Appendix E:
Location-Based Distribution Grid Needs

Hawaiian Electric

Location-Based Distribution Grid Needs

March 2023

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1. Introduction

This document describes the development of the location-based distribution grid needs that are derived from the Distribution Planning process and will be used as part of the Integrated Grid Planning ("IGP") process. 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.

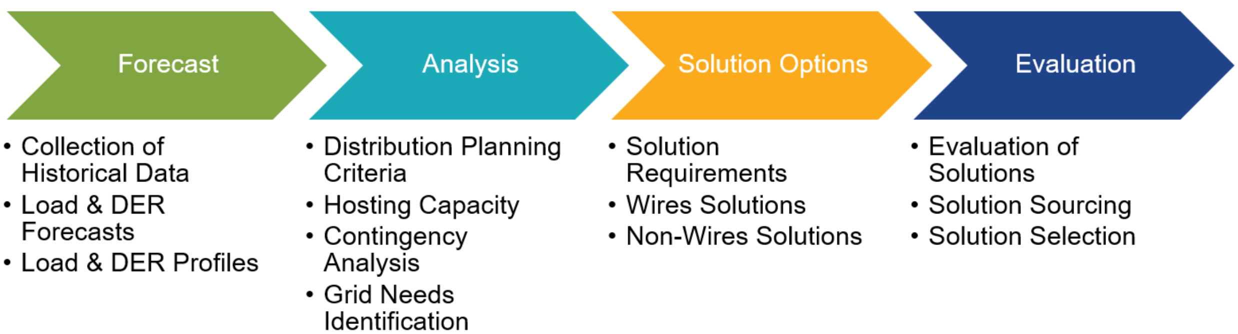

Figure 1-1: Stages of the Distribution Planning Process

On November 5, 2021, the Companies submitted their Location-Based Distribution Forecasts ("November 2021 Forecasts") in the IGP Grid Needs Assessment Methodology Review Point filed under Docket No. 2018-0165.[1] That document described the first stage, the Forecast Stage. It included the methodology to develop substation transformer and circuit location-based forecasts in accordance with the Distribution Planning Process described in the *Distribution Planning Methodology* document, updated to address the Technical Advisory Panel comments and questions.[2] On March 3, 2022, the

[1] *See* Hawaiian Electric Exhibit 3 – Location-Based Distribution Forecasts filed on November 5, 2021 in Docket No. 2018-0165, Instituting a Proceeding to Investigate Integrated Grid Planning.

[2] *See* Hawaiian Electric Companies' Grid Needs Assessment Methodology Review Point, Exhibit 1 Distribution Planning Methodology, filed on November 5, 2021 in Docket No 2018-0165.

Commission stated it "is satisfied with how Hawaiian Electric described the purpose and functionality of its modeling tools and accepts Hawaiian Electric's explanation of the modeling tools it uses…".[3]

This document describes the subsequent process (see "Analysis" in Figure 1-1) to identify the grid needs required based on the November 2021 Forecasts. For this analysis, the adequacy of the electric distribution system is assessed by comparing the location-based distribution forecasts against the distribution planning criteria described in the *Distribution Planning Methodology* to determine if the distribution circuits and substation transformers can serve the forecasted load growth (includes layers for distributed energy resources, electric vehicles, energy efficiency, and time of use). If the planning criteria is not met, grid needs required to meet the planning criteria are identified. This process differs from the hosting capacity grid needs which assesses each circuit's ability to accommodate DER growth specifically and as described in the *Distribution DER Hosting Capacity Grid Needs.*[4] These two analyses have the potential to overlap in requirements, since both consider contributions from DER to different extents; however, in this current planning horizon there were no circuits found with differing grid needs for the location-based distribution forecast and DER hosting capacity.

This 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 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 location-based distribution forecasts filed in November 2021 were developed using the corporate forecasts and scenarios provided in the Hawaiian Electric Revision to Updated and Revised Inputs and Assumptions ("August Update") filed on August 19, 2021.[5] The forecasts were based on three scenarios to provide a range of higher and lower loads: the Base, High Load Customer Technology Adoption Bookend, and the Low Load Customer Technology Adoption Bookend. On March 3, 2022, the Commission requested a fourth scenario, Fast Customer Technology Adoption, to "reflect a plausible future aligned with the State's RPS and emissions reductions goals".[6]

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

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[3] *See* Order No. 38253 issued on March 3, 2022 in Docket No. 2018-0165, Approving, with Modifications, Hawaiian Electric's Revised Inputs and Assumptions.

[4] *See* Hawaiian Electric Companies' Grid Needs Assessment Methodology Review Point, Exhibit 4 Distribution DER Hosting Capacity Grid Needs, filed on November 5, 2021 in Docket No 2018-0165.

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

[6] *See* Order No. 38253 issued on March 3, 2022 in Docket No. 2018-0165, Approving, with Modifications, Hawaiian Electric's Revised Inputs and Assumptions

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

the system level are disaggregated to create a total demand forecast for each substation transformer and circuit. The four scenarios and the associated corporate forecast layers are summarized below.

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
4	Fast Customer Technology Adoption	High Forecast	High Forecast	High Forecast	Managed EV Charging

Since the November 2021 Forecasts were developed, the Company has received various service requests for new loads and the November 2021 Forecasts were updated to reflect these changes. The analysis herein references the updated forecasts that are referred to as the November 2021 Forecast Update in this document.[8]

1.1 Location-Based Grid Needs

The overall process and methodology, using modeling tools such as LoadSEER[9] to develop the grid needs driven by location-based demand forecasts is provided herein. Since this report addresses the location-based grid needs specifically, the distribution planning process figure discussed at the Stakeholder Technical Working Group meeting in June 2021[10] was streamlined to show details related only to this analysis and is shown in Figure 1-2. Potential wires and non-wires alternative ("NWA")

8 The updated 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 Section 5 for a description of the files provided.

9 *See* Hawaiian Electric, *Distribution Planning Methodology*, November 2021 for an overview of the LoadSEER and Synergi models.

10 *See* Hawaiian Electric, *Distribution Planning Methodology*, November 2021 for descriptions of the distribution planning criteria.

solutions opportunities using the *Non-Wires Opportunity Evaluation Methodology*[11] will be evaluated separately as part of the IGP process.

The distribution planning criteria establishes technical guidelines to ensure the distribution system has adequate capacity to serve load growth and reliability (e.g., back-tie capability) for the Company's customers. Thus, planning for operation under both normal and contingency conditions is necessary as described in the *Distribution Planning Methodology*.

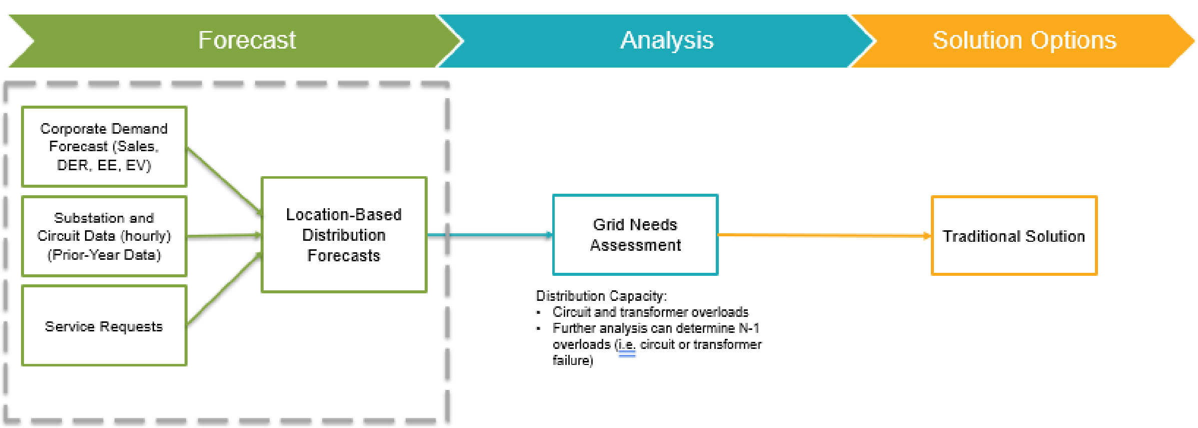

Figure 1-2 Location-Based Distribution Grid Needs Identification Stages

The following steps are used to identify substation transformers and circuits with planning criteria violations in the study period based on the forecast scenarios described above:

1. Determine the demand forecast (kW) by substation transformer and circuit.
2. Screen substation transformers and circuits for analysis.
3. Perform hourly grid needs analysis.
4. Identify solution options.

The first step above was described in the November 2021 Forecasts. That process developed the net peak forecast by substation transformer and circuit. Initially, when the distribution planning process started in year 2021, the study period spanned the next ten years (year 2021 through 2030). For the purposes of this report, the study period was adjusted to align with the current year and spans year 2023 through 2030. This report focuses on steps 2 and 3 to describe the analysis to identify the grid needs resulting from the demand forecasts.

[11] The Non-Wires Opportunity Evaluation Methodology was filed in the Grid Needs Assessment (Nov. 2021, Dkt. No. 2018-0165). An updated methodology is provided in Appendix F: NWA Opportunity Evaluation Methodology March 2023 Update of this filing to reflect the first time applying this methodology in the IGP cycle and additional feedback received from the Technical Advisory Panel such as defined thresholds for the NWA evaluation criteria.

