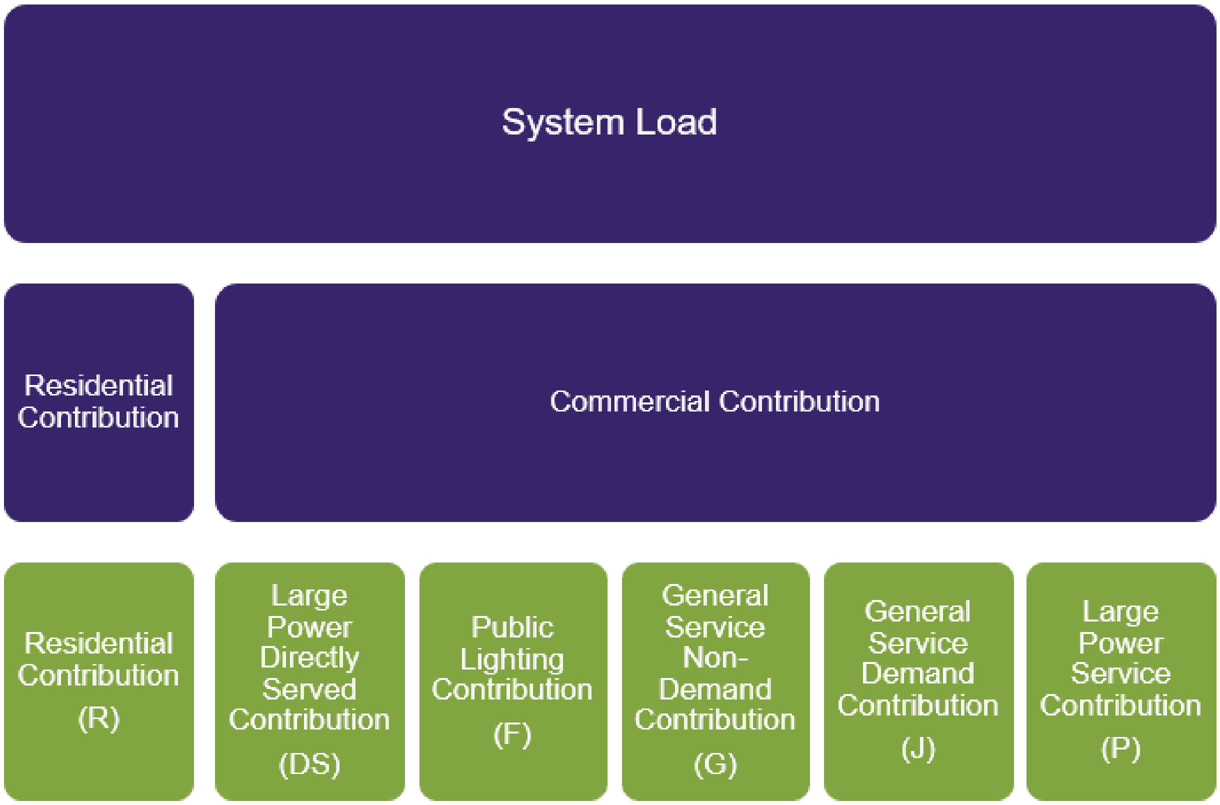

Figure 9: System Load Disaggregation into Customer Rate Classes

In order to minimize double counting service requests that may already be accounted for in the corporate forecast, the amount specified in the input files for the underlying load are reduced by the LoadSEER program based on the map adjustments described in Section 2.2.

Hawai'i Island and Maui County (Preparation for Allocation Based on Existing Load)

Similar to the process described for LoadSEER preparation, the monthly peak is extracted for each year from 2021 through 2030 using the Underlying Load Forecast 8760 from Workbook 3 of the August Update. An additional step is then needed to adjust the underlying load for load growth anticipated in specific areas. As described in Section 2.2, the Company receives service requests for anticipated loads in specific areas. The underlying load to be allocated is reduced by the total amount (MW) of service requests to avoid double counting load to be allocated. This amount is then allocated amongst the circuits as described in Section 2.4.2.1.

2.3.2 Distributed Energy Resources

The DER forecast layers provided in Workbook 3 of the August Update consist of separate layers for DGPV and DBESS by rate class. The following 8760 load profiles from the corporate forecasts serve as the starting point to determine the total DGPV and DBESS amounts to be allocated:

- DGPV[17]
- DBESS Residential (Schedule-R)
- DBESS Small Commercial (Schedule-G)
- DBESS Medium Commercial (Schedule-J)
- DBESS Large Commercial (Schedule-P)

In addition, the corporate DER and BESS forecast includes a monthly capacity (kW) forecast by rate class (e.g., Schedule-R, Schedule-G, Schedule-J, and Schedule-P) for the forecast period.

<u>O'ahu (Preparation for Allocation in LoadSEER)</u>

Starting with the DER and DBESS monthly capacity forecast, the incremental amount of DER added in each month is determined for years 2021 through 2030 for each rate class. These incremental amounts are then used to create input files used by LoadSEER for each rate class. This process is repeated to create input files for both DGPV and DBESS for each rate schedule:

- DGPV (Schedule-R)
- DGPV (Schedule-G)
- DGPV (Schedule-J)
- DGPV (Schedule-P)
- DBESS (Schedule-R)
- DBESS (Schedule-G)
- DBESS (Schedule-J)
- DBESS (Schedule-P)

An additional LoadSEER input file is also created for the CBRE Phase 2 small projects program capacity on O'ahu to be account for the 30 MW small project capacity described in the latest Order.[18] This LoadSEER input file allocates the 30 MW evenly across each month for 5 years (year 2021 through 2025).

The LoadSEER program requires an 8760 or 576 load shape/profile for each layer in the forecast. In some cases, there are no existing or default load shapes, as in the case for DBESS, EE, or EV layers. To address this, the 8760 corporate load forecast for the DBESS in Workbook 3 is used to create an average load shape for each rate class. To do this, the average hourly load

[17] DGPV layer includes impacts of behind the meter PV.

[18] *See* Order No. 37879 issued on July 27, 2021 in Docket No. 2015-0389, Approving the March 30 CBRE Filings, with Modifications.

shape for the final year of the forecast period (2030) is used to create a normalized 8760 load shape that can be imported into the LoadSEER program. These load profiles are scaled by LoadSEER at the individual service points where the DBESS (or other asset such as DGPV, EE, etc.) is allocated throughout the system when creating the circuit level forecast. The following figures show sample average DBESS load shapes for different customer rate schedules under the Base scenario for the study period.

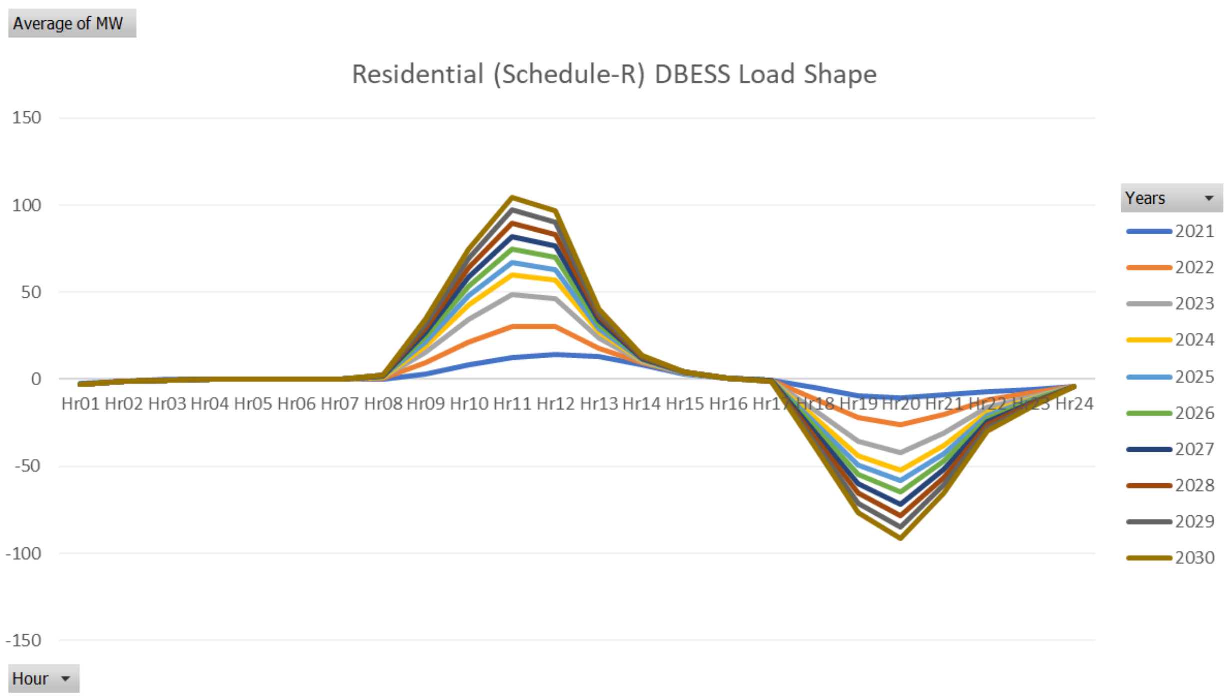

Figure 10: Residential (Schedule-R) DBESS Load Shape – Base Scenario

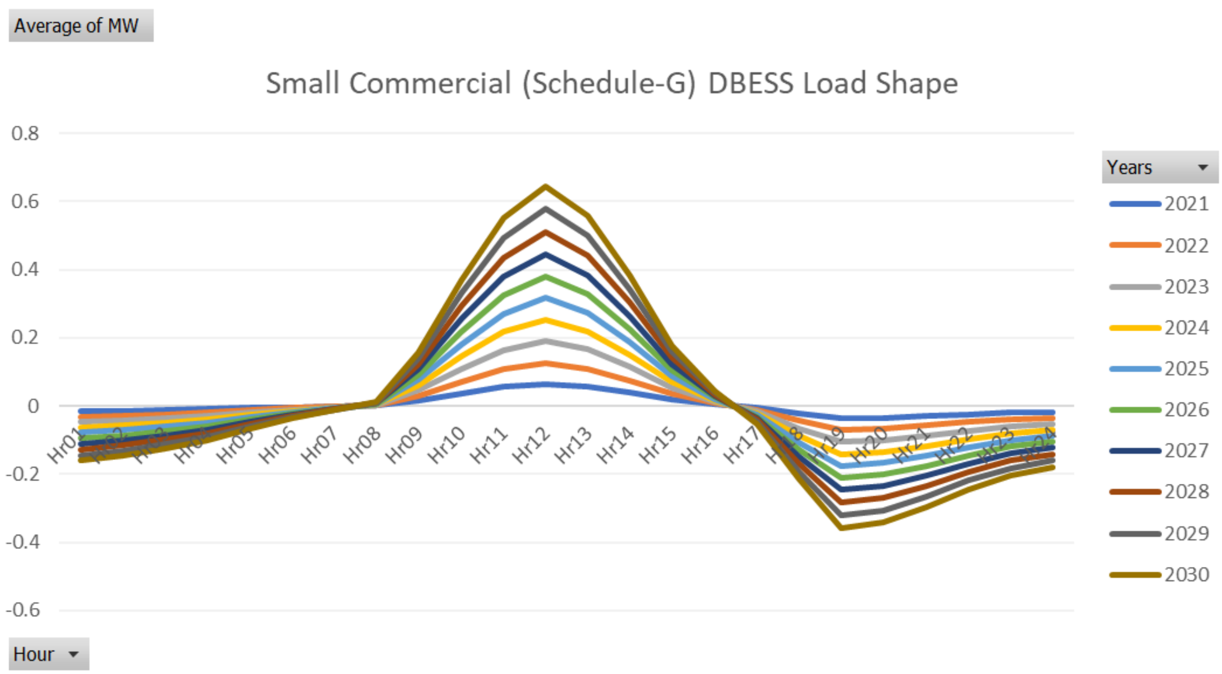

Figure 11: Small Commercial (Schedule-G) DBESS Load Shape – Base Scenario

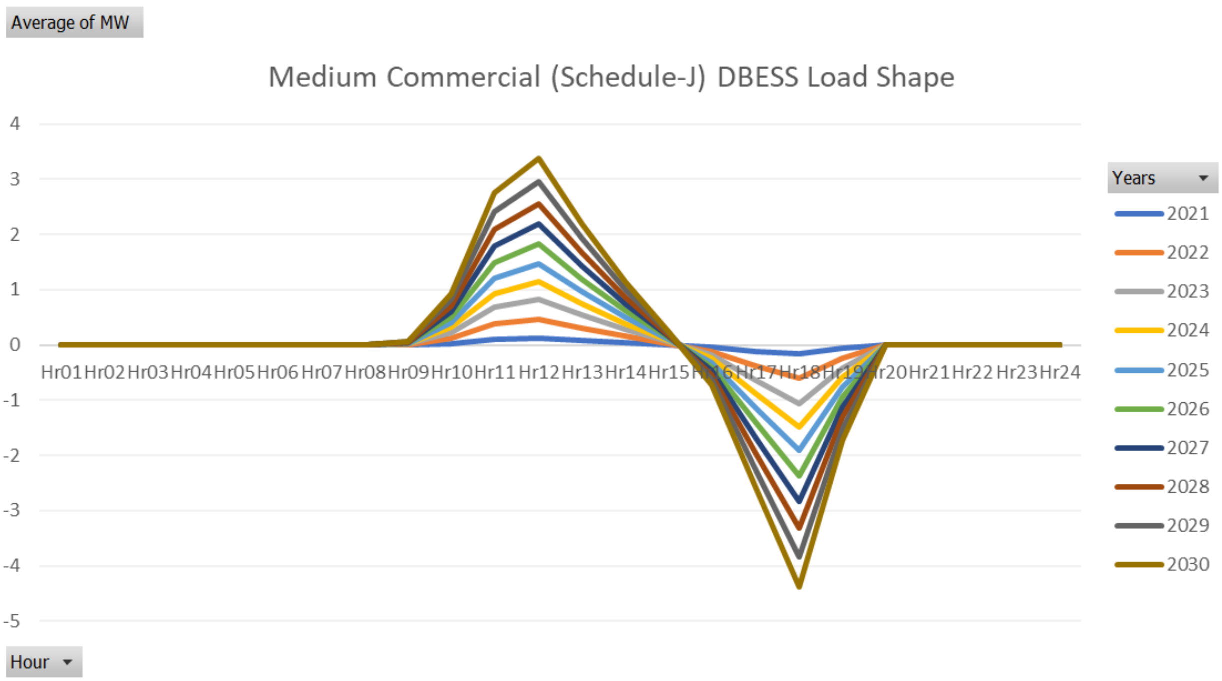

Figure 12: Medium Commercial (Schedule-J) DBESS Load Shape - Base Scenario

<u>Hawai'i Island and Maui County (Preparation for Allocation Based on Existing DGPV)</u>

The process to determine the DGPV allocation amount is consistent with the methodology used to determine the DER forecast allocation based on existing DER described in the *Distribution DER Hosting Capacity Grid Needs* document provided in the August Update.[19,20] An annual incremental amount is determined from the DER capacity forecast then adjusted by adding the CBRE Phase 2 small projects program. This sum is then allocated amongst the circuits using the process described in Section 2.4.2.2. Similar to the process described for LoadSEER preparation, the BESS capacity forecast is used to determine the incremental amount of DBESS added in each year for years 2021 through 2030. This incremental amount is then allocated amongst the circuits using the process described in Section 2.4.2.2.

[19] *See* https://www.hawaiianelectric.com/documents/clean_energy_hawaii/integrated_grid_planning/20210803_heco_submittal_of_igp_inputs_and_assum_and_der_hosting_capacity.pdf

[20] This is also consistent with the methodology described in the *Distribution DER Hosting Capacity Grid Needs November 2021 Update* filed concurrently with this report (Nov. 2021, Dkt. No. 2018-0165).

2.3.3 Electric Vehicle

<u>O'ahu (Preparation for Allocation in LoadSEER)</u>

Starting with the EV-Managed Base Forecast from Workbook 3 of the August Update, the monthly peaks are extracted from the 8760 data. Those peak values are used to create the LoadSEER input file which relates the Corporate level forecast to the circuit level spatial allocation. After the allocation, circuit level forecasts can be computed for the EV layer.

The same process is used to create the LoadSEER input files for the EV-Managed Low Forecast and EV-Unmanaged High Forecast from Workbook 4 of the August Update.

