Power Supply Improvement Plan Update Report

Power Supply Improvement Plan: Supplemented, Amended, and Updated

1 April 2016

Hawaiian Electric
Maui Electric
Hawai'i Electric Light

Preface

The Hawaiian Electric Companies respectfully submit this supplemented, amended, and updated Power Supply Improvement Plan (PSIP) to comply with Order No. 33320 issued by the Hawai'i Public Utilities Commission on November 4, 2015 in Docket No. 2014-0183.

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Executive Summary

SHARED COMMITMENT TO A CLEAN ENERGY FUTURE

With an unprecedented 100% Renewable Portfolio Standard, Hawai'i's clean energy leadership is clear and indisputable. Achieving this critical goal will require a comprehensive transformation of our island power grids. A multidimensional planning process that requires near-term actions to set the foundation for the plan and a recognition that flexibility is critical as the specifics for the long-term continue to change as technology and costs continue to evolve. While there are many views on the best path to achieve our 100% RPS goal, there is notable unity in Hawai'i in recognizing the critical importance of addressing the negative economic, environmental and energy security impacts of our state's dependence on imported petroleum oil. Most of all, that shared mindset will be required for our entire community – government, business, developers, community and environmental groups, utilities, and customers – to come together to address the issues that must be resolved to achieve this goal for our island home.

A Dynamic Energy Environment

Changes that took place in the 18 months since we filed our Power Supply Improvement Plans in 2014 demonstrate how dynamic our Hawai'i energy environment is. Consider just a few of the changes:

- Passage of Act 97, which extended a 40% RPS requirement in 2030 to a 100% RPS in 2045.
- Dramatic decline in the price of fuel oil by more than 75%, creating significant changes and uncertainty in forecasted costs, and much lower bills.
- Hawai'i Public Utilities Commission (Commission) Decision & Order No. 33258 ending the Net Energy Metering (NEM) program for new solar customers and

concurrently creating two new replacement programs: Customer Grid-Supply and Customer Self-Supply.

- Valuable ongoing experience with increasing levels of distributed generation (DG), including the testing and installation of advanced inverters to allow greater amounts of DG and reduce the need for distribution upgrades.
- In addition, NextEra Energy and the Hawaiian Electric Companies have proposed a merger which is pending before the Commission.

Energy technology and policy is constantly evolving and customer needs and expectations are changing.

Therefore, our planning in this context of change must include:

Actions to be taken in the immediate future to take advantage of available resources and achieve near-term energy goals, satisfy customer preferences, and provide a hedge against uncertainty in future oil prices.

Near-term steps that help us further understand, explore, and develop longer-term resources.

Long-term energy planning using the best information available today but recognizing the limitations on insights into the future. The actions identified in the 2025–2045 time period are less certain, and are expected to be further optimized and adjusted based on changing circumstances in future planning updates to reach our 100% renewable energy goal in other ways.

Preservation of a reliable and resilient power grid. Hawai‘i’s small and islanded power grids make this especially challenging and even more critical to achieve. The resiliency of our grid and reliability of service is vital for our economy, for our military partners, and for critical infrastructure. Our customers expect and deserve it.

Key Results—What Are the Takeaways?

There are several notable high level results from this Power Supply Improvement Plan Update:

1. **Our companies’ project we can exceed the RPS requirements** as defined under the current law and can also chart a path to achieve true 100 percent renewable energy for electricity by 2045. The *Additional Insights* section (below) highlights some considerations and challenges to meeting these bold goals.

2. Customer participation through the use of market-based distributed energy resources (DER) plays a critical role. We project that the capacity of installed **DER, largely private rooftop solar, can grow by about 370 percent** compared to our 2014 PSIPs.

3. We can essentially re-invent our power system—by modernizing generation to be more flexible and efficient, transforming our transmission and distribution system to be smarter and better integrate distributed private and larger scale renewables, and obtain the energy security and environmental benefits from a 100% renewable future—all while **keeping electric rates stable and relatively flat** on a real dollar basis.

4. **Liquefied Natural Gas (LNG) as a transitional fuel**, combined with more efficient and flexible modern generation, provides the best path with the lowest cost and lowest carbon footprint to reach Hawaiʻi's 100%renewable energy goal.

Additional Insights

Despite future uncertainties, long-term planning should be viewed as providing useful directional insights. Some of these insights include:

a. Our long term portfolios must include a diverse set of resources. With greater use of renewable energy, a diverse mix of renewable resources provides greater assurance of self-sufficiency and energy resiliency as weather patterns vary and other unforeseen events occur.

b. Dispatchable, firm renewable energy (currently biomass and geothermal) on Maui and Hawaiʻi Island are key to achieving high levels of renewable energy at reasonable costs.

This suggests that policymakers, government agencies, and private organizations with interests in energy, agriculture, water use and land use, need to be involved in developing clear policies and rules that will determine the feasibility of these options for the future.

c. With their more abundant open spaces, the neighbor islands will lead the way and in fact, Molokaʻi and Lānaʻi are projected to reach a 100% RPS by 2030, while Maui and Hawaiʻi Island could achieve a 100% RPS by 2040. This will help Oʻahu, with its larger population and energy needs challenged with limited land and on-island renewable resources, meet the 2030 70% RPS goal.

To reach 100% RPS in 2045, Oʻahu appears to need additional resources beyond those available on island (e.g., currently, offshore wind, biofuels, neighbor island renewables transmitted via interisland cable). These alternatives need to be studied further to better understand their respective risks and relative costs. Such endeavors require the efforts and input of our entire state, not just the utility. Policies, environmental permits, community and cultural issues and concerns must be addressed. Changes in state policies, statutes, and regulations governing resource development may also be needed. And as circumstances change in the years ahead, the alternatives for O'ahu may be revised.

In the context of the potential need for resources to be shared amongst the islands to cost-effectively achieve 100% renewable energy, the concept of consolidated rates for the Hawaiian Electric Companies should be evaluated.

d. Planning must be looked at as a continuous process—a process in which analysis is updated for changing circumstances, new technologies, changing economics, and new policies. Action plans and long-term directions should be reviewed continuously, especially given the rapid change in the clean energy sector.

KEY RESULTS: THE PATH TO 100% RENEWABLE ENERGY

Each Preferred Plan considered a number of factors.

Electricity Rate and Bill Impacts. Recognizing the importance of affordability to our customers, limiting overall costs and annual rate increases was a high priority.

Customer Choice. To meet the diverse needs of our customers, all plans must facilitate customer choice and aim to be fair to all customers.

Future Fuel Prices. Because of changing fuel markets, each plan must be evaluated for different oil, biofuel, and LNG price scenarios.

Infrastructure Investments. To ensure electric grid resiliency and meet our state's clean energy goals, all approaches require investment in new infrastructure by customers, developers, and the utility.

Service Reliability and Resiliency. To meet the needs of our customers and our state's economy, the modernized grid must be reliable and resilient to ensure all resources remain connected, even during severe or abnormal weather conditions.

Flexibility. Recognizing our dynamic energy environment and the benefits for our customers, plans must adapt to accommodate future technology and pricing breakthroughs.

Minimizing Risks. Our Preferred Plans minimize the risks—financial, implementation, and technology among them—inherent in any plan of this magnitude.

Under the current Preferred Plans, our tri-company consolidated renewable energy mix in 2045 could be the amounts listed in Table ES-1.

Renewable Resource	MW
Total DG-PV	1,220
FIT*	40
Utility-scale PV	870
Onshore Wind	530
Offshore Wind	800
Hydro	20
Geothermal	120
Waste/Biomass	130

* = all solar

Table ES-1. 2045 Renewable Energy Resources

Figure ES-1 shows the total capacity of renewable energy included in the Preferred Plans on a consolidated basis. By 2045, the total capacity of renewable energy on the systems is more than double the total of the system peaks to be served.

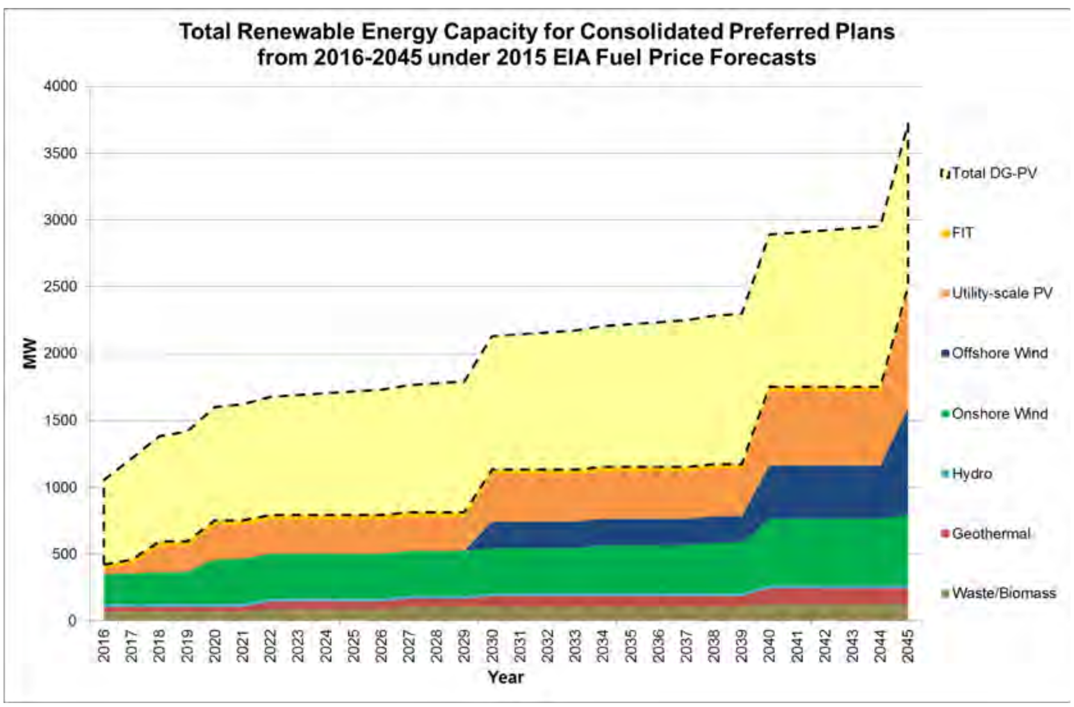

Figure ES-1. Total Renewable Energy Capacity for Consolidated Preferred Plans from 2016-2045 under 2015 EIA Fuel Price Forecasts

Again, while instructive for directional planning, this prediction of a renewable resource mix 30 years into the future is certain to evolve as we adapt to take advantage of rapidly evolving technology, policies, and energy options.

Achieving the RPS

Under the current Preferred Plans, RPS will exceed requirements as our companies move toward 100% renewable energy by 2045 (Figure ES-2).

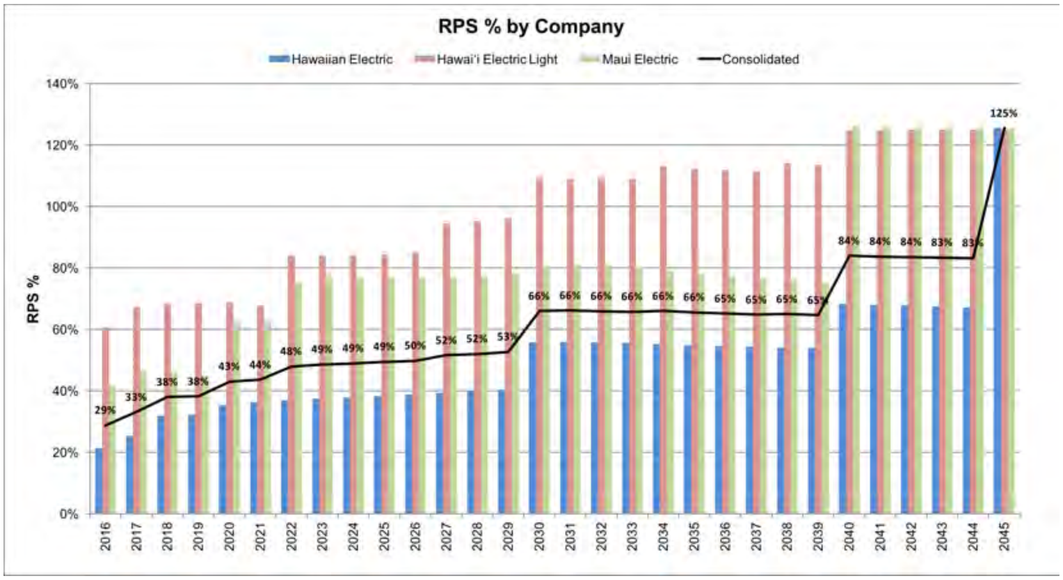

Figure ES-2. Renewable Portfolio Standards Compliance of Preferred Plans

The calculation of the RPS per the law does result in values over 100%. To emphasize that we are committed to achieving 100% renewable energy in 2045, Figure ES-3 shows the renewable energy as a percent of total energy including customer-sited generation.

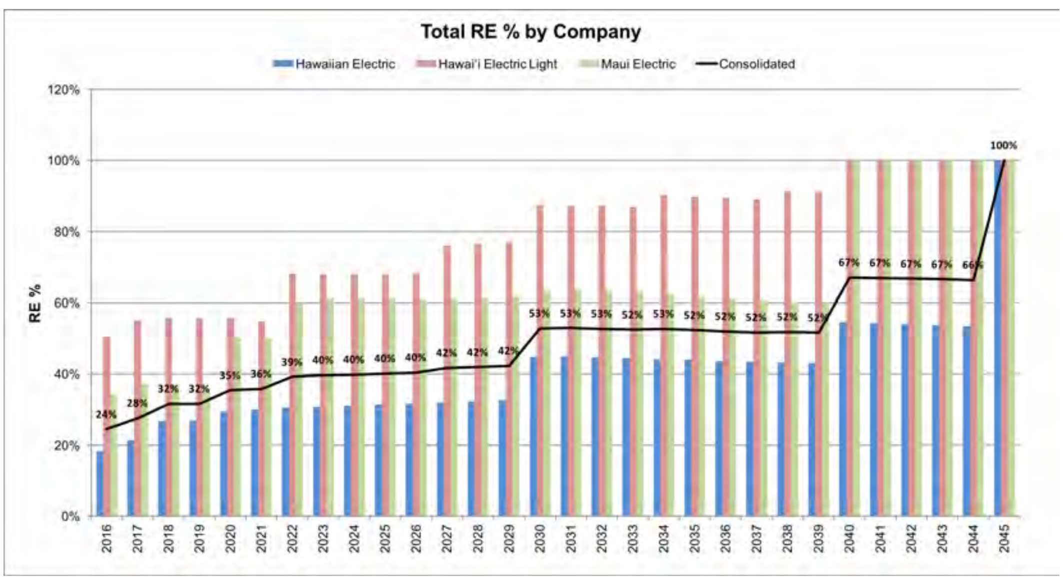

Figure ES-3. Total Renewable Energy Percent of Preferred Plans

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Figure ES-4 provides a long-term view of a path towards 100% renewable in 2045. Under the current Preferred Plans, the possible path as our tri-companies move toward 100% renewable energy by 2045 is as follows:

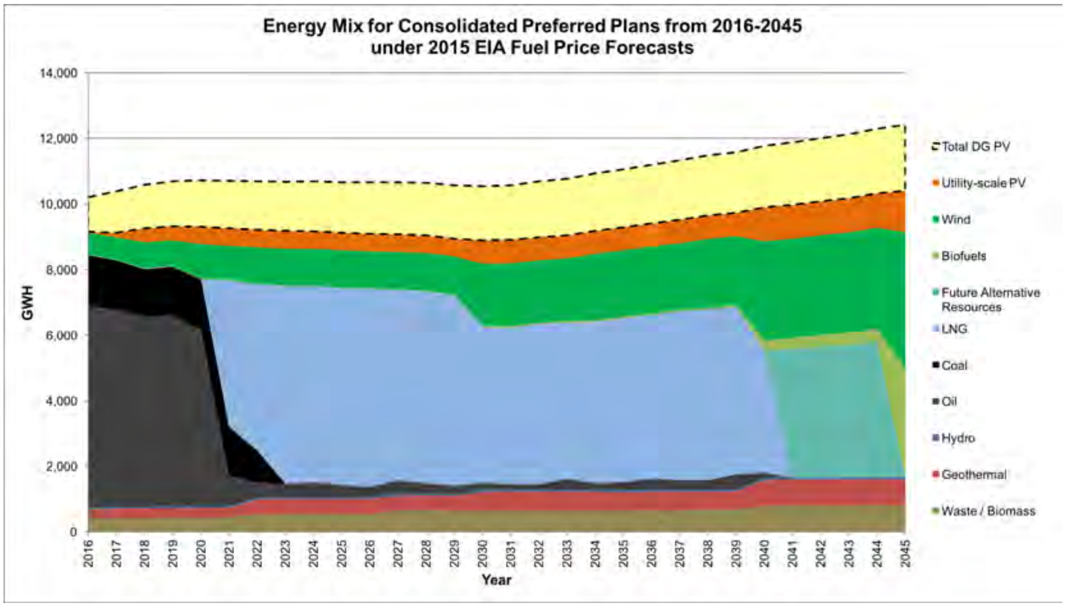

Figure ES-4. Energy Mix for Theme 2 on O'ahu from 2016-2045 under 2015 EIA Fuel Price Forecasts

Future Alternative Fuels: During the last intervening years in the transition to 100% renewable energy, potential fuels at this time could include biofuels, LNG, oil, other renewable options or a mix of options. Given rapidly evolving energy options and technology, the exact fuel mix is difficult to predict today.

Multiple Benefits Provided from Demand Response Programs

Demand Response (DR) programs—market-based programs that incentivize customers for change in electricity usage patterns—play a key role in integrating variable renewables. In addition to providing capacity and load shifting, DR can also provide other ancillary services, such as regulating reserves. Load shifting DR programs to encourage more usage at times when solar generation is most abundant appears to provide the most value.

Distributed Energy Resources Plays a Critical Role

Economic, market-based DER contributes a significant portion of the resource mix, resulting in a 250% increase over current levels and a 370% increase over the starting point level in our 2014 PSIP. The current PSIP Update assumes market-based levels of DER for O'ahu, Hawai'i Island and Maui and higher levels of DG-PV for Moloka'i and Lāna'i, as those smaller islands are leading the rest of the state in developing new solutions for DG integration challenges. However, because the market-based DER is expected to largely be variable solar PV, the energy contribution of market- based DER, while still significant, is smaller than the megawatt capacity suggests. This is the assumption for now, but as we continue to analyze the long-term options for addressing the challenge of closing the gap to 100% renewable energy on O'ahu and as technologies and their prices change, the option of pursuing a higher DG-PV strategy on O'ahu in later years should be kept open.

Community-Based Renewable Energy (CBRE) Enables Broader Customer Benefits

Community-Based Renewable Energy (CBRE) could also provide a significant contribution to the attainment of 100% renewable energy, and allow many other customers to participate and benefit from renewable energy options like solar PV who otherwise cannot or would not.

Liquefied Natural Gas (LNG) as a Bridge Fuel Provides the Most Affordable Pathway to 100% Renewables

There appears to be alignment among most stakeholders that Hawai'i must achieve the 100% RPS goal in a cost-effective manner. Our PSIP Update confirms that LNG and generation modernization (as described below) offer the best path forward in the transition to 100% RPS.

LNG is a prudent choice because it will displace 80 percent of our imported oil use between 2021-2040, keep electric rates lower than they were 18 months ago, lessen price volatility, and significantly reduce our carbon footprint. This is true across the range of fuel prices evaluated in this PSIP for O'ahu, Maui and Hawai'i Island combined.

The Governor has stated his concern that using LNG will divert focus away from a 100%renewable energy future. We understand our responsibility in working with others throughout the state not to let that happen. We believe we can move aggressively towards 100% renewables with LNG as a transitional bridge fuel through 2040, limiting permanent infrastructure while allowing for variable demand and lessening the cost burden on customers as we make the transition to renewables.

Although, as noted below, the current LNG option and the significant benefits it can provide customers is available only under the merged scenario, we would still be interested in pursuing LNG in an unmerged scenario if an option is developed and provides meaningful cost savings, reliability and environmental benefits for our customers. However, the merged scenario below provides a clearer and more immediate path for delivery and earlier benefits for customers.

Furthermore, the case utilizing LNG and the advanced combined cycle generator produces fewer carbon dioxide emissions than the accelerated renewable generation planning scenario by over 4 million tons during the 30-year planning period. These results demonstrate the value of efficient and flexible generation utilizing clean burning natural gas along with renewable generation additions while meeting the 100% RPS targets by 2045. Not only will customers realize the lowest overall cost, but they will also receive the long-term benefits of a cleaner environment.

The Need for Flexible and Efficient Generation Is Needed

As the Commission has recognized in its Inclinations paper, "the Hawaiian Electric Companies should continue to evaluate opportunities to retire and replace older, high cost plants with new resources with valuable characteristics that provide required support services cost-effectively to maintain a reliable electricity grid with high levels of renewable resources."[1] One example of a flexible and efficient generator is an advanced combined cycle unit planned for O'ahu. Such generators have many benefits -- fast starting, cycling, fast ramping, fuel efficiency, low emissions, and improved reliability— all of which lower operating costs for customers. The flexibility of these units supports the variable nature of renewable generation and the transition to 100% RPS, as well as reduces the size of costly energy storage systems. When sited at existing generating stations, they can take advantage of existing infrastructure, minimizing the impact to the local community. On Maui and Hawai'i Island, existing dispatchable combined cycle generators already provide a considerable amount of flexible generation, allowing higher levels of renewable generation on those islands. Use of LNG in these generators can enhance their flexibility while lowering costs and reducing emissions. LNG was not found to be cost-effective for use on Moloka'i and Lāna'i.

The PSIP Update results indicate that for Oahu, the lowest overall cost and lowest emissions are achieved in the case that includes a large-scale advanced combined cycle facility to replace older steam generators at the Kahe power plant combined with the use of LNG. Updated generation facilities will also make our overall system more resilient as a result of siting the new facilities outside of recently revised tsunami inundation zones.

[1] Docket No. 2012-0036, Order No. 32052: Regarding Integrated Resource Planning, Exhibit A: Commission's Inclinations on the Future of Hawai'i's Electric Utilities, at 7.

More specifically, with input from NextEra Energy, we have identified a 383 MW 3x1 combined cycle facility to replace Kahe Units 1–4 which could use LNG as a substitute for oil. This scenario—only possible as a merged entity—results in lower costs to customers over the planning period of cases evaluated, supports an increasing amount of renewables, reduces environmental emissions, and improves grid reliability and security. Furthermore, this advanced 3x1 combined cycle option appears to be advantageous with or without LNG, but is clearly better when using LNG as a transitional fuel source to get to a 100% RPS. In fact, when utilizing both LNG and the advanced combined cycle option on O‘ahu, carbon dioxide emissions would be reduced by over 4.1 million tons by 2023. This is the equivalent of removing over 110,000 passenger vehicles from the road each year.

Again, such a scenario combined with other projects and programs envisioned for this same timeframe (such as Smart Grid, Schofield Generating Station projects, and others) would require the financial backing and development capacity of the merged organization.

Grid-Connected Microgrids on Military Installations Enhance Statewide Resiliency

In Hawai‘i, there is a growing and important role for distributed generation at military sites to enhance energy resiliency and security.

Microgrids on military sites that operate in complementary fashion interconnected to the utility grid:

- Provide resiliency and energy security for all our customers by using diversified locations for firm generation.
- Provide enhanced energy resiliency and security on military bases that are key to national defense and emergency or disaster response. These bases house airfields, ports, logistics, manpower, and housing necessary for major humanitarian response missions.
- Help ensure our state is capable of supporting military core missions and therefore remains a key sector of our economy.

In addition to the Schofield Barracks Generating Station previously approved by the Commission and well into the development process, this PSIP Update also includes plans for similar distributed generation on Marine Corps Base Hawai‘i and Joint Base Pearl Harbor-Hickam.

FIVE-YEAR ACTION PLANS: SETTING A COURSE FOR OUR RENEWABLE FUTURE

Hawaiʻi is well on its way to meeting its energy goals as the Hawaiian Electric Companies exceeded a 23% RPS in 2015, substantial progress from 9% achieved in 2008, the year Hawaiʻi broke new ground with bold new renewable energy goals under the Hawaiʻi Clean Energy Initiative. The five year Action Plans will keep up the momentum.

Again, given the uncertainty and the future changes inherent in planning for a 30-year horizon, it's most important to focus on five-year action plans that keep up our progress, support the integration of increasing amounts of variable energy and reduce risk. The Action Plans are designed not to foreclose any future resource option.

Key Steps In Our Five-Year Action Plans

Implementing a Smart Grid Foundation Project to install the modern wireless network, smart meters and other enhanced technology to modernize and improve the efficiency of our existing power grids.

Implementing a Demand Response Management System (DRMS) to enable greater use of evolving DR programs.

Pursuing Market-Based DER for Oʻahu, Hawaiʻi Island and Maui and High DG-PV for Molokaʻi and Lānaʻi. High DG-PV will be considered for Oʻahu in later years as an option to help close the gap to get to 100% renewable energy. In the near-term Action Plan period, market-based and High DG-PV levels are similar. DER programs by their nature can be adjusted to meeting changes in market interest, technology, pricing, value, and system needs.

Installing Circuit Level Improvements on All Islands. Enabling monitoring and controls to DER systems, upgraded conductors, voltage regulators, transformer replacements, reconfiguring circuits, distributed energy storage while leveraging existing and future advanced inverter functionality.

Pursuing Energy Storage Options:

- Installing 90 MW of utility-scale battery storage on Oʻahu to provide contingency reserve power to help maintain reliability in an emergency situation, ensure energy resiliency under low inertia operating conditions, and to help meet fluctuating energy needs due to variable wind and solar resources.
- Install energy storage on Maui and Hawaiʻi Island to provide contingency reserves.
- Participating in many energy storage pilot projects with technologies that may provide grid services. Some of these pilots include (not an exhaustive list)

partnerships with innovative start-ups, such as Stem[2] and Shifted Energy[3]. Based on what we learn, we can pursue "front-of-the-meter" storage options and demand response programs, both directly and indirectly.

- Implementing several Moloka'i projects including:
  - A battery storage research project in partnership with Hawaii Natural Energy Institute to determine applications for batteries in high solar PV penetration scenarios.
  - A pilot program in partnership with E-Gear LLC, installing their specialized Energy Management Controller and storage technology to allow at least 10 rooftop PV systems in the queue to move forward. The program will test the equipment monitoring capability and controllability of such systems by Molokai system operators and the impact of such advanced PV systems on the grid.
- Evaluation of other storage options, including for load shifting, as technologies improve and costs reduce.

Implementing Community-Based Renewable Energy using a phased approach to help ensure a sustainable program, in line with the market demand, while respecting the technical limitations of the electric grid. Community-bases renewable energy programs are intended to provide affordable renewable energy options for our many customers who are renters or live in multi-unit buildings. The first phase is envisioned to last two years, to commence upon Commission approval. Learnings from the first phase will inform the planning process for the second phase.

Issuing Requests for Proposals to seek over 351 MW of additional renewable energy by 2022 via a competitive processes.

- 225 MW of utility- scale wind and solar for O'ahu. This includes 25MW under a proposed CBRE program.
- 20 MW of firm dispatchable renewable capacity for Hawai'i Island in 2022.
- 60 MW of variable renewable and 38 MW of firm dispatchable renewable or renewable-capable generation capacity for Maui to address the anticipated retirement of the Kahului Power Plant in 2022, growth in customer demand, constrained South Maui transmission capability, and Hawaiian Commercial & Sugar (HC&S) ceasing operations.
- 5 MW of wind energy for Moloka'i and 3 MW of wind energy for Lana'i for 2020

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[2] Stem is an energy storage provider that has deployed a pilot project aimed at demonstrating how distributed storage can help the utility affordably integrate more renewable energy onto the system.

[3] Hawaiian Electric is working with a company called Shifted Energy to deploy 499 grid interactive water heaters at the Kapolei Lofts development project (housing in Kapolei developed by Forest City) for the demand response program. See http://www.greentechmedia.com/articles/read/hawaii-to-test-smart-water-heaters-as-grid-resources.

Researching alternative curtailment policies to help ensure cost-effectiveness and flexibility in contracting renewable resources and supporting the reliable operation of the grid.

Deactivating generation not well suited to support the integration of renewables. For O'ahu, under the plan using LNG, Kahe Units 1 to 3 and Waiau Units 3 and 4 will be deactivated. On Maui, Kahului Units 1 to 4; and on Hawai'i Island, the plan assumes the Puna Steam Unit will be deactivated.

Taking the next steps to pursue the benefits of LNG. Given the environmental, cost saving, price stability and price hedging benefits of LNG, we plan to submit an application to the Commission for approval of an LNG fuel supply agreement and related regulatory applications for the modernization of generation at O'ahu's Kahe Generating Station described in the Need for Flexible and Efficient Generation section above.

Improving flexibility of existing generation to help facilitate the integration of variable renewable generation (lower operating levels, ramp improvements).

Investments for Hawai'i's Renewable Future

Achieving 100 percent renewable energy takes substantial capital investment. All options, whether the Preferred Plans or other candidate plans, require substantial amounts of capital, compensated for by customer savings over time. The total capital investment over the next 30 years for Hawai'i is estimated to be $25.8 billion (in nominal dollars), of which the utility may invest 53%, or $13.6 billion. The balance may be made by project developers, customers, and the State (via tax incentives).

However, with this investment, we are able to modernize generation to be more flexible and efficient, transform our transmission and distribution system to better integrate both distributed and larger utility-scale renewables, and obtain the energy security and environmental benefits by achieving a 100% renewable future, all while keeping electric rates stable and relatively flat on a real dollar basis. Figure ES-5 through Figure ES-8 depicts the average monthly residential bill for O'ahu over the planning period.

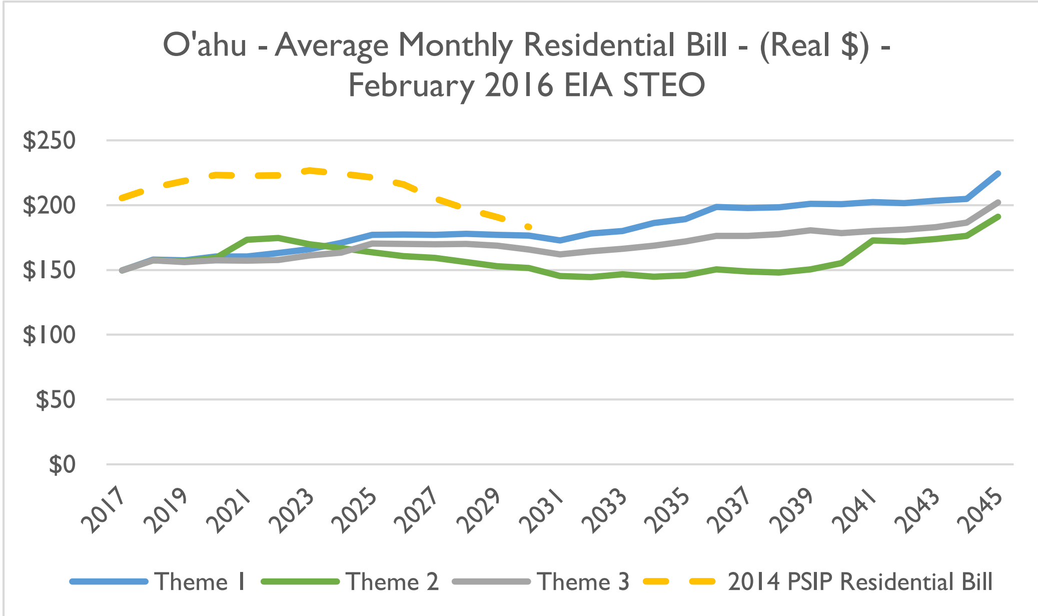

Figure ES-5. Residential Bill (Real 2016 $): February 2016 EIA STEO

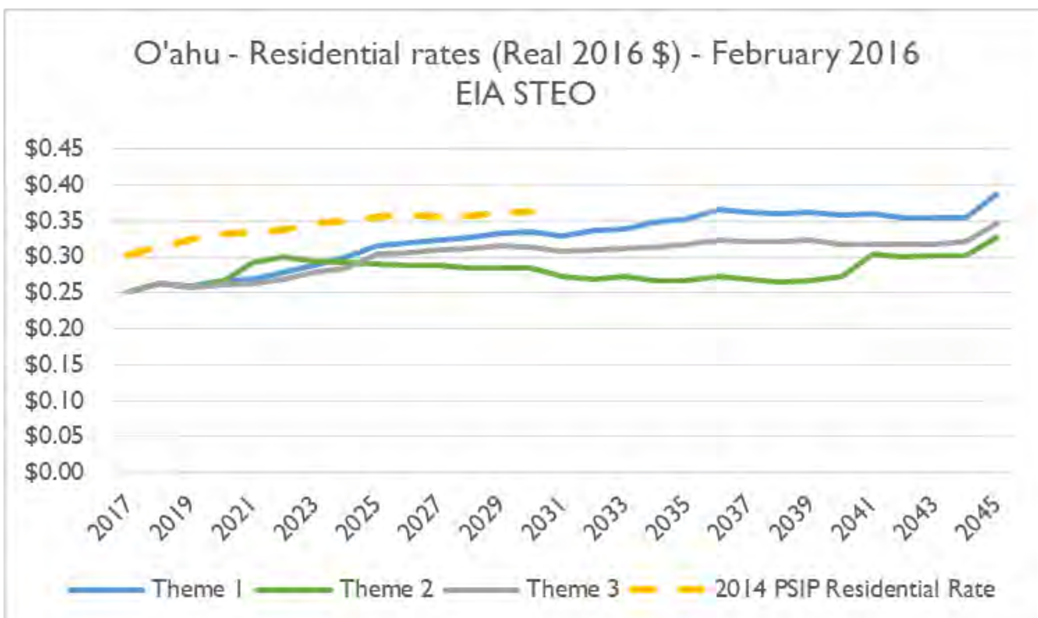

Figure ES-6. Residential Rates (Real 2016 $): February 2016 EIA STEO

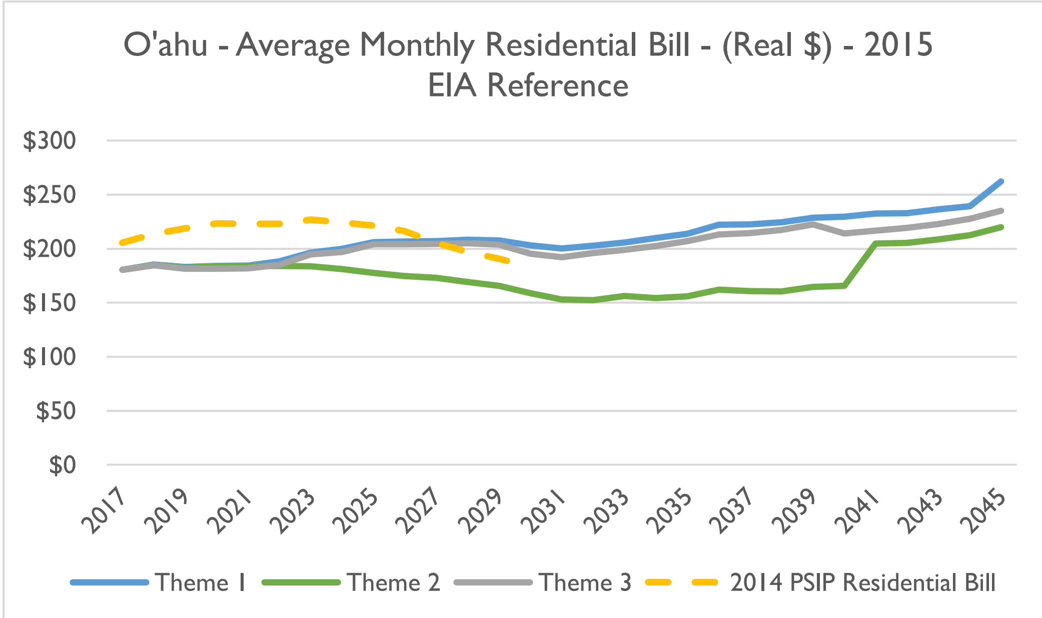

Figure ES-7. Residential Bill (Real 2016 $): 2015 EIA Reference

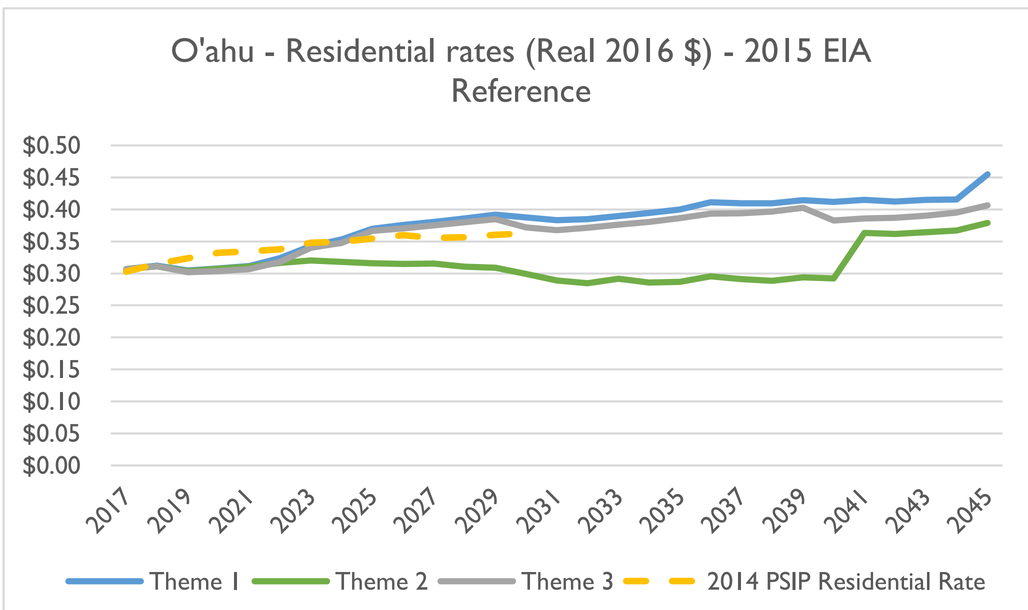

Figure ES-8. Residential Rates (Real 2016 $): 2015 EIA Reference

Stakeholder Input

Consistent with the Commission's directive, on January 15, 2016, most of the Parties in this docket filed reports providing input into the process outlined in Order 33320. In addition, we held a stakeholder conference on December 17, 2015 and participated in an

Executive Summary Planning Status of Our PSIP Update Interim Status Report technical conference on January 7, 2016. The Commission also held another Technical Conference on March 8, 2016. We've also proposed another Technical Conference to be held on April 15, 2016.

We've considered the input received and have incorporated it, to the largest extent possible, into our analyses. Also, we've addressed several key points of feedback from the Parties. Examples include: sharing of resource cost assumptions with the Parties; establishment of an FTP site to facilitate sharing data and other information with the Parties and obtaining their feedback; use of a "decision framework" to establish a clear basis for how plan objectives will be prioritized; and introduction of a "PSIP Optimization process" consisting of iterative cycles for Distributed Energy, Demand Response and Utility-Scale Resources to capture analytical steps in achieving the 100% RPS goal.

We invited Parties in the docket to attend and participate in our working meetings where we reviewed analysis, made decisions on further refinements, and discussed the modeling analysis for completing the 2016 updated PSIPs. Representatives from DBEDT, the Consumer Advocate, and the County of Hawai'i participated in about 10 meetings.

As indicated in our Proposed PSIP Revision Plan, additional organizations provided independent technical analyses to help address issues of concern. These stakeholders include the Hawaii Natural Energy Institute, Electric Power Research Institute, U.S. Department of Energy, University of Hawai'i Economic Research Organization, National Renewable Energy Laboratory, and Hawai'i Energy.

Unprecedented Process

The 2016 updated PSIP is a first of a kind planning analysis that aims to optimize resources across those owned by customers, other third parties, and utilities, to include behind-the-meter DER, distribution resources, transmission, and centralized power plants. Though this massive planning process we are completely transforming our power grids.

To create our 2016 updated PSIPs, we developed new tools, new processes, and new methods to plan for the utility of the future and used a team of industry-leading consultants. Because of schedule constraints, we have not been able to fully utilize some of these new tools, processes, and methods, nor fully realize their benefits. After the April 1 filing, we plan to continue using these newly developed methodologies as we continue our work in this docket and in other related (such as DER and DR) dockets.

NEXT STEPS

Given the scope of that directive and the timeframe in which to complete it, we have completed a thorough analysis to develop PSIP updates that include five-year action plans that can be implemented in the short-term. We will continue to evaluate the potential long-term renewable resource options especially for the period of time after 2030.

Updated Fuel Price Forecasts

One of the foundations of our analysis is the fuel price forecasts for LNG and petroleum-based fuels. The U.S. Energy Information Administration issues updated fuel price forecasts generally mid-year. After we receive these forecasts, we can update our analysis based on these updated prices. We expect to file an addendum to our 2016 updated PSIPs within two months after these fuel price forecasts are published.

Analyze Inter-Island Transmission

Given the findings of the PSIP Update that O'ahu will likely need a substantial amount of off–island renewable resources in order to meet a 100% renewable energy goal in 2045, we plan to reassess the scope and requirements for an interisland cable. As a follow-up action, we plan to (a) identify viable resource alternatives, such as wind and geothermal, and resource availability and location; (b) develop capital cost estimates for the alternatives, including cost to integrate the resources; and (c) complete the analyses comparing the alternatives and mixes of alternatives.

Perform Further Research on Offshore Wind

Although our current plan projects the use of significant amounts of offshore wind energy, we plan to perform further evaluation of the viability of these resources. This would include assessing the resource potential, evaluating possible onshore interconnection configurations, identifying risks factors (for example, permitting, community acceptance, natural hazards and hazards from human activity), and refining resource development and installation costs. These evaluations will be performed in conjunction with our planned analysis of an interisland cable system.

Perform Additional System Security Analysis for the Preferred Plans

While system security analyses were performed as part of the PSIP Update, additional analysis will be completed, including a protection coordination study, reactive power requirements and voltage stability analysis.

WORKING TOGETHER FOR HAWAI'I'S RENEWABLE ENERGY FUTURE

Although our energy environment is changing more rapidly than ever, what is clear is that Hawai'i's 100% RPS goal is achievable, technology and pricing will continue to change to make this possible, and foundational investments in more flexible generation and use of cleaner fuels in the transition can be an important step as increasing amounts of variable renewable energy resources are added on our path to 100% renewable energy. Most importantly, achieving the groundbreaking 100 percent renewable energy goal for our state will take *our entire community working together* to make the difficult decisions needed to achieve this clean energy future for our state.

1. Introduction

The Companies fully embrace attaining Hawai‘i’s 100% Renewable Portfolio Standard (RPS) goal. For our 2016 supplemented, amended, and updated PSIP, we have developed a set of Preferred Plans and their attendant Five-Year Action Plans that explain how we intend to deliver affordable, reliable, clean energy. Each plan not only meets the intermediate milestone RPS targets, but also attains 100% renewable energy generation by 2045.

A COMPREHENSIVE GRID TRANSFORMATION

The Companies face an unprecedented situation: a comprehensive transformation of our five electric power grids. Attaining our state’s renewable energy goals represents uncharted territory for both short-term and long-term resource planning. Performing the analyses necessary to attain this goal is a complicated resource planning process, requiring new tools and new processes: modeling across generation, transmission, distribution, infrastructure, and behind-the-meter resources options.

Several high-level objectives drive our planning process, chief among them attaining 100% renewable energy, establishing reasonable customer bills in light of the state’s bold renewable goal, and maintaining reliability. During our planning, we considered numerous variables: customer rate and bill impacts, customer choice, resource costs and availability, distributed energy resources (DER), demand response (DR) as a component of DER, energy storage, new technologies, generation modernization, existing generating assets, transmission and distribution infrastructure modernization and upgrade, fuel selections, environmental considerations, system security, ancillary services, capital cost considerations, and risks.

Many entities are involved in this process: expert teams from our three operating utilities together with several knowledgeable and experienced consulting firms, each running different modeling tools to analyze various paths toward developing a reasonable Preferred Plan for each island we serve. In addition, we incorporated input from several of the Parties and from most of the intervenors to the docket.

Goals of the PSIP

Our 2016 updated PSIP attains these goals:

- Offer customer choices in generating and saving energy.
- Systematically integrate cost-effective renewable energy over the next 30 years.
- Meet or exceed all RPS milestone targets.
- Exceed the 100% RPS by attaining 100% of generation from renewable resources by 2045.
- Implement a revised suite of DR programs.
- Reduce customers exposure to fuel price risk and volatility.
- Modernize the generation fleet to cost effectively integrate higher levels of variable renewable energy resources.
- Systematically retire older, less-efficient and less flexible fossil generation.
- Reduce must-run fossil generation.
- Increase generation operational flexibility.
- Utilize new technologies for grid services.
- Meet and exceed environmental requirements.
- Maintain the level of system reliability our state relies on.

Developing Meaningful, Well-Reasoned Plans

Planning for this intensive resource and grid transformation requires critical inputs and forecasts as well as modeling tools that simulate future configuration of a power grid—which is how we proceeded for these updated PSIP. Our planners must then evaluate resultant configurations, and arrive at decisions that are virtually unprecedented in energy resource planning. The decisions facing our resource planners, and ultimately the state of Hawaiʻi, cannot be overstated. These decisions are monumental.

In addition, we must arrive at these decisions without the benefit of being able to compare and contrast them with similar decisions by other utilities. We are on our own.

We updated resource assumption inputs and engaged stakeholders for input, then developed and analyzed nearly 200 candidate plans—or cases—from which we chose our final Preferred Plans. Throughout, we followed a Decision Framework to make critical assessments and decisions along the way in a transparent manner and included intervenors in the process to observe, ask questions, and provide comments. That process led us to this 2016 updated PSIP.

We created the 2016 updated PSIP based on the current state of our power grid, forecast conditions; reasonable assumptions regarding technology readiness, availability, performance, applicability, and costs; and on the ability to maintain system security requirements. As a result, these plans present an actionable, cost-effective path to transforming our power systems into the ultimate model of sustainability. We have attempted to fully document and be transparent about the assumptions and processes utilized to develop the plans.

This supplemented, amended, and updated PSIP:

- Includes long-term analysis of the integrated grid systems to better evaluate specific, prudent near-term capital investments and other near-term decisions.
- Provides context and sound analysis to inform well-considered choices and illuminate trade-offs between major interrelated or mutually exclusive resource strategies and choices.
- Provides assurance that the overall operational cost and rate impacts and proposed resource acquisitions are reasonable and economically affordable to benefit all customers.
- Identifies risks and uncertainties that inform the issues and trade-offs associated with resource acquisition and system operation decisions.

As circumstances change, we will continue to evaluate the impacts of any changes to our material assumptions, seek to improve the planning methodologies, and evaluate and revise this PSIP to best meet the needs of our customers.

ATTAINING 100% RPS

Our 2016 updated PSIP meets, and exceeds, each of the RPS milestones set by law in 2020, 2030, 2040, and 2045. In addition, the 2016 updated PSIP attains 100% renewable generation by 2045.

Our Renewable Generation Goal

The Hawai‘i State legislature mandated that each electric utility company that sells electricity for consumption in Hawai‘i must establish set percentages of “renewable electrical energy” sales.

Subject to Commission approval of the proposed merger, NextEra Energy stated their intent to “undertake good faith efforts to achieve a consolidated RPS” more aggressively than the statutory requirements.

Table 1-2 lists the statutory milestones together with these more aggressive RPS percentages.

Milestone Date	Renewable Electrical Energy Generation as a Percentage of Sales	Merged Commitment for Renewable Energy
December 31, 2020	30%	35%
December 31, 2030	40%	50%
December 31, 2040	70%	70%
December 31, 2045	100%	100%

Table 1-2. Commitments for Attaining State RPS Law

The Companies are committed to transforming the generation fleet so that 100% of the power generated comes from renewable sources. Thus, under the RPS formula established by the Legislature, we will exceed the 100% RPS goal.

Regardless of whether or not pending legislation is enacted, we are today committed to attaining 100% renewable generation by 2045. All of our planning, modeling, analyses, and evaluations are based on this goal.

COMPONENTS FOR ACHIEVING THE 100% RPS TARGET

Hawai'i has set a bold target for achieving a 100% RPS by 2045. For the state to meet these targets, we undertook a thorough evaluation of the options to attain that goal. We believe that this can be best understood with a methodical analysis of the building blocks needed to achieve a 100% renewable energy solution and a reasonable path to get there, with a particular focus on the near-term steps needed to enable the reasonable path.

As a whole, the combination of market-level cost-effective distributed energy resources with firm, dispatchable renewable biomass and geothermal plus utility-scale wind are key renewable resources needed to achieve a 100% renewable energy goal. These renewables need to be integrated with demand response and optimized amounts of energy storage and biofuels. Liquefied natural gas as a transitional fuel and generation modernization affords a significant opportunity to reduce customers bill as the transition is made to higher levels of renewable energy.

The Role of Distributed Energy Resources

Distributed energy resources (DER) provide a core component of the potential renewable additions to the islands. DER can take many forms and encompass several approaches, including demand response, energy efficiency, electric vehicles, customer-owned generation, and customer-owned storage technologies.

As we evaluate the landscape today, the most significant form of DER is distributed generation photovoltaics, or DG-PV: solar PV generation installed at the homes and businesses of Hawai'i. While a critical component of our efforts to achieve a 100% renewable future, the implementation, timing, and adoption of residential and commercial solar generation is not fully within our control, nor necessarily the Commission's. Rather, it will be dictated in large part by the individual decisions of businesses and homeowners in response to products and service offerings from an emerging DER market.

The adoption of DER is also driven by customer economics, which is then driven by two factors: the benefits of the DER system to the customer (for example, avoided electricity purchases from the utility and compensation received for exports to the grid) and the capital and operating cost of the DER system. We forecasted DER adoption in two ways. First, we assumed that compensation to DER customers for exports is based on the cost of a utility-scale solar plant ("market DG-PV"). Second, we forecasted a high DG-PV case based on enhanced compensation for DER exports ("high DG-PV").

Table 1-3 depicts the total projected installed capacities of the optimized DG-PV forecasts for the RPS milestone dates for the entire planning period of the updated PSIP.

Milestone Date	Market DG-PV Forecast	High DG-PV Forecast
December 31, 2015	487 MW	487 MW
December 31, 2020	848 MW	853 MW
December 31, 2030	991 MW	1,466 MW
December 31, 2040	1,129 MW	2,161 MW
December 31, 2045	1,204 MW	2,508 MW
Growth (2015–2045)	717 MW	2,023 MW
Growth Percent	247%	515%

Table 1-3. DG-PV Forecasts Under Market and High Scenarios (total for all islands)

In developing the 2016 updated PSIP, we have sought to estimate the likely rate of DG-PV adoption, ensuring any plan is robust enough to encompass higher or lower adoption rates while maintaining a path towards a 100% RPS. Our PSIP takes these sensitivities into account. We are committed to continuing to evaluate and optimize DER under various adoption rates. DER alone, though. cannot meet the 100% RPS target for Hawai‘i.

The Companies are leaders in the initial growth stage of DER. On O‘ahu alone, 32% of single–family homes have rooftop PV systems installed or approved for installation. Coupled with continued innovation in other forms of DER—such as electric vehicles (EV) and distributed energy storage systems (DESS)—our operating utilities are proactively planning for future additions of DER. The rapid adoption of these technologies requires us to design programs that optimize the system, leverage these resources in planning and operations, and maximize customer benefits.

Optimizing the system implies utilizing the resources in a cost-effective and reliable manner that minimizes overall customer bills and reduces exposure to fuel price risk. Further, with more DER options, customers can effectively be a “prosumer”, that is one who consumes utility power supply and utilizes grid services as well as provides power supply and grid support services to the utility and for oneself.

To ensure an optimal system and maximum customer benefits, DER provisions of power supply and grid services should be maximized when DER can provide the services cost-effectively and efficiently. Put another way, if DER can adequately, reliably, and cost-effectively provide these services, customers should be enabled to provide power supply and grid services to the electric system (customer choice). Enabling customer choice cost-effectively is one of several objectives of the PSIP.

Demand Response

Demand response (DR) is an important and integral component of our resource mix. In addition to providing capacity and load shifting, DR can also provide ancillary services, such as regulating reserves.

We developed a portfolio of DR programs and described those programs for O'ahu in the DR Dockets.[4] In the PSIP analyses, we optimized the use of these DR programs for the five islands we serve through iterations of the PSIP modeling results. The DR programs developed align with the grid services needed by each of our systems, and with program design and costs aligned with market studies developed in the DR Docket. The DR programs enable our customers to better manage their energy use and cost. We continue to aggressively pursue DR programs that best meet these goals.

We intend to implement DR programs that appeal to residential and commercial customers, and that provide cost-efficient services most beneficial to the grid. It is absolutely essential that DER and DR remain connected to the grid to provide their contributions to the system. A highly reliable grid is necessary for DER and DR resources to function properly; as such, system security becomes ever more important.

Cost-Effective Utility-Scale Renewable Generation

After fully utilizing economical levels of DER and DR, the 2016 updated PSIP analyzed and optimized the use of cost-effective, utility scale renewable solutions. The candidate renewable resources include solar PV; onshore wind for all islands; offshore wind for O'ahu; geothermal for Hawai'i Island and Maui; and biomass for Hawai'i Island, Maui, Lana'i, and Moloka'i. While these resources were specifically analyzed in this PSIP update, we fully recognize that other, new renewable resources will become portfolio options in the future. We will consider inter-island transmission, as well as other renewable resources, for further optimization of renewables in future analyses.

The Hawaiian Islands have abundant renewable resource potential, but face many challenges due to the nature of each island's unique physical and societal characteristics. The approach utilized in the development of the PSIP methodically evaluates the feasibility of adding available utility scale renewable wind and solar to each island. With assistance from third-party organizations, we undertook several supporting efforts to better understand the reasonable wind and solar resource potential of each island.

For O'ahu, it is clear that the aggregate potential of variable renewables such as utility-scale solar, onshore wind, and distributed-solar, while significant, is not sufficient to reach the 100% RPS goal without additional renewable resources. As such, we

[4] Docket Nos. 2007-0341 and 2015-0412.

considered offshore wind resources in addition to inter-island transmission as competitive alternatives to biofuels.

Our analysis for all of our utilities, therefore, sought resource mixes that considered variable renewables, in addition to the following:

- The addition of energy storage systems.
- Strategic use of curtailment. (We evaluated the economics of curtailing variable renewable resources assuming the curtailed energy is paid for under a "take or pay" arrangement and the regulation benefit of the unused energy versus energy storage systems.)
- Liquefied natural gas (LNG) as a cost-effective transitional bridge fuel toward attaining 100% RPS.
- Renewable liquid biofuels burned in existing or modernized generation facilities.
- Offshore wind resources that would be constructed on floating platforms.
- Geothermal as a firm, dispatchable renewable resource.
- Biomass as a firm, dispatchable renewable resource.

The addition of an inter-island cable, which could function as a grid-tie between Oʻahu and Maui and Hawaiʻi Island, might unlock the development of additional renewable resources on those islands where renewable resource potential exceeds what could reasonably be consumed locally.

Waste-to-energy (WTE) plants fulfill a broader societal role. The timing of their implementation, however, is not under our control. WTE projects depend on a steady and predictable flow of municipal solid waste, tipping fees paid to the owner of the WTE plant, and the value of the electricity produced by the WTE plant based on alternative sources of generation. Each of these factors contribute to a WTE plant's economic viability. Local county governments typically instigate the development of WTE projects on their own or in conjunction with a private developer. Analysis of a WTE resource option requires specific information regarding the size, operating profile, fixed costs, and energy costs for WTE on any particular island. Therefore, WTE projects were not explicitly considered in this PSIP update. Specific proposals will be modeled as they are received.

Energy Storage

Energy storage is a set of rapidly advancing technologies. We believe that continued transformative shifts in energy storage technologies could further enable the integration of renewables onto the system, in a cost-effective manner. As we developed our updated PSIP analyses, we evaluated the use of energy storage technologies. Specifically, we considered battery energy storage systems (BESS) and pumped storage hydro (PSH). A flywheel option was also developed, but does not specifically appear in any of our plans, and would be considered at the time when the storage resources are procured.

Energy storage can be utility-scale or distributed at the customer level, both providing load-shifting capabilities. As DR can also provide that capability, we assessed energy storage potential considering the contribution from market-priced, cost-effective DR also providing load shifting and have defined the system security requirements in technology neutral terms so that DR resources can be evaluated.

Energy storage can also provide ancillary services, such as fast frequency reserves, primary frequency reserves, regulation reserves, and replacement reserves. Using storage to provide these functions provides an alternative to obtaining these services from online generation and can increase the ability of the system to accept more renewable energy.

While energy storage prices (particularly BESS technologies) are forecasted to decline in cost and improve in performance, they still come at a cost. Therefore, in our analyses we evaluated the tradeoffs between curtailment of variable renewable resources (that is, wind and solar PV), the installation of energy storage, and use of biofuels. Our final and preferred plans reflect an optimized balance between curtailment of variable renewable resources, the costs of BESS systems, and biofuels.

LNG as a Cost-Effective Transitional Bridge Fuel

There appears to be alignment among most stakeholders that Hawai‘i must achieve the 100% RPS goal in a cost-effective manner. LNG is a prudent choice because it will allow us to significantly lower emissions, reduce fuel costs and customer bills, and reduce customer exposure to fuel price volatility as we transition our system to achieving our energy goals.

Our findings show that LNG plans offer the best long-term economics for our customers while we transition to 100% renewable energy. Without LNG, a substantial amount of oil will be burned during the transition to renewables under any transition scenario, with continued significant exposure to higher oil prices and volatility risk for some time to come.

For O‘ahu, the remaining solar and onshore wind potential only partially attains the amount needed to reach 100% renewables. This means that offshore resources will be required to meet the RPS goals: inter-island cable, offshore wind, or liquid biofuels. These alternatives still need to be fully evaluated, as all three present substantial risks:

Offshore Wind. There has never been an offshore wind project sited in waters as deep as those in Hawai‘i, and integrating large quantities of offshore variable renewables injected into the O‘ahu system at only a few points presents substantial interconnection and operational challenges.

Inter-Island Transmission. Undersea transmission systems are in service around the world and are a proven commercial technology. The current plans, paths, and projected costs for inter-island transmission require further evaluation to ensure the impact to the existing transmission system is addressed.

Biofuels. Sufficient quantities of biofuels, in the short term, appear to be questionable.

While initial steps need to be taken now to make such off-island resources viable options for the long–term, accelerating these projects into the near term rather than waiting until they perhaps might be more fully developed is risky and very likely to be more expensive.

Given the foregoing, LNG provides a hedge against oil price volatility and development risk inherent in offshore resources such as deep-water offshore wind and inter-island cables while reducing emissions. Even with LNG, these resources will be needed, but LNG allows time for these options to mature, their risks to diminish, and their prices to decline.

Renewable Biofuels

Renewable biofuels, particularly liquid or gaseous biofuels, play an important role in achieving the 100% RPS. Utilizing biofuels as a complement to DER, wind, solar and energy storage has the benefit of using a portion of the dispatchable thermal generation mix as part of the overall generation solution. This can help avoid the commitment of new capital for other renewable generation or additional resources to provide ancillary services that can be provided by existing and modernized replacement thermal generation. The flexibility of the dispatchable thermal generators will need to be a critical component in compensating for the variable nature of the wind and solar resources, providing energy during low renewable generation periods or seasons, thereby helping to ensure that our customers can continue to receive electricity from a safe and reliable system.

Offshore Wind

Offshore wind has been considered as a resource option for O‘ahu in the PSIP updates. Two developers have announced their intentions to pursue the installation of offshore wind to serve O‘ahu:

- Alpha Wind Energy proposes to develop a 408 MW offshore wind project in federal waters off O‘ahu’s northwest and southern coasts. The announced capital cost of the project is $1.6 billion (approximately $3,925 per kilowatt).[5]

[5] http://www.hawaiicleanenergyinitiative.org/wind-in-oahus-waves/.

- Progression Energy Hawai'i Offshore Wind Inc. proposes to develop a 400 MW offshore wind project off Barbers Point in O'ahu. The announced capital cost of the project is also $1.6 billion (approximately $4,000 per kilowatt).[6]

We do not have agreements with either of these developers to purchase their power; we would likely further the vetting and evaluation of these projects though an RFP process.

Both developers propose using floating platforms, each supporting an 8 MW wind turbine, with undersea cables connecting the platforms to points on land. Floating offshore platforms in the proposed water depths (approximately 1,000 meters) have never been developed. Integrating such large quantities of a variable renewable resource, tied into the O'ahu system at a few interconnection points, poses significant technical challenges, and costs for upgrades in the O'ahu transmission system and will need to be studied. Notwithstanding these challenges, off-island resources will be required, so we must seriously investigate the offshore wind option.

Inter-Island Transmission

Inter-island transmission interconnections present another possible tool for achieving our 100% renewable energy goal. Undersea transmission systems are in service around the world and are a proven technology.

In Hawai'i, inter-island interconnections could allow the sharing of renewable resources across the islands and possibly provide other operating and economic benefits. For O'ahu in particular, inter-island transmission presents a potential alternative (or complement) to offshore wind systems, for bringing renewable energy to O'ahu from other islands.

Like offshore wind, inter-island interconnections with injections of relatively large amounts of power through a few interconnection points pose integration challenges and will need to be studied. Again however, because of Hawai'i's aggressive renewable energy goals, the inter-island option must be on the table and fully investigated.

Our analysis ultimately showed that we would require more capacity than was being included in our 2014 assumptions for inter-island transmission. Because of this, we plan to further analyze an array of inter-island transmission options after April 1, 2016.

Geothermal

Our findings indicate that firm renewable resources may be cost effective on the neighbor islands. Geothermal is one such option. Geothermal potential is proven on the east side

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6 http://www.utilitydive.com/news/developers-propose-competing-16b-400-mw-offshore-wind-projects-in-hawaii/406957/.

of Hawai‘i Island. Additional explorations of geothermal potential on the west side of Hawai‘i Island have been considered.

Maui may also have geothermal potential, but this requires additional explorations to prove its viability.

Development of geothermal will require community support and to date there has been significant community opposition to this development. One significant impediment to the development of future geothermal that was identified by the developers who participated in the recent Hawai‘i Island Geothermal RFP was the current County of Hawai‘i nighttime drilling ban ordinance. Policy makers and private organizations with interest in energy, land use, and water, should carefully consider the implications of geothermal energy development and develop the appropriate permitting and approval guidelines.

Biomass

Biomass is another firm renewable resource option.

HC&S's January 2016 announcement of ceasing sugar production and power sales, and the planned retirement of Maui Electric's Kahului Power Plant, present unique opportunities for the island of Maui. Given the most recent electricity forecasts, Maui expects to have a need for new generation or firm capacity to meet a reserve capacity shortfall in the 2017–2022 timeframe. We are evaluating several measures including demand response, energy storage, time-of-use rates and distributed and centralized generation to meet the needs of the island.

Biomass is one renewable resource that can meet the demands required of a firm power provider without the use of fossil fuel. Typically one hurdle for a biomass facility is to produce or identify enough feedstock. However the HC&S land previously held in sugarcane may be suitable for feedstock production. Using the land to produce biomass ensures this land will stay in agricultural use and help Maui to preserve our open spaces, while at the same time contribute to energy security by lessening our dependence on imported fuel. For the purposes of this PSIP update, the agricultural feedstock for a Maui biomass plant was assumed to be burned in a biomass steam unit.

On Hawai‘i Island, there appears to be substantial potential for biomass power. Policy makers and private organizations with an interest in agriculture, land use and water use, should investigate the potential and the policy implications of the use of agricultural land for energy crops.

Taking Advantage of Our Natural Resources

Hawai'i enjoys an abundance of natural energy resources that can be obtained from the sun, the wind, the ocean, biofuels, and geothermal. The technologies to extract energy and convert it to electricity are commercially available today for solar, wind, biofuels, and geothermal. New technologies will undoubtedly emerge over the next 30 years—technologies that will tap the ocean's energy potential for generating electricity and that will make current renewable generation more efficient.

We cannot, however, afford to wait for these technological improvements to emerge. We must start on a path to 100% clean renewable energy today, and continue to review and adjust our plans as circumstances change.

We are on the cusp of a revolution in energy storage technologies that will allow us to take greater advantage of variable solar and wind resources to reliably meet the needs of our customers. The realities of achieving 100% renewable energy requires cooperation and collaboration with the communities we serve, our government, and other stakeholders. We cannot do it alone.

DEVELOPING THE PREFERRED PLANS AND FIVE-YEAR ACTION PLANS

In developing our 2016 updated PSIP, we focused on a path for attaining 100% of generation from renewable resources in 2045 at a reasonable cost while maintaining system security. We were not married to any solution or resource, but rather focused on resources and solutions that attained our goal. The Action Plans identified the near term steps we need to undertake to attain 100% renewables.

Our modeling, analysis, and decision-making centered on a foundation of reasonable cost and risk while maintaining reliability as a means for attaining 100% renewable generation by 2045.

Foundational Elements of the PSIP

Decision Framework for Developing the Updated PSIP

We developed and employed a Decision Framework to develop the 2016 updated PSIP. The Decision Framework is based on four factors that form the foundation of our analysis, and a three-step iterative process employed to help us arrive at our chosen Preferred Plans.

Four factors comprise our Decision Framework.

Objectives. The specific results that the planning process aims to achieve. We defined these as lowest cost to the system, minimizing risks, and other considerations (such as renewable content).

Requirements. Fixed parameters around which a plan must be built and that do not vary between plans or plan sensitivities. We defined these as meeting RPS milestone dates, attaining 100% renewable generation, environmental compliance, planning criteria (including system security), and customer choice.

Input Parameters. Elements that can be varied to deal with uncertainty and to understand the sensitivity of a plan to a change in assumptions. Examples include demand, energy efficiency, DR potential, and DER potential, and their integration costs.

Decision Variables. Variables that can be varied toward achieving the Objectives. Our decision variables were based on the quantity and timing of DER, DR, and utility-scale resources.

The objectives, requirements, and input parameters all feed into the planning, modeling, and plan development by adjusting Decision Variables.

These four factors formed the basis for the planning, modeling, analysis, and decision-making we employed to arrive at our Preferred Plans. We performed several iterative cycles around DER, DR, and utility-scale resources and their costs to attain results that served as inputs to production simulation models. Results from the models help planners garner insights on how inputs drive the outputs and on how successive rounds of iteration should be performed. These new insights serve as inputs to continue the iterative cycles until reasonably optimal results are achieved.

Appendix C: Analysis Methodologies explains the Decision Framework in detail.

Modeling Methods and Analysis

In our analysis, we employed a number of modeling tools and worked with several experienced consultants to develop our 2016 updated PSIP. These consultants included Black & Veatch, Boston Consulting Group, Energy Exemplar, Ascend Analytics, Energy and Environmental Economics (E3), and PA Consulting. Almost all employed a modeling tool to generate results that were used to evaluate and develop various aspects of our plans.

Black & Veatch used their Adaptive Planning for Production Simulation tool in our DR forecasts. Their tool evaluates resource plans on a sub-hourly basis considering supply side and demand side resources, and security ancillary services and operational protocols.

The Boston Consulting Group DG-PV Adoption Model forecasts customer adoption of DG–PV (with and without storage) considering the economics of DG-PV from the customer's perspective. The BCG Customer Energy Storage Adoption Model forecasts customer adoption of energy storage systems considering customer economics. Both models helped us forecast DER levels.

Ascend's PowerSimm uses stochastic modeling to provide a unified framework of physical and financial risk factors impacting resource planning including ancillary services, operations, fuel price risk, carbon prices, and meteorology.

E3's RESOLVE evaluates investment decisions as well as operations to find a least cost portfolio solution over the planning time horizon.

Energy Exemplar ran PLEXOS, a sub-hourly simulation model, to optimize the portfolio of available resources considering system demand, fuel, reserves, installed capacity, green energy, water, and emissions.

All three of these models supported our development of the candidate plans, and ultimately our Preferred Plans. Appendix H: Analytical Models and Methods describes each of these modeling tools.

Assumptions

We accessed a number of outside organizations for data to use as assumptions in our planning and analysis. These organizations included the National Renewable Energy Laboratories (NREL), Lazard, Energy Information Administration (EIA), Electric Power Research Institute (EPRI), IHS Energy, NextEra Energy, Gas Turbine World, and RSMeans. We also included input from two of the Parties, our internal data and estimates for the cost of internal combustion engines (ICE), and system interconnection costs.

Input from the Parties

Our Revision Plan stated that we "intend to engage the parties and participants in this docket (collectively the 'Parties') as well as other stakeholders to solicit valuable input that can be incorporated into our own analysis and planning."[7] In addition, it stated that we "intend to incorporate stakeholder input to the greatest extent possible, within the time frames established, to inform the assumptions, methods, and evaluation metrics to arrive at a recommended course of action."[8]

We have followed through on each of these statements. Appendix B: Input from the Parties details the stakeholder and technical conferences we held and attended, our

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[7] Order No. 33320 Compliance Filing, filed November 25, 2015 in Docket No. 2014-0183, at 1.

[8] *Ibid.*, at 28.

efforts to engage the Parties, and how we incorporated their input into our analyses. To further the transparency of our process, we invited intervenors to attend our internal planning meetings; three accepted and participated in the process on several occasions.