2. Analysis

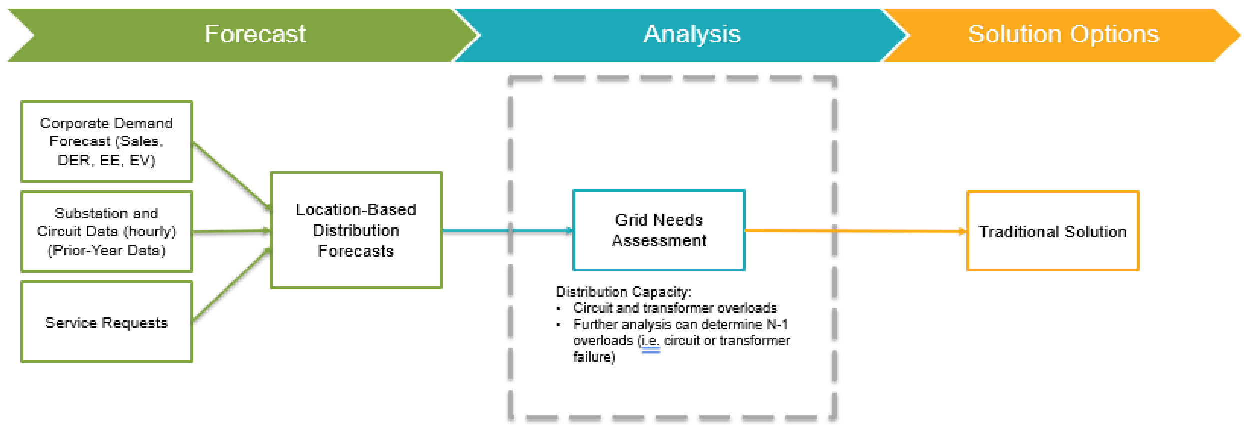

Figure 2-1 Analysis Stage of the Distribution Planning Process

This section describes steps 2 and 3 used to identify circuits and transformers that violate the distribution planning criteria indicating a grid need:

1. Determine the demand forecast (kW) by substation transformer and circuit.
2. **Screen transformers and circuits for analysis.**
3. **Perform hourly grid needs analysis.**
4. Identify solution options.

Planning criteria violations occur when there is existing or forecasted thermal loading or voltage levels on the Company's circuits or substation transformers that are outside of the acceptable range identified in the *Distribution Planning Methodology*.[12] An assessment for planning criteria violations was conducted for both normal condition and contingency (N-1) condition.

2.1 Screening Circuits and Transformers

Initially, substation transformers and circuits are screened to determine if there are violations based on the forecasted annual peak demand. If there is insufficient capacity to serve the forecasted demand,

[12] Distribution planning criteria applied to 46 kV and below for circuits on O'ahu and 12 kV and below for circuits on Hawai'i Island, Maui, Lāna'i, and Moloka'i. Distribution substation transformer planning criteria applied to 46 kV to 12 kV transformers.

additional hourly analysis is performed to determine if there is a grid need. This process is summarized in the following figure.

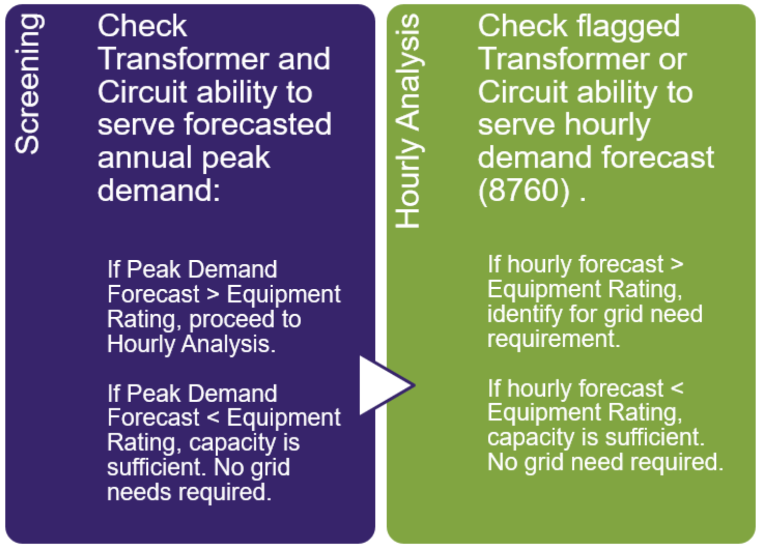

Figure 2-2: Summary of Screening and Hourly Analysis Process

The steps described in this section to select the substation transformers and circuits for analysis were repeated for each of the forecast scenarios: Base, High Load Customer Technology Adoption, Low Load Customer Technology Adoption, and Fast Customer Technology Adoption.

The screening process flags substation transformers and circuits for planning criteria violations to determine if there is a potential for identifying a grid need. The thermal rating or equipment rating is compared against the respective annual forecast in the November 2021 Forecast Update. Transformers and circuits are selected for further analysis if the forecast is greater than the thermal or equipment rating. This comparison is done for each year of the forecast to determine in what year(s) the violation(s) occur.

If the Demand Forecast by Transformer is less than the Transformer Rating or the Demand Forecast by Circuit is less than the Equipment Rating, there are no potential grid needs and no further analysis is required.

2.2 Screening Examples with No Potential Grid Needs

For the following substation transformer, the total demand forecast for that transformer is lower than the transformer rating for the entire period. Similar to the circuit example above, there are no potential grid needs and no further analysis required.

Table 2-1: Substation Transformer Screening Example – No Grid Needs

Substation Transformer	Equipment Rating (MVA)	Demand Forecast by Transformer (MW)									
		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
KEWALO 1	12.5	5.997	6.045	6.613	6.621	6.625	6.607	6.618	6.603	6.625	6.614

For the following circuit, the total demand forecast is lower than the equipment rating for the entire period. Therefore, there are no potential grid needs and no further analysis is required.

Table 2-2: Circuit Screening Example – No Grid Needs

Circuit	Equipment Rating (MVA)	Demand Forecast by Circuit (MW)									
		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
KEWALO 1	9.1	2.077	2.109	3.330	3.330	3.314	3.308	3.306	3.304	3.302	3.297

The screening process is performed for operation under normal conditions and operation under contingency conditions with separate criteria for each type.

2.2.1 Normal Condition

The screening criteria to flag substation transformers and circuits for planning criteria violations and subsequent analysis is based on the normal equipment rating (e.g., thermal rating). Circuits are selected for analysis if the thermal rating of the main conductor out of the substation under normal conditions is lower than the total demand forecast for that circuit (i.e. "Demand Forecast by Circuit"). Substation transformers are selected for analysis if the equipment rating[13] is lower than the total demand forecast for that transformer (i.e. "Demand Forecast by Transformer"). This comparison is done for each year of the forecast to determine in what year(s) the violation(s) occur.

In general, analysis occurs if:

- **Substation Transformer**: Demand Forecast by Transformer (MW) is greater than the Transformer Rating (MVA)[14]
- **Circuits**: Demand Forecast by Circuit (MW) is greater than Equipment Rating (MVA)[15]

[13] Equipment rating is the larger rating with fans operating ("FA") if applicable; otherwise, the rating with fans off ("OA") is provided. Equipment rating is the highest installed nameplate capacity rating (OA/FA) of the distribution substation transformer (MVA).

[14] Highest installed nameplate capacity rating (OA/FA) of the distribution substation transformer. If available, a 0% loss of life rating is used for normal conditions.

[15] Thermal rating of the main conductor out of the substation under normal conditions.

If the Demand Forecast by Transformer is less than the Transformer Rating or the Demand Forecast by Circuit is less than the Equipment Rating, there are no grid needs and no further analysis is required.

If a transformer or circuit is flagged for analysis, the hourly grid needs are determined using the approach described in Section 2.3.

Normal Condition Screening Example

An example of the substation transformer selection process is shown below for the Kewalo T3 substation transformer on O'ahu using the Base Scenario. The 50 MVA Equipment Rating is compared against the Demand Forecast by Circuit (MW) for each year of the forecast (years 2021 through 2030). From year 2027 through 2030, the forecast is higher than the Equipment Rating as shown highlighted in orange. Therefore, the transformer is selected for further analysis.

Table 2-3: Substation Transformer Screening Example – Normal Condition

Substation Transformer	Equipment Rating (MVA)	Demand Forecast by Transformer (MW)									
		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Kewalo T3	50	24.483	25.171	24.995	32.411	36.316	45.101	59.946	60.019	60.049	60.074

An example of the circuit selection process is shown below for the Kewalo 7 circuit on O'ahu using the Base Scenario. The 17 MVA Equipment Rating is compared against the Demand Forecast by Circuit (MW) for each year of the forecast (years 2021 through 2030). From year 2026 through 2030, the forecast is higher than the Equipment Rating as shown highlighted in orange. Therefore, the circuit is selected for further analysis.

Table 2-4: Circuit Screening Example – Normal Condition

Circuit	Equipment Rating (MVA)	Demand Forecast by Circuit (MW)									
		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Kewalo 7	17.0	8.459	8.775	8.631	10.143	12.491	19.016	34.547	34.688	34.659	34.628

2.2.2 Contingency Condition (N-1)

Because there may be various switching options for contingency conditions, it isn't feasible to evaluate each N-1 loading scenario against equipment ratings. Instead, the initial screening criteria to flag transformers and circuits for planning criteria violations under contingency conditions (N-1) is to compare the forecast against 75% of the equipment rating. Seventy-five percent of equipment rating was selected based on engineering judgement to select transformers and circuits for more detailed analysis. The equipment with demand exceeding the 75% threshold would be limited in the amount of backup capacity that it provides in a contingency scenario. This estimate was shown to be rather conservative since at most 64 out of 351 transformers and 90 out of 635 circuits were flagged for further analysis in a scenario[16], which is about 18% and 14%, respectively.