Similar to the DBESS layer, the 8760 data from Workbook 3 is also used to create an average load shape that is imported into the LoadSEER program. The same Managed adjustment shape was used for both Base and Low scenarios. A separate load shape was created and imported for the Unmanaged high scenario.

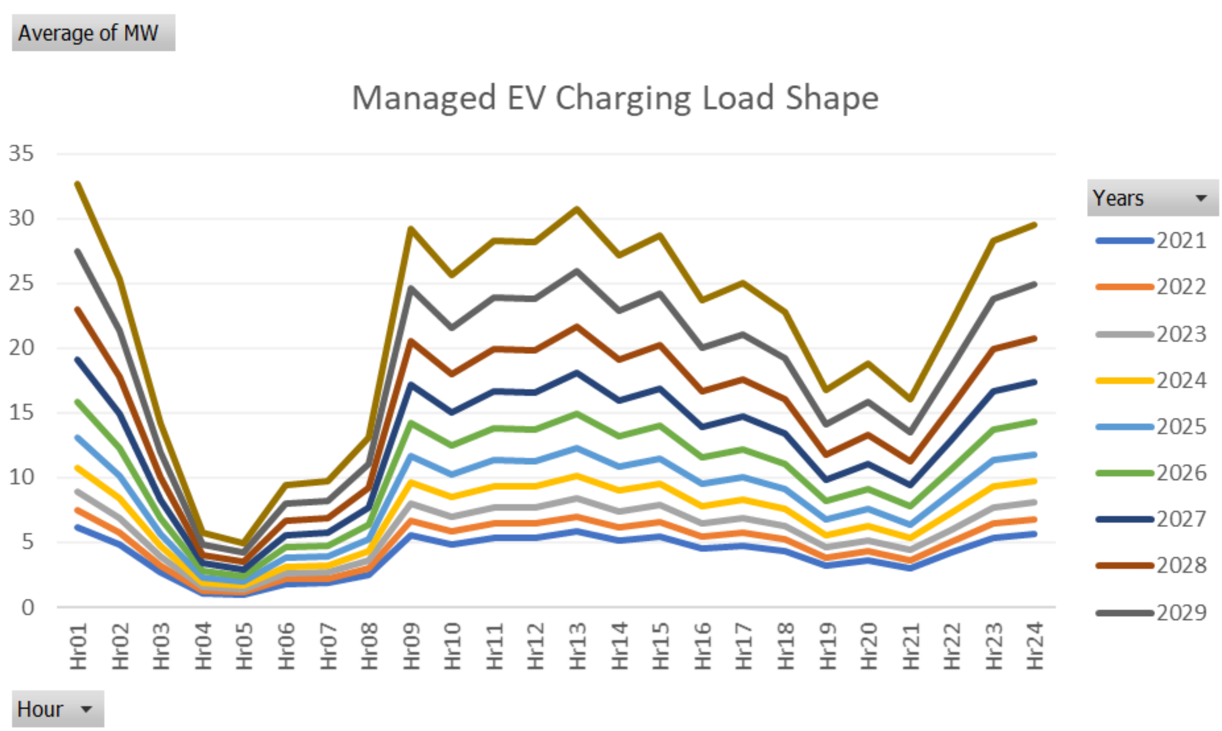

Figure 13: Managed EV Charging Load Shape

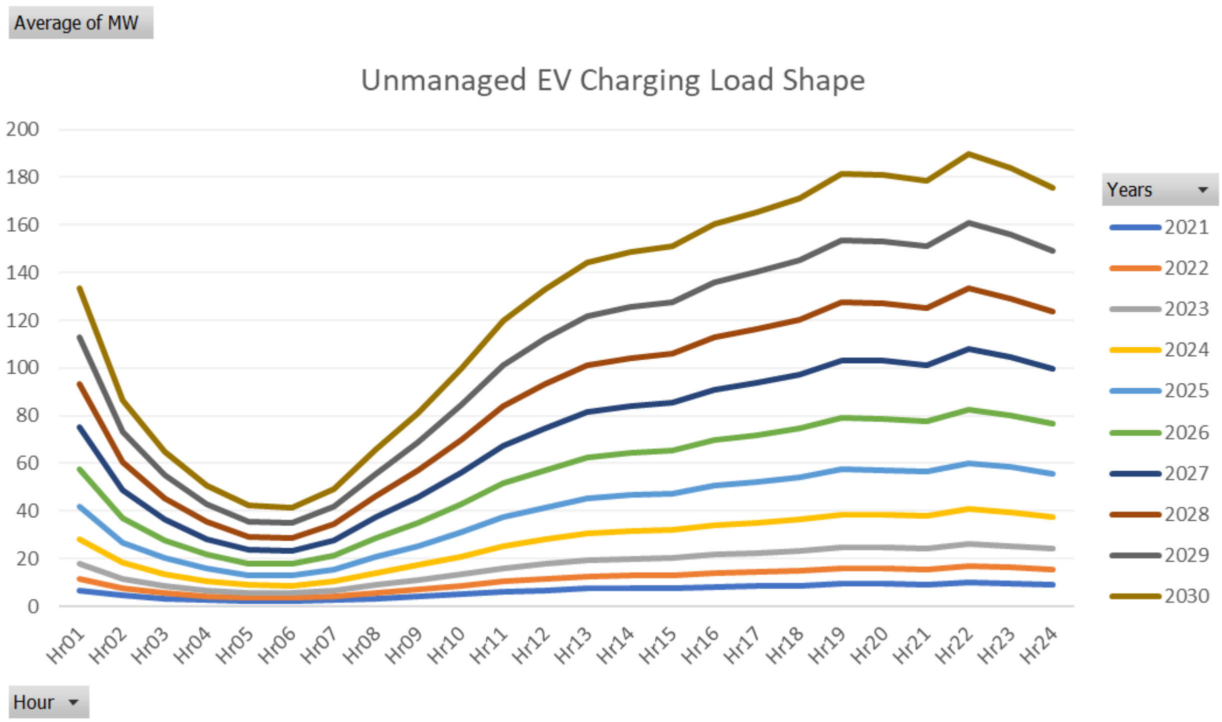

Figure 14: Unmanaged EV Charging Load Shape

Hawai'i Island and Maui County (Preparation for Allocation Based on Existing Load)

Similar to the process described for LoadSEER preparation, the monthly peaks are extracted for each year from 2021 through 2030 using the Managed EV – Base Forecast from Workbook 3 of the August Update for the Base Modeling Case. The same process is used to determine the allocation amounts for the Managed EV – Low Forecast and the Unmanaged EV – High Forecast from Workbook 4 of the August Update. This amount is then allocated amongst the circuits as described in Section 2.4.2.3.

2.3.4 Energy Efficiency

O'ahu (Preparation for Allocation in LoadSEER)

Starting with the EE-Base Forecast from Workbook 3 of the August Update, the monthly minimum (which provides the largest energy reduction) is extracted from the 8760 data. The minimums (or largest load reductions) are used to create the LoadSEER input file which relates the corporate level forecast to the circuit level spatial allocation. After the allocation, circuit level forecasts can be computed for the EE layer.

The same process is used to create the LoadSEER input files for the EE-High Forecast and EE-Low Forecast from Workbook 4 of the August Update.

Similar to the DBESS and EV layers, the 8760 data from Workbook 3 and 4 is used to create an average load shape that is imported into the LoadSEER program as described previously in Section 2.3.2. However, for the EE layer, separate load shapes were imported and used for the 3 scenarios: Base, Low, and High.

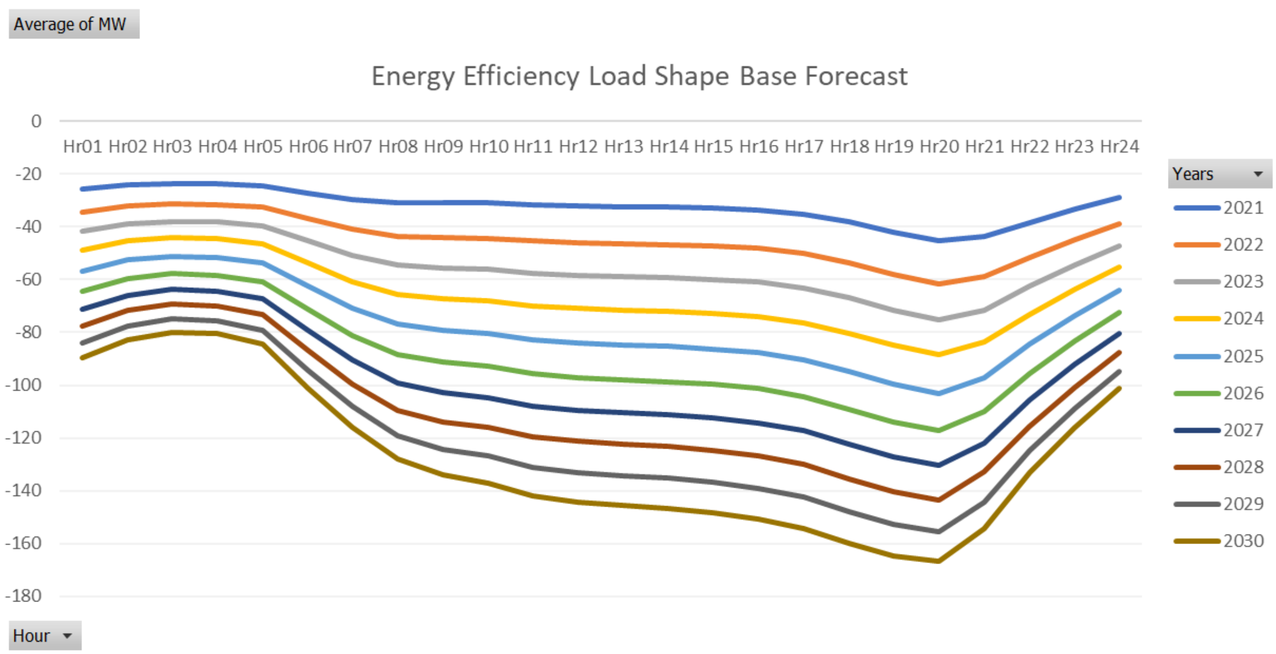

Figure 15: Energy Efficiency Load Shape – Base Forecast

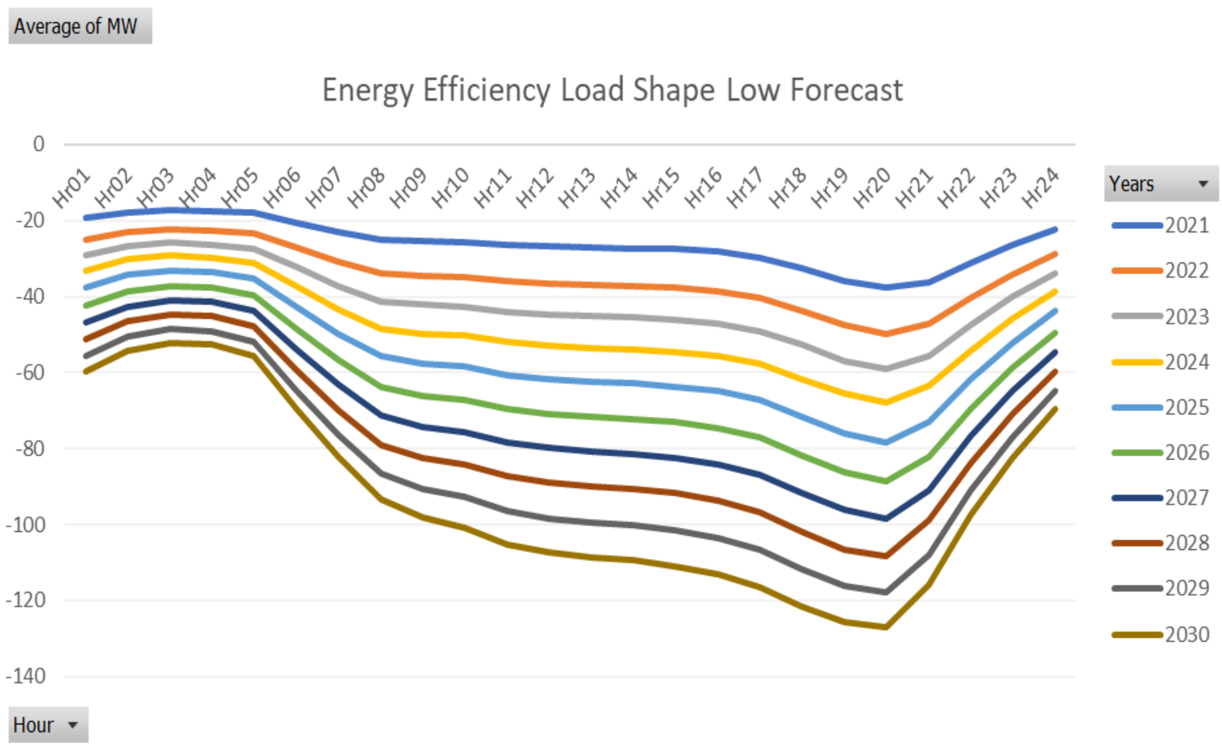

Figure 16: Energy Efficiency Load Shape – Low Forecast

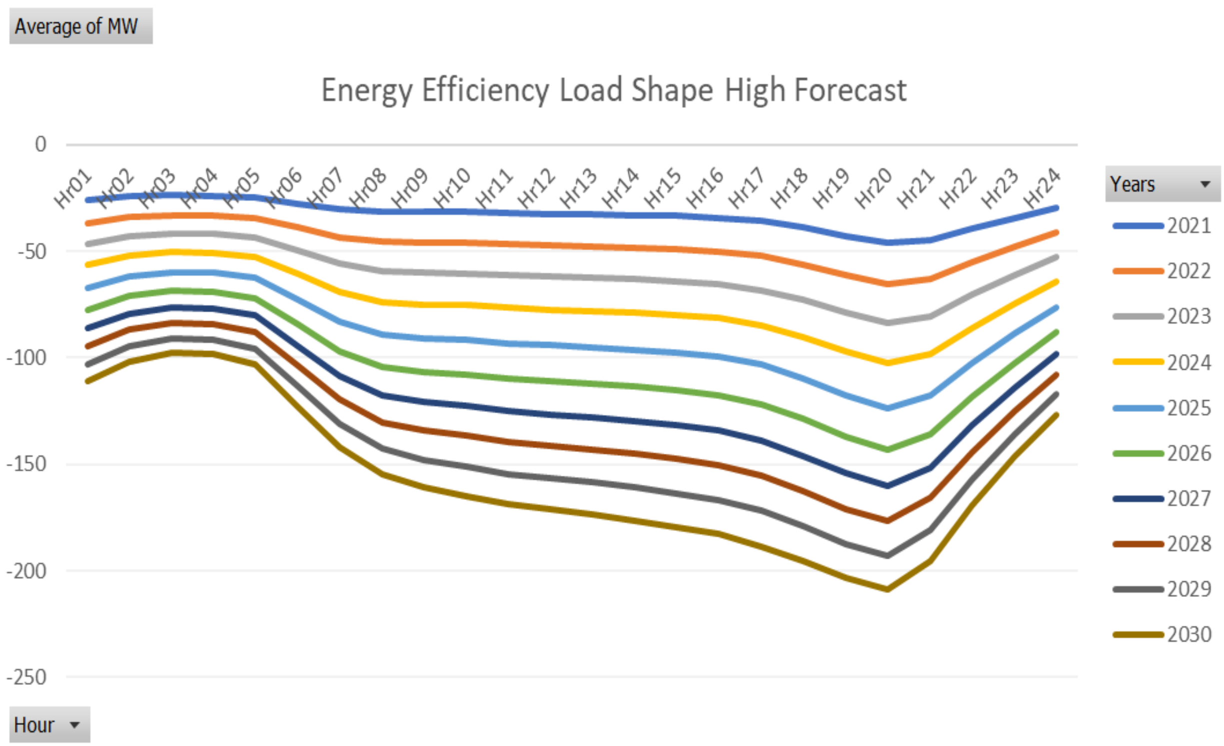

Figure 17: Energy Efficiency Load Shape – High Forecast

Hawai'i Island and Maui County (Preparation for Allocation Based on Existing Load)

Similar to the process described for LoadSEER preparation, the monthly minimum (which provides the largest energy reduction or similarly, the largest load reduction) is extracted for each year from 2021 through 2030 using the EE – Base Forecast from Workbook 3 of the August Update. The same process is used to determine the allocation amounts for the EE – Low Forecast and the EE – High Forecast from Workbook 4 of the August Update. This amount is then allocated amongst the circuits as described in Section 2.4.2.4.