Eight Observations and Concerns

The Commission noted eight Observations and Concerns,[9] each of which encompasses a wide swath of areas under analysis in developing our 2016 updated PSIP. None of these eight Observations and Concerns can be considered as isolated issues in developing our PSIP. As such, we have integrated seven of these eight Observations and Concerns throughout our planning, modeling, analyses, and decision-making. Our analysis surrounding Observations and Concerns #7 regarding an inter-island cable will continue after filing our PSIP. For our 2016 updated PSIP, we concentrated on fully analyzing O'ahu's on-island resource potential and quantifying needed resource requirements

Chapter 2: Eight Observations and Concerns explains how we integrated these issues into our work.

Reasonable Plan Components

The Commission also noted a number of component plans[10] for us to consider. As with the eight Observations and Concerns, these component plans are not isolated issues, but integral to the overall development of our PSIP. As such, we included the content required from each of these plans in our planning, modeling, analysis, and decision-making.

Appendix M: Component Plans describes our work for each of these plans.

Arriving at the Preferred Plans

Our planning and analysis in developing the 2016 updated PSIP began with a number of cases being initially developed, transformed into three foundational themes (which spawned about two hundred candidate plans) and ultimately evolving into our Preferred Plans and attendant five-year Action Plans.

Themes

After our interim report, we began to develop the full array of plans reflective not only of issues that we feel are important, but also to address the different visions that different stakeholders have regarding the best way forward to achieve 100% RPS or renewable energy.

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[9] Order No. 33320, Docket No. 2014-0183, at 44–45.

[10] *Ibid.*, at 138–139.

The result was to develop plans around three "themes" summarized as follows:

Theme 1: Accelerate Renewables. This theme assumes that accelerated pursuit of deployment of renewable resources, perhaps achieving interim and final RPS and renewable energy goals ahead of schedule.

Theme 2: Renewables With LNG. This theme utilizes LNG as a bridge fuel to more immediately reduce the use of oil as a fuel, while we progress towards our goal of 100% renewable energy. It also includes modernization of the existing thermal generation fleet with an efficient, flexible combined–cycle plant selected to support the growing renewable fleet. Theme 2 has the lowest emissions of the three themes

Theme 3: Renewables Without LNG. This theme does not use LNG, and continues our progress towards 100% renewable energy based on the existing RPS interim milestones.

These themes are more fully explained in Chapter 3.

Key Policy Decisions and Development of Candidate Plans

Finding the "right" resource plan going forward hinges on a relatively small number of crucial policy and technical decisions. To do this we identified key Decision Variables:

- Distributed Energy Resources
- Demand Response
- Utility-Scale Renewables
- Energy Storage Technologies
- Thermal Generation and Fuel Choices
- Renewable Energy Milestones

The Decision Variables guided the development of approximately 200 candidate plans that we tested, analyzed, and selected for additional analysis. We cycled through an analysis of the plans, using the outputs from one iteration as inputs to subsequent iterations. This process, coupled with analytic review, inexorably dwindled the field of candidate plans that complied with our objectives.

System Security

Integrating renewables into our system needs to be accomplished safely and reliably. Improving the flexibility of the generating fleet and limiting the magnitude of contingencies are important pieces to integrating larger amounts of variable resources. Failure to maintain the security of the grid impedes its ability to withstand sudden disturbances. System security and resilience are maintained by operating the system with sufficient inertia, fast frequency response, or primary frequency response. To accomplish this, the system operator, at times, must sacrifice efficiency for reliability and run dispatchable generators at higher minimum levels to maintain adequate reserves.

In this update, we defined and determined the amount of technology-neutral ancillary services required to meet reliability criteria, rather than solely relying on must-run generating units. This philosophy highlights the opportunity for distributed resources and demand response technologies to provide the ancillary services needed for a resilient, secure grid. For instance, if abundant PV resources along with emerging storage technologies are able to support the system with fast frequency response and regulating reserves, then these distributed resources can further displace traditional oil fired firm generation. Finally, the grid is wholly secured by re-purposing the retired firm generators as synchronous condensers or installing new ones to ensure sufficient system fault current is available to operate protective relays, an ancillary service not currently available from inverter-based generators, which historically was provided by running fossil fueled generating units.

Preferred Plans

After multiple iterations and careful analysis and decision-making, we arrived at optimum resource plans for each Theme, for each island.

These plans were then taken and applied to the financial model to determine financial impacts of each plan. The financial model provides a projection of financial metrics that include: capital expenditures, rates, and average customer bills. From these final candidate plans, we developed a set of Preferred Plans, taking into account costs and risks.

Five-Year Action Plans

We constructed optimal, long-term, renewable resource plans—our Preferred Plans—focusing on the near–term decisions that must be made within the next five years. From this, we developed detailed five-year Action Plans coupled with each Preferred Plan.

Near-term decisions can be made in the next five years. Many of the resources in our plans are projected to be placed into service well beyond the five–year near-term planning period. Because of the potential long lead times for feasibility determinations, procurement, permitting, and construction, and with the need for consensus among our communities and government entities, we believe it prudent to start working on the long-term decisions during these five years. Policy makers, private organizations, and our communities must begin now to discuss and develop clear policies, market mechanisms, and commercial arrangements necessary to implement the renewable generation necessary to achieve our 100% RPS goal by 2045.

Next Steps

We have endeavored to file an updated PSIP as directed by the Commission. We have completed a considerable amount of analyses and are reporting herein on a number of actionable findings. Given the scope of the Commission's directives and the limited amount of time to accomplish the considerable amount of analyses, there are still tasks to be completed. The five-year action plan in Chapter 9 provides details regarding our next steps.

OTHER CONSIDERATIONS

Various Risks Impact Each Theme

We assessed our Preferred Plans through the lens of several risks.

Planning Flexibility Risk. All plans must maintain a level of flexibility and optionality to incorporate technological advancements or to adjust should future expectations fall short.

Technology Risk. Renewable technologies have various levels of commercial readiness and availability. We must not base our Preferred Plans on technologies that are unproven or have unknown feasibility.

Fuel Price Risk. One of the most important risk variables is the projected cost of fuels such as oil, coal, LNG, and biofuels. High fossil fuel prices make variable renewables more attractive because the "fuel" for those resources is essentially free. Low fuel prices make fossil fuels more attractive from a customer bill impact standpoint. This is an important sensitivity in our PSIP analysis.

Financing Risk. The large amounts of capital required to transform our energy system will require that the Companies, IPPs, and customers raise capital. The ability to raise capital, and the cost of that capital, are a function of overall risk, including regulatory and political risks, as well as the risks mentioned above.

Implementation Risk. Development of large infrastructure projects is complex under the best of circumstances. Unique factors in Hawai'i add complexity. This is an external risk that is outside our control. We cannot base our Preferred Plans on projects that have little chance of being constructed.

Stranded Costs. Consideration must be given to minimize or eliminate the prospect of stranded costs in any capital invested in pursuit of implementing a plan.

Customer Adoption Risk. How much customers participate in energy generation must be considered in light of their financial investment. How lifestyle considerations affect their energy management and participation in grid services must be assessed.

Demand Forecast Risks. There are also risks associated with future demand forecasts. These forecasts assume that the state's aggressive energy efficiency portfolio standard (EEPS) is met, and that the uptake of DER by customers as forecasted is actually realized. Finally our future need for capacity and ancillary services from generating resources is impacted by whether or not our forecasted demand response quantities come about.

Strategies for Developing the PSIP

In its Inclinations, the Commission articulated a number of strategies[11] related to the generation system, which it suggested would lower and stabilize the costs of generation. We respond to those strategies here.

Seek high penetrations of lower-cost, new utility-scale resources

Utility-scale renewable resources were evaluated as part of this PSIP update. In general utility scale resources were found to be cost effective and are included in our Preferred Plans.

Modernize the generation system to achieve a future with high penetrations of renewable resources

As part of the analysis for this 2016 updated PSIP, we evaluated modernizing the generation system running with and without LNG. Modernization, in general, is only less expensive in the short term if the savings from using a lower cost fuel (such as LNG) offsets the increased costs from the capital expenditure.

Exhaust all opportunities to achieve operational efficiencies in existing plants.

Operational efficiencies come in the form of lower heat rates. Operational efficiency gains require capital investments. To be effective, the cost savings realized from efficiencies must outstrip their cost. As such, we have not exhausted all opportunities; however, we have evaluated and continue to evaluate all reasonable opportunities, and implement them when they are cost effective as a normal course of our operations as we monitor heat rate of our units continuously. We have implemented capital projects when necessary to restore efficiencies or maintain reliability. In most cases, projects have had both reliability and efficiency benefits.

[11] *Ibid.*, at 42.

Pursue opportunities to lower fuel costs in existing power plants

Through comprehensive source testing and analysis, we have been able to minimize fuel costs for the MATS compliance plan for Hawaiian Electric and expect to comply with the MATS limits using 100% LSFO in all Hawaiian Electric steam units. Initially, we planned to switch to an LSFO and diesel-fuel blend in our steam generating units. Through the testing program, we have developed a cost effective MATS compliance plan based on optimized operating parameters (such as excess O_2, fuel firing temperatures, and soot blowing frequency), boiler and air heater washes, Opacitrol fuel additive (combustion catalyst) on select units, and steam atomization to improve combustion.

In addition, our analysis continues to indicate that LNG is a prudent choice that allows us to significantly lower emissions, reduce fuel costs and customer bills, and reduce customers' exposure to fuel price volatility as we transition our system to achieving 100% renewable energy.

CHANGES AFFECTING OUR RESOURCE PLANNING FOR THE UPDATED PSIP

Over the course of the nineteen months since we filed our 2014 PSIPs, a substantial number of circumstances have changed that dramatically affected the underlying assumptions and condition for planning our 2016 updated PSIP. The Commission noted a number changed circumstances;[12] we identified several additional developments. We respond to these as directed.

All of these changes affect our planning over the next five years—essentially the time period for developing a short-term plan—as well as for our planning over the next 30 years. In effect, then, we are not creating a supplemented, amended, and updated PSIP—we are creating an entirely new PSIP. This is the basis from which we have proceeded in our modeling, analyses, and assessments, all ultimately affecting how we plan to meet both the immediate and long-term energy needs for Hawai‘i.

[12] Order No. 33320 at 133.

Integrating Sixteen Changed Circumstances into Our Updated PSIP

Here are the major changed circumstances that have transpired over the relatively short period of time of nineteen months—changes that we integrated into our modeling and analysis for creating our Preferred Plans. The Commission identified the first five changed circumstances.

1. Passage of Act 97 (2015), which changed a 40% RPS target in 2030 to attaining a 100% RPS in 2045. This change alone affected the fundamental underpinnings of our resource planning: our planning horizon, originally set for 15 years, has now been extended to 30 years.
2. Substantial decreases in the prices of fuel oil, affecting both our current supply as well as our forecasted costs.
3. The delay in LNG implementation from 2017 (as projected in our 2014 PSIPs) until 2021, and an announcement by the Governor of the State of Hawaiʻi regarding the administration's view regarding utilization of LNG fuels for electric utility power production.
4. Rescheduling of the Oʻahu battery energy storage system (BESS) project from 2016 until 2019.
5. The issuance, and subsequent stay (by the U.S. Supreme Court on February 9, 2016), of the Clean Power Plan Final Rule that portends further tightening of emission standards for greenhouse gases from existing fossil-fuel electric generation.
6. The pending proposed merger between NextEra Energy and the Hawaiian Electric Companies.
7. A good faith commitment by NextEra Energy (if the merger is approved) to exceed the RPS requirements: 35% by 2020 (instead of the statutory 30%) and 50% by 2030 (instead of the statutory 40%).
8. The closing of the Net Energy Metering (NEM) program by the Commission and its concurrent replacement with two new DER programs: customer grid-supply and customer self-supply.
9. The enactment of advanced inverter standards to mitigate DG-PV impacts (attained through the DER docket).
10. Filed tariffs for new DR programs (awaiting Commission decision) and the development of ancillary services requirements (in the DR docket).

11. The termination of the Hu Honua Bioenergy power purchase agreement due to Hu Honua's default and continued failure to meet critical construction milestones guaranteed under the PPA.
12. Ormat's withdrawal from contract negotiations to provide additional geothermal generation on Hawai'i Island.
13. A pending asset purchase agreement with Hamakua Energy Partners (HEP).
14. Deferral of the retirement date of the Kahului Power Plant from 2019 to 2022.
15. Termination of three PPAs for solar facilities on O'ahu totaling 109 MW due to the project companies' failures to meet guaranteed project milestones and substantial commitment milestones in their PPAs.
16. HC&S notified Maui Electric that it was ceasing sugar operations and terminating the PPA effective January 6, 2017.

Taken all together, these changes have created a vastly different environment for energy planning. The near future may also present comparable changes. Because of this continued dynamic environment, we strive to build flexibility into our resource planning.

Continually Evolving Energy Environment

Renewable generation clearly is burgeoning. As with virtually all other emerging, maturing, and evolving technologies, we expect breakthrough developments, decreasing prices, increasing implementation, and growing community acceptance.

Consider the profound impact on the environment, on culture, and on energy demand, should electric vehicles replace gas-fueled cars in large numbers and the impact they will have on the electric grid. Consider the profound impact on renewable generation should the cost of energy storage decrease by 70% over the next 15 years (as was predicted in January 2016). Consider the rapid shift in generation toward renewables as other jurisdictions demonstrate the same forward-thinking mind set of the Hawai'i Legislature and adopt more progressive goals for transitioning to renewable generation.

We, as electric companies and as a state, must adequately prepare and plan for such a future. These are the challenges that we face, and continually work toward solving, in our resource planning.

Accomplishments Since the 2014 PSIP Filing

Much has transpired since we filed our original PSIPs. We have:

- Applied for and obtained approval for the 50 MW Schofield Generating Station.
- Retired two oil–fired generating units on Hawai'i Island.
- Applied for and received approval for two utility-scale PV projects on Maui.
- Increased DG-PV on all five islands from 328 MW to 487 MW at the end of 2015.
- Progressed LNG plans from concept to finalizing LNG contract negotiations and preparation of an LNG application.
- Attained a consolidated RPS of 23.2% by the end of 2015.
- Filed an application for the Smart Grid Foundation Project.

This is just a sampling of our accomplishments. We will continue making progress after filing our 2016 updated PSIP.

OUR VISION AND STRATEGIC OBJECTIVES

Our vision is to deliver cost-effective, clean, reliable, and innovative energy services to our customers, creating meaningful benefits for Hawai'i's economy and environment, and making Hawai'i a leader in the nation's energy transformation. We intend to continue innovating, exploring, and evaluating new technologies for a cleaner generation system with affordable costs for our customers.

To reach our vision, we focus on three overarching goals, while attaining increased customer satisfaction overall.

<table>
<tr><th>Goals</th><th>Description</th><th>Company-Wide</th><th>Hawaiian Electric</th><th>Maui Electric</th><th>Hawai‘i Electric Light</th></tr>
<tr><td>Cost-Effective Clean Energy Portfolio</td><td>▪ Ensure cost-effective, transparent, and less volatile prices for customers.
▪ Eliminate potential market inefficiencies.
▪ Reduce environmental footprint by reducing emissions.
▪ Reduce dependence on imported fossil fuels through existing resources.</td><td>▪ Generation operations flexibility program
▪ Leverage ancillary services capabilities of renewable resources, DER, and DR
▪ LNG application
▪ Inter-Island transmission analysis
▪ RFP for additional renewables
▪ DR programs</td><td>▪ Generation modernization
▪ Replacement projects for terminated waiver project PPAs.
▪ Defer deactivation of Waiau 3 & 4</td><td>▪ Two utility-scale solar PV PPAs.
▪ RFP for replacement generation
▪ Reserve capacity shortfall mitigation</td><td>▪ Hamakua Energy Partners (HEP) purchase
▪ RFP for firm, dispatchable renewable generation to displace fossil-fired capacity and energy.
▪ Cost effective utilization of existing resources.</td></tr>
<tr><td>Modern Grid & Technology Platform</td><td>▪ Continue to ensure a safe and reliable power grid.
▪ Develop a platform to enable more renewables, more efficient delivery, and greater resiliency.
▪ Contribute to Hawai‘i’s economic growth and environment.</td><td colspan="4">▪ Smart Grid
▪ Storage applications
▪ Further integration of wind and solar forecasting into System Operations
▪ Expanded monitoring and data capture from real–time systems through PMU data for post-disturbance review and model updates
▪ Adaptive underfrequency load-shed
▪ Monitoring and control of DER and variable resources
▪ Transmission and distribution upgrades.</td></tr>
<tr><td>Quality Customer Experience & Innovative Energy Solutions</td><td>▪ Enable and support changing customer needs and preferences in light of energy alternatives.
▪ Ensure fair treatment to all customers.
▪ Be a front-runner in clean innovations.
▪ Enable third parties to provide innovative solutions in Hawai‘i.</td><td colspan="4">▪ DER policies
▪ Community-Based Renewable Energy (CBRE)
▪ Demand Response Management System (DRMS)
▪ Demand response portfolio tariff structure</td></tr>
</table>

Table 1-4. Overview on Related Proceedings and Corporate Actions to the PSIP Update

Addressing Near-Term Filings

The updated PSIP lays the foundation for other near-term filings, some of which are detailed in our five-year action plans.

Company-Wide

DER Policies (Docket No. 2014-0192). The updated PSIP incorporates the decisions of last year's DER Phase 1 proceeding and work on selected non-policy related DER issues to prepare for the upcoming DER Phase II proceeding.

- *Circuit-Level Hosting Capacity.* In the updated PSIP, we have expanded on the circuit-level hosting capacity methodology by identifying several DG-PV integration options and estimating costs of these integration options for various amounts of DG-PV. In this PSIP, we explicitly consider DG-PV integration costs in the resource plan optimization. Results of this integration cost analysis can inform and help the DER Phase II proceeding identify appropriate policies for DER integration.
- *System-Level Hosting Capacity.* System-level hosting capacity analysis was performed on a filtered set of cases ensuring those are fulfilling all reliability related planning criteria.
- *New DER Products (Self-Supply, Grid-Supply).* In line with decisions of the DER Phase 1 proceeding, we have developed DG-PV adoption forecasts for the new customer Self-Supply and Grid-Supply products absent program caps. In addition, we explored the implications of adding additional amounts of DG-PV to the system. DER policies related to achieving these DG-PV projections in a safe, reliable, cost-effective way will need to be discussed during the DER Phase II proceeding.
- *Advanced Inverters.* In the updated PSIP, we assumed that are technologies are advancing such that control of customer DG–PV will be feasible by mid-2018.
- *Time-of-Use Rates.* The updated PSIP's production simulation results provide some of the necessary data to develop adjusted Time-of-Use rates during the DER Phase II proceeding.

Demand Response Portfolio Tariff Structure (Docket No. 2015-0412). A major building block of the PSIP update decision-making process has been the DR iterative cycle, calculating avoided costs by individual themes and cases, and developing forecasts for DR portfolios for the individual islands for the PSIP planning horizon. The technology neutral system security requirements defined in this PSIP will be used to inform DR products in our planned June 2016 DR product filing.

Demand Response Management System (DRMS) (Docket No. 2015-0411). DRMS is a key enabler to integrate high amounts of DER and to leverage DR resources. The updated PSIP assumes the DRMS is implemented by mid-2017. The DRMS application filed on December 30, 2015 incorporates not only traditional DRMS functionality, but a full suite of distributed energy management capabilities that will be required to fully leverage the value of various DER. Hawaiian Electric is targeting initiation of the DRMS project by late 2016 to early 2017, depending on Commission approval timing.

Smart Grid. Smart grid initiatives are key to our achieving all three overarching goals. An Advanced Metering Infrastructure (AMI) and Meter Data Management Systems (MDMS) can enable more cost-effective and transparent prices for customers. Conservation voltage reduction (CVR) controls voltage and enhances power quality and conservation. Direct load control (DLC) enables two-way communication and control. Both can enable more renewables (including DER), more efficient delivery, and greater resiliency. AMI and technologies that provide customers with a seamless integrated mobile and web energy platform can help address customer expectations of a modern utility.

The updated PSIP assumes significant amounts of DER and DR are achieved, and Smart Grid is implemented. Smart grid initiatives like AMI, MDMS, CVR, and DLR enable higher levels of DG-PV and robust DR programs. We filed an application for approval of the Smart Grid Foundation Project on March 31, 2016, and plan to implement Smart Grid upon approval.

Generation Operational Flexibility Projects. In the updated PSIP, we analyzed operational flexibility pilots and projects designed to accommodate greater quantities of low cost, renewable energy resources. This analysis deepened our understanding of how generation operational flexibility projects impact the overall system and the implications for resources and cost. PSIP results will be considered in the Generation Operational Flexibility Projects proceeding.

Community-Based Renewable Energy (Docket No. 2015-0389). Various resources are required to achieve 100% RPS, including DER, utility-scale resources, and potentially, community-based renewable energy (CBRE). For planning purposes, the 2016 updated PSIP assumed some CBRE. Upon Commission review and approval of the CBRE program, these resources can be solidified in future refinements of the plans.

RFP for Additional Renewables. Various new, cost-effective renewable resources are required to achieve 100% renewable energy. The updated PSIP Preferred Plans identified a set of renewable projects by island system that will require the launch of new, competitive procurement processes.

LNG Application. The updated PSIP performed a rigorous assessment on the economic feasibility of LNG that would enable us to procure a lower cost and cleaner fuel for Hawai‘i. As a result of these analyses, we plan to submit an application for an LNG fuel supply agreement, and a General Order No. 7 application for to make capital expenditures related to LNG-related dual fuel unit conversions and related infrastructure. Commission approval of these applications will allow us to procure International Organization for Standardization compliant intermodal cryogenic containers (ISO Containers) for the transport of the LNG, and to receive, store, and regasify LNG, and utilize natural gas at the designated generation facilities. These applications will be filed shortly after the filing of this PSIP update.

Storage Applications. Consistent with the Preferred Plans, the Companies will be evaluating the potential procurement of energy storage resources.

Capital Budget. We have recently filed our interim budget. The budget will need to be updated once the updated PSIP have been established.

Inter-Island Transmission (Docket No. 2013-0169). The Commission directed us to develop economic analysis on the cost-effectiveness of inter-island transmission options. Inter-island transmission is a unique resource with unique costs and operational benefits that require detailed calculation in order to be characterized correctly. The development of an optimized interisland transmission system is in process, but was not completed in time to be included in this filing. Insights developed through this PSIP update (i.e. estimates of off-island energy needed to achieve 100% renewable energy on O‘ahu) will be used to scope a more informed inter-island transmission analysis after April 1, 2016.

Merger (Docket No. 2015-0022). In the updated PSIP, the cases including LNG assume the proposed merger of NextEra Energy and Hawaiian Electric Companies is approved. Combined with other projects and programs envisioned for this same timeframe (such as Smart Grid, Schofield Generating Station, and other projects), the cases that include LNG will require the financial backing and development capacity of the merged organization.

Hawaiian Electric

Kahe Combined Cycle Generation Modernization Application (Replacement Generation). The 2016 updated PSIP analyzed the benefits of generation modernization, which includes a flexible 383 MW, 3x1 advanced combined cycle generation unit in O‘ahu, located at the existing Kahe Generating Station site. The analyses in this PSIP update demonstrates that this generation unit replacement is beneficial for the customers and helps achieve the state goals in a cost-effective way. Therefore, we are planning to file an application for the 3x1 CC unit. This application will be conditioned on approval of the merger.

Power Barge at JBPHH and ICE Units at MCBH. Hawaiian Electric plans to pursue the installation of distributed generation at Joint Base Pearl Harbor–Hickam (JBPHH) and at Marine Corps Base Hawai‘i (Kaneohe) (MCBH). These generation additions will support the retirement of existing Kahe and Waiau units and the expiration of the PPA for AES Hawai‘i’s coal unit by the end of 2022.

Potential New RFP for Replacement Capacity for Waiver Projects. Three of the four approved PPAs for the waiver projects were terminated due to developer non-performance. We desire to procure low-cost renewables and are considering all options to replace these projects including issuing a new RFP to replace the capacity represented by the terminated waiver project PPAs. For planning purposes, the 2016 updated PSIP assumes the terminated waiver projects will be replaced by similar resources.

Defer Deactivation of Waiau 3 and 4. We reviewed and evaluated retirement options for generation capacities on O‘ahu ensuring cost-effectiveness to all customers. We have summarized our findings in Appendix M: Component Plans.

Hawai‘i Electric Light

Hamakua Energy Partners (HEP) Purchase (Docket No. 2016-0033). For the updated PSIP modeling and financial analysis, HEP is modeled as an IPP plant. On February 12, 2016, we filed an application for Commission approval of our proposed purchase of the 60 MW dual-fuel combined-cycle HEP plant. The application describes the purchase terms and the significant cost benefits to our customers that would result from this purchase.

Hu Honua PPA Termination. On March 1, 2016, we terminated the PPA with Hu Honua Bioenergy based on Hu Honua’s default and failure to meet critical PPA milestones. The 2016 updated PSIP analysis therefore assumes Hu Honua as being not available.

Hawai‘i Geothermal RFP. While the recent geothermal RFP did not result in a project, we remain hopeful that geothermal generation can be a viable option on Hawai‘i Island in the future and can help Hawai‘i meet its 100% renewable energy goal while lowering customer bills. The updated PSIP therefore assessed several cases with new geothermal capacities available on Hawai‘i Island, including West Hawai‘i geothermal resources. The development of additional geothermal resources will require the support of communities and government agencies.

Maui Electric

South Maui Renewable Resources (Docket No. 2015-0225) and Kuia Solar (Docket No. 2015-0224) PPA Applications. In February 2016, the Commission approved, with conditions, the power purchase agreements for these two utility–scale solar PV projects. These resources contribute to the cost-effective pursuit of RPS milestones. For planning purposes, we assumed these solar resources are available and included them in the updated PSIP analysis.

Potential RFP for Replacement Generation. The 2016 updated PSIP analyzed several retirement scenarios. A potential full retirement of Kahului Power Plant during the planning horizon would require procurement of replacement generation to fulfill system demand.

Central Maui Transmission Upgrades. Retirement of KPP will require upgrades to the 23 kV transmission system in Central Maui in order to maintain system reliability.

RFP of Emergency Generator for Reserve Capacity Shortfalls. Given the most recent load forecasts, Maui expects to have a need for new generation or firm capacity to meet reserve capacity shortfalls in the 2017–2022 timeframe. We are evaluating several measures, including DR, energy storage, time–of–use rates and distributed and centralized generation to meet the needs of Maui Electric's customers.

Our Role: To Create and Implement a Strategic PSIP

Our role is to create and implement a Preferred Plan for each operating utility that fulfills the state's policy goals of 100% RPS by 2045, meets the diverse service requirements of our customers at reasonable and more stable rates, and maintains reliable energy service. Our PSIP, created in a rapidly changing environment, can then serve as a strategic basis and provide context to inform future investments, programs, and operational decisions until they are updated again.

2. Eight Observations and Concerns

The Commission noted eight Observations and Concerns,[13] each of which encompasses a wide swath of areas under analysis in developing our 2016 updated PSIP. None of these eight Observations and Concerns can be considered in isolation. As such, we have integrated them throughout our planning, modeling, analyses, and decision-making.

#1. CUSTOMER RATE AND BILL IMPACTS

Chapter 3 fully describes the overall planning process, plan development, and iterative optimization process from the 1st iteration, which was included in the PSIP Interim Status Report filed February 16, 2016, through the development of the Final Plans and selection of the Preferred Plans. Financial analysis and "all-in" results are presented in Chapter 4. The Net Present Value of cumulative revenue requirements, under both 2015 EIA Annual Energy Outlook Reference and February 2016 EIA Short Term Energy Outlook fuel price forecasts, have been calculated for the best evaluated resource plan for each theme. Residential customer rates and monthly bill impacts, in nominal and real (2016) $/kWh, are provided for both fuel price forecasts. It should be noted that all finalist and Preferred Plans meet or exceed all statutory RPS requirements.

To maximize the accuracy of our analyses, we updated all input assumptions, including resource costs, fuel costs, and resource availability assumptions. We also shared all relevant assumptions with the Parties to solicit feedback. In addition, we engaged NREL to independently assess resource cost assumptions and provide an analysis of wind and PV availability. NREL's reports can be found in Appendix F.

[13] Order No. 33320, Docket No. 2014-0183, at 44–45.

Theme 2, which uses the LNG fuel price forecasts included in Appendix J, produced significant cost savings and has the largest beneficial impact to customer bills. To address the uncertainty in future fuel prices, sensitivity analyses were completed for both the 2015 EIA Annual Energy Outlook Reference fuel price forecast and February 2016 EIA Short Term Energy Outlook fuel price forecast for each case. While there is no way to accurately predict future fuel prices, results from Ascend Analytics' stochastic modeling of all-in delivered LNG and oil indicate that oil prices are characterized by "higher levels of volatility and slower rates of mean reversion as compared to natural gas. Higher volatility in oil prices translates to more uncertainty in future oil prices and a wider 90-percent confidence band in comparison to LNG." Figure 2-1 depicts these results.

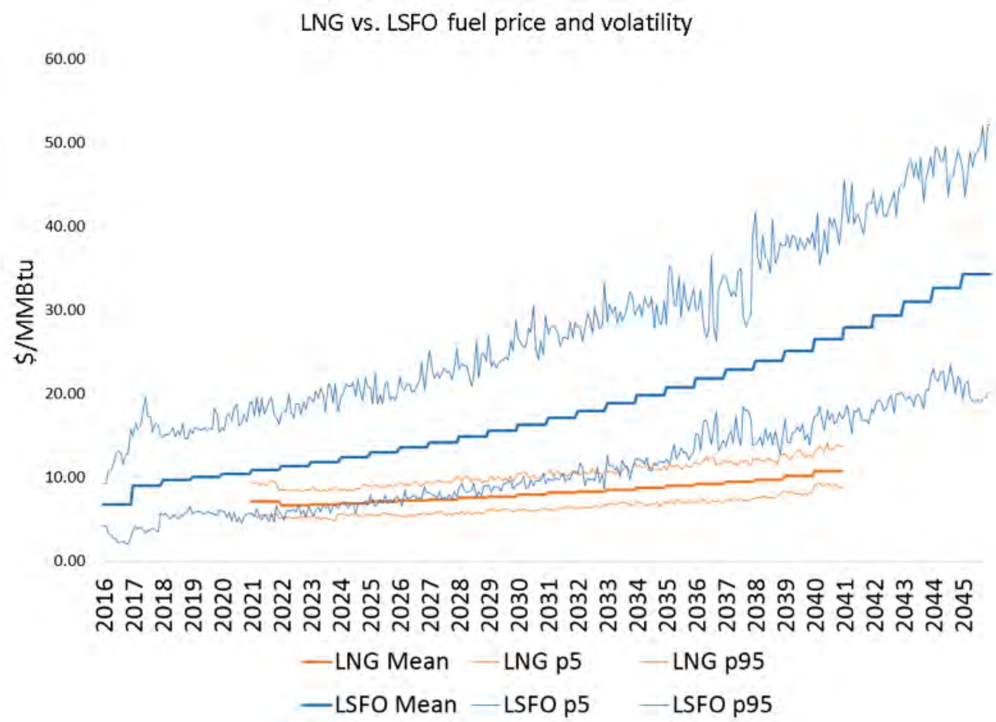

Figure 2-1. Stochastic Fuel Price Forecast, Ascend Analytics

To address the capital expenditure constraints, revenue requirement projections which included capital expenditure projections for power supply, smart grid, ERP, and all other utility capital expenditures (referred to as "balance of utility business capital expenditures") were considered. As described in detail in Appendix I, the balance of utility business capital expenditures have been calculated using a top down approach for the high fuel price scenario. Chapter 4 summarizes the capital expenditures by category for each Theme.

#2. TECHNICAL COSTS AND RESOURCE AVAILABILITY

Utility-scale resources are a key decision variable in the Decision Framework, which assesses the cost-effectiveness of various resource types.

We started by updating all resource costs, including capital costs, interconnection costs, fuel costs, O&M costs, and resource availability assumptions. Virtually all deployable technologies were considered. Though found not to be cost-effective at this time, new concepts such as accelerating alternative fuel vehicle adoptions (electric vehicles and hydrogen vehicles) and flexible electrification where electric vehicles could be used for load balancing were evaluated by E3. We retained NREL to independently assess our new resource cost assumptions and made appropriate adjustments to our assumptions as a result. We also commissioned NREL to develop independent assessments of the utility–scale solar PV and wind levels that could be developed on each island based on topographic, land-use restrictions, proximity to urban areas, and renewable energy production potentials in specific locations. NREL's reports can be found in Appendix F.

Although adjustments were made to O'ahu for utility scale PV and onshore wind to be consistent with NREL's resource potential estimates, cases including high levels of PV were developed and analyzed. We compared case results of varying levels of energy storage and biofuels, and developed an optimized-mix of these dispatchable resources. In addition, we included community-based renewable energy (CBRE), DER and DR resources, utility scale PV, geothermal, onshore and offshore wind, biomass, biofuels, pumped storage hydro, and battery energy storage systems. (After this filing, we will complete our analysis of an inter-island transmission system, including estimated costs and benefits relative to offshore renewable energy serving O'ahu and benefits of combined grid operations.)

Chapter 3 fully describes the planning process and Appendix K provides all of the cases considered. Both high DG-PV and market DG-PV cases were evaluated. Integration requirements for DG-PV are discussed in detail in Appendix N. Identification and consideration of integration costs for DG-PV was included in all of the analyses. In addition, accelerating renewables (Theme 1) which achieves 100% RE on the neighbor islands (including Lana'i and Moloka'i) by 2030 were developed and optimized for cost. As noted in Chapter 3 and Appendix C, the overarching objective of the planning process was to optimize and find the lowest cost mix of resources and plan to achieve the statutory RPS requirements. The resulting near-term actions to acquire cost-effective RE projects are described in Chapter 8.

#3. DISTRIBUTED ENERGY RESOURCES INTEGRATION

DER is one of three key resource-types that were optimized as part of the Decision Framework, and we evaluated the full spectrum of DER. Energy efficiency attainment and electric vehicle adoption were forecast and incorporated in system net load for all PSIP cases. Demand response, distributed storage, and DG-PV were optimized through iterative cycles to achieve lowest system cost while enabling customers to provide cost-effective and reliable grid services. Self-consumption economics were based on retail rates; grid export economics were based on the value the DER provides the system (utility-scale PV LCOE for DG-PV, value of storage to the system for distributed storage, value to the system for DR).

Multiple options were developed to integrate DG-PV on over-hosting capacity circuits and the lowest cost integration option was selected for explicit consideration in the economics for those DG-PV systems forecast to be installed on an over-hosting capacity circuit. The DG-PV integration strategies and costs are more fully described in Appendix N.

We determined high-value system-level use cases for DER in 2016 - 2020 as follows. Robust DG-PV adoption compensated at utility-scale PV LCOE reduces the need to procure utility-scale PV and helps meet near-term RPS targets cost-effectively. Storage was analyzed as a decision variable in the various PSIP cases, and was found to be cost effective for selected use cases in DR programs.

We sought cost effective solutions by weighing the costs and benefits of (full or partial) inverter retrofit against alternative ones when addressing either circuit or system-level interconnection barriers. For instance, we are currently considering the cost and benefits of legacy inverters without ride-through capabilities in our contingency battery analysis. We considered retrofit of inverters to ones that have reactive power capabilities for voltage mitigation in the DG-PV integration analysis (see, Appendix N).

A cornerstone of the DR program portfolio is the aggregation of DR resources. All of the proposed DR services utilize various DER technologies to achieve this aggregation philosophy. Furthermore, the demand response management system that will be used to deliver the DR services through the intelligent management and optimization of groups of DERs has been specified to allow for the attribution, selection and dispatch of these resources across various zones. These zones map to the physical topography of the various islands' systems and span from the system level at the highest level down to the individual circuit at the lowest level. As such, the current architecture and system design of the DR portfolio implementation allows for targeted deployment of DERs, which is suitable and appropriate as a tool for helping to address distribution or transmission level constraints such as those being considered by non-transmission alternatives in South Maui.

We varied RPS attainment in the analysis cases and, through iterative cycles, optimized DER amounts across islands and across cases to determine the role and contribution of DER in high-RPS attainment scenarios. In addition to the DG-PV adoption forecast optimized for the system, we analyzed a "high DG-PV" forecast to further characterize the role and contribution of DER in aggressive RPS attainment scenarios. DER plays a significant role in the preferred plans. Further work on how to achieve the sustainable DER adoption as envisioned by the preferred plans will be covered in the DER 2.0 proceedings.

#4. FOSSIL-FUEL PLANT DISPATCH AND RETIREMENTS

Chapter 3 outlines the breadth of cases considered in the three iterations completed, around three Themes: Theme 1–Accelerate Renewables, Theme 2–Renewables With LNG, and Theme 3–Renewables Without LNG. Cases considered various mixes and amounts of resources. The multiple cases were specifically designed to iterate towards a low-cost objective, and address risks associated with changes in fuel price by analyzing both LNG and oil, and analyzing various fuel price forecasts. We refined those cases to incorporate results from preceding runs of DER, DR, and utility-scale resources iterations to determine low cost potential with minimized risks, and analyzed grid modernization to characterize the tradeoffs and risks of modernizing our generating fleet versus other resource options. We identified potential dates for displacement of fossil generation, then updated our Fossil Generation Retirement Plans. Additional details for the Fossil Generation Retirement Plan can be found in Chapter 8 and the Component Plans included in Appendix M.

Theme 2 included LNG as a transitional fuel on O‘ahu, Maui, and Hawai‘i Island and modernization of the generation fleet on O‘ahu with efficient, flexible replacement generation selected to support the growing renewable fleet on O‘ahu. Additional details of LNG as a transitional fuel are described below. For all cases, both high and low fuel price forecasts were evaluated to understand the respective cost impact. The analyses suggest that the most significant savings can be achieved with LNG and modernization of the generation fleet with market DG-PV. Details of the Preferred Plan are provided in Chapters, 5, 6, and 7, and the financial results are provided in Chapter 4. It should be noted that all cases comply with statutory RPS requirements.

As part of our analysis, we reviewed and clarified our environmental compliance strategies, and updated our Environmental Compliance Plan and Key Generator Utilization Plan. Finally, we updated our Generation Commitment and Economic Dispatch Review. All of these plans are included in Appendix M, Component Plans.

LNG as a Transitional Fuel

We have highlighted the need for modernized and flexible generation resources in order to minimize costs, reduce emissions and facilitate the increased integration of variable renewable resources. Even with these new resources in place, the Companies' current fuel source for its dispatchable generation during the transition period to a 100% RE will be petroleum-based fuels.

As a result, customers will be exposed to a petroleum-based fuel which is:

- Forecasted to cost more than LNG.
- Significantly more volatile in price than LNG.
- Subject to increasing restrictions under tightening federal environmental standards.

With LNG as a transition fuel, the Companies see an opportunity to lower the cost to customers, reduce pricing volatility, and accelerate the reduction in air emissions. An LNG plan has been designed specifically as a transition solution for Hawai'i that seeks to limit the amount of investment in permanent island infrastructure. Further, the Companies' plan contemplates that the LNG seller will have the ability to remarket excess LNG, which will reduce the risk for potential variability in the demand for LNG as the integration of renewable resources increases. Hawaiian Electric does not view LNG as substituting for, or competing with, new renewable resources on the islands. Rather LNG represents a complementary solution which can help achieve the Companies' goals of keeping costs to the customers as low as possible while mitigating impacts to the environment and flexibility integrating intermittent renewable resources. LNG represents a good value proposition to customers under a wide range of potential renewable penetration scenarios, especially when combined with the flexible, efficient, modernized generation described in the previous section.

Overview of the LNG Delivery System

In initially evaluating an LNG delivery solution for Hawai'i, the Companies looked at (1) land based LNG import terminals and (2) Floating Storage and Regasification Units (FSRU), both of which entailed installation of permanent infrastructure on and offshore, new gas pipelines, and long permitting processes. Therefore, the Companies opted to issue a request for proposal (RFP) for a containerized LNG solution to land LNG in Hawai'i and distribute it to its generation fleet across the State. This solution would use International Standards Organization (ISO) containers, metal vessels that can be loaded and transported on a conventional truck, to transport LNG locally and, maximize flexibility and reduce requirements for dedicated land based infrastructure.

A possible LNG supply chain would consist of the following components:

- Natural gas sourced from some of the most prolific gas reserves located in Northeast British Columbia. The gas would be transported from the gas reserves to Fortis BC's Tilbury liquefaction plant on the Fraser River by pipeline where it would be liquefied.
- The LNG would be loaded onboard ships for transport to Hawaiʻi. Upon arrival in Hawaiʻi, the LNG would be delivered in ISO containers to points of use on Oʻahu, Maui, and Hawaiʻi Island.
- Multiple ships, owned and operated by the seller, would be employed to ensure a steady rate of LNG delivery to the various generating stations.

The containerized supply chain was selected as the option with the greatest congruence with the following evaluation criteria set forth by the Companies.

Flexibility with Minimal Permanent Infrastructure: To be consistent with achieving the RPS goals, the Companies required any fuel supply to have flexibility to accommodate a dynamic energy environment and generation from renewable resources. The fuel supply system should have minimal permanent infrastructure that could limit flexibility and increase the risk of stranded assets.

Neighbor Island Coverage: The Companies required a cost-effective solution that could supply fuel to Maui and Hawaiʻi Island just as easily as to Oʻahu without making substantial modifications to the overall supply chain.

Minimal Permitting: To expedite adoption of cheaper natural gas in the fuel portfolio, the Companies required non-permanent infrastructure for the LNG supply system to avoid extensive and time-consuming permitting processes associated with developing an LNG terminal.

Security of Supply: To mitigate geo-political risk and ensure continuity of supply, the Companies sought a fuel supply from a North America as opposed to gas sourced from politically sensitive global locations.

Lower Price Volatility to Customers-Gas vs. Oil Indexed Pricing: Globally, LNG is typically priced off a formula which is indexed to oil prices. To reduce dependence on oil-linked, fuel pricing (current fuel portfolio) and minimize commodity pricing volatility, the Companies required LNG to be indexed off of North American natural gas prices.

Ability to Serve Other Customers in Hawaiʻi: The Companies wanted the LNG seller to have the ability to sell excess volumes to third party off-takers and/or for the Companies to take additional spot volumes if available.

Unit Conversions

Under a merged scenario between the Hawaiian Electric Companies and NextEra Energy, the Companies intend to enter into an agreement to acquire approximately 800,000 metric tons of LNG annually from the Fortis LNG facility in Vancouver, BC. Deliveries could start in 2021 and coincide with the commencement of commercial operations of modernized combined cycle units at Kahe. In addition to the modernized units, the Companies would convert five of their existing generation units (six including HEP if its purchase by the Companies is approved by the Commission) to allow them to use LNG in addition to petroleum-based fuels. This involves installation of new equipment to receive, store and regasify the LNG, and conversion of the existing generating units to allow for gas utilization (with total estimated cost of the conversions at approximately $340 million). Although not yet negotiated, it is assumed that the two combustion turbines at the Kalaeloa Partners LP Generating Station would also be modified to use LNG. After the completion of the modernization and conversions, the Companies would have approximately 1,100 MW of generation capacity capable of using LNG-based fuel during the transition period to 100% RPS (as outlined in Table 2-1).

Unit Name	Status	Unit Capacity (MW)	Unit Ownership
Kahe 5	Existing	140	Hawaiian Electric
Kahe 6	Existing	140	Hawaiian Electric
Kalaeloa	Existing	208	IPP
Kahe Combined Cycle	New	383	Hawaiian Electric
Ma'alaea 14/15/16	Existing	58	Maui Electric
Ma'alaea 17/18/19	Existing	58	Maui Electric
Keahole 4/5/7	Existing	60	Hawai'i Electric Light
HEP CT1/CT1	Existing	60	Hawai'i Electric Light or IPP

Table 2-1. Unit Conversions to Dual Fuel

#5. SYSTEM SECURITY REQUIREMENTS

Selected resource cases from each of the three Themes for each island grid were screened for system security with a focus on loss of generator and electrical transmission fault disturbances. These selected resource plans formed the basis for performing a limited system security analyses that defined in a technology neutral manner the fast frequency response (FFR) and primary frequency response (PFR) requirements for selected years of a plan. The results of the security analysis are presented in Appendix O.

Since filing our 2014 PSIPs, we have updated and revised our system security requirements and focused this analysis on single contingency loss of generation events to determine acceptable under frequency load shedding (UFLS)[14] capacities. Loss of generation contingencies have a greater impact on resource plans because it dictates on-line reserve requirements which in turn, establish FFR and PFR requirements. A full system security analysis that includes voltage stability, rotor angle stability and fault current protection coordination on for all islands will be performed for the preferred plans.

For Oʻahu, HI-TPL-001 was revised to allow no UFLS for single generator contingency events (previous criteria allowed 12% customer loss) while Maui and Hawaiʻi Island allow 15% loss of system load (previous criteria allowed 15% customer loss). The Molokaʻi and Lanaʻi systems were removed from HI-TPL-001 since these systems are unique island distribution systems that do not qualify as transmission systems. Further revisions to HI-TPL-001 are required for multiple contingency events, both loss of generation and/or loss of transmission elements.

The more stringent HI-TPL-001 criteria for Oʻahu is designed to minimize the risk of deep load shed events, and potential island-wide blackouts with an appropriately sized FFR resource such as a BESS which become more likely in the future with even more distributed PV. Under high levels of distributed PV penetration, the residential load net of PV is reduced so UFLS schemes are less effective, compromising system security. UFLS is designed to shed low impact loads and avoid critical load like hospitals, emergency responders, military bases, schools, etc. The proliferation of distributed PV is primarily on residential distribution circuits so the daytime UFLS capacities continue to degrade and it is becoming more difficult to find sufficient load to shed during a single contingency event. Additionally, the more stringent criterion support the use of distributed resources to supply fast frequency response. Load shedding of the

[14] Under-frequency load shedding (UFLS) is a means to restore system frequency to operating equilibrium for various loss of generation contingency events. Ultimately, it is the last line of defense of system security to prevent system blackouts but it has shortcomings for future conditions in Hawaiʻi.

distribution system, as allowed under the previous criteria, would be counterproductive since it would disconnect demand response resources from the system.

The limited system security analysis for Hawaiʻi Island was expanded to simulate the impacts of transmission faults that cause loss of generation contingency events for selected resource plans. Hawaiʻi Island's transmission infrastructure covers a very large territory that increases its exposure to electrical faults that can cause large capacities of DG-PV to disconnect from the system. Additional analyses were performed to determine FFR and PFR requirements to ensure system security for Hawaiʻi Island and should be indicative findings when these analyses are conducted for the preferred plan.

Fundamentally, distributed generation (primarily PV) poses one of the biggest challenges to system security because it imposes conflicting requirements on the electrical system: 1) the reduction of system load displaces synchronous generators and 2) distributed resources increases regulating and frequency response reserve requirements that are traditionally provided by synchronous generators. More specifically, transformation of the electrical system must address the following system security issues:

- DG-PV displaces synchronous generators that provide essential grid services like inertia, regulating reserves, and system fault current.
- DG-PV reduces the capacity of the system’s under frequency load shed scheme (UFLS).
- Legacy DG-PV and their less flexible frequency ride through ability increases the magnitude of a loss of generation or fault contingency.
- DG-PV is currently not controllable by and is invisible to the system operator.

The process of identifying needs and designing solutions follows a several-step process that we believe addresses the Commission’s concerns regarding the prior PSIP filing. (Note that this process was outlined as six steps in the Companies’ February 2016 filing. The revised process is equivalent, but reorganized to complement the rest of the PSIP more clearly.) The five steps are:

1. Establish operational reliability criteria.
2. Define technology-neutral ancillary services for meeting reliability criteria.
3. Determine the amount of ancillary services needed to support the resource plan.
4. Find the lowest reasonable cost solution, considering all types of qualified resources.
5. Identify flexible planning and future analyses to optimize over time.

The amounts of each type of ancillary service needed to meet system security vary by island, resource plan, and time period. That is because Frequency Response needs are driven by the size of the largest contingency event, which is generally the loss of the largest unit online at the time (combined with potential sympathetic loss of legacy DG-PV). Regulation needs are driven by the variability of net load (that is, load minus variable generation output), which depends especially on the amount of PV and wind, and Replacement Reserve needs are driven by the amounts of Frequency Response and Regulation needed after an event.

The Companies defined fast frequency response and primary frequency response requirements in technology-neutral terms so any qualified resource can meet them, whether traditional generation, advanced features of inverter-interfaced generation and storage, or demand response. Our objective is to identify the lowest reasonable cost combination that ensures system security for a given resource plan and in subsequent iterations, let the market and specific resource applications determine available resources. To do so, we break the analysis into three steps:

1. Construct an initial pre-DR solution that meets system security needs;
2. Substitute DR to the full extent it is cost-effective, producing a revised resource strategy;
3. Consider whether the solution would affect system conditions (especially unit commitment and dispatch, affecting inertia and the amount of Primary Frequency Reserves available) to warrant another iteration of analysis.

There was not sufficient time to complete these three steps for the preferred plans. These steps will be done in conjunction with development of the Demand Response Programs.

#6. ANCILLARY SERVICES

As part of this filing, the Companies' analyses began with the establishment of operational reliability criteria and the refinement of grid service definitions sufficient to meet these reliability criteria. This refinement of ancillary services was grounded in the definitions of grid services found in the Supplemental Report filed under Docket No. 2007-0341, filed November 30, 2015.

In particular, Fast Frequency Response (FFR) was refined into several sub-categories of FFR, including: Instantaneous Inertia (II), Primary Frequency Reserves (PFR), Fast Frequency Reserves 1 Up (FFR1Up) and 2 Up (FFR2Up), and Fast Frequency Reserves Down (FFRDown). Further, Supplemental Reserves was recast to Replacement Reserves (RR) and Regulating Reserves was refined to Regulation Reserves Up (RegUp) and Regulating Reserves Down (RegDown). The Companies then revised these ancillary services needs for the O'ahu cases.

These revised ancillary service needs for O'ahu were coupled with the existing needs defined for the other island systems and a set of resources that are capable of cost-effectively meeting the ancillary service needs were identified. Included in this resource pool was utility-scale, centralized energy storage resource options as well as a DR portfolio that included the use of distributed, behind-the-meter storage options. As part of the DR optimization effort, the Companies developed respective optimal and most cost-effective implementation of the combination of these resources. The final optimized potential of distributed storage will be iterated and refined prior to filing the Final DR Program Portfolio application.

Consistent with the previous methodology applied during the development of the Interim DR Program Portfolio application (Docket No. 2015-0412), the Companies assessed the quantities of these service needs over a 30-year horizon and developed the value of these services by virtue of the costs associated with delivering them. With these values defined, the Companies were then positioned to assess substitution opportunities for delivering these services via the most cost-effective means possible.

The DR portfolio, utilizing a growing population of DERs, was considered as a cost effective substitution option for delivering these ancillary services. The Companies refined the DR portfolio based on previous feedback in an attempt to find the lowest reasonable cost solution considering all types of qualified resources for all islands. The Companies then identified flexible planning and future analyses to optimize the DR portfolio over time. This process is not complete, but will continue until the Final DR Program Portfolio application is filed in mid-2016.

Finally, the Companies updated our Must-Run Generation Reduction Plans and Generation Flexibility Plans to include these ancillary service refinements.

#7. INTER-ISLAND TRANSMISSION

Our PSIP analyses show that, for O‘ahu to achieve 100% renewable energy in 2045, significantly greater off–island renewable resources will be required (if found to be more cost effective than biofuels).

Analysis performed in this updated PSIP has shown that O‘ahu would require more offshore capacity than was included in our 2014 PSIP assumptions. Because of this, we plan to further analyze an array of inter-island transmission options after April 1, 2016. A plan for addressing the interisland transmission analysis is discussed in Chapter 9: Next Steps. In conjunction with the analysis, we also plan to further investigate offshore wind.

#8. IMPLEMENTATION RISKS AND CONTINGENCIES

Our Decision Framework contains nine risks and uncertainties that we used as part of our assessment to develop our 2016 updated PSIP. The risks identified in the Decision Framework were used as parameters in the selection of representative resource plans for each Theme on each island and ultimately to select each island's Preferred Plan.

Chapter 3 describes the multiple initial cases, which were specifically designed to iterate toward a low-cost objective. The impact of accelerating the implementation of renewable energy resources, LNG and generation modernization, while accounting for risks attributed to changes in fuel prices for both LNG and oil, were evaluated. We refined these cases to incorporate results from preceding runs of DER, DR, and utility-scale resource iterative cycles, iterated to achieve low-cost and minimized risk objectives, and analyzed grid modernization to characterize tradeoffs and risks of capital investments.

We ran production simulation using different modeling software (via consultants) for comparative purposes, conducted stochastic analysis to characterize risks associated with fuel price forecasts (through Ascend Analytics as described above), and ran sensitivity analyses using high and low fuel price forecasts.

We calculated present values of revenue requirements, and the relative difference in revenue requirements between cases for initial cases. Capital expenditure constraints were considered as described above. Using the Decision Framework, the Preferred Plans were selected and five-year action plans to implement the Preferred Plans were developed. It should be noted that with the exception of Theme 2 which requires LNG, generation modernization, and unit conversions, the near term actions for all final plans are very similar.

3. Planning Themes and Candidate Plans

The overall plan development and selection process was iterative in nature. The general process was:

First iteration consisted of the development of initial cases that were discussed in the PSIP Update Interim Status Report filed February 16, 2016.

Second iteration expanded the number of cases from the first iteration to evaluate numerous other alternative cases as candidate plans under three themes.

- Theme 1 is a path to accelerate pursuing 100% renewable energy with minimal imported liquid biofuels.
- Theme 2 is a path to achieve 100% renewable energy with LNG as a transitional fuel.
- Theme 3 is a path to achieve 100% renewable energy without LNG as a transitional fuel.

Third iteration refined a smaller set of candidate plans under each theme using knowledge gained from the analysis through the second iteration.

Final plans, one under each theme, were selected based on the results from the third iteration.

Figure 3-1 illustrates the general overview of the process.

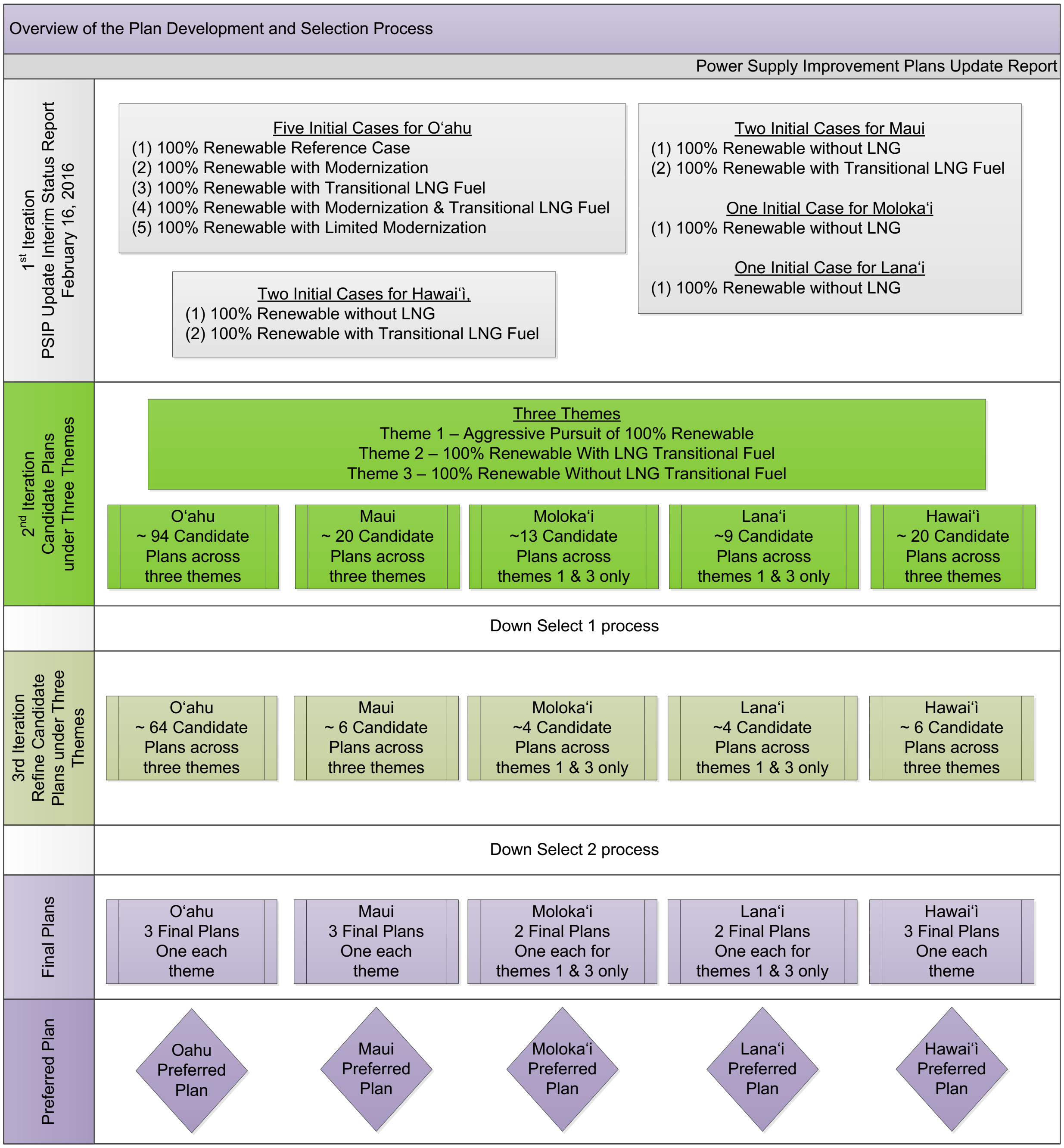

Figure 3-1. Overview of the Plan Development and Selection Process

DEVELOPMENT OF CANDIDATE PLANS

Numerous unique 30-year resource plans ("cases") across the five islands served by the Hawaiian Electric Companies were developed by specifically considering the following:

- Three major paths—themes—for achieving 100% renewable energy by 2045.
- Decision variables based on the Commission's Observations and Concerns, and input from stakeholders.
- System specific considerations (for example, island specific levels of resource availability, current levels of RPS attainment, resource availability on a specific island).

The cases were evaluated, screened to select plans for further consideration, and then further screened to select an optimal resource plan for each of the three Themes. This chapter explains the process for building the candidate plans, the criteria and processes used to evaluate the plans, the major findings as we evaluated and screened the plans, and the resulting final plans – one plan for each theme.

As noted earlier, the themes and decision variables applied in the second and third iterations.

Because of the large volume of analytical work performed in the second and third iterations and it is impractical to explain each step and every decision made in each iteration, the following sections should be considered a narrative of the process as it applied primarily to the third iteration. Some of the same steps were used in the second iteration and it would be redundant to repeat them below. The third iteration is the most relevant since it is the basis from which the final decisions were made.

The Three Themes

The Companies recognize that there are different visions for attaining 100% renewable energy. Accordingly, we developed different resource plans around three major themes.

- Theme 1 accelerates renewable energy (RE) deployment across the Hawaiian Electric territories and achieves 100% RE in 2030 for Maui, Moloka'i, Lana'i, and Hawai'i Island and in 2045 for O'ahu, uses imported liquid biofuels sparingly for firming purposes, does not use LNG, and maximizes use of non-fuel burning RE resources like PV, wind, and geothermal. Theme 1 could be implemented under a merged or an unmerged scenario.
- Theme 2 meets interim RPS mandates across the Hawaiian Electric territories on-time and achieves 100% RE in 2040 for Maui, Moloka'i, Lana'i, and Hawai'i Island and in 2045 for O'ahu , balances the use of both fuel and non-fuel burning RE, and uses LNG.

Because NextEra Energy's financial backing is required to implement Theme 2, this Theme can be considered a "merged" scenario where the proposed merger of the Companies and NextEra Energy is completed.

- Theme 3 meets interim RPS mandates across the Hawaiian Electric territories on-time and achieves 100% RE in 2040 for Maui, Moloka‘i, Lana‘i, and Hawai‘i Island and in 2045 for O‘ahu, balances the use of both fuel and non-fuel burning RE, and for planning analysis, presumes that LNG is not available. Theme 3 could be implemented under a merged or an unmerged scenario.

Error! Reference source not found. summarizes the three major themes.

Theme Element	Theme 1	Theme 2	Theme 3
Short Description	Accelerate Renewables	Renewables With LNG	Renewables Without LNG
Theme Description	Accelerate renewables using DER, variable renewable resources, energy storage (if necessary) and minimal liquid biofuels on O‘ahu. Accelerate renewables using firm renewable energy resources, variable renewable energy resources, energy storage (if necessary) and minimal imported liquid biofuels on the neighbor islands. 100% renewable energy generation by 2030 on neighbor islands and 2045 on O‘ahu.	Meet the RPS milestones (as presently defined) on a state-wide basis using DER, LNG, firm (if available) and variable renewable resources, energy storage (if necessary). 100% renewable energy generation by 2040 on Maui and Hawai‘i island and 2045 on O‘ahu.	Meet the RPS milestones (as presently defined) on a state-wide basis using DER, firm (if available) and variable renewable resources, energy storage (if necessary). 100% renewable energy generation by 2040 on Maui, Moloka‘i, Lana‘i, and Hawai‘i island and 2045 on O‘ahu.
LNG	No LNG	LNG 2021–2040	No LNG
Merger	Unmerged.	Requires merger.	Unmerged.
100% Renewable Energy Achievement	2030 RE on Maui, Hawai‘i Island 2030 RE on Moloka‘i, Lana‘i 2045 RE on O‘ahu	2040 RE on Maui, Hawai‘i Island 2045 RE on O‘ahu (Not applicable to Moloka‘i & Lana‘i)	2040 RE on Maui, Hawai‘i Island 2040 RE on Moloka‘i, Lana‘i 2045 RE on O‘ahu
Renewables	Maximize use of variable, non-fuel burning renewable resources, including DER. Use firm renewables (for example, biomass, geothermal) when cost effective vs. variable renewables.	Balance of non-fuel burning renewable resources and firm renewable resources.	Balance of non-fuel burning renewable resources and firm renewable resources.
DG-PV	High	High and Market evaluated	High and Market evaluated
Demand Response	All cases in all themes employ demand response to provide grid services. Quantities and pricing based on DR market potential study and avoided cost iterations.		

Table 3-1. Summary of the Three Themes

Selection of Decision Variables

Decision variables can be varied to test the suitability of different combinations of supply side resources and fuel, energy storage, and demand-side resources for achieving the Objectives. Decision variables include resources and programs that can be leveraged by the utility in a given plan to achieve the Objectives. Decision variables were developed by specifically considering the Commission's Eight Observations & Concerns, and high impact variables.

Table 3-2 summarizes the decision variables selected, how they address the eight Observations and Concerns, and how they were applied in the analyses of the various cases.

Decision Variable	Eight Observations & Concerns	Context and Application of the Decision Variable
Primary Fossil Fuel	O&C #4: Proposed plans for fossil-fueled power plants not sufficiently justified.	Fossil generation plans were evaluated by considering alternate fuel price scenarios, cost-effective fossil generation replacement plan consistent with high renewable strategy, and a long-term fuel supply strategy to minimize fuel cost and price volatility risk. Plans were evaluated under February 2016 EIA STEO and 2015 EIA Reference fuel price scenarios.
Energy Storage	O&C #2: PSIPs do not appear to aggressively seek lower-cost, new utility-scale renewable resources (requests to identify and consider key enabling technologies to support renewable strategy e.g. bulk energy storage). O&C #6: Proposed plan for provision of ancillary services lacks transparency and may not be most cost-effective option (requests to review proposed energy storage resources to determine and demonstrate optimal, cost-effective sizing and utilization strategies).	Updated resource capital cost forecasts suggest battery-based storage technology costs are forecast to decrease dramatically (in real terms), which may lead to storage playing a critical role in attaining 100% RPS. Pumped storage hydro (PSH) was evaluated as a storage resource option. Resource capital cost forecasts show flat capital costs for PSH (in real terms). Based on these and other factors, energy storage was considered as an option in a number of plans and compared to other options for renewable resource management (e.g. renewable resource curtailment, use of firm renewables that do not require storage) varied across islands in the cases. PSH was evaluated as a resource on applicable islands. Plans were evaluated without must-run fossil fueled generation after a particular date (2022 for O'ahu for Theme 2 and 2025 in Themes 1 and 3; 2022 for Maui; 2016 for Moloka'i and Lana'i; and 2019 for Hawai'i island). This enabled other resources, such as demand response and energy storage (batteries, PSH or flywheels) to have a fair opportunity to provide cost-effective ancillary services (frequency response and frequency regulation), and other options, such as synchronous condensers, to provide voltage regulation in lieu of a thermal generation in order to accept more renewable energy. After the resource plans were constructed, system security requirements were reassessed and if other resources such as demand response and energy storage were not of sufficient capacity to cover all of the system needs, minimal thermal generation was added to serve those needs.

Decision Variable	Eight Observations & Concerns	Context and Application of the Decision Variable
Utility-Scale Renewables	O&C #2: PSIPs do not appear to aggressively seek lower-cost, new utility-scale renewable resources (requests to optimize renewable resource portfolio alternatives considering full potential of available renewable resource options without unsubstantiated constraints; identify actions to support acquisition of near-term cost-effective RE projects to meet 2020 RPS; and develop strategic direction and decision rules for cost-effective high renewable strategy).	The updated resource cost forecasts show variable renewable resource capital costs are expected to decline modestly (in real terms) through the study period. The updated resource availability potential study performed by NREL shows variable renewable resource (i.e. wind and solar-PV) potential is high on neighbor islands, but constrained on O‘ahu. Several developers are proposing offshore wind projects to serve O‘ahu. Inter-island cable(s) may provide a means of delivering renewable energy to O‘ahu from resources located on the neighbor islands. Based on these and other factors including RPS attainment, amount and type of renewable resource was varied by island in the cases. While inter-island cable scenarios will be examined further beyond the date of this filing, offshore wind was considered in the O‘ahu cases; these cases serve as a proxy for non- O‘ahu sited renewable resources that could serve O‘ahu through an inter-island cable.
Renewable Energy Percent Timing	O&C #2: PSIPs do not appear to aggressively seek lower-cost, new utility-scale renewable resources (requests to optimize renewable resource portfolio alternatives considering full potential of available renewable resource options without unsubstantiated constraints; develop and implement Lana‘i and Moloka‘i High RE plans; and develop strategic direction and decision rules for cost-effective high renewable strategy).	The following 100% RPS and 100% renewable energy (RE) generation attainment schedules were considered: ▪ Accelerate RE reaching 100% RE by 2030 on the neighbor islands. (Theme 1) ▪ 100% RE achievement by 2040 or 2045 on Maui and Hawai‘i Island and 2040 on Moloka‘i and Lana‘i. (Themes 2 and 3). ▪ 100% RE achievement by 2045 on O‘ahu.
DG-PV Amount	O&C #3: PSIPs do not adequately address utilization and integration of DER (requests to include DER in overall system optimization instead of "treating DG-PV as an end state", to explicitly consider integration costs, and to consider the role and potential contribution of DER in high-RPS attainment scenarios).	Market DG Scenario: DG PV adoption was forecast with DG export compensation based on utility-scale PV equivalent. This allows DG-PV customers to provide cost-effective grid services, while also optimizing system costs. High DG Scenario: DG-PV adoption was forecast assuming compensation meaningfully higher than utility-scale PV equivalent, driving higher DG-PV adoption at an incrementally higher cost than other similar resources. Both DG-PV adoption scenarios account for integration costs. In the market DG-PV" forecast, adoption was re-calculated under the system upgrade costs attributable to DG-PV customers and was allocated to those DG-PV customers. DG-PV integration costs presume advanced inverter functionality to provide a level of voltage response and the ability to allow for remote monitoring and control.

Decision Variable	Eight Observations & Concerns	Context and Application of the Decision Variable
Demand Response	O&C #3: PSIPs do not adequately address utilization and integration of DER (requests evaluation of full spectrum of DER in analysis, including distributed energy storage). O&C #6: Proposed plan for provision of ancillary services lacks transparency and may not be the most cost-effective option (requests evaluation and consideration of potential contributions from all potential sources of grid services including DER and DR).	All cases analyzed for the PSIP assume that demand response programs will be in place to leverage DESS and DR resources to provide ancillary services based on the potential study and avoided cost methodology.

Table 3-2. Application of Decision Variables on the Eight Observations and Concerns

O‘ahu Decision Variables

In addition to the general application of the decision variables across all islands, Table 3-3 summarizes specific considerations for applying the decision variables to O‘ahu cases.