Transformers and circuits are selected for analysis if Demand Forecast by Transformer or Demand Forecast by Circuit is greater than 75% of the respective Equipment Rating. This comparison is done for each year of the forecast to determine in what year(s) the violation(s) occur.

In general, analysis occurs if:

- **Substation Transformer**: Demand Forecast by Transformer (MW) is greater than 75% of Transformer Rating (MVA)[17]
- **Circuits**: Demand Forecast by Circuit (MW) is greater than 75% of Equipment Rating (MVA)[18]

If the Demand Forecast by Transformer is less than 75% of the Transformer Rating or the Demand Forecast by Circuit is less than 75% of the Equipment Rating, there are no grid needs and no further analysis is required.

If a transformer or circuit is flagged for additional analysis, the hourly grid needs are determined using the approach described in Section 2.3.

2.3 Hourly Grid Needs Analysis

Once a substation transformer or circuit is identified for further analysis using the screening criteria described in Section 2.1, the next step is to perform a more detailed analysis to determine if there is a criteria violation and if there is, define the hourly grid needs in technology-neutral terms: capacity (MW), energy (MWh), and duration (hours). This is done by creating an hourly ("8760") profile[19] derived from the annual peak demand forecast using the November 2021 Forecast Update. The 8760 profile is compared against the equipment rating to determine the hourly grid needs as was described above in the screening process using the annual forecast.

The capacity (kW) need or magnitude of the overload is calculated by the greatest difference between the forecasted demand and the equipment rating. The annual energy requirement (MWh) is calculated by summing the magnitude of overload hours in a calendar year. Lastly, the duration (hours) is calculated based on the maximum hours in a single day where there are overloads.

[16] The highest number of flagged transformers and circuits occurred in the High Load Customer Technology Adoption Bookend case, or Scenario 2.

[17] Highest installed nameplate capacity rating (OA/FA) of the distribution substation transformer. If available, a 1% loss of life rating is used for contingency conditions.

[18] Thermal rating of the main conductor out of the substation under normal conditions.

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

Defining the hourly grid needs is similar in concept for all islands, but performed using different tools. As mentioned in the November 2021 Forecasts, LoadSEER was used to develop the location-based forecasts for O‘ahu, but was unavailable for the neighbor island modeling.[20] Thus, LoadSEER was used to perform the analysis to determine the hourly grid needs for O‘ahu. A process to create similar 8760 profiles for the neighbor islands was developed using a scaling method. These two processes are described in the following sections.

2.3.1 LoadSEER

The 8760 profiles are developed using LoadSEER and are based on the annual demand forecasts.[21] LoadSEER creates an 8760 profile of the forecasted demand for each transformer and/or circuit from years 2023 to 2030. Similar to the screening process described in Section 2.1, the hourly forecasted demand (kW) is compared against the equipment rating. If the forecasted demand is greater than the equipment rating, that hour is noted as having an overload.

2.3.2 Scaling Method

In the absence of LoadSEER modeling to develop 8760 profiles, a scaling method is used to mimic the process done in LoadSEER to create hourly demand forecasts by circuit and transformer.

This process starts with the historical hourly profile for the circuit used to determine the circuit peak loads.[22] The unitized profiles for EV, PV, BESS, EE, and load were extracted from LoadSEER and scaled to the allocated values determined in the location-based forecast. The resulting profiles for each layer were then added to the base load profile to get the hourly forecasted demand shape for each year. This is the profile that is compared to the equipment rating to determine the grid need. To get the transformer hourly forecasted demand, the shapes for each feeder fed from that transformer are summed together.

This process was completed for both normal and contingency conditions.

[20] The implementation of LoadSEER for the neighbor islands is targeted for early 2023 as reported in Exhibit 2 of Hawaiian Electric’s Quarterly DER Technical Report filed on December 28, 2022 in Docket No 2019-0323.

[21] The process to derive the 8760 profiles is described in Hawaiian Electric Exhibit 3 – Location-Based Distribution Forecasts filed on November 5, 2021 in Docket No. 2018-0165, Instituting a Proceeding to Investigate Integrated Grid Planning.

[22] *Id*, Section 2.1.

2.3.3 Hourly Grid Needs Analysis Example

Using the example discussed in Section 2.2.1, the Kewalo 7 circuit on O'ahu was selected for further analysis in the Base Scenario. The hourly forecasted demand (8760 profile) was compared to the equipment rating for each hour of each year in the analysis timeframe. A sample day with an overload is shown in the plots below for two different years. The red line represents the forecasted demand (kW) and the dashed gray line represents the equipment rating (kW) for the circuit. The red shaded area is the overload.

The earliest year the overload occurs is in year 2026. In the chart below, on this particular day forecasted in year 2026, the plot illustrates an overload duration of approximately two hours (from hour 20 to hour 21) with a capacity need of approximately 2,000 kW and energy requirement of about 3,000 kWh.

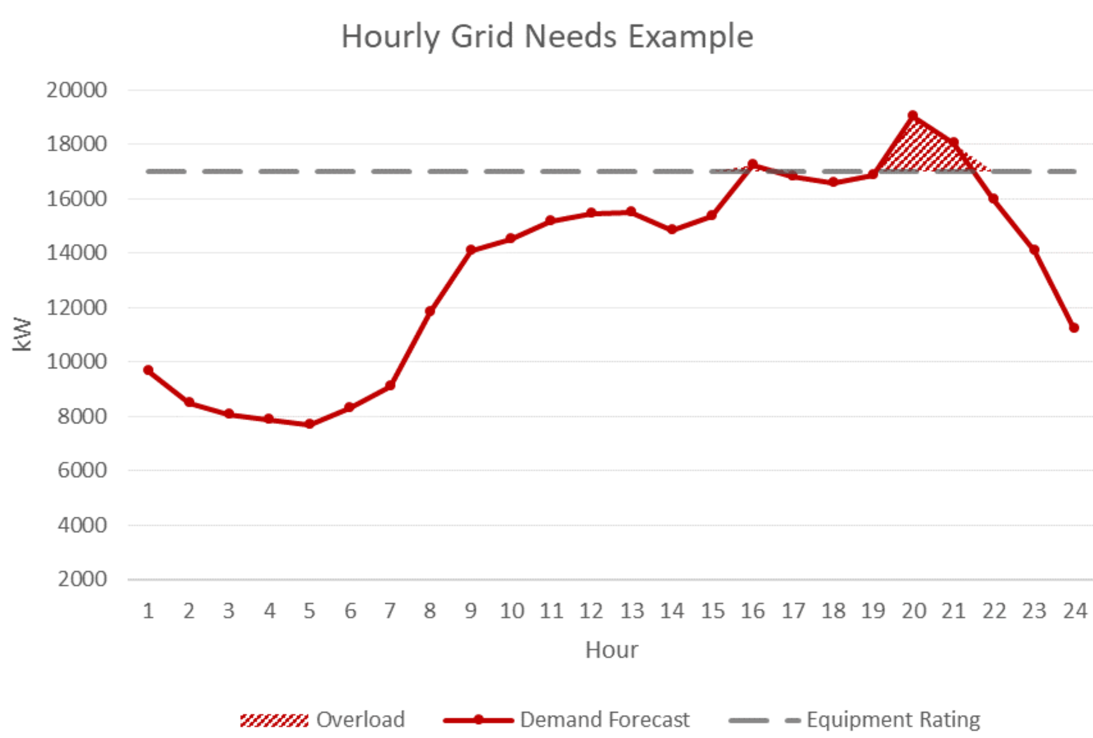

Figure 2-3: Hourly Grid Needs Example – Kewalo 7 Circuit (Year 2026)

The forecasted overload for this circuit grows in the following year. In the chart below, on this day forecasted in year 2027, the plot illustrates an overload duration of approximately 17 hours (from hour 8 to hour 24) with a peak capacity need of approximately 17,500 kW and energy requirement of 164,000 kWh.