2.4 LOCATION-BASED ALLOCATION

Once the total forecasted amounts (MW) to be allocated for each layer are determined, the following processes are used to perform the load allocation amongst circuits.

2.4.1 Forecast Allocation in LoadSEER

The forecast allocation is performed in LoadSEER for O'ahu.

2.4.1.1 Scenario 1 – Base

The following average daily hourly load profiles for a sample circuit in the Base scenario are shown in the figure below for comparison:

- Underlying Load
- DGPV and DBESS Base Forecast
- Managed EV Base Forecast
- Energy Efficiency Base Forecast

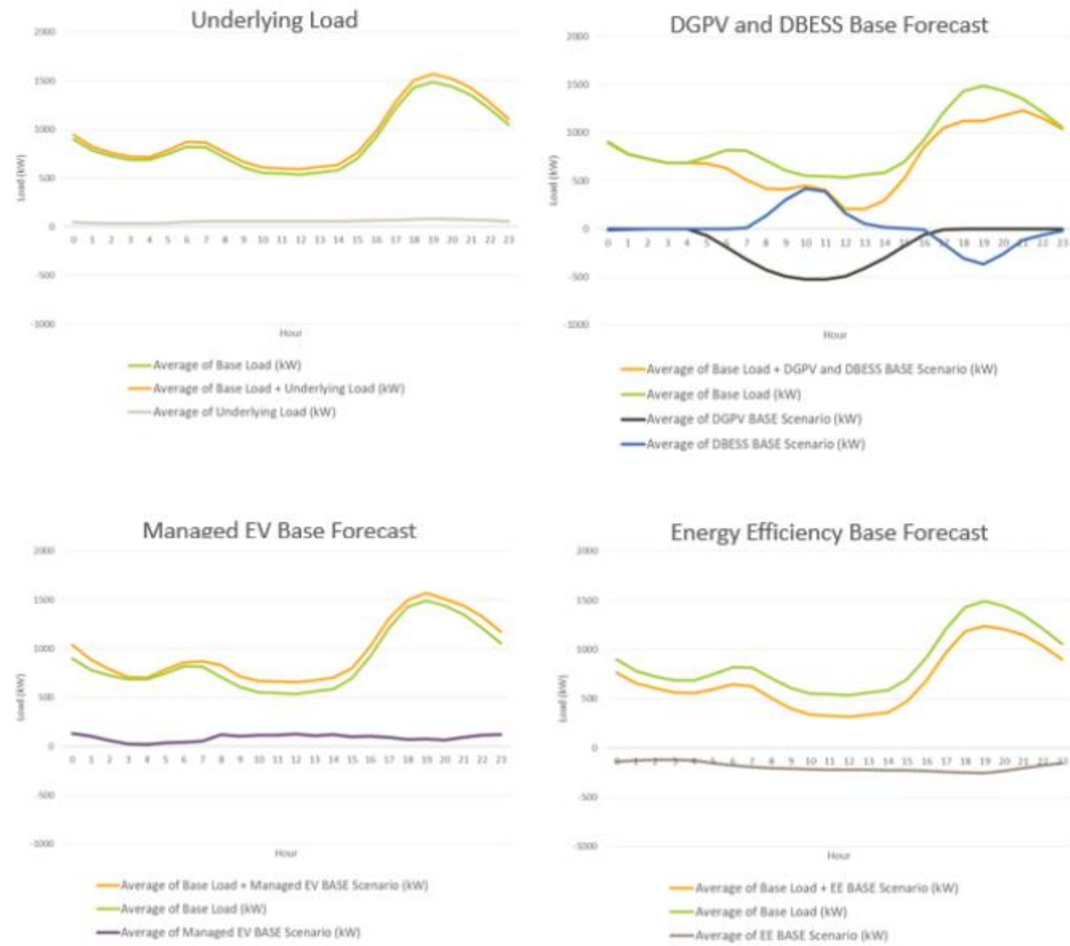

Figure 18: Scenario 1 Average Daily Hourly Load Profiles by Layer (Underlying Load, DGPV and BESS, EV, and EE) for Sample Circuit

The following figures display the same information as the previous figures, but with emphasis on the effect of the aggregated (or stacked) load layers that results in the average shape by layer.

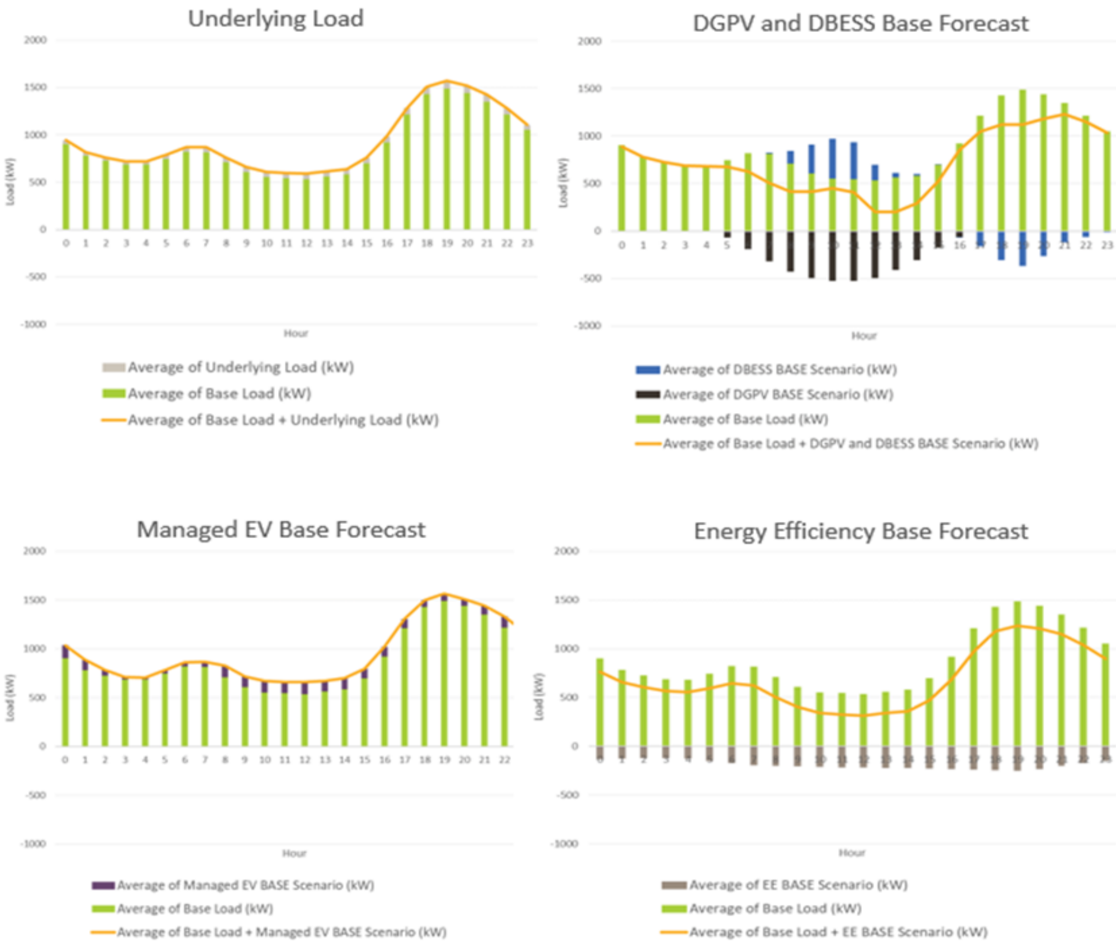

Figure 19: Scenario 1 Average Daily Hourly Load Profiles by Layer (Underlying Load, DGPV and BESS, EV, and EE) with Stacked Load for Sample Circuit

Scenario 1 - Total Forecast

The following chart shows the average base load and average forecasted load for the Base Scenario. For this circuit the average forecasted load decreases due to the impact of the forecasted layers in this scenario.

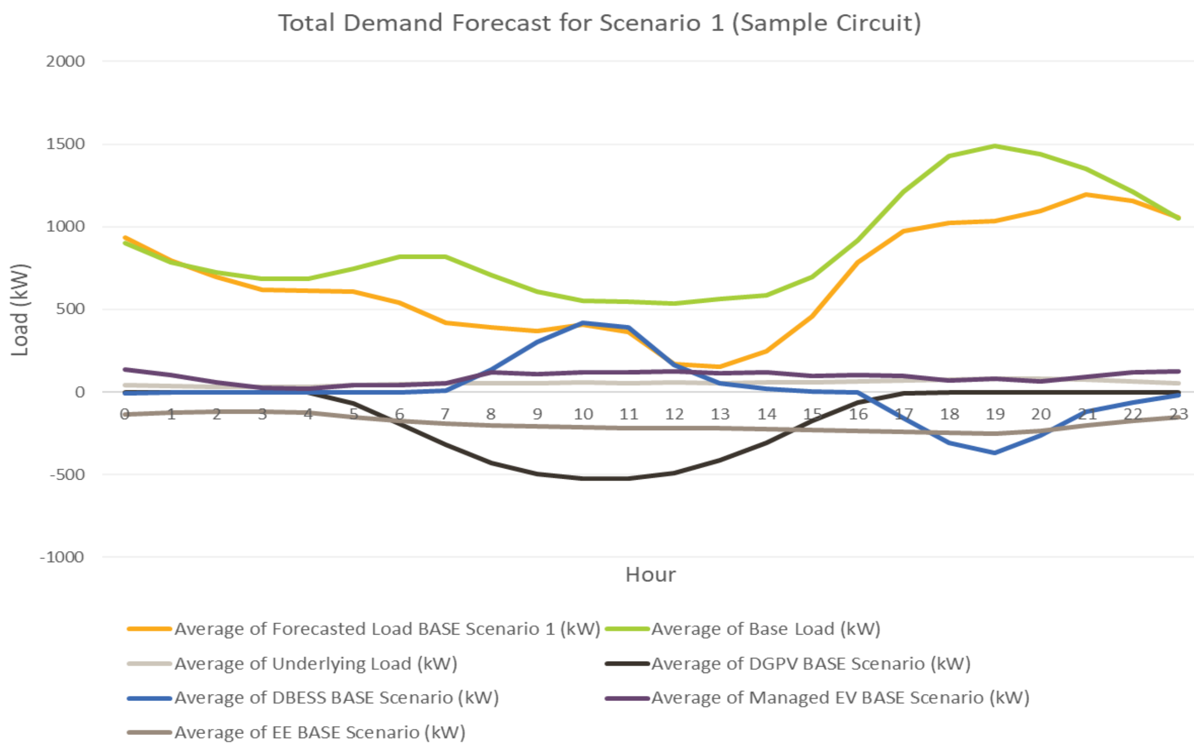

Figure 20: Total Demand Forecast for Scenario 1 (Sample Circuit)

The following figure displays the same information as the previous figure but emphasizes the contribution of the forecast layers on the forecasted load shape.

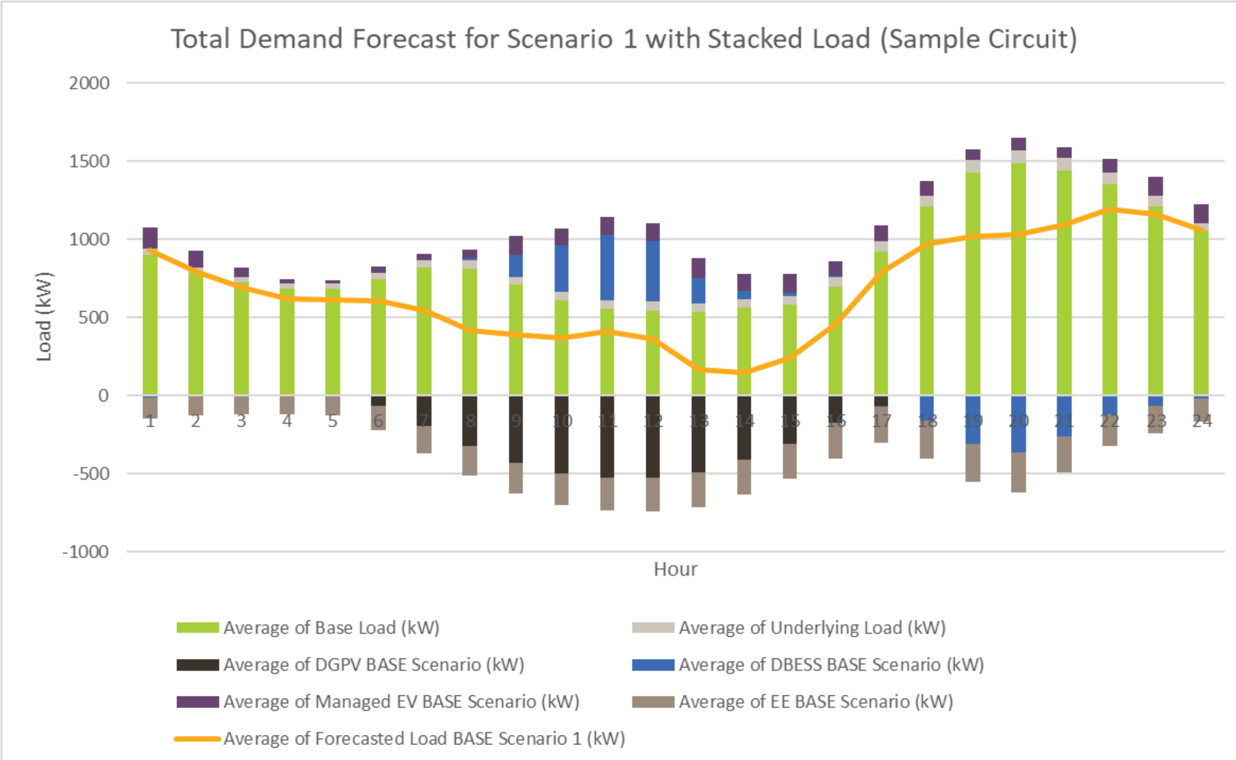

Figure 21: Total Demand Forecast for Scenario 1 with Stacked Load (Sample Circuit)

This process of computing the forecast is repeated for Scenario 2 - High Load Customer Technology Adoption Bookend and Scenario 3 - Low Load Customer Technology Adoption Bookend with the appropriate layers selected for each.