Decision Variable	O‘ahu Drivers	Context and Application of the Decision Variables Specific to O‘ahu
Primary Fossil Fuel	O‘ahu's energy requirements allow volumes of alternative, low-cost, clean fuels (for example, LNG) to be feasible.	Analyze LNG (with new 3x1 Kahe combined-cycle) under Theme 2 and plans without LNG under Themes 1 and 3. Analyze plans under February 2016 EIA STEO and 2015 EIA Reference fuel price scenarios.
Energy Storage	O‘ahu may require energy storage in order to integrate large quantities of variable renewables required late in the planning period.	Analyze cases with and without storage. Consider economics of storage to avoid over-generation of renewable energy vs. economics of using curtailed (dispatched) variable energy as an operational resource.
Utility-Scale Renewables	O‘ahu is constrained in its ability to site on-island variable renewable resources (based on NREL resource potential study).	Maximize the remaining potential on O‘ahu. Evaluate off-island resources (offshore wind or inter-island cable(s)).
Renewable Energy Percent Timing	O‘ahu is constrained in its ability to site on-island variable renewable resources (based on NREL resource potential study). There may be a desire by some to limit the use of liquid biofuels on O‘ahu.	Consider strategies for achieving RPS and RE goals by accelerating achievement of RPS milestones on the neighbor islands, and appropriate compensation mechanisms to those customers, allowing time to develop solutions for O‘ahu that will be required late in the study period (that is, 2040–2045). Consider strategies for utilizing biofuels in a more strategic manner (that is, backup for variable renewables).
DG-PV Amount	In all cases, DG-PV plays an important role in achieving 100% RE on O‘ahu.	Analyze the cost effectiveness of DG-PV under a market based DG-PV scenario (whereby DG-PV is compensated based on the value of utility-scale PV) versus a high DG-PV scenario (whereby a premium is paid for DG-PV output relative to utility-scale PV).
Demand Response	In all cases, DR can play a role in providing grid services on O‘ahu.	Analyze and optimize the uptake of DR programs based on its potential and its value, based on an avoided cost analysis.

Table 3-3. Decision Variable Applications for O‘ahu Cases

Hawai'i Island Decision Variables

Table 3-4 summarizes specific considerations for applying the decision variables to Hawai'i Island cases.

Decision Variable	Hawai'i Island Drivers	Context and Application of the Decision Variable Specific to Hawai'i Island
Primary Fossil Fuel	Use of LNG on Hawai'i Island will require transport of LNG and conversion of units to burn LNG.	Evaluate feasibility of use of LNG on Hawai'i Island, taking into account that volumes not used on Hawai'i island will need to be used on O'ahu to maintain LNG pricing. Analyze plans under February 2016 EIA STEO and 2015 EIA Reference fuel price scenarios.
Energy Storage	Hawai'i Island already has a high penetration of variable renewable resources. However, Hawai'i Island has virtually unlimited variable resource potential (according to the NREL resource potential study).	Evaluate firm renewables versus controllable variable renewables and energy storage.
Utility-Scale Renewables	Hawai'i Island can support variable renewables (wind and solar PV) and firm renewables (biomass, geothermal). However, wind available on Hawai'i Island has a much higher capacity factor than utility-scale solar PV.	Evaluate firm renewables versus controllable variable renewables and energy storage.
Renewable Energy Percent Timing	Hawai'i Island is already close to 50% RE (48.7% in 2015), achieved with geothermal and variable renewables.	Evaluate firm renewables versus controllable variable renewables and energy storage.
DG-PV Amount	In all cases, DG-PV plays an important role in achieving 100% RE on Hawai'i Island.	Analyze the cost effectiveness of DG-PV under a market based DG-PV scenario (whereby DG-PV is compensated based on the value of utility-scale PV) versus a high DG-PV scenario (whereby a premium is paid for DG-PV output relative to utility-scale PV).
Demand Response	In all cases, DR can play a role in providing grid services on Hawai'i island.	Analyze and optimize the uptake of DR programs based on its potential and its value, based on an avoided cost analysis.

Table 3-4. Decision Variable Applications for Hawai'i Island Cases

Maui Decision Variables

Table 3-5 summarizes specific considerations for applying the decision variables to Maui cases.

Decision Variable	Maui Drivers	Context and Application of the Decision Variable Specific to Maui
Primary Fossil Fuel	Use of LNG on Maui will require transport of LNG and conversion of units to burn LNG.	Evaluate feasibility of use of LNG on Maui, taking into account that volumes not used on Maui will need to be used on O'ahu to maintain LNG pricing. Analyze plans under February 2016 EIA STEO and 2015 EIA Reference fuel price scenarios.
Energy Storage	Maui already has a high penetration of variable renewable resources (and some energy storage associated with renewable resources). However, Maui has substantial variable resource potential (according to the NREL resource potential study).	Evaluate firm renewables versus variable renewables and energy storage.
Utility-Scale Renewables	Maui faces a capacity shortfall beginning in 2016. with the retirement of HC&S generation and increasing capacity shortfall with the retirement of the Kahului station in 2022.	Evaluate suitability of variable renewable resources versus firm renewable resources Evaluate capacity need to determine size and type of new firm resources Evaluate potential benefits to Maui from a grid-tie with O'ahu.
Renewable Energy Percent Timing	Maui (including Moloka'i and Lana'i) achieved 35.4% RPS in 2015, achieved mostly with variable renewables.	Evaluate firm renewables versus variable renewables and energy storage.
DG-PV Amount	In all cases, DG-PV plays an important role in achieving 100% RE on Maui.	Analyze the cost effectiveness of DG-PV under a market based DG-PV scenario (whereby DG-PV is compensated based on the value of utility-scale PV) versus a high DG-PV scenario (whereby a premium is paid for DG-PV output relative to utility-scale PV).
Demand Response	In all cases, DR can play a role in providing grid services on Maui.	Analyze and optimize the uptake of DR programs based on its potential and its value, based on an avoided cost analysis.

Table 3-5. Decision Variable Applications for Maui Cases

Lanaʻi and Molokaʻi Decision Variables

Table 3-6 summarizes specific considerations for applying the decision variables to Lanaʻi and Molokaʻi cases.

Decision Variable	Lanaʻi and Molokaʻi Drivers	Context and Application of the Decision Variable Specific to Lanaʻi and Molokaʻi
Primary Fossil Fuel	Lanaʻi and Molokaʻi loads are too small to justify shipments of LNG. Lanaʻi operates a CHP plant for one of its largest customers.	Evaluate feasibility of small ICE units fired with diesel fuel versus variable renewables. Analyze plans under February 2016 and 2015 EIA Reference fuel price scenarios.
Energy Storage	High variable renewable penetrations will require energy storage to meet the energy needs.	Evaluate energy storage in conjunction with variable renewables.
Utility-Scale Renewables	There is adequate wind and solar PV potential on Molokaʻi and Lanaʻi.	Large scale wind turbines (greater than 1 MW class turbines) will be expensive to build due to mobilization costs. Consider utility-grade small wind turbines (100 KW class turbines) that can be erected without heavy cranes, and solar PV.
Renewable Energy Percent Timing	There is an opportunity to accelerate attainment of 100% RE by 2030.	Build Molokaʻi and Lanaʻi cases to achieve 100% RE by 2030 and 2040.
DG-PV Amount	Molokaʻi has significant penetrations of DG-PV.	Consider integration costs for higher penetrations of DG-PV on Molokaʻi.
Demand Response	DR may be possible on Molokaʻi and Lanaʻi but may be limited by small scale.	Analyze and optimize the uptake of DR programs based on its potential and its value, based on an avoided cost analysis.

Table 3-6. Decision Variable Applications for Lanaʻi and Molokaʻi Cases

Development of Cases for Evaluation

The decision variables described in the previous sections were combined to develop unique cases for modeling and analysis. In general, the cases were designed around various combinations of the decision variables in order to create an array of possible plans or cases. In addition, each case was tested against fuel price inputs representing a February 2016 EIA STEO fuel price projection and a 2015 EIA Reference fuel price projection.

- For Oʻahu, a total of 168 cases were developed.
- For Hawaiʻi Island, a total of 30 cases were developed.
- For Maui, a total of 31 cases were developed.
- For Lanaʻi, a total of 13 cases were developed.
- For Molokaʻi, a total of 17 cases were developed.

Resource Plan Development Process

For each case, a resource plan was developed. In order to determine near-optimal resource sizing, types and timing, a spreadsheet tool was developed. The tool identifies what new resource is cost-effective when, and how much that new resource can be curtailed while remaining cost-effective. This tool compares the cost of new resources to that of existing resources, and the amount of curtailment up to which that new resource is still lower cost than existing resources. It indicates when new cost-effective resources should be introduced into a plan. Figure 3-2. compares forecasted resource rates on Maui in 2030.

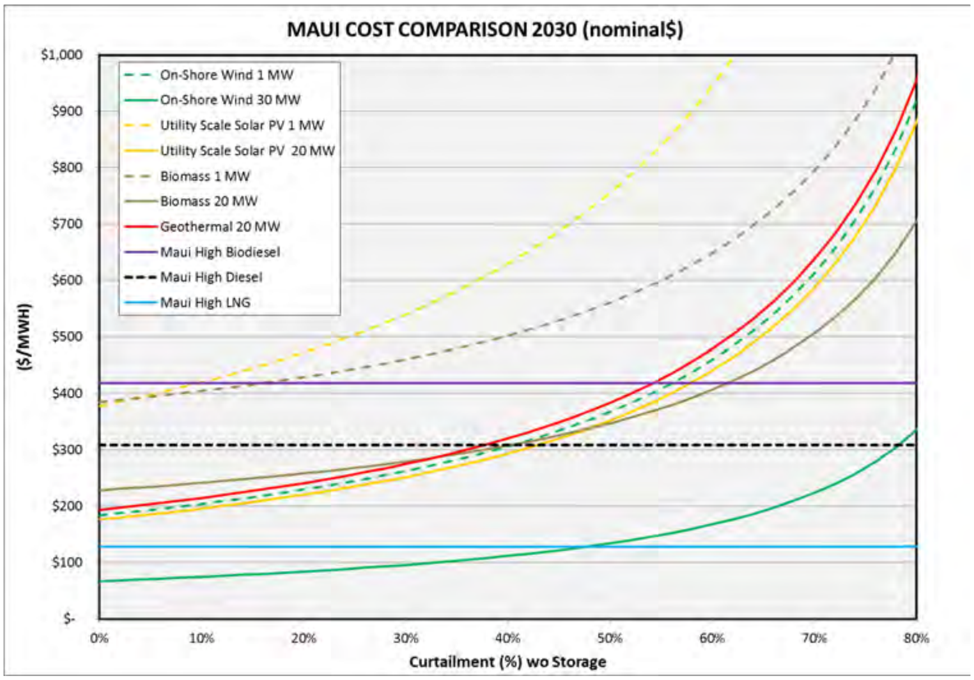

Figure 3-2. Forecasted Resource Cost Comparison: Maui

The y-axis represents the levelized cost per MWh of a resource, and the x-axis represents an approximation of the resource cost under increasing levels of over-generation from variable resources. It was assumed that if less energy is accepted by the system, the cost per MWh would be greater, which is shown by the up sloped lines. The horizontal lines represent the approximate operational cost of an existing generating asset in a future year (2030 in this example) under various fuel prices. Therefore, resources that fall below horizontal lines suggest cost effect resources when compared to an existing generating unit under a forecasted fuel price.

Long-term resource plans out to 2045 were developed with the help of this tool.

The list of all cases and the resulting resource plans developed for each case are included as Appendix K.

EVALUATION PROCESS

Evaluation Criteria

The criteria for evaluating the various plans are based on the Objectives. The primary objectives are:

- Achieve the lowest cost for our customers.
- Minimize risk to our customers.

In general, if a plan does not meet the primary objectives it is dropped from further consideration.

Important, but secondary, objectives include:

- Types of resources to meet state renewable energy goals.
- Reduce emissions.

Plans that remain after meeting the primary objectives were evaluated against these additional objectives.

Table 3-7 summarizes the objectives and evaluation criteria that were used to evaluate the cases.

Objectives		Evaluation Criteria	Description	Metric
Primary Objectives	Achieve Lowest Cost for Customers	Plan NPV Revenue Requirement	Net present value of revenue requirements associated with each resource plan. At the first level filter, this includes only incremental resource plan costs and total fuel costs.	Resource plan NPV
		Retail Rate Impact	This is a comparison across plans of the total retail rate to full-service customers.	Full-service customer retail rate.
		Average Customer Bill	This is a comparison across plans of the average monthly customer bill for a 500 KWH/month customer.	Full-service customer average monthly bill.
		Capital Investment Requirements	This is the total capital requirement associated with a plan, including utility capital, IPP capital and customer capital.	Total capital and total capital by year.
		Fuel Cost Exposure	This is the total fuel cost associated with a given resource plan. This is an indicator of the relative exposure to fuel cost among candidate plans.	Total NPV fuel cost.
	Minimize Risk to Customers	Plan Flexibility	This considers the ability of the plan to accommodate disruptive changes during the planning period.	Inspection of plans

Objectives		Evaluation Criteria	Description	Metric
		Plan Implementation Risk	This considers the risk in implementing a given plan. Does the plan include technologies that may be difficult to permit and finance? Does the plan overly rely on a certain type of resource? Are the risks inherent in the plan near-term or long-term risks?	Inspection of plans.
		Stranded Cost Risk	This considers the risk that a major capital project will become economically obsolete during its life.	Inspection of plans.
		Fuel Price Volatility	This considers the resilience of the plan to different fuel price scenarios.	Evaluate the plans under a range of fuel prices.
Secondary Objectives	Meet State Energy Policy Goals	Renewable Portfolio Standard	Does the plan meet the RPS statute as it currently exists?	% RPS attainment (current definition)
		Renewable Energy Generation	Does the plan attain a 100% renewable energy generation portfolio?	% of total energy generated with renewable energy resources.
		DER Utilization	Does the plan accommodate customer choice? Does the plan cost effectively utilize DER?	Market DG-PV levels High DG-PV levels Demand response utilization
	Reduce Emissions	Estimate emissions	What are the estimated CO_2 emissions of the plan?	Tons of CO_2 emissions

Table 3-7. Planning Objectives and Evaluation Criteria

Screening Process

Candidate Plans. As described above, candidate plans were created based on the themes, decision variables, and fuel scenarios.

First Iteration

The first iteration involved the development and analysis of plans for the Companies' PSIP Update Interim Status Report, which was filed on February 16, 2016. The case runs, logic and considerations in developing the cases, and comparative results of the cases runs were all presented in the Interim Status Report.

As stated in the report, in this first iteration, optimized demand response programs were included in the analysis of the plans for O'ahu. For the neighbor islands, demand response program information was not yet available so they were not included in the neighbor island analyses at that point.

In addition, the fuel price forecasts used in the first iteration were based on the 2015 EIA Reference, 2015 FAPRI Reference, and 2015 EIA Average Henry Hub Spot Prices for

Natural Gas fuel price forecasts, and the February 2016 Forward/Hybrid Curve, 2015 FAPRI Low, and Chicago Mercantile Exchange Henry Hub Natural Gas Futures (Escalated) fuel price forecasts.

In this first iteration, plans were developed for all islands to achieve 100% renewable energy by 2045 and biofuels were used liberally to help meet the 100% renewable energy requirement.

Second Iteration

The second iteration constructed candidate plans under the three themes discussed previously for various sizes, types and timing of renewable energy and energy storage additions. This is discussed in more detail below.

In addition, an updated February 2016 EIA STEO Price Forecast for oil and LNG was developed and used. This February 2016 EIA STEO Price Forecast was based on the EIA's Short-Term Energy Outlook (STEO). This was used in lieu of the February 2016 Forward/Hybrid Curve and the Chicago Mercantile Exchange Henry Hub Natural Gas Futures (Escalated) fuel price forecasts. The biofuel forecast was also revised to correct an anomaly in the later years of the forecast.

In contrast with the first iteration, options for the neighbor islands to achieve 100% renewable energy sooner than 2045 were evaluated. This is because O‘ahu's demand is much higher than that of the neighbor islands (in fact, O‘ahu's peak demand is over twice as high as the peak demand of all of the neighbor islands combined) while O‘ahu's on-island renewable energy potential is lower than that of the neighbor islands. Therefore, the neighbor islands may need to accelerate their renewable energy integration in order for the RPS requirements to be cost-effectively met across the Hawaiian Electric territories.

For the neighbor islands in this second iteration, alternative renewable energy resources to biofuels were used to help meet the 100% renewable energy requirement.

NPV Screen. The revenue requirements for each candidate plan were determined based on the resource plan, the production simulations for the given resource plan (which provides fuel cost, O&M costs, renewable curtailment, and reliability indicators), and the fixed revenue requirements associated with the resource plan.

Down Select 1. The first set of candidate plans was selected based on the net present value of revenue requirements associated with each case. Plans were selected under both 2015 EIA Reference and February 2016 EIA STEO fuel price forecasts, which bracketed the plans within future fuel price scenarios. Representatives from the Consumer

Advocate, DBEDT, and County of Hawai‘i were present in the room and via a web meeting link during this process.

Refine Remaining Cases 1. The remaining cases were analyzed and discussed using the evaluation criteria. Refinements to the cases were identified. Representatives from the Consumer Advocate, DBEDT, and County of Hawai‘i were present in the room and via a web meeting link during this process. Based on the identified refinements, the planning teams then processed new runs of the production simulations and revenue requirements for the remaining cases.

Third Iteration

As a result of the insights provided by the second iteration, the candidate plans were adjusted. In addition, new information was integrated into the analysis.

For the neighbor islands, plans were optimized to lower plan costs by reducing biofuel usage and increasing renewable energy and energy storage resources.

In this iteration, circuit-level integration costs were developed and used in the plan analyses. These circuit-level integration costs included items such as service transformer upgrades, conductor upgrades, distributed energy storage and communication and controls for advanced inverters. In addition, in order to achieve a high level of DG-PV, it was assumed that customers would need to be incentivized with higher credits for exporting their energy to the grid. This was captured in the analysis.

Within this iteration, a re-optimized demand response package was analyzed on a limited basis to determine its impact on the overall costs. The impacts appeared minimal. Furthermore, tests were conducted to determine if distributed energy storage could be a cost-effective substitute for bulk load-shifting energy storage. This did not appear to be the case due to the economy of scale provided by bulk energy storage.

In addition, because it was assumed the fixed costs for LNG would be allocated among the islands proportionately by volume consumed, cost allocations were recalculated based on the results of the case runs. These reallocated costs were folded into the overall financial analysis.

Also within this phase, adjustments were made in the neighbor island analyses to remove all must-run constraints in order to better determine how ancillary services could be most cost-effectively provided, whether by operating a generating unit or by some other resource, such as demand response, energy storage or synchronous condensers.

Review and Assess First Set of Refined Cases. The next set of case analyses and results were presented by the planning teams for each island. Each case was analyzed by comparing NPV revenue requirements, customer bill impacts, DER feasibility and renewable energy attainment. Each case was discussed in the context of risk factors and other decision variables. Representatives from the Consumer Advocate and DBEDT were present in the room and via a web meeting link during this process. The County of Hawai‘i representative was not available for this process.

Down Select 2. During the review and assessment of the first set of refined cases, a number of issues were identified for further investigation and analysis. Certain adjustments to various cases were identified for additional analysis.

Refine Remaining Cases 2. Based on these issues and refinements, the planning teams then processed additional runs of the production simulations and revenue requirements for the cases.

The primary goal of this process was to select one final plan under each theme.

The three fundamental decisions to be made were:

- LNG or No LNG
- High DG-PV or Market DG-PV
- 100% RE in 2040 or 2045 for the neighbor islands.

Plans were developed for different possible futures – 2015 EIA Reference / February 2016 EIA STEO Fuel Prices and High/Market DG-PV.

Review and Assess Second Set of Refined Cases. The second refinement of the cases were presented to the Hawaiian Electric Companies’ executive team. Minor changes and additional analyses to address executive questions and comments were identified.

Select Plans. The final plans for each Theme were selected.

Final Review. The final plans for each Theme were reviewed.

Final Theme Plans. Final plans for each theme were documented for determination of the Preferred Plan.

EVALUATION PROCESS AND RESULTS

O'ahu Results

Down Select 1 – O'ahu

The primary purpose of the Down Select 1 was to apply a revenue requirements filter to the various candidate plans to select the lowest cost plans under 2015 EIA Reference and February 2016 EIA STEO fuel scenarios.

In one of the group meetings (noted as "Down Select 1" above), the group compared the plan costs and other attributes (e.g., RPS, energy mix). The primary findings for O'ahu were:

- Theme 2 (with LNG) was lowest cost compared to Themes 1 and 3 in both the 2015 EIA Reference Fuel Price case and the February 2016 EIA STEO Fuel Price case.
- More analyses needed to be done to determine if plans with High DG-PV or Market DG-PV were lower cost. The analyses at that point were inconclusive.

Table 3-8 presents the O'ahu results from the Down Select 1 process after screening on a NPV revenue requirements basis. These plans represented the best plans under February 2016 EIA STEO and 2015 EIA Reference fuel forecasts and were therefore selected for additional analysis.

Candidate Plans – Down Select 1 – O'ahu			
	Theme 1	Theme 2	Theme 3
NPV RR $ millions February 2016 EIA STEO Fuel	$17,751	$15,097	$15,521
NPV RR $ millions 2015 EIA Reference Fuel	$20,774	$17,354	$19,701
Spread 2015 EIA Reference to February 2016 EIA STEO Fuel	17%	15%	27%
DER Forecast	High	Market	Market
100% RPS / RE	100% RE and RPS in 2045	100% RE and RPS in 2045	100% RE and RPS in 2045
Deactivations	Honolulu 8/9 converted to synchronous condensers 1/2019 AES contract terminated 9/2022 Waiau 3 & 4 deactivated 1/2023 and converted to synchronous condensers Kahe 6 deactivated 1/2025 and converted to synchronous condensers Waiau 5/6 deactivated 1/2030	Honolulu 8/9 converted to synchronous condensers 1/2019 Kahe 1, 2, and 3 deactivated 12/2020 and converted to synchronous condensers AES contract terminated 9/2022 Waiau 3 & 4 deactivated 1/2022 Kahe 4 deactivated 1/2022 Waiau 5/6 deactivated 1/2024 Waiau 7/8 deactivated 1/2030	Honolulu 8/9 converted to synchronous condensers 1/2019 AES contract terminated 9/2022 Waiau 3 & 4 deactivated 1/2023 and converted to synchronous condensers Kahe 6 deactivated 1/2025 and converted to synchronous condensers Waiau 5/6 deactivated 1/2030

Candidate Plans – Down Select 1 – O'ahu			
Variable Renewable Additions	27.6 MW Waiver PV 2016 15 MW onshore solar 2018 (CBRE) 10 MW onshore wind 2018 (CBRE) 24 MW NPM Wind 2018 109.6 MW Waiver PV 2018 360 MW onshore solar PV 2020 20 MW onshore wind 2020 1600 MW offshore wind 2025	27.6 MW Waiver PV 2016 15 MW onshore solar 2018 (CBRE) 10 MW onshore wind 2018 (CBRE) 24 MW NPM Wind 2018 109.6 MW Waiver PV 2018 30 MW onshore wind 2020 60 MW onshore solar PV 2020 400 MW offshore wind 2025 520 MW onshore solar PV 2040 1200 MW offshore wind 2045	27.6 MW Waiver PV 2016 15 MW onshore solar 2018 (CBRE) 10 MW onshore wind 2018 (CBRE) 24 MW NPM Wind 2018 109.6 MW Waiver PV in 2018 30 MW onshore wind 2020 400 MW offshore wind 2025 420 MW of solar PV 2045 800 MW offshore wind 2045
Firm Renewable Additions	None	None	None
Thermal Generation Additions	50 MW Schofield ICE 2018 100 MW JBPHH Plant 2022 54 MW KMCBH Plan 2023	50 MW Schofield ICE 2018 100 MW JBPHH Plant 2020 27 MW KMCBH Plant 6/2021 3x1 CC in 6/2021	50 MW Schofield ICE 2018 100 MW JBPHH Plant 2022 54 MW KMCBH Plan 2023
Energy Storage Additions	90 MW Contingency BESS 2019	90 MW Contingency BESS 2019	90 MW Contingency BESS 2019

Table 3-8. Candidate Plans from Down Select 1

After Down Select 1, these plans became the basis for further analysis across the three themes.

Note: Net Present Value Revenue Requirements. At this stage, these represent only the incremental fixed revenue requirements associated with the resource plan i.e. revenue requirements associated with new resources, DER integration costs, fixed and variable O&M, and fuel. These NPV revenue requirements do *not* include the revenue requirements associated with a) embedded costs of existing generation, transmission, distribution and general plant b) non-power supply related capital expenditures, c) and base capital expenditures. These are accounted for in the financial model and in the results presented in Chapters 4, 5, 6, 7 and 8.

Initial Findings and Observations for O'ahu

In the review of the results of the first down select process, the following initial findings were made for O'ahu:

- Theme 2 offers the best economics for O'ahu when viewed over the entire study period.
- Because of the constraints on the development of renewable resources on O'ahu (i.e., no geothermal, very limited on-island biomass resources, constrained land area for additional solar and onshore wind), achieving 100% renewables on O'ahu will require either (i) extensive use of liquid biofuels and/or (ii) extensive access to offshore

resources (e.g. offshore wind, renewable resources located on neighbor islands interconnected to O'ahu via inter-island cable).

- The renewable constraints on O'ahu and the timeframes for development of off-island resources to serve O'ahu, mean that continued use of imported fossil fuels is required well into the study period for all three themes.
- Theme 1 will require substantial amounts of renewable energy resources (modeled in at this stage as offshore wind) relative early in the study period (2025). For Theme 1, this concentrates a great deal of implementation risk early in the study period, since the scenario is reliant on very large quantities of very deep water offshore wind (with uncertain capital costs and unproven feasibility).
- A possible strategy should be tested whereby 100% RPS achievement on Maui and Hawai'i Island is accelerated (ensuring 70% consolidated RPS is achieved by 2040), and allowing for additional options to materialize for O'ahu late in the study period.
- Even with a high penetration of variable renewables in the resource mix, curtailment strategies (assuming the provider is compensated for curtailed energy) or strategic use of biofuels in thermal generation are both economically more advantageous than use of large quantities of energy storage that would be required to take all of the variable renewable energy.
- Theme 1 is substantially more expensive than either Theme 2 or Theme 3.
- The analyses were inconclusive in determining if plans with the Market based penetrations of DG-PV are more economical than the high DG-PV scenario.

Down Select 2 – O'ahu

In the next group meeting (noted as Down Select 2 above), the updated results were reviewed.

The findings for O'ahu were similar to those of the first meeting.

Plan risks, in terms of fuel price risk, technological risk, resource cost and availability risk, and stranded cost risk were also discussed at the meeting. Plans with LNG would have risks associated with locking in a long-term contract. Plans without LNG would have higher oil price volatility risk. Plans with geothermal would have development risks.

Following the conference call, there was additional discussion on how the final plan for each island should be selected. It was decided that each Theme should have a final plan and that the selected final plan for each theme could be one of the following: (1) the plan derived in the 2015 EIA Reference Fuel Price case; or (2) the plan derived in the February 2016 EIA STEO Fuel Price case; or (3) a hybrid constructed from knowledge gained from (1) and (2).

O'ahu used Method (3) and created a hybrid plan based on the insights learned from the numerous cases evaluated up to that point.

- Plans with Market DG-PV were the lowest cost in most cases.
- With the neighbor islands achieving 100% RE by 2030 in Theme 1 and 2040 in Themes 2 and 3, the O'ahu plans added a mix of onshore solar and offshore wind to meet the intermediate RPS goals.

Further refinements were made before the final plans were passed on to the Financial Model.

The results of modified runs and evaluation of the results of several sensitivities around 2015 EIA Reference and February 2016 EIA STEO fuel, as shown in Table 3-9.

Final Plans – Down Select 2 – O'ahu			
	Theme 1	Theme 2	Theme 3
NPV RR $ millions February 2016 EIA STEO Fuel	$16,299	$14,782	$15,765
NPV RR $ millions 2015 EIA Reference Fuel	$20,303	$17,413	$20,441
Spread 2015 EIA Reference to February 2016 EIA STEO Fuel	25%	18%	30%
DER Forecast	High	Market	Market
100% RPS / RE	100% RE and RPS in 2045	100% RE and RPS in 2045	100% RE and RPS in 2045
Deactivations	AES in 2022 Waiau 3 & 4 in 2023 Kahe 6 in 2025 Waiau 5 & 6 in 2030	Kahe 1,2,3 in 2020 AES in 2022 Waiau 3 & 4 in 2022 Kahe 4 in 2022 Waiau in 2024 Waiau 7 & 8 in 2030	AES in 2022 Waiau 3 & 4 in 2023 Kahe 6 in 2025 Waiau 5 & 6 in 2030
Variable Renewable Additions	27.6 MW Waiver PV 2016 15 MW CBRE solar2018 10 MW onshore wind 2018 (CBRE) 24 MW NPM Wind 2018 109.6 MW Waiver PV 2018 30 MW onshore wind 2020 200 MW solar PV 2020 200 MW solar PV 2022200 MW solar PV 2024 200 MW offshore wind 2030 200 MW offshore wind 2032 200 MW offshore wind 2034 200 MW offshore wind 2036	27.6 MW wavier PV 2016 15 MW CBRE solar 2018 10 MW onshore wind 2018 (CBRE) 24 MW NPM Wind 2018 109.6 MW Waiver PV 2018 30 MW onshore wind 2020 60 MW solar PV 2020 100 MW solar PV 2030 200 MW offshore wind 2030 200 MW solar PV 2040 200 MW offshore wind 2040 300 MW solar PV 2045 400 MW offshore wind 2045	27.6 MW wavier PV 2016 15 MW CBRE solar 2018 10 MW onshore wind 2018 (CBRE) 24 MW NPM Wind 2018 109.6 MW Waiver PV 2018 30 MW onshore wind 2020 60 MW solar PV 2020 100 MW solar PV 2030 200 MW offshore wind 2030 200 MW solar PV 2040 200 MW offshore wind 2040 300 MW solar PV 2045 400 MW offshore wind 2045

Final Plans – Down Select 2 – O‘ahu			
Firm Renewable Additions	None	None	None
Thermal Generation Additions	50 MW Schofield ICE 2018 100 MW JBPHH Plant 2022 54 MW KMCBH Plan 2023	50 MW Schofield ICE 2018 100 MW JBPHH Plant 2020 27 MW KMCBH Plant 6/2021 3x1 CC 2021	50 MW Schofield ICE 2018 100 MW JBPHH Plant 2022 54 MW KMCBH Plan 2023
Energy Storage Additions	90 MW Contingency BESS 2019	90 MW Contingency BESS 2019	90 MW Contingency BESS 2019

Table 3-9. Final Plans from Down Select 2

Hawai‘i Island Results

Down Select 1 – Hawai‘i Island

The primary purpose of the Down Select 1 was to apply a revenue requirements filter to the various candidate plans to select the lowest cost plans under 2015 EIA Reference and February 2016 EIA STEO fuel scenarios.

The primary findings for Hawai‘i Island were:

- Plans with Market DG-PV were the lowest cost in all scenarios.
- Theme 2 (with LNG) was lowest cost compared to Themes 1 and 3 in the 2015 EIA Reference Fuel Price case but Theme 3 (No LNG) was lowest cost compared to Themes 1 and 2 in the February 2016 EIA STEO Fuel Price case.

Overall, it was found that Plans with 100% RE in 2040 on the neighbor islands appeared to aid in meeting the 70% RPS in 2040 across the Hawaiian Electric territories since O‘ahu appeared to have a more difficult time meeting that level.

The decision was made to freeze the Maui and Hawai‘i island RE assumption at meeting 100% RE in 2040 and only those cases from Themes 2 and 3, as well as all cases from Theme 1, were carried forward to the next phase of plan selection.

Table 3-10 presents the Hawai'i Island results from the Down Select 1 process after screening on a NPV revenue requirements basis. These plans represented the best plans under February 2016 EIA STEO and 2015 EIA Reference fuel forecasts and were therefore selected for additional analysis.

Candidate Plans – Down Select 1 – Hawai'i Island			
	Theme 1	Theme 2	Theme 3
NPV RR $ millions February 2016 EIA STEO Fuel	2561	2461	2465
NPV RR $ millions 2015 EIA Reference Fuel	2906	2762	2922
Spread 2015 EIA Reference to February 2016 EIA STEO Fuel	13 %	12 %	19 %
DER Forecast	High DG PV Forecast	Market DG-PV	Market DG-PV
100% RPS / RE	2030	2040	2040
Deactivations	Puna Steam 2022 Hill 5 2024 Hill 6 2026	Puna Steam 2022 Hill 5 2024 Hill 6 2026	Puna Steam 2022 Hill 5 2024 Hill 6 2026
Variable Renewable Additions	30 MW Wind 2028	20 MW Wind 2034 20 MW Wind 2038	20 MW Wind 2034 20 MW Wind 2038
Firm Renewable Additions	20 MW Geothermal 2022 20 MW Biomass 2024 20 MW Geothermal 2026	20 MW Geothermal 2022 20 MW Biomass 2027 20 MW Geothermal 2030	20 MW Geothermal 2022 20 MW Biomass 2027 20 MW Geothermal 2030
Thermal Generation Additions	None	None	None
Energy Storage Additions	30 MW Pump Storage 2030 30 MW Load shifting BESS 2030	Contingency Reserve Storage only. None for load-shifting	Contingency Reserve Storage only. None for load-shifting

Table 3-10. Candidate Plans from Down Select 1: Hawai'i Island

After Down Select 1, these plans became the basis for further analysis across the three themes.

Initial Findings and Observations for Hawai'i Island

In the review of the results of the first down select process, the following initial findings were made for Hawai'i Island:

- Themes 2 and 3 offer the best economics for Hawai'i Island when viewed over the entire study period.
- Firm renewable resources provide the most value (e.g., displacement of fossil fuel consumption, contribution to renewable energy %, and provision of grid services) to Hawai'i Island compared to variable renewables which will require either curtailment

or energy storage to manage in a system already heavy with variable renewables (wind, DG-PV).

- Hawai'i Island has available feedstock such as eucalyptus that can be used to fuel biomass generation. However, additional detailed analysis will be required to determine the feedstock requirements for a biomass plant and favorable pricing as biomass fuel.
- Geothermal resources can continue to play a role in providing renewable energy to Hawai'i Island. However, community concerns will need to be addressed in order for energy users on Hawai'i island to expand the use of this resource. Additional exploration of available geothermal resources on Hawai'i Island, in particular in West Hawai'i, should be a priority of state agencies and private organizations involved in energy, land and water issues
- There is substantial potential for wind energy on Hawai'i Island, many times greater than the energy requirements of the island. The relatively high capacity factors of the available wind make additional wind resources attractive. However, strategies for managing the variability of the wind, such as energy storage combined with dispatchable wind resources will be required as renewable energy levels grow, factoring in the economics of the multitude of options.
- Energy storage will be required to support additional variable renewable resources on Hawai'i Island. This will presents opportunities to explore in detail, through procurement strategies, market-based solutions for energy storage including BESS and pumped storage hydroelectric.
- Theme 1 is generally more expensive than either Theme 2 or Theme 3.
- Market based penetrations of DG-PV are more economical than the high DG-PV scenario.

Down Select 2 – Hawai'i Island

The findings for Hawai'i Island were:

- Plans with Market DG-PV were still the lowest cost in all scenarios.
- Theme 2 (with LNG) was lowest cost compared to Themes 1 and 3 in the 2015 EIA Reference Fuel Price case but Theme 3 (No LNG) was lowest cost compared to Themes 1 and 2 in the February 2016 EIA STEO Fuel Price case. These results were consistent with the results from the previous meeting.

Plan risks, in terms of fuel price risk, technological risk, resource cost and availability risk, and stranded cost risk were also discussed at the meeting. Plans with LNG would have risks associated with locking in a long-term contract. Plans without LNG would have higher oil price volatility risk. Plans with geothermal would have development risks.

The results at this point were then viewed in totality. Based on the analytical results for Maui and Hawaiʻi Island, the decision was made that the final plan for these islands would assume Market DG-PV. Therefore, two of the three decisions were made (i.e., 100% RE by 2040 and Market DG-PV).

Following the conference call, there was additional discussion on how the final plan for each island should be selected. It was decided that each Theme should have a final plan and that the selected final plan for each theme could be one of the following: (1) the plan derived in the 2015 EIA Reference Fuel Price case; or (2) the plan derived in the February 2016 EIA STEO Fuel Price case; or (3) a hybrid constructed from knowledge gained from (1) and (2).

It was decided that for Hawaiʻi Island, it would be the plan based on the 2015 EIA Reference Fuel Price case. Further refinements were made before the final plans were passed on to the Financial Model.

The results of modified runs and evaluation of the results of several sensitivities around 2015 EIA Reference and February 2016 EIA STEO fuel, for Hawai'i Island are presented in Table 3-11.

Final Plans – Down Select 1 – Hawai'i Island			
	Theme 1	Theme 2	Theme 3
NPV RR $ millions February 2016 EIA STEO Fuel	$2,563	$2,464	$2,467
NPV RR $ millions 2015 EIA Reference Fuel	$2,908	$2,765	$2,924
Spread 2015 EIA Reference to February 2016 EIA STEO Fuel	13%	12%	19%
DER Forecast	High DG-PV Forecast	Market DG-PV	Market DG-PV
100% RPS / RE	2030	2040	2040
Deactivations	Puna Steam 2022 Hill 5 2024 Hill 6 2026	Puna Steam 2022 Hill 5 2024 Hill 6 2026	Puna Steam 2022 Hill 5 2024 Hill 6 2026
Variable Renewable Additions	30 MW Wind 2028	20 MW Wind 2034 20 MW Wind 2038	20 MW Wind 2034 20 MW Wind 2038
Firm Renewable Additions	20 MW Geothermal 2022 20 MW Biomass 2024 20 MW Geothermal 2026	20 MW Geothermal 2022 20 MW Biomass 2027 20 MW Geothermal 2030	20 MW Geothermal 2022 20 MW Biomass 2027 20 MW Geothermal 2030
Thermal Generation Additions	None	None	None
Energy Storage Additions	30 MW Pump Storage 2030 30 MW Load shifting BESS 2030	Contingency Reserve Storage only. None for load-shifting	Contingency Reserve Storage only. None for load-shifting

Table 3-11. Final Plans from Down Select 2: Hawai'i Island

Additional Findings and Observations for Hawai'i Island

- Due to limited renewable resource potential on O'ahu, the neighbor islands, having the renewable resource potential to meet 100% renewable energy in 2040, can contribute to attain consolidated corporate RPS goals.
- Adding new firm renewable and variable generation renewable resources in lieu of biofuel in conventional generating units in 2040 is a more cost effective way to attain 100% RPS and 100% renewable energy.
- Higher costs result when 100% renewable energy is accelerated from 2045 to 2040.
- Additional refinements included the adjustment of storage and the timing of future resources to attain 100% renewable energy.
- LNG use in Theme 2 ends following December 31, 2039, based on attainment of 100% RE in 2040.
- Increased costs for Hawai'i Island in order to reach corporate goal of 70% RPS in 2040.

- Additional resource costs, such as for synchronous condensers, must be included if must-run requirement for fossil fuel generation is removed in advance of the addition of new dispatchable resources.

Based on these additional findings and observations, the final plans for each Theme were developed for Hawai‘i Island.

Maui Results

Down Select 1 – Maui

The primary purpose of the Down Select 1 was to apply a revenue requirements filter to the various candidate plans to select the lowest cost plans under 2015 EIA Reference and February 2016 EIA STEO fuel scenarios.

The primary findings for Maui were:

- Plans with Market DG-PV were the lowest cost in all scenarios.
- Theme 2 (with LNG) was lowest cost compared to Themes 1 and 3 in the February 2016 EIA STEO Fuel Price case but Theme 3 (No LNG) was lowest cost compared to Themes 1 and 2 in the 2015 EIA Reference Fuel Price case.

Complete results for Lana‘i and Moloka‘i were not available at this point.

Overall, it was found that Plans with 100% RE in 2040 on the neighbor islands appeared to aid in meeting the 70% RPS in 2040 across the Hawaiian Electric territories since O‘ahu appeared to have a more difficult time meeting that level.

The decision was made to freeze the Maui and Hawai‘i island RE assumption at meeting 100% RE in 2040 and only those cases from Themes 2 and 3, as well as all cases from Theme 1, were carried forward to the next phase of plan selection.

Refinements to the remaining plans were made after this meeting.

Table 3-12 presents the Maui results from the Down Select 1 process after screening on a NPV revenue requirements basis. These plans represented the best plans under February 2016 EIA STEO and 2015 EIA Reference fuel forecasts and were therefore selected for additional analysis.

Candidate Plans – Down Select 1 – Maui			
	Theme 1	Theme 2	Theme 3
NPV RR $ millions February 2016 EIA STEO Fuel	$3,533	$3,387	$3,416
NPV RR $ millions 2015 EIA Reference Fuel	$3,981	$3,937	$3,928
Spread 2015 EIA Reference to February 2016 EIA STEO Fuel	13%	16%	15%
DER Forecast	High	Base	Base
100% RPS / RE	2030	2040	2040
Deactivations			
Variable Renewable Additions	■ 30 MW Wind 2020 ■ 30 MW Wind 2040 ■ 30 MW Wind 2045	■ 60 MW Wind 2020 ■ 30 MW Wind 2040 ■ 60 MW PV 2045 ■ 120 MW Wind 2045	■ 60 MW Wind 2020 ■ 30 MW Wind 2022 ■ 30 MW Wind 2025 ■ 30 MW Wind 2040 ■ 60 MW PV 2045 ■ 60 MW Wind 2045
Firm Renewable Additions	■ 20 MW Biomass 2022 ■ 40 MW Geothermal 2030	■ 20 MW Biomass 2022 ■ 20 MW Biomass 2040	■ 20 MW Biomass 2022 ■ 20 MW Biomass 2040
Thermal Generation Additions	■ Remove must-run for fossil fuel generation	■ 2x9 MW ICE 2022 ■ Remove must-run for fossil fuel generation	■ 2x9 MW ICE 2022 ■ Remove must-run for fossil fuel generation
Energy Storage Additions	■ 30 MW PSH 2022 ■ 30 MW, 6hr LS BESS 2030	■ 20 MW LS BESS 2022 ■ 30 MW LS BESS 2037 (Replacement)	■ 20 MW LS BESS 2022 ■ 30 MW LS BESS 2037 (Replacement)

Table 3-12. Candidate Plans from Down Select 1 – Maui

After Down Select 1, these plans became the basis for further analysis across the three themes.

Initial Findings and Observations for Maui

In the review of the results of the first down select process, the following initial findings were made for Maui:

- Theme 2 offers the best economics for Maui when viewed over the entire study period.
- Given the most recent electricity forecasts, Maui expects to have a need for new generation or firm capacity to meet a reserve capacity shortfall in the 2017-2022 timeframe. We are evaluating several measures including demand response, energy storage, time-of-use rates and distributed and centralized generation to meet the needs of the island, however it is likely that combination of some, if not all, of these resources will be required.

- Firm renewable resources (i.e. biomass, geothermal) provide the most value to Maui compared to variable renewables, which will require either curtailment or energy storage to manage in a system already heavy with variable renewables (wind, DG-PV).
- Biomass is a firm renewable resource that can meet energy demands without the use of fossil fuel. Typically one hurdle for a biomass facility is to produce or identify enough feedstock. HC&S' January 2016 announcement that it is ceasing sugar production present unique opportunities for the island of Maui. HC&S land previously held in sugarcane may be suitable for feedstock production. Using the land to produce biomass ensures this land will stay in agricultural use and help Maui to preserve our open spaces, while at the same time contribute to energy security by lessening our dependence on imported fuel. Again, this suggests updated research on biomass feedstock should be a priority of State agencies and private organizations involved in energy, agriculture, land, and water issues. Although we modeled and evaluated an energy crop opportunity on Maui as a biomass resource, an alternative form of biofuel (liquid or gaseous) grown, processed and used for energy production on Maui could have similar benefits to Maui's energy system and Maui Electric's customers if the alternative forms of biofuels combined with the generating resource are similar in costs to biomass resource evaluated for this PSIP.
- Geothermal could potentially play a role in providing a source of firm renewable power for Maui. Additional exploration of available geothermal resources on Maui should be a priority of state agencies and private organizations involved in energy, land and water issues.
- Theme 1 is substantially more expensive than either Theme 2 or Theme 3.
- Market based penetrations of DG-PV are more economical than the high DG-PV scenario.

Down Select 2 – Maui

The findings for the Maui were:

- Plans with Market DG-PV were still the lowest cost in all scenarios.
- Theme 2 (with LNG) was lowest cost compared to Themes 1 and 3 in the February 2016 EIA STEO Fuel Price case but Theme 3 (No LNG) was lowest cost compared to Themes 1 and 3 in the 2015 EIA Reference Fuel Price case. These results were consistent with the results from the previous meeting.

Plan risks, in terms of fuel price risk, technological risk, resource cost and availability risk, and stranded cost risk were also discussed at the meeting. Plans with LNG would have risks associated with locking in a long-term contract. Plans without LNG would have higher oil price volatility risk. Plans with geothermal would have development risks.

The results at this point were then viewed in totality. Based on the analytical results for Maui and Hawai'i island, the decision was made that the final plan for these islands should have Market DG-PV. Therefore, two of the three decisions were made (i.e., 100% RE by 2040 and Market DG-PV).

Following the conference call, there was additional discussion on how the final plan for each island should be selected. It was decided that each Theme should have a final plan and that the selected final plan for each theme could be one of the following: (1) the plan derived in the 2015 EIA Reference Fuel Price case; or (2) the plan derived in the February 2016 EIA STEO Fuel Price case; or (3) a hybrid constructed from knowledge gained from (1) and (2).

- Plans with Market DG-PV were the lowest cost in all scenarios.
- With the neighbor islands achieving 100% RE by 2030 in Theme 1 and 2040 in Themes 2 and 3, the O'ahu plans added a mix of onshore solar and offshore wind to meet the intermediate RPS goals.

It was decided that for Maui, it would be the plan based on the 2015 EIA Reference Fuel Price case.

Further refinements were made before the final plans were passed on to the Financial Model.

Further details on the down selection process are provided below.

The results of modified runs and evaluation of the results of several sensitivities around 2015 EIA Reference and February 2016 EIA STEO fuel, are shown in Table 3-13.

Final Plans – Down Select 2 – Maui			
	Theme 1	Theme 2	Theme 3
NPV RR $ millions February 2016 EIA STEO Fuel	$3,769	$3,207	$3,079
NPV RR $ millions 2015 EIA Reference Fuel	$4,351	$3,635	$3,651
Spread 2015 EIA Reference to February 2016 EIA STEO Fuel	15%	13%	19%
DER Forecast	High	Base	Base
100% RPS / RE	2030	2040	2040
Deactivations			
Variable Renewable Additions	▪ 30MW Wind 2020 ▪ 30 MW Wind 2040 ▪ 30 MW Wind 2045	▪ 60MW Wind 2020 ▪ 120 MW Wind 2040 ▪ 40 MW Utility PV 2045 ▪ 30 MW Wind 2045	▪ 60MW Wind 2020 ▪ 30 MW Wind 2022 ▪ 30 MW Wind 2025 ▪ 60 MW Wind 2040 ▪ 40 MW Utility PV 2045 ▪ 30 MW Wind 2045
Firm Renewable Additions	▪ 20 MW Biomass 2022 ▪ 40 MW Biomass 2030 ▪ 40 MW Geothermal 2030	▪ 20 MW Biomass 2022 ▪ 20 MW Biomass 2040 ▪ 40 MW Geothermal 2040	▪ 20 MW Biomass 2022 ▪ 20 MW Biomass 2040 ▪ 40 MW Geothermal 2040
Thermal Generation Additions	▪ Remove must-run for fossil fuel generation	▪ 2x9 MW ICE 2022 ▪ Remove must-run for fossil fuel generation	▪ 2x9 MW ICE 2022 ▪ Remove must-run for fossil fuel generation
Energy Storage Additions	▪ 30 MW PSH 2022 ▪ 30 MW, 6hr LS BESS 2030	▪ 20 MW LS BESS 2022 ▪ 30 MW LS BESS 2037 (Replacement)	▪ 20 MW LS BESS 2022 ▪ 30 MW LS BESS 2037 (Replacement)

Table 3-13. Final Results and Expansion Plans from Down Select 2 – Maui

Additional Findings and Observations for Maui

- Due to limited renewable resource potential on Oʻahu, the neighbor islands, having the renewable resource potential to meet 100% renewable energy in 2040, can contribute to attain consolidated corporate RPS goals.
- Adding new firm renewable and variable generation renewable resources in lieu of biofuel in conventional generating units in 2040 is a more cost effective way to attain 100% RPS and 100% renewable energy.
- Higher costs when 100% renewable energy is accelerated from 2045 to 2040.
- Additional refinements included the additions of geothermal, biomass, and wind in 2040 to attain 100% renewable energy.
- LNG use in Theme 2 ends following December 31, 2039, based on attainment of 100% RE in 2040.
- Increased costs for Maui in order to reach corporate goal of 70% RPS in 2040.
- Addition of synchronous condensers is needed on the Maui system for system security and assist in reduction of the must-run requirement for fossil fuel generation.

Based on these additional findings and observations, the final plans for each Theme were developed for Maui.

Lanaʻi Results

Down Select 1 – Lanaʻi

The primary purpose of the Down Select 1 was to apply a revenue requirements filter to the various candidate plans to select the lowest cost plans under 2015 EIA Reference and February 2016 EIA STEO fuel scenarios.

Table 3-14 presents the Lanaʻi results from the Down Select 1 process after screening on a NPV revenue requirements basis. These plans represented the best plans under February 2016 EIA STEO and 2015 EIA Reference fuel forecasts and were therefore selected for additional analysis. (Note: Theme 2 was not applicable to Lanaʻi)

Candidate Plans – Down Select 1 – Lana'i		
	Theme 1	Theme 3
NPV RR $ millions February 2016 EIA STEO Fuel	$132	$138
NPV RR $ millions 2015 EIA Reference Fuel	$150	$161
Spread 2015 EIA Reference to February 2016 EIA STEO Fuel	14%	17%
DER Forecast	High	Base
100% RPS / RE	2030	2030
Deactivations		
Variable Renewable Additions	■ 3 MW Wind 2020 ■ 1 MW Wind 2030 ■ 1 MW Wind 2045	■ 2 MW Wind 2020 ■ 1 MW Wind 2030 ■ 1 MW Wind 2045
Firm Renewable Additions	None	None
Thermal Generation Additions	Remove must-run for CAT 1 & 2.	
Energy Storage Additions	1 MW LS BESS 2040	

Table 3-14. Candidate Results and Expansion Plans from Down Select 1 – Lana'i

After Down Select 1, these plans became the basis for further analysis across the three themes.

Findings and Observations for Lana'i

In the review of the results of the down select process, the following findings were made for Lana'i:

- Theme 1 offers the best strategy for Moloka'i when viewed over the entire study period.
- Firm renewable generation is limited and at a higher cost than existing generating resources.
- New wind resources are cost effective, including reduction in energy taken due to curtailment.
- Lower cost liquid fuel would be beneficial on Lana'i .
- Reduction in must-run fossil fuel generation provides opportunities to accept more lower cost variable renewable generation.
- Large scale battery energy storage is not cost effective
- Due to compensation cost of future DER resources and the limited number of existing non-controllable DER systems, there are opportunities for controllable DER resources on Lana'i .

- For the final plans, removing 1 MW load shifting battery energy storage forecasted to be added late in the plan reduces costs.
- Synchronous condensers are needed on the Lana'i system for system security and to assist in reduction of must-run fossil fuel generation.
- Removed the must-run requirement for fossil fuel generation.
- The finding for Lana'i was that Theme 1 was lower cost than Theme 3 in both the February 2016 EIA STEO Fuel Price case and the 2015 EIA Reference Fuel Price case.

Based on these additional findings and observations, the final plans for Theme 1 and Theme 3 were developed for Lana'i.

Final Plans – Down Select 2 – Lana'i		
	Theme 1	Theme 3
NPV RR $ millions February 2016 EIA STEO Fuel	$126	$130
NPV RR $ millions 2015 EIA Reference Fuel	$149	$153
Spread 2015 EIA Reference to February 2016 EIA STEO Fuel	19%	18%
DER Forecast	High	Base
100% RPS / RE	2030	2030
Deactivations		
Variable Renewable Additions	▪ 3 MW Wind 2020 ▪ 1 MW Wind 2030 ▪ 1 MW Wind 2045	▪ 3 MW Wind 2020 ▪ 1 MW Wind 2030 ▪ 1 MW Wind 2040
Firm Renewable Additions	None	None
Thermal Generation Additions	Remove must-run for CAT 1 & 2.	Remove must-run for CAT 1 & 2.
Energy Storage Additions		

Table 3-15. Final Plans from Down Select 2 – Lana'i

Moloka'i Results

Down Select 1 – Moloka'i

The primary purpose of the Down Select 1 was to apply a revenue requirements filter to the various candidate plans to select the lowest cost plans under 2015 EIA Reference and February 2016 EIA STEO fuel scenarios.

Table 3-16 presents the Moloka'i results from the Down Select 1 process after screening on a NPV revenue requirements basis. These plans represented the best plans under February 2016 EIA STEO and 2015 EIA Reference fuel forecasts and were therefore selected for additional analysis.

Candidate Plans – Down Select 1 – Moloka'i		
	Theme 1	Theme 3
NPV RR $ millions February 2016 EIA STEO Fuel	$87	$91
NPV RR $ millions 2015 EIA Reference Fuel	$100	$106
Spread 2015 EIA Reference to February 2016 EIA STEO Fuel	15%	18%
DER Forecast	High	Base
100% RPS / RE	2030	2030
Deactivations		
Variable Renewable Additions	■ 3 MW Wind 2020 ■ 1 MW Wind 2030 ■ 1 MW Wind 2045	■ 4 MW Wind 2020 ■ 1 MW Wind 2040
Firm Renewable Additions	None	None
Thermal Generation Additions	Remove must-run conditions for CAT 1 & 2	
Energy Storage Additions	1 MW Load Shifting BESS 2040	

Table 3-16. Candidate Plans from Down Select 1 – Moloka'i

After Down Select 1, these plans became the basis for further analysis across the three themes.

Findings and Observations for Moloka'i

In the review of the results of the down select process, the following findings were made for Moloka'i:

- Firm renewable generation is limited and at a higher cost than existing generating resources.
- New wind resources are cost effective, including reduction in energy taken due to curtailment.
- Lower cost liquid fuel would be beneficial on Moloka'i .
- Reduction in must-run fossil fuel generation provides opportunities to accept more lower cost variable renewable generation.
- Large scale battery energy storage is not cost effective.
- Due to compensation cost of future DER resources, there are opportunities for controllable DER resources on Moloka'i. However, the opportunities are limited due to the number of existing uncontrollable DER.
- For the final plans, removing 1 MW load shifting battery energy storage forecasted to be added late in the plan reduces costs.

- Synchronous condensers are needed on the Moloka'i system for system security and to assist in reduction of must-run fossil fuel generation.
- Removed the must-run requirement for fossil fuel generation.
- The finding for Lana'i was that Theme 1 was lower cost than Theme 3 in both the February 2016 EIA STEO Fuel Price case and the 2015 EIA Reference Fuel Price case.
- The finding for Moloka'i was that Theme 1 was lower cost than Theme 3 in the February 2016 EIA STEO Fuel Price case but Theme 3 was lower cost than Theme 1 in the 2015 EIA Reference Fuel Price case.
- Theme 1 offers the best economics for Moloka'i when viewed over the entire study period.

Based on these additional findings and observations, the final plans for Theme 1 and Theme 3 were developed for Moloka'i.

Final Plans – Down Select 2 – Moloka'i		
	Theme 1	Theme 3
NPV RR $ millions February 2016 EIA STEO Fuel	$107	$103
NPV RR $ millions 2015 EIA Reference Fuel	$125	$121
Spread 2015 EIA Reference to February 2016 EIA STEO Fuel	17%	18%
DER Forecast	High	Base
100% RPS / RE	2030	2030
Deactivations		
Variable Renewable Additions	■ 5 MW Wind 2020 ■	■ 5 MW Wind 2020 ■ 1 MW Wind 2045
Firm Renewable Additions	None	None
Thermal Generation Additions	Remove must-run conditions for CAT 1 & 2	Remove must-run conditions for CAT 1 & 2
Energy Storage Additions		

Table 3-17. Final Plans from Down Select 2 – Moloka'i

4. Financial Impacts

This chapter provides the financial analyses of the Final Plan for each Theme. It presents the total revenue requirement over the period for each Company and the residential customer electricity rate and bill impacts for each of the three Themes. Results are presented under both fuel forecasts and in both real (2016) and nominal dollars[15]. For each of the customer rate and bill impact analyses, a comparison with the analogous results from the 2014 PSIP is also provided.

These analyses should not be used as precise long-term projections of customer rates. The value of these projections is not in the precise values but in the relative results of the planning Themes and scenarios to inform a preferred plan. Actual values could vary significantly with changes in assumptions including resource costs, new renewable technologies, fuel prices, energy efficiency, etc.

O'AHU FINANCIAL IMPACTS

For O'ahu, Theme 2 (100% Renewable Energy with LNG) results in the lowest net present value of annual revenue requirements[16] over the 2017 to 2045 planning period, under both fuel price forecasts.

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[15] Throughout this Chapter, results presented in nominal dollars have been escalated by a 1.8% inflation rate.

[16] Net Present Value of annual revenue requirements is the present value, in 2016 $, of the 29 year stream of annual revenue requirements from 2017 through 2045.

Revenue Requirement Analysis

Total utility company revenue requirements, under both fuel forecasts, have been calculated for the Final Plan for each Theme. Table 4-1 shows the Net Present Value of the annual revenue requirements for each Theme and Figure 4-1 through Figure 4-4 compare each Theme's annual revenue requirement under the 2015 EIA Reference and February 2016 EIA STEO fuel forecasts respectively, in real (2016 $) and nominal dollars.

Net Present Value of Revenue Requirement ($000)	2015 EIA Reference	February 2016 EIA STEO
NPV of Theme 1 Revenue Requirement	$28,481,004	$24,601,630
NPV of Theme 2 Revenue Requirement	$25,826,376	$23,325,106
NPV of Theme 3 Revenue Requirement	$29,044,299	$24,357,219

Table 4-1. Net Present Value of Revenue Requirement

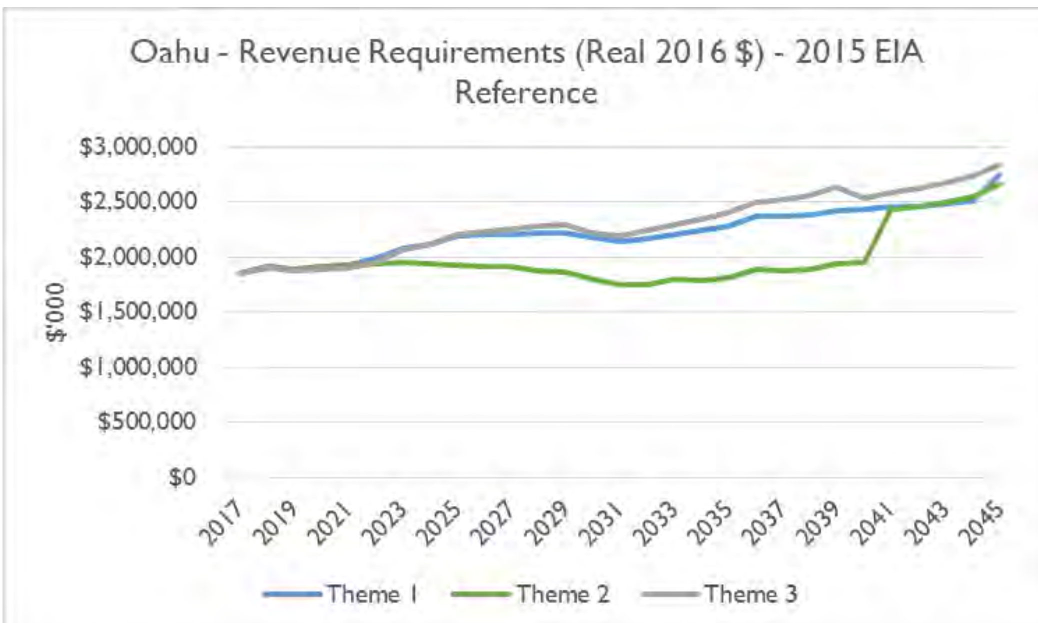


Figure 4-1. Comparison of Revenue Requirement (Real 2016 $) – 2015 EIA Reference

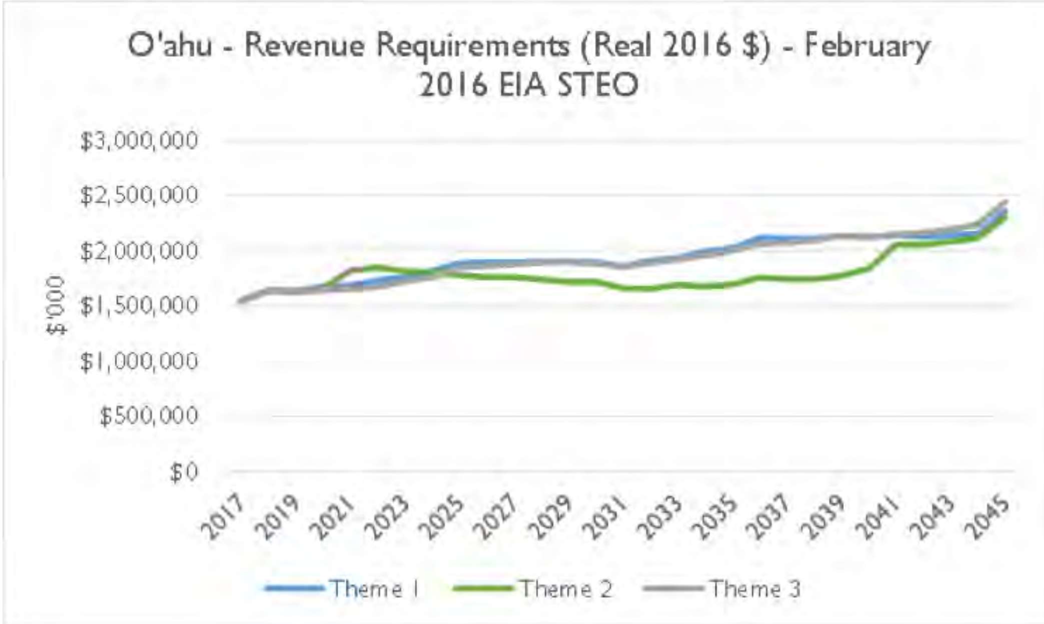


Figure 4-2. Comparison of Revenue Requirement (Real 2016 $) – February 2016 EIA STEO

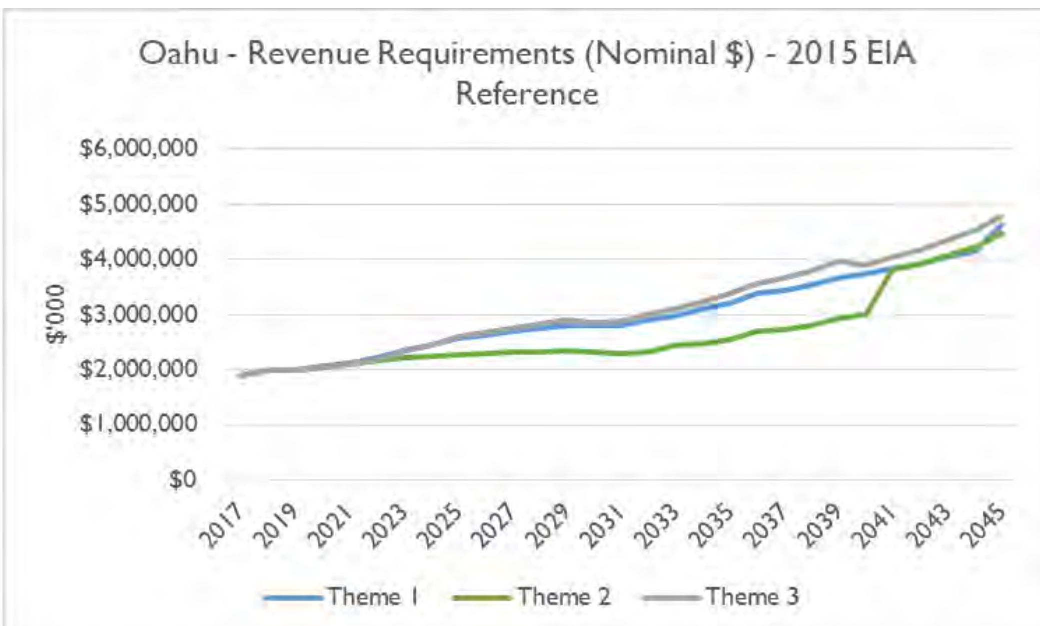


Figure 4-3. Comparison of Revenue Requirement (Nominal $) – 2015 EIA Reference

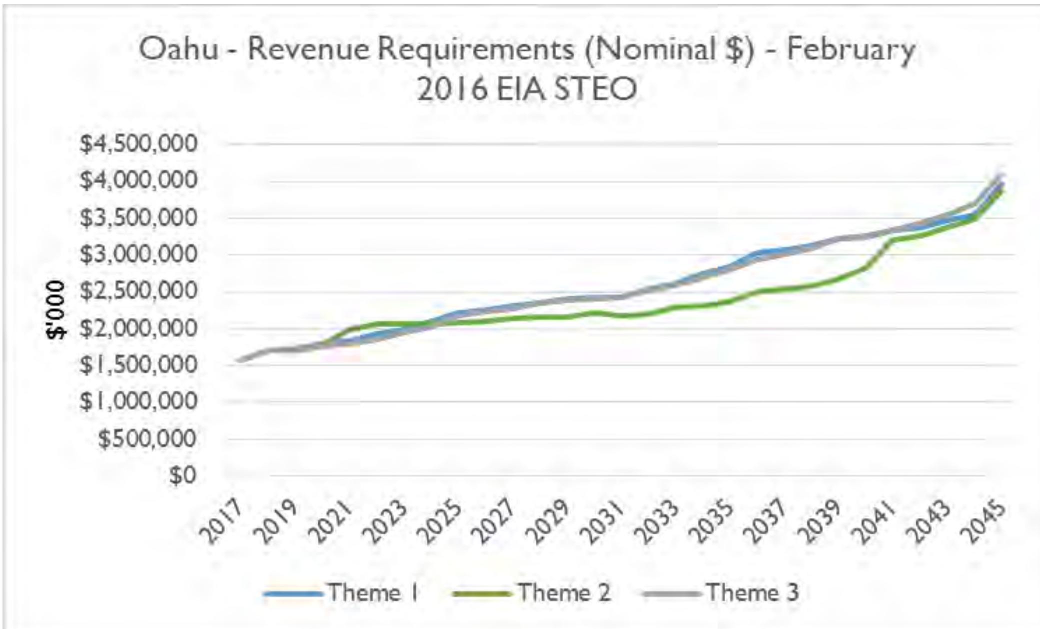


Figure 4-4. Comparison of Revenue Requirement (Nominal $) – February 2016 EIA STEO

Customer Rate Impact Analysis

Customer rates are generally a function of the revenue requirement allocated across projected kWh sales. Thus, declining kWh sales will increase rates and increasing kWh sales will decrease rates. Over the planning period, kWh sales are generally projected to decline consistent with our state's energy efficiency goals and the assumed load reduction from distributed generation. As a result of an increasing revenue requirement in combination with declining sales, residential customer rates, in real 2016 $, consistently rise over the planning period for Themes 1 and 3 under both fuel price forecasts. For Theme 2, customer rates hold relatively steady through 2040 under both fuel price forecasts.

Compared to the 2014 PSIP results, Theme 2 customer rates in real terms are projected to be consistently lower for either fuel price forecast. Themes 1 and 3 are projected to be lower than 2014 PSIP results for the February 2016 EIA STEO fuel price forecast, while under the 2015 EIA Reference fuel price forecast customer rates would be somewhat higher than the 2014 projections from the mid-2020s through 2030.

Customer rates in nominal terms show consistent increases as inflation, even at the historically low levels used in this analysis, dramatically impacts the value of a dollar over the almost 30 year planning period.

The residential customer rate for the three Themes, under the 2015 EIA Reference fuel price forecast, is presented in real 2016 $ in Figure 4-5 and and in nominal $ in Figure 4-6. 2014 PSIP results are also shown for comparison purposes.