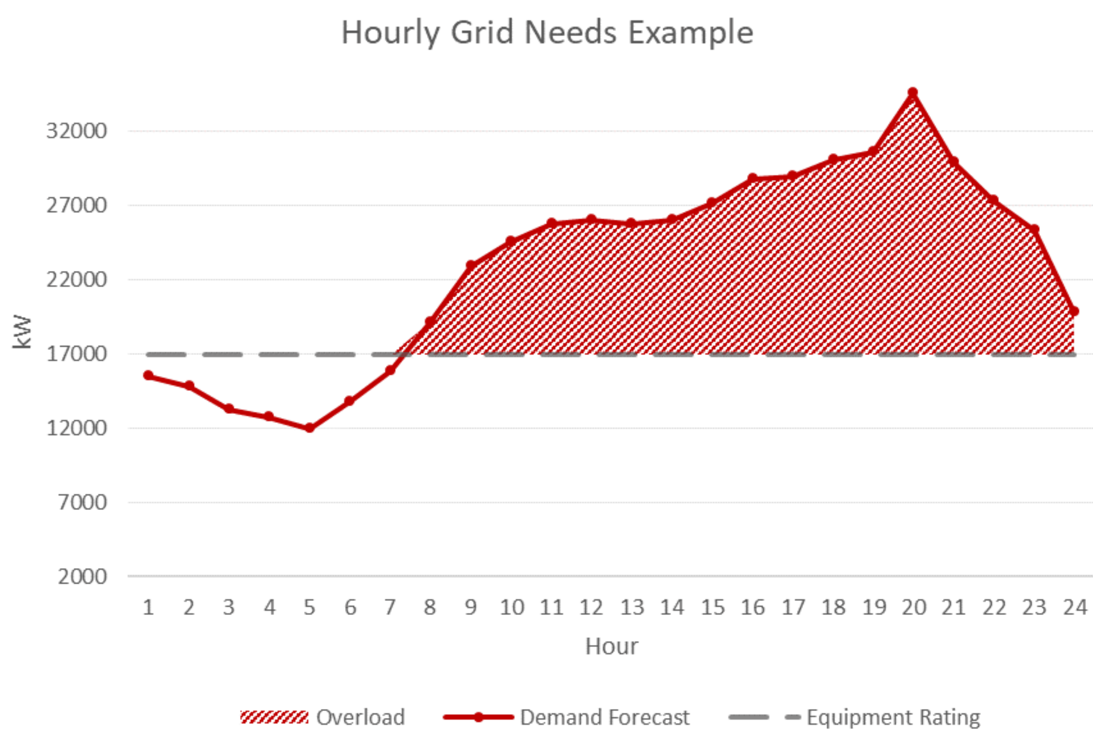

Figure 2-4: Hourly Grid Needs Example – Kewalo 7 Circuit (Year 2027)

2.4 Hourly Grid Needs Analysis Summary

The number of substation transformers and circuits flagged for hourly analysis and the grid needs identified are summarized in the following tables by island. Mitigation options for the identified grid needs are discussed further in Section 3.

O'ahu

The table below is a summary of the transformers that were identified for hourly analysis. Through the hourly analysis, the transformers with grid needs were identified.

Table 2-5: O'ahu Hourly Grid Needs Summary – Substation Transformers

Substation Transformer	Normal		Contingency	
	Identified For Hourly Analysis	Grid Need Identified	Identified For Hourly Analysis	Grid Need Identified
Scenario 1 (Base)	5	2	31	8
Scenario 2 (High Load)	12	3	61	12

Scenario 3 (Low Load)	7	3	29	6
Scenario 4 (Fast Adoption)	10	4	39	8

The table below is a summary of the circuits that were identified for hourly analysis. Through the hourly analysis, the circuits with grid needs were identified.

Table 2-6: O'ahu Hourly Grid Needs Summary – Circuits

Circuits	Normal		Contingency	
	Identified For Hourly Analysis	Grid Need Identified	Identified For Hourly Analysis	Grid Need Identified
Scenario 1 (Base)	8	3	46	9
Scenario 2 (High Load)	20	6	84	20
Scenario 3 (Low Load)	8	3	42	7
Scenario 4 (Fast Adoption)	12	5	58	12

For O'ahu, an hourly grid need analysis was performed on 472 transformers and circuits that were identified in the four scenarios for both normal and contingency conditions. Of these, 111 grid needs were identified through the analysis across all four scenarios.

Hawai'i Island

The tables below is a summary of the transformers that were identified for hourly analysis. Through the hourly analysis, the transformers with grid needs were identified.

Table 2-7: Hawai'i Island Hourly Grid Needs Summary – Substation Transformers

Substation Transformer	Normal		Contingency	
	Identified For Hourly Analysis	Grid Need Identified	Identified For Hourly Analysis	Grid Need Identified
Scenario 1 (Base)	2	0	2	0
Scenario 2 (High Load)	2	0	2	0
Scenario 3 (Low Load)	2	0	2	0
Scenario 4 (Fast Adoption)	2	0	2	1

The table below is a summary of the circuits that were identified for hourly analysis. Through the hourly analysis, the circuits with grid needs were identified.

Table 2-8: Hawai'i Island Hourly Grid Needs Summary – Circuits

Circuits	Normal		Contingency	
	Identified For Hourly Analysis	Grid Need Identified	Identified For Hourly Analysis	Grid Need Identified
Scenario 1 (Base)	0	0	5	3
Scenario 2 (High Load)	0	0	5	3
Scenario 3 (Low Load)	0	0	5	3
Scenario 4 (Fast Adoption)	0	0	5	3

For Hawai'i Island, an hourly grid need analysis was performed on 36 transformers and circuits that were identified in the four scenarios for both normal and contingency conditions. Of these, 13 grid needs were identified through the analysis.

Maui Island

The tables below is a summary of the transformers that were identified for hourly analysis. Through the hourly analysis, the transformers with grid needs were identified.

Table 2-9: Maui Island Hourly Grid Needs Summary – Substation Transformers

Substation Transformer	Normal		Contingency	
	Identified For Hourly Analysis	Grid Need Identified	Identified For Hourly Analysis	Grid Need Identified
Scenario 1 (Base)	0	0	1	0
Scenario 2 (High Load)	0	0	1	0
Scenario 3 (Low Load)	0	0	1	0
Scenario 4 (Fast Adoption)	0	0	1	0

The table below is a summary of the circuits that were identified for hourly analysis. Through the hourly analysis, the circuits with grid needs were identified.

Table 2-10: Maui Island Hourly Grid Needs Summary – Circuits

Circuits	Normal		Contingency	
	Identified For Hourly Analysis	Grid Need Identified	Identified For Hourly Analysis	Grid Need Identified
Scenario 1 (Base)	0	0	1	1
Scenario 2 (High Load)	0	0	1	1
Scenario 3 (Low Load)	0	0	1	1
Scenario 4 (Fast Adoption)	0	0	1	1

For Maui Island, an hourly grid need analysis was performed on 8 transformers and circuits that were identified in the four scenarios for both normal and contingency conditions. Of these, 4 grid need was identified through the analysis.

Lānaʻi

No substation transformers or circuits were flagged for hourly analysis on Lānaʻi. Therefore, no grid needs are identified.

Molokaʻi

No substation transformers or circuits were flagged for hourly analysis on Molokaʻi. Therefore, no grid needs are identified.

3. Grid Needs

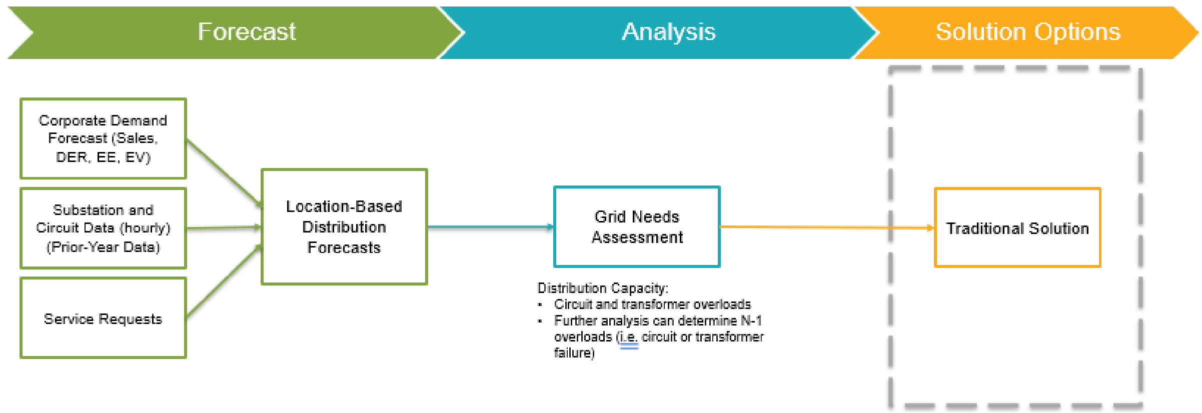

Figure 3-1: Solution Options Stage of the Distribution Planning Process

This section describes the last step to identify distribution grid needs:

1. Determine the demand forecast (kW) by substation transformer and circuit.
2. Screen substation transformers and circuits for analysis.
3. Perform hourly grid needs analysis.
4. **Identify solution options.**

3.1 Solutions Assessment

Solutions are identified for substation transformers and circuits requiring mitigation resulting from the hourly grid needs analysis. As described in Section 2, solutions are required if the equipment rating or transformer rating is lower than the demand forecast. The year(s) where the forecast is higher than the equipment rating are the year(s) where there is a grid need and mitigation is required.

As described in the *Distribution Planning Methodology*, a traditional solution will be defined for each grid need identified and include:[23]

- **Substation**: Transformer asset identification
- **Circuit**: Feeder asset identification

[23] Hawaiian Electric, *Distribution Planning Methodology*, November 2021 at 20.

- **Distribution Service Required**: Distribution capacity or distribution reliability (back-tie) service
- **Primary Driver of Grid Need**: Defines whether the identified grid need is primarily driven by DER growth, demand growth, other factor(s), or a combination of factors
- **Operating Date**: The date at which traditional infrastructure must be constructed and energized, in advance of the forecasted grid need to maintain safety and reliability
- **Equipment Rating**: Equipment's rated capacity
- **Peak Load**: Peak loading on asset for given year
- **Deficiency**: Deficiency divided by the rating for each of the forecasted years
- **Traditional Solution**: Traditional solution identified for mitigation (Solution Options)
- **NWA Qualified Opportunity**: Defines whether the grid need is a qualified opportunity for further evaluation based on technical requirements and timing of need
- **Cost Estimate**: Estimated cost to provide traditional solution identified

The location-based distribution grid needs assessment tables shown in the following sections are simplified and do not include all the fields defined above as some are not applicable for these grid needs, or the fields are consistent for all islands for all years. The following fields are applicable to all islands and are not replicated in the tables in the subsequent sections:

- Distribution Service Required: Distribution capacity or distribution reliability (back-tie) service
- Primary Driver of Grid Need: Demand growth

A summary of the total number of circuits and transformers requiring grid needs is shown below for each scenario. The number of grid needs is highest in the High Load Scenario followed by the Fast Customer Technology Adoption Scenario. The number of grid needs are lower in the Base and Low Load Scenarios. Some grid needs may be required in two or more scenarios.