2.4.1.2 Scenario 2 – High Load Customer Technology Adoption Bookend

The following average daily hourly load profiles for a sample circuit in Scenario 2, the High Load Customer Technology Adoption Bookend scenario, are shown in the figure below for comparison:

- Underlying Load
- DGPV and DBESS Low Forecast
- Unmanaged EV High Forecast
- Energy Efficiency Low Forecast

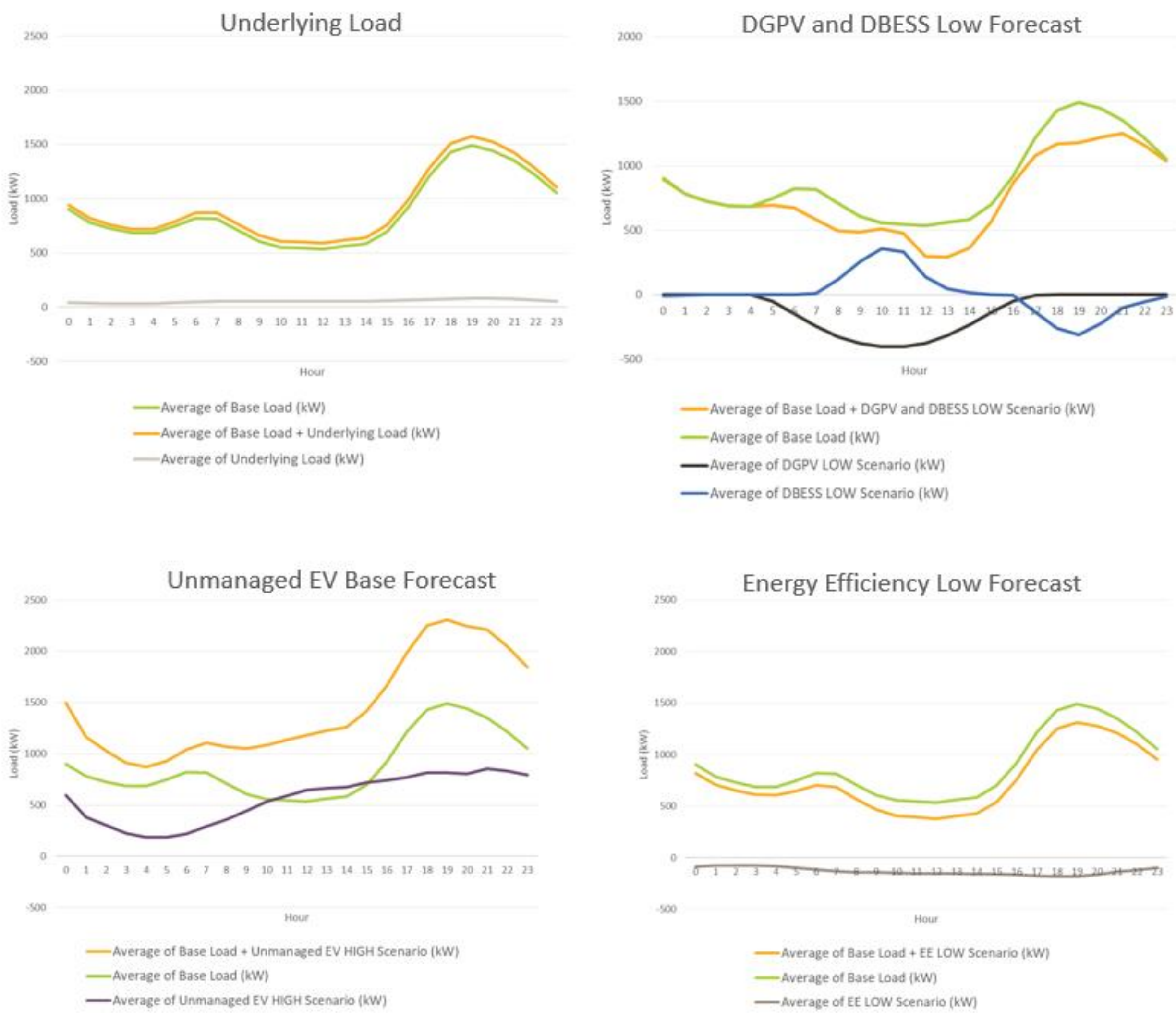

Figure 22: Scenario 2 Average Daily Hourly Load Profiles by Layer (Underlying Load, DGPV and BESS, EV, and EE) for Sample Circuit

As shown for Scenario 1 in the previous section, the following figures display the same information as the above figures, but with emphasis on the effect of the aggregated (or stacked) load layers that results in the average shape by layer.

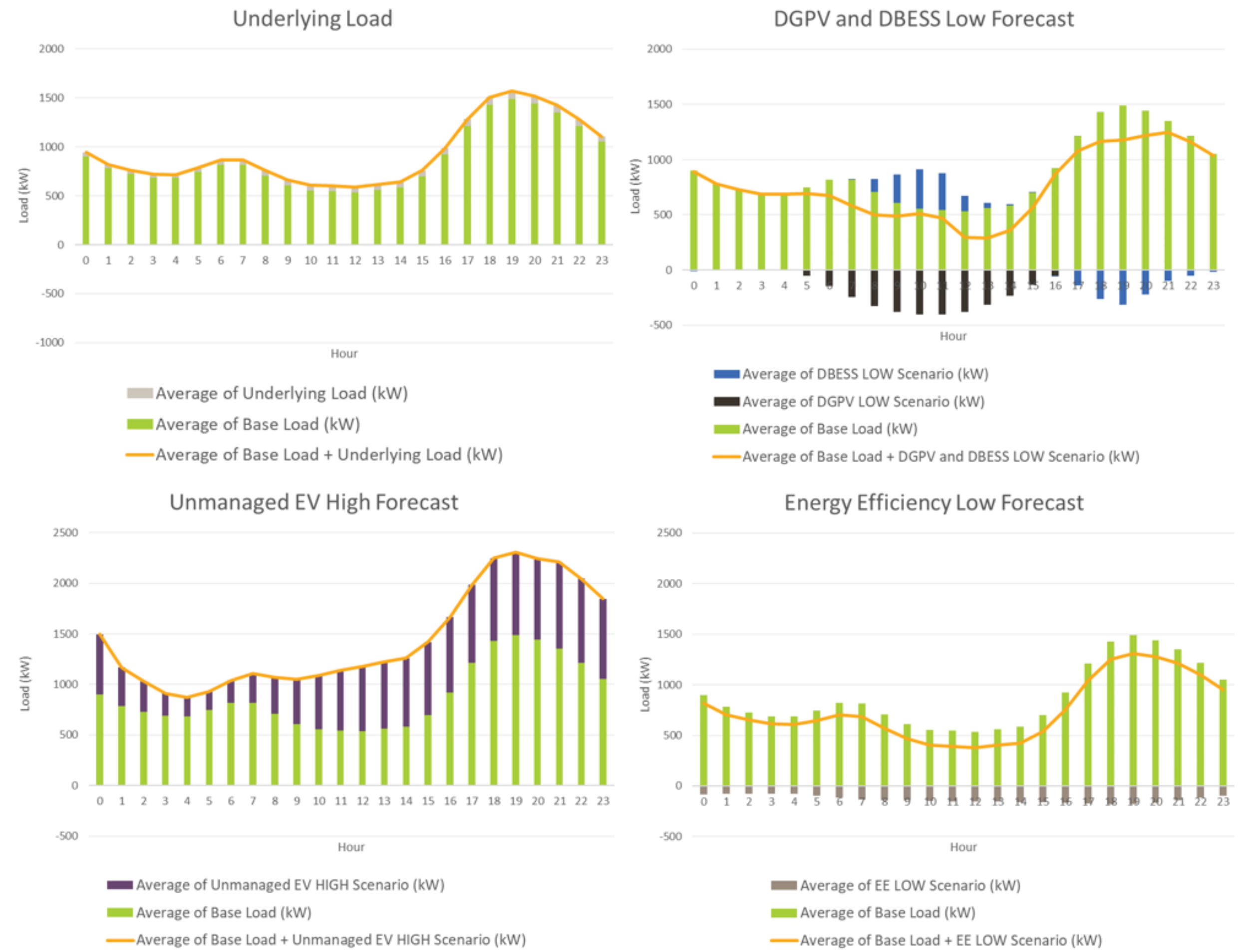

Figure 23: Scenario 2 Average Daily Hourly Load Profiles by Layer (Underlying Load, DGPV and BESS, EV, and EE) with Stacked Load for Sample Circuit

Scenario 2 – Total Forecast

This chart shows the average base load and average forecasted load for the High Load Technology Adoption Bookend Scenario. For this circuit the average forecasted load increases due to the impact of the forecasted layers in this scenario.

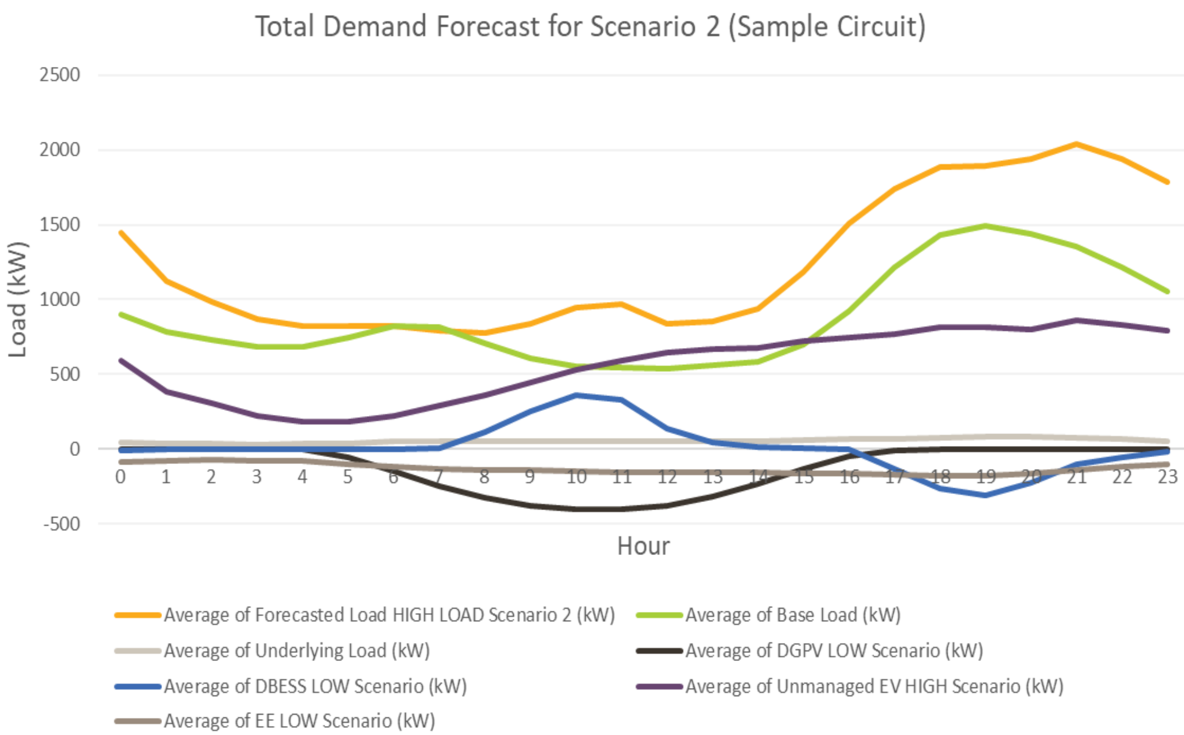

Figure 24: Total Demand Forecast for Scenario 2 (Sample Circuit)

This chart displays the same information as the previous, however it emphasizes the contribution of the forecast layers on the forecasted load shape. For this circuit there is a large contribution due to EV on the average peak forecasted load.

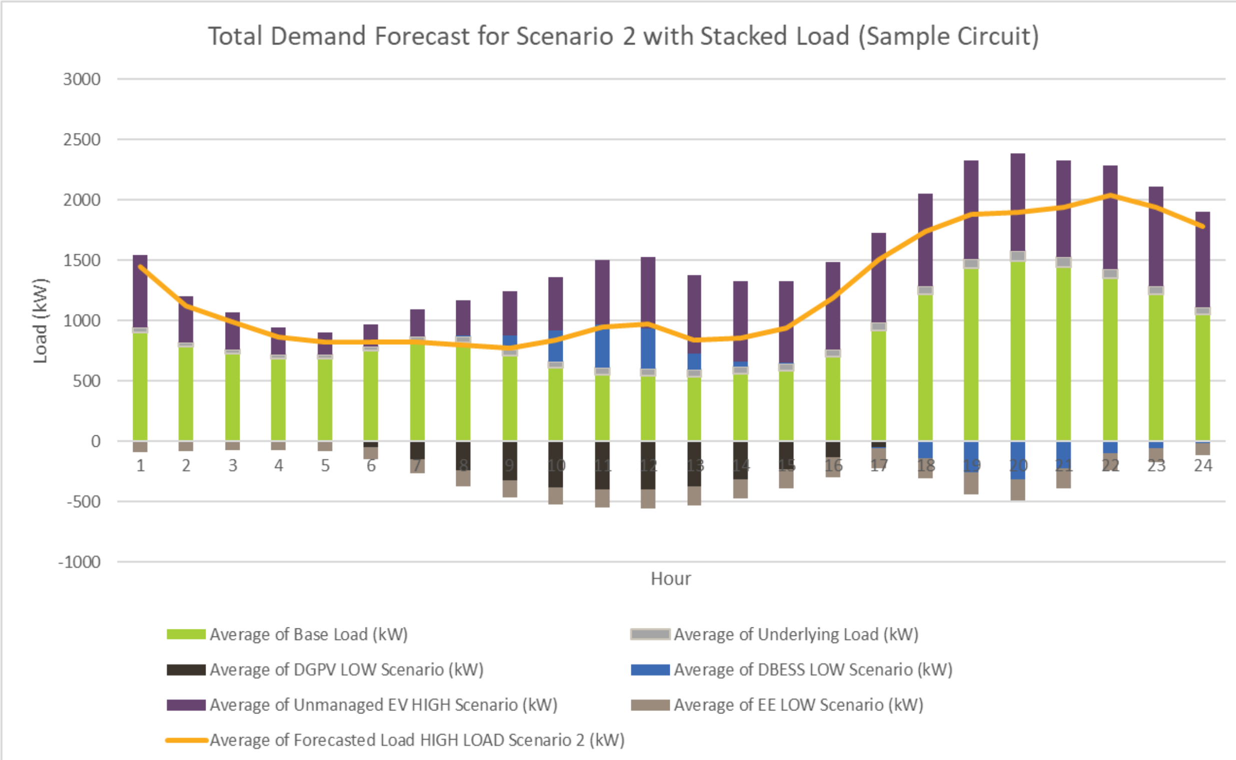

Figure 25: Total Demand Forecast for Scenario 2 with Stacked Load (Sample Circuit)

2.4.1.3 Scenario 3 – Low Load Customer Technology Adoption Bookend

The following average daily hourly load profiles for a sample circuit in Scenario 3, the Low Load Customer Technology Adoption Bookend scenario, are shown in the figure below for comparison:

- Underlying Load
- DGPV and DBESS High Forecast
- Managed EV Low Forecast
- Energy Efficiency High Forecast

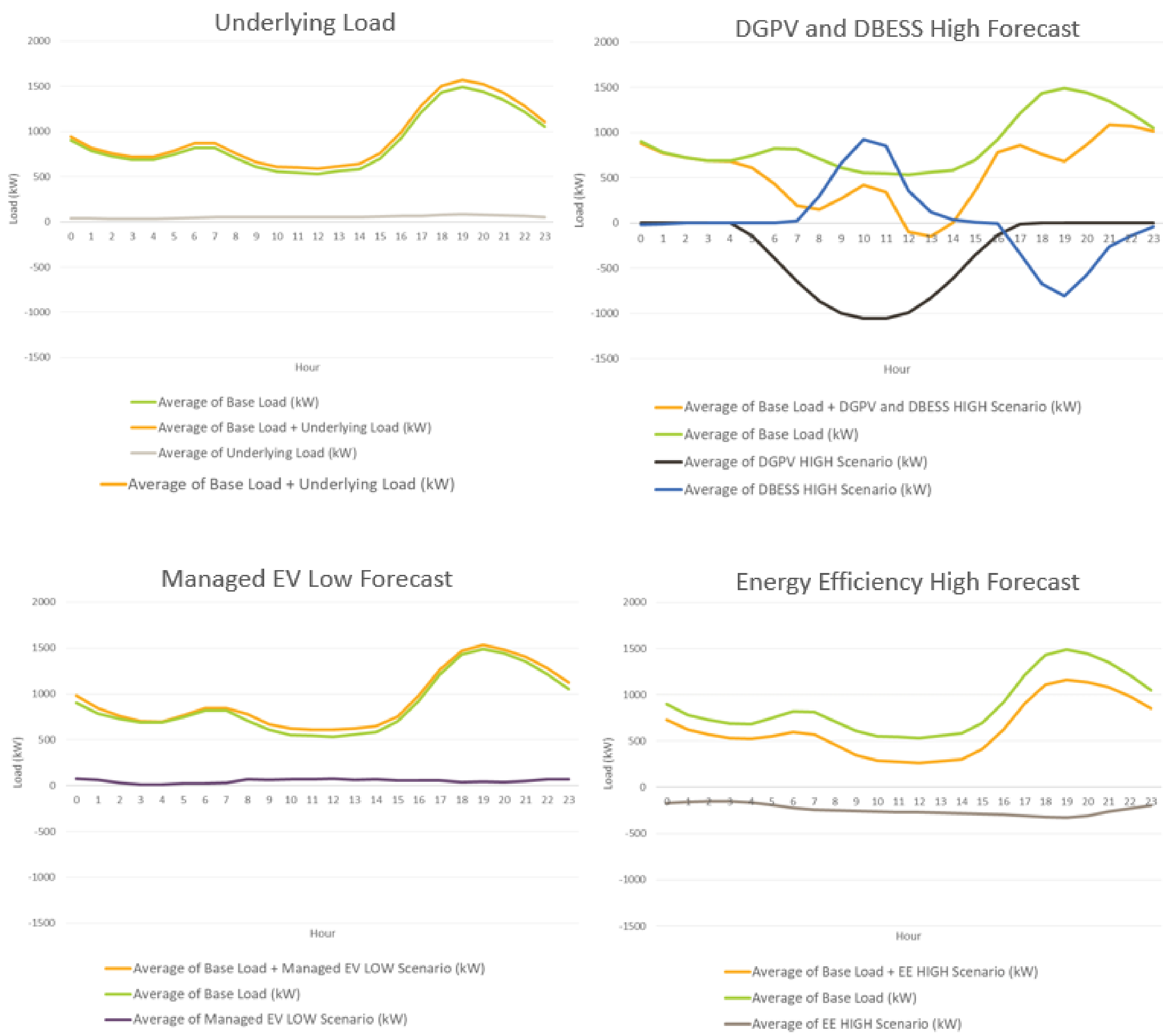

Figure 26: Scenario 3 Average Daily Hourly Load Profiles by Layer (Underlying Load, DGPV and BESS, EV, and EE) for Sample Circuit

As shown for Scenario 1 and 2 in the previous sections, the following figures display the same information as the above figures, but with emphasis on the effect of the aggregated (or stacked) load layers that results in the average shape by layer.