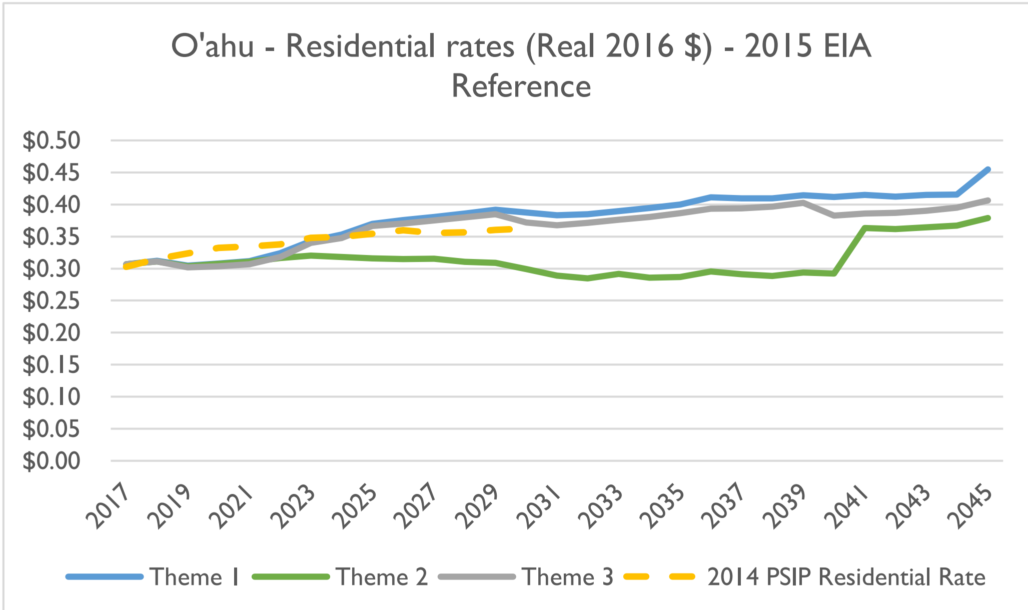


Figure 4-5. Residential Rates (Real 2016 $): 2015 EIA Reference

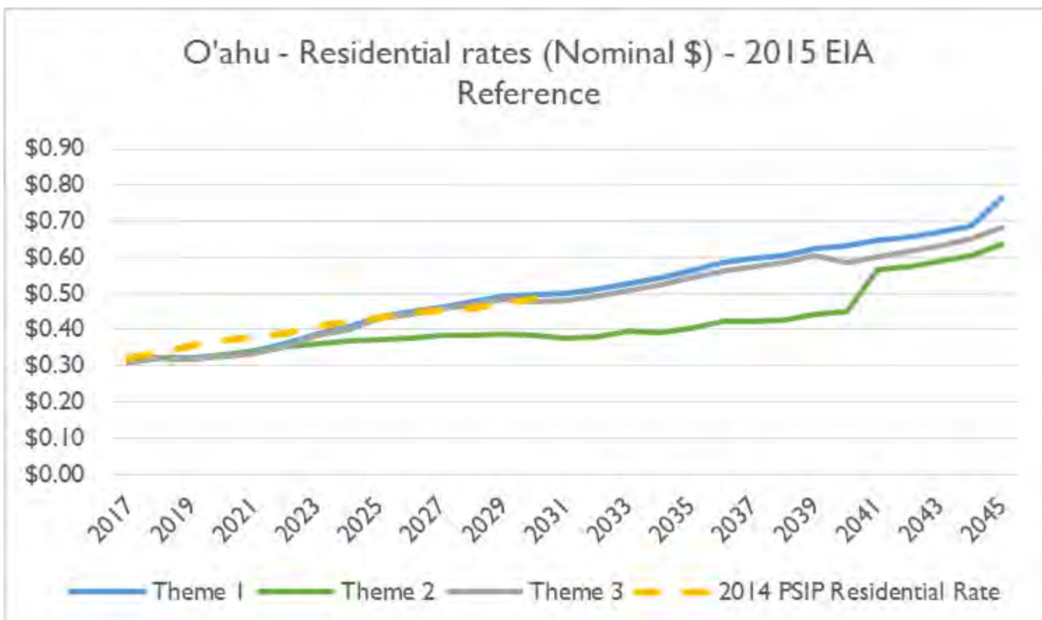


Figure 4-6. Residential Rates (Nominal $): 2015 EIA Reference

The residential customer rate for the three Themes, under the February 2016 EIA STEO fuel price forecast, is presented in real 2016 $ in Figure 4-7 and in nominal $ in Figure 4-8. 2014 PSIP results are also shown for comparison purposes.

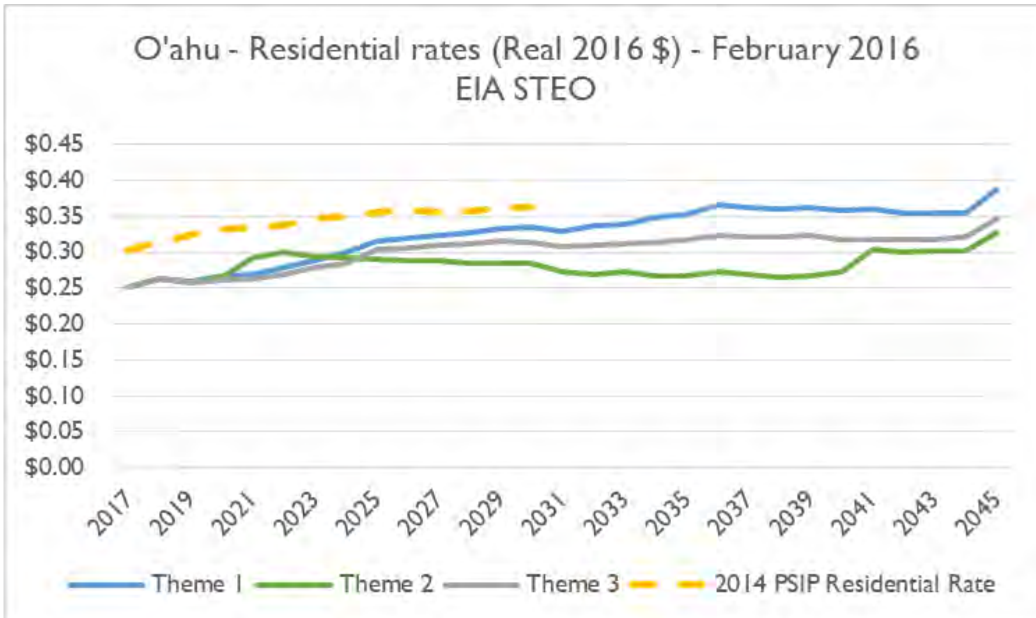


Figure 4-7. Residential Rates (Real 2016 $): February 2016 EIA STEO

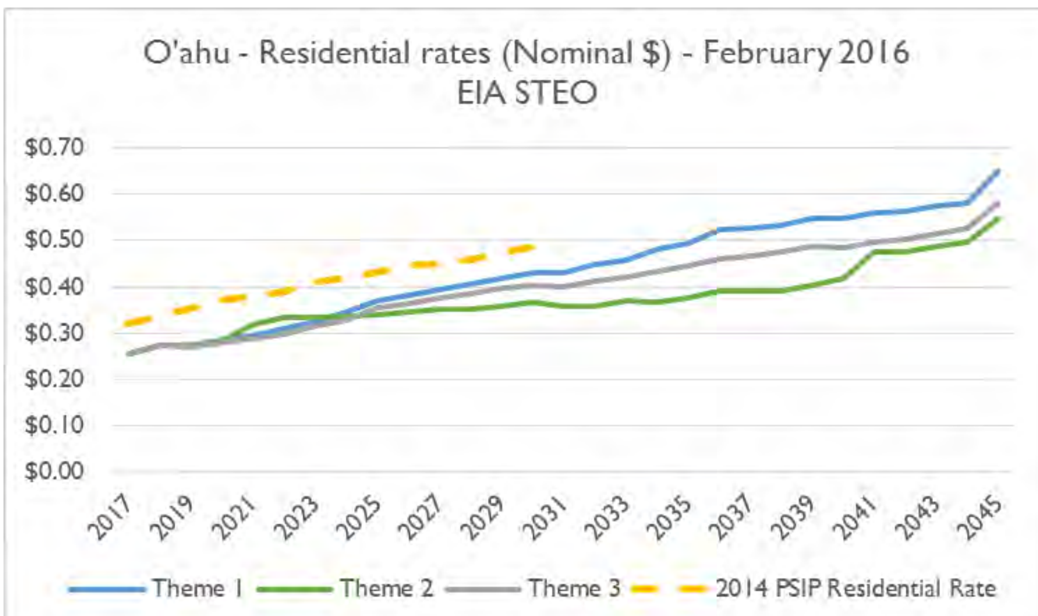


Figure 4-8. Residential Rates (Nominal $): February 2016 EIA STEO

Residential Customer Bill Impact Analysis

The overall impact on a customer's bill is the combination of usage and rates. Over the planning period, usage per customer is expected to decline, consistent with the Energy Efficiency Portfolio Standard goals.[17] The residential customer bill analyses below present each Theme's projected residential bill impact for the average non-DG-PV customer.

The residential customer bill impact for the three Themes, under the 2015 EIA Reference fuel price forecast, is presented in real 2016 $ in Figure 4-9 and in nominal $ in Figure 4-10. 2014 PSIP results are also shown for comparison purposes. The increase seen in Theme 2 between the years of 2041 and 2045 is attributed to transition from LNG to future alternative resources.

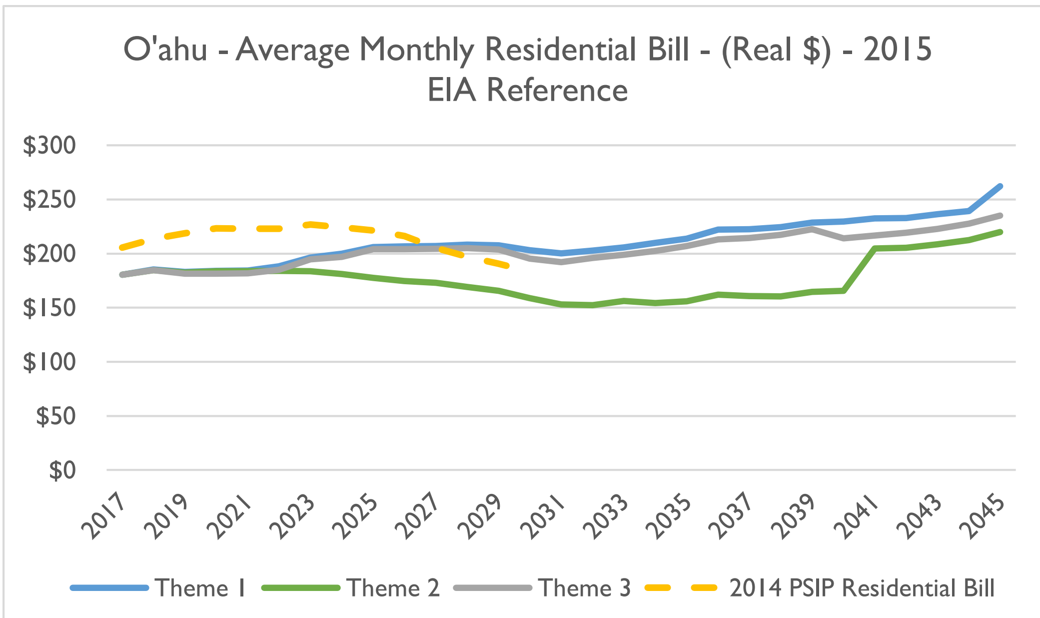


Figure 4-9. Residential Bill (Real 2016 $): 2015 EIA Reference

[17] Please see Appendix I for further discussion of the impact of the Energy Efficiency Portfolio Standard on customer rate and bill impact analyses.

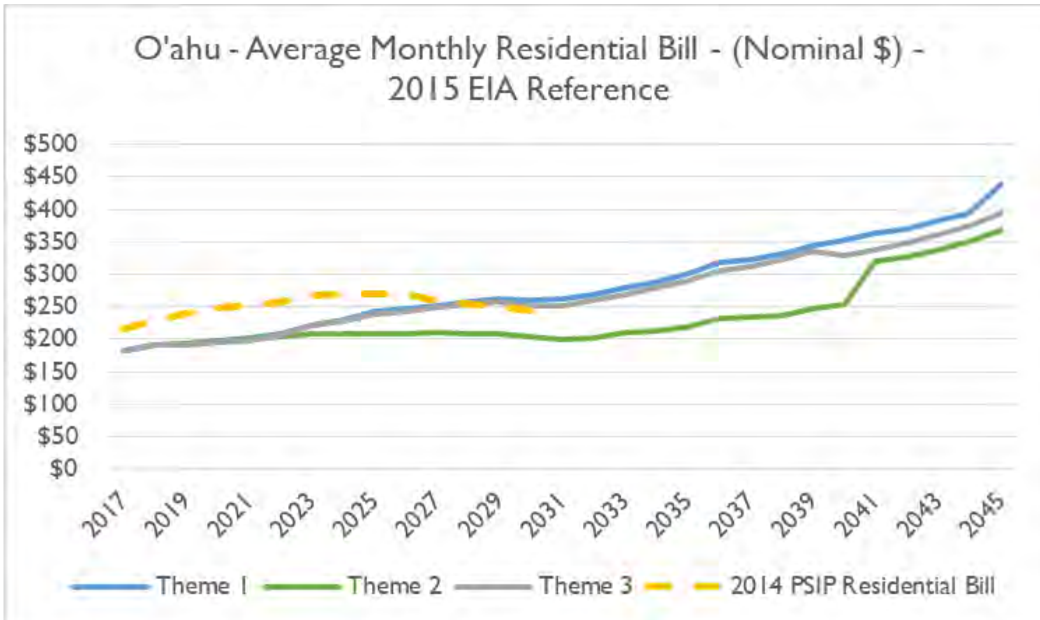


Figure 4-10. Residential Bill (Nominal $): 2015 EIA Reference

The residential customer bill impact for the three Themes, under the February 2016 EIA STEO fuel price forecast, is presented in real 2016 $ in Figure 4-11 and in nominal $ in Figure 4-12 below. 2014 PSIP results are also shown for comparison purposes.

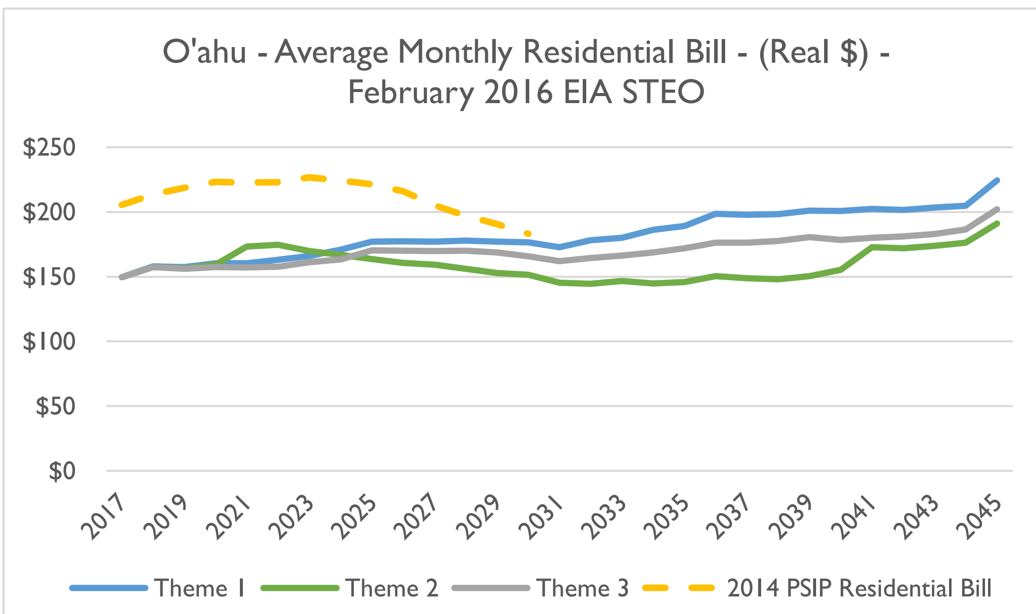


Figure 4-11. Residential Bill (Real 2016 $): February 2016 EIA STEO

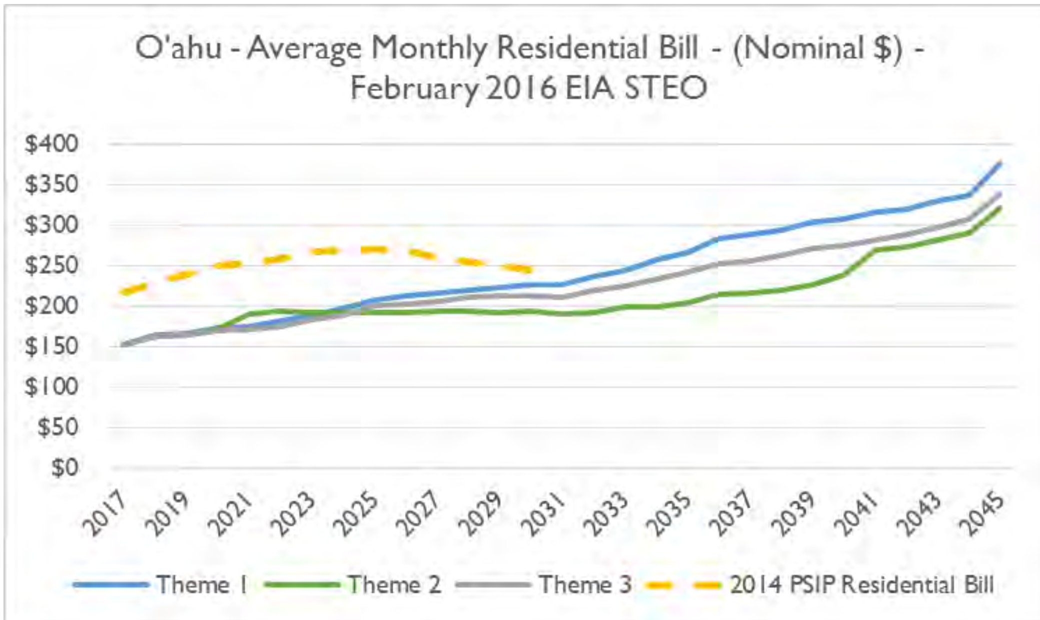


Figure 4-12. Residential Bill (Nominal $): February 2016 EIA STEO

Capital Expenditure Projections

The revenue requirement projections for each Theme include capital expenditure projections for power supply, smart grid, ERP, and all other utility capital expenditures (referred to as "balance-of-utility business capital expenditures"). The Power Supply capital expenditures range from $1.8B ($1.0B in the first 9 years) for Theme 3 to $2.4B ($1.8B in the first 9 years) for Theme 2, consistent with the mix and timing of resource additions and retirements.

Smart Grid and ERP are treated separately, as these proposed capital projects have different costs under a merged and an unmerged future. As Theme 2 is only possible in a merged future, the analysis uses the merged capital costs for both of these projects for Theme 2 capital expenditures. While Themes 1 and 3 can occur in either a merged or an unmerged future, in order to clearly focus on the differences in revenue requirements and bills caused solely by differences in Power Supply costs we need to use a uniform value for these costs in each Theme. For this reason, in this analysis we have used the capital expenditures for these projects that would be appropriate if the Next Era merger is consummated.

As described in detail in Appendix I, the balance-of-utility business capital expenditures have been calculated using a top down manner for the 2015 EIA Reference fuel price scenario and have been consistently applied across all three Themes for both fuel cases. The tables below summarize the capital expenditures by category for each Theme.

Theme 1

Under the Theme 1 resource plan, $2.1B (nominal) of capital will be invested by the utility in Power Supply assets over the 29 year planning period, with $1.2B (nominal) of this investment occurring in the first 9 years of the period.

Theme 1 ('000)	2017-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	Total
Power Supply	$421,744	$746,744	$313,854	$455,006	$90,381	$87,688	$2,115,417
Smart Grid	$171,507	$24,277	$23,374	$25,081	$2,663	$0	$246,904
ERP	$36,993	$0	$0	$0	$0	$0	$36,993
Balance-of-utility business	$655,000	$1,055,314	$1,153,773	$1,261,419	$1,379,108	$1,507,777	$7,012,390
Total	1,285,244	$1,826,334	$1,491,001	$1,741,508	$1,472,152	$1,595,465	$9,411,705

Table 4-2. Theme 1 Capital Expenditures (Nominal $)

Theme 2

Under the Theme 2 resource plan, $2.4B (nominal) of capital will be invested by the utility in Power Supply assets over the 29 year planning period, with $1.8B (nominal) of this investment occurring in the first 9 years of the period.

Theme 2 ('000)	2017-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	Total
Power Supply	$1,511,957	$288,327	$96,185	$245,008	$206,296	$96,754	$2,444,527
Smart Grid	$171,507	$24,277	$23,374	$25,081	$2,663	$0	$246,904
ERP	$36,993	$0	$0	$0	$0	$0	$36.993
Balance-of-utility business	$655,000	$1,055,314	$1,153,773	$1,261,419	$1,379,108	$1,507,777	$7,012,390
Total	$2,375,457	$1,367,918	$1,273,332	$1,531,510	$1,588,067	$1,604,531	$9,740,814

Table 4-3. Theme 2 Capital Expenditures (Nominal $)

Theme 3

Under the Theme 3 resource plan, $1.8B (nominal) of capital will be invested by the utility in Power Supply assets over the 29 year planning period, with $1.0B (nominal) of this investment occurring in the first 9 years of the period.

Theme 3 - ('000)	2017-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	Total
Power Supply	$378,874	$655,004	$255,271	$408,219	$36,137	$35,250	$1,768,756
Smart Grid	$171,507	$24,277	$23,374	$25,081	$2,663	$0	$246,904
ERP	$36,993	$0	$0	$0	$0	$0	$36.993
Balance-of-utility business	$655,000	$1,055,314	$1,153,773	$1,261,419	$1,379,108	$1,507,777	$7,012,390
Total	$1,242,374	$1,734,595	$1,432,419	$1,694,721	$1,417,909	$1,543,027	$9,065,043

Table 4-4. Theme 3 Capital Expenditures (Nominal $)

Risk Analysis

Planning to achieve an affordable and resilient electricity supply that meets Hawaii's clean energy policy goals is a complex and challenging effort for all stakeholders. There are important future uncertainties to consider, including fuel prices and technology developments, and the investment decisions made today by customers, third parties, the State, and Hawaiian Electric will impact customers for decades to come. These uncertainties impact the risks facing our customers and Hawaiian Electric, including:

- Electricity price risk, in terms of absolute level
- Electricity price risk, in terms of volatility
- "Buyer's Remorse" risk for capital investments made in long term assets
- Ability to afford the investments necessary to ensure the reliability and security of the electricity grid

These risks are somewhat different under each of the three Themes. Table 4-5 provides a qualitative assessment of each of these risks under each of the Themes. An up arrow indicates a better, less risky result, relative to the other Themes.

Risk	Theme 1	Theme 2	Theme 3
Price level	↓	↑	↓
Price volatility	↑	↑	↓
Capital investment	↔	↓	↑
Grid reliability & security	↓	↑	↓

Table 4-5. Risk Assessment

TOTAL SOCIETAL COSTS FOR ENERGY: HAWAIIAN ELECTRIC

As Hawai'i selects the best path to achieve its renewable energy future, the total societal cost of electricity is an important consideration. For this analysis, the total societal cost of electricity is the sum of the costs for independent generation, investments in distributed generation and storage, federal and state tax incentives, fuel, and all other utility operating costs. The chart below provides, by Theme, the Net Present Value of this cost stream over the period 2017 through 2045.

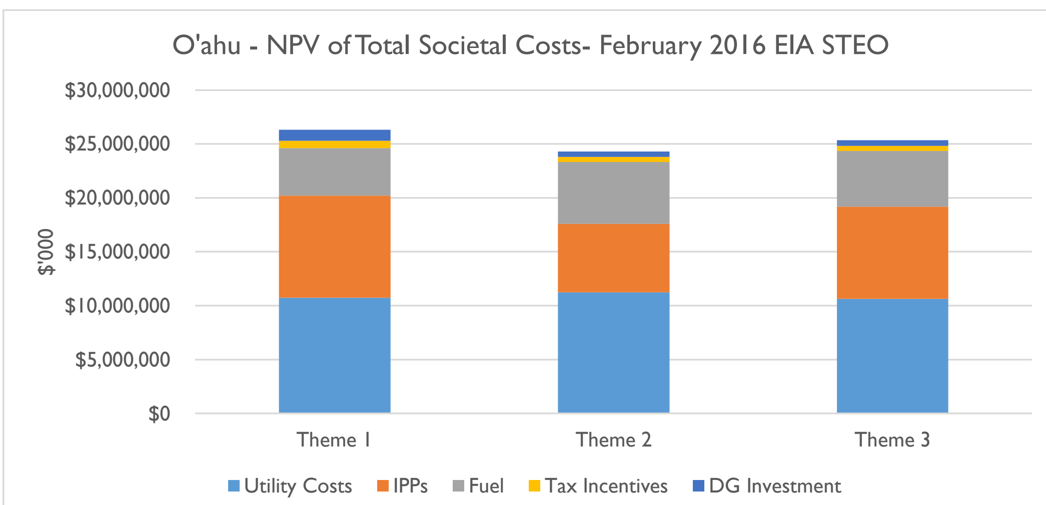


Figure 4-13. Total Societal Costs of the Plans 2017 through 2045

TOTAL SOCIETAL INVESTMENT: HAWAIIAN ELECTRIC

Significant investments by home and business owners across the State, project developers and independent power producers, Federal and State government, and the Company are all required to achieve Hawaii's goal of 100% renewable energy. The capital expenditures required to achieve Hawaii's energy policy goals on Oahu range from $16.4B in Theme 3 to $18B in Theme 1. Hawaiian Electric Company investments represent only a fraction of that total, ranging from $8.9B to $9.7B across the Themes. Table 4-6 through Table 4-8 provide the Company's projections of this total investment, by stakeholder, for each Theme.

Investor	2017 -20	2021-25	2026-30	2031-35	2036-40	2041-45	Total
Distributed Generation & Storage Owners	$302,900	$407,400	$564,600	$551,200	$544,500	$537,900	$2,908,500
Utility Scale Renewable Generation	$697,738	$831,155	$884,820	$1,793,562	$922,853	$0	$5,130,128
Federal Tax Incentives	$468,791	$230,432	$56,068	$54,595	$53,564	$52,114	$915,564
Hawaii Tax Incentives	$131,723	$21,360	$500	$1,000	$500	$0	$155,083
Hawaiian Electric	$1,582,453	$1,396,284	$1,582,385	$1,676,665	$1,342,615	$1,337,688	$8,918,090
Theme 1 Total	**$3,183,605**	**$2,886,631**	**$3,088,373**	**$4,077,022**	**$2,864,032**	**$1,927,702**	**$18,027,365**

Table 4-6. Total Societal Energy Investment – Theme 1

Investor	2017 -20	2021-25	2026-30	2031-35	2036-40	2041-45	Total
Distributed Generation & Storage Owners	$302,900	$161,200	$154,300	$149,600	$150,000	$158,600	$1,076,600
Utility Scale Renewable Generation	$451,725	$0	$1,092,238	$0	$1,361,910	$2,607,669	$5,513,542
Federal Tax Incentives	$468,791	$24,441	$33,533	$9,968	$54,620	$76,425	$667,778
Hawaii Tax Incentives	$131,723	$10,860	$3,000	$0	$5,500	$8,000	$159,083
Hawaiian Electric	$2,375,457	$1,367,918	$1,273,332	$1,531,510	$1,588,067	$1,604,531	$9,740,815
Theme 2 Total	**$3,730,596**	**$1,564,419**	**$2,556,403**	**$1,691,078**	**$3,160,097**	**$4,455,225**	**$17,157,818**

Table 4-7. Total Societal Energy Investment – Theme 2

4. Financial Impacts

Total Societal Investment: Hawaiian Electric

Investor	2017 -20	2021-25	2026-30	2031-35	2036-40	2041-45	Total
Distributed Generation & Storage Owners	$309,200	$163,400	$154,300	$149,600	$150,000	$158,600	$1,085,100
Utility Scale Renewable Generation	$451,725	$0	$1,092,238	$0	$1,361,910	$2,607,669	$5,513,542
Federal Tax Incentives	$363,357	$24,441	$33,533	$9,968	$54,620	$76,425	$562,344
Hawaii Tax Incentives	$128,223	$10,860	$2,500	$500	$5,500	$8,000	$155,583
Hawaiian Electric	$1,242,374	$1,734,595	$1,432,419	$1,694,721	$1,417,909	$1,543,027	$9,065,045
Theme 3 Total	**$2,494,879**	**$1,933,296**	**$2,714,990**	**$1,854,789**	**$2,989,939**	**$4,393,721**	**$16,381,614**

Table 4-8. Total Societal Energy Investment – Theme 3

The above investment totals do not include energy efficiency investments made by customers or demand response investments made by DR providers or customers.

MAUI FINANCIAL IMPACTS

The data and analyses presented in this section cover all of Maui Electric's service territory and customers, unless clearly noted. Moloka'i and Lana'i are included in the Maui results, and there is a section below that addresses each of those islands individually.

For Maui, Themes 2 and 3 have virtually the same net present value of revenue requirements over the 2017 to 2045 planning period, under both fuel price forecasts. Theme 1 is clearly a higher cost solution, as compared either Theme 2 or Theme 3, for Maui. The Lana'i and Moloka'i results included in these county-wide analyses are for Theme 1 only.

Revenue Requirement Analysis

Total Maui Electric revenue requirements, under both fuel forecasts, have been calculated for the Final Plan for each Theme. Table 4-9 shows the Net Present Value of the annual revenue requirements for each Theme and Figure 4-14 through Figure 4-17 compare each Theme's annual revenue requirement under the 2015 EIA Reference and February 2016 EIA STEO fuel forecasts respectively, in both real (2016$) and nominal dollars.

Net Present Value of Revenue Requirement ($000)	2015 EIA Reference	February 2016 EIA STEO
NPV of Theme 1 Revenue Requirement	$6,156,969	$5,551,132
NPV of Theme 2 Revenue Requirement	$5,413,969	$4,978,143
NPV of Theme 3 Revenue Requirement	$5,435,341	$4,840,345

Table 4-9. Net Present Value of Revenue Requirement

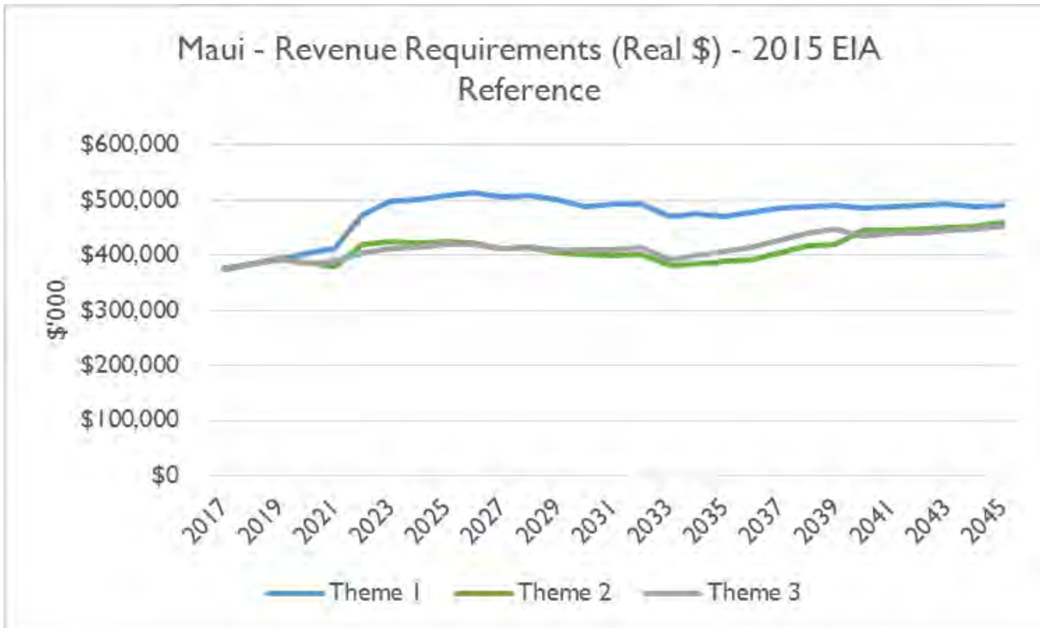


Figure 4-14. Comparison of Revenue Requirement (Real 2016 $) – 2015 EIA Reference

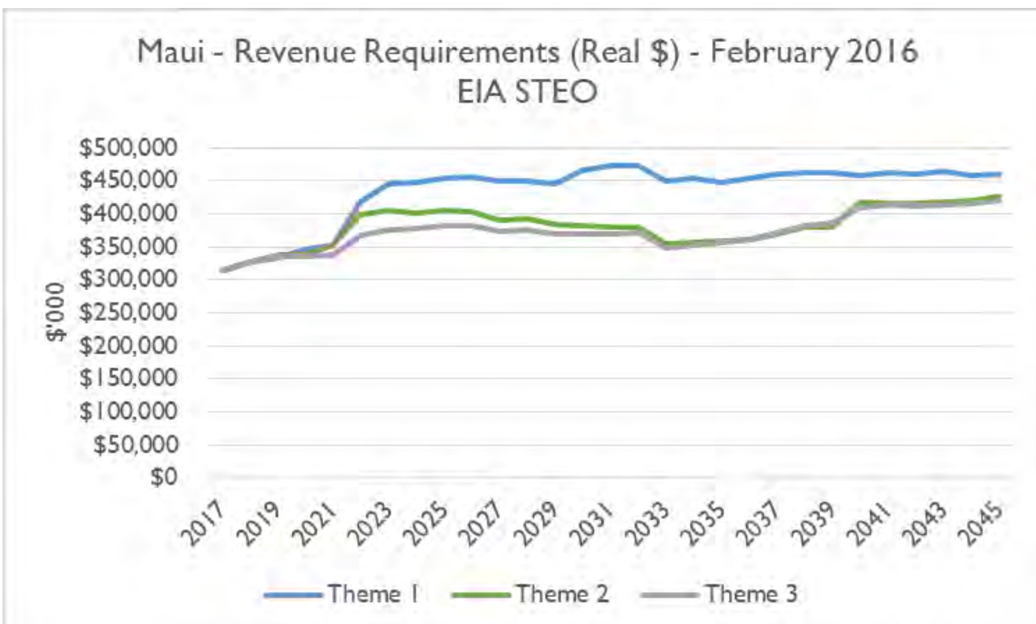


Figure 4-15. Comparison of Revenue Requirement (Real 2016 $)– February 2016 EIA STEO

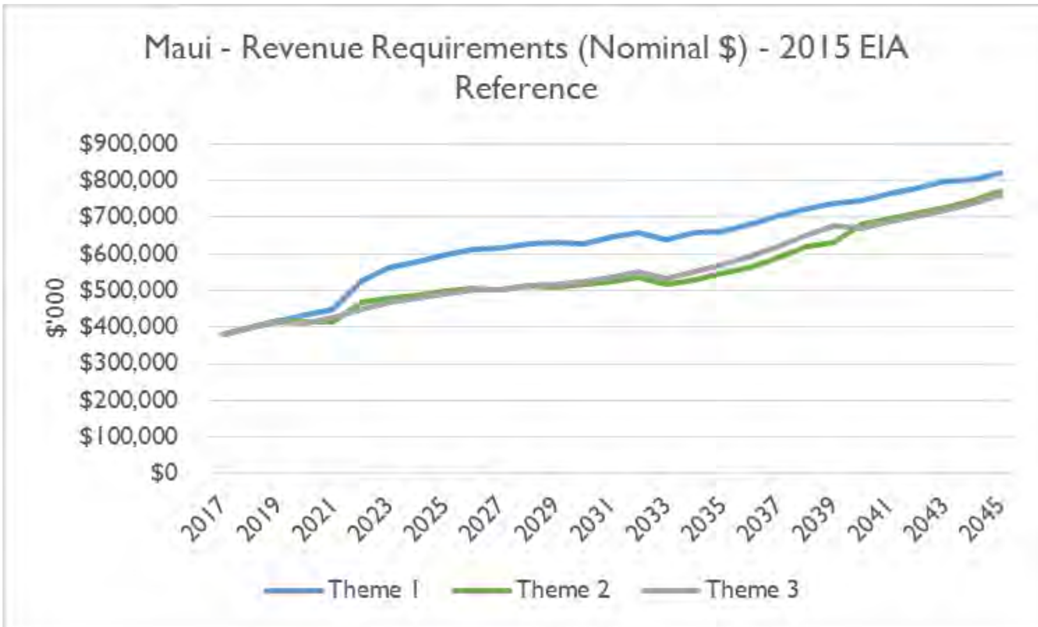


Figure 4-16. Comparison of Revenue Requirement (Nominal $) – 2015 EIA Reference

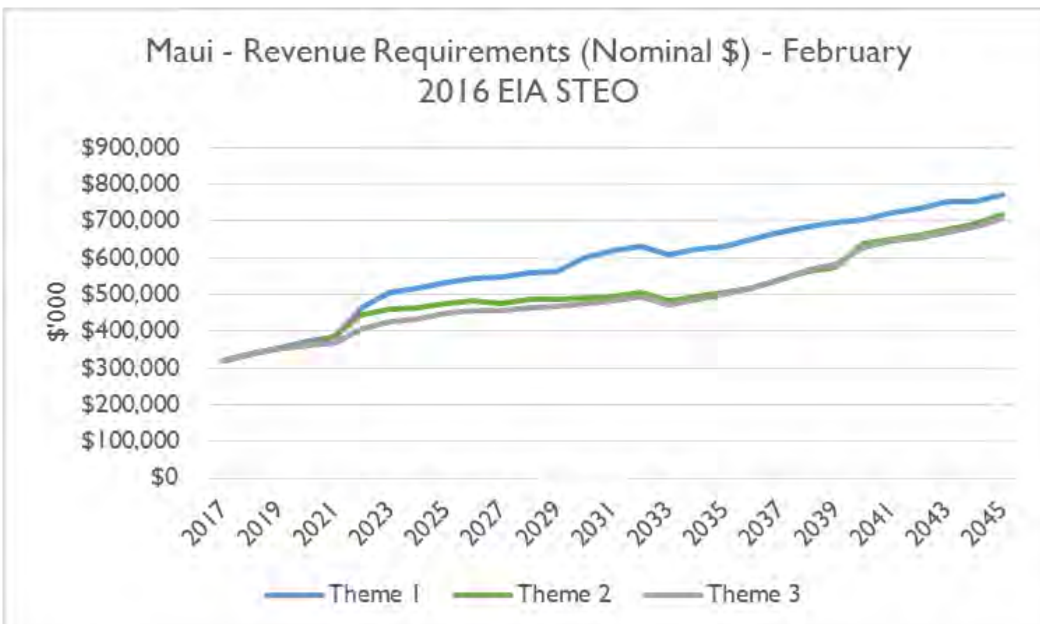


Figure 4-17. Comparison of Revenue Requirement (Nominal $) – February 2016 EIA STEO

Customer Rate Impact Analysis

Residential customer rates, in real 2016 $, fall over the planning period for Themes 2 and 3 under the 2015 EIA Reference fuel price forecast and stay roughly flat under the February 2016 EIA STEO fuel price forecast. In contrast, customer rates in real 2016 $, increase for Theme 1, under both the 2015 EIA Reference and February 2016 EIA STEO price fuel forecasts.

Compared to the 2014 PSIP results, customer rates in real terms are projected to be consistently lower under Themes 2 and 3, under either fuel price forecast. Theme 1 results in rates higher than the 2014 PSIP results, in real terms.

Customer rates in nominal terms show consistent increases as inflation, even at the historically low levels used in this analysis, dramatically impacts the value of a dollar over the almost 30 year planning period.

The residential customer rate for the three Themes, under the 2015 EIA Reference fuel price forecast, is presented in real 2016 $ in Figure 4-18 and in nominal $ in Figure 4-19. 2014 PSIP results are also shown for comparison purposes.

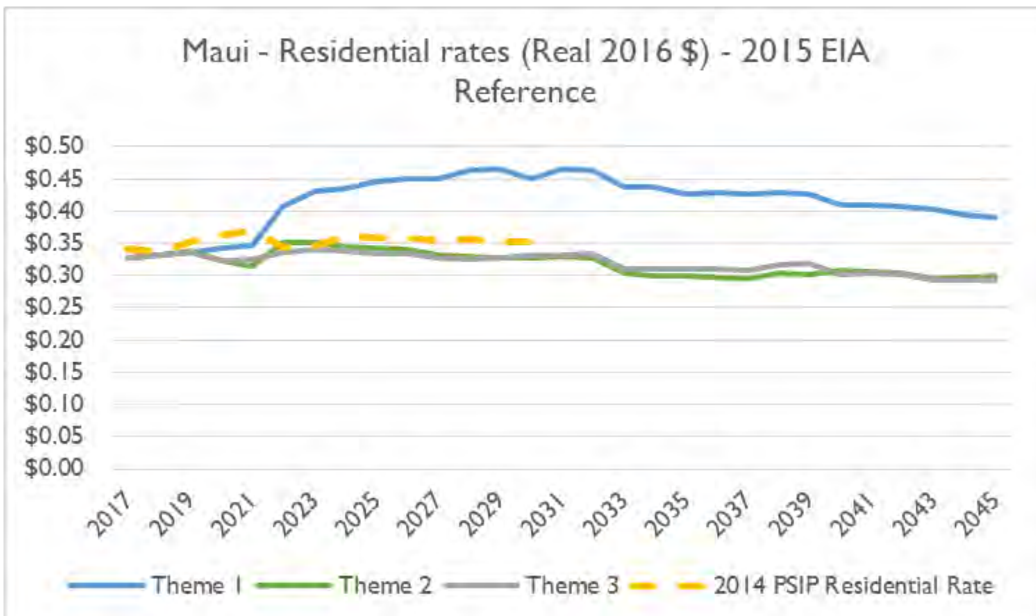


Figure 4-18. Residential Rates (Real 2016 $): 2015 EIA Reference

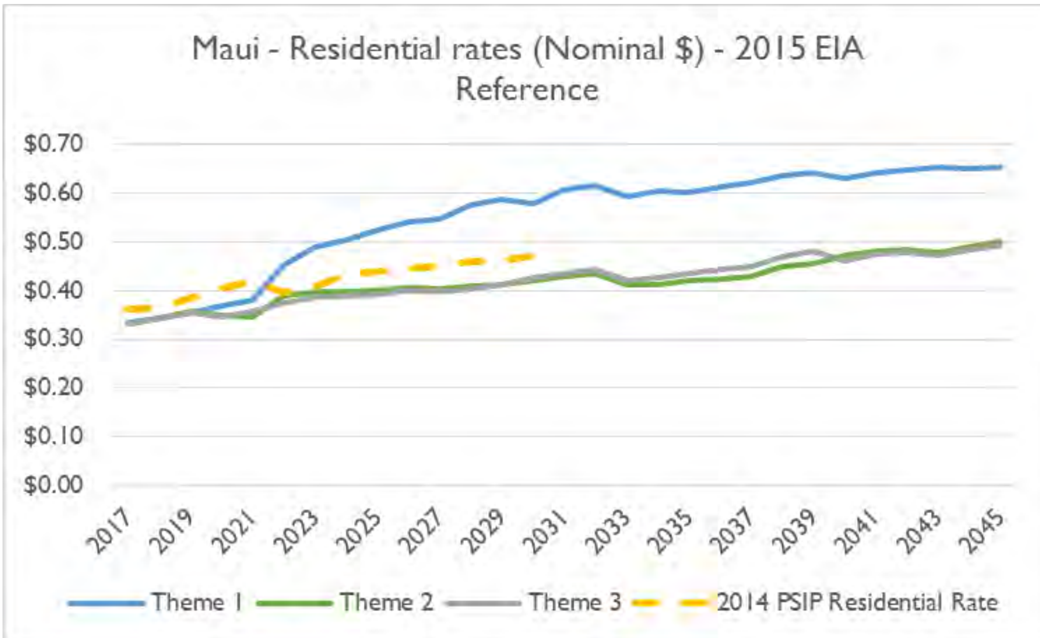


Figure 4-19. Residential Rates (Nominal $): 2015 EIA Reference

The residential customer rate for the three Themes, under the February 2016 EIA STEO fuel price forecast, is presented in real 2016 $ in Figure 4-20 and in nominal $ in Figure 4-21 below. 2014 PSIP results are also shown for comparison purposes.

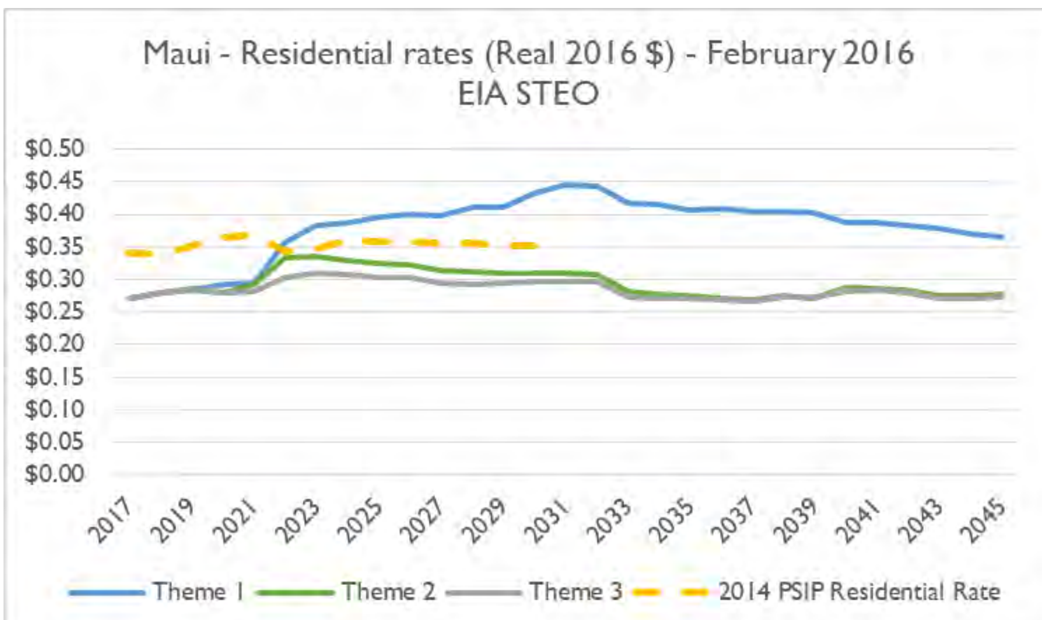


Figure 4-20. Residential Rates (Real 2016 $): February 2016 EIA STEO

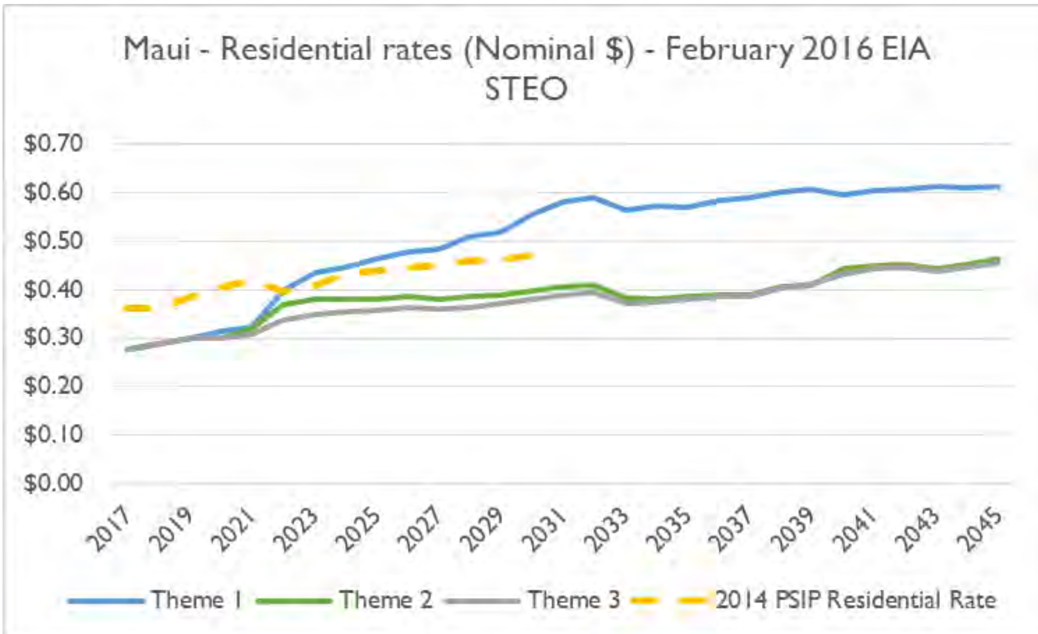


Figure 4-21. Customer Rates (Nominal $): February 2016 EIA STEO

Residential Customer Bill Impact Analysis

The overall impact on a customer's bill is the combination of usage and rates. Over the planning period, usage per customer is expected to decline, consistent with the Energy Efficiency Portfolio Standard goals. The residential customer bill analyses below present each Theme's projected residential bill impact for the average non-DG-PV customer.

The residential customer bill impact for the three Themes, under the 2015 EIA Reference fuel price forecast, is presented in real 2016 $ in Figure 4-22 and in nominal $ in Figure 4-23. 2014 PSIP results are shown for comparison purposes.

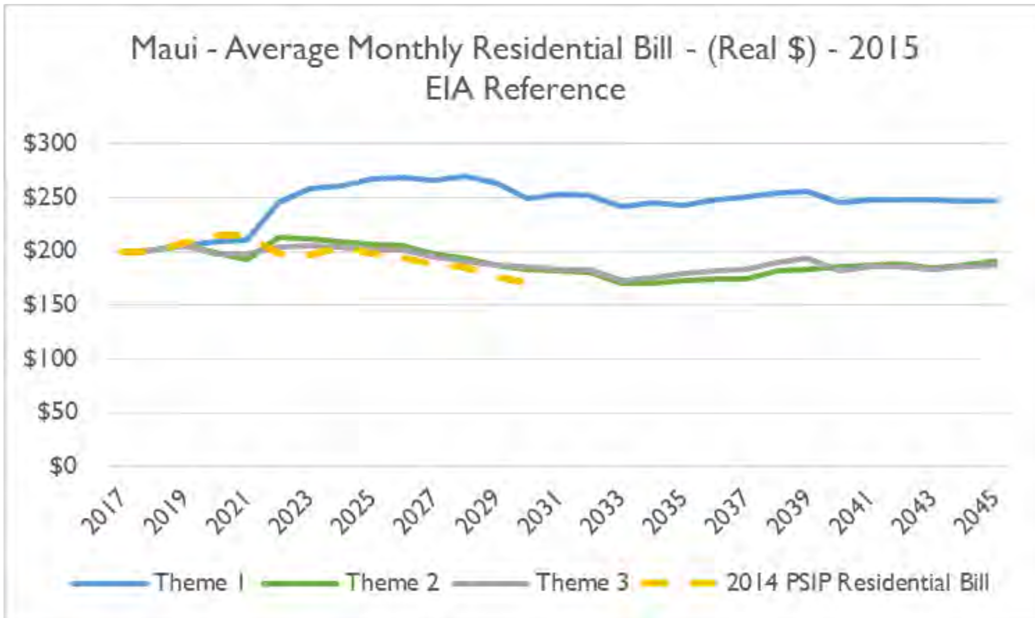


Figure 4-22. Residential Bill (Real 2016 $): 2015 EIA Reference

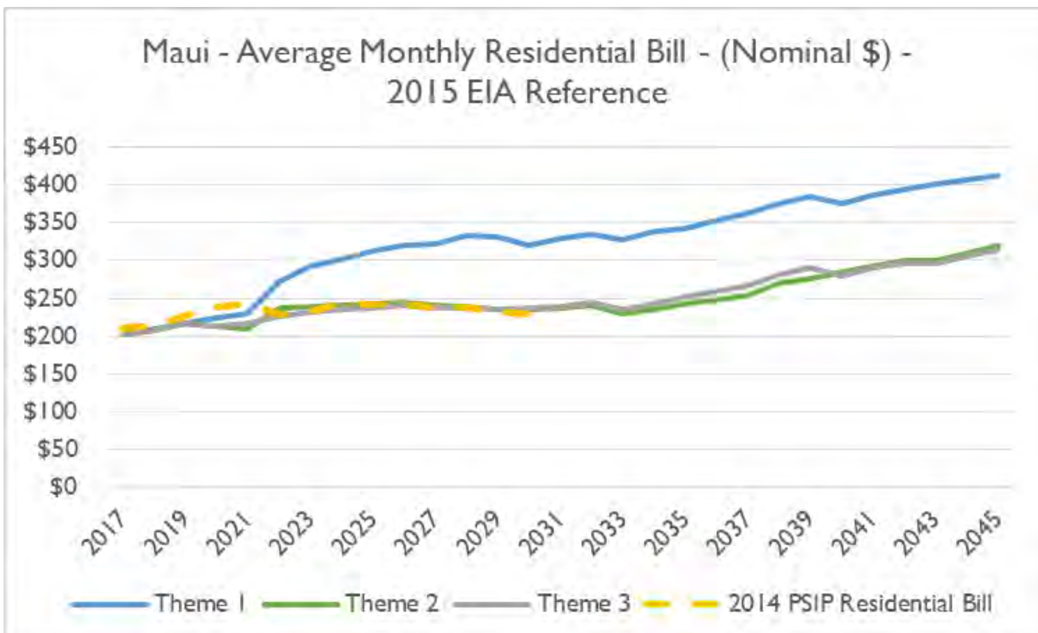


Figure 4-23. Residential Bill (Nominal $): 2015 EIA Reference

The residential customer bill impact for the three Themes, under the February 2016 EIA STEO fuel price forecast, is presented in real 2016 $ in Figure 4-24 and in nominal $ in Figure 4-25. 2014 PSIP results are shown for comparison purposes.

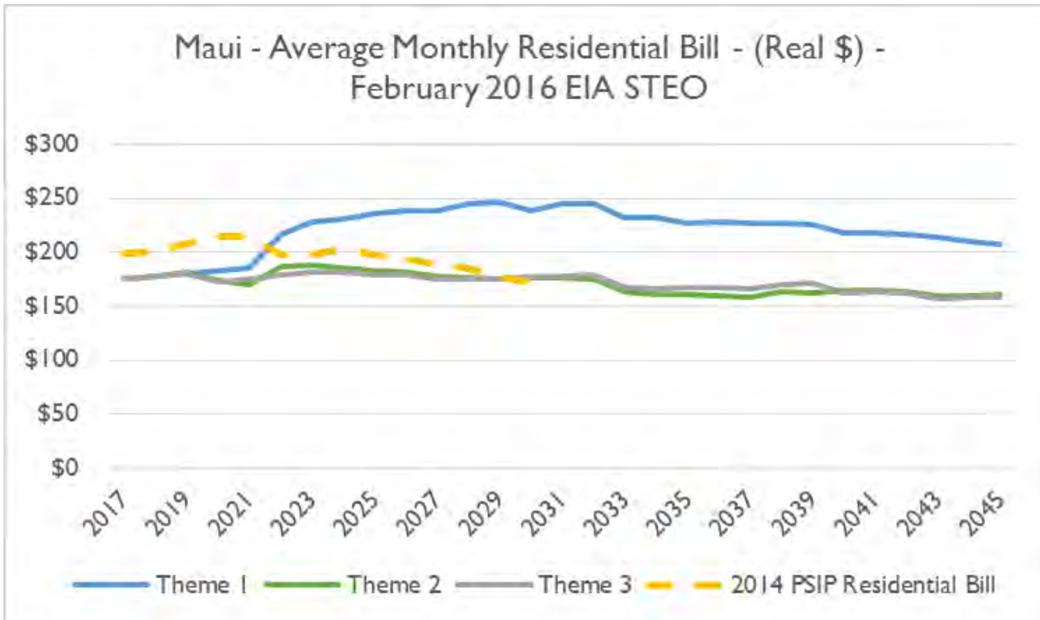


Figure 4-24. Residential Bill (Real 2016 $): February 2016 EIA STEO

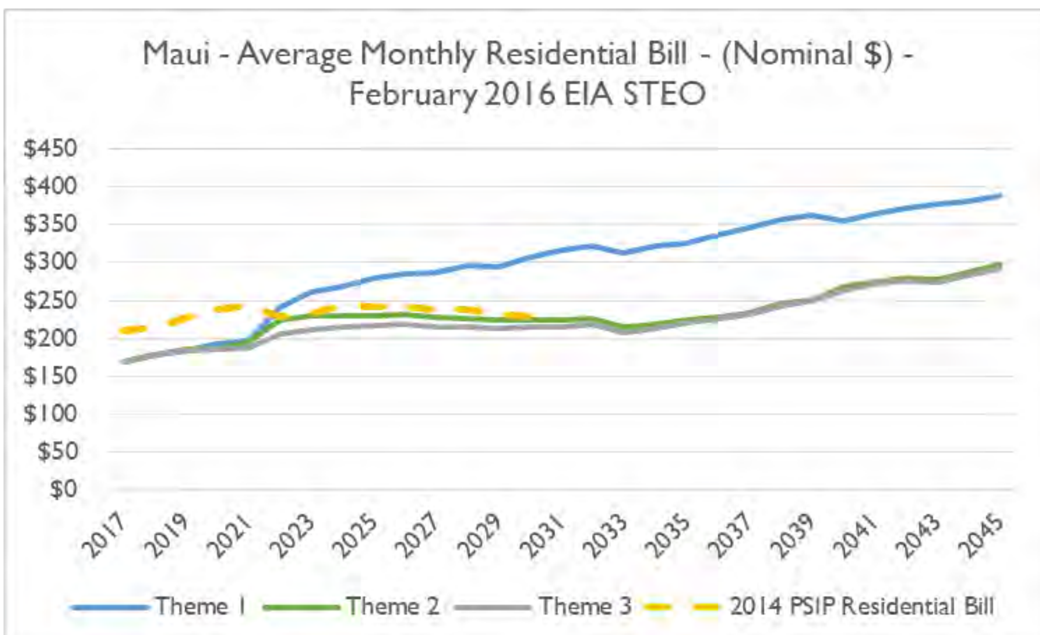


Figure 4-25. Residential Bill (Nominal $): February 2016 EIA STEO

Moloka'i and Lana'i

Moloka'i and Lana'i Theme 1 results have been included in all of the Maui Electric analyses presented above, as they were in the 2014 PSIP. Due to scale and logistic limitations, LNG was not evaluated on Moloka'i or Lana'i and thus only Theme 1 and

Theme 3 plans were developed and analyzed. Figure 4-26 through Figure 4-33 compare the annual real and nominal revenue requirement for Theme 1 and Theme 3 for each island under both fuel forecasts.

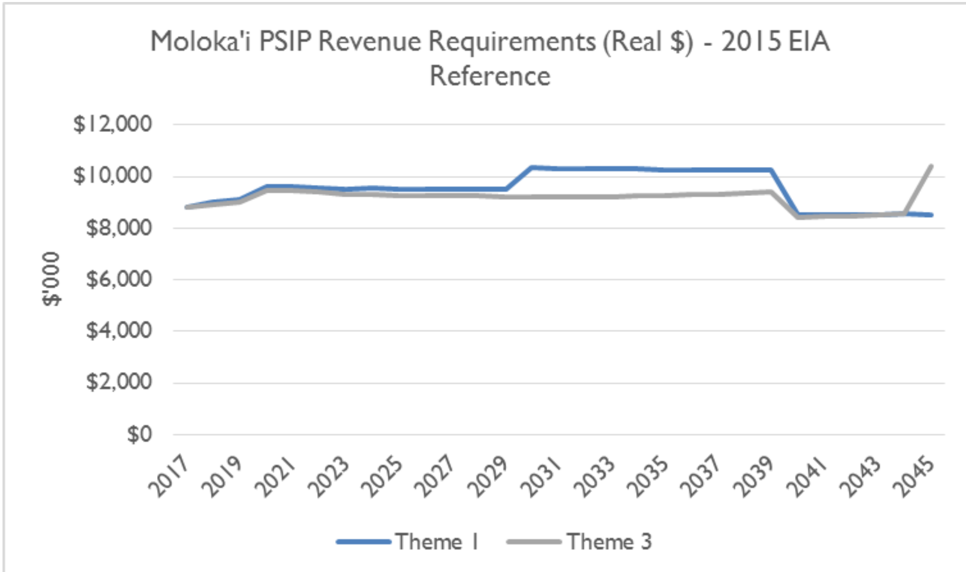


Figure 4-26. Comparison of Revenue Requirement (Real 2016 $) – 2015 EIA Reference

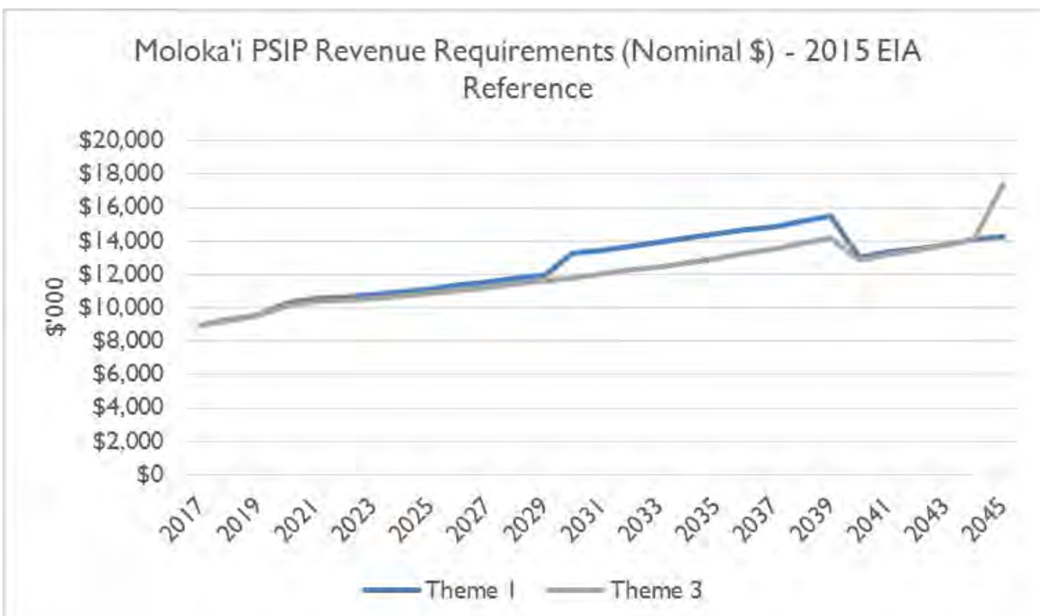


Figure 4-27. Comparison of Revenue Requirement (Nominal $) – 2015 EIA Reference

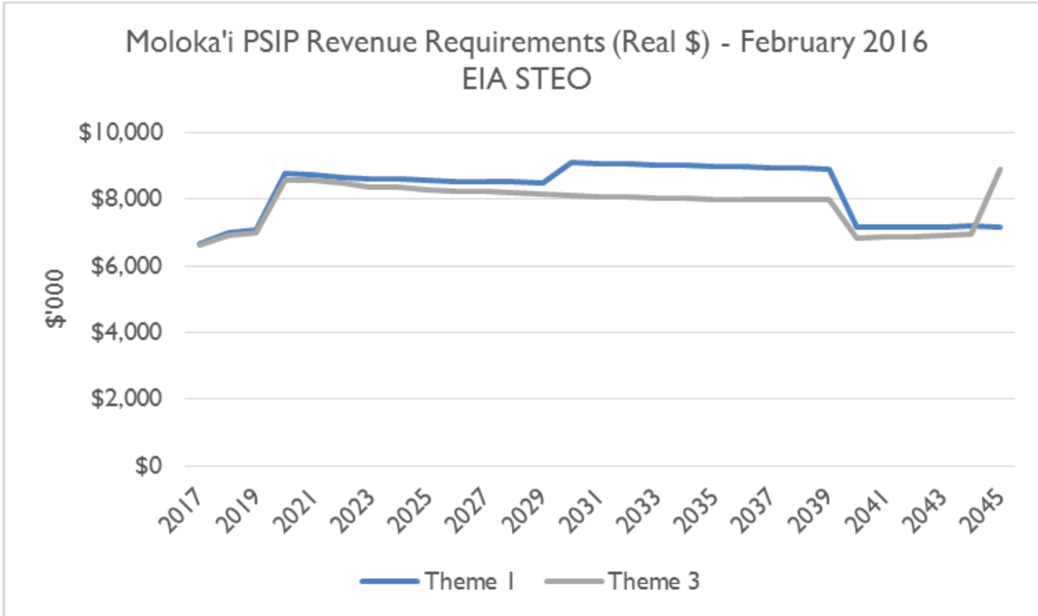


Figure 4-28. Comparison of Revenue Requirement (Real 2016 $)– February 2016 EIA STEO

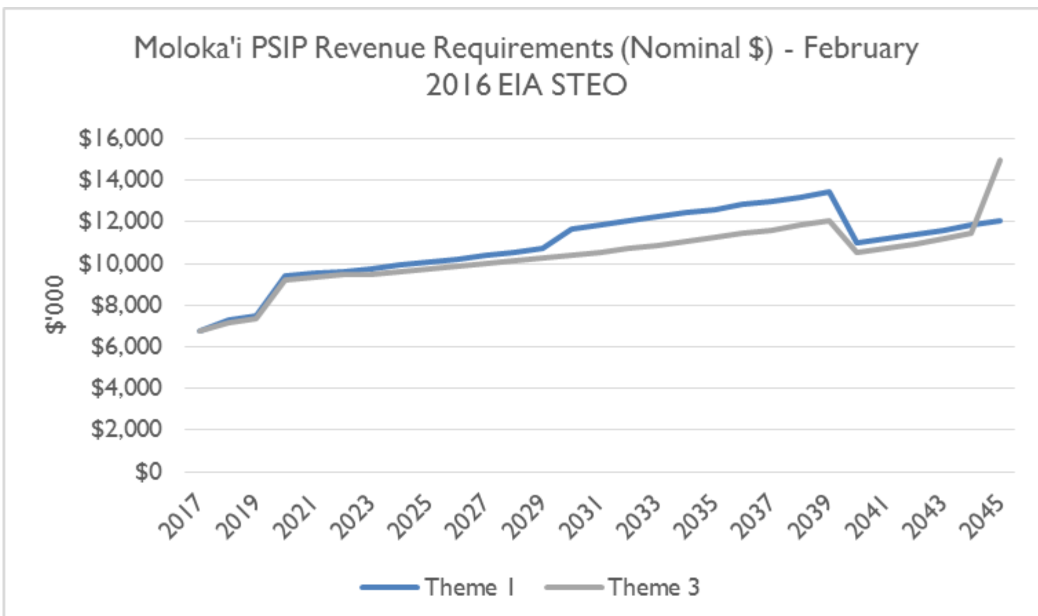


Figure 4-29. Comparison of Revenue Requirement (Nominal $) – February 2016 EIA STEO

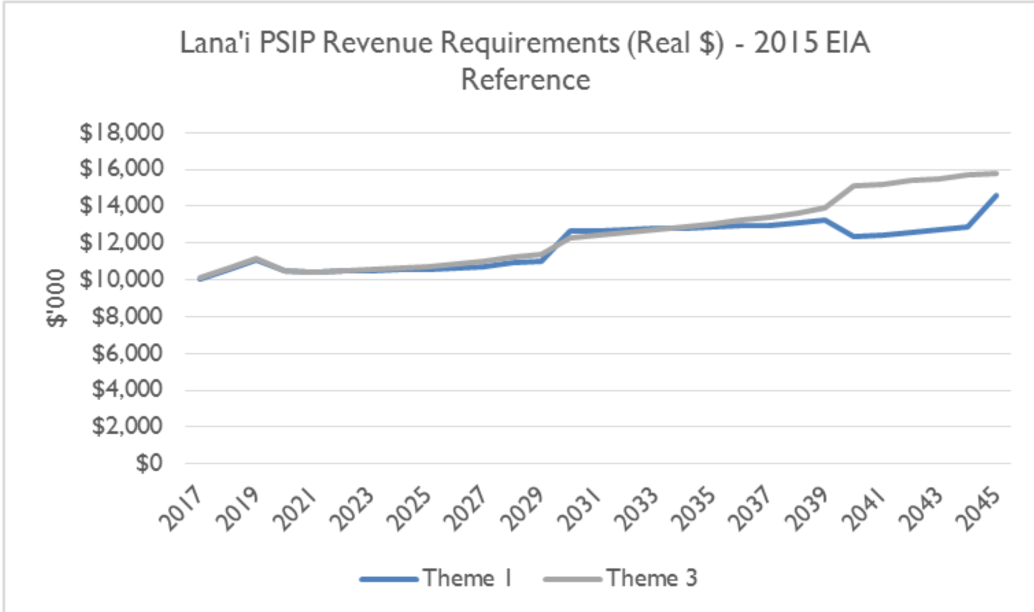


Figure 4-30. Comparison of Revenue Requirement (Real 2016 $) – 2015 EIA Reference

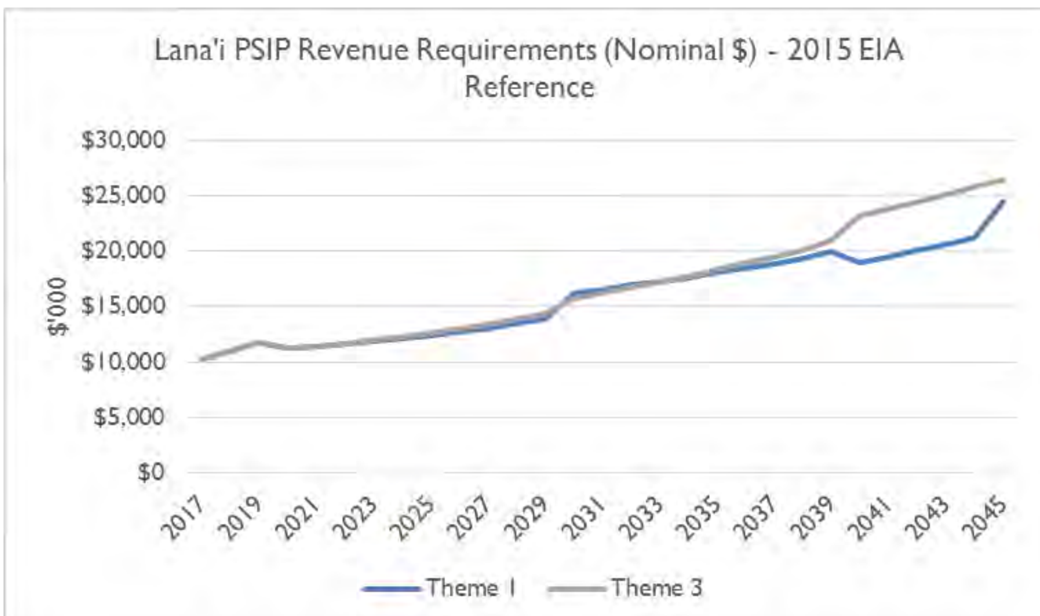


Figure 4-31. Comparison of Revenue Requirement (Nominal $) – 2015 EIA Reference

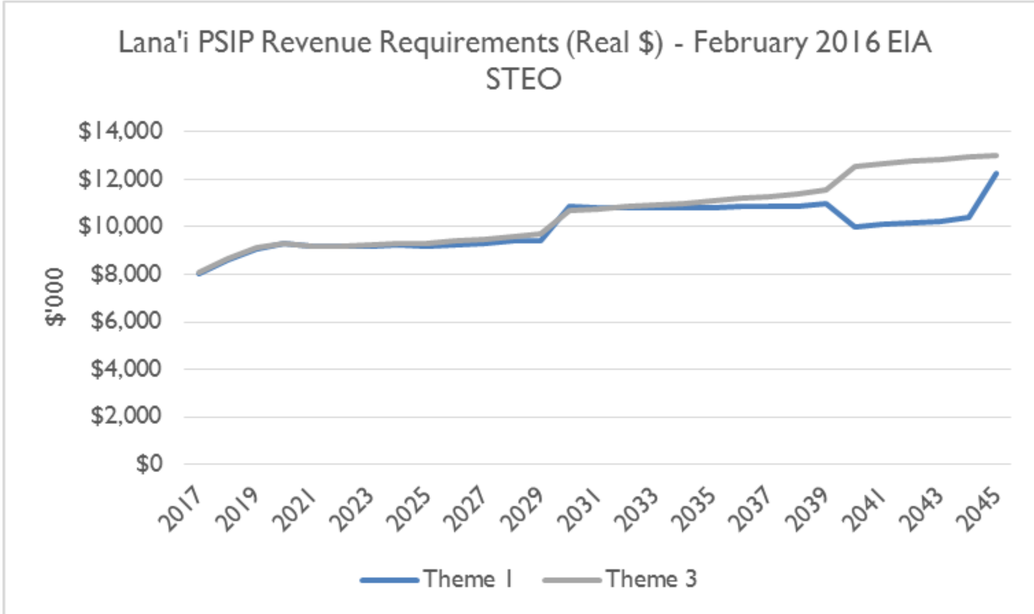


Figure 4-32. Comparison of Revenue Requirement (Real 2016$)– February 2016 EIA STEO

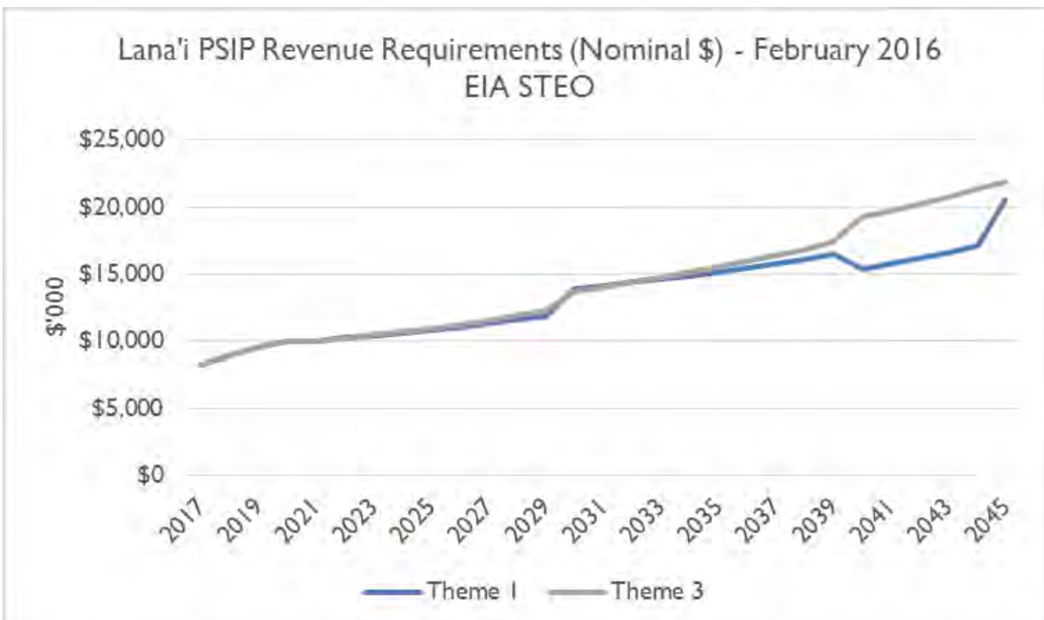


Figure 4-33. Comparison of Revenue Requirement (Nominal $) – February 2016 EIA STEO

The Company has not built a complete financial model for Moloka'i and Lana'i and so is not able to produce residential rate and bill impact analyses that are fully comparable to those presented in this report for the other islands. The available analysis tools do provide an understanding of the system average rate and this is presented in real and nominal dollars in Figure 4-34 through Figure 4-41.