Table 3-1: Grid Needs Assessment Summary

Island	Total Substation Transformers	Total Circuits	Total (Tsf and Ckt)	Total Grid Needs			
				Scenario 1 (Base)	Scenario 2 (High Load)	Scenario 3 (Low Load)	Scenario 4 (Fast Adoption)
O'ahu	204	393	597	22	42	19	29
Hawai'i Island	82	148	230	3	3	3	4
Maui Island	62	93	155	1	1	1	1
Lana'i	1	3	4	-	-	-	-
Moloka'i	2	8	10	-	-	-	-
Total (All Islands)	351	645	996	26	46	23	34

3.1.1 Traditional Solution Selection

Once the hourly grid needs analysis is performed and the grid needs are defined in technology-neutral terms, wires solutions that meet the grid needs are identified. This provides a baseline comparison for future evaluation of solution options in the IGP process. The following procedure is used to select the traditional solution that best mitigates the grid need; this is typically the least-cost traditional solution. The solution development process is similar for both normal and contingency conditions.

The following options are assessed and typically progress from evaluating the simpler, lower-cost solution first, then to more complex, highest-cost solutions if necessary:

1. Circuit or transformer load balancing or load shifting
2. Sectionalizing load
3. Circuit reconductoring
4. Installing new infrastructure (i.e. new circuit, transformer, or substation which may include an upgrade or additional unit installed)

The first option to eliminate a circuit or transformer overload is to assess if load balancing is feasible by assessing available capacity on adjacent circuits for load shifting capability. In other words, can a portion of or the entire load (MW/MVA) be transferred to another circuit or transformer using existing sectionalizing devices to eliminate the overload on the circuit or transformer of study. Load balancing is the first option as it’s typically a low- or minimal cost solution.

The second option is to sectionalize load in the area if load balancing is not feasible. This is done by installing a switch that transfers the entire load or a portion of the load to another circuit or transformer to eliminate the overload. In some cases, installing one or more switches to create multiple section ties may be required to eliminate the overload.

The third option is to evaluate reconductoring if load balancing and sectionalizing is not feasible. Upgrading cables in the overloaded section is evaluated to determine if the overload is eliminated. If so, the type and length of cable required is selected.

Lastly, if none of the first three options are feasible in eliminating the overload, new infrastructure is evaluated. This may include new circuiting, the installation of a new transformer and/or a new substation. This is typically the costliest solution.

High-level cost estimates for circuit and transformer mitigations based on unit cost information from previous similar projects are provided.

3.1.2 Base Scenario

The grid needs by transformer and circuit identified by island using the Base Scenario are provided in the following tables.

Oʻahu

Table 3-2: Oʻahu Grid Needs and Traditional Solutions Using the Base Scenario – Normal Condition

Substation Transformer	Circuit	Distribution Service Required	Operating Date	Traditional Solution
KEWALO T3	KEWALO 7	Capacity	2026	New circuits
KEWALO T3	N/A	Capacity	2027	New substation transformer
WAIPIO 1	N/A	Capacity	2025	New substation transformer
WAIPIO 1	WAIPIO 1	Capacity	2027	New circuit
WAIPIO 1	WAIPIO 2	Capacity	2026	New circuit

Table 3-3: Oʻahu Grid Needs and Traditional Solutions Using the Base Scenario – Contingency Condition (N-1)

Substation Transformer	Circuit	Distribution Service Required	Operating Date	Traditional Solution
CEIP 3	CEIP 46	Reliability	2025	Reconductor
IWILEI T3	IWILEI 9	Capacity, Reliability	2023	New circuits
KAMOKILA 2	N/A	Reliability	2027	Circuit line extension
KAPOLEI 2	KAPOLEI 4	Reliability	2026	Circuit line extension
KEWALO T3	KEWALO 7	Reliability	2027	New circuits
KEWALO T3	N/A	Reliability	2027	New substation transformer
KUILIMA 2	N/A	Reliability	2028	New substation transformer
WAHIAWA 3 (138kV)	N/A	Reliability	2028	New substation transformer and circuit
WAHIAWA 3 (138kV)	WAHIAWA-WAIMANO	Reliability	2026	New substation transformer and circuit
WAIAU A	N/A	Reliability	2024	Split bus
WAIAU B	N/A	Reliability	2024	Split bus
WAIPIO 1	N/A	Reliability	2025	New substation transformer
WAIPIO 1	WAIPIO 1	Reliability	2026	New circuit
WAIPIO 1	WAIPIO 2	Reliability	2026	New circuit
WAIPIO 2	N/A	Reliability	2025	New substation transformer
WAIPIO 2	WAIPIO 3	Reliability	2026	New circuit
WAIPIO 2	WAIPIO 4	Reliability	2026	New circuit

Hawaiʻi Island

There are no grid needs for Hawaiʻi Island in the Base Scenario under normal condition.

Table 3-4: Hawaiʻi Island Grid Needs and Traditional Solutions Using the Base Scenario – Contingency Condition (N-1)

Substation Transformer	Circuit	Distribution Service Required	Operating Date	Traditional Solution
HALAULA	HALAULA 2	Reliability (back-tie)	2023	New switch and recircuiting
HONOMU	HONOMU 1	Reliability (back-tie)	2023	Voltage conversion and tie
OOKALA	OOKALA 11	Reliability (back-tie)	2023	Voltage conversion and tie

Maui Island

There are no grid needs for Maui in the Base Scenario under normal condition.

Table 3-5: Maui Island Grid Needs and Traditional Solutions Using the Base Scenario – Contingency Condition (N-1)

Substation Transformer	Circuit	Distribution Service Required	Operating Date	Traditional Solution
HUELO	Huelo 74A/Huelo	Reliability (back-tie)	2023	Upgrade substation transformer

Lanaʻi

There are no grid needs for Lānaʻi in the Base Scenario.

Molokaʻi

There are no grid needs for Molokaʻi in the Base Scenario.

3.1.3 High Load Customer Technology Adoption Bookend Scenario

The grid needs by transformer and circuit identified by island using the High Load Customer Technology Adoption Bookend Scenario are provided in the following tables.

O'ahu

Table 3-6: O'ahu Grid Needs and Traditional Solutions Using the High Load Scenario – Normal Condition

Substation Transformer	Circuit	Distribution Service Required	Operating Date	Traditional Solution
CEIP 3	CEIP 46	Capacity	2025	Reconductor
KAMOKILA 2	N/A	Capacity	2029	Circuit line extension
KEWALO T3	KEWALO 7	Capacity	2026	New circuits
KEWALO T3	N/A	Capacity	2027	New substation transformer
PUUNUI 2	HEIGHTS	Capacity	2029	Reconductor, voltage regulator, and fuse resizing
WAIAU A	WAIAU-MILILANI	Capacity	2028	New substation transformer and circuit
WAIPIO 1	N/A	Capacity,	2025	New substation transformer
WAIPIO 1	WAIPIO 1	Capacity,	2027	New circuit
WAIPIO 1	WAIPIO 2	Capacity,	2026	New circuit

Table 3-7: O'ahu Grid Needs and Traditional Solutions Using the High Load Scenario – Contingency Condition (N-1)

Substation Transformer	Circuit	Distribution Service Required	Operating Date	Traditional Solution
CEIP 2	CEIP 3	Reliability	2028	Circuit line extension
CEIP 3	CEIP 46	Reliability	2023	Reconductor
EWA NUI 1	EWA NUI 1	Reliability	2029	Circuit line extension
EWA NUI 2	EWA NUI 2	Reliability	2025	New substation transformer and circuit
FORT WEAVER 1	FORT WEAVER 2	Reliability	2028	New circuit
FORT WEAVER 1	N/A	Reliability	2028	New substation transformer
HAUULA	HAUULA	Reliability	2028	Reconductor
HOAEAE 1	HOAEAE 1	Reliability	2029	New switch
IWILEI T3	IWILEI 9	Reliability	2023	New circuits
KAHUKU	KAHUKU	Reliability	2028	Reconductor
KAMOKILA 2	KAMOKILA 4	Reliability	2030	Circuit line extension
KAMOKILA 2	N/A	Reliability	2025	Circuit line extension
KANEOHE 1	HEEIA	Reliability	2029	Transfer load
KAPOLEI 2	KAPOLEI 4	Reliability	2025	New substation transformer and circuit
KAPOLEI 2	N/A	Reliability	2027	Circuit line extension

KEWALO T3	KEWALO 7	Reliability	2027	New circuits
KEWALO T3	N/A	Reliability	2027	New substation transformer
KUILIMA 2	N/A	Reliability	2026	New substation transformer
KUNIA MAKAI 1	N/A	Reliability	2028	New switch and transfer load
MAKAHA 2	N/A	Reliability	2030	New switch
WAHIAWA 3 (138kV)	N/A	Reliability	2028	New substation transformer and circuit
WAHIAWA 3 (138kV)	WAHIAWA-WAIMANO	Reliability	2025	New substation transformer and circuit
WAIALUA 2	KAENA PT	Reliability	2023	Reconductor
WAIAU A	N/A	Reliability	2024	Split bus
WAIAU A	WAIAU-MILILANI	Reliability	2026	New substation transformer and circuit
WAIAU B	N/A	Reliability	2024	Split bus
WAIPIO 1	N/A	Reliability	2024	New substation transformer
WAIPIO 1	WAIPIO 1	Reliability	2026	New circuit
WAIPIO 1	WAIPIO 2	Reliability	2026	New circuit
WAIPIO 2	N/A	Reliability	2024	New substation transformer
WAIPIO 2	WAIPIO 3	Reliability	2026	New circuit
WAIPIO 2	WAIPIO 4	Reliability	2026	New circuit

Hawai'i Island

There are no grid needs for Hawai'i Island in the High Load Scenario under normal condition.