Figure 27: Scenario 3 Average Daily Hourly Load Profiles by Layer (Underlying Load, DGPV and BESS, EV, and EE) with Stacked Load for Sample Circuit

Scenario 3 – Total Forecast

This chart shows the average base load and average forecasted load for the Low Load Technology Adoption Bookend Scenario. For this circuit the average forecasted load decreases due to the impact of the forecasted layers in this scenario.

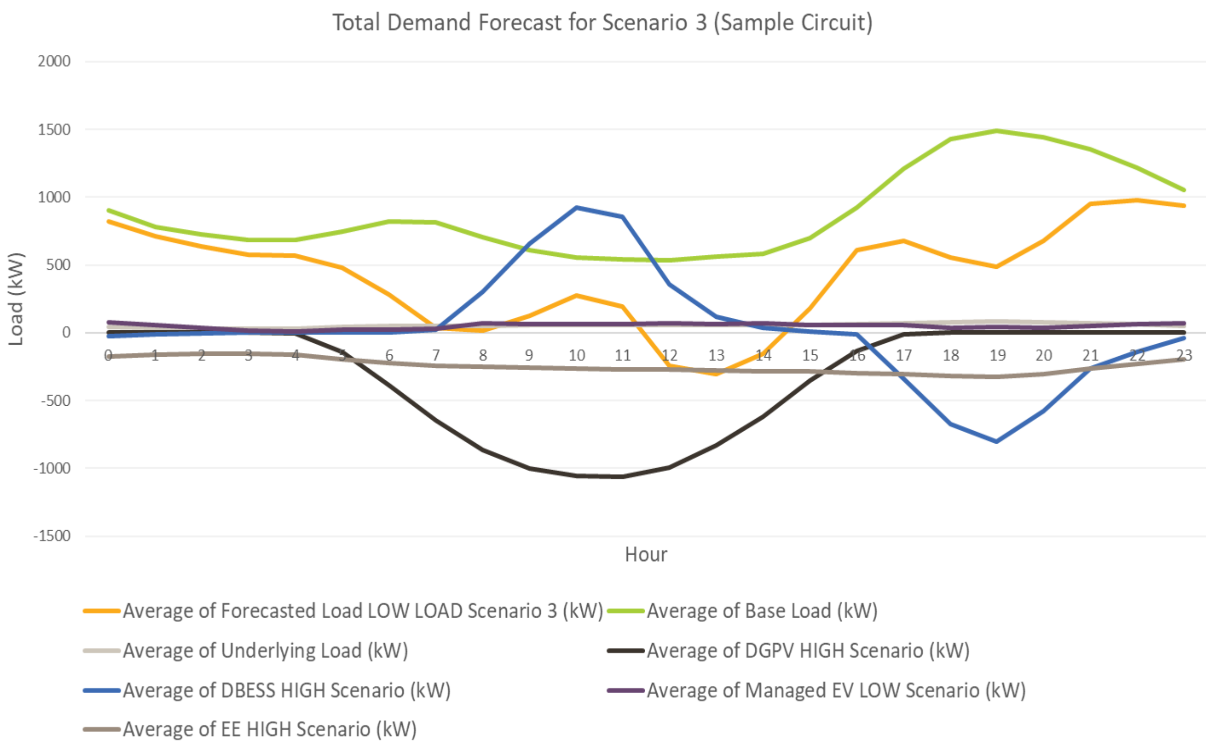

Figure 28: Total Demand Forecast for Scenario 3 (Sample Circuit)

This chart displays the same information as the previous, however it emphasizes the contribution of the forecast layers on the forecasted load shape. For this circuit there is a large contribution due to DGPV and DBESS on the average forecasted load.

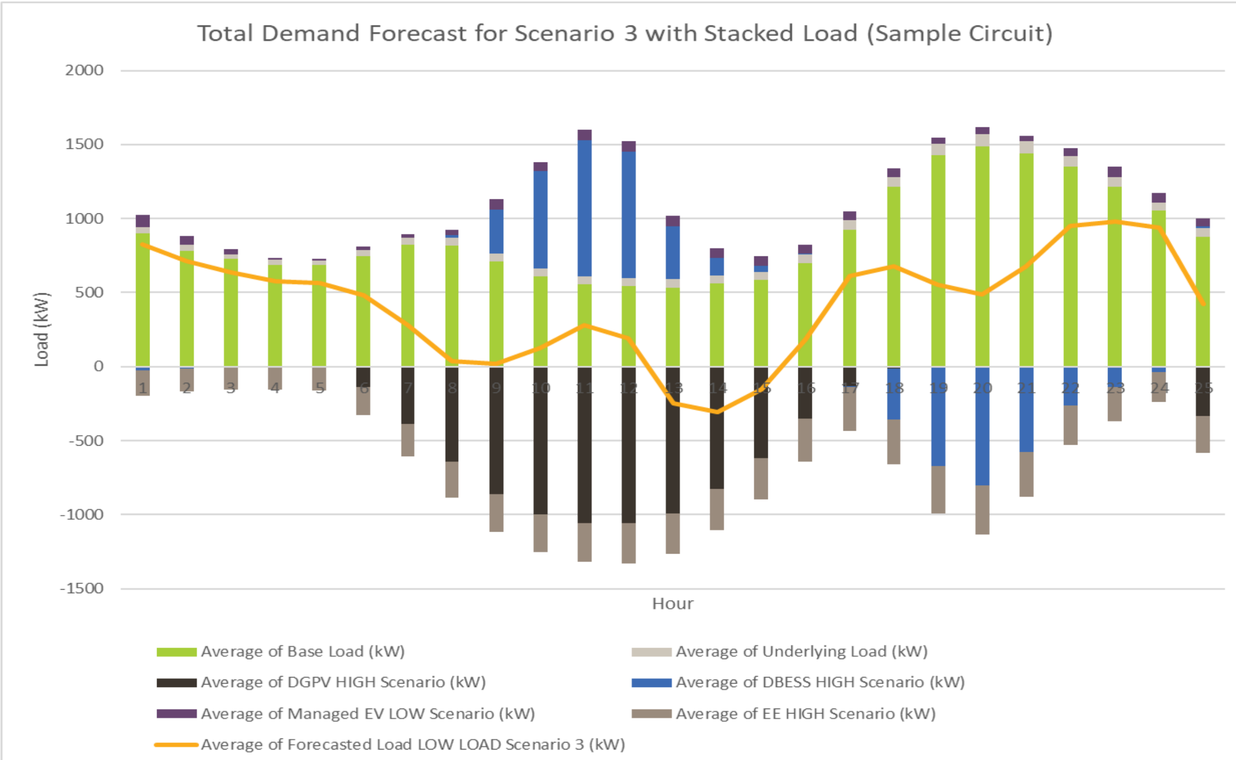

Figure 29: Total Demand Forecast for Scenario 3 with Stacked Load (Sample Circuit)

The process for extracting 8760 hourly data for the circuits and transformers from LoadSEER can be performed individually by scenario, layer selection, circuit (or transformer), and year. For each combination, a single file is required to be created and downloaded, which makes the process of extracting the 8760 hourly data for all scenarios, layers, circuits, transformer, and years time consuming and labor intensive. Therefore, the above sample circuit was selected to illustrate the effect of each layer under the different scenarios. The total demand forecast is described further in Section 3.1.

2.4.2 Forecast Allocation Based on Base Load and DGPV

The forecast allocation for Hawai'i Island and Maui County is based on existing load and DGPV as LoadSEER models are not yet available for these islands. This procedure mimics the allocation steps done in LoadSEER, but through a manual process. Therefore, the resulting location-based demand forecasts are not provided in a form as granular as the forecasts developed using LoadSEER. Through this manual process, peak load values are determined for each layer rather than the hourly demand profiles that LoadSEER can create. In general, the annual corporate forecast layers described in Section 2.3 are allocated amongst circuits using an allocation percentage for each circuit based on the base load or DGPV.

2.4.2.1 Forecasted Load Growth

As described in Section 2.3.1., the total annual underlying load to be allocated is first reduced by the total amount (MW) of service requests anticipated in the respective year to avoid double counting future loads. Next, the remaining underlying load is distributed amongst the circuits.

The amount allocated to each circuit is calculated based on the percentage of a circuit's base load relative to the sum of the base load for all circuits. This allocation process is repeated for each year (2021 through 2030) using the same percentage.

Finally, the underlying load allocated to each circuit is summed with the load growth adjustments (service requests) described in Section 2.2. to create the total forecasted load growth by circuit by year.

In summary, the steps to allocate the forecasted load growth by year is:

1. Determine the base load as a percentage of the sum of all circuit base loads.

$$\% \, Circuit\ Allocation_{Base\ Load} = \frac{Circuit\ Base\ Load}{\sum Circuit\ A\ Base\ Load + Circuit\ B\ Base\ Load + \cdots + Circuit\ n\ Base\ Load}$$

2. Determine the total underlying load to be allocated after accounting for service requests.

$$Total\ Underlying\ Load = Underlying\ Load\ Forecast - Service\ Requests$$

3. Allocate the underlying load from Step 2 using the percent allocation from Step 1.

$$\text{Underlying Load Allocation} = (\% \, Circuit\ Allocation_{Base\ Load}) \times (Total\ Underlying\ Load)$$

4. Sum the underlying load allocation from step 3 to the load growth adjustments described in Section 2.2.for the respective year.

$$Forecasted\ Load\ Growth = Service\ Requests + Underlying\ Load\ Allocation$$

5. Repeat steps 2 through 4 for each year in the study period.

While these steps are followed for Hawai'i Island and Lana'i, total amount of load anticipated due to service requests is greater than the underlying load forecast. Thus, only the service requests are allocated to the specific circuits where the new load growth is anticipated.

2.4.2.2 DER (DGPV and BESS)

The allocation of the DGPV and DBESS layers follow a similar procedure as the underlying load allocation in the previous section. However, rather than allocating the DER based on a circuit peak percentage, the allocation percentage is based on the historical residential DGPV allocation. This is consistent with the methodology used to determine the DER forecast allocation based on existing DER described in the *Distribution DER Hosting Capacity Grid Needs* document provided in the August Update.[21],[22]

In summary, the steps to allocate the DER layers by year are:

1. Calculate the executed DGPV in the selected programs[23] on each circuit as a percentage of total executed DGPV in those selected programs on that island.

$$\%\ Circuit\ Allocation_{DGPV} = \frac{Executed\ DGPV\ in\ selected\ programs\ on\ Circuit}{Total\ Executed\ DGPV\ in\ selected\ programs}$$

2. Allocate the DGPV layer (e.g., DBESS or DGPV) from Section 2.3.2 using the percent allocation from Step 1.

$$\text{DGPV Allocation} = (\%\ Circuit\ Allocation_{DGPV}) \times (Total\ DGPV\ Load)$$

3. Repeat step 2 for each year in the study period.

The above steps are used for both the DBESS and DGPV layers.

2.4.2.3 Electric Vehicle

The electric vehicle load layer allocation follows a similar process as the DER allocation described in Section 2.4.2.2. The EV load layer described in Section 2.3.3. is distributed

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21 *See* https://www.hawaiianelectric.com/documents/clean_energy_hawaii/integrated_grid_planning/20210803_heco_submittal_of_igp_inputs_and_assum_and_der_hosting_capacity.pdf

22 This is also consistent with the methodology described in the *Distribution DER Hosting Capacity Grid Needs November 2021 Update* filed concurrently with this report (Nov. 2021, Dkt. No. 2018-0165).

23 Selected programs include: Net Energy Metering ("NEM"), Feed-In Tariff ("FIT"), Customer Grid Supply ("CGS"), Customer Self-Supply ("CSS"), Customer Grid Supply Plus ("GSP"), Smart Export ("ISE"), Net Energy Metering Plus ("NEM Plus" or "NMP"), Standard Interconnection Agreement ("SIA"), Community-Based Renewable Energy ("CBRE") Phase 1, Power Purchase Agreement ("PPA").

amongst the circuits using the % Circuit Allocation based on residential DGPV calculated in step 1 of Section 2.4.2.2.

In summary, the steps to allocate the electric vehicle load by year are:

1. Allocate the electric vehicle load from Section 2.3.3 using the percent circuit allocation based on residential DGPV.

$$\text{EV Load Allocation} = (\%\ Circuit\ Allocation_{DGPV}) \times (Total\ EV\ Load)$$

2. Repeat step 1 for each year in the study period.

2.4.2.4 Energy Efficiency

The energy efficiency load layer allocation follows a similar process as the underlying load allocation described in Section 2.4.2.1. The energy efficiency load layer described in Section 2.3.4. is distributed amongst the circuits using the % Circuit Allocation calculated in step 1 of Section 2.4.2.1.

In summary, the steps to allocate the energy efficiency load by year are:

1. Allocate the energy efficiency load from Section 2.3.4 using the percent circuit allocation.

$$\text{EE Load Allocation} = (\%\ Circuit\ Allocation_{Base\ Load}) \times (Total\ EE\ Load)$$

2. Repeat step 1 for each year in the study period.

2.4.2.5 Total Demand Forecast

To create the location-based forecast, the annual values for each layer on each circuit are aggregated by year for years 2021 through 2030. The forecast layers for the forecasted load growth, DER (DGPV and DBESS), EV, and EE are added to the base load (See Section 2.1) to create the total demand forecast.

In summary, the total demand forecast for each year is:

$$Total\ Demand\ Forecast = \sum Base\ Load + Forecast\ Layers\ (Forecasted\ Load\ Growth, DER, EV, EE)$$

The total demand forecast is described further in Section 3.

3 Location-Based Forecasts

The location-based forecasts derived using the process described in Section 2 are provided by circuit and by transformer consistent with grid needs documentation described in the *Distribution Planning Methodology.*[24]

3.1 DEMAND FORECAST

The demand forecast lists the grid assets and shows the net peak forecast for these assets for years 2021 through 2030 and include:

- **Facility Type**: Substation transformer and/or circuit
- **Facility Name**: Substation transformer and circuit names
- **Equipment Rating (MVA)**: Transformer rating[25]
- **Peak Load (MW)**: Peak circuit load forecast for corresponding year

Demand forecasts by Circuit and Demand Forecasts by Transformer available on the Company website (see Appendix A: for a description of the files provided).

The following chart is a visual representation of the data that is provided in the demand forecast. The chart shows the peak day for 2030, extracted from the same residential circuit 8760 hourly Base scenario forecast shown in the previous section. The green plot is the Peak Day Base Load (historical load) and the orange plot is the total forecasted load (shown as Peak Day Forecasted Load BASE Scenario 1). The peak load value of the total forecasted load (orange) corresponds to the 2030 peak load value provided in the demand forecasts for circuits and transformers.

[24] DP methodology at 19.

[25] Transformer rating provided is the larger rating with fans operating ("FA") if applicable; otherwise, the rating with fans off ("OA") is provided.