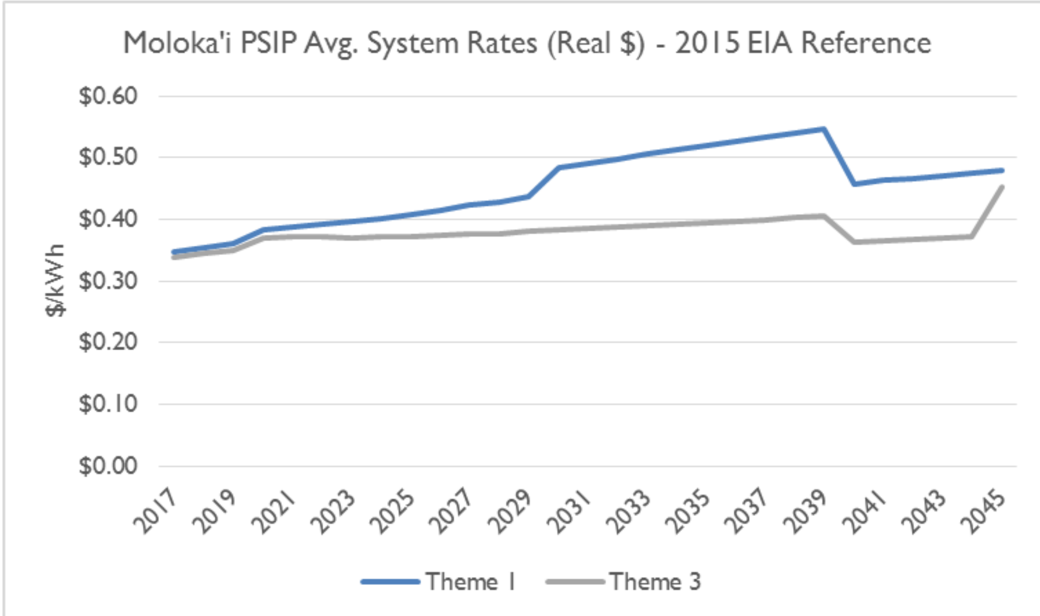


Figure 4-34. Comparison of Moloka'i System Average Rates (Real 2016 $) – 2015 EIA Reference

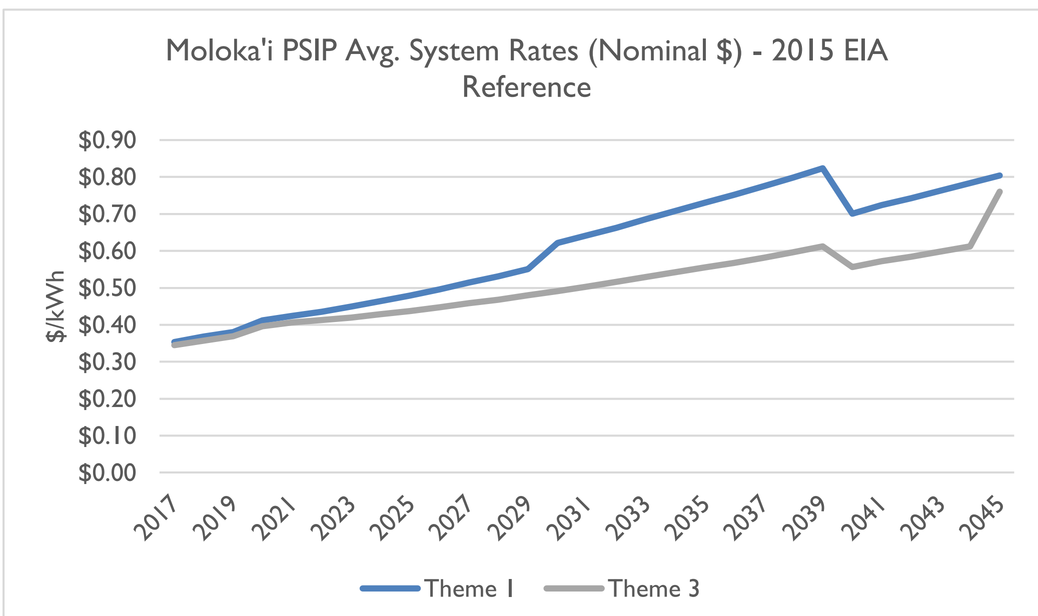


Figure 4-35. Comparison of Moloka'i System Average Rates (Nominal $) – 2015 EIA Reference

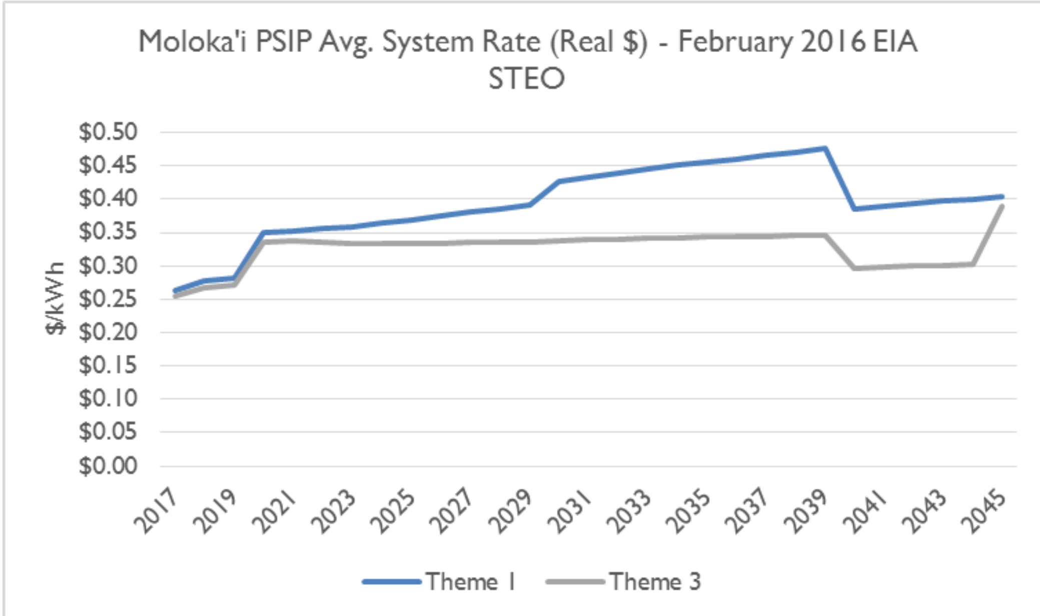


Figure 4-36. Comparison of Moloka'i System Average Rate (Real 2016 $) – February 2016 EIA STEO

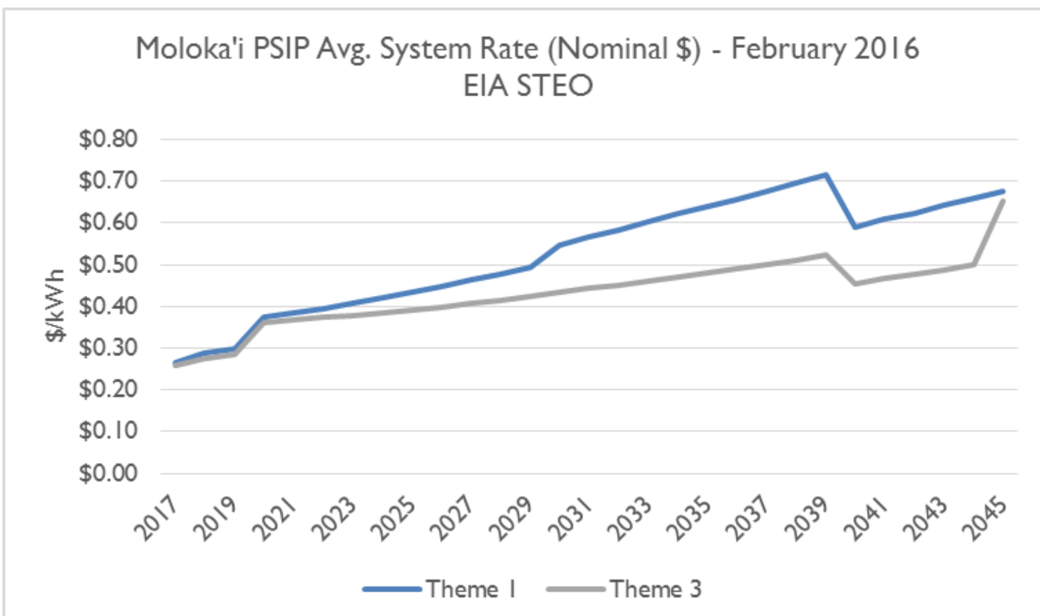


Figure 4-37. Comparison of Moloka'i System Average Rate (Nominal $) – February 2016 EIA STEO

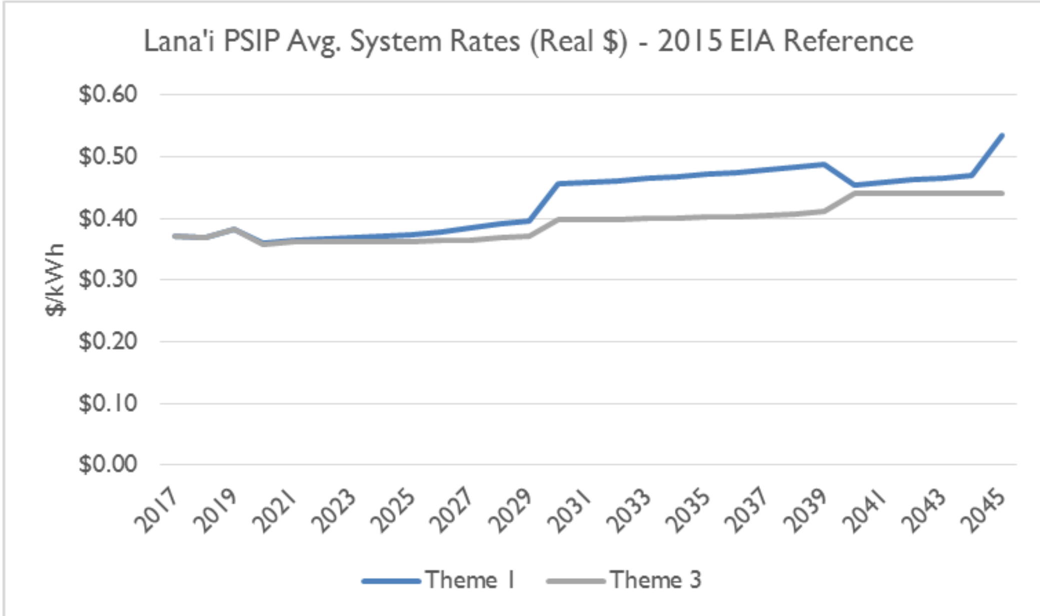


Figure 4-38. Comparison of Lana'i System Average Rates (Real 2016 $) – 2015 EIA Reference

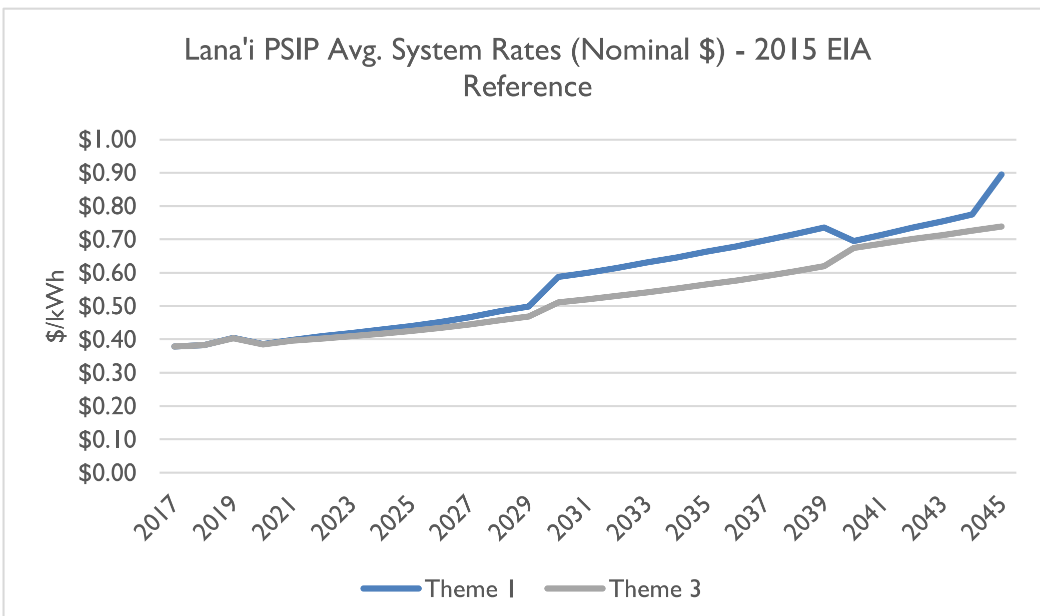


Figure 4-39. Comparison of Lana'i System Average Rates (Nominal $) – 2015 EIA Reference

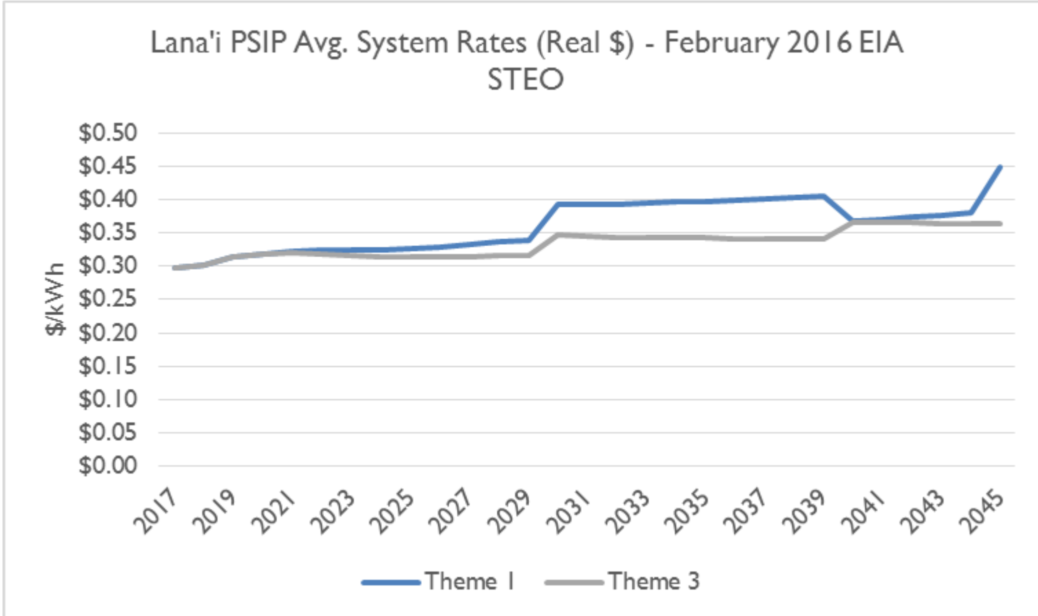


Figure 4-40. Comparison of Lana'i System Average Rates (Real 2016 $) – February 2016 EIA STEO

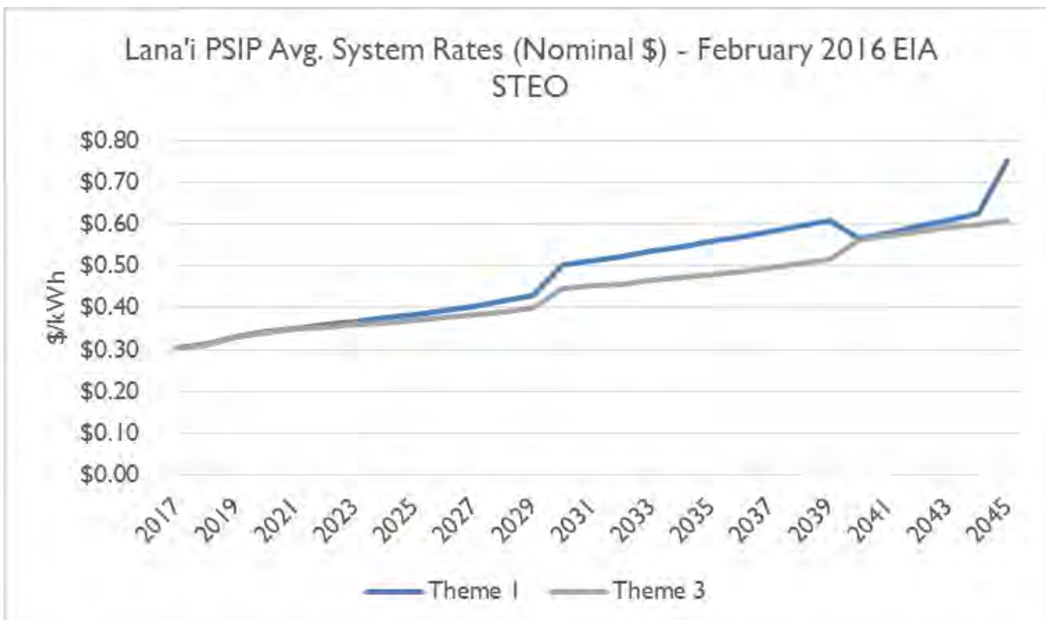


Figure 4-41. Comparison of Lana'i System Average Rates (Nominal $) – February 2016 EIA STEO

Capital Expenditure Projections

The revenue requirement projections for each Theme include capital expenditure projections for power supply, smart grid, ERP, and all other utility capital expenditures (referred to as "balance-of-utility business capital expenditures"). The Power Supply capital expenditures range from $0.5B ($0.25B in the first 9 years) for Theme 3 to $1.0B

($0.4B in the first 9 years) for Theme 1, consistent with the mix and timing of resource additions and retirements.

Smart Grid and ERP are treated separately, as these proposed capital projects have different costs under a merged and an unmerged future. As Theme 2 is only possible in a merged future, the analysis uses the merged capital costs for both of these projects for Theme 2 capital expenditures. While Themes 1 and 3 can be occur in either a merged or an unmerged future, we have used the merged capital expenditures for these projects in this analysis, in order to ease the comparability of results between Themes.

As described in detail in Appendix I, the balance-of-utility business capital expenditures have been calculated using a top down manner for the 2015 EIA Reference fuel price scenario and have been consistently applied across all three Themes for both fuel cases. The tables below summarize Maui Electric's capital expenditures by category for each Theme for all three islands.

Theme 1

Under the Theme 1 resource plan, $1.0B (nominal) of capital will be invested by the utility in Power Supply assets over the 29 year planning period, with $0.4B (nominal) of this investment occurring in the first 9 years of the period.

Theme 1 ('000)	2017-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	Total
Power Supply	$122,192	$285,023	$172,041	$159,038	$146,173	$100,082	$984,549
Smart Grid	$34,487	$2,288	$3,176	$4,299	$523	$0	$44,773
ERP	$7,132	$0	$0	$0	$0	$0	$7,132
Balance-of-utility business	$99,393	$128,219	$140,181	$153,260	$167,559	$183,192	$871,804
Total	$263,203	$415,530	$315,398	$316,597	$ 314,256	$283,274	$1,908,258

Table 4-10. Theme 1 Capital Expenditures (Nominal $)

Theme 2

Under the Theme 2 resource plan, $0.6B (nominal) of capital will be invested by the utility in Power Supply assets over the 29 year planning period, with $0.37B (nominal) of this investment occurring in the first 9 years of the period.

Theme 2 ('000)	2017-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	Total
Power Supply	$204,966	$168,298	$53,688	$43,101	$131,432	$26,043	$627,528
Smart Grid	$34,487	$2,288	$3,176	$4,299	$523	$0	$44,773
ERP	$7,132	$0	$0	$0	$0	$0	$7,132
Balance-of-utility business	$99,393	$128,219	$140,181	$153,260	$167,559	$183,192	$871,804

Total	$345,978	$298,805	$197,045	$200,660	$299,514	$209,235	$1,551,238

Table 4-11. Theme 2 Capital Expenditures (Nominal $)

Theme 3

Under the Theme 3 resource plan, $0.5B (nominal) of capital will be invested by the utility in Power Supply assets over the 29 year planning period, with $0.25B (nominal) of this investment occurring in the first 9 years of the period.

Theme 3 - ('000)	2017-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	Total
Power Supply	$124,909	$134,635	$53,688	$43,101	$131,432	$26,043	$513,807
Smart Grid	$34,487	$2,288	$3,176	$4,299	$523	$0	$44,773
ERP	$7,132	$0	$0	$0	$0	$0	$7,132
Balance-of-utility business	$99,393	$128,219	$140,181	$153,260	$167,559	$183,192	$871,804
Total	$265,920	$265,141	$197,045	$200,660	$299,514	$209,235	$1,437,516

Table 4-12. Theme 3 Capital Expenditures (Nominal $)

Risk Analysis

Planning to achieve an affordable, reliable, and secure electricity supply that meets Hawaii's clean energy policy goals is a complex and challenging effort for all stakeholders. There are important future uncertainties to consider, including fuel prices and technology developments, and the investment decisions made today by customers, third parties, the State, and Maui Electric will impact customers for decades to come. These uncertainties impact the risks facing our customers and Maui Electric, including:

- Electricity price risk, in terms of absolute level
- Electricity price risk, in terms of volatility
- "Buyer's Remorse" risk for capital investments made in long term assets
- Ability to afford the investments necessary to ensure the reliability and security of the electricity grid

These risks are somewhat different under each of the three Themes. Table 4-13 provides a qualitative assessment of each of these risks under each of the Themes. An up arrow indicates a better, less risky result, relative to the other Themes.

Risk	Theme 1	Theme 2	Theme 3
Price level	↓	↑	↑
Price volatility	↑	↑	↓
Capital investment	↓	↑	↑
Grid reliability & security	↓	↑	↑

Table 4-13. Risk Assessment

TOTAL SOCIETAL COSTS FOR ENERGY: MAUI ELECTRIC

As Hawai'i selects the best path to achieve its renewable energy future, the total societal cost of electricity is an important consideration. For this analysis, the total societal cost of electricity is the sum of the costs for independent generation, investments in distributed generation and storage, federal and state tax incentives, fuel, and all other utility operating costs. The chart below provides, by Theme, the Net Present Value of this cost stream over the period 2017 through 2045.

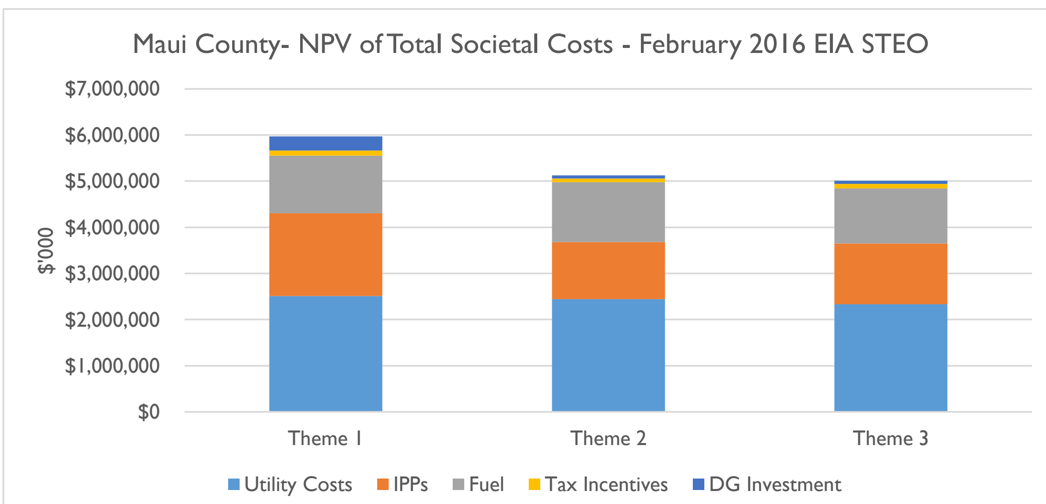


Figure 4-42. Total Societal Costs of the Plans 2017 through 2045

TOTAL SOCIETAL INVESTMENT: MAUI ELECTRIC

Significant investments by home and business owners across the State, project developers and independent power producers, Federal and State government, and the Company are all required to achieve Hawai'i's goal of 100% renewable energy. The capital expenditures required to achieve Hawai'i's energy policy goals for Maui, Moloka'i, and Lana'i range from $4.4B in Theme 3 to $6.3B in Theme 1. Maui Electric investments represent only a fraction of that total, ranging from $1.4B to $1.9B across the Themes. Table 4-14 through Table 4-16 provides the Company's projections of this total investment, by stakeholder, for each Theme.

Investor	2017 -20	2021-25	2026-30	2031-35	2036-40	2041-45	Total
Distributed Generation & Storage Owners	$302,900	$407,400	$564,600	$551,200	$544,500	$537,900	$2,908,500
Utility Scale Renewable Generation	$100,062	$144,943	$808,112	$0	$117,773	$131,282	$1,302,172
Federal Tax Incentives	$47,314	$18,592	$19,027	$18,424	$17,970	$17,493	$138,820
Hawaii Tax Incentives	$28,535	$4,378	$500	$0	$1,000	$1,500	$35,913
Maui Electric	$263,203	$415,530	$315,398	$316,597	$314,256	$283,274	$1,908,258
Theme 1 Total	**$742,014**	**$990,843**	**$1,707,637**	**$886,221**	**$995,499**	**$971,449**	**$6,293,663**

Table 4-14. Total Societal Energy Investment – Theme 1

Investor	2017 -20	2021-25	2026-30	2031-35	2036-40	2041-45	Total
Distributed Generation & Storage Owners	$302,900	$161,200	$154,300	$149,600	$150,000	$158,600	$1,076,600
Utility Scale Renewable Generation	$280,400	$0	$0	$0	$1,226,956	$197,291	$1,704,647
Federal Tax Incentives	$72,466	$2,392	$689	$694	$714	$799	$77,754
Hawaii Tax Incentives	$20,887	$1,187	$0	$0	$3,000	$0	$25,074
Maui Electric	$345,978	$298,805	$197,045	$200,660	$299,514	$209,235	$1,551,238
Theme 2 Total	**$1,022,631**	**$463,584**	**$352,034**	**$350,954**	**$1,680,184**	**$565,925**	**$4,435,313**

Table 4-15. Total Societal Energy Investment – Theme 2

Investor	2017 -20	2021-25	2026-30	2031-35	2036-40	2041-45	Total
Distributed Generation & Storage Owners	$309,200	$163,400	$154,300	$149,600	$150,000	$158,600	$1,085,100
Utility Scale Renewable Generation	$162,299	$330,326	$6,205	$0	$998,450	$204,786	$1,702,066
Federal Tax Incentives	$83,286	$13,966	$689	$694	$714	$9,840	$109,189
Hawaii Tax Incentives	$24,887	$3,187	$500	$0	$2,000	$3,500	$34,074
Maui Electric	$265,920	$265,141	$197,045	$200,660	$299,514	$209,235	$1,437,516
Theme 3 Total	**$845,592**	**$776,020**	**$358,739**	**$350,954**	**$1,450,678**	**$585,961**	**$4,367,945**

Table 4-16. Total Societal Energy Investment – Theme 3

The above investment totals do not include energy efficiency investments made by customers or demand response investments made by DR providers or customers.

HAWAI'I ISLAND FINANCIAL IMPACTS

For Hawai'i Island, the selection between Themes, based on financial metrics, is somewhat more nuanced than it is for the other islands. Theme 1 results in the lowest net present value of revenue requirements over the 2017 to 2045 planning period, under both fuel price forecasts. And Theme 2 results in the lowest residential rates and customer bills over the planning period. This divergence is driven by the higher level of Grid Export DG-PV under Theme 1 and the bill credits associated with it. So, while the absolute revenue requirement is lower under Theme 1, the rate and bill impact of a residential customer without DG-PV is lower under Theme 2.

Revenue Requirement Analysis

Total company revenue requirements, under both fuel forecasts, have been calculated for the best evaluated resource plan for each Theme. Table 4-17 shows the Net Present Value of the annual revenue requirements for each Theme and Figure 4-43 through Figure 4-46 compare each Theme's annual revenue requirement under the 2015 EIA Reference and February 2016 EIA STEO fuel forecasts respectively, in real (2016 $) and nominal dollars.

Net Present Value of Revenue Requirement ($000)	2015 EIA Reference	February 2016 EIA STEO
NPV of Theme 1 Revenue Requirement	$4,676,993	$4,372,196
NPV of Theme 2 Revenue Requirement	$4,750,970	$4,491,804
NPV of Theme 3 Revenue Requirement	$4,879,952	$4,455,761

Table 4-17. Net Present Value of Revenue Requirement

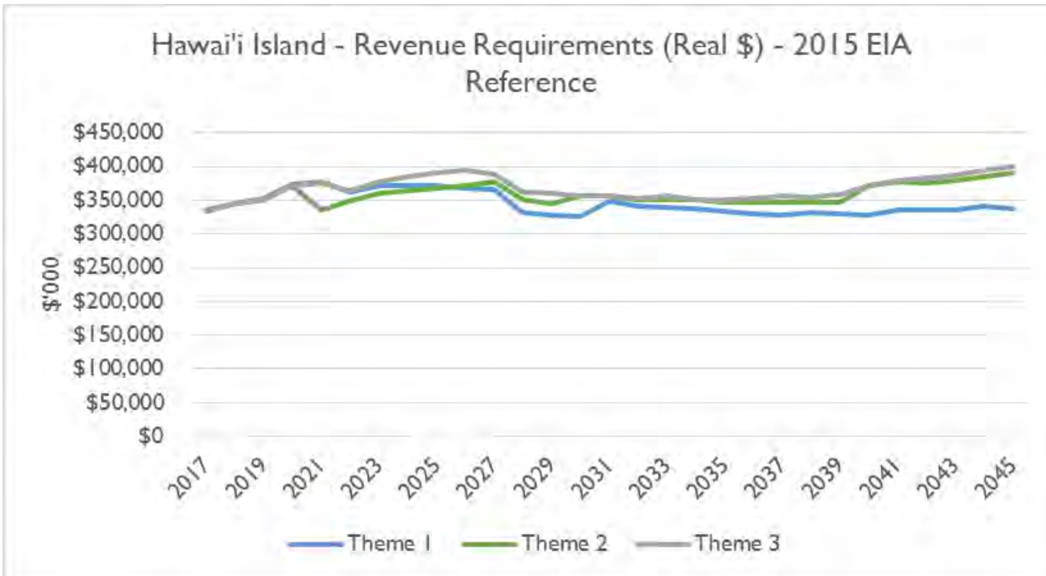


Figure 4-43. Comparison of Revenue Requirement (Real 2016 $) –2015 EIA Reference

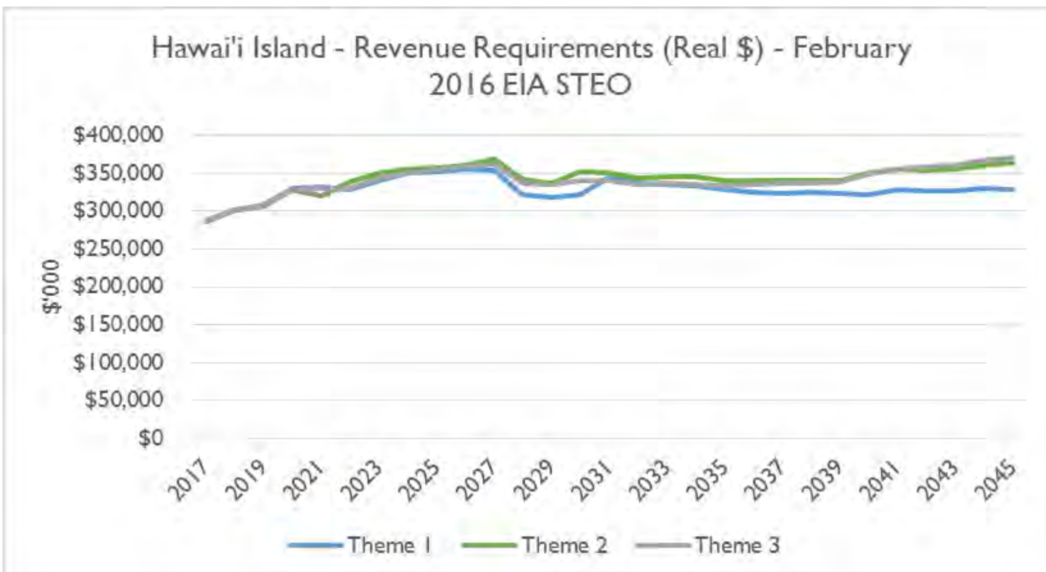


Figure 4-44. Comparison of Revenue Requirement (Real 2016$) – February 2016 EIA STEO

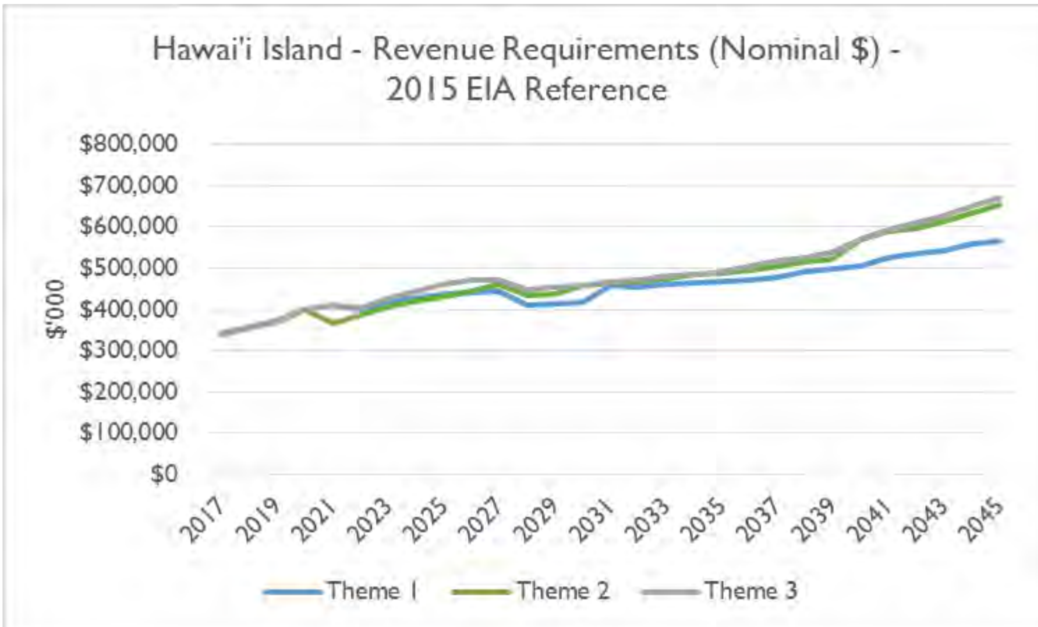


Figure 4-45. Comparison of Revenue Requirement (Nominal $) – 2015 EIA Reference

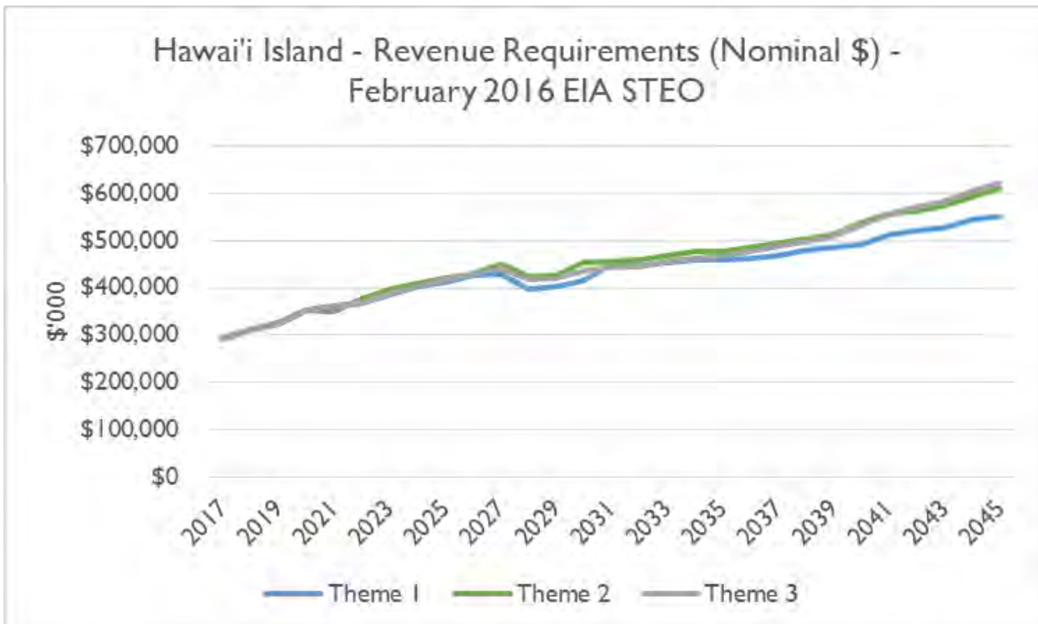


Figure 4-46. Comparison of Revenue Requirement (Nominal $) – February 2016 EIA STEO

Customer Rate Impact Analysis

Residential customer rates, in real 2016 $, trend flat to slightly lower over the planning period for Themes 1 and 2 under the 2015 EIA Reference fuel price forecast. Both of these Themes show a slight increase in real terms over the first 10 years of the planning period, before declining back to the starting level under the February 2016 EIA STEO fuel price forecast. Rates for Theme 3 are consistently higher than Themes 1 and 2 under both forecasts.

Compared to the 2014 PSIP results, customer rates for Themes 1 and 2 are projected to be consistent lower through 2030 under both fuel forecasts.

Customer rates in nominal terms show consistently increases as inflation, even at the historically low levels used in this analysis, dramatically impacts the value of a dollar over the almost 30 year planning period.

The residential customer rate for the three Themes, under the 2015 EIA Reference fuel price forecast, is presented in real 2016 $ in Figure 4-47 and in nominal $ in Figure 4-48. 2014 PSIP results are also shown for comparison purposes.

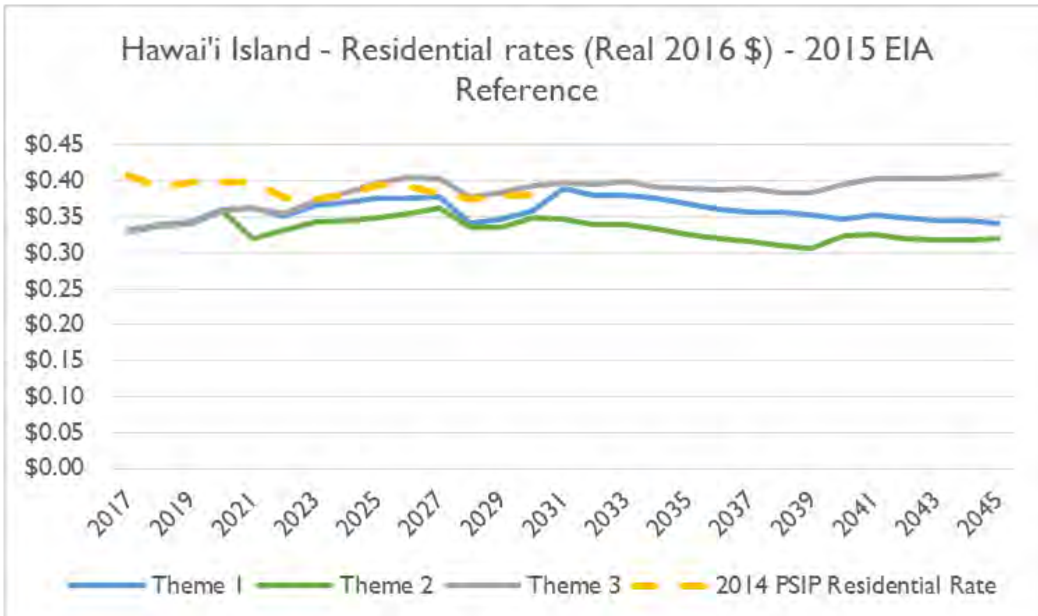


Figure 4-47. Residential Rates (Real 2016 $): 2015 EIA Reference

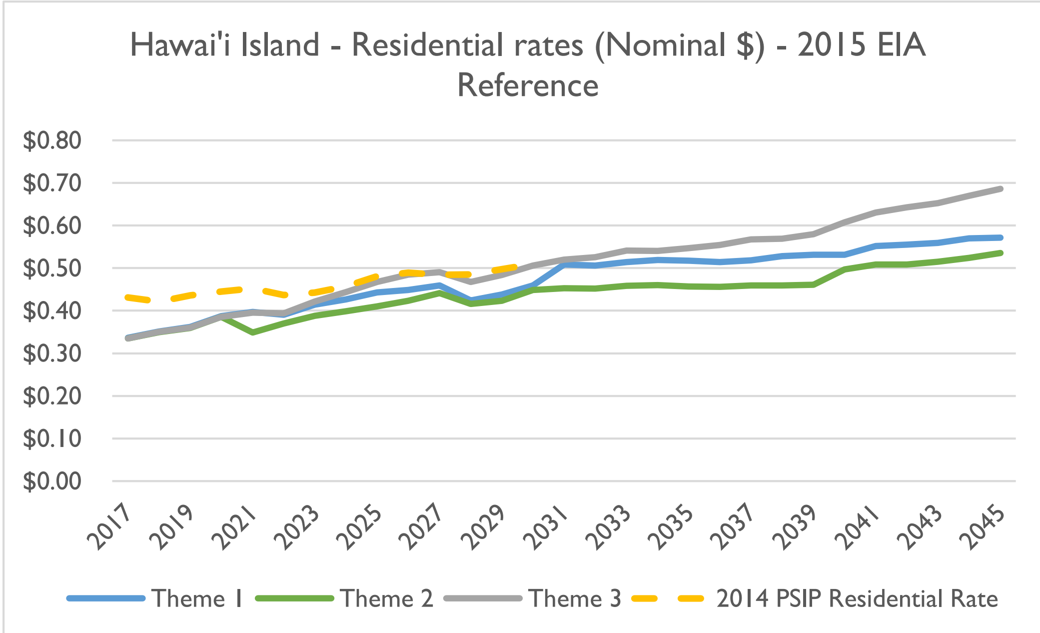


Figure 4-48. Residential Rates (Nominal $): 2015 EIA Reference

The residential customer rate for the three Themes, under the February 2016 EIA STEO fuel price forecast, is presented in real 2016 $ in Figure 4-49 and in nominal $ in Figure 4-50. 2014 PSIP results are also shown for comparison purposes.

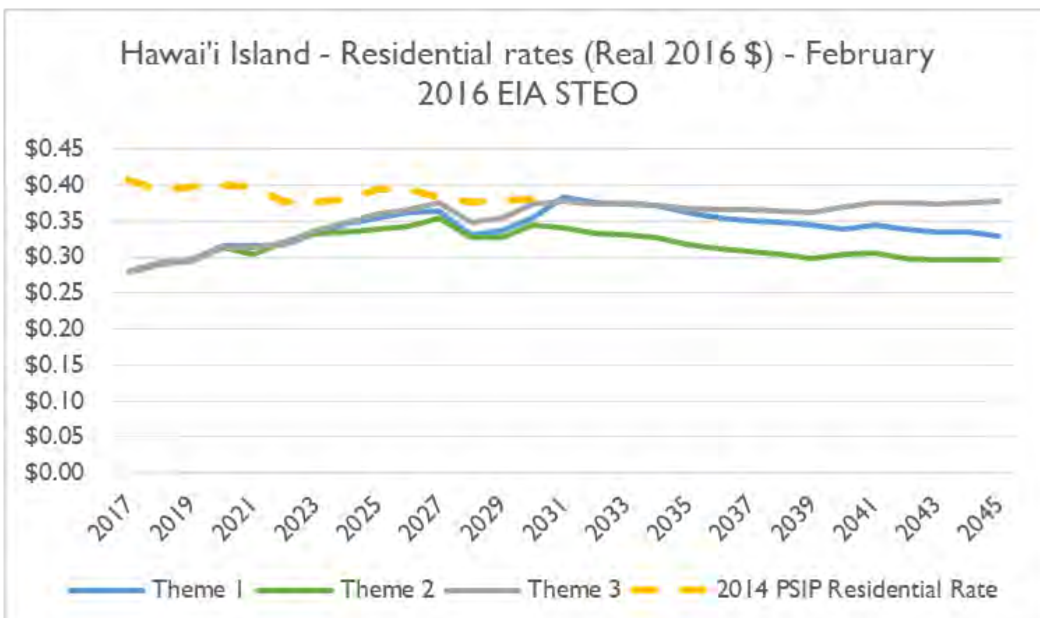


Figure 4-49. Residential Rates (Real 2016 $): February 2016 EIA STEO

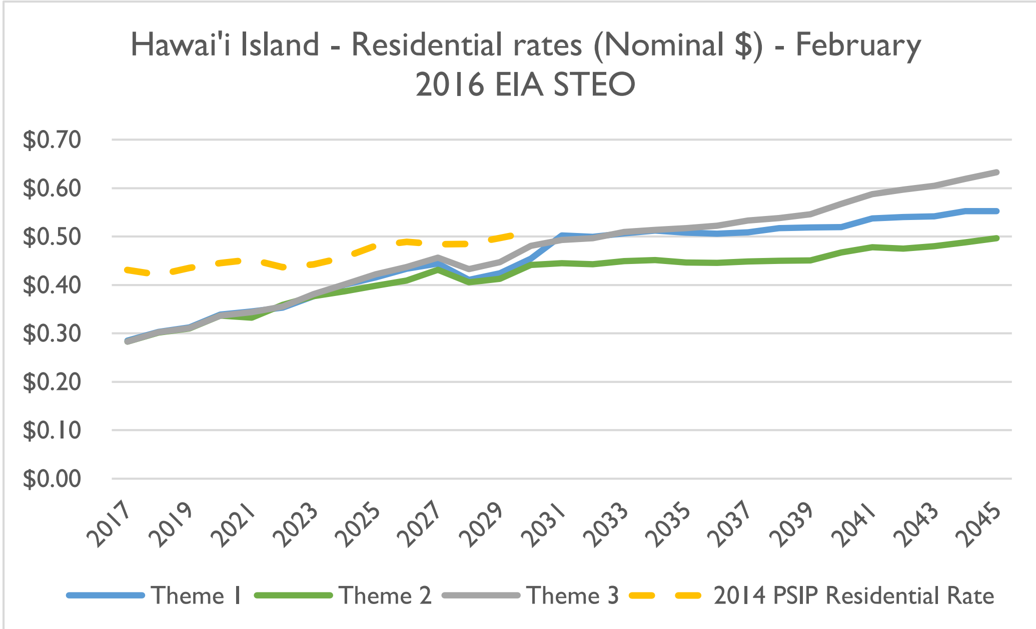


Figure 4-50. Residential Rates (Nominal $): February 2016 EIA STEO

Residential Customer Bill Impact Analysis

The overall impact on a customer's bill is the combination of usage and rates. Over the planning period, usage per customer is expected to decline, consistent with the Energy Efficiency Portfolio Standard goals. The residential customer bill analyses below present each Theme's projected residential bill impact for the average non-DGPV customer.

The residential customer bill impact for the three Themes, under the 2015 EIA Reference fuel price forecast, is presented in real 2016 $ in Figure 4-51 and in nominal $ in Figure 4-52. 2014 PSIP results are also shown for comparison purposes.

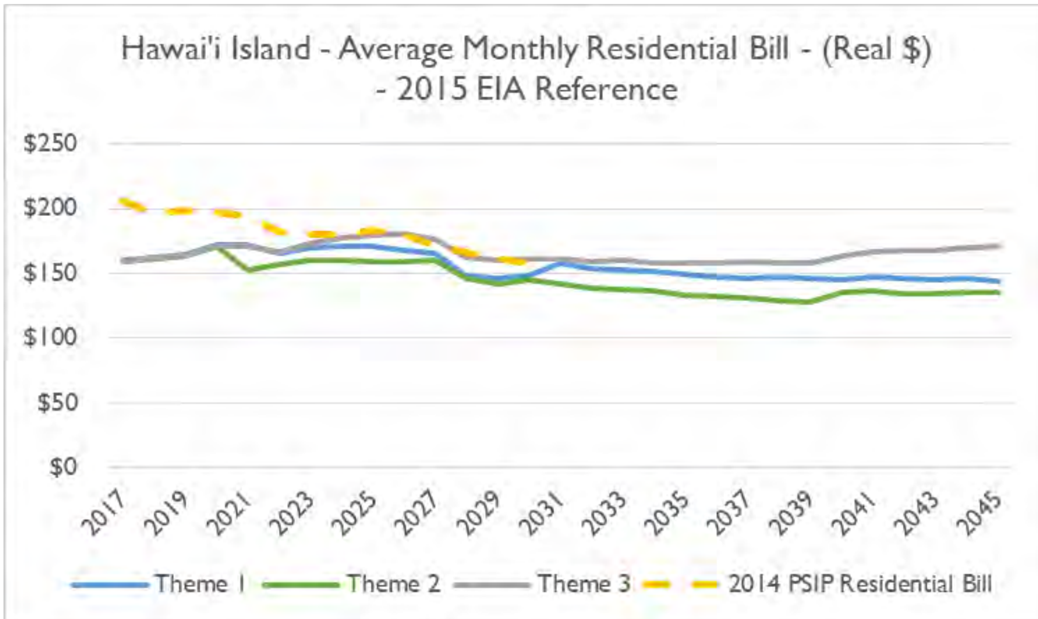


Figure 4-51. Residential Bill (Real 2016 $): 2015 EIA Reference

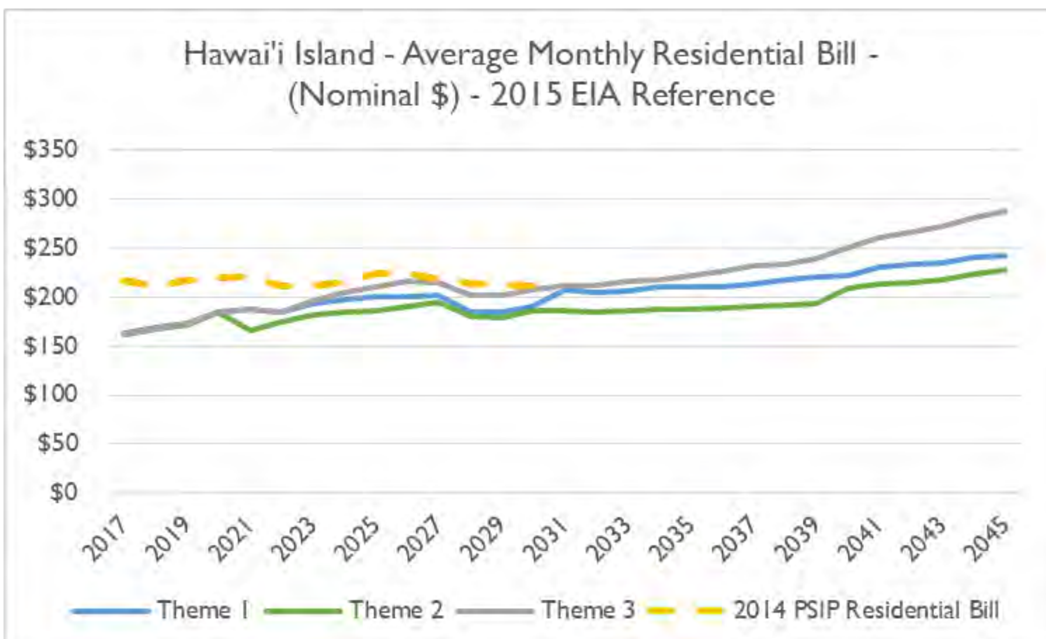


Figure 4-52. Residential Bill (Nominal $): 2015 EIA Reference

The residential customer bill impact for the three Themes, under the February 2016 EIA STEO fuel price forecast, is presented in real 2016 $ in Figure 4-53 and in nominal $ in Figure 4-54. 2014 PSIP results are also shown for comparison purposes.

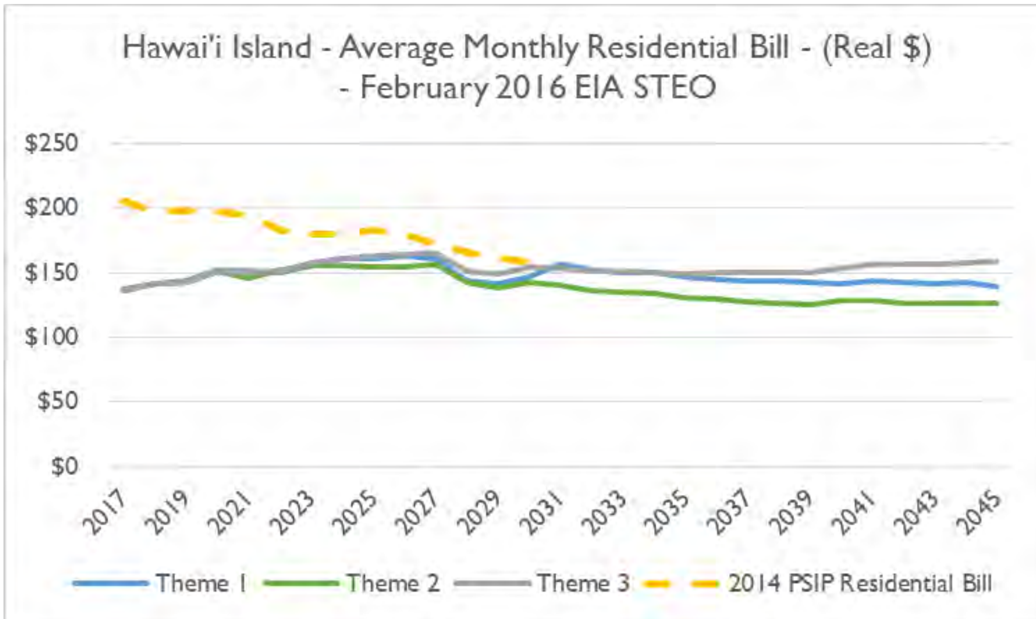


Figure 4-53. Residential Bill (Real 2016 $): February 2016 EIA STEO

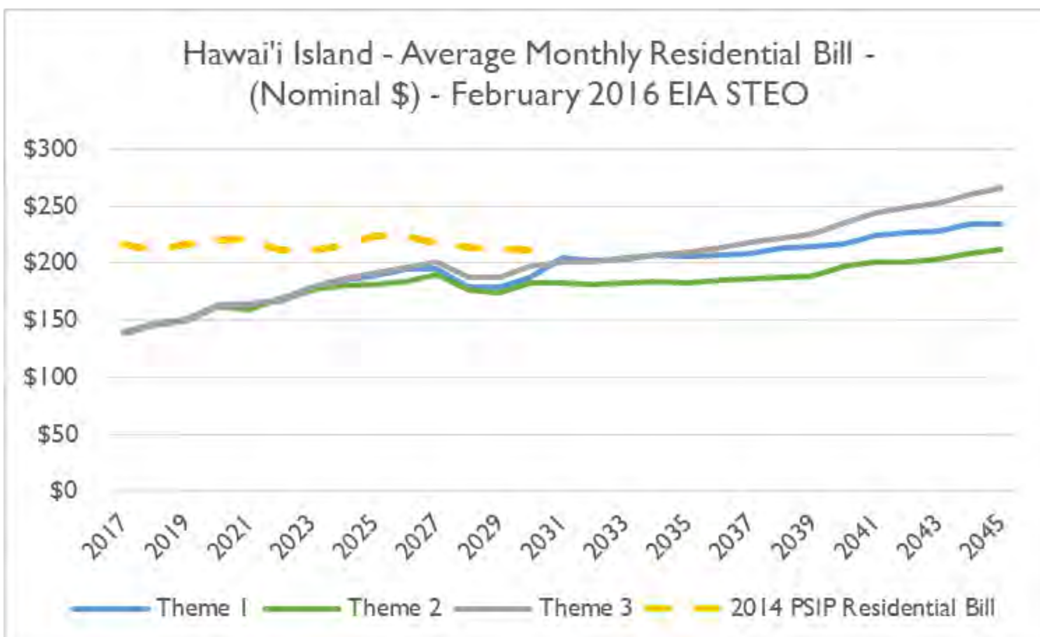


Figure 4-54. Residential Bill (Nominal $): February 2016 EIA STEO

Capital Expenditure Projections

The revenue requirement projections for each Theme include capital expenditure projections for power supply, smart grid, ERP, and all other utility capital expenditures (referred to as "balance-of-utility business capital expenditures"). The Power Supply capital expenditures range from $0.6B ($0.3B in the first 9 years) for Theme 3 to $1.0B ($0.3B in the first 9 years) for Theme 1, consistent with the mix and timing of resource additions and retirements.

Smart Grid and ERP are treated separately, as these proposed capital projects have different costs under a merged and an unmerged future. As Theme 2 is only possible in a merged future, the analysis uses the merged capital costs for both of these projects for Theme 2 capital expenditures. While Themes 1 and 3 can occur in either a merged or an unmerged future, in order to clearly focus on the differences in revenue requirements and bills caused solely by differences in Power Supply costs we need to use a uniform value for these costs in each Theme. For this reason, in this analysis we have used the capital expenditures for these projects that would be appropriate if the Next Era merger is consummated.

As described in detail in Appendix I, the balance-of-utility business capital expenditures have been calculated using a top down manner for the 2015 EIA Reference fuel price scenario and have been consistently applied across all three Themes for both fuel cases. The tables below summarize the capital expenditures by category for each Theme.

Theme 1

Under the Theme 1 resource plan, $1.0B (nominal) of capital will be invested by the utility in Power Supply assets over the 29 year planning period, with $0.3B (nominal) of this investment occurring in the first 9 years of the period.

Theme 1 ('000)	2017-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	Total
Power Supply	$139,206	$142,509	$338,181	$110,095	$93,913	$140,101	$964,006
Smart Grid	$42,587	$2,348	$3,984	$4,554	$596	$0	$54,069
ERP	$8,275	$0	$0	$0	$0	$0	$8,275
Balance-of-utility business	$169,538	$212,476	$232,300	$253,973	$ 277,668	$ 303,574	$ 1,449,529
Total	$359,607	$357,333	$574,464	$368,622	$372,177	$443,676	$2,475,879

Table 4-18. Theme 1 Capital Expenditures (Nominal $)

Hawaiian Electric
Maui Electric
Hawai'i Electric Light

Theme 2

Under the Theme 2 resource plan, $0.8B (nominal) of capital will be invested by the utility in Power Supply assets over the 29 year planning period, with $0.4B (nominal) of this investment occurring in the first 9 years of the period.

Theme 2 ('000)	2017-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	Total
Power Supply	$255,715	$156,226	$100,648	$105,891	$80,828	$81,075	$780,384
Smart Grid	$42,587	$2,348	$3,984	$4,554	$596	$0	$54,069
ERP	$8,275	$0	$0	$0	$0	$0	$8,275
Balance-of-utility business	$169,538	$212,476	$232,300	$253,973	$ 277,668	$ 303,574	$ 1,449,529
Total	$476,116	$371,050	$336,931	$364,418	$359,092	$384,650	$2,292,257

Table 4-19. Theme 2 Capital Expenditures (Nominal $)

Theme 3

Under the Theme 3 resource plan, $0.6B (nominal) of capital will be invested by the utility in Power Supply assets over the 29 year planning period, with $0.3B (nominal) of this investment occurring in the first 9 years of the period.

Theme 3 - ('000)	2017-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	Total
Power Supply	$135,362	$134,908	$105,685	$99,120	$80,828	$81,075	$636,978
Smart Grid	$42,587	$2,348	$3,984	$4,554	$596	$0	$54,069
ERP	$8,275	$0	$0	$0	$0	$0	$8,275
Balance-of-utility business	$169,538	$212,476	$232,300	$253,973	$ 277,668	$ 303,574	$ 1,449,529
Total	$355,762	$349,732	$341,969	$357,646	$359,092	$ 384,560	$ 2,148,851

Table 4-20. Theme 3 Capital Expenditures (Nominal $)

Risk Analysis

Planning to achieve an affordable, reliable, and secure electricity supply that meets Hawai'i's clean energy policy goals is a complex and challenging effort for all stakeholders. There are important future uncertainties to consider, including fuel prices and technology developments, and the investment decisions made today by customers, third parties, the State, and Hawaiian Electric will impact customers for decades to come. These uncertainties impact the risks facing our customers and Hawaiian Electric, including:

- Electricity price risk, in terms of absolute level
- Electricity price risk, in terms of volatility

- "Buyer's Remorse" risk for capital investments made in long term assets
- Ability to afford the investments necessary to ensure the reliability and security of the electricity grid

These risks are somewhat different under each of the three Themes. Table 4-21 provides a qualitative assessment of each of these risks under each of the Themes. An up arrow indicates a better, less risky result, relative to the other Themes.

Risk	Theme 1	Theme 2	Theme 3
Price level	↓	↑	↓
Price volatility	↑	↑	↓
Capital investment	↓	↔	↑
Grid reliability & security	↓	↑	↑

Table 4-21. Risk Assessment

TOTAL SOCIETAL COSTS FOR ENERGY: HAWAI'I ELECTRIC LIGHT

As Hawai'i selects the best path to achieve its renewable energy future, the total societal cost of electricity is an important consideration. For this analysis, the total societal cost of electricity is the sum of the costs for independent generation, investments in distributed generation and storage, federal and state tax incentives, fuel, and all other utility operating costs. The chart below provides, by Theme, the Net Present Value of this cost stream over the period 2017 through 2045.

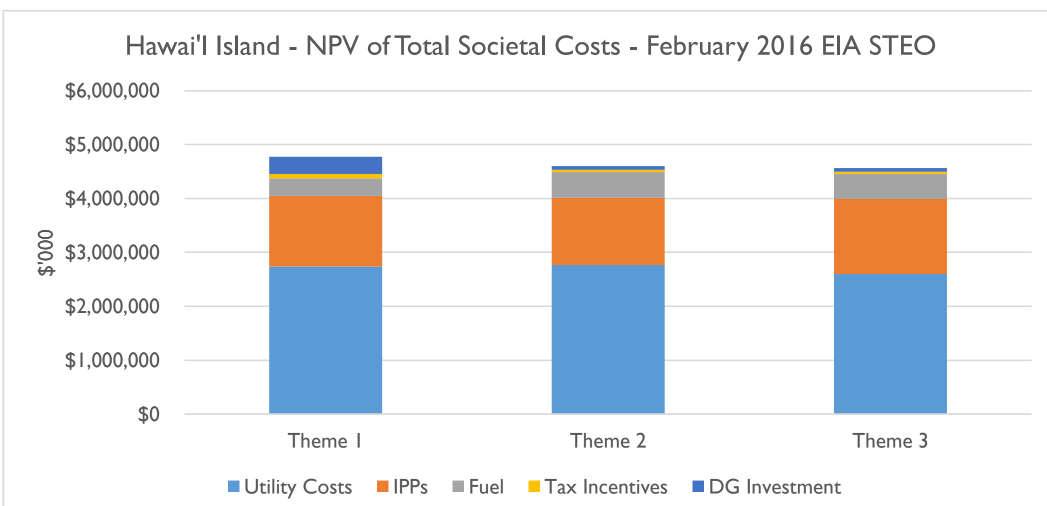


Figure 4-55. Total Societal Costs of the Plans

TOTAL SOCIETAL INVESTMENT: HAWAI'I ELECTRIC LIGHT

Significant investments by home and business owners across the State, project developers and independent power producers, Federal and State government, and the Company are all required to achieve Hawai'i's goal of 100% renewable energy. The capital expenditures required to achieve Hawai'i's energy policy goals for Hawai'i Island range from $4.0B in Theme 3 to $6.2B in Theme 1. Hawai'i Electric Light investments represent only a fraction of that total, ranging from $2.1B to $2.5B across the Themes. Table 4-22 through Table 4-24 provide the Company's projections of this total investment, by stakeholder, for each Theme.