Table 3-8: Hawai'i Island Grid Needs and Traditional Solutions Using the High Load Scenario – Contingency Condition (N-1)

Substation Transformer	Circuit	Distribution Service Required	Operating Date	Traditional Solution
HALAULA	HALAULA 2	Reliability (back-tie)	2023	New switch and recircuiting
HONOMU	HONOMU 1	Reliability (back-tie)	2023	Voltage conversion and tie
OOKALA	OOKALA 11	Reliability (back-tie)	2023	Voltage conversion and tie

Maui Island

There are no grid needs for Maui in the High Load Scenario under normal condition.

Table 3-9: Maui Island Grid Needs and Traditional Solutions Using the High Load Scenario – Contingency Condition (N-1)

Substation Transformer	Circuit	Distribution Service Required	Operating Date	Traditional Solution
HUELO	Huelo 74A/Huelo	Reliability (back-tie)	2023	Upgrade substation transformer

Lanaʻi

There are no grid needs for Lānaʻi in the High Load Scenario.

Molokaʻi

There are no grid needs for Molokaʻi in the High Load Scenario.

3.1.4 Low Load Customer Technology Adoption Bookend Scenario

The grid needs by transformer and circuit identified by island using the Low Load Customer Technology Adoption Bookend Scenario are provided in the following tables.

Oʻahu

Table 3-10: Oʻahu Grid Needs and Traditional Solutions Using the Low Load Scenario – Normal Condition

Substation Transformer	Circuit	Distribution Service Required	Operating Date	Traditional Solution
KEWALO T3	KEWALO 7	Capacity	2026	New circuits
KEWALO T3	N/A	Capacity	2027	New substation transformer
WAHIAWA 3 (138kV)	N/A	Capacity	2028	New substation transformer and circuit
WAIPIO 1	N/A	Capacity	2026	New substation transformer
WAIPIO 1	WAIPIO 1	Capacity	2027	New circuit
WAIPIO 1	WAIPIO 2	Capacity	2027	New circuit

Table 3-11: O'ahu Grid Needs and Traditional Solutions Using the Low Load Scenario – Contingency Condition (N-1)

Substation Transformer	Circuit	Distribution Service Required	Operating Date	Traditional Solution
CEIP 2	CEIP 3	Reliability	2023	Circuit line extension
IWILEI T3	IWILEI 9	Reliability	2023	New circuits
KEWALO T3	KEWALO 7	Reliability	2023	New circuits
KEWALO T3	N/A	Reliability	2023	New substation transformer
KUILIMA 2	N/A	Reliability	2028	New substation transformer
WAIAU A	N/A	Reliability	2023	Split bus
WAIAU B	N/A	Reliability	2027	Split bus
WAIPIO 1	N/A	Reliability	2027	New substation transformer
WAIPIO 1	WAIPIO 1	Reliability	2029	New circuit
WAIPIO 1	WAIPIO 2	Reliability	2024	New circuit
WAIPIO 2	N/A	Reliability	2024	New substation transformer
WAIPIO 2	WAIPIO 3	Reliability	2024	New circuit
WAIPIO 2	WAIPIO 4	Reliability	2026	New circuit

Hawai'i Island

There are no grid needs for Hawai'i Island in the Low Load Scenario under normal condition.

Table 3-12: Hawai'i Island Grid Needs and Traditional Solutions Using the Low Load Scenario – Contingency Condition (N-1)

Substation Transformer	Circuit	Distribution Service Required	Operating Date	Traditional Solution
HALAULA	HALAULA 2	Reliability (back-tie)	2023	New switch and recircuiting
HONOMU	HONOMU 1	Reliability (back-tie)	2023	Voltage conversion and tie
OOKALA	OOKALA 11	Reliability (back-tie)	2023	Voltage conversion and tie

Maui Island

There are no grid needs for Maui in the Low Load Scenario under normal condition.

Table 3-13: Maui Grid Needs and Traditional Solutions Using the Low Load Scenario – Contingency Condition (N-1)

Substation Transformer	Circuit	Distribution Service Required	Operating Date	Traditional Solution
HUELO	Huelo 74A/Huelo	Reliability (back-tie)	2023	Upgrade substation transformer

Lanaʻi

There are no grid needs for Lānaʻi in the Low Load Scenario.

Molokaʻi

There are no grid needs for Molokaʻi in the Low Load Scenario.

3.1.5 Fast Customer Technology Adoption Scenario

The grid needs by transformer and circuit identified by island using the Fast Customer Technology Adoption Scenario are provided in the following tables.

Oʻahu

Table 3-14: Oʻahu Grid Needs and Traditional Solutions Using the Fast Scenario – Normal Condition

Substation Transformer	Circuit	Distribution Service Required	Operating Date	Traditional Solution
CEIP 2	CEIP 3	Capacity	2025	New switch
KEWALO T3	KEWALO 7	Capacity	2026	New circuits
KEWALO T3	N/A	Capacity	2027	New substation transformer
WAHIAWA 3 (138kV)	N/A	Capacity	2026	New substation transformer and circuit
WAIAU A	N/A	Capacity	2030	New substation transformer and circuit
WAIAU A	WAIAU-MILILANI	Capacity	2029	New substation transformer and circuit
WAIPIO 1	N/A	Capacity	2026	New substation transformer
WAIPIO 1	WAIPIO 1	Capacity	2027	New circuit
WAIPIO 1	WAIPIO 2	Capacity	2026	New circuit

Table 3-15: O'ahu Grid Needs and Traditional Solutions Using the Fast Scenario – Contingency Condition (N-1)

Substation Transformer	Circuit	Distribution Service Required	Operating Date	Traditional Solution
CEIP 2	CEIP 3	Reliability	2027	Circuit line extension
CEIP 3	CEIP 46	Reliability	2027	Reconductor
IWILEI T3	IWILEI 9	Reliability	2027	Reconductor
KAMOKILA 2	N/A	Reliability	2023	New circuits
KAPOLEI 2	KAPOLEI 4	Reliability	2026	Circuit line extension
KEWALO T3	KEWALO 7	Reliability	2026	Circuit line extension
KEWALO T3	N/A	Reliability	2027	New circuits
KUILIMA 2	N/A	Reliability	2027	New substation transformer
WAHIAWA 3 (138kV)	N/A	Reliability	2029	New substation transformer
WAHIAWA 3 (138kV)	WAHIAWA-WAIMANO	Reliability	2029	New substation transformer and circuit
WAIAU A	N/A	Reliability	2026	New substation transformer and circuit
WAIAU A	WAIAU-MILILANI	Reliability	2024	Split bus
WAIAU B	N/A	Reliability	2028	New substation transformer and circuit
WAIPIO 1	N/A	Reliability	2024	Split bus
WAIPIO 1	WAIPIO 1	Reliability	2024	New substation transformer
WAIPIO 1	WAIPIO 2	Reliability	2026	New circuit
WAIPIO 2	N/A	Reliability	2026	New circuit
WAIPIO 2	WAIPIO 3	Reliability	2024	New substation transformer
WAIPIO 2	WAIPIO 4	Reliability	2026	New circuit

Hawai'i Island

There are no grid needs identified for Hawai'i Island in the Fast Scenario under normal condition.

Table 3-16: Hawai'i Island Grid Needs and Traditional Solutions Using the Fast Scenario – Contingency Condition (N-1)

Substation Transformer	Circuit	Distribution Service Required	Operating Date	Traditional Solution
HALAULA	HALAULA 2	Reliability (back-tie)	2023	New switch and recircuiting
HONOMU	HONOMU 1	Reliability (back-tie)	2023	Voltage conversion and tie
OOKALA	OOKALA 11	Reliability (back-tie)	2023	Voltage conversion and tie

WAIKOLOA	N/A	Reliability	2030	New circuit and tie

Maui Island

There are no grid needs identified for Maui in the Fast Scenario under normal condition.

Table 3-17: Maui Island Grid Needs and Traditional Solutions Using the Fast Scenario – Contingency Condition (N-1)

Substation Transformer	Circuit	Distribution Service Required	Operating Date	Traditional Solution
HUELO	Huelo 74A/Huelo	Reliability (back-tie)	2023	Upgrade substation transformer

Lanaʻi

There are no grid needs for Lānaʻi in the Fast Scenario.

Molokaʻi

There are no grid needs for Molokaʻi in the Fast Scenario.

3.1.6 Traditional Solutions Summary

The traditional solutions listed above in Sections 3.1.2 through Section 3.1.5 include one solution for each circuit and transformer with a grid need. However, there are situations where a traditional solution is a common solution that could solve multiple grid needs simultaneously.