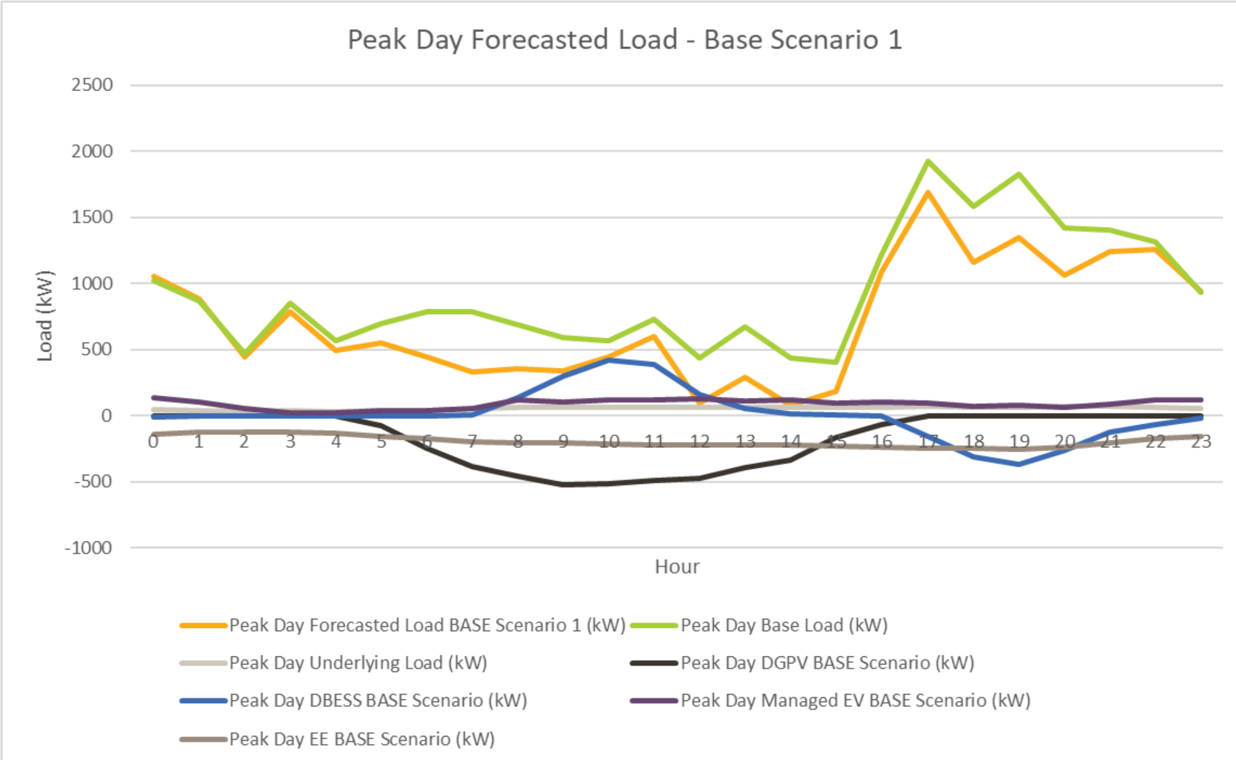

Figure 30: Peak Day Forecasted Load – Base Scenario 1

Note the sum of the circuit forecasts do not add up to the total transformer forecast. This occurs because the peaks of those circuits are not coincident and occur at different times throughout the year, whereas the transformer peak is determined as the peak of the combined hourly circuit profiles.

3.2 DEMAND FORECAST BY LOAD TYPE

A demand forecast by load type is provided for years 2021 through 2030. For each circuit, the corresponding transformer along with the following load type allocation is provided for each corresponding year on the Company website (see Appendix A: for a description of the files provided):

- **Forecasted Load Growth**: Underlying load allocation and new service requests
- **Base Load:** Historical peak demand[26]
- **DGPV**: Distributed generation photovoltaic systems load allocation
- **DBESS**: Distributed battery energy storage systems load allocation

[26] Provided for Hawai‘i Island and Maui County (Maui, Lāna‘i, and Moloka‘i) only. See Section 2.1.

- **Electric Vehicle Charging**: Managed or Unmanaged EV Charging load allocation
- **Energy Efficiency**: Energy efficiency load allocation

Similar to the non-coincidence of the circuit peaks to transformer peak, the demand forecast peak value for each year is determined by the summation of all the hourly forecast layers and underlying load. The values listed in the appendices show the maximum values of each layer for each year, which likely occur at different times throughout the year. Because of the noncoincidence of the values listed in the tables, the sum of those forecast values listed will not equal the net forecast value as illustrated in Figure 30 above.

To compare the impact of the different scenarios and layers, in addition to the residential circuit shown in the previous sections, the 8760 hourly data for a primarily commercial circuit was also compiled from LoadSEER. Both circuits have a relatively large amount of DGPV allocated in the circuit level forecast. A comparison of the circuits and the impact of the scenarios and different layers is discussed in the following sections.

3.2.1 Residential Circuit Example Using LoadSEER

The following chart is a comparison of the average hourly demand forecast (shown as Forecasted Load) for the final forecast year (2030) for the three scenarios for a circuit with primarily residential customers. Each line represents the average forecasted load for 2030 for a different scenario. The primarily residential circuit shows a noticeable difference between the three scenarios. The magnitude of the allocation is large in comparison to the existing load on the circuits, so their impact is more visible than on the primarily commercial transformer example in the following section.

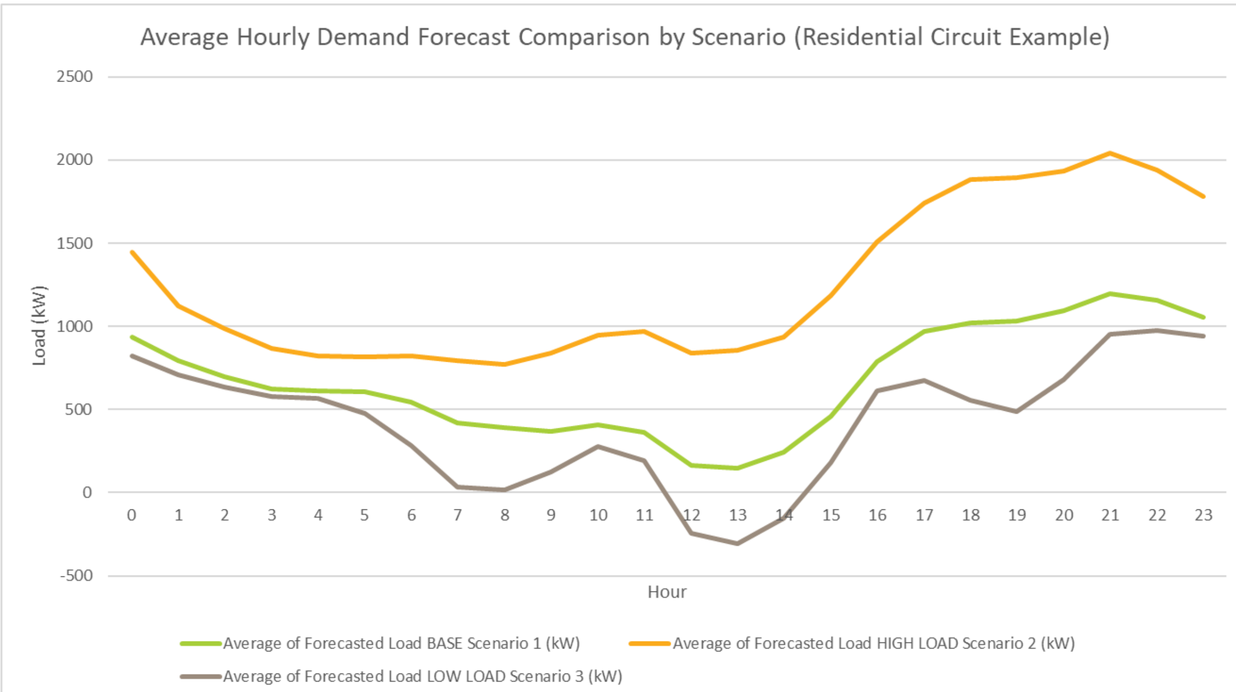

Figure 31: Average Hourly Demand Forecast Comparison by Scenario (Residential Circuit Example)

The following charts are for the Base scenario and shows the average base load, average forecasted load, and the individual forecast layers. This chart shows the forecasted hourly load shape and illustrates the impact the forecast layers have on the base load.

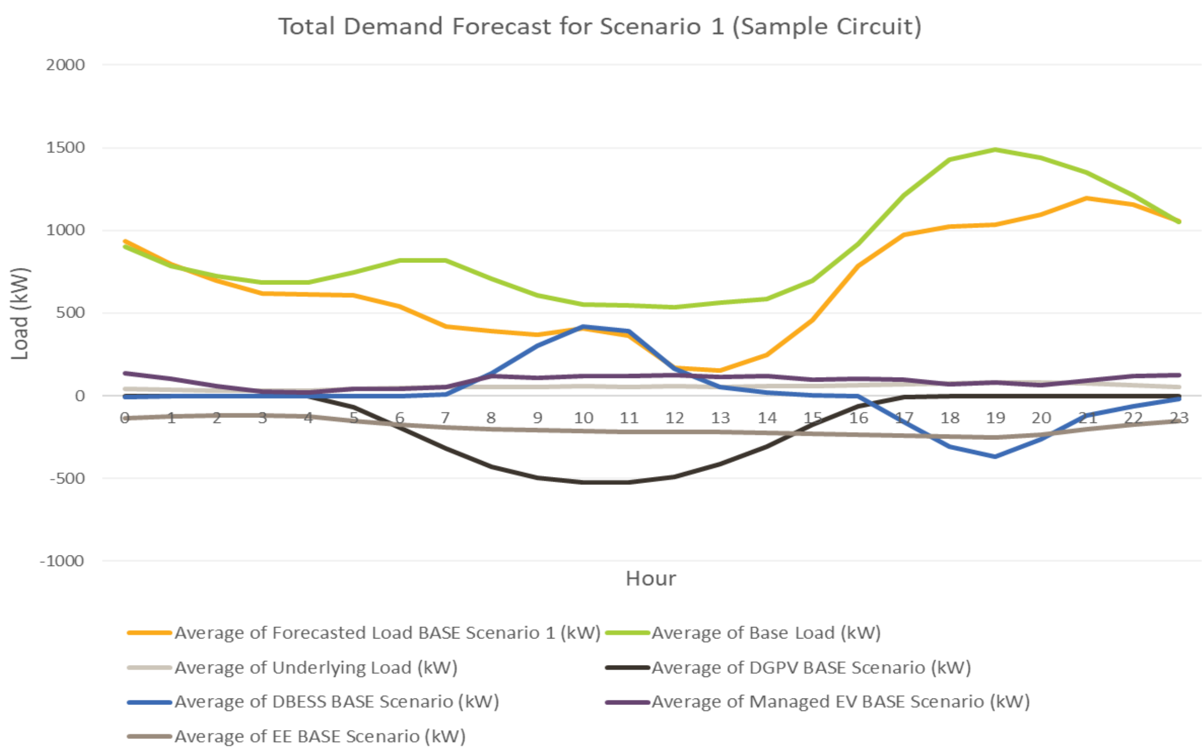

Figure 32: Hourly Demand Forecast (Residential Circuit Example)

The following chart is for the Base scenario and shows the average load profiles for the underlying load, DGPV, DBESS, EV, EE, and the cumulative impact of all the layers. The peak values provided in the demand forecast by load type are non-coincident, which can be visualized with this chart; the peak value for each layer occurs at different times.

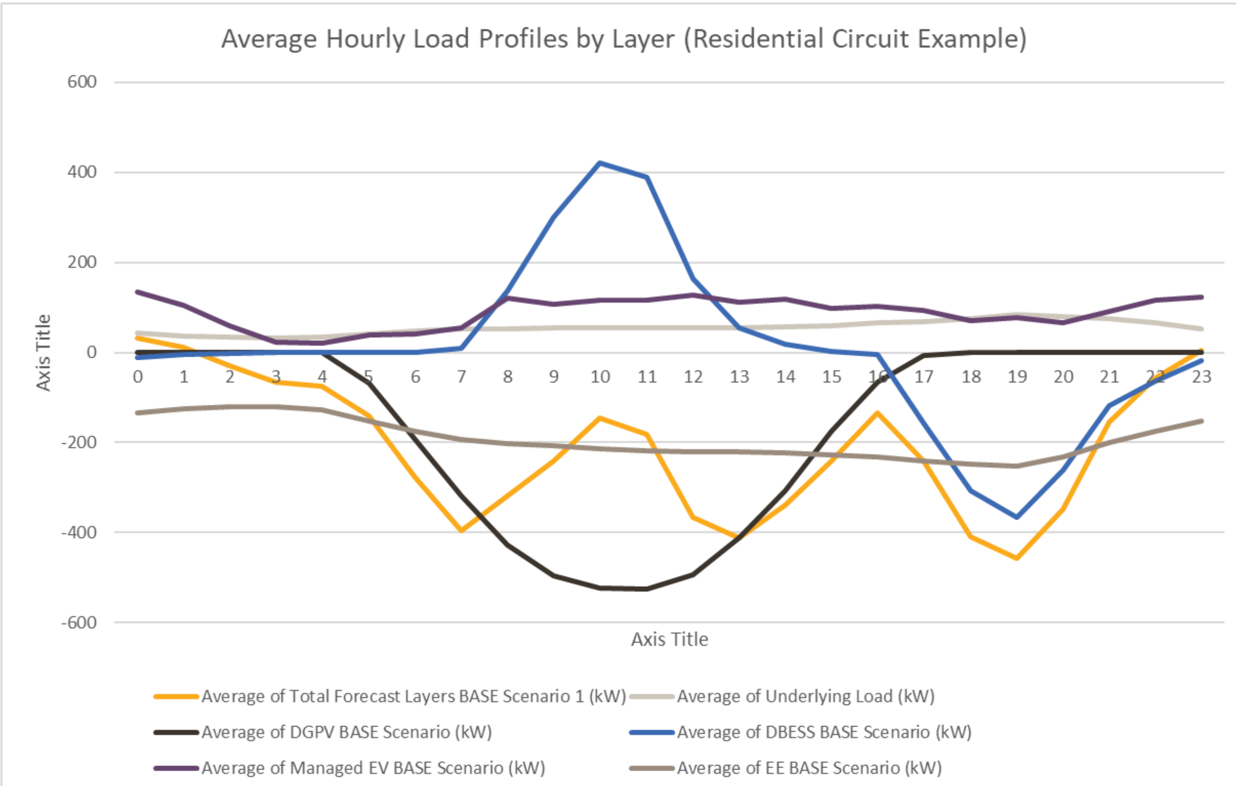

Figure 33: Average Hourly Load Profiles by Layer (Residential Circuit Example)

The following charts are for the Base scenario and show the forecasted peak day for 2030. This chart shows the forecasted hourly load shape and illustrates the impact the forecast layers have on the base load.

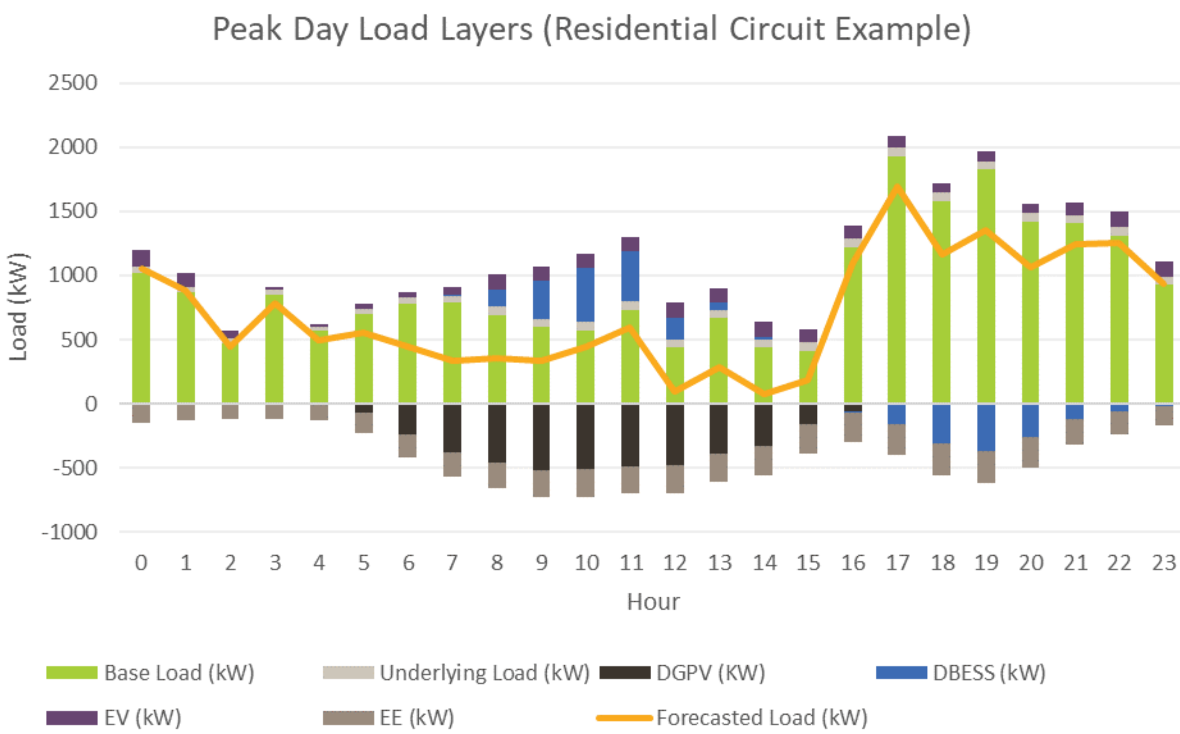

Figure 34: Peak Day Load Layers (Residential Circuit Example)

This chart includes the same layer data as the previous without the base load or forecasted load to focus on the individual layer contributions.