Investor	**2017 -20**	**2021-25**	**2026-30**	**2031-35**	**2036-40**	**2041-45**	**Total**
Distributed Generation & Storage Owners	$302,900	$407,400	$564,600	$551,200	$544,500	$537,900	$2,908,500
Utility Scale Renewable Generation	$0	$355,946	$326,346	$0	$0	$0	$682,292
Federal Tax Incentives	$32,851	$19,455	$20,055	$19,490	$19,147	$18,800	$129,798
Hawaii Tax Incentives	$22,551	$4,511	$1,000	$0	$0	$0	$28,062
Hawaii Electric Light	$359,607	$357,333	$574,464	$368,622	$372,177	$443,676	$2,475,879
Theme 1 Total	**$717,909**	**$1,144,645**	**$1,486,465**	**$939,312**	**$935,824**	**$1,000,376**	**$6,224,531**

Table 4-22. Total Societal Energy Investment – Theme 1

Investor	**2017 -20**	**2021-25**	**2026-30**	**2031-35**	**2036-40**	**2041-45**	**Total**
Distributed Generation & Storage Owners	$302,900	$161,200	$154,300	$149,600	$150,000	$158,600	$1,076,600
Utility Scale Renewable Generation	$0	$206,939	$394,202	$73,700	$76,762	$0	$751,603
Federal Tax Incentives	$24,871	$3,228	$1,105	$1,122	$1,193	$1,361	$32,880
Hawaii Tax Incentives	$17,230	$1,570	$0	$500	$500	$0	$19,800
Hawaii Electric Light	$476,116	$371,050	$336,931	$364,418	$359,092	$384,650	$2,292,257
Theme 2 Total	**$821,117**	**$743,987**	**$886,538**	**$589,340**	**$587,547**	**$544,611**	**$4,173,140**

Table 4-23. Total Societal Energy Investment – Theme 2

Investor	2017 -20	2021-25	2026-30	2031-35	2036-40	2041-45	Total
Distributed Generation & Storage Owners	$309,200	$163,400	$154,300	$149,600	$150,000	$158,600	$1,085,100
Utility Scale Renewable Generation	$0	$206,939	$394,202	$73,700	$76,762	$0	$751,603
Federal Tax Incentives	$24,871	$3,228	$1,105	$1,122	$1,193	$1,361	$32,880
Hawaii Tax Incentives	$17,230	$1,570	$0	$500	$500	$0	$19,800
Hawaii Electric Light	$355,762	$349,732	$341,969	$357,646	$359,092	$384,650	$2,148,851
Theme 3 Total	**$707,063**	**$724,869**	**$891,576**	**$582,568**	**$587,547**	**$544,611**	**$4,038,234**

Table 4-24. Total Societal Energy Investment – Theme 3

The above investment totals do not include energy efficiency investments made by customers or demand response investments made by DR providers or customers.

ADDITIONAL FINANCIAL CONSIDERATIONS

The above analysis was performed and presented on a Company and island specific basis. However, with the potential need to resources amongst the islands to cost effectively achieve 100% renewable energy, the prospects and value of consolidated state-wide rates for Hawaiian Electric Company should be further evaluated.

5. Hawaiian Electric Preferred Plan

Hawaiian Electric performed comprehensive analyses of different paths to achieving 100% renewable energy by 2045. This chapter will provide key results of the analysis for the Final Plans leading to the selection of the Preferred Plan.

ENERGY MIX OF FINAL PLANS FOR O'AHU

As discussed in Chapter 3, different paths to achieving 100% renewable energy in 2045 were analyzed. Figure 5-1 summarizes the annual RPS[18] for each year. Theme 1 accelerates RPS targets while Themes 2 and 3 strategically achieve the same RPS targets.

18 Per the RPS law (HRS § 269-91), RPS is not the same as all grid-based electricity coming from renewable energy resources, which in the calculation of RPS can result in values greater than 100%.

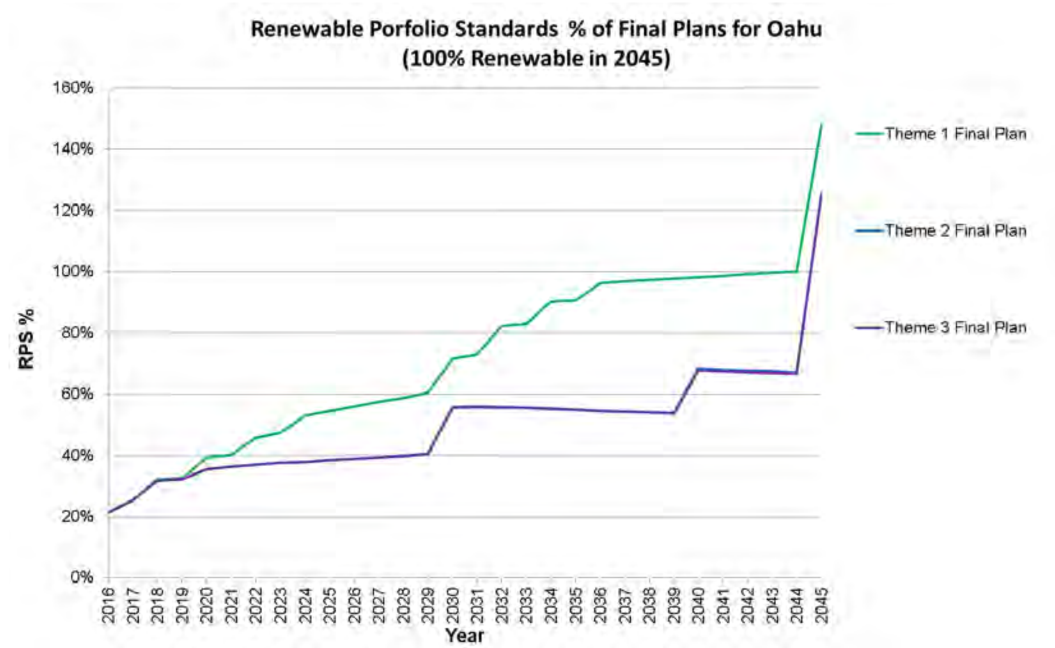


Figure 5-1. Renewable Portfolio Standards Percent of Final Plans for O'ahu (100% Renewable in 2045)

The resource mix for the final plans changes over time as it reaches 100% renewable in 2045. The figures below reveal how the energy mix in the final plan under each theme grow to 100% renewable energy.

The annual energy served by resource type is shown in Figure 5-2 for the Theme 1 final plan under the 2015 EIA Reference Fuel Price Forecasts. The accelerated transition to renewable wind and solar can be easily seen as the fossil fuel (oil and coal) significantly decreases over time.

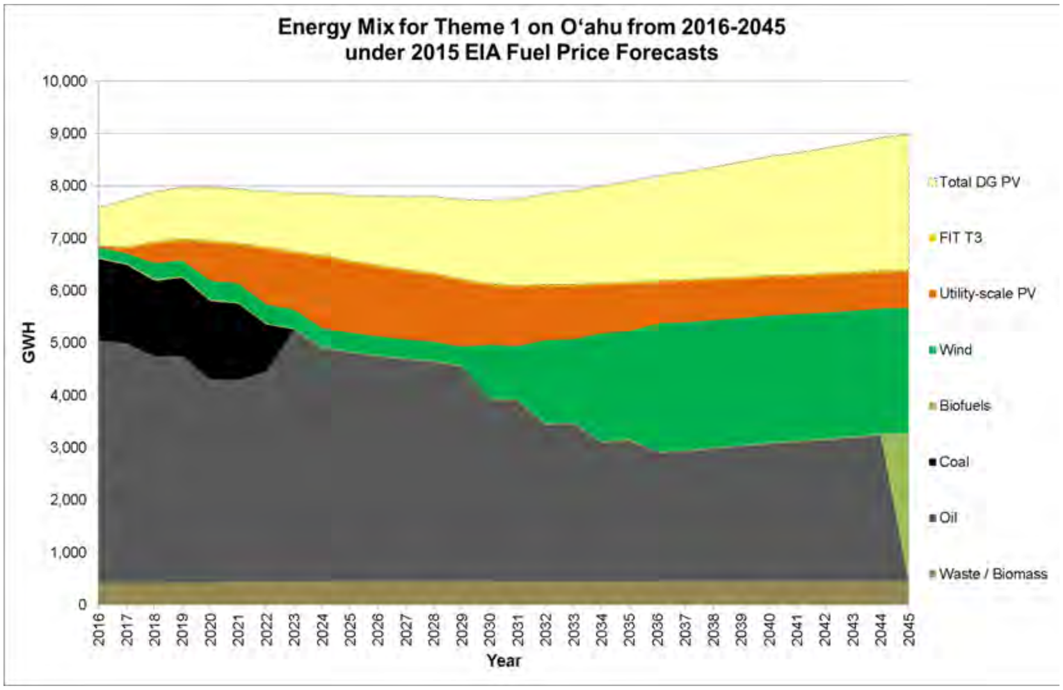


Figure 5-2. Energy Mix for Theme 1 on O'ahu from 2016-2045 under 2015 EIA Fuel Price Forecasts

Each final plan was evaluated under a range of fuel prices and Figure 5-3 shows the energy mix of Theme 1 under the February 2016 EIA STEO Fuel Price Forecasts. The lower fuel prices did not noticeably change the energy mix.

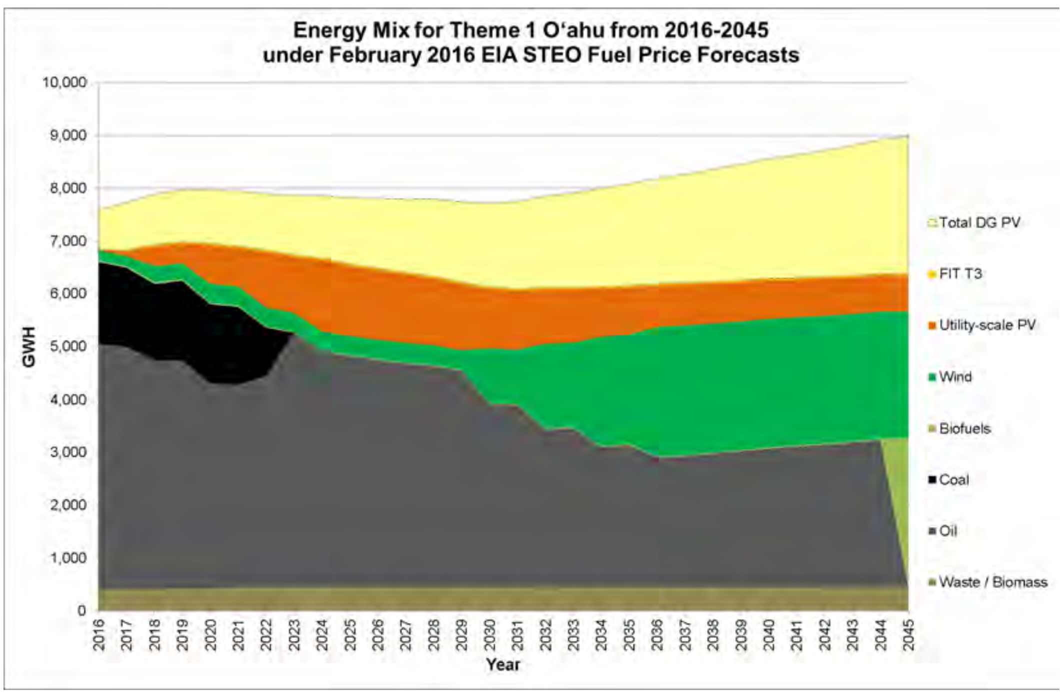


Figure 5-3. Energy Mix for Theme 1 on O'ahu from 2016–2045 under February 2016 EIA STEO Fuel Price Forecasts

The Theme 2 final plan adds new flexible generation to replace existing thermal generation and uses LNG as a transitional fuel from oil to assist with the integration of renewable energy. Renewable energy is added strategically meet intermediate RPS targets and ultimately 100% renewable energy in 2045. The energy mix for Theme 2 under the 2015 EIA Reference Fuel Price Forecasts is shown in Figure 5-4. The transition to LNG occurs during the planned contract period of 2021-2040. At the conclusion of the 20-year LNG contract, alternative fuels to provide the remaining power to the island during this 70% RPS period were considered. Potential fuels include to provide this energy include LNG, oil, biofuels, or a mix of all three. Under the current fuel prices forecasts, oil is cheaper than biofuels so it was selected as the fuel until the use of biofuels was necessary in 2045 to meet the 100% renewable energy.

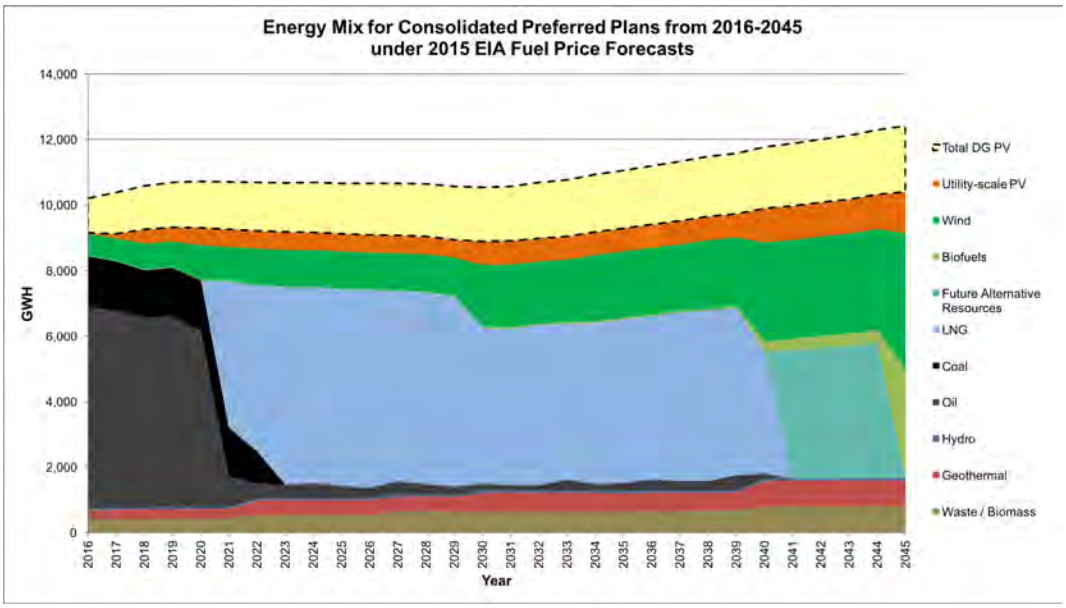


Figure 5-4. Energy Mix for Theme 2 on O'ahu from 2016-2045 under 2015 EIA Fuel Price Forecasts

Future Alternative Fuels: During the last intervening years in the transition to 100% renewable energy, potential fuels at this time could include biofuels, LNG, oil, other renewable options or a mix of options. Given rapidly evolving energy options and technology, the exact fuel mix is difficult to predict today.

The energy mix of Theme 2 under the February 2016 EIA STEO Fuel Price Forecasts did not noticeably change under the lower fuel prices as shown in Figure 5-5.

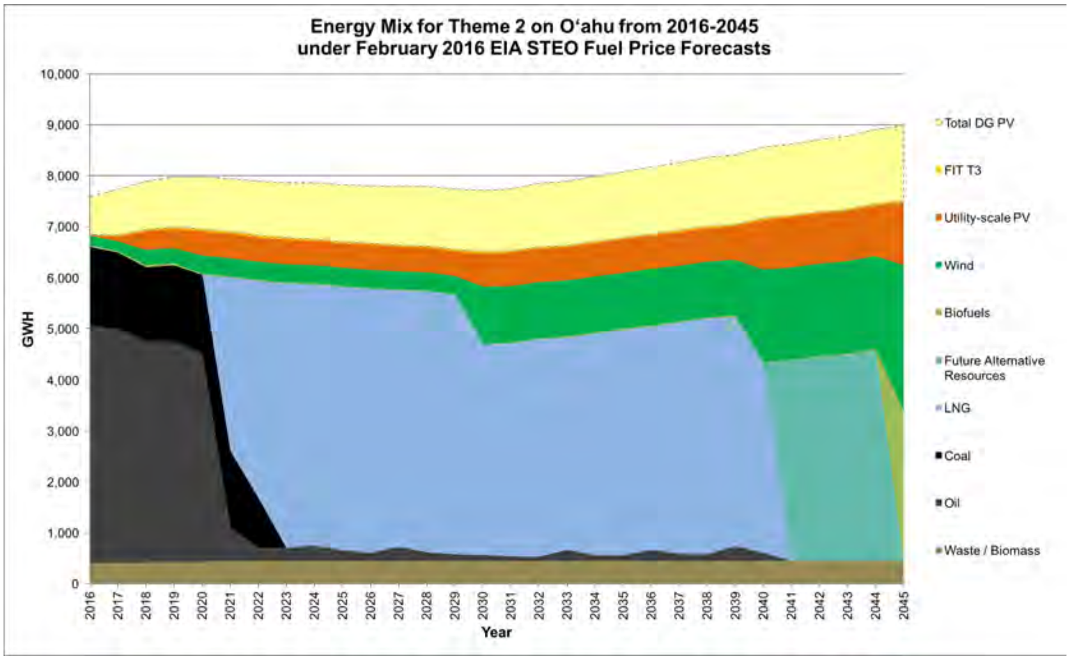


Figure 5-5. Energy Mix for Theme 2 on O'ahu from 2016-2045 under February 2016 EIA STEO Fuel Price Forecasts

Future Alternative Fuels: During the last intervening years in the transition to 100% renewable energy, potential fuels at this time could include biofuels, LNG, oil, other renewable options or a mix of options. Given rapidly evolving energy options and technology, the exact fuel mix is difficult to predict today.

The final plan for Theme 3 makes the planning assumption that LNG is not an available fuel and strategically increases renewable energy to meet the intermediate RPS targets as in Theme 2. Figure 5-6 illustrates the energy mix under the 2015 EIA Reference Fuel Price Forecasts.

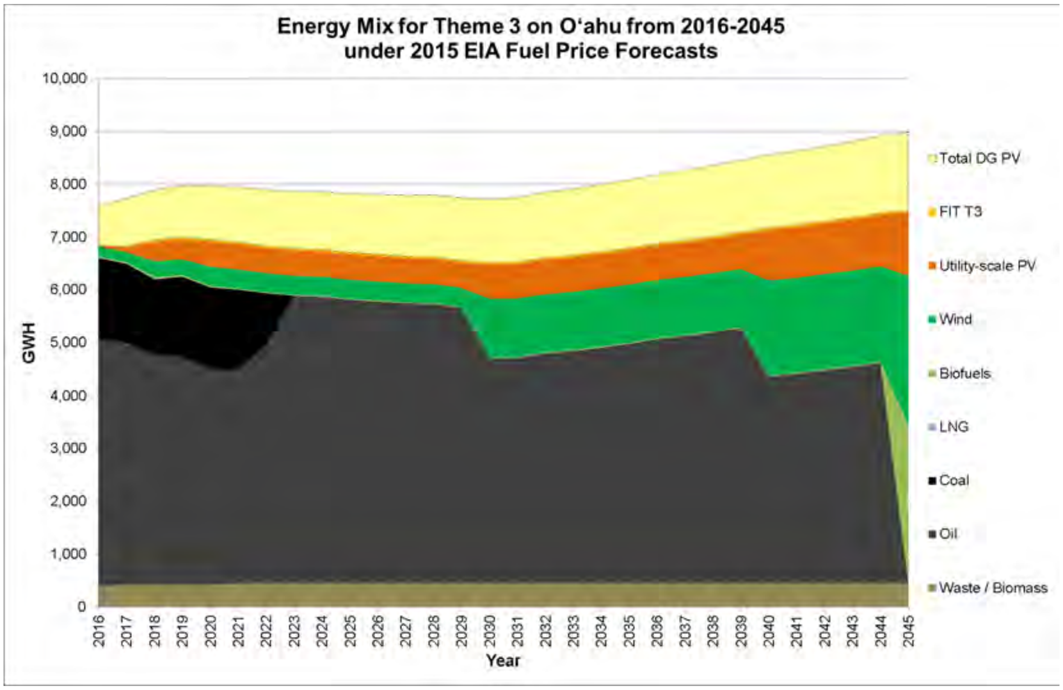


Figure 5-6. Energy Mix for Theme 3 on O'ahu from 2016-2045 under 2015 EIA Fuel Price Forecasts

Similar to the final plans in Themes 1 and 2, the energy mix of Theme 3 under the February 2016 EIA STEO Fuel Price Forecasts did not noticeably change under the lower fuel prices as shown in Figure 5-7.

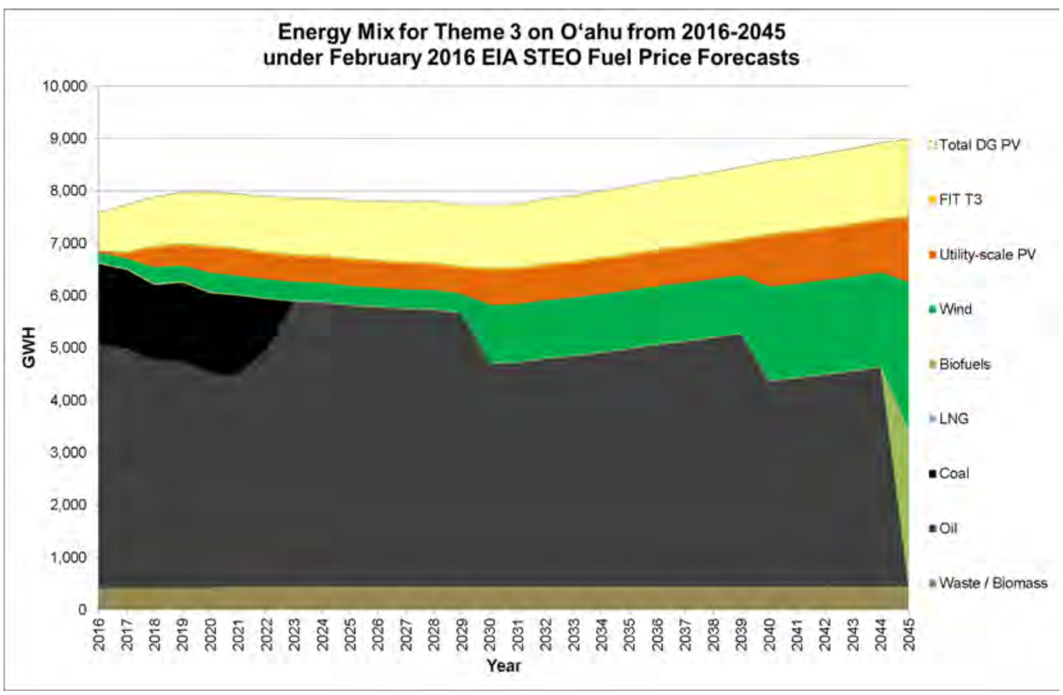


Figure 5-7. Energy Mix for Theme 3 on O'ahu from 2016-2045 under February 2016 EIA STEO Fuel Price Forecasts

The different paths of Themes 1, 2, and 3 to achieving the 100% renewable energy are clearly displayed in Figure 5-2 through Figure 5-7. Although Theme 1 reduces dependency on fossil fuels faster than Themes 2 and 3, the higher levels of DG-PV and accelerated pursuit of renewable energy increases costs as discussed in Chapter 4. Theme 2 reduces costs compared to Themes 1 and 3, as it switches a portion of fossil generation from oil to cleaner, lower cost LNG while strategically adding renewable resources.

PERCENT OVER-GENERATION OF TOTAL SYSTEM OF FINAL PLANS FOR O'AHU

Hawaiian Electric has been actively increasing the flexibility of the existing generating units to integrate increasing levels of variable generation. All the final plans include the capability to operate existing generating units at lower minimum load levels, minimizing baseload operation of the existing generators, and adding new firm flexible generation along with increasing wind and solar generation. Even with more flexible firm generating units, there may still be instances of over-generation of variable resources during low demand periods (which may occur during daytime hours due to influence of DG-PV, as well as during typical night time low load hours).

As increasingly more renewable energy is added to the system, over-generation occurrences will become inevitable. Figure 5-8 provides estimates of the percent over-generation of the total system annual energy for the final plans under the 2015 EIA Reference Fuel Price Forecasts. Since Theme 1 integrates greater amounts of variable renewable energy (utility scale and High DG-PV) than Themes 2 and 3, the percent over-generation increases significantly and much earlier than in Themes 2 and 3. Adding storage to accept the over-generation would be an option but is dependent on the cost of the storage technologies. However, situations of over-generation provide opportunities, coupled with appropriate controls systems, to use wind and solar generation as regulation resources in addition to use as a reserve resource. This provides additional value compared to a resource providing energy only. In combination, wind and solar used for energy and some level of regulation and reserve appears to be cheaper than the alternative of additional storage, at least at moderate over-generation levels. For the purposes of this PSIP Update, we include the full cost of the utility-scale wind and solar resources in cost calculations, regardless of over-generation levels and provide a simplified accounting for other services from these resources.

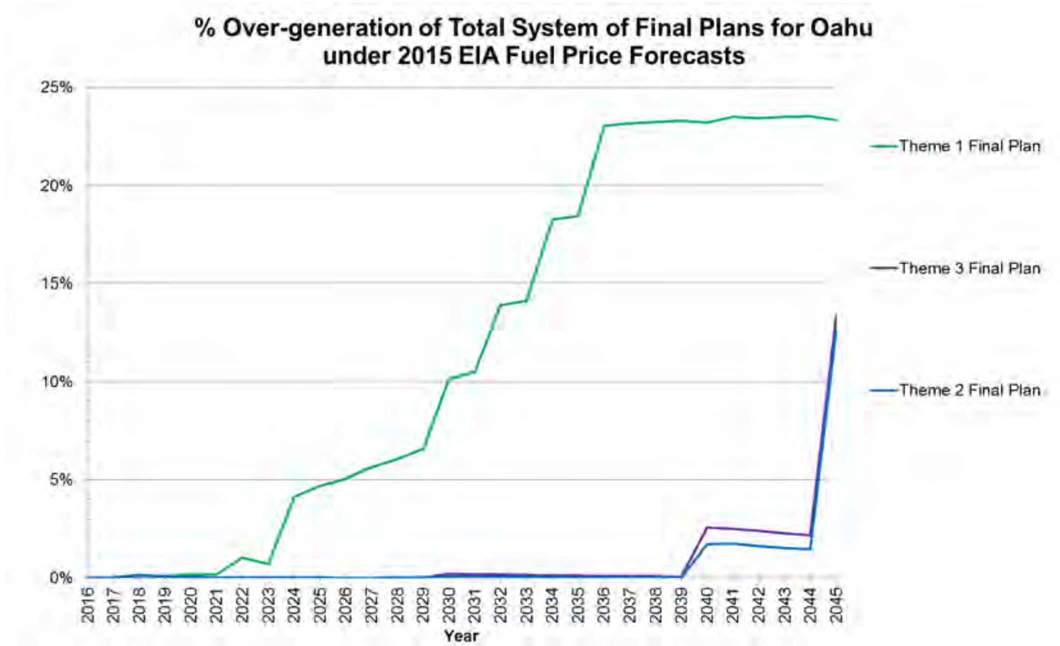


Figure 5-8. Percent Over-generation of Total System of Final Plans for O'ahu under the 2015 EIA Reference Fuel Price Forecasts

Similar estimates of the percent over-generation for the final plans under the February 2016 EIA STEO Fuel Price Forecasts is in Figure 5-9. Again, there isn't a visible difference between the two fuel price forecasts.

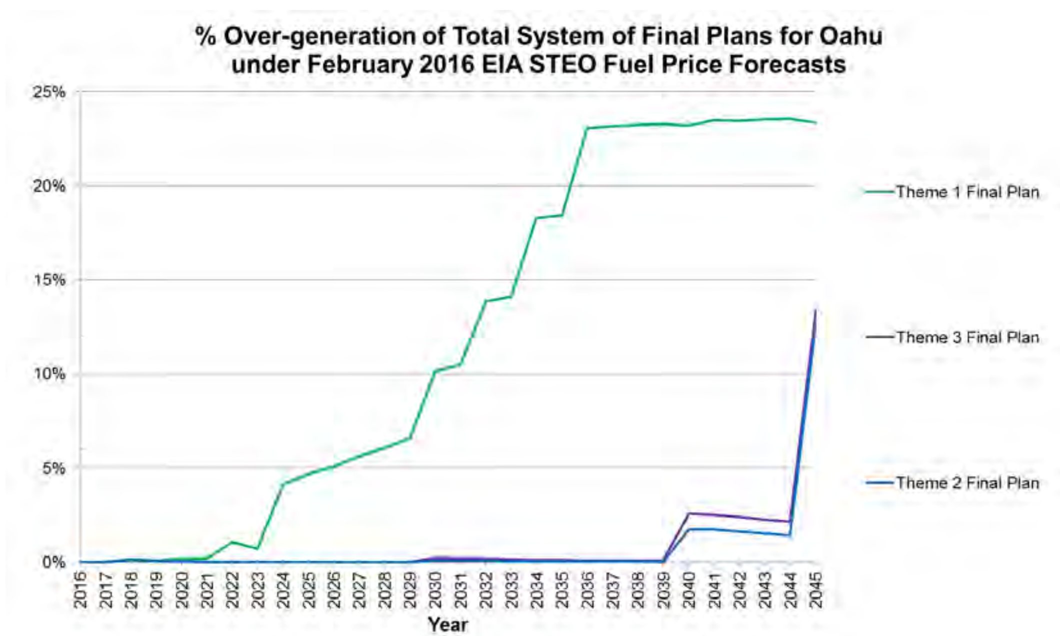


Figure 5-9. Percentage of Over-generation of Total System of Final Plans for O'ahu under the February 2016 EIA STEO Fuel Price Forecasts

TOTAL SYSTEM RENEWABLE ENERGY UTILIZED OF FINAL PLANS FOR O'AHU

The previous section discussed over-generation of energy provided by resources, but another view is to assess how much renewable energy is being utilized by the system. The year-by-year amount of renewable energy being utilized for Theme 1 is shown in Figure 5-10. Theme 1 is utilizing 100% of the renewable energy in the near term and slowly decreases to about 91% in 2030. The lowest amount utilized is about 78% in the later years (2036-2044) and the average over the entire 30 year period is about 85.5%. The results shown in Figure 5-10 is the same under both fuel price forecasts.

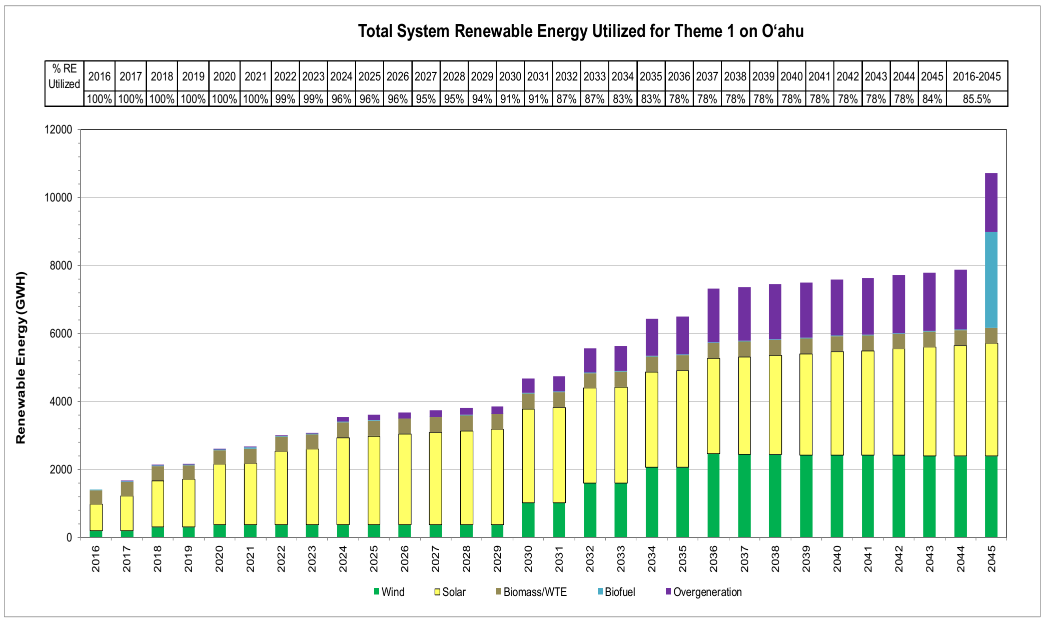
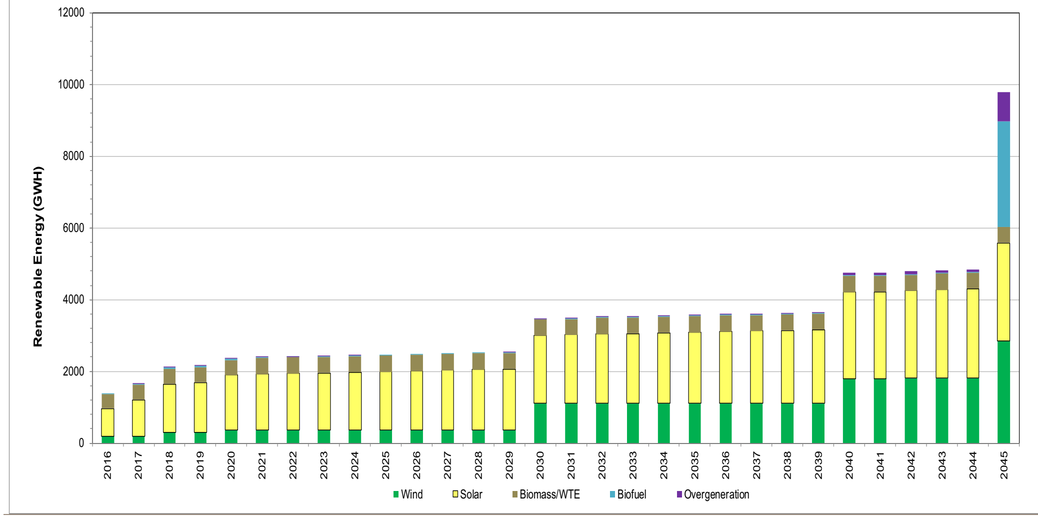


Figure 5-10. Total System Renewable Energy Utilized for Theme 1 on O'ahu

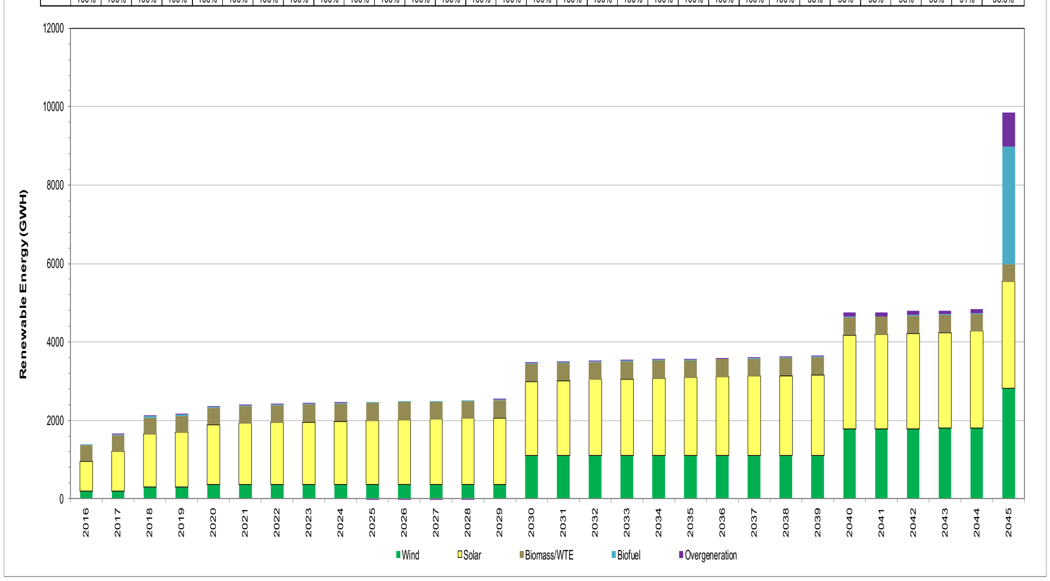
As shown in Figure 5-11, Theme 2 is utilizing 100% of the renewable energy available until about 2040. The lowest amount utilized is about 92% in 2045 and the average over the entire 30 year period is about 98.8%. The results shown in Figure 5-11 are the same under both fuel price forecasts.



% RE Utilized	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2016-2045
	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	98%	98%	99%	99%	99%	92%	98.8%

Figure 5-11. Total System Renewable Energy Utilized for Theme 2 on O‘ahu

Theme 3 has the same levels of renewable energy as Theme 2 and has very similar utilization of the energy. Figure 5-12 indicates that Theme 3 is utilizing 100% of the renewable energy available until about 2040. The lowest amount utilized is about 91% in 2045 and the average over the entire 30 year period is about 98.6%. The results shown in Figure 5-12 is the same under both fuel price forecasts.



% RE Utilized	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2016-2045
	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	98%	98%	98%	98%	98%	91%	98.6%

Figure 5-12. Total System Renewable Energy Utilized for Theme 3 on O‘ahu

DAILY ENERGY CHARTS OF FINAL PLANS FOR O'AHU

The charts in the previous sections displayed annual views of how renewable energy is being integrated into the final plans. This section will convey a more granular view by providing the energy mix for select days of some years of the final plans that were modeled.

All the final plans have the same starting point. Based on the modeling assumptions, the day with the highest penetration of solar energy is September 12, 2016 and

Figure 5-13. Modeled Energy Profile for September 12, 2016 of the Final Plans

provides a view of how much solar is being accepted on the system.

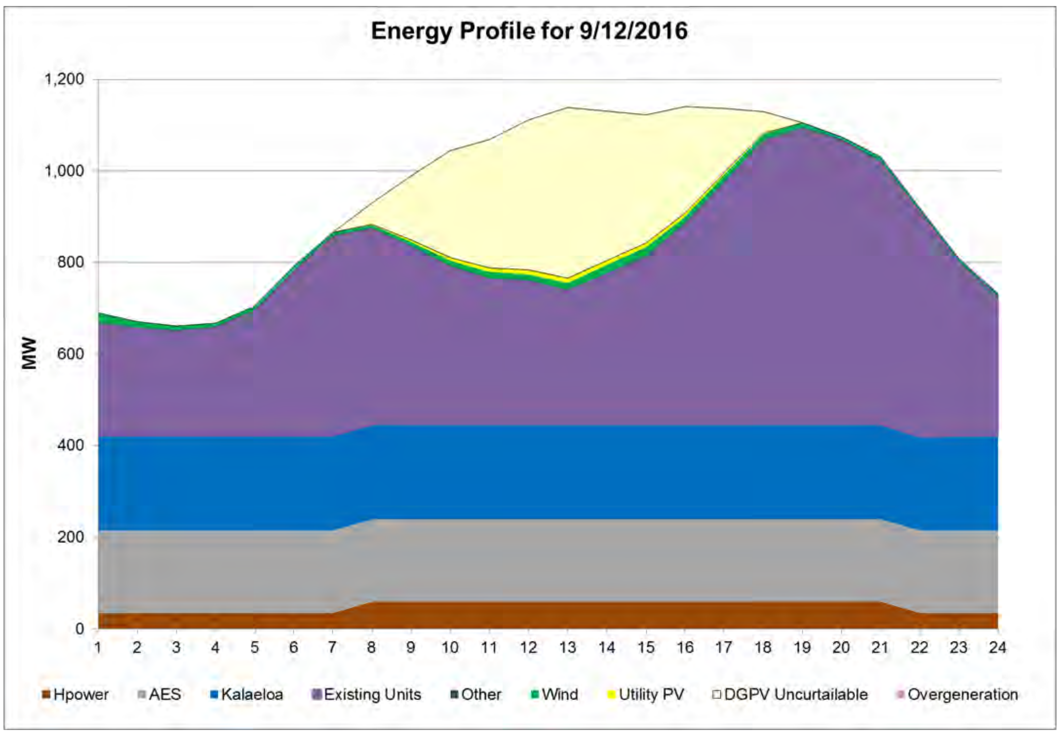


Figure 5-13. Modeled Energy Profile for September 12, 2016 of the Final Plans

Based on the modeling assumptions, the day with the highest penetration of wind energy is August 6, 2016. Figure 5-14 provides a view of how much wind is being accepted on the system.

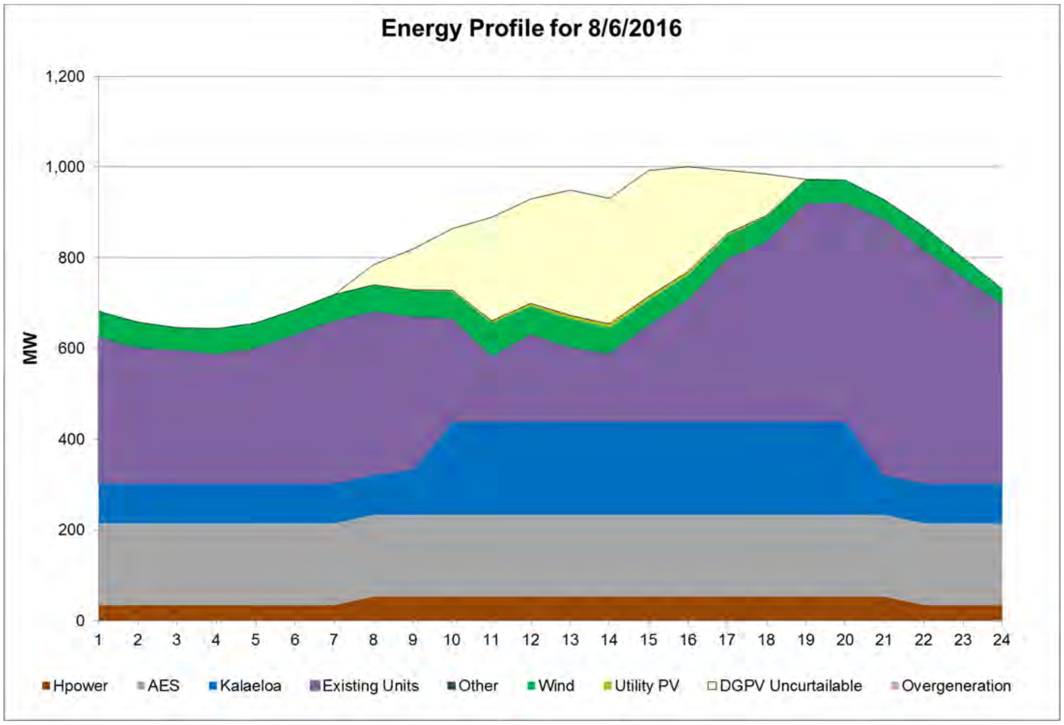


Figure 5-14. Modeled Energy Profile for August 6, 2016 of the Final Plans

In Theme 2, LNG becomes available from 2021. Based on the modeling assumptions, the day with the highest penetration of solar energy is June 6, 2021. Theme 1 includes the higher level of DG-PV; Figure 5-15 shows that there is over-generation in the middle of the day. Theme 2, shown in Figure 5-16, and Theme 3, shown in Figure 5-17, include the Market DG-PV forecast and does not have over-generation on this particular day. It can also be seen that Theme 2 has the 3x1 CC unit and LNG so the economic dispatch of the thermal generators are slightly different when compared to Theme 3.

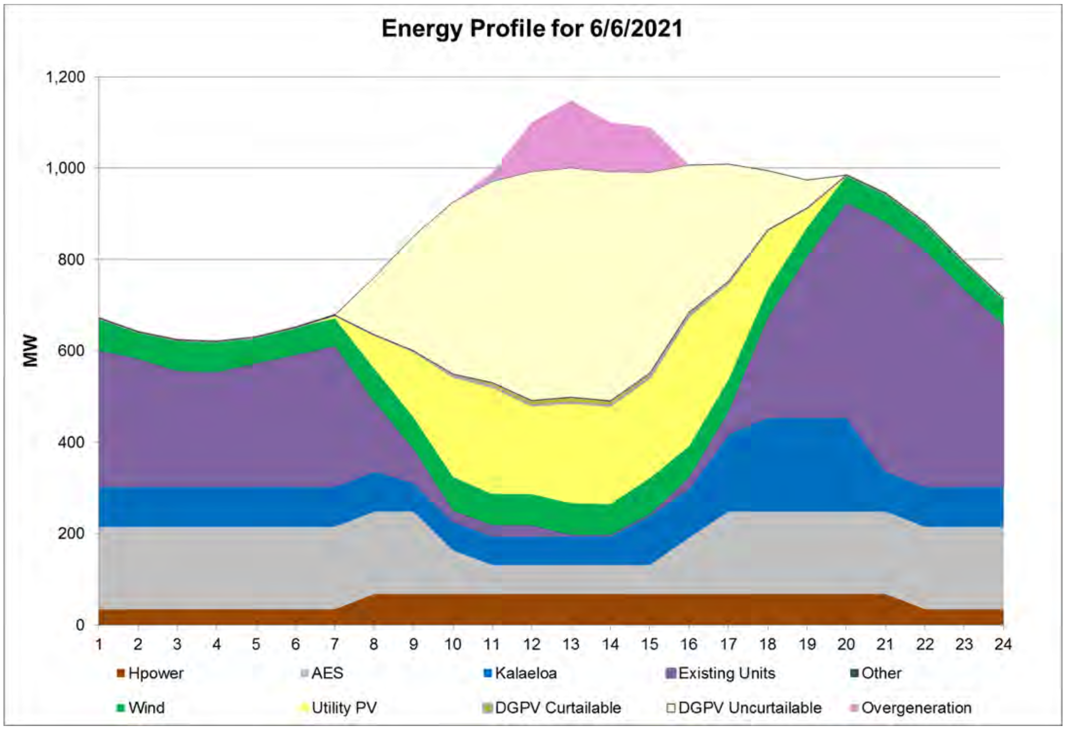


Figure 5-15. Modeled Energy Profile for June 6, 2021 of Theme 1

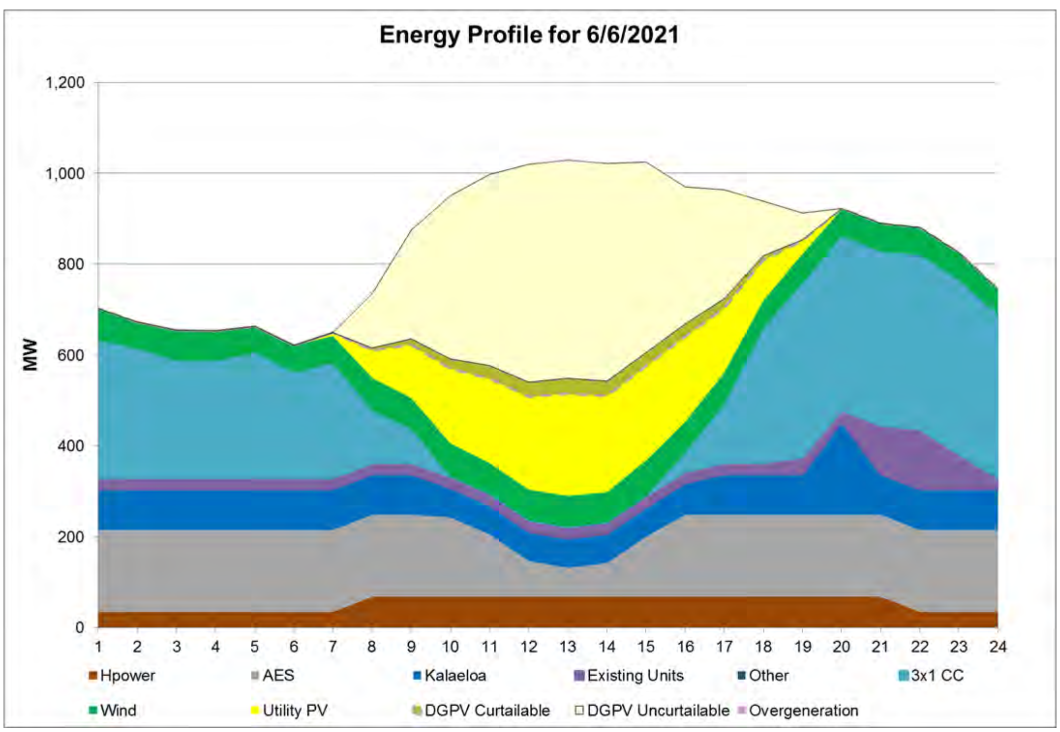


Figure 5-16. Modeled Energy Profile for June 6, 2021 of Theme 2

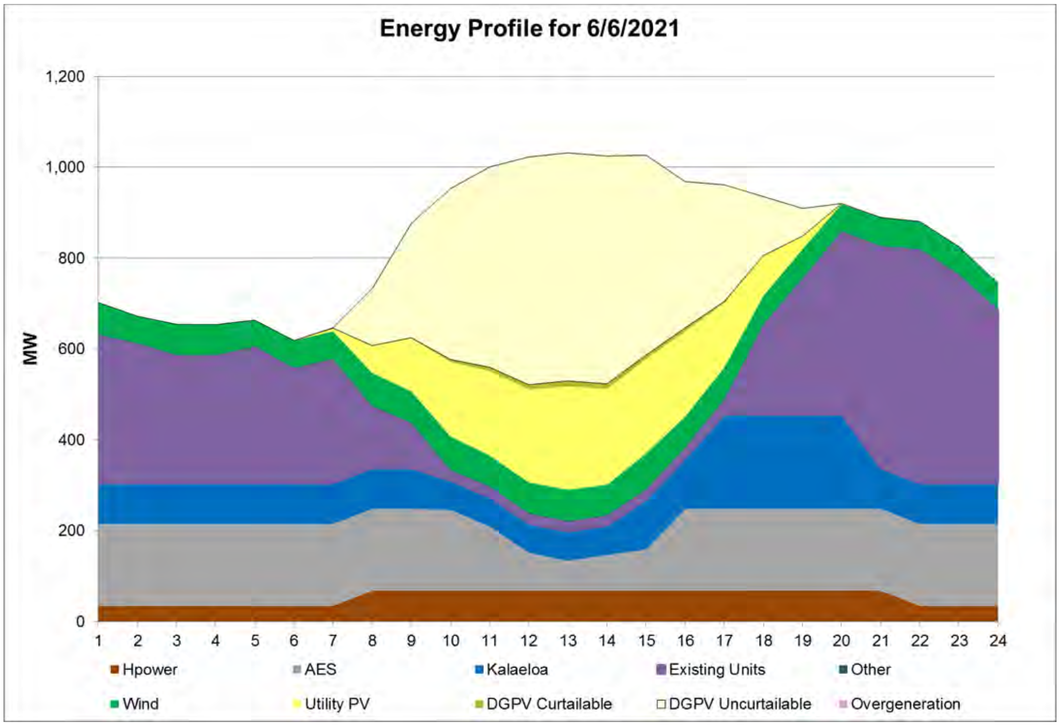


Figure 5-17. Modeled Energy Profile for June 6, 2021 of Theme 3

As indicated by the % over-generation and % renewable energy utilized presented earlier, higher levels of variable renewable generation will result in more instances where over-generation will occur. Looking out further in the planning period to 2030, the day with the highest penetration of solar energy is August 17, 2030 for Theme 1 as shown in Figure 5-18. There is over-generation of solar in the middle of the day under Theme 1.

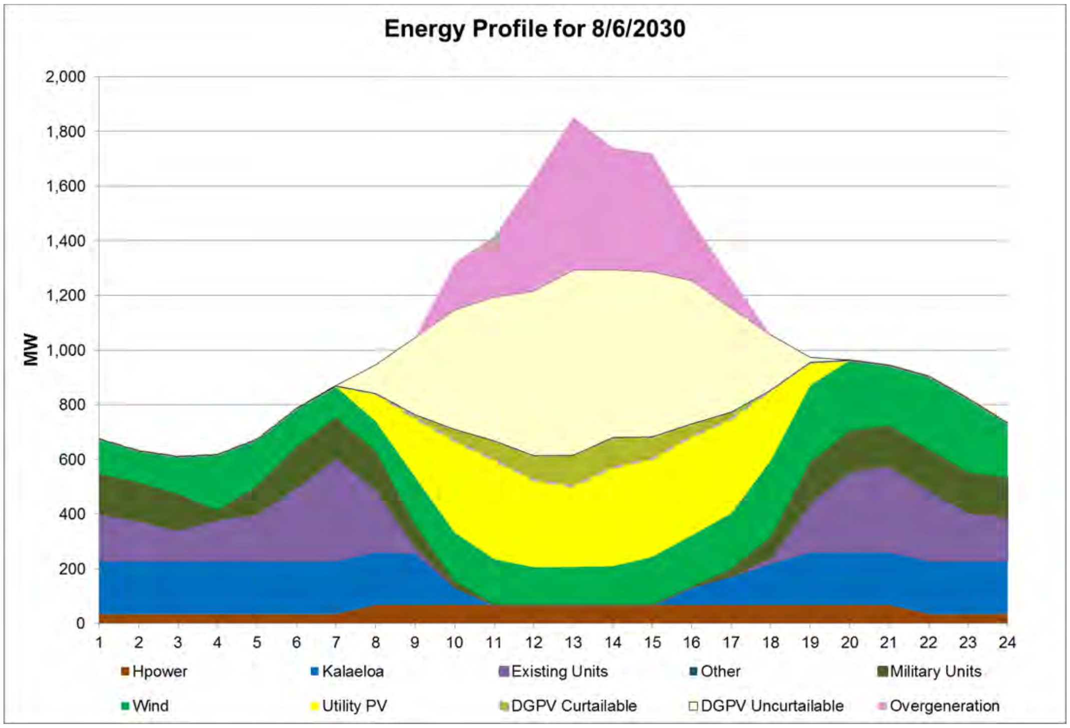


Figure 5-18. Modeled Energy Profile for August 6, 2030 of Theme 1

With the Market DG-PV, there is no visible over-generation in the middle of the day for Theme 2, shown in Figure 5-19, and small amounts of over-generation shown for Theme 3, in Figure 5-20.

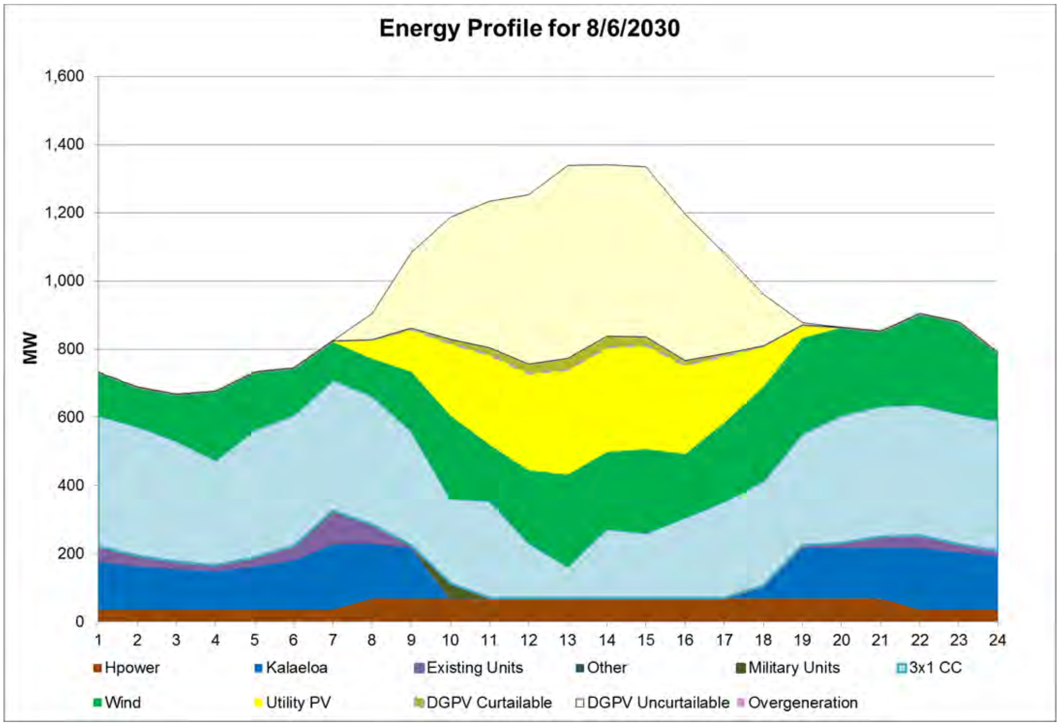


Figure 5-19. Modeled Energy Profile for August 6, 2030 of Theme 2

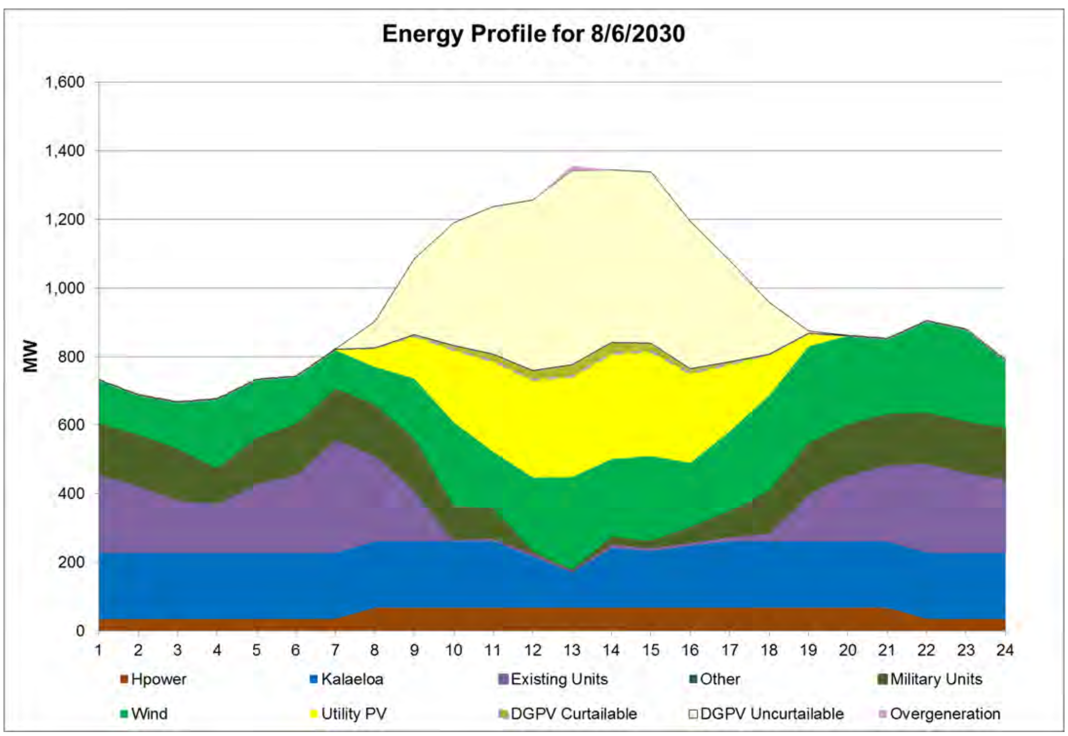


Figure 5-20. Modeled Energy Profile for August 6, 2030 of Theme 3

Moving towards 100% renewable in 2045, Figure 5-21 illustrates how most of the demand is being served by variable renewable energy but that there is a significant amount of over-generation for Theme 1 on the highest solar penetration day, August 19, 2045.

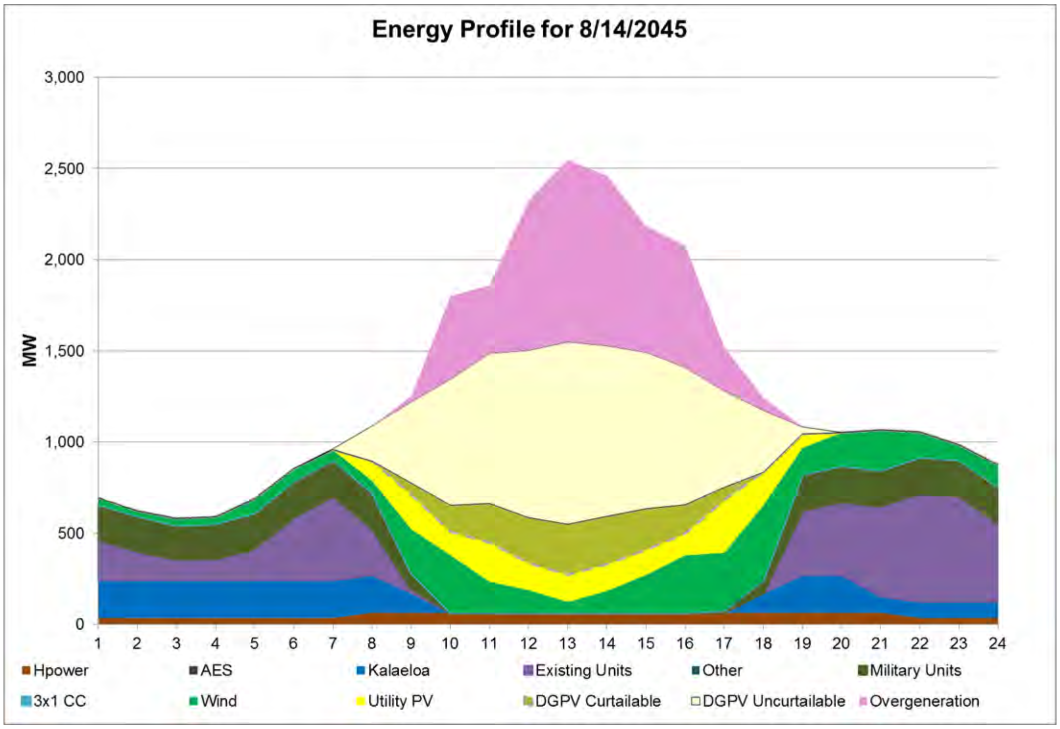


Figure 5-21. Modeled Energy Profile for August 14, 2045 of Theme 1

Although Theme 2 in Figure 5-22 and Theme 3 in Figure 5-23 have Market DG-PV, there is still significant over-generation in the middle of the day on this high solar day in 2045.

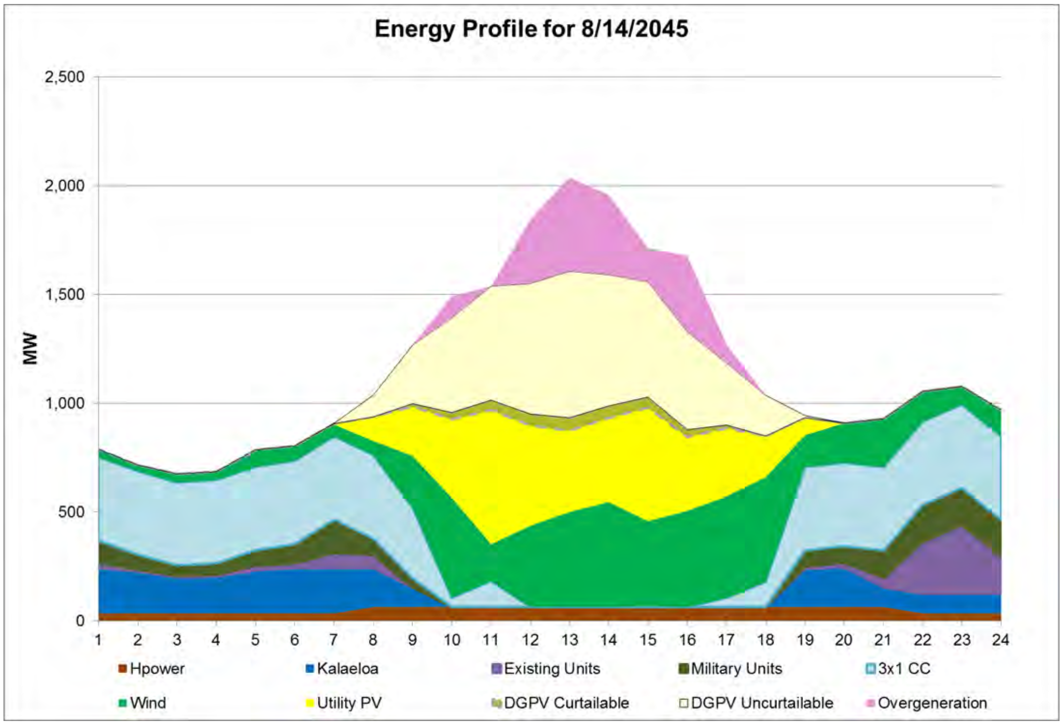


Figure 5-22. Modeled Energy Profile for August 14, 2045 of Theme 2

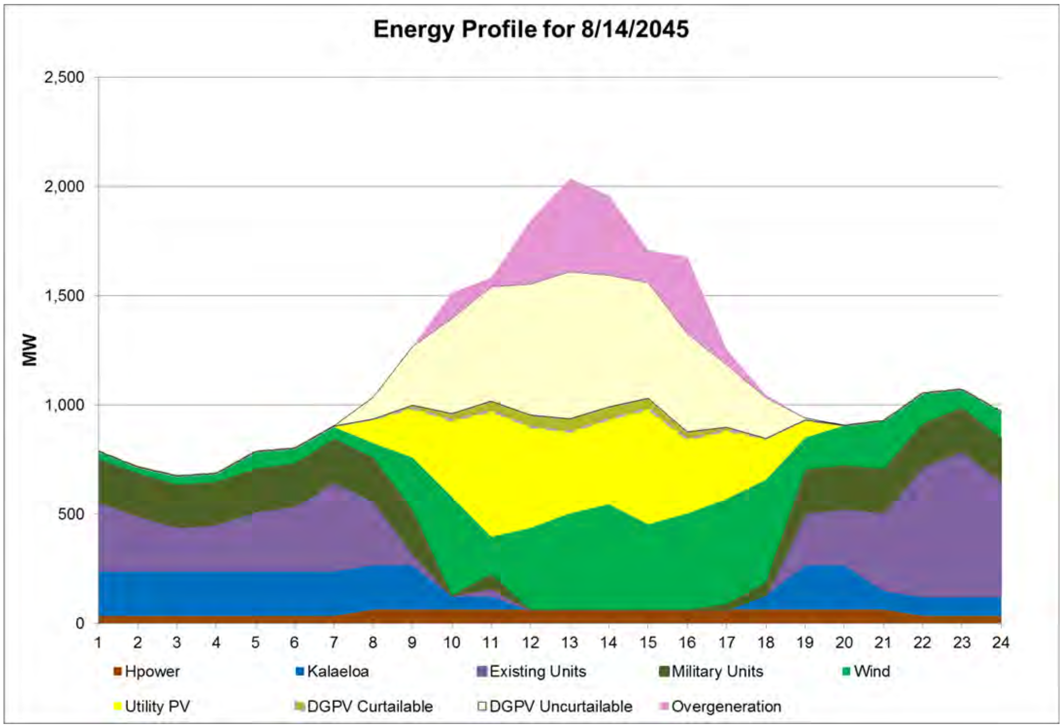


Figure 5-23. Modeled Energy Profile for August 14, 2045 of Theme 3

While it may appear in the charts that the amount of over-generation, if stored, could be used to displace a significant portion of the thermal generation using biofuels in 2045, the charts are not representative of all days in the year. The following charts are based on a day in 2045 that has the least amount of available generation from solar and wind. Figure 5-24 has minimal over-generation for Theme 1 and there is no over-generation for Themes 2 (Figure 5-25) and 3 (Figure 5-26) to store so thermal generation would be required to serve the demand.

The daily energy charts are a simple means to illustrate the complex and challenging issue of determining the "right size" of storage that makes economic sense. In the iterative process described in Chapter 3, there were cases analyzed that added varying amounts of storage and all cases with storage, based on the current cost assumptions, increased the total costs of the plan which is why all the final plans do not include load shifting storage.