For example, in Table 3-2 and Table 3-3, a new circuit is identified as a solution for the Waipio 1 circuit under normal condition in year 2027 and for the Waipio 3 circuit under contingency condition in year 2026. Each new circuit has a cost estimate of approximately $2.9M. If a new circuit is installed in the area to mitigate the Waipio 3 contingency overload, which occurs in the earlier year, that new circuit would also solve the overload projected for Waipio 1 circuit.

The list of traditional solutions was reviewed for any situations where mitigation would provide a common solution. This resulted in a shorter list of resulting wires projects (i.e. minimum wires solutions).

Table 3-18: Minimum Grid Needs Solutions Identified

Island	Scenario 1 (Base)	Scenario 2 (High Load)	Scenario 3 (Low Load)	Scenario 4 (Fast Adoption)
O'ahu	12	25	10	14
Hawai'i Island	3	3	3	4
Maui	1	1	1	1
Lāna'i	-	-	-	-
Moloka'i	-	-	-	-
Total	16	29	14	19

The total cost of distribution upgrades needed for the minimum wires solutions is summarized below.[24]

Table 3-19: Minimum Grid Needs Solutions Identified – Cost Summary (Wires Solutions)

Island	Scenario 1 (Base)	Scenario 2 (High Load)	Scenario 3 (Low Load)	Scenario 4 (Fast Adoption)
O'ahu	$47,173,000	$67,576,000	$48,201,000	$56,103,000
Hawai'i Island	$2,680,000	$2,680,000	$2,680,000	$3,153,000
Maui	$63,000	$63,000	$63,000	$63,000
Lāna'i	-	-	-	-
Moloka'i	-	-	-	-
Total	$49,916,000	$70,319,000	$50,944,000	$59,319,000

3.1.7 Base Scenario Summary

The minimum wires solutions by island using the Base Scenario are provided in the following tables.

O'ahu

Project	Substation Transformer	Circuit	Operating Date	Traditional Solution	Cost Estimate (Nominal $)
CEIP 46 – Circuit Upgrade	CEIP 3	CEIP 46	2025	Reconductor	$3,930,000
Iwilei – New Circuits (25 KV)	IWILEI T3	IWILEI 9	2023	New circuits	$3,960,000
Kamokila 2 – Line Extension	KAMOKILA 2	N/A	2027	Circuit Line Extension	$1,913,740

24 Cost estimates were prepared in Q4 2022 and will be updated as more detailed engineering design is completed.

Kapolei 4 – Line Extension	KAPOLEI 2	KAPOLEI 4	2026	Circuit Line Extension	$2,091,012
Kewalo – New Transformer and Circuits (25 KV)	KEWALO T3	KEWALO 7	2026	New circuits	$4,865,000
	KEWALO T3	N/A	2027	New substation transformer	$6,404,000
Kuilima – Transformer Upgrade	KUILIMA 2	N/A	2028	Upgrade substation transformer	$3,160,000
Ewa Nui – New Transformer and Circuits	WAHIAWA 3 (138kV)	WAHIAWA-WAIMANO	2026	New substation transformer and circuits	$15,012,000
	WAIAU A	N/A	2024		
Waipio – New Transformer and Circuits	WAIPIO 1	N/A	2025	New substation transformer	$2,880,000
	WAIPIO 1	WAIPIO 1	2027	New circuit	$2,957,000
	WAIPIO 1	WAIPIO 2	2026		
Total					$47,173,000

Hawaiʻi Island

Project	Substation Transformer	Circuit	Operating Date	Traditional Solution	Cost Estimate (Nominal $)
Halaula – Recircuiting	HALAULA	HALAULA 2	2023	New switch and recircuiting	$65,000
Honomu – Voltage Conversion	HONOMU	HONOMU 1	2023	Voltage conversion and tie	$999,000
Ookala – Voltage Conversion	OOKALA	OOKALA 11	2023	Voltage conversion and tie	$1,616,000
Total					$2,680,000

Maui Island

Project	Substation Transformer	Circuit	Operating Date	Traditional Solution	Cost Estimate (Nominal $)
Huelo – Transformer Upgrade	HUELO	Huelo 74A/Huelo	2023	Upgrade substation transformer	$63,000
Total					$63,000

Lanaʻi

There are no grid needs for Lānaʻi in the Base Scenario.

Molokaʻi

There are no grid needs for Molokaʻi in the Base Scenario.

3.1.8 High Load Customer Technology Adoption Bookend Scenario Summary

The minimum wires solutions by island using the High Load Customer Technology Adoption Bookend Scenario are provided in the following tables.

Oʻahu

Project	Substation Transformer	Circuit	Operating Date	Traditional Solution	Cost Estimate (Nominal $)
CEIP 3 – Line Extension	CEIP 2	CEIP 3	2028	Circuit line extension	$5,072,000
CEIP 46 – Circuit Upgrade	CEIP 3	CEIP 46	2023	Reconductor	$3,930,000
Ewa Nui 1 – Line Extension	EWA NUI 1	EWA NUI 1	2029	Circuit line extension	$149,000
Ewa Nui – New Transformer and Circuits	EWA NUI 2	EWA NUI 2	2025	New substation transformer and circuit	$3,634,000
Fort Weaver – New Transformer and Circuits	FORT WEAVER 1	FORT WEAVER 2	2028	New circuit	$1,109,000
	FORT WEAVER 1	N/A	2028	New substation transformer	$3,160,000
Hauula – Circuit Upgrade	HAUULA	HAUULA	2028	Reconductor	$780,000
Hoaeae 1 – Circuit Upgrade	HOAEAE 1	HOAEAE 1	2029	New switch	$25,000
Iwilei - New Circuits (25 KV)	IWILEI T3	IWILEI 9	2023	New circuits	$3,960,000
Kahuku – Circuit Upgrade	KAHUKU	KAHUKU	2028	Reconductor	$187,000
Kamokila 2 – Line Extension	KAMOKILA 2	N/A	2025	Circuit line extension	$2,480,000
Heeia – Load Transfer	KANEOHE 1	HEEIA	2029	Transfer load	$26,000

Kapolei – New Transformer and Circuits	KAPOLEI 2	KAPOLEI 4	2025	New substation transformer and circuit	$3,684,000
Kewalo - New Transformer and Circuits (25 KV)	KEWALO T3	KEWALO 7	2026	New circuits	$4,865,000
	KEWALO T3	N/A	2027	New substation transformer	$6,404,000
Kuilima – New Transformer	KUILIMA 2	N/A	2026	New substation transformer	$2,970,000
Kunia Makai – Circuit Upgrade	KUNIA MAKAI 1	N/A	2028	New switch and transfer load	$26,000
Makaha 2 – Circuit Upgrade	MAKAHA 2	N/A	2030	New switch	$26,000
Heights – Circuit Upgrade	PUUNUI 2	HEIGHTS	2029	Reconductor, voltage regulator, and fuse resizing	$473,000
Ewa Nui – New Transformer and Circuits (46kV)	WAHIAWA 3 (138kV)	WAHIAWA-WAIMANO	2025	New substation transformer and circuit	$15,012,000
Kaena PT – Circuit Upgrade	WAIALUA 2	KAENA PT	2023	Reconductor	$17,000
Waiau – Bus Upgrade	WAIAU A	N/A	2024	Split bus	$965,000
Waipio – New Transformer and Circuits	WAIPIO 1	N/A	2024	New substation transformer	$2,790,000
	WAIPIO 1	WAIPIO 1	2026	New circuit	$2,916,000
	WAIPIO 1	WAIPIO 2	2026	New circuit	$2,916,000
Total					$67,576,000

Hawaiʻi Island

Project	Substation Transformer	Circuit	Operating Date	Traditional Solution	Cost Estimate (Nominal $)
Halaula 2 – Circuit Upgrade	HALAULA	HALAULA 2	2023	New switch and recircuiting	$65,000
Honomu 1 – Circuit Upgrade	HONOMU	HONOMU 1	2023	Voltage conversion and tie	$999,000
Ookala 11 – Circuit Upgrade	OOKALA	OOKALA 11	2023	Voltage conversion and tie	$1,616,000

Total	$2,680,000

Maui Island

Project	Substation Transformer	Circuit	Operating Date	Traditional Solution	Cost Estimate (Nominal $)
Huelo – Transformer Upgrade	HUELO	Huelo 74A/Huelo	2023	Upgrade substation transformer	$63,000
Total					$63,000

Lanaʻi

There are no grid needs for Lānaʻi in the High Load Scenario.

Molokaʻi

There are no grid needs for Molokaʻi in the High Load Scenario.

3.1.9 Low Load Customer Technology Adoption Bookend Scenario Summary

The minimum wires solutions by island using the Low Load Customer Technology Adoption Bookend Scenario are provided in the following tables.