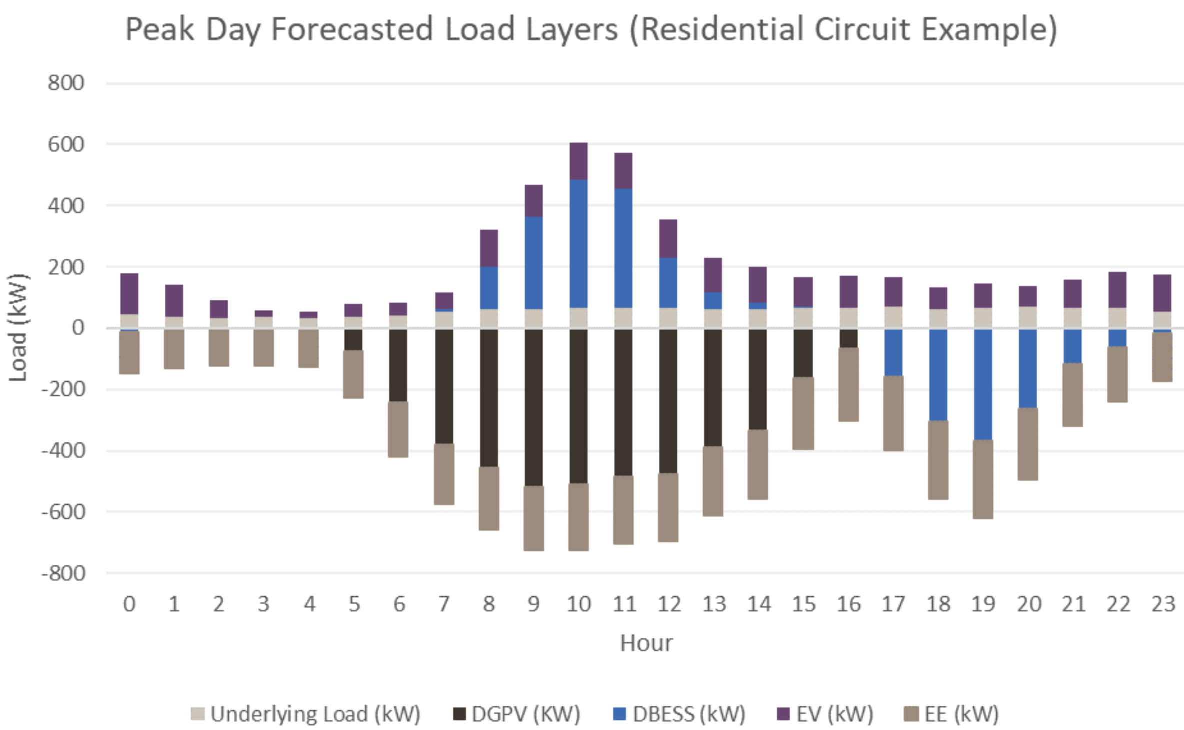

Figure 35: Peak Day Forecasted Load Layers (Residential Circuit Example)

3.2.2 Commercial Transformer Example Using LoadSEER

The following chart is a comparison of the average hourly demand forecast (shown as Forecasted Load) for the final forecast year (2030) for the three scenarios for a transformer with primarily commercial customers. Each line represents the average forecasted load for 2030 for a different scenario. The magnitude of the forecast layers is smaller in comparison to the existing load and service requests, so the cumulative impact of the different scenarios for this mainly commercial transformer is more subtle in comparison to the primarily residential circuit example in the previous section.

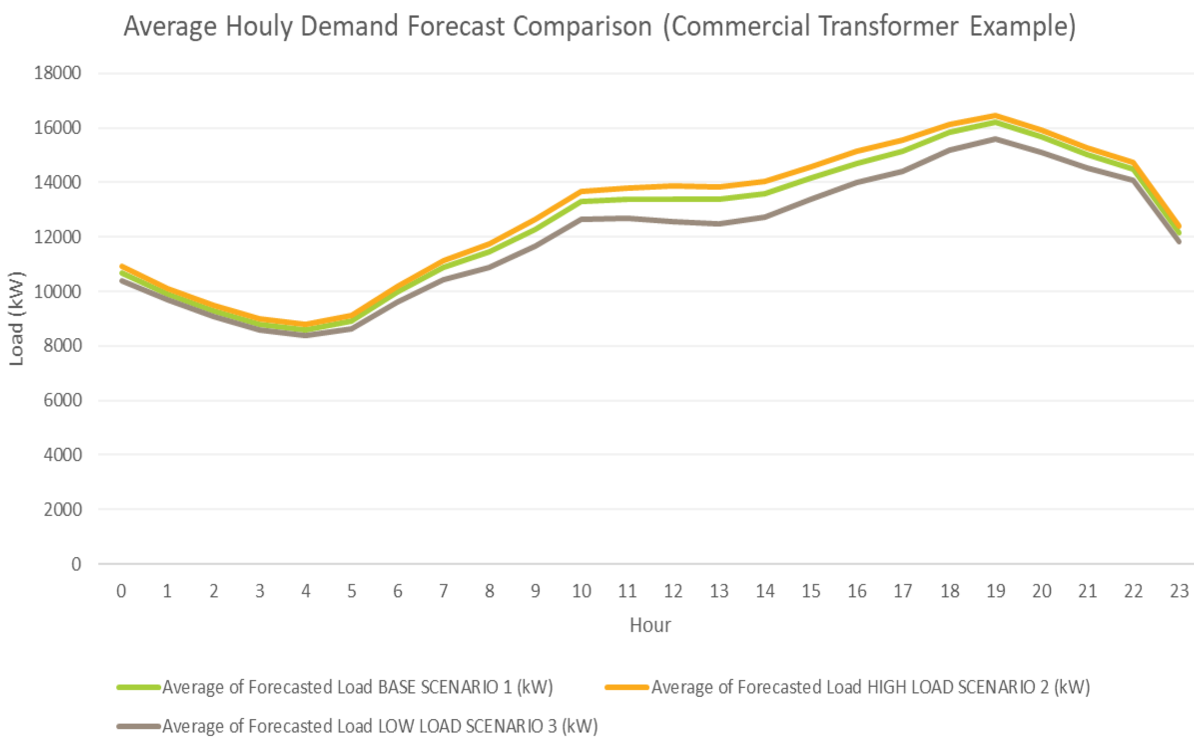

Figure 36: Average Hourly Demand Forecast Comparison by Scenario (Commercial Transformer Example)

The following charts are for the Base scenario and shows the average base load, average forecasted load, and the individual forecast layers. This chart shows the forecasted hourly load shape and illustrates the impact the forecast layers have on the base load.

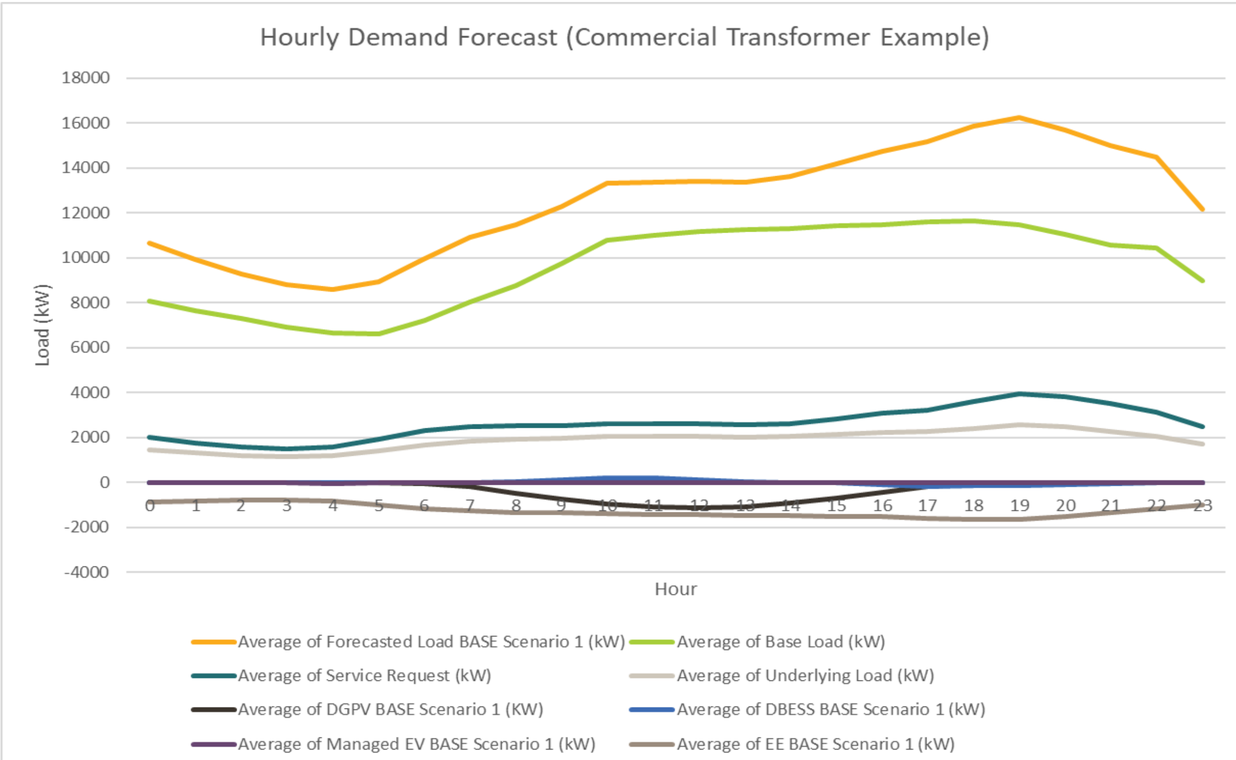

Figure 37: Hourly Demand Forecast (Commercial Transformer Example)

The following chart is for the Base scenario and shows the average load profiles for the service requests, underlying load, DGPV, DBESS, EV, EE, and the cumulative impact of all the layers. The peak values provided in the demand forecast by load type are non-coincident, which can be visualized with this chart; the peak value for each layer occurs at different times.

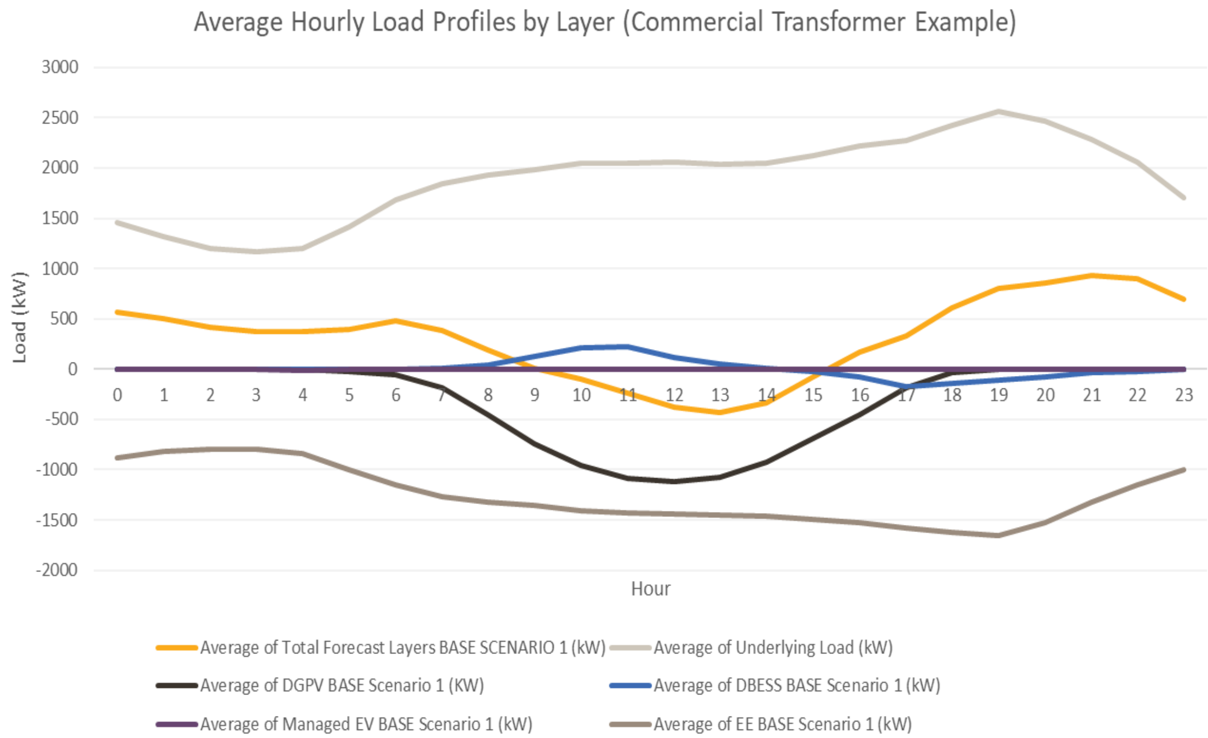

Figure 38: Average Hourly Load Profiles by Layer (Commercial Transformer Example)

The cumulative impact of all layers for each hour is shown below as the Forecasted Load in the following figure and compared against the individual load layers. The following charts are for the Base scenario and show the forecasted peak day for 2030. This chart shows the forecasted hourly load shape and illustrates the impact the forecast layers have on the base load.

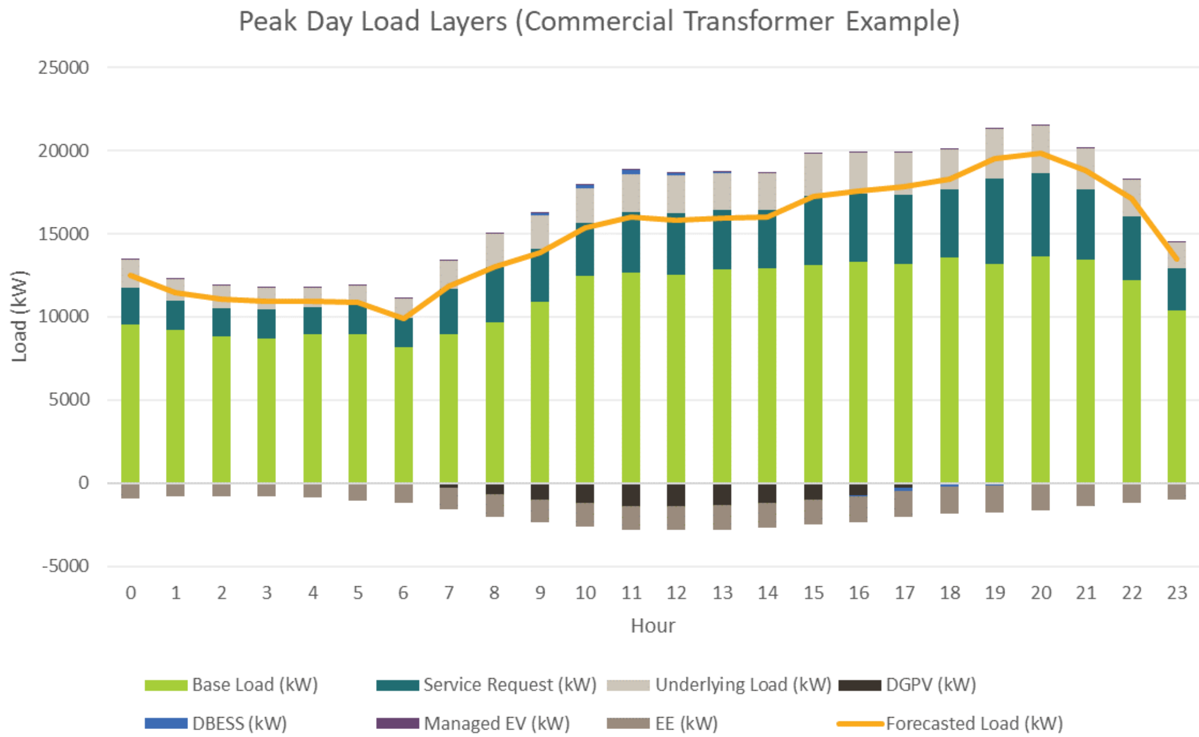

Figure 39: Peak Day Load Layers (Commercial Transformer Example)

This chart includes the same layer data as the previous without the base load or forecasted load to focus on the individual layer contributions.