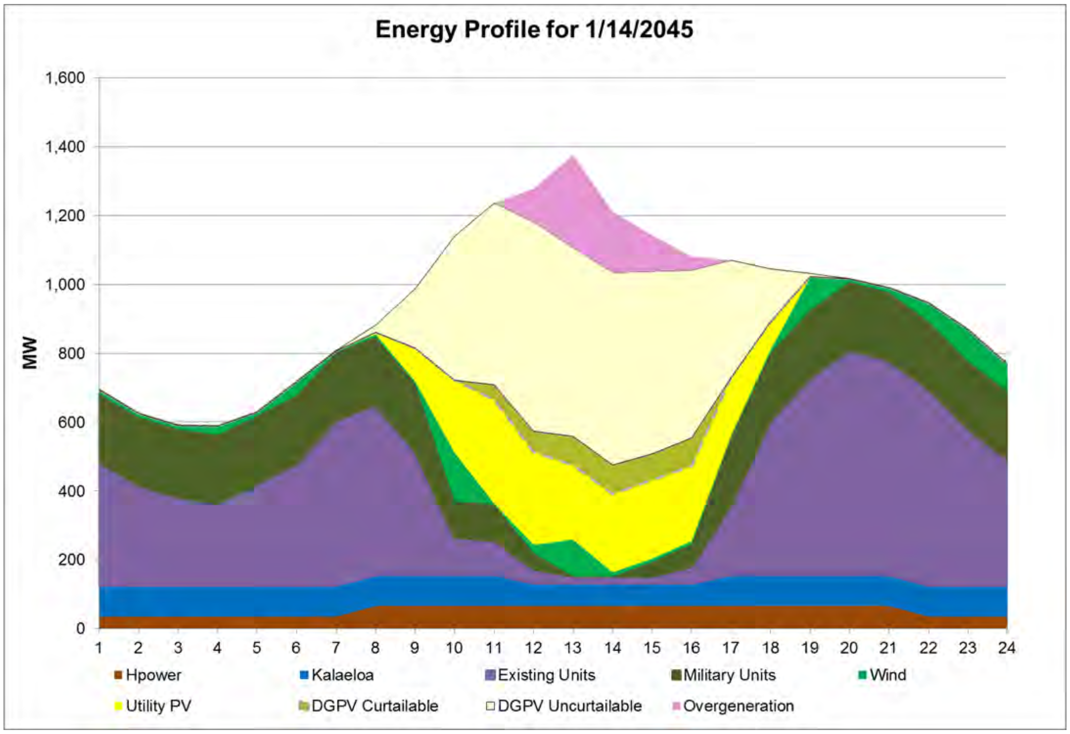


Figure 5-24. Modeled Energy Profile for January 14, 2045 of Theme 1

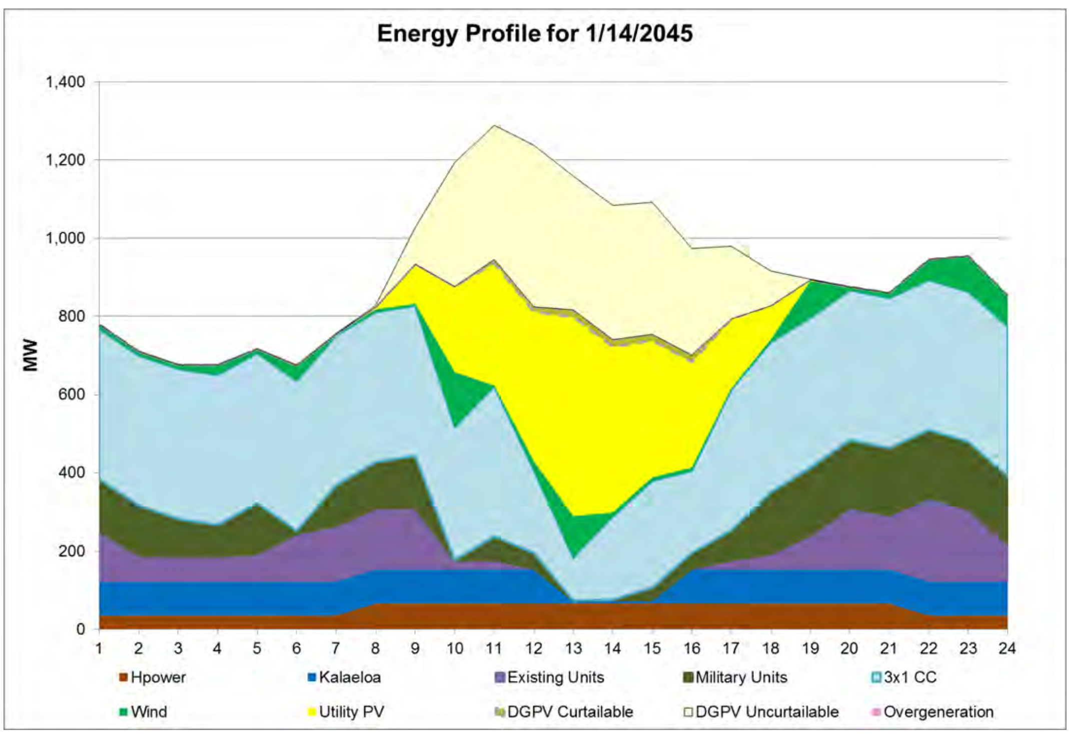


Figure 5-25. Modeled Energy Profile for January 14, 2045 of Theme 2

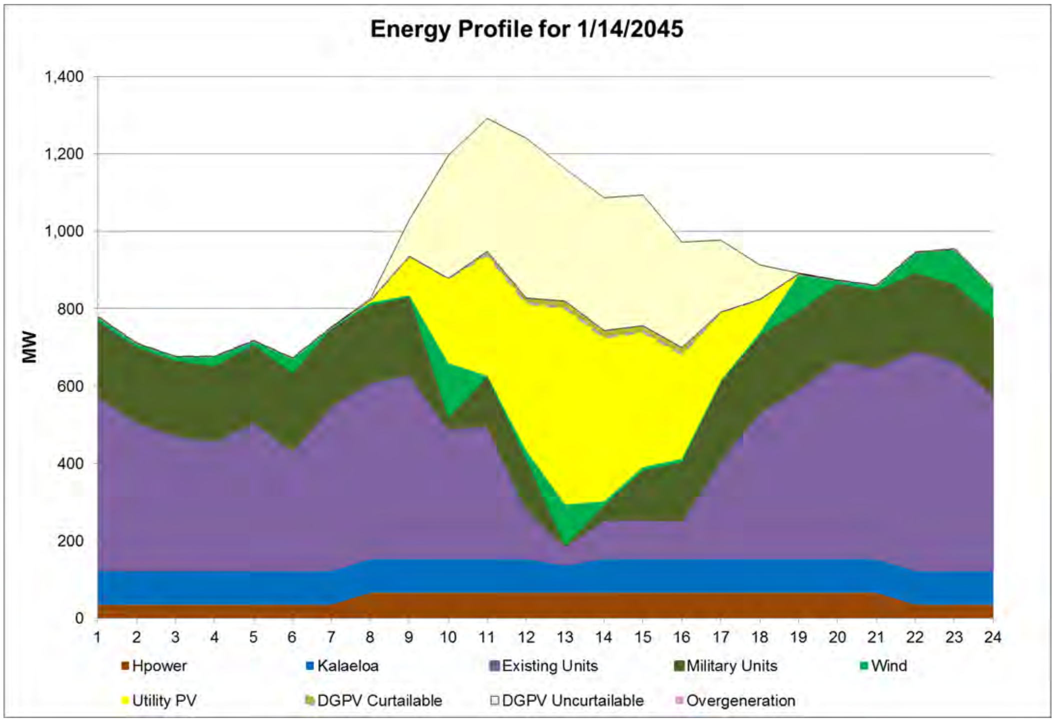


Figure 5-26. Modeled Energy Profile for January 14, 2045 of Theme 3

EMISSIONS OF FINAL PLANS FOR O‘AHU

The CO_2 emissions of the final plans were estimated and are shown in Figure 5-27. Theme 3 has the highest projected emissions among the three final plans since a bulk of the thermal generation remains on oil until 2045. Theme 1 has lower projected emissions than Theme 3 due to the increasing levels of renewables displacing oil. Theme 2 has the lowest projected emissions of all three themes as a result of a combination of modernized generation and switch to LNG. Although Theme 1 accelerates renewable resources earlier than in Theme 2, the offset of emissions is greater by switching from oil to LNG and by replacing existing thermal generation with an efficient combined cycle unit.

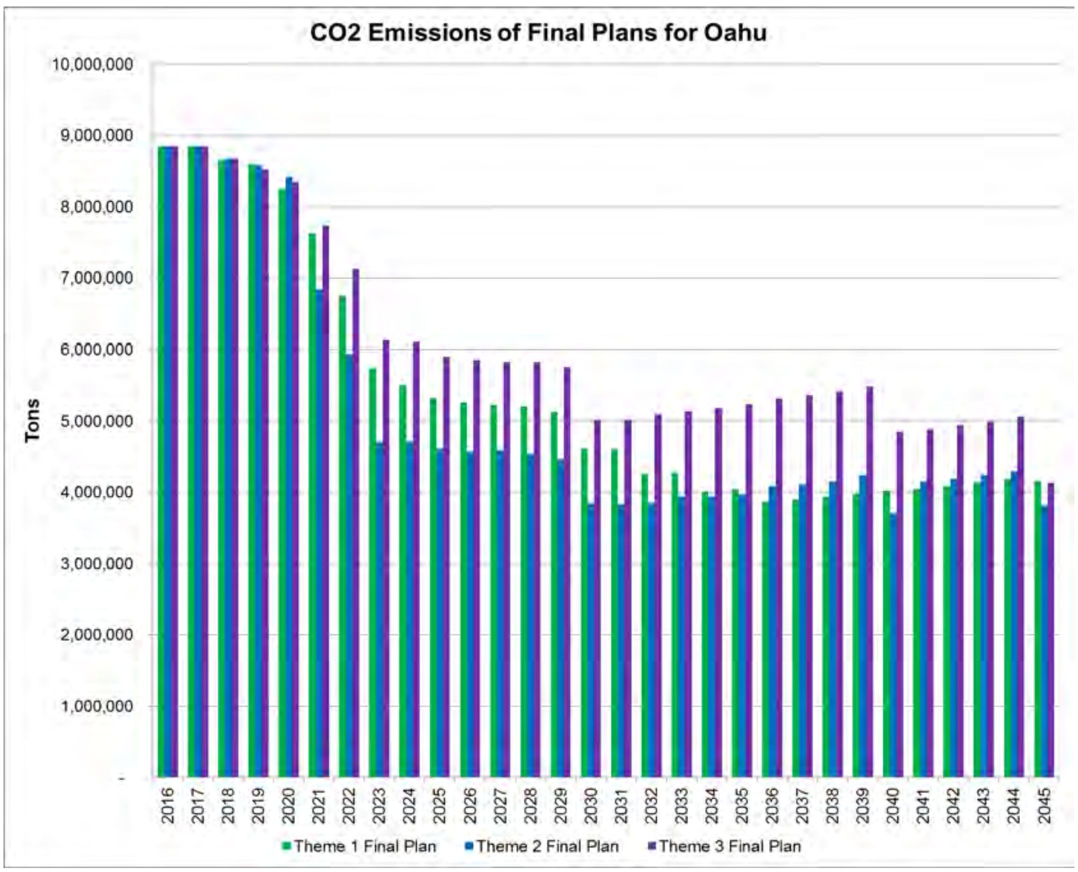


Figure 5-27. Estimated CO_2 Emissions of the Final Plans for O‘ahu

O‘AHU SELECTION OF THEME 2

The rigorous long-term analyses of the three themes provided insights on the different strategies for achieving 100% renewable energy by 2045. They provide directional guidance to inform the risks and the level of "no regrets" in short- term actions, particularly as you compare long-term resources across multiple themes. Although the steps along the paths to 2045 are different among the final plans, the starting point is the same. The purpose of the Preferred Plan is to inform the evaluation of specific near-term actions that are implementable based on the direction that the longer-term view of the plan provides. The Preferred Plan will balance technical, economic, environmental, and cultural considerations.

Based on the results of the analyses, Theme 2 will add a substantial amount of flexible, firm generation that will allow for the retirement of older generating units, incorporate significant amounts of variable renewable generation, and stabilizes customer bills by using lower cost fuel in the transition to 100% renewable.

5. Hawaiian Electric Preferred Plan

O'ahu Selection of Theme 2

Year	Preferred Plan (Final Plan from Theme 2)
2016	27.6 MW Waiver PV Project added 12/31/2016
2017	
2018	Six -8.14 MW Schofield Plants added Install 24MW NPM Wind 109.6 MW Waiver PV Projects added 1/1/2018 Install 15MW Onshore Solar PV (CBRE) Install 10 MW Onshore Wind (CBRE)
2019	90 MW Contingency BESS Convert Honolulu 8 & 9 to Synchronous Condensers
2020	Install 100MW JBPHH Plant, 12/2020 Kahe 1, 2, 3 Deactivated, 12/2020 Install 30MW of Onshore Wind Install 60MW of Onshore Solar PV
2021	Install 27 MW KMCBH Plant, 6/2021 Install 3x1 CC, 6/2021 LNG Units: K5-6, KPLP, 3x1CC
2022	AES Deactivated 9/2022 Waiau 3 & 4 Deactivated, 1/2022 Kahe 4 Deactivated, 1/2022
2023	
2024	Waiau 5 & 6 Deactivated, 1/2024
2025	
2030	Waiau 7 & 8 Deactivated, 1/2030 Install 100MW of Onshore Solar PV Install 200MW of Offshore Wind
2040	Install 200MW of Onshore Solar PV Install 200MW of Offshore Wind
2045	Install 300MW of Onshore Solar PV Install 400MW of Offshore Wind

Table 5-1. Hawaiian Electric Preferred Plan

6. Maui Electric Preferred Plan

Maui Electric developed this Preferred Plan for transforming the system from current state to a future vision of the utility in 2045 that is consistent with the Commission's Observations and Concerns.

Implementation of Maui Electric's Preferred Plan would safely transform the electric systems of Maui, Lana'i, and Moloka'i, and achieve unprecedented levels of renewable energy production. The electric systems of the future would integrate a balanced portfolio of renewable energy resources, thermal generation, energy storage, and demand response.

The Preferred Plan for the island of Maui increases variable renewable energy, and uses firm renewable sources to assist with the operation of the grid. Existing fossil-fuel steam generating units will be replaced with more flexible, fast-starting, cycling thermal generating units, and renewable firm generation is scheduled to displace existing fossil fuel generating units. The generators from retired steam generating units will be repurposed as synchronous condenser units to maintain fault current requirements and provide a level of rotating inertia. Demand response will also be used to further reduce fossil fuel utilization by providing ancillary services. The Preferred Plans for Lana'i and Moloka'i strive for accelerated energy independence with minimal reliance on imported liquid fuels.

Our vision will advance our systems towards our goal of decreasing fossil fuels, integrating more renewable energy, and maintaining system reliability. Our commitment to reshaping our systems will result in achieving 100% renewable generation by 2040.

The Preferred Plans outline the transformation that we will undertake to evolve into a utility of the future—meeting the current and future needs of the community and customers we serve. While specific resources are included in the Preferred Plan, we will continually seek more cost-effective, renewable resources to meet the needs of the system through a competitive process.

Maintaining flexibility in the resource options positions us to provide many alternatives to increase renewable energy while ensuring reliability to our customers. As we execute the Maui Preferred Plan we will incorporate more firm, cost-effective renewable resources, such as biomass and geothermal, and more variable renewable resources, such as wind and solar PV. We will take advantage of technology that can produce larger, centralized projects that can benefit the entire community, and also distributed energy resources (DER) projects that are sited at customers' residential and business premises.

Our plan also includes a non-transmission alternative for the South Maui Area. Firm generation is proposed for South Maui to support the electrical system instead of new overhead transmission infrastructure. Initially, our plan includes internal combustion engines to meet the firm generation need. The internal combustion engines proposed for South Maui may be candidates for relocation to Central Maui when the firm capacity renewable generation in South Maui is commercialized. Other non-transmission alternative such as combined PV/battery systems or wind/battery systems that are able to provide firm power on command in the South Maui area are also candidates.

Our plan selectively chose cost effective renewable resources using a relative comparison based on capital, O&M costs, and energy utilization. This provided a plan that considered both cost and risk while meeting (and exceeding) renewable energy goals. Evaluation of curtailment with respect to cost savings was also incorporated in the plan development. Curtailed variable renewable resources were still found to be cost effective when compared to storage options and the curtailed energy provides regulation and other ancillary services beneficial to grid operations.

The following resources were identified as low cost options, as shown in Figure 6-1:

- Wind is the lowest cost resource
- Biomass, Geothermal and Utility scale PV were the next lowest cost resources. These three resources were cost competitive against one another.
- Biomass and Geothermal provides firm, dispatchable power, more valuable to the grid at costs comparable to PV.

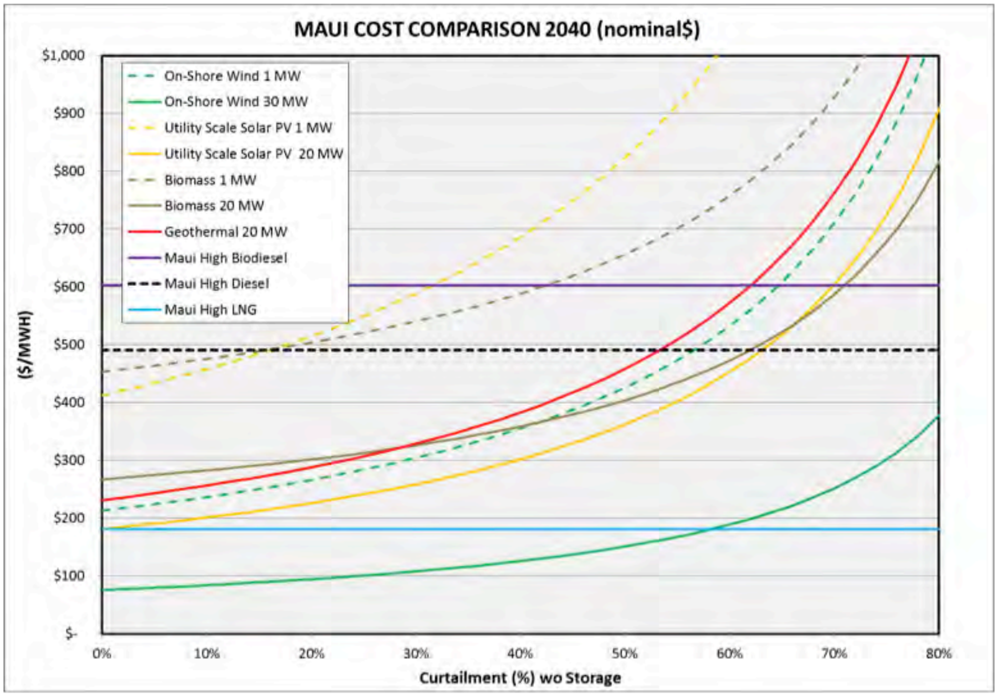


Figure 6-1. Forecasted Resource Cost Comparison: Maui 2040

Maui Preferred Plan

Maui Electric's Maui Division Preferred Plan is referred to as Theme 2 in Chapter 3, which meets interim RPS mandates across the Hawaiian Electric service areas and achieves 100% RE in 2040 on Maui while balancing the use of both fuel and non-fuel burning RE, and uses LNG. Because NextEra Energy's financial backing is required to implement Theme 2, this Theme can be considered a "merged" scenario where the proposed merger of the Companies and NextEra Energy is completed.

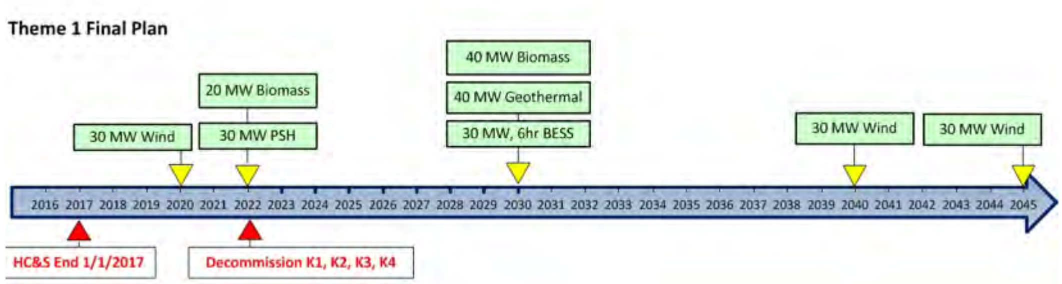


Figure 6-2. Maui Final Plans - Schedule of Resources: Theme 1

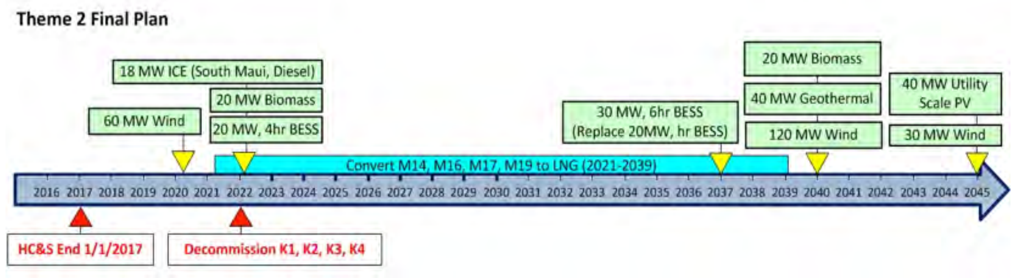


Figure 6-3. Maui Final Plans - Schedule of Resources: Theme 2

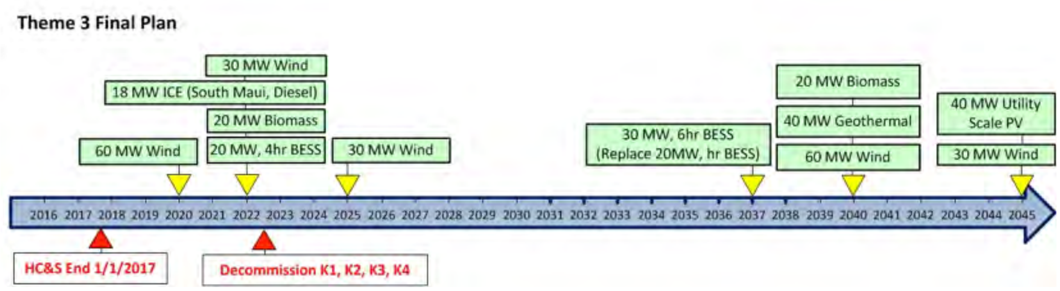


Figure 6-4. Maui Final Plans - Schedule of Resources: Theme 3

EMISSIONS OF FINAL PLANS FOR MAUI

The CO_2 emissions of the final plans were estimated and are shown in Figure 6-3 below. Theme 3 has the highest projected emissions among the three final plans since a bulk of the thermal generation remains on fossil fuel until 2039. Theme 2 has lower emissions with the switch to LNG. Theme 1 has the lowest projected emissions due to the increasing levels of renewables displacing fossil fuels.

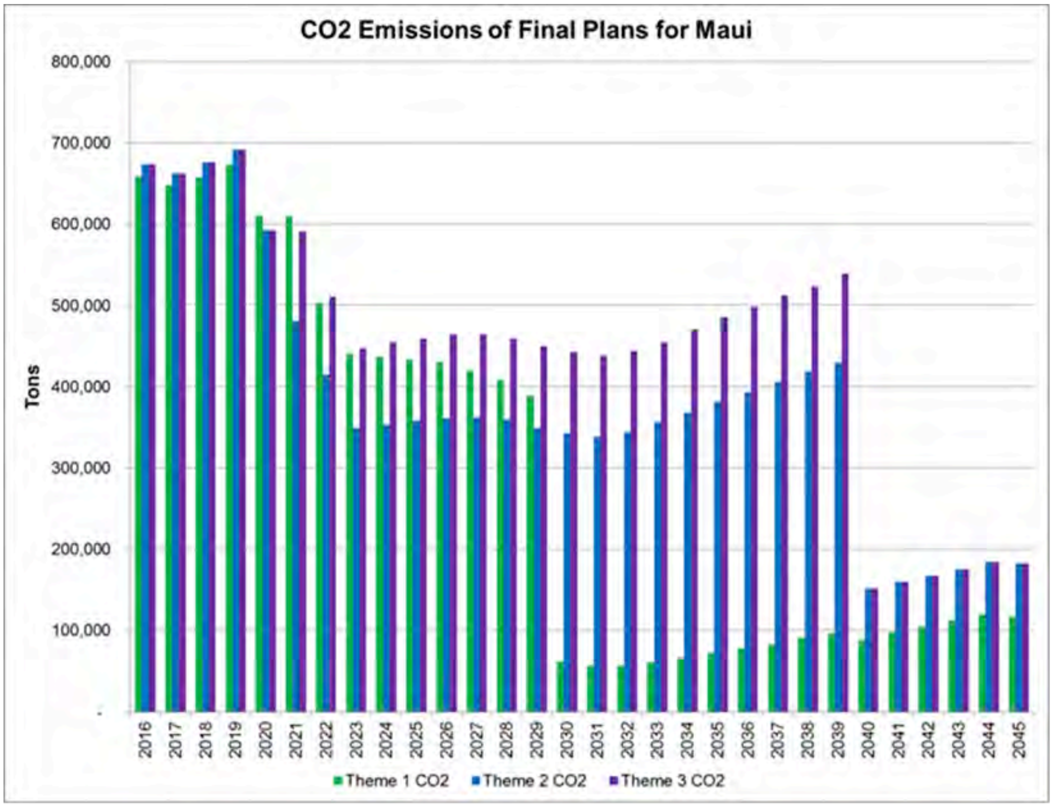


Figure 6-5. CO2 Emissions of Final Plans for Maui

ENERGY MIX OF FINAL PLANS FOR MAUI

Our commitment to reshaping our systems will result in Renewable Portfolio Standards (RPS) meeting or exceeding the requirement of 70% by 2040, and a vision of energy independence from fossil fuel by 2045 and possibly as early as 2040.

All of Maui Electric's Final Plans will add significantly more renewable energy to meet or exceed the mandated Consolidated RPS targets in 2020, 2030, and 2040. Our Consolidated RPS is planned to meet or exceed the 70% RPS by 2040 before transitioning to fully renewable energy electrical system by 2045.

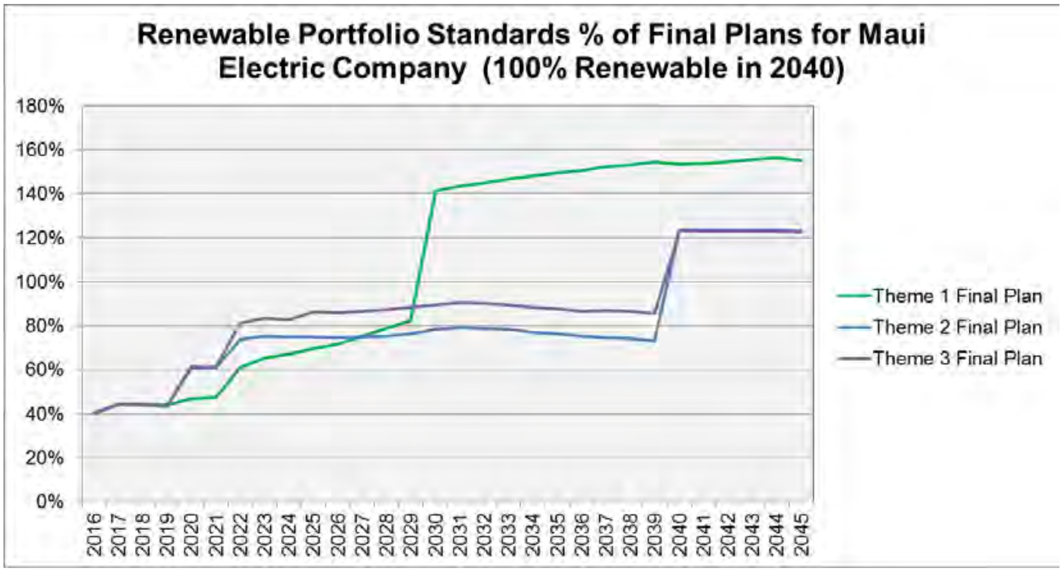


Figure 6-6. Renewable Portfolio Standards Percent of Final Plans for Maui (100% Renewable in 2040)

The Maui Preferred Plan will change over time to convert thermal units to LNG and incorporate greater amounts of renewable energy out to 2045. The figures that follow shows how the resource mix of the three Maui themes vary in generation and transforms over time. The accelerated transition to renewable resources of Theme 1 final plan can be seen in Figure 6-2 for the plan under the 2015 EIA Reference Fuel Price Forecasts and Figure 6-3 for the plan under the February 2016 EIA STEO Fuel Price Forecasts. The plan adds pumped storage hydro, biomass and geothermal resources to compliment increasing amounts of wind and High DG-PV resources. Theme 1 achieves 100% renewable energy on Maui by 2030 with the addition of geothermal and biomass resources along with biodiesel switching for conventional generation. Under both the 2015 EIA and February 2016 STEO Fuel Price Forecasts, the system resource energy mix are identical.

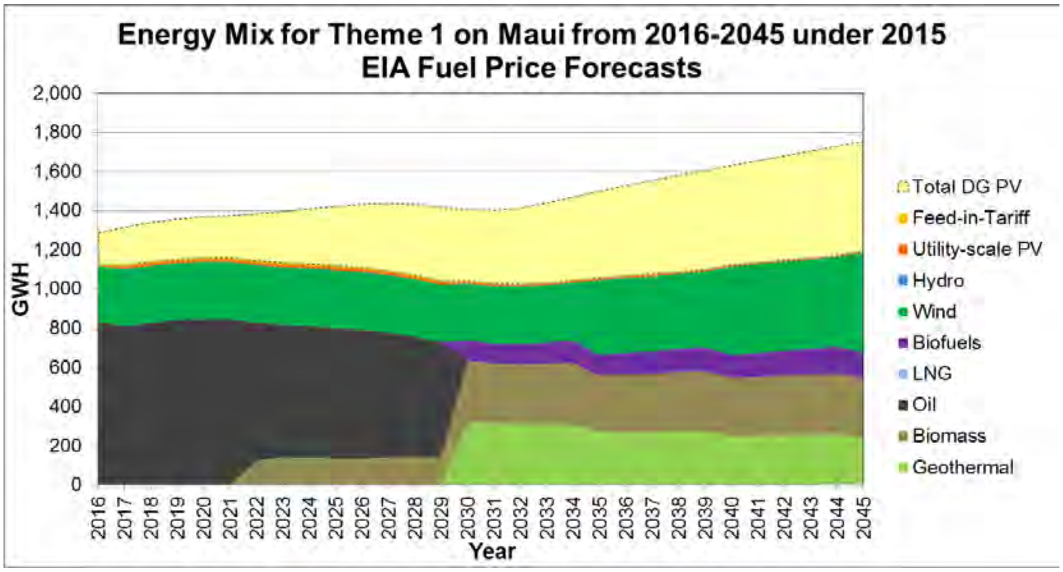


Figure 6-7. Energy Mix for Theme 1 on Maui from 2016-2045 under 2015 EIA Fuel Price Forecasts

Theme 2 final plan incorporates LNG as a transitional fuel as shown in Figure 6-4 for the plan under the 2015 EIA Reference Fuel Price Forecasts and Figure 6-5 for the plan under the February 2016 EIA STEO Fuel Price Forecasts. LNG fueling of the combined-cycle units at Ma'alaea allows for the reduction of oil use from 2021 to 2039 on Maui. The addition of biomass, wind, and geothermal resources along with biodiesel switching for conventional generation achieves 100% renewable energy on Maui in 2040. Under both the 2015 EIA and February 2016 STEO Fuel Price Forecasts, the system resource energy mix are identical.

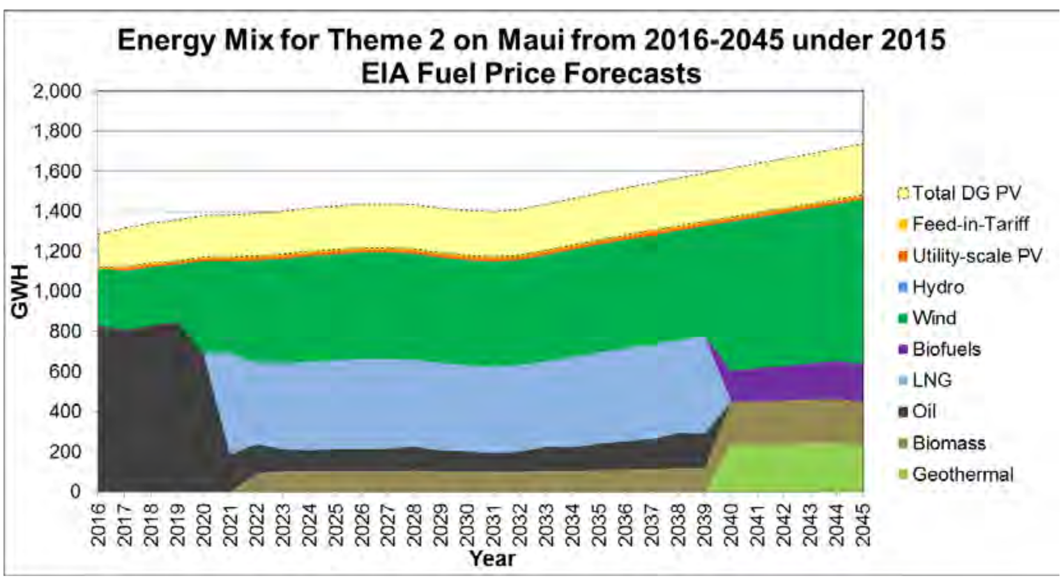


Figure 6-8. Energy Mix for Theme 2 on Maui from 2016-2045 under 2015 EIA Fuel Price Forecasts

Theme 3 final plan economically incorporates renewable resources and continues to use oil instead of LNG as shown in Figure 6-6 for the plan under the 2015 EIA Reference Fuel Price Forecasts and Figure 6-7 for the plan under the February 2016 EIA STEO Fuel Price Forecasts. The addition of wind resources in 2022 and 2025 results in oil use reduction from 2020 to 2039 on Maui. The addition of geothermal, biomass and wind resources along with biodiesel switching for conventional generation achieves 100% renewable energy on Maui in 2040. Under both the 2015 EIA and February 2016 STEO Fuel Price Forecasts, the system resource energy mix are identical.

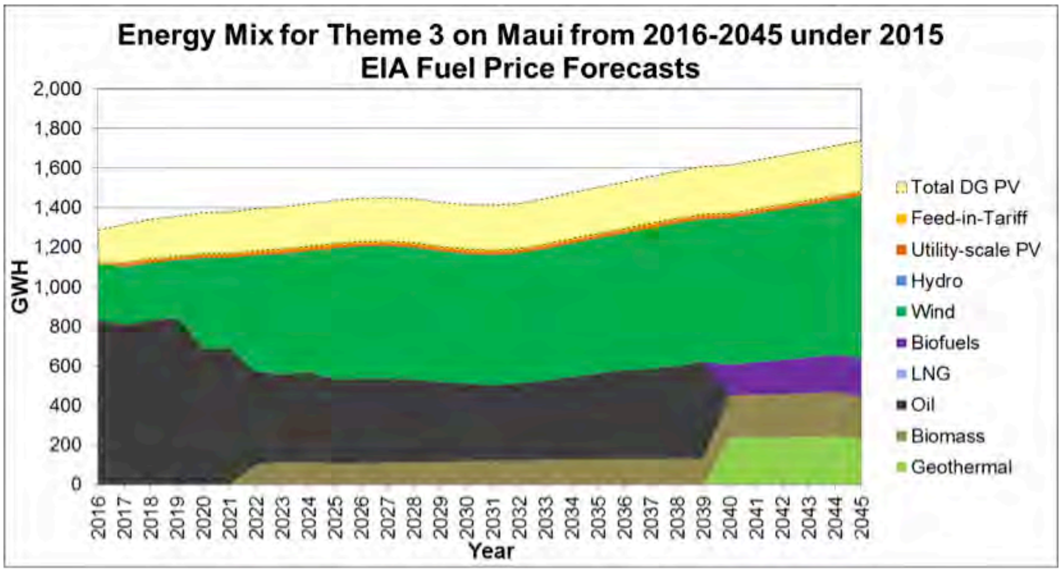


Figure 6-9. Energy Mix for Theme 3 on Maui from 2016-2045 under 2015 EIA Fuel Price Forecasts

The generation mix in all themes has increasing levels of renewable energy replacing fossil generation. Renewable energy from distributed PV continues to grow over time and new wind, biomass and geothermal are also added to the system. As existing firm generating units are decommissioned, new flexible firm generation is added in its place.

TOTAL SYSTEM RENEWABLE ENERGY UTILIZED OF FINAL PLANS FOR MAUI

The extent to which renewable energy can be utilized on Maui will depend on factors such as the total system load or energy demand, the amount of downward regulation that must be carried on the system to counteract an unexpected loss of load, the total output from variable generation resources, and the position of the variable generation resource in the curtailment sequence. In all Themes Maui Electric strives for high utilization of renewable energy on the system to achieve 100% RE. Under both the 2015 EIA and February 2016 STEO Fuel Price Forecasts, the total system renewable energy utilization are identical.

Renewable Energy Utilization

% RE	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2016-2045
Utilized	97%	98%	99%	98%	92%	93%	99%	99%	98%	98%	97%	97%	95%	94%	93%	92%	92%	92%	92%	91%	91%	91%	91%	91%	87%	86%	86%	86%	86%	82%	91%

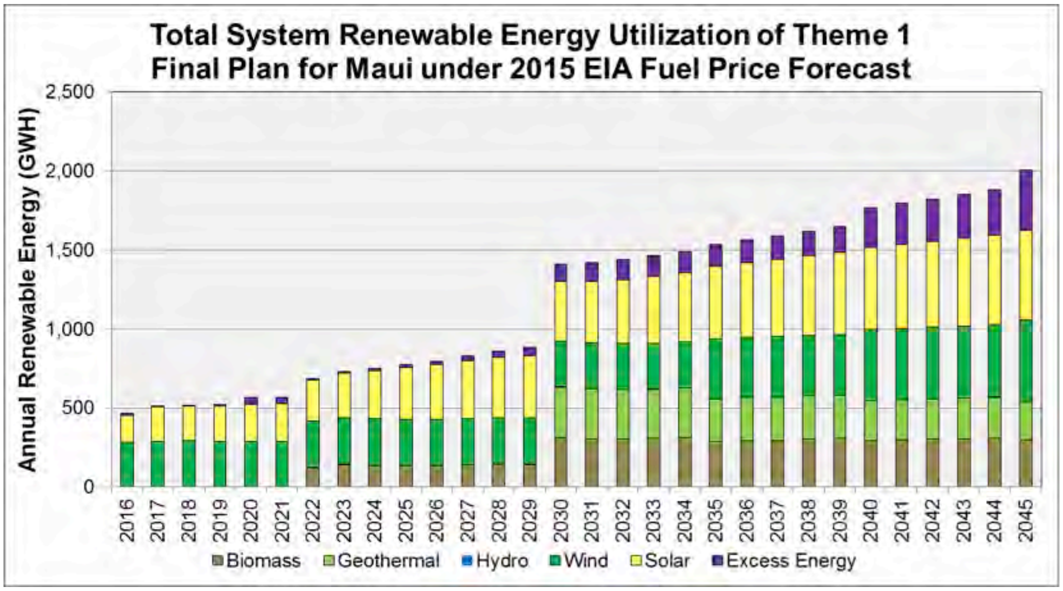


Figure 6-10. Total System Renewable Energy Utilization of Theme 1 Final Plan for Maui Under 2015 EIA Fuel Price Forecast

Renewable Energy Utilization

% RE	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2016-2045
Utilized	98%	99%	99%	97%	87%	87%	94%	96%	96%	97%	97%	97%	96%	96%	96%	96%	96%	97%	97%	98%	98%	98%	99%	99%	82%	83%	84%	84%	85%	82%	91%

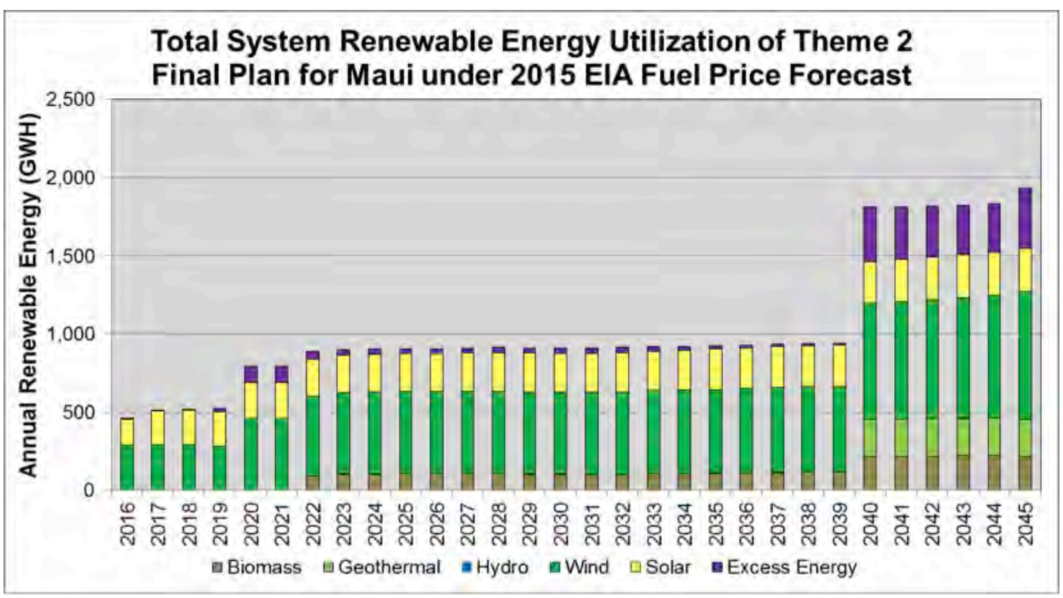


Figure 6-11. Total System Renewable Energy Utilization of Theme 2 Final Plan for Maui Under 2015 EIA Fuel Price Forecast

Renewable Energy Utilization

% RE	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Utilized	98%	99%	99%	98%	86%	87%	90%	92%	92%	86%	87%	87%	86%	86%	86%

% RE	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2016-2045
Utilized	86%	86%	87%	88%	88%	89%	90%	91%	92%	82%	83%	83%	84%	84%	83%	87%

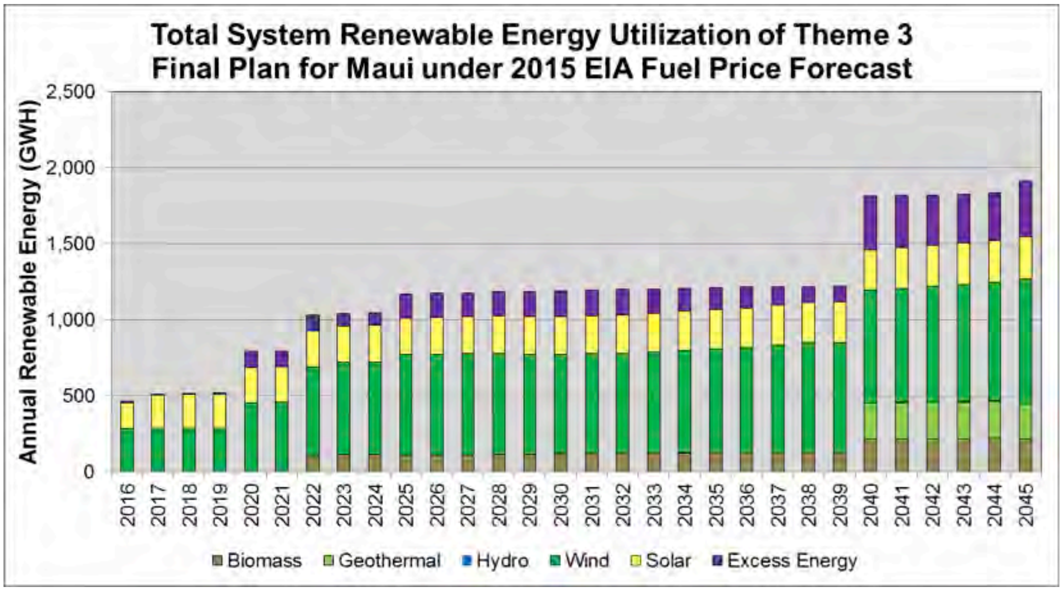


Figure 6-12. Total System Renewable Energy Utilization of Theme 3 Final Plan for Maui Under 2015 EIA Fuel Price Forecast

PERCENT OVER-GENERATION OF TOTAL SYSTEM OF FINAL PLANS FOR MAUI

The Maui Electric system has greatly increased the amounts of variable generation that can be utilized. By acquiring additional new flexible firm renewable generation along with increasing wind generation, lower levels of curtailment are achieved during low demand periods (which may occur during daytime hours due to influence of DG-PV, as well as during typical night time low load hours). However, even with these improvements, non-firm renewable generation such as wind is occasionally available in quantities that cannot be effectively utilized by the system. A combination of reducing must-run generation and adding load shifting energy storage in 2022 significantly reduced curtailment.

However, situations of over-generation are not fully eliminated and provide opportunities, coupled with appropriate controls systems, to use wind and solar generation as regulation resources in addition to use as a reserve resource. This provides more value than a resource providing energy only. In combination, wind and solar used for energy and some level of regulation and reserve appear to be cheaper than the alternative of additional storage, at least at moderate over-generation levels. For the purposes of this PSIP update, we include the full cost of the utility scale variable generation resources in cost calculations, regardless of over-generation levels and provides a simplified accounting for other services from these resources.

Figure 6-13 shows the annual levels of curtailment on the Maui system for each Theme. Under both the 2015 EIA and February 2016 STEO Fuel Price Forecasts, the total system renewable energy utilization are identical.

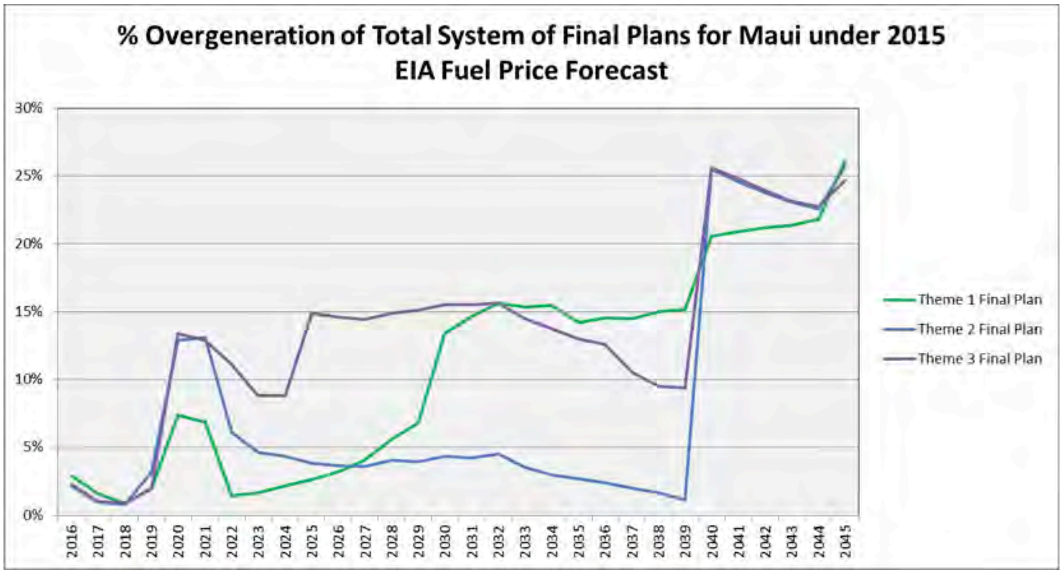


Figure 6-13. Percent Over-Generation of Total System of Final Plans for Maui under 2015 EIA Fuel Price Forecast

DAILY ENERGY CHARTS OF FINAL PLANS FOR MAUI

The utilization of renewable energy is mostly dependent on the system load, amount of available renewable generation, and must-run generation. For example, the greater the system load, the more opportunity exists to utilize renewable energy. Conversely, a lower system load would restrict the utilization of renewable energy. In addition, when renewable generation is not available, then other resources, such as liquid fuel generation, will be required to meet the system load.

Historically, wind and solar have seasonal tendencies with respect to the amount of available generation produced. As shown in the following figure, the Maui wind and solar resources tend to have more generation in the months of March to October. Therefore, as wind and solar resources are added to the Maui system, then a lower percentage of renewable energy is utilized. In the months of November to February, without significant quantities of wind and solar, the system load will not be able to be met by variable renewable energy alone.

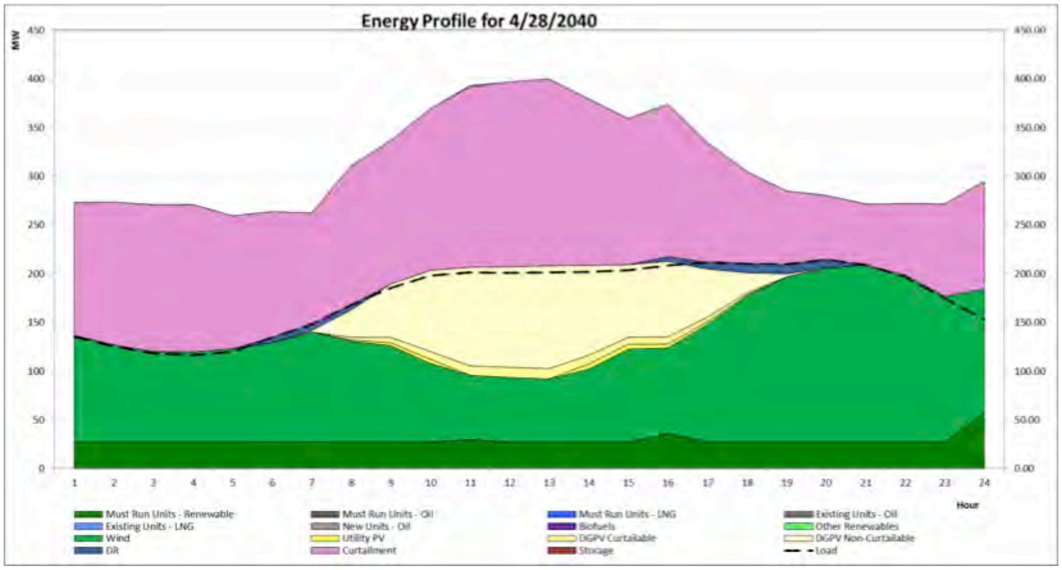


Figure 6-14. Seasonal Potential Renewable Energy Profile

Conceptually, if the amount of wind and solar energy generated in a year is equal to the total annual system load, then there would be enough renewable energy to serve the load on an annual basis. However, due to the seasonal tendency of wind and solar, there would be an imbalance from month to month. A storage component would be required to shift the load over seasons in order to utilize all the renewable energy. This is "seasonal energy shifting". In the figure below, the dashed line represents the seasonal monthly load. Periods where the potential renewable resource energy falls under the load, indicates periods where there is an insufficient amount of renewable generation to serve the load. Periods where the potential renewable resource energy is above the load, indicates periods where there is excess renewable generation.

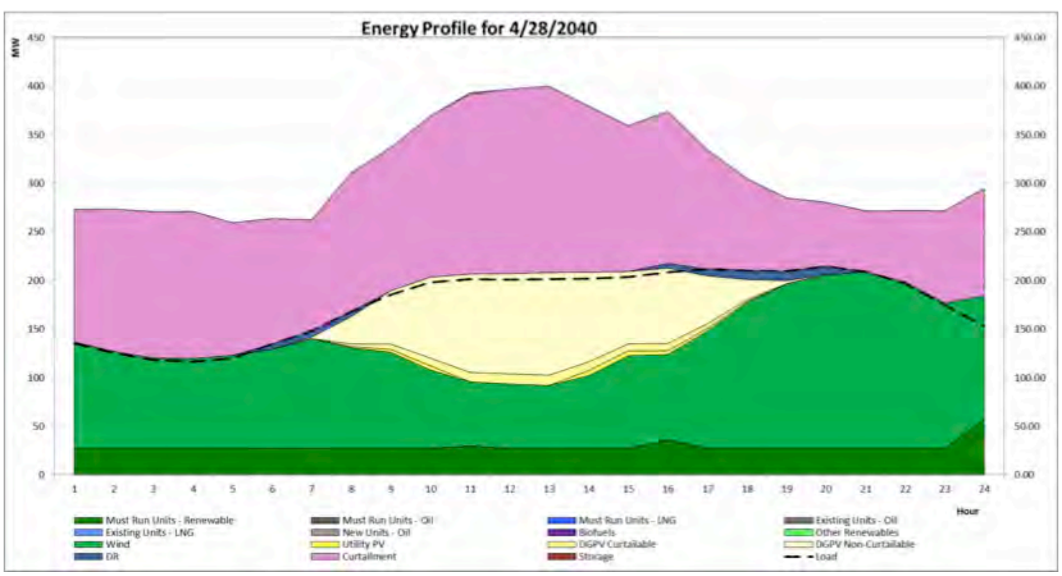


Figure 6-15. Seasonal Potential Renewable Energy Profile and System Load

Load shifting resources that have the ability to charge over the March to October period, store the energy over an extended period of time, and then discharge in the months of November to February could conceivably provide a solution. For example, if there is 170 GWh of annual curtailed energy, then storage technology of approximately 230 units at 30 MW with operation duration of 24 hours would be required for the seasons that have insufficient renewable energy to serve the load. This would essentially eliminate curtailment for the entire year and potentially eliminate the need to operate conventional generation. However, the larger the storage requirement, the greater the cost will be. An approximate cost of the battery energy storage system would be $40 billion based on a cost of $246/kWh in 2045. This example shows that energy storage for seasonal load shifting with the purpose of eliminating curtailment is unrealistic.

Another use for energy storage could be for day to day purposes to reduce curtailment and the use of conventional generation. Day to day operation would require far less energy storage than a seasonal load shifting battery. For example, if 180 MWh of load shifting was appropriate on a day to day basis, then a single 30 MW/180MWh energy storage resource could be utilized on the system. The approximate cost of this battery energy storage system would be $44 million. However, with this limited operational size and duration, when exhausted, other resources would have to be called upon to satisfy the system load (i.e. conventional generation). Daily load shifting energy storage, such as pumped storage hydro and load shifting batteries were considered in the plans. These storage resources were also credited with firm capacity benefit by reducing peak load. Limited amounts of energy storage are economical when storage can be installed for peaking capacity needs in lieu of new firm conventional generating resources. The figure below shows the comparative capital and Fixed O&M costs of peaking generating resources. Peaking resources would be needed to provide generation during the daily priority peak period of 5 pm to 9 pm.

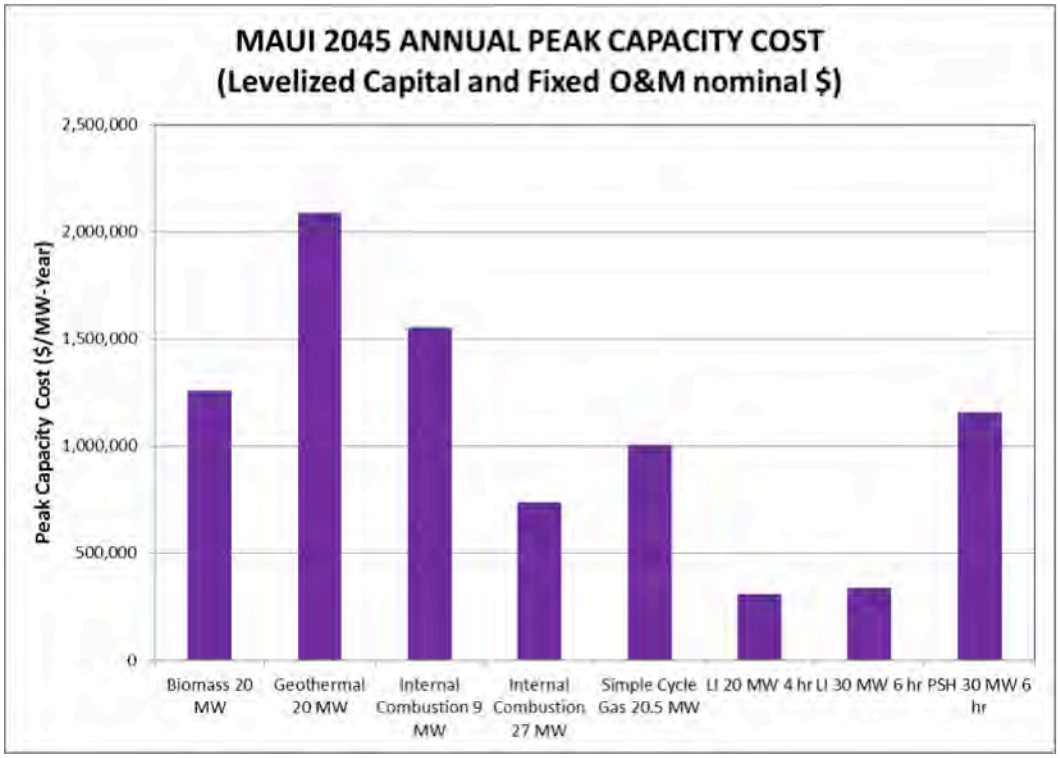


Figure 6-16. Maui 2045 Annual Peak Capacity Cost

The following figure shows the advantage of a diversified portfolio of resources such as, firm dispatchable, variable generation, demand response, and load shifting storage to serve our customer's energy needs.

The resources and components of the figure are:

- The dashed black line is the system load prior to load shifting (i.e. time of use, storage, and demand response) and without the effects of DG-PV.
- The blue area represents the peak shaving effects of demand response.
- The red area represents the peak shaving effects of load shifting storage.
- The pink area represents the curtailed energy.
- The 3 shades of yellow represent PV.
- The light green area represents wind.
- The dark green area represents the firm renewable resources.
- The purple area represents conventional generation on biodiesel.

Results from the production simulation show that on May 12, 2040, of the Theme 2 final plan, several dynamic interactions of different resources are shown:

- Periods where the conventional generation is providing energy shows times where the either the wind energy decreased or when conventional generation was required to meet the system load when other renewables (i.e. PV and wind) were insufficient.
- The area under the curtailed energy profile and above the dashed black line is amount of load that has been shifted to the daytime period as a result of charging the energy storage resource and executing the load contribution portion of the demand response programs. It is implicit that load shifting occurred as increased levels of PV were utilized during the daytime periods. Thereby increasing renewable energy taken that would have been otherwise been curtailed without demand response and energy storage.

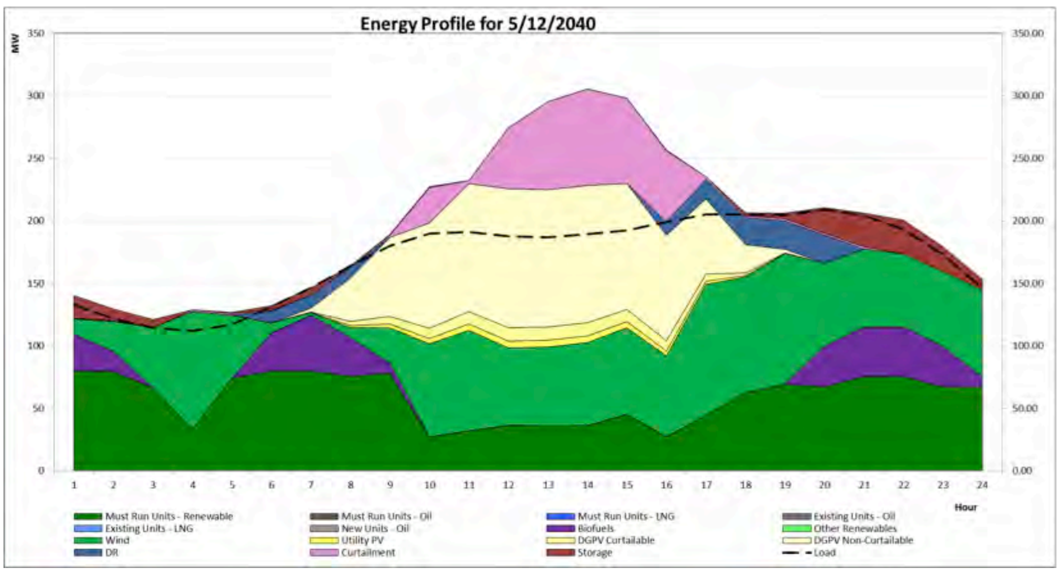


Figure 6-17. Theme 2 Maui 2040 Daily Energy Chart – Dynamic Mix of Generation

The following figure shows a day in a high renewable energy season where there is an overabundance of variable generation (i.e. wind and PV). An artifact of the desire to increase the levels of variable renewable generation is increasing amounts of curtailment when the renewable energy production is greater than the system demand over the entire day. Therefore, there are essentially no opportunities to shift load to reduce curtailment.

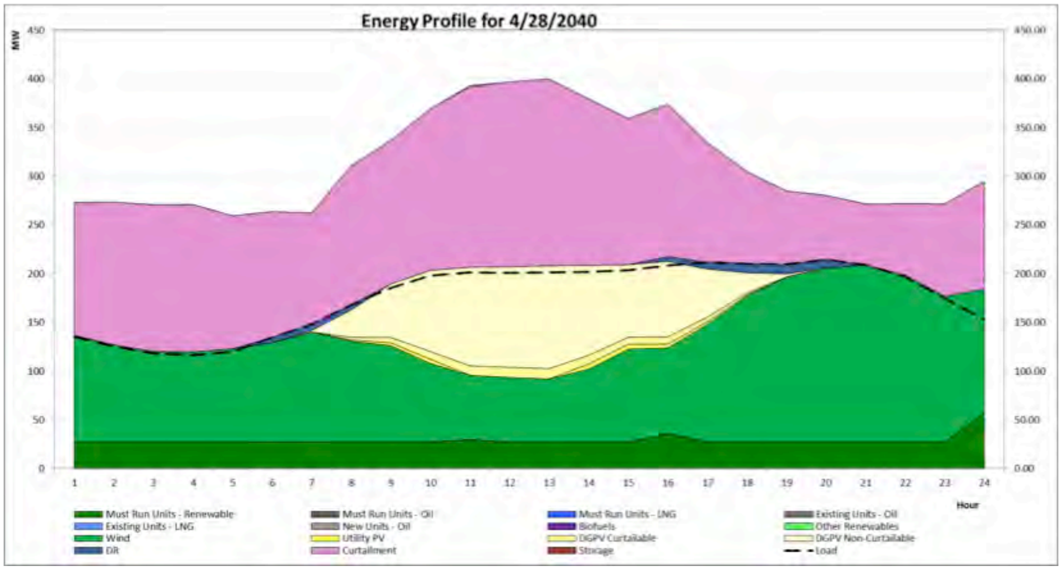


Figure 6-18. Theme 2 Maui 2040 Daily Energy Chart – High Wind and PV

Conversely, the following figure shows a day where greater reliance on firm generation (including renewable and conventional generation) is required due to the absence of sufficient variable renewable energy to serve the system load. It shows that biomass and geothermal are operating at or near normal top load throughout the day, requiring less biodiesel conventional generation. Therefore, incorporation of additional firm renewable generation is desirable to achieve greater levels of total renewable generation without necessitating the curtailment of seasonal variable generating resources.

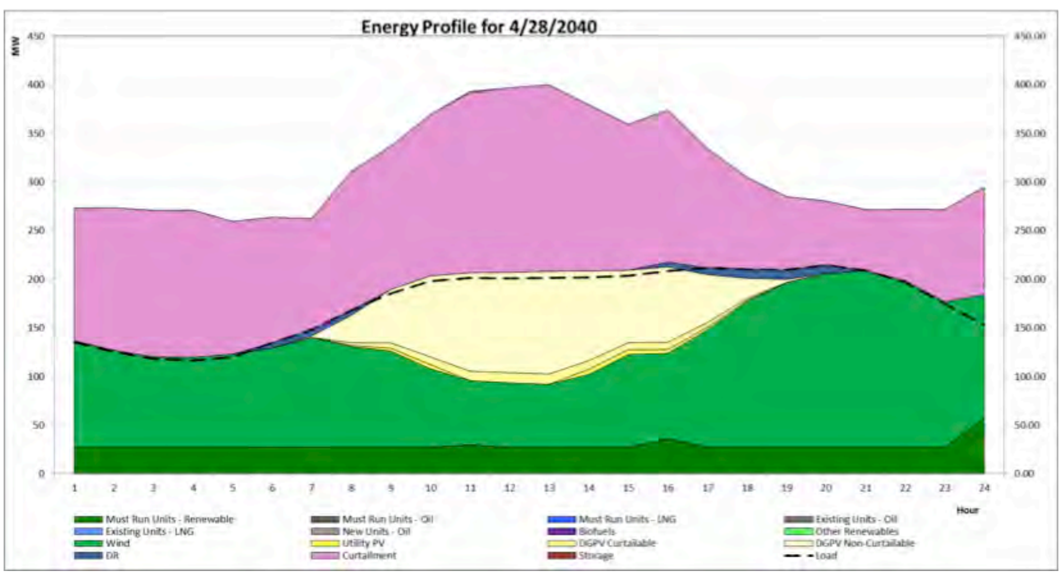


Figure 6-19. Theme 2 Maui 2040 Daily Energy Chart – Low Wind and PV

The following charts show various levels of renewable energy resources at different times for each Theme. The charts depict periods of:

- Abundance of wind and PV generation.
- Absence of wind and PV generation.