Oʻahu

Project	Substation Transformer	Circuit	Operating Date	Traditional Solution	Cost Estimate (Nominal $)
CEIP 3 – Line Extension	CEIP 2	CEIP 3	2028	Circuit line extension	$5,072,000
Iwilei – New Circuits (25 KV)	IWILEI T3	IWILEI 9	2023	New circuits	$3,960,000
Kewalo – New Transformer and Circuits (25 KV)	KEWALO T3	KEWALO 7	2026	New circuits	$4,865,000
	KEWALO T3	N/A	2027	New substation transformer	$6,404,000
Kuilima – New Transformer	KUILIMA 2	N/A	2029	New substation transformer	$3,260,000
Ewa Nui – New Transformer and Circuits (46kV)	WAHIAWA 3 (138kV)	N/A	2028	New substation transformer and circuit	$15,012,000

Waiau – Bus Upgrade	WAIAU A	N/A	2024	Split bus	$965,000
Waipio – New Transformer and Circuits	WAIPIO 1	N/A	2024	New substation transformer	$2,790,000
	WAIPIO 1	WAIPIO 1	2026	New circuit	$2,916,000
	WAIPIO 1	WAIPIO 2	2027	New circuit	$2,957,000
Total					$48,201,000

Hawaiʻi Island

Project	Substation Transformer	Circuit	Operating Date	Traditional Solution	Cost Estimate (Nominal $)
Halaula 2 – Circuit Upgrade	HALAULA	HALAULA 2	2023	New switch and recircuiting	$65,000
Honomu 1 – Circuit Upgrade	HONOMU	HONOMU 1	2023	Voltage conversion and tie	$999,000
Ookala 11 – Circuit Upgrade	OOKALA	OOKALA 11	2023	Voltage conversion and tie	$1,616,000
Total					$2,680,000

Maui Island

Project	Substation Transformer	Circuit	Operating Date	Traditional Solution	Cost Estimate (Nominal $)
Huelo – Transformer Upgrade	HUELO	Huelo 74A/Huelo	2023	Upgrade substation transformer	$63,000
Total					$63,000

Lanaʻi

There are no grid needs for Lānaʻi in the Low Load Scenario.

Molokaʻi

There are no grid needs for Molokaʻi in the Low Load Scenario.

3.1.10 Fast Customer Technology Adoption Bookend Scenario Summary

The minimum wires solutions by island using the Fast Customer Technology Adoption Bookend Scenario are provided in the following tables.

O'ahu

Project	Substation Transformer	Circuit	Operating Date	Traditional Solution	Cost Estimate (Nominal $)
Industrial – Line Extension	BARBERS PT TANK FARM 2	INDUSTRIAL	2027	Circuit line extension	$5,072,000
CEIP 3 – Circuit Upgrade	CEIP 2	CEIP 3	2025	New switch	$23,000
CEIP 46 – Circuit Upgrade	CEIP 3	CEIP 46	2027	Reconductor	$3,930,000
Iwilei - New Circuits (25 KV)	IWILEI T3	IWILEI 9	2023	New circuits	$3,960,000
Kamokila 2 – Line Extension	KAMOKILA 2	N/A	2026	Circuit line extension	$1,858,000
Kapolei 4 – Line Extension	KAPOLEI 2	KAPOLEI 4	2026	Circuit line extension	$2,091,000
Kewalo – New Transformer and Circuits (25 KV)	KEWALO T3	KEWALO 7	2026	New circuits	$4,865,000
	KEWALO T3	N/A	2027	New substation transformer	$6,404,000
Kuilima – New Transformer	KUILIMA 2	N/A	2029	New substation transformer	$3,260,000
Ewa Nui – New Transformer and Circuits (46kV)	WAHIAWA 3 (138kV)	N/A	2026	New substation transformer and circuit	$15,012,000
Waiau – Bus Upgrade	WAIAU A	N/A	2024	Split bus	$965,000
Waipio – New Transformer and Circuits	WAIPIO 1	N/A	2024	New substation transformer	$2,790,000
	WAIPIO 1	WAIPIO 1	2026	New circuit	$2,916,000
	WAIPIO 1	WAIPIO 2	2026	New circuit	$2,957,000
Total					$56,103,000

Hawai'i Island

Project	Substation Transformer	Circuit	Operating Date	Traditional Solution	Cost Estimate (Nominal $)
Halaula 2 – Circuit Upgrade	HALAULA	HALAULA 2	2023	New switch and recircuiting	$65,000
Honomu 1 – Circuit Upgrade	HONOMU	HONOMU 1	2023	Voltage conversion and tie	$999,000
Ookala 11 – Circuit Upgrade	OOKALA	OOKALA 11	2023	Voltage conversion and tie	$1,616,000
Waikoloa – New Circuit	WAIKOLOA	N/A	2030	New circuit and tie	$473,000
Total					$3,153,000

Maui Island

Project	Substation Transformer	Circuit	Operating Date	Traditional Solution	Cost Estimate (Nominal $)
Huelo – Transformer Upgrade	HUELO	Huelo 74A/Huelo	2023	Upgrade substation transformer	$63,000
Total					$63,000

Lana'i

There are no grid needs for Lāna'i in the Fast Scenario.

Moloka'i

There are no grid needs for Moloka'i in the Fast Scenario.

3.2 Hourly Grid Needs

For the grid needs identified earlier in Section 3.1.2 through Section 3.1.5, solution requirements are defined in technology-neutral terms (e.g., amounts of energy, time(s) of day, and days of the year). The hourly grid needs summary includes:

- **Substation**: Transformer asset identification

- **Circuit**: Feeder asset identification
- **Capacity**: Amount of power required to mitigate the grid need
- **Energy**: Amount of energy required to mitigate the grid need
- **Delivery Time Frame**: Months/hours when the planning criteria violations occur
- **Duration**: Length of time of the grid need
- **Maximum Number of Calls Per Year**: Maximum number of days in the year requiring mitigation.

A complete list of the hourly grid needs for each circuit and transformer is available in the Distribution Grid Needs Workbook.[25] An example of the data provided in the workbook is explained below.

3.2.1 Hourly Grid Needs Example

Hourly overloads identified in each year are aggregated and the corresponding grid needs are shown in the following tables. The Kewalo 7 circuit has a forecasted capacity (MW) need from year 2026 through 2030. The need ranges from about 2 MW starting in year 2026 and grows to about 17.5 MW in years 2027 through 2030.

Table 3-20: Kewalo 7 Capacity Need (kW)

Circuit	Equipment Rating (MVA)	Demand Forecast by Circuit (MW)									
		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Kewalo 7	17.0	0	0	0	0	0	2.039	17.57	17.711	17.682	17.651

The corresponding energy need (MWh) for years when the circuit is overloaded is shown below.

Table 3-21: Kewalo 7 Circuit Energy Need (MWh)

Circuit	Equipment Rating (MVA)	Demand Forecast by Circuit (MWh)									
		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Kewalo 7	17.0	0	0	0	0	0	3.3	166.6	168.5	168.1	167.7

The number of hours each year when the circuit is overloaded is shown below.

Table 3-22: Kewalo 7 Circuit Need (Hours)

Circuit	Equipment Rating (MVA)	Demand Forecast by Circuit (Hours)									
		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Kewalo 7	17.0	0	0	0	0	0	5	19	19	19	19

[25] The hourly grid needs are voluminous and therefore not provided in this report in table format. The complete list of distribution grid needs is available on the Company website in an Excel workbook. See Section 5.

The maximum number of calls each year is shown below.

Table 3-23: Kewalo 7 Circuit Maximum Number of Calls Per Year

Circuit	Equipment Rating (MVA)	Maximum Number of Calls Per Year									
		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Kewalo 7	17.0	0	0	0	0	0	34	365	365	365	365

4. Summary and Next Steps

Using the location-based forecasts for substation transformers and primary distribution circuits, grid needs to serve load growth through year 2030 are identified in this analysis. During this process, 351 substation transformers and 645 circuits were assessed across all five islands and less than 5% have grid needs identified. A summary of the grid needs by scenario are shown below. This list includes

Table 4-1: Grid Needs Summary

Scenario	Description	Total Grid Needs (All Islands)	Total Cost ($)
1	Base	16	$49.9 M
2	High Load Customer Technology Adoption	29	$70.3 M
3	Low Load Customer Technology Adoption	14	$50.9 M
4	Fast Customer Technology Adoption	19	$59.3 M

Consistent with the *Non-Wires Opportunity Evaluation Methodology,* cost estimates are developed for traditional wires solutions identified to solve distribution grid needs. These estimates will be used as an input to evaluate if the grid need may qualify as a favorable NWA opportunity, and if so, be procured as part of the overarching IGP process where a portfolio of solutions will be selected to address the identified grid needs.

5. Workbook Index

The grid needs assessment, hourly grid needs, and revised 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.[26]

A summary of the workbooks is provided below.

Table 5-1: Location-Based Distribution Grid Needs Workbook Index[27]

No.	Workbook[28]
1	Location-Based Grid Needs (EXCEL)

Table 5-2: November 2021 Forecast Update Workbook Index

Island	No.	Scenario	Workbook[29]
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)
	4	Fast Customer Technology Adoption	Oahu Location-Based Forecasts Scenario 4 (EXCEL)
Hawai'i Island	1	Base	Hawaii Island Location-Based Forecasts Scenario 1 (EXCEL)
	2	High Load Customer Technology Adoption Bookend	Hawaii Island Location-Based Forecasts Scenario 2 (EXCEL)

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

[27] Includes grid needs assessment and hourly grid needs.

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

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

	3	Low Load Customer Technology Adoption Bookend	Hawaii Island Location-Based Forecasts Scenario 3 (EXCEL)
	4	Fast Customer Technology Adoption	Hawaii Island Location-Based Forecasts Scenario 4 (EXCEL)
Maui Island	1	Base	Maui Location-Based Forecasts Scenario 1 (EXCEL)
	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)
	4	Fast Customer Technology Adoption	Maui Location-Based Forecasts Scenario 4 (EXCEL)
Lānaʻi	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)
	4	Fast Customer Technology Adoption	Lanai Location-Based Forecasts Scenario 4 (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)
	4	Fast Customer Technology Adoption	Molokai Location-Based Forecasts Scenario 4 (EXCEL)