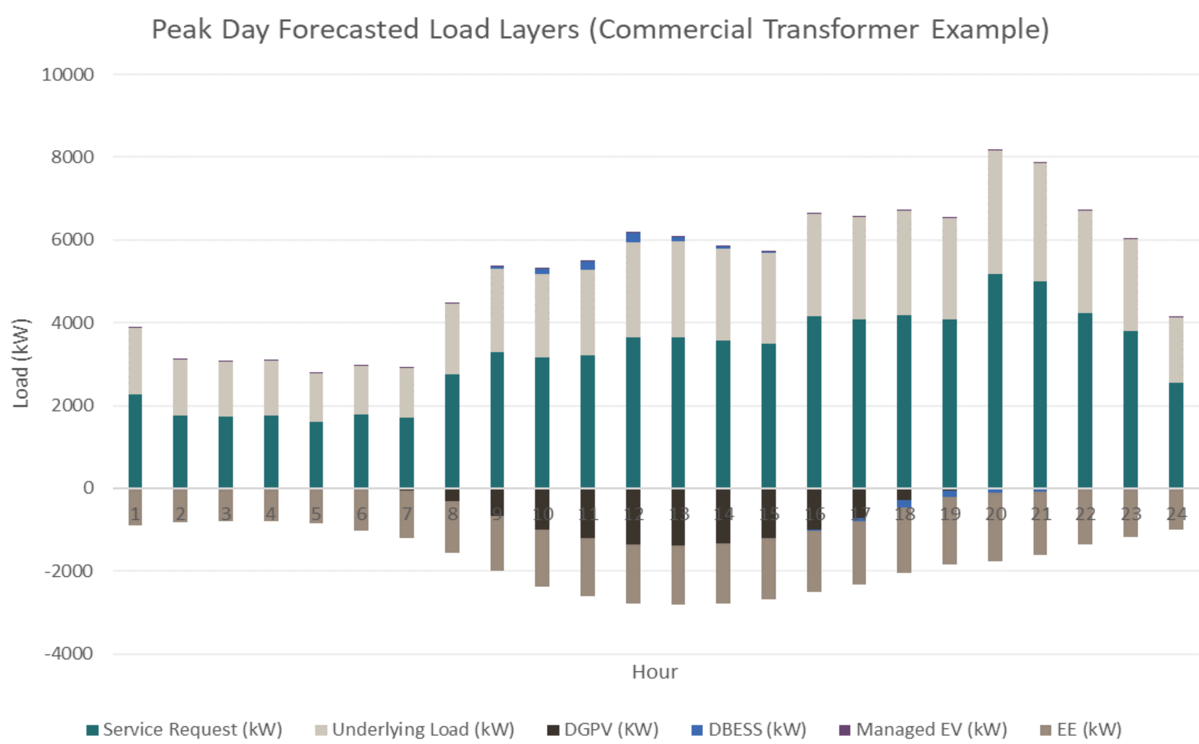

Figure 40: Peak Day Forecasted Load Layers (Commercial Transformer Example)

3.2.3 Circuit Example Based on Existing Load and DGPV

The charts in this section depict the total demand forecasts for a circuit on Hawaiʻi Island or Maui County that was developed with the different layers allocated based on the existing load and DGPV rather than through LoadSEER.

The following chart shows the total demand forecast under the three modeling scenarios for this example circuit.

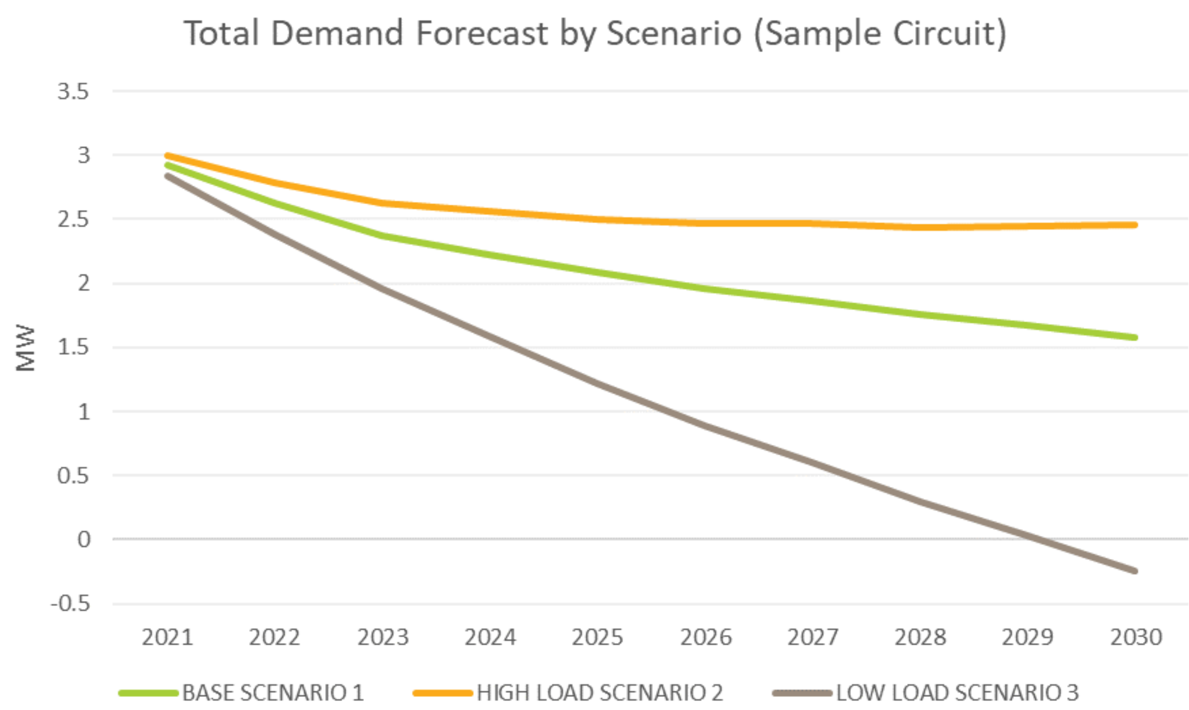

Figure 41: Total Demand Forecast Comparison by Scenario

The following charts show the total demand forecast by modeling scenario for the same example circuit broken down into the forecast layers. Since the forecast layers are small in comparison to the base load and total demand forecast, charts are also included with the total demand forecast and the base load layer removed to give a better picture of the breakdown of the Forecasted Load Growth, DER, EE, EV layers.

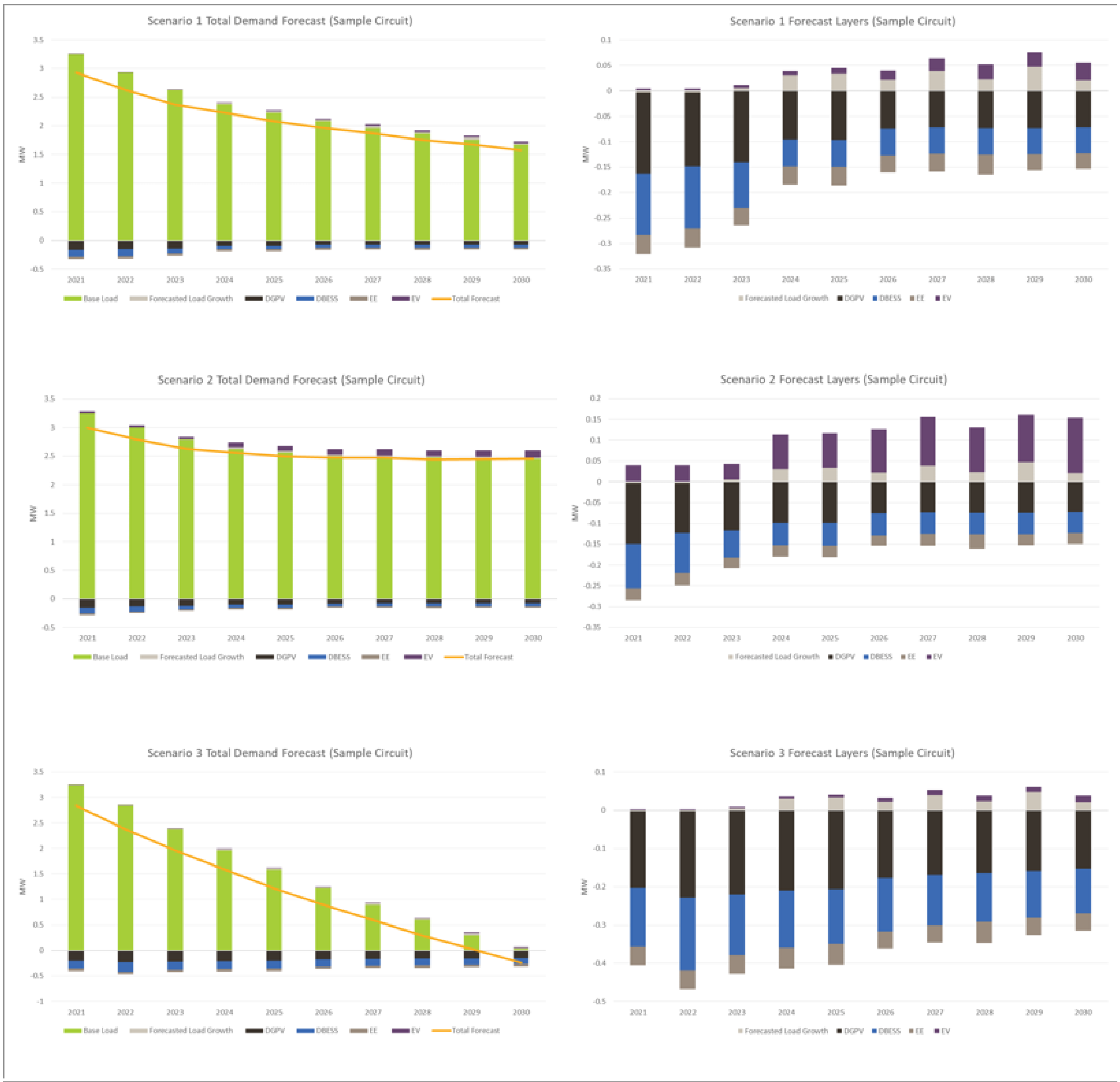

Figure 42: Total Demand Forecast and Forecast Layers by Scenario

4 Next Steps

As mentioned earlier, this document describes the first step of the Distribution Planning Process, the Forecast Stage.

A preliminary version of this report[27] and sample forecasts were provided to the Stakeholder Technical Working Group ("STWG") for review and to receive feedback. The process to derive the forecasts was discussed with the Stakeholder Technical Working Group ("STWG") on October 6, 2021. Shortly thereafter on October 8, 2021, the location-based forecasts for each island and each scenario were provided on the Company website as well for review.[28] A summary of the feedback received from the STWG is discussed in Appendix B: and will be considered for incorporation into the GNA Review Point.

After review, no revisions to the forecasts provided on October 8 were necessary at this time. A summary of the forecasts available on the Company website is outlined in Appendix A:.

In the next stage of the planning process, the analysis stage, the location-based forecasts will be used to assess the adequacy of the electric distribution system by comparing the forecasts against the distribution planning criteria. Through this next step, grid needs required to serve load growth and accommodate higher levels of DER will be identified.

[27] *See* https://www.hawaiianelectric.com/documents/clean_energy_hawaii/integrated_grid_planning/20211008_location_based_distribution_forecasts_draft.pdf

[28] *See* https://www.hawaiianelectric.com/clean-energy-hawaii/integrated-grid-planning/stakeholder-engagement/key-stakeholder-documents

Appendix A: Workbook Index

The location-based forecasts for each scenario by island are available on the Company's website in Excel workbooks as the tables are too voluminous to provide in table format herein.[29]

A summary of the workbooks is provided below.

Table A-1: Location-Based Distribution Forecasts Workbook Index

Island	Scenario	Modeling Case	Workbook[30]
O'ahu	1	Base	Oahu Location-Based Forecasts Scenario 1 (EXCEL)
	2	High Load Customer Technology Adoption Bookend	Oahu Location-Based Forecasts Scenario 2 (EXCEL)
	3	Low Load Customer Technology Adoption Bookend	Oahu Location-Based Forecasts Scenario 3 (EXCEL)
Hawai'i Island	1	Base	Hawaii Location-Based Forecasts Scenario 1 (EXCEL)
	2	High Load Customer Technology Adoption Bookend	Hawaii Location-Based Forecasts Scenario 2 (EXCEL)
	3	Low Load Customer Technology Adoption Bookend	Hawaii Location-Based Forecasts Scenario 3 (EXCEL)
Maui Island	1	Base	Maui Location-Based Forecasts Scenario 1 (EXCEL)

[29] *See* https://www.hawaiianelectric.com/clean-energy-hawaii/integrated-grid-planning/stakeholder-engagement/key-stakeholder-documents

[30] File name as it appears on the Company website.

Island	Scenario	Modeling Case	Workbook[30]
	2	High Load Customer Technology Adoption Bookend	Maui Location-Based Forecasts Scenario 2 (EXCEL)
	3	Low Load Customer Technology Adoption Bookend	Maui Location-Based Forecasts Scenario 3 (EXCEL)
Lanaʻi	1	Base	Lanai Location-Based Forecasts Scenario 1 (EXCEL)
	2	High Load Customer Technology Adoption Bookend	Lanai Location-Based Forecasts Scenario 2 (EXCEL)
	3	Low Load Customer Technology Adoption Bookend	Lanai Location-Based Forecasts Scenario 3 (EXCEL)
Molokaʻi	1	Base	Molokai Location-Based Forecasts Scenario 1 (EXCEL)
	2	High Load Customer Technology Adoption Bookend	Molokai Location-Based Forecasts Scenario 2 (EXCEL)
	3	Low Load Customer Technology Adoption Bookend	Molokai Location-Based Forecasts Scenario 3 (EXCEL)

Appendix B: Stakeholder Feedback

The Company recognizes stakeholder engagement as an integral part of the IGP process. In an effort to proactively solicit stakeholder feedback on this report, the Company provided a draft report to stakeholders for review and comment on October 1, 2021. The Company subsequently met with the STWG on October 6, 2021 to address questions and receive feedback from the stakeholders. Meeting minutes capturing feedback from the discussion and presentation materials from the meeting can be found on the IGP website. [31]

Additionally, the Company received feedback from various Organizations which is consolidated anonymously below. Feedback from stakeholders in this section are shown in bold, and the Company's response to the questions or feedback are shown in italics.

1. **At 39, if the service requests are greater than the underlying load forecast in certain circuits, would this indicate a forecasting error?**

   The corporate underlying load forecast is allocated to the circuit level using spatial forecasting capabilities to aid in the identification of granular pockets of area load growth. The forecasts have inherent uncertainties. In comparison, service requests are actual customer requests for specific new loads which are typically based on detailed watts per unit or watts per square foot estimates.

2. **Are the location-based distribution forecasts calibrated to the overall load forecast (i.e. if all location-based forecasts were summed up, would they equal the overall system load forecast?)**

   The location-based distribution forecasts are related to the overall load forecast by the incremental system load growth that is used as an input file to LoadSEER. Forecasted layers are grown on the distribution circuits until the aggregate amount reaches the respective corporate limit specified by the input files. The aggregated amount will roughly

[31] *See* https://www.hawaiianelectric.com/documents/clean_energy_hawaii/integrated_grid_planning/stakeholder_engagement/working_groups/stakeholder_technical/20211006_stwg_meeting_notes.pdf

equal the incremental value of the corporate forecast. However, because LoadSEER is meant to be used at the distribution level, it is normally not recommended to aggregate forecasts above the substation level and they will not sum to the overall system load forecast.