Theme 1

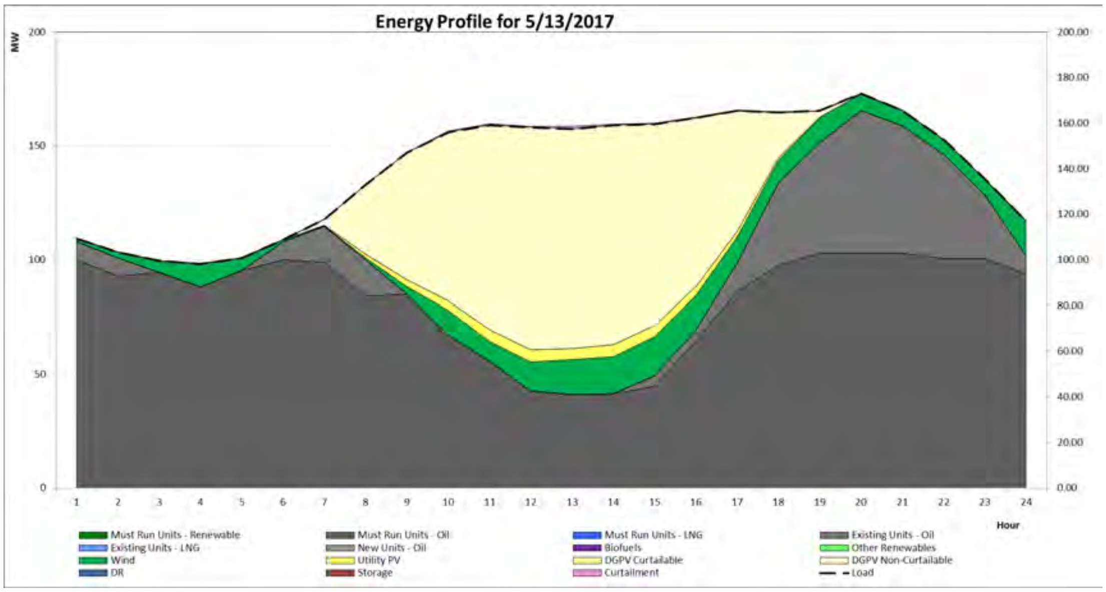


Figure 6-20. Theme 1 Max PV Day 5/13/2017

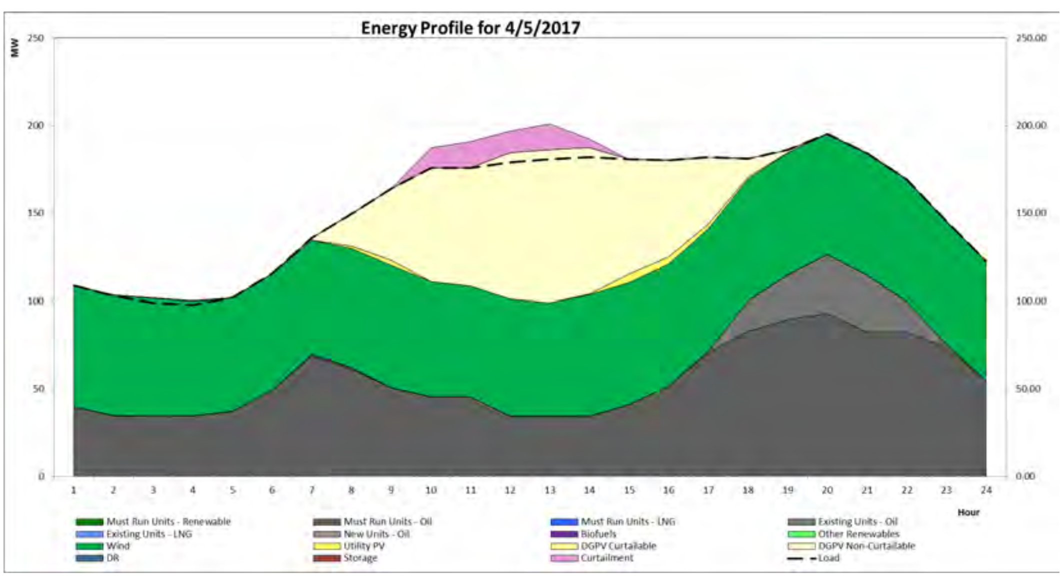


Figure 6-21. Theme 1 Max Wind Day 4/5/17

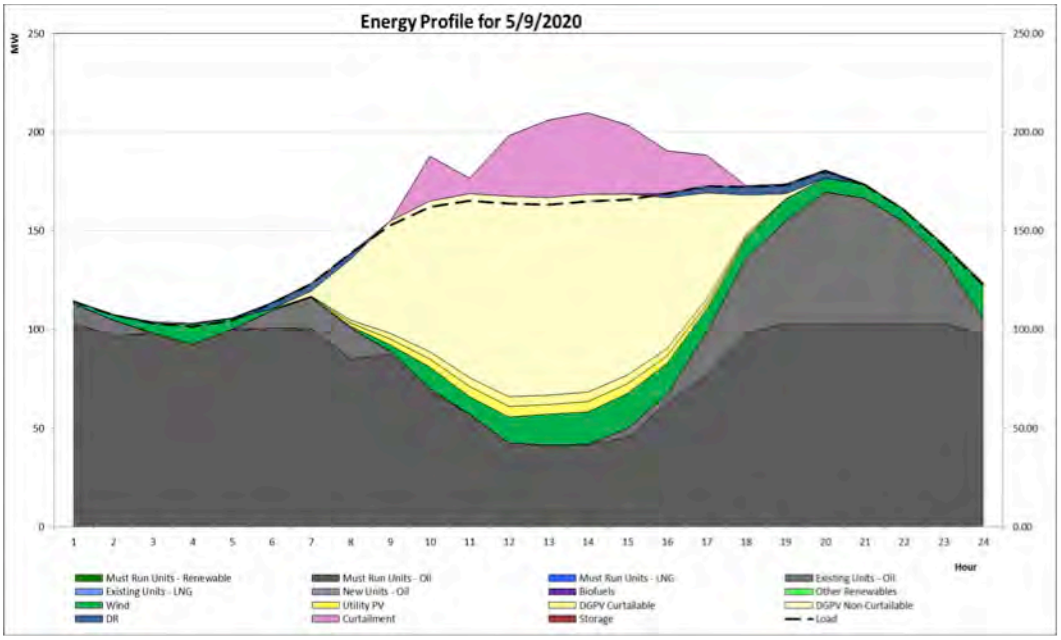


Figure 6-22. Theme 1 Max PV Day 5/9/20

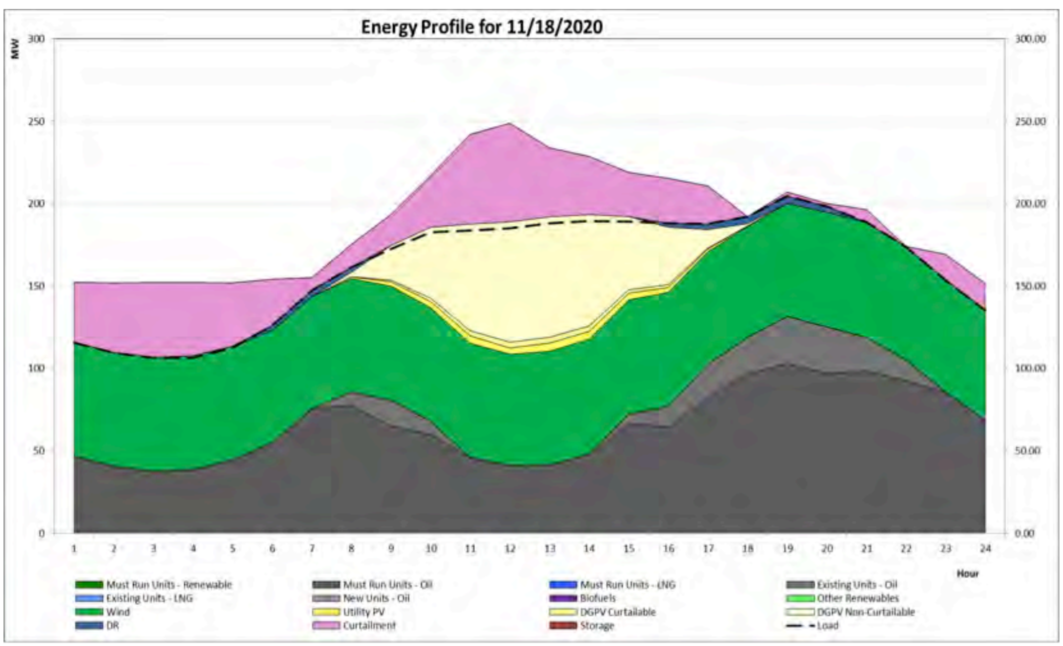


Figure 6-23. Theme 1 Max Wind Day 11/18/20

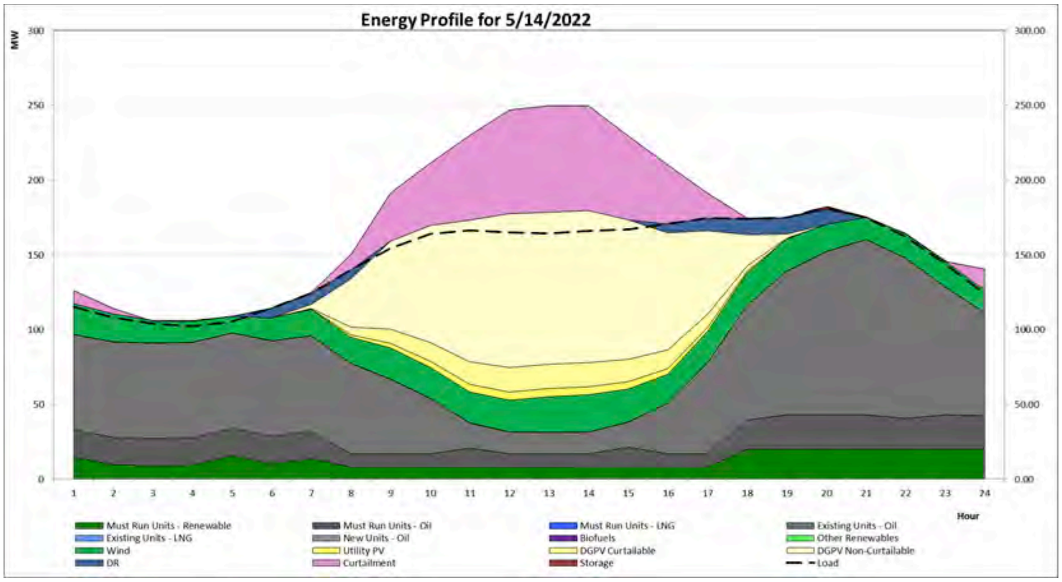


Figure 6-24. Theme 1 Max PV Day for 5/14/21

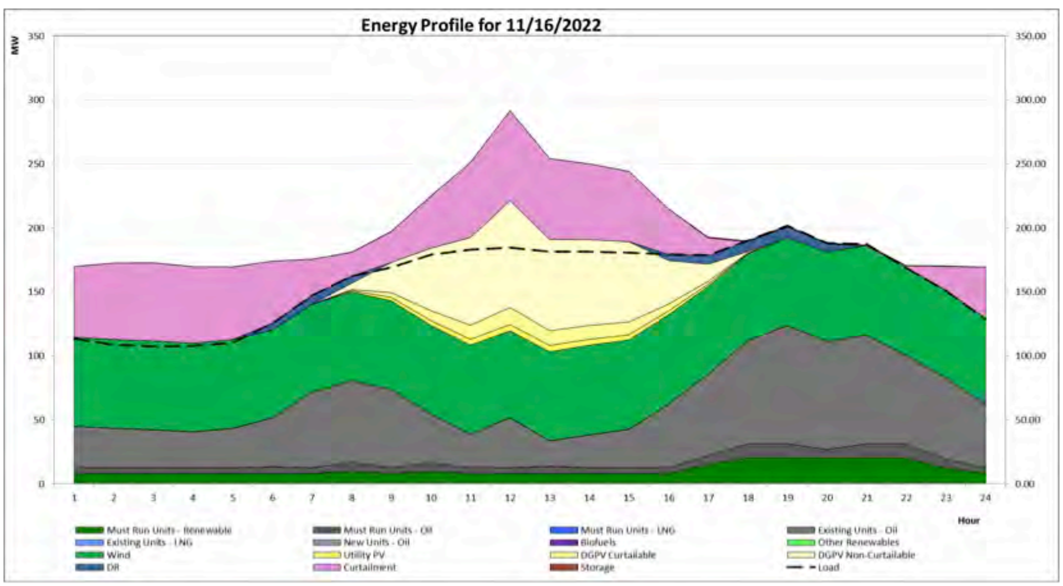


Figure 6-25. Theme 1 Max Wind Day for 11/16/22

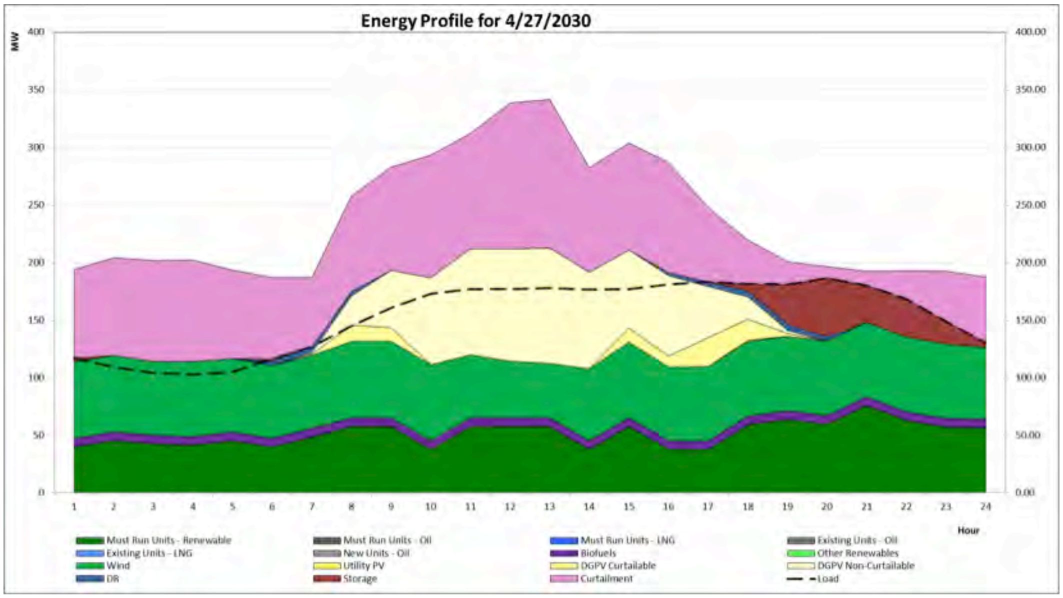


Figure 6-26. Theme 1 Max PV and Wind Day 4/27/30

Theme 2

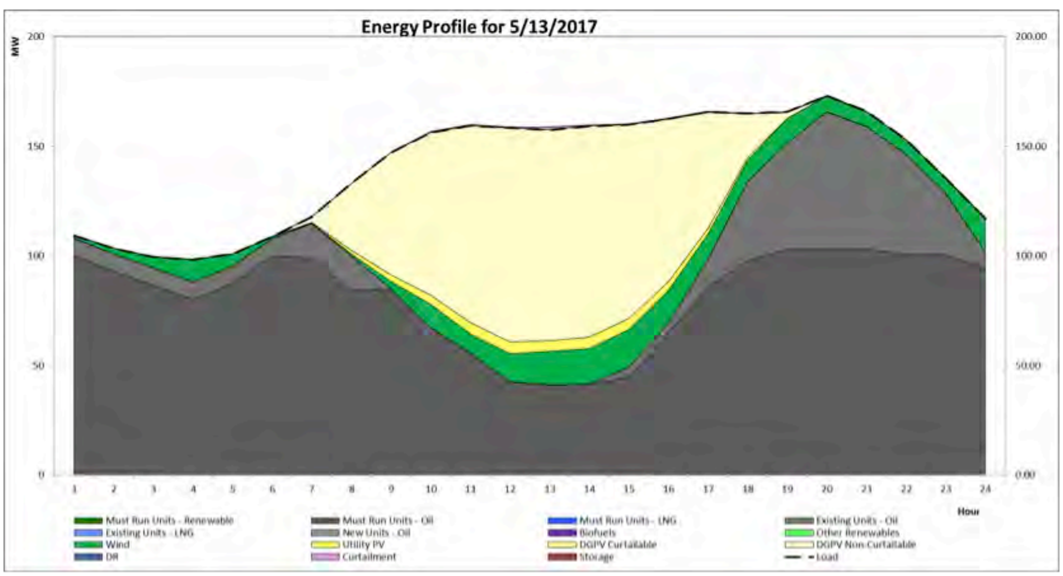


Figure 6-27. Theme 2 Max PV Day 5/13/17

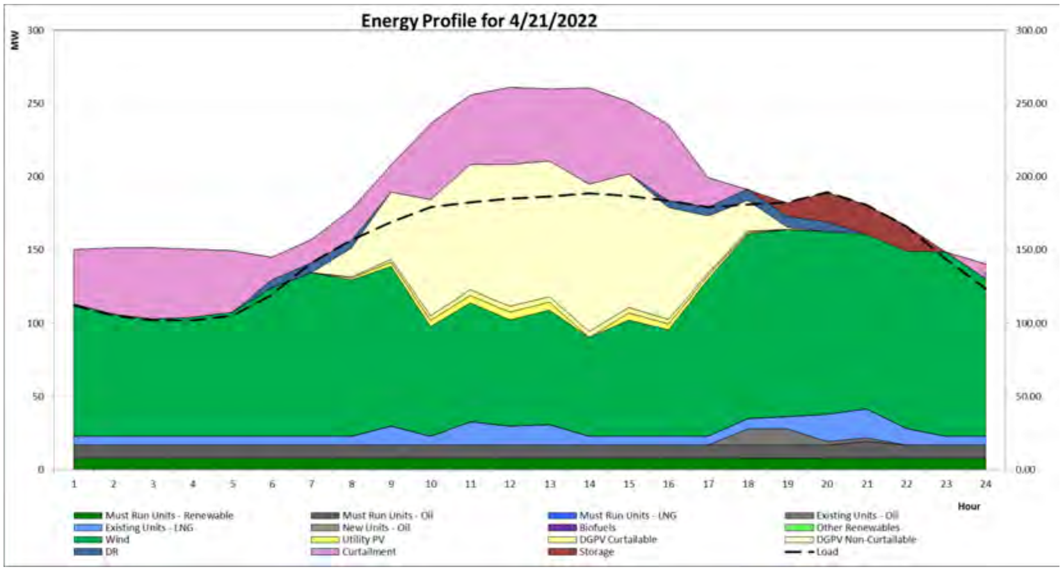


Figure 6-28. Theme 2 Max Wind Day 4/21/22

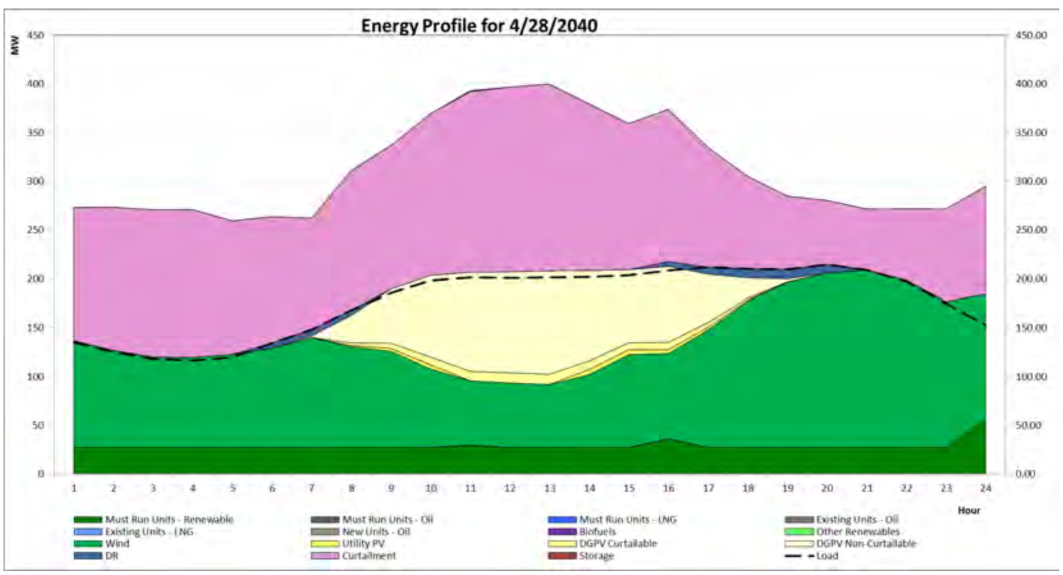


Figure 6-29. Theme 2 Max PV and Wind Day 4/28/40

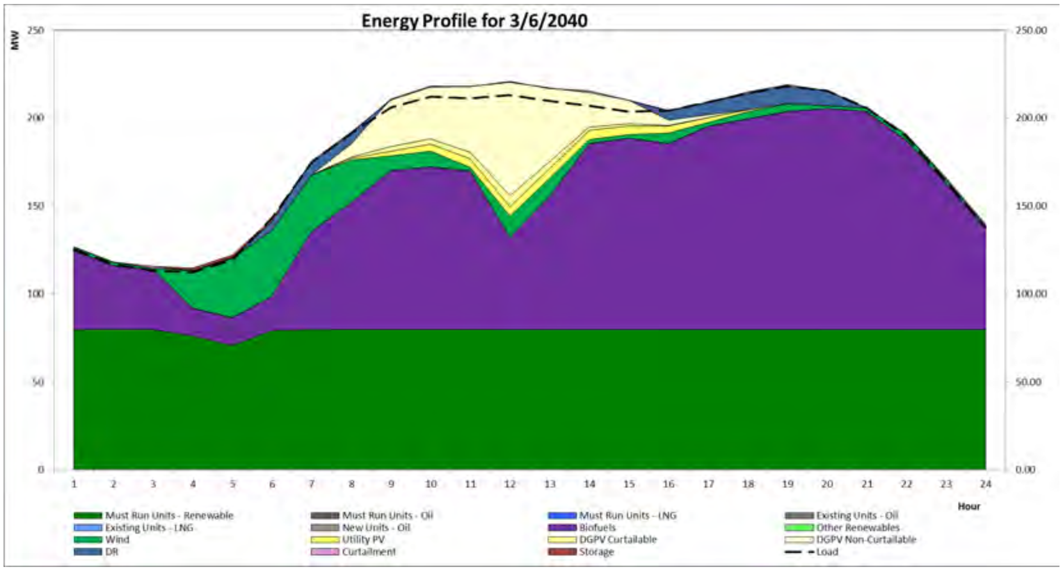


Figure 6-30. Theme 2 Least PV and Wind Day 3/6/40

Theme 3

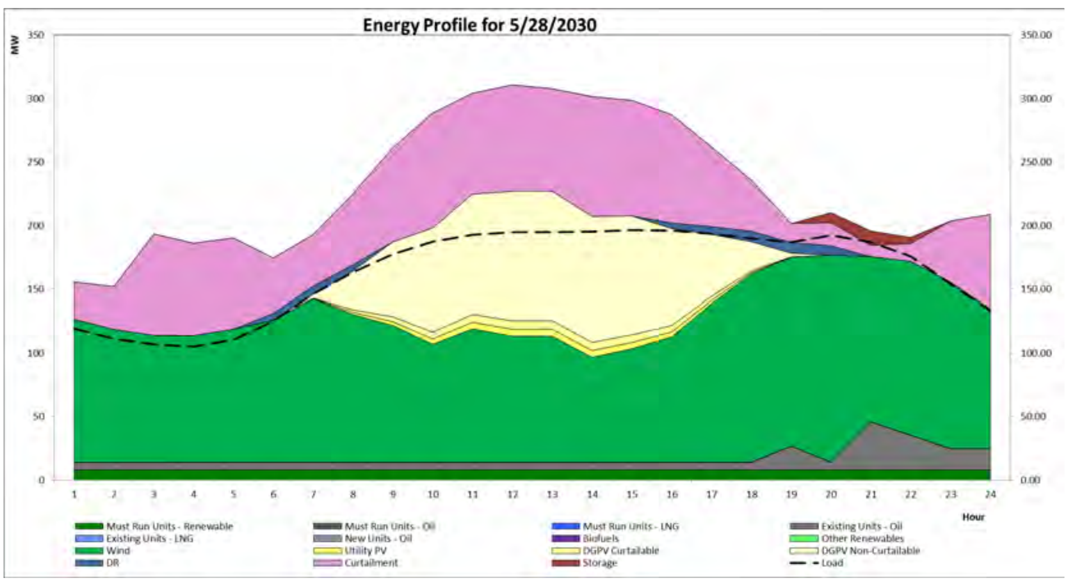


Figure 6-31. Theme 3 Max Wind and PV Day 5/28/30

Least Wind and PV Day 3/5/30

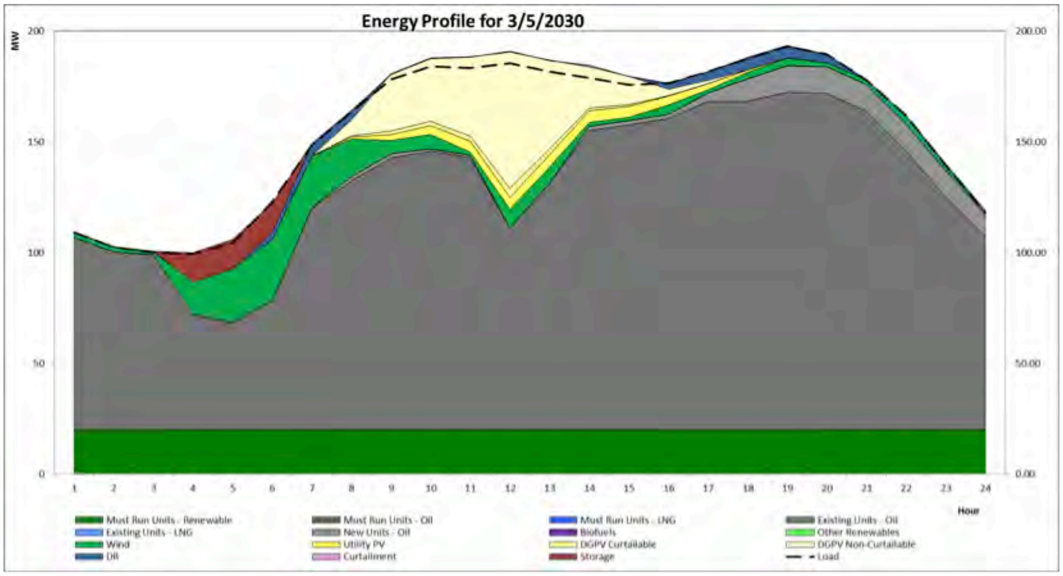


Figure 6-32. Theme 3 Least Wind and PV Day 3/5/30

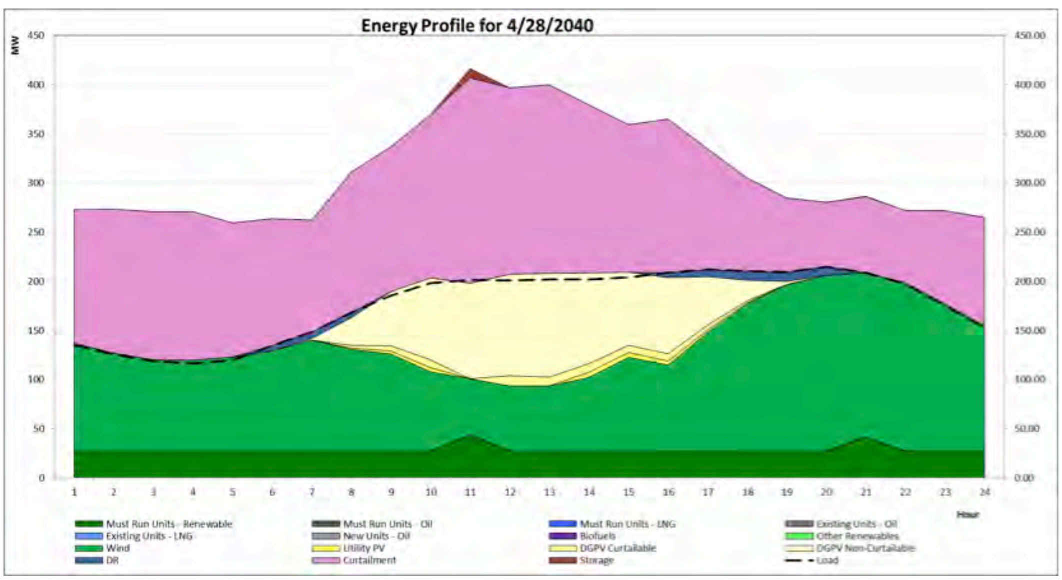


Figure 6-33. Theme 3 Max Wind and PV Day 4/28/40

MAUI SELECTION OF THEME 2

The rigorous long-term analyses of the three themes provided insights on the different strategies for achieving 100% renewable energy by 2040. They provide directional guidance to inform the risks and the level of “no regrets” in short- term actions, particularly as you compare long-term resources across multiple themes. Although the steps along the paths to 2045 are different among the final plans, the starting point is the same. The purpose of the Preferred Plan is to inform the evaluation of specific near-term actions that are implementable based on the direction that the longer-term view of the plan provides. The Preferred Plan will balance technical, economic, environmental, and cultural considerations.

Based on the results of the analyses, Theme 2 will add a diverse mix of renewables resources - with a considerable contribution from firm renewables - coupled with flexible, firm generation and energy storage. In the modernization of Maui’s generation system, Kahului Power Plant will be retired. The net result of this is a lower-cost resource plan with less exposure to volatile oil prices and lower rates compared with alternatives in the transition to 100% renewable.

Case Name	Preferred Plan
Case Label	MHB40
DER Forecast	Market DG-PV
Fuel Price	2015 EIA Reference
2016	
2017	5.74 MW of PV Projects
2018	
2019	
2020	Install Two - 30 MW Future Wind (60 MW Total Wind)
2021	
2022	Install Two - 9 MW ICE (18 MW Total ICE) Install 20 MW Biomass Install 20 MW 4 hour BESS for Capacity Install 20 MW 1hr BESS for South Maui Non-Transmission Alternative Install Two - 30 MVA Synchronous Condenser (Ma'alaea) (60 MVA Total) Install Two - 9 MW ICE
2023	Convert K1, K2, K3, K4 to Synchronous Condensers – 41 MVA
2024–2036	*No additions 2024–2036*
2037	Replace 20 MW 4hr BESS with a 30 MW 6 hour BESS for Capacity
2038	
2039	
2040	Install 20 MW Biomass Install Two - 20 MW Geothermal Install Four - 30 MW Future Wind Install Two - 20 MW 1hr BESS for Regulation
2041	
2042	
2043	
2044	
2045	Install 30 MW Future Wind Install Two - 20 MW Future PV

Table 6-1. Maui Preferred Plan

LANA'I AND MOLOKA'I

We conducted analysis for the islands of Lana'i and Moloka'i for two of the three Themes described in Chapter 3 to develop final plans to reach 100% renewable options in 2030 in Theme 1 and 2040 in Theme 3. The Preferred Plans below are based on modeling results and could change in response to community acceptance, refinement of system analysis, and actual costs of additional resources.

Maui Electric developed this Preferred Plan for transforming the system from current state to a future vision of the utility in 2030 that is consistent with the Commissions Observations and Concerns.

The Preferred Plans for Lana'i and Moloka'i strive for accelerated energy independence with minimal reliance on imported liquid fuels. The Preferred Plans for the islands of Lana'i and Moloka'i reduces "must-run" generation, increases variable renewable energy, and uses firm renewable sources to help stabilize the grid. Demand response will also be used to further reduce fossil fuel utilization.

Our vision will advance our systems towards our goal of decreasing fossil fuels, integrating more renewable energy, and maintaining system reliability. Our commitment to reshaping our systems will result in Renewable Portfolio Standards (RPS) meeting or exceeding the consolidated company requirement of 70% by 2040, and a vision of energy independence from fossil fuel by 2045 and possibly as early as 2040.

The Preferred Plans outline the transformation that we will undertake to evolve into a utility of the future—meeting the current and future needs of the community and customers we serve.

Moloka'i and Lana'i Preferred Plans

Maui Electric's Moloka'i and Lana'i Divisions Preferred Plans are referred to as Theme 1 in Chapter 3, which meets interim RPS mandates across the Hawaiian Electric service areas and achieves 100% RE in 2030, while balancing the use of both fuel and non-fuel burning RE.

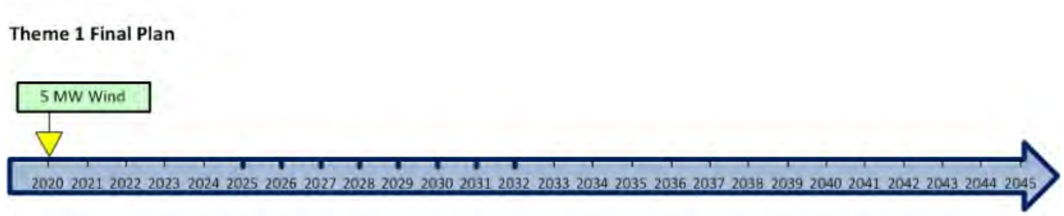


Figure 6-34. Moloka'i Final Plans - Schedule of Resources Theme 1

Figure 6-35. Moloka‘i Final Plans - Schedule of Resources Theme 3

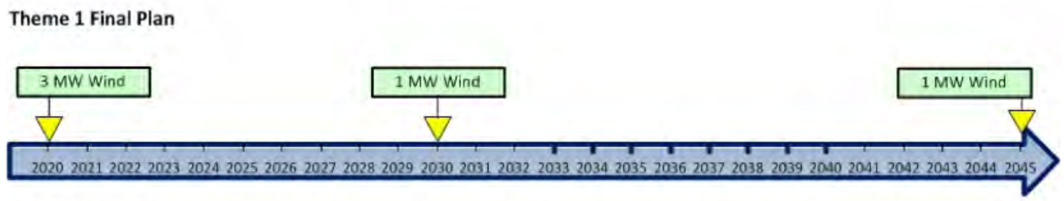


Figure 6-36. Lana‘i Final Plans - Schedule of Resources – Theme 1

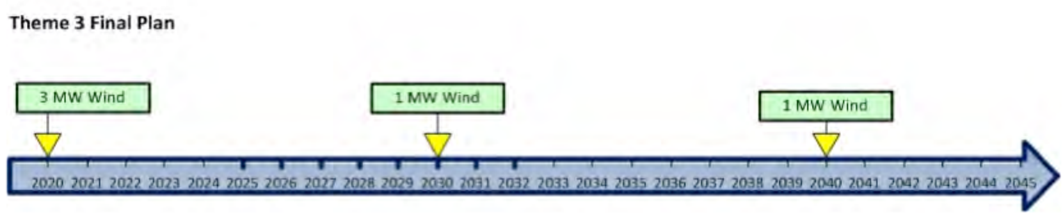


Figure 6-37. Lana‘i Final Plans - Schedule of Resources – Theme 3

ENERGY MIX OF FINAL PLANS FOR MOLOKA'I

Our commitment to reshaping our systems will result in Renewable Portfolio Standards (RPS) meeting or exceeding the requirement of 70% by 2040, and a vision of energy independence from fossil fuel by 2045 and possibly as early as 2040.

All of Maui Electric's Final Plans will add significantly more renewable energy to meet or exceed the mandated Consolidated RPS targets in 2020, 2030, and 2040. Our Consolidated RPS is planned to meet or exceed the 70% RPS by 2040 before transitioning to fully renewable energy electrical system by 2045. On Moloka'i, Theme 1 attains 100% renewable generation by 2030 and Theme 3 attains 100% renewable generation by 2040.

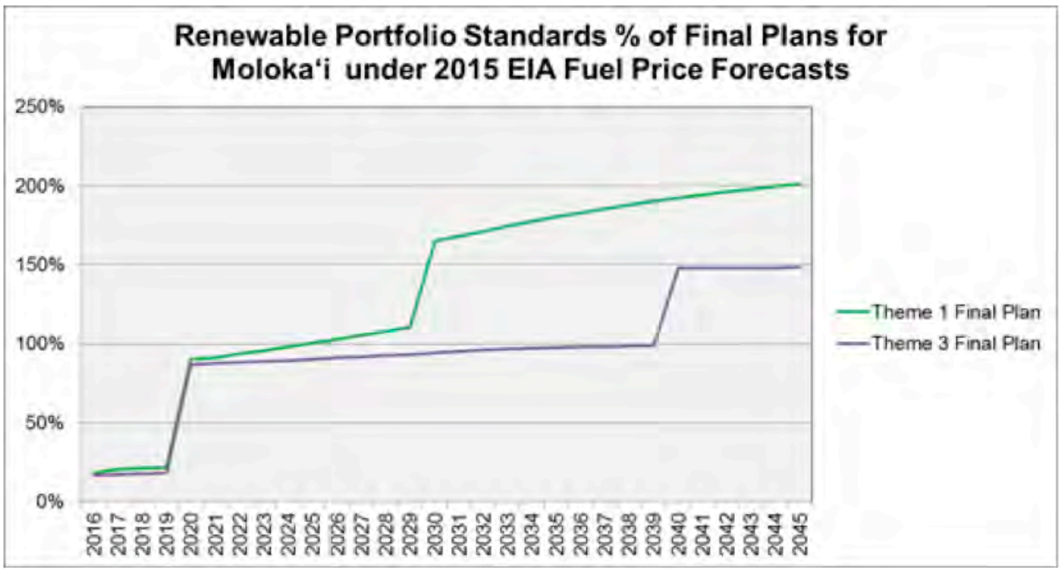


Figure 6-38. Renewable Portfolio Standards Percent of Final Plans for Moloka'i

The Moloka'i Preferred Plan will change over time to reduce and eventually eliminate must-run fuel burning thermal units and incorporate greater amounts of renewable energy out to 2045. The figures that follow shows how the resource mix of the two Moloka'i themes vary in generation and transforms over time. Under both the 2015 EIA and February 2016 STEO Fuel Price Forecasts, the system resource energy mix are identical.

Theme 1

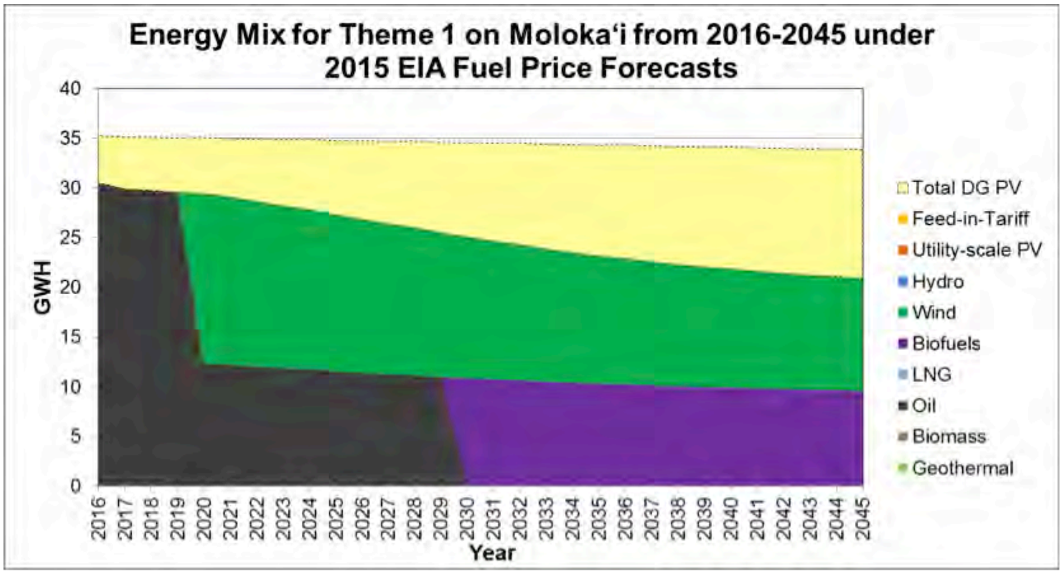


Figure 6-39. Energy Mix for Theme 1 on Moloka'i from 2016-2045 under 2015 EIA Fuel Price Forecasts

Theme 3

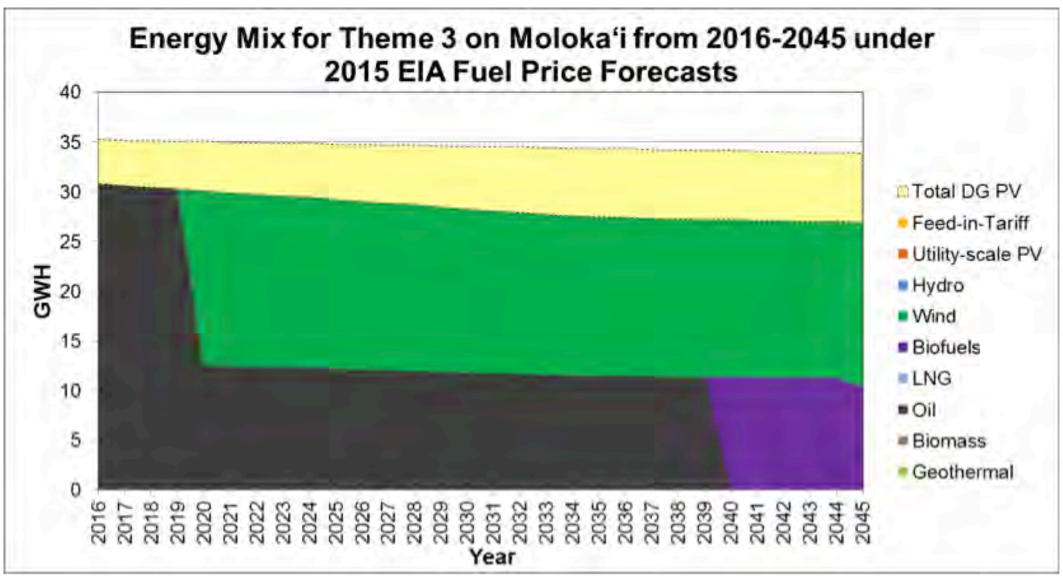


Figure 6-40. Energy Mix for Theme 1 on Moloka'i from 2016-2045 under 2015 EIA Fuel Price Forecasts

The generation mix in all themes has increasing levels of renewable energy replacing fossil generation. Renewable energy from distributed PV continues to grow over time and new wind resources are also added to the system. As firm generating units are removed from must-run operation, system security measures will be required. The theme 1 plan provides the most integration of DER over the term of the planning horizon.

PERCENT OVER-GENERATION OF TOTAL SYSTEM OF FINAL PLANS FOR Molokaʻi

The Molokaʻi electric system will greatly increase the amounts of variable generation that can be utilized. By eliminating must-run fossil fuel generation along with increasing wind generation and DER, lower levels of curtailment will be achieved during low demand periods (which may occur during daytime hours due to influence of DG-PV, as well as during typical night time low load hours). However, even with these improvements, non-firm renewable generation such as wind is occasionally available in quantities that cannot be effectively utilized by the system. Under both the 2015 EIA and February 2016 STEO Fuel Price Forecasts, the total system renewable energy utilization are identical.

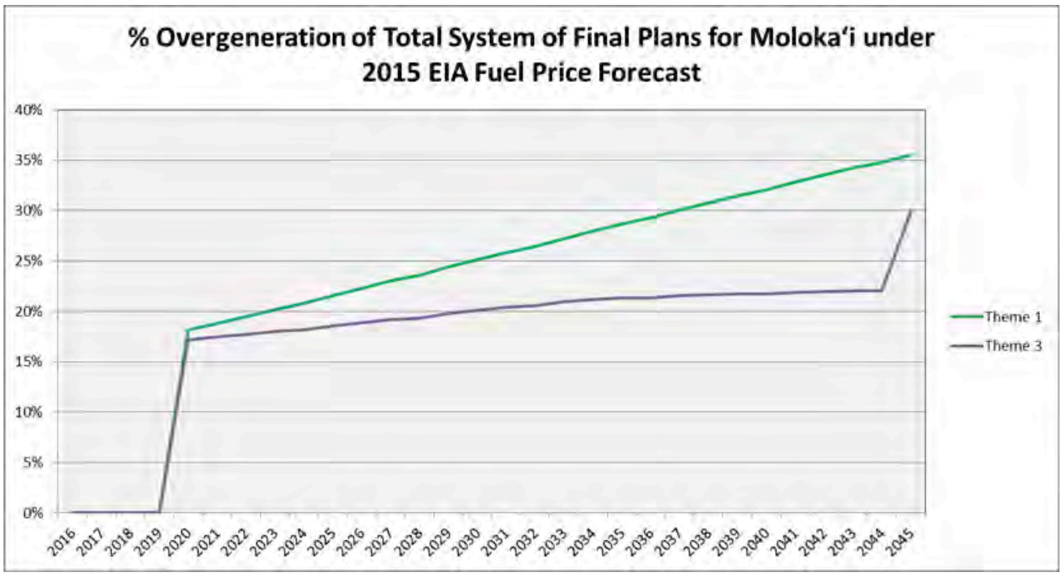


Figure 6-41. Percent Over-Generation of Total System of Final Plans for Molokaʻi under 2015 EIA Fuel Price Forecast

TOTAL SYSTEM RENEWABLE ENERGY UTILIZED OF FINAL PLANS FOR MOLOKAʻI

The extent to which renewable energy can be utilized on Molokaʻi will depend on factors such as the total system load or energy demand, the amount of downward regulation that must be carried on the system to counteract an unexpected loss of load, the total output from variable generation resources, and the position of the variable generation resource in the curtailment sequence. Under both the 2015 EIA and February 2016 STEO Fuel Price Forecasts, the total system renewable energy utilization are identical.

Theme 1

Renewable Energy Utilization

% RE	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Utilized	100%	100%	100%	100%	82%	81%	81%	80%	79%	78%	78%	77%	76%	76%	81%

% RE	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2016-2045
Utilized	81%	80%	79%	79%	78%	78%	77%	76%	75%	75%	74%	74%	73%	72%	72%	78%

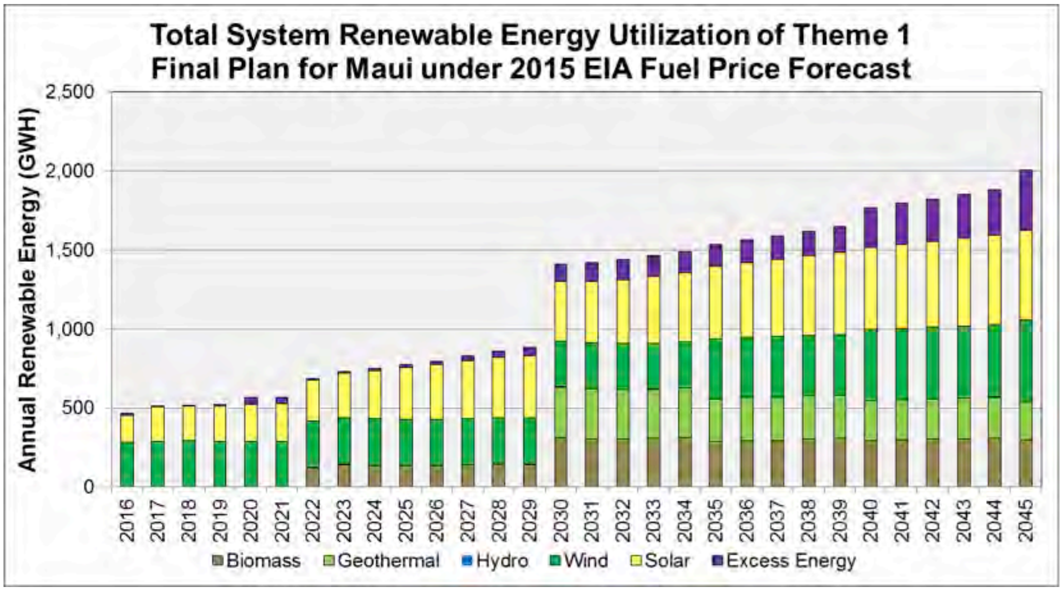


Figure 6-42. Total System Renewable Energy Utilization of Theme 1 Final Plan for Moloka'i Under 2015 EIA Fuel Price Forecast

Theme 3

Renewable Energy Utilization

% RE	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Utilized	82%	82%	82%	82%	81%	81%	81%	81%	80%	80%	80%	79%	79%	79%	79%

% RE	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2016-2045
Utilized	79%	78%	78%	78%	84%	84%	84%	84%	84%	77%	0%	0%	0%	0%	0%	81%

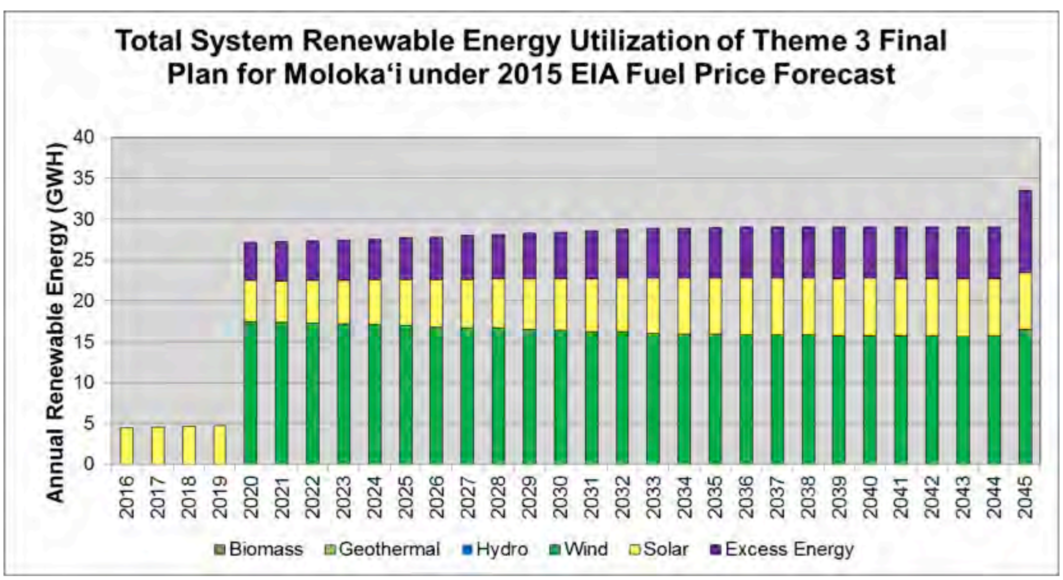


Figure 6-43. Total System Renewable Energy Utilization of Theme 3 Final Plan for Moloka'i Under 2015 EIA Fuel Price Forecast

DAILY ENERGY CHARTS OF FINAL PLANS FOR MOLOKA'I

The following charts illustrate representative study days on Moloka'i with increasing renewable energy contributions that displace fossil fueled generation over time. These charts show the advantage of a diversified portfolio of resources such, firm dispatchable, variable generation, and demand response to serve our customer's energy needs.

A noticeable occurrence in each chart is the large contribution of PV energy during daylight hours, and in some instances, an excess of PV generation during daylight hours. During non-daylight hours, customer needs will need to be met by the portfolio of resources other than PV, such as load shifting storage, wind, and firm dispatchable generation.

Theme 1

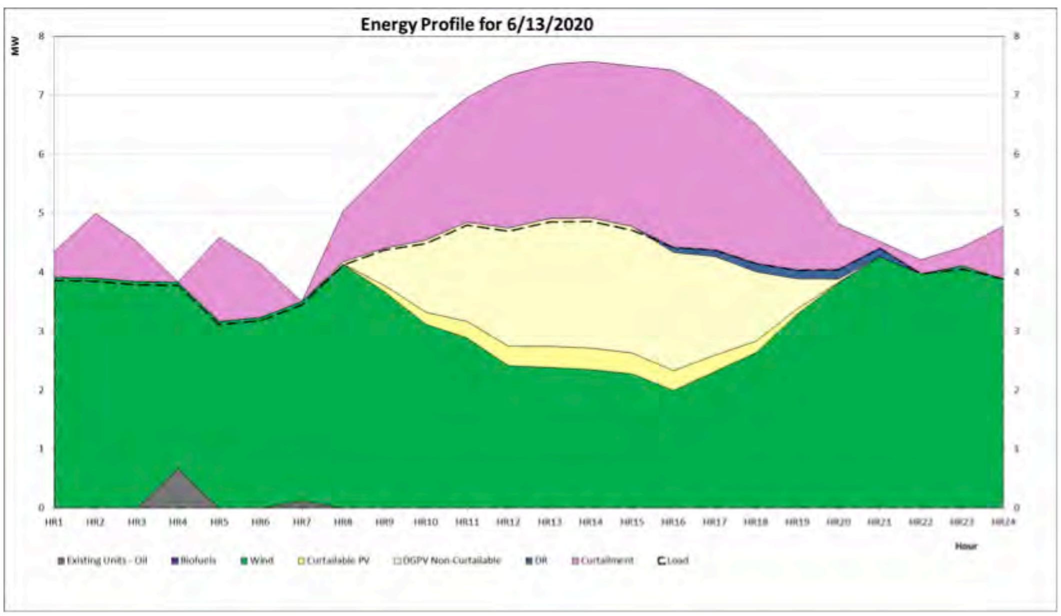


Figure 6-44. Theme 1 Max PV Day 6/13/20

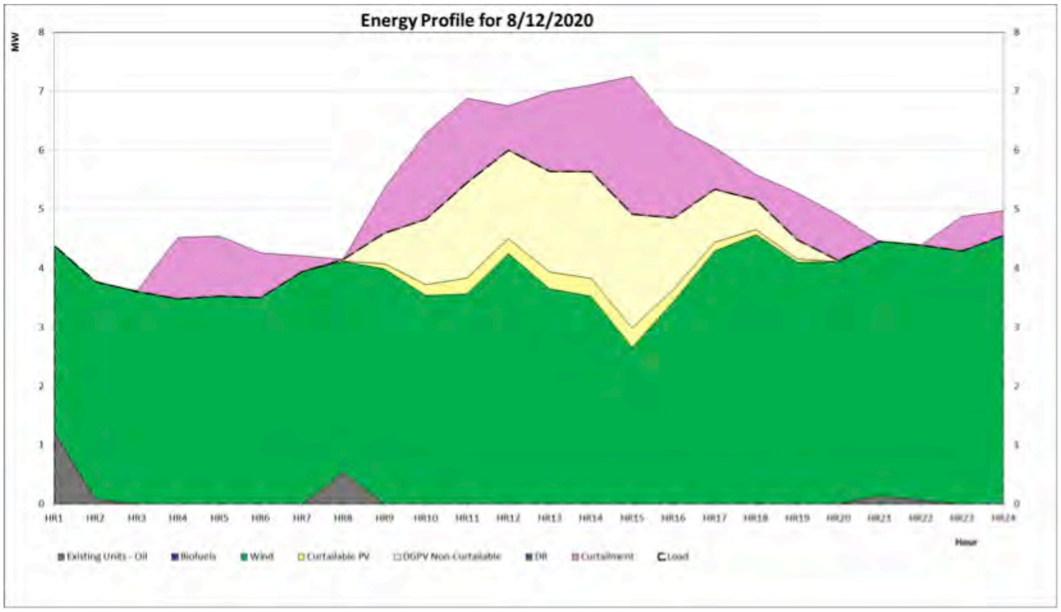


Figure 6-45. Theme 1 Max Wind and PV Day 8/12/20

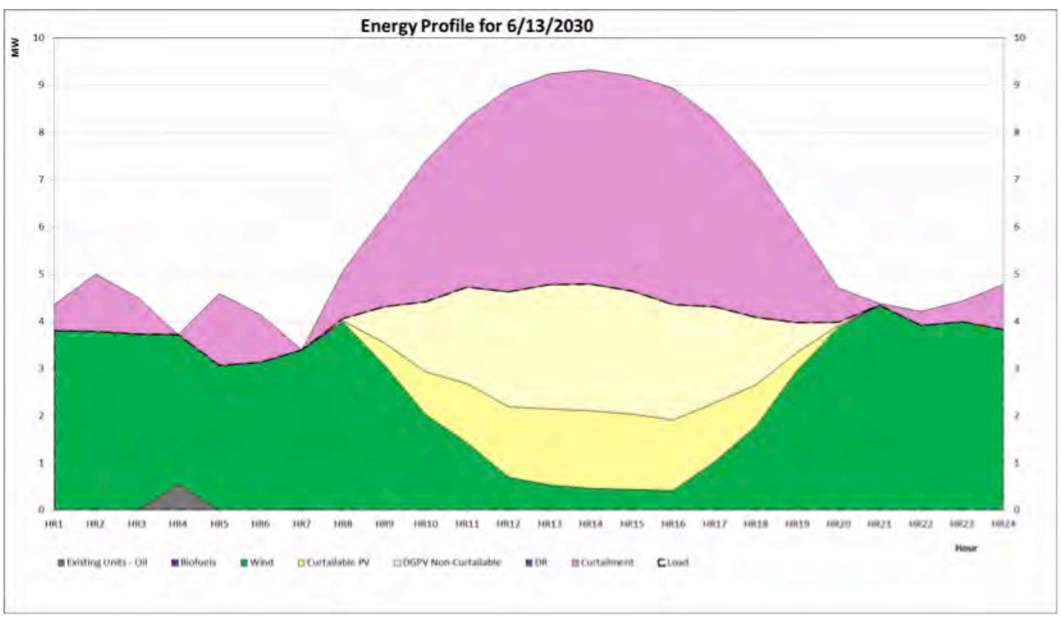


Figure 6-46. Theme 1 Max PV Day 6/13/30

6. Maui Electric Preferred Plan

Daily Energy Charts of Final Plans for Moloka'i

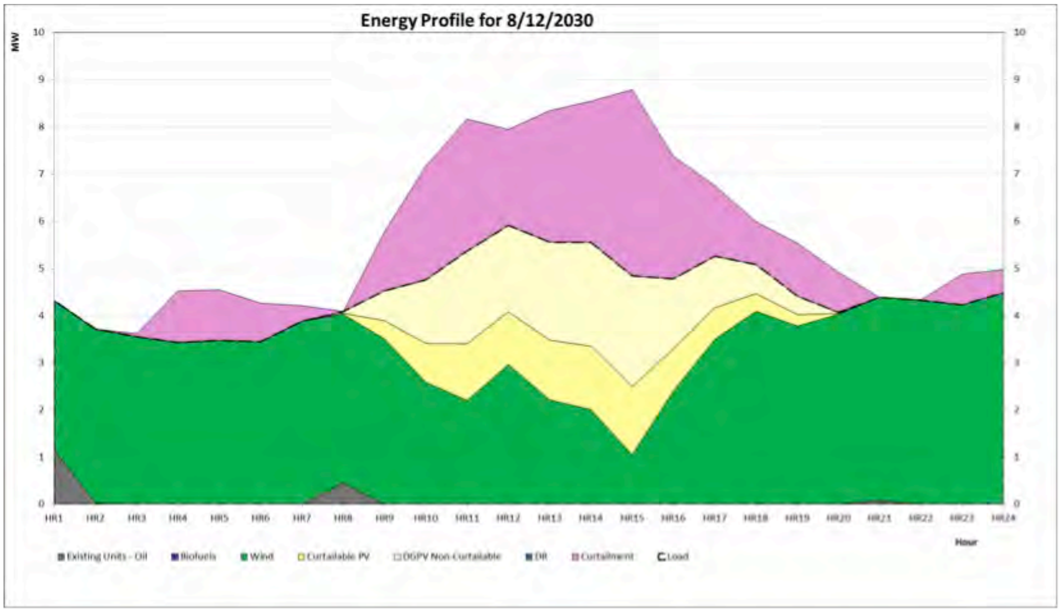


Figure 6-47. Theme 1 Max Wind and PV Day 8/12/30

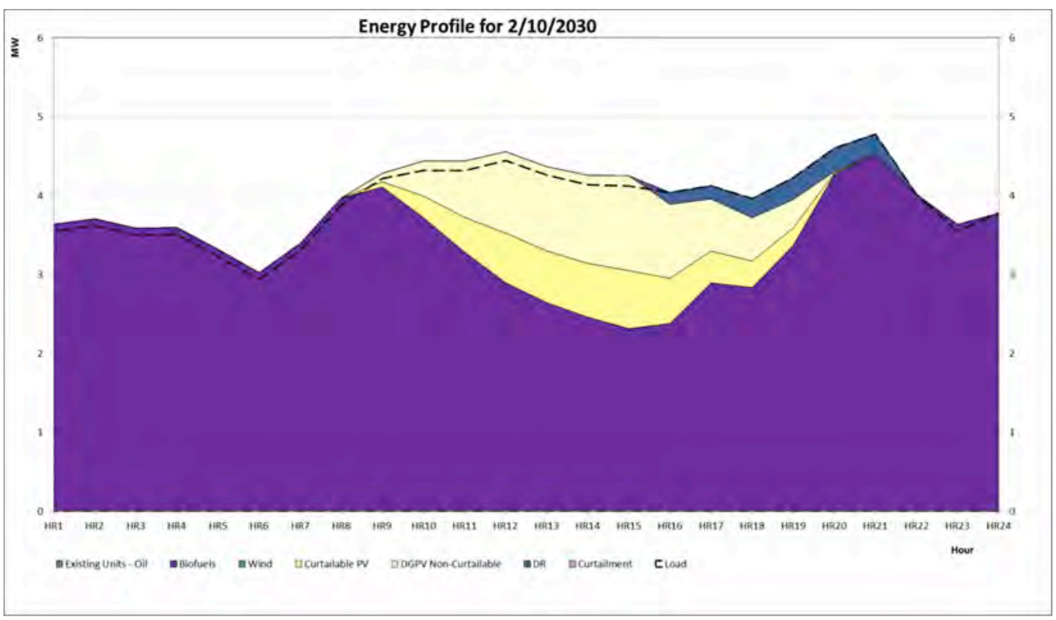


Figure 6-48. Theme 1 Least PV and Wind Day 2/10/30

Hawaiian Electric
Maui Electric
Hawai'i Electric Light

Theme 3

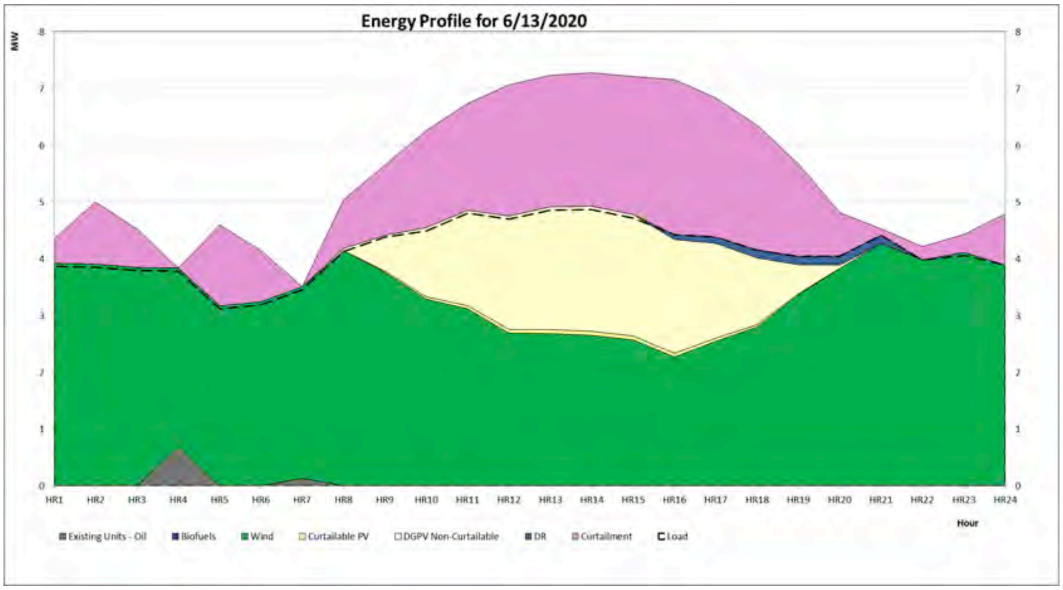


Figure 6-49. Theme 3 Max PV Day 6/13/20

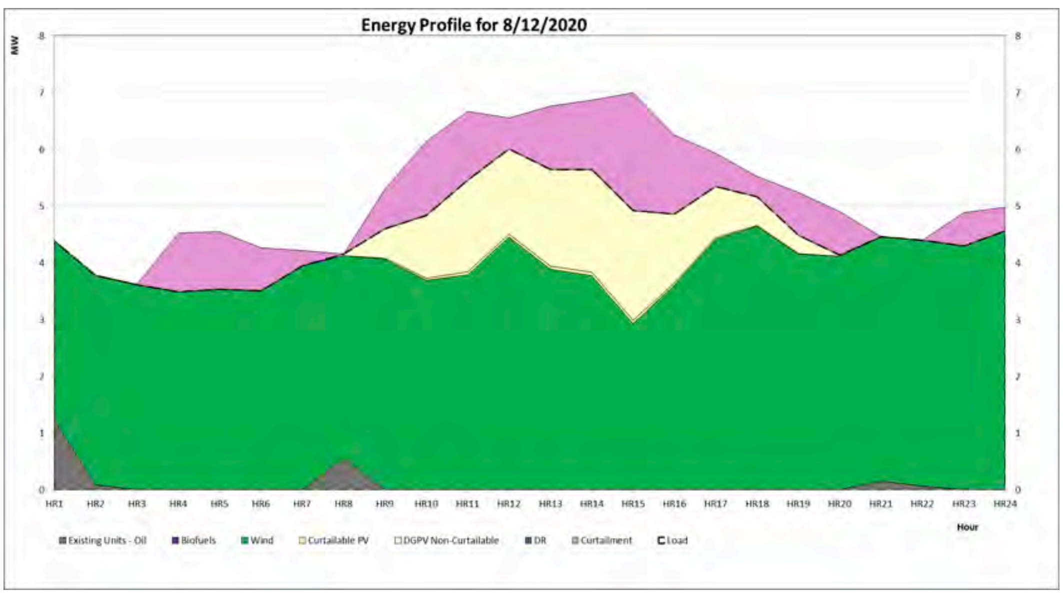


Figure 6-50. Max Wind and PV Day 8/12/20

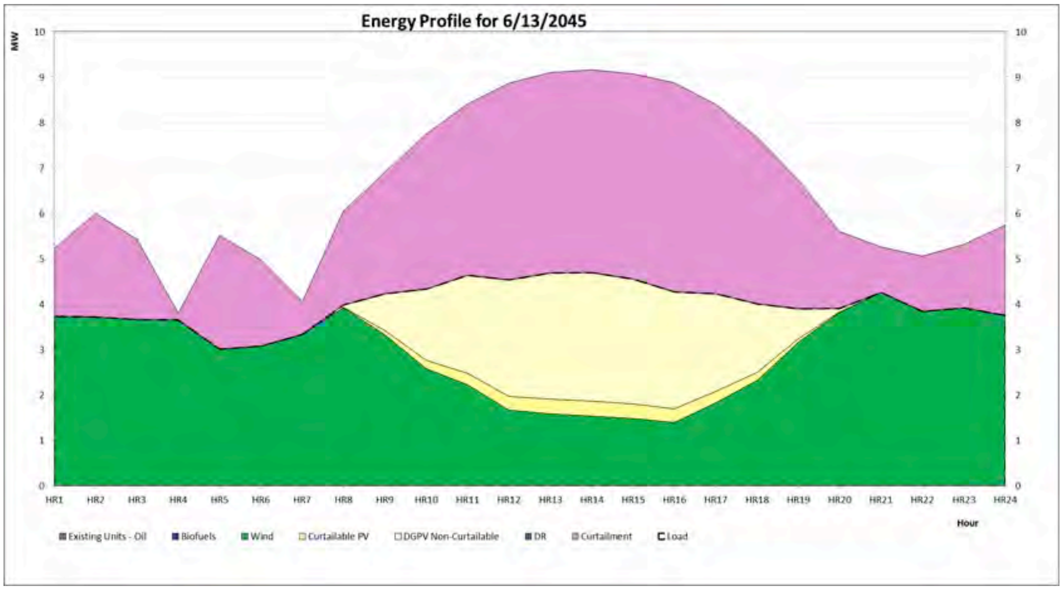


Figure 6-51. Theme 3 Max PV Day 6/13/45

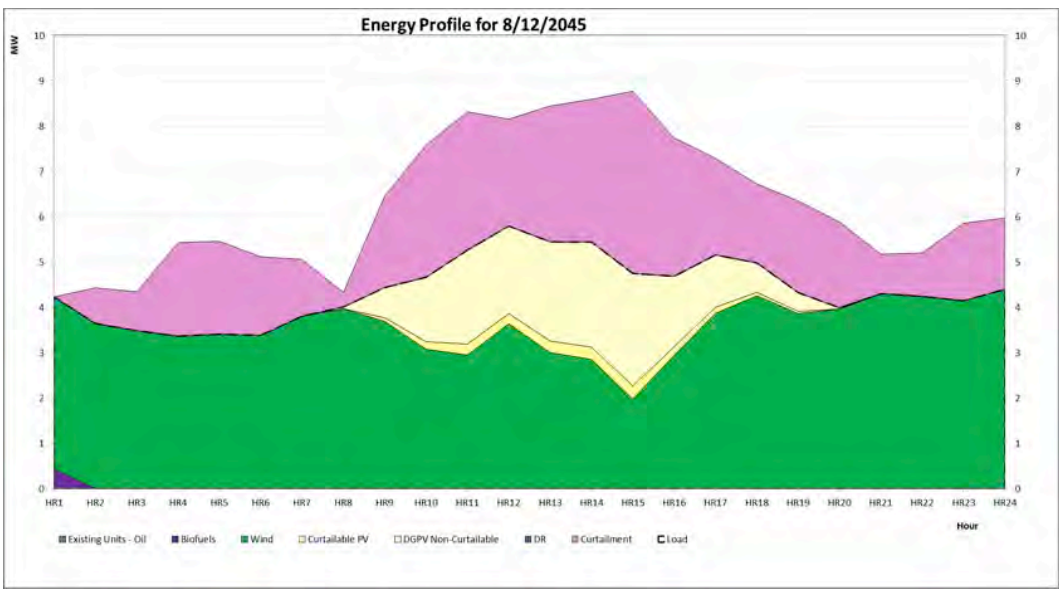


Figure 6-52. Theme 3 Max PV and Wind Day 8/12/45

MOLOKA'I SELECTION OF THEME 1

Theme 1 will add significant amounts of variable renewable generation in conjunction with the removal of "must-run" conventional generation upon installation of system security measures. Moloka'i will achieve 100% renewable energy by 2030.

Case Name	Preferred Plan
Case Label	
DER Forecast	High DG-PV
Fuel Price	2015 EIA Reference
2016	
2017	
2018	Install two - 5 MVA Synchronous Condenser (10 MVA Total)
2019	
2020	5 MW Wind
2021–2045	*No additions after 2020*

Table 6-2. Moloka'i Preferred Plan

ENERGY MIX OF FINAL PLANS FOR LANA'I

Our commitment to reshaping our systems will result in Renewable Portfolio Standards (RPS) meeting or exceeding the requirement of 70% by 2040, and a vision of energy independence from fossil fuel by 2045 and possibly as early as 2040.

All of Maui Electric's Final Plans will add significantly more renewable energy to meet or exceed the mandated Consolidated RPS targets in 2020, 2030, and 2040. Our Consolidated RPS is planned to meet or exceed the 70% RPS by 2040 before transitioning to fully renewable energy electrical system by 2045. On Lana'i, Theme 1 attains 100% renewable generation by 2030 and Theme 3 attains 100% renewable generation by 2040.

Lana'i ownership could have an impact on the ability of Maui Electric meeting its stated goals going forward. Maui Electric continues to work in conjunction with the Lana'i ownership on the development of the Lana'i system and customer needs.

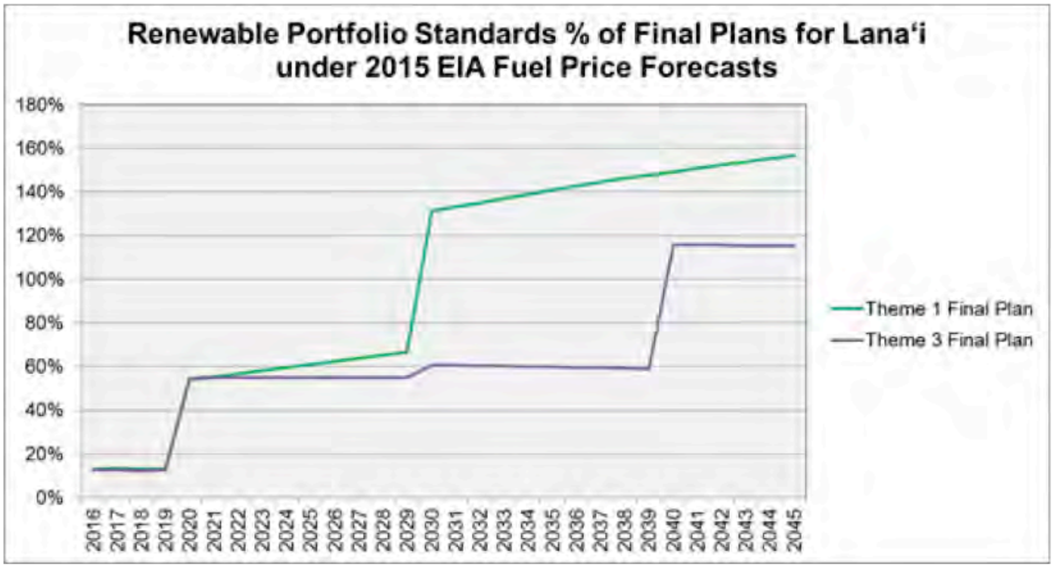


Figure 6-53. Renewable Portfolio Standards Percent of Final Plans for Lana‘i (100% Renewable in 2040)

The Lana‘i Preferred Plan will reduce and eventually eliminate must-run fossil fuel burning thermal units and incorporate greater amounts of renewable energy out to 2045. The figures that follow shows how the resource mix of the two Lana‘i themes vary in generation and transforms over time. Under both the 2015 EIA and February 2016 STEO Fuel Price Forecasts, the system resource energy mix are identical.

Theme 1

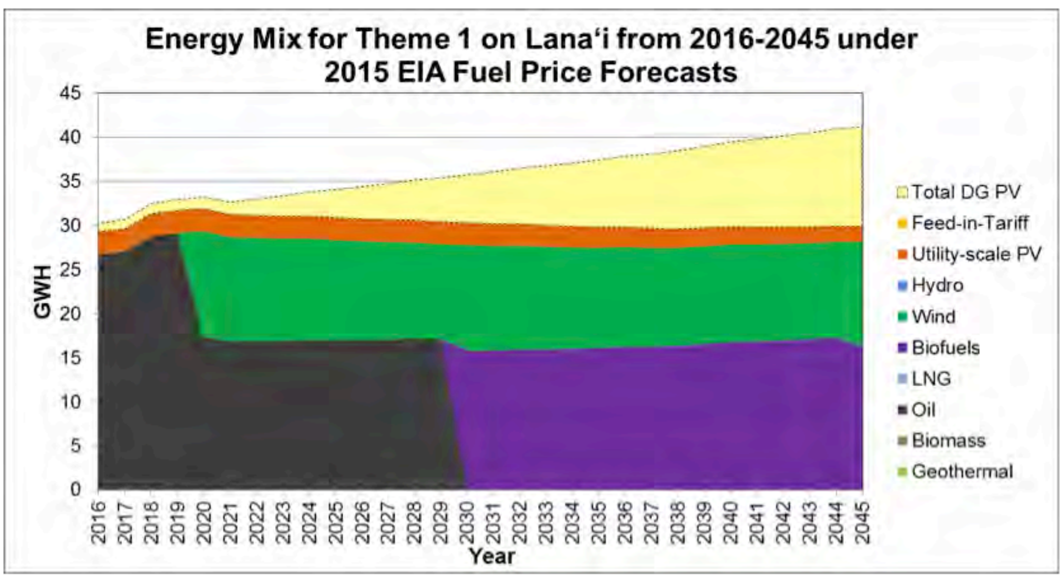


Figure 6-54. Energy Mix for Theme 1 on Lana‘i from 2016-2045 under 2015 EIA Fuel Price Forecasts

Theme 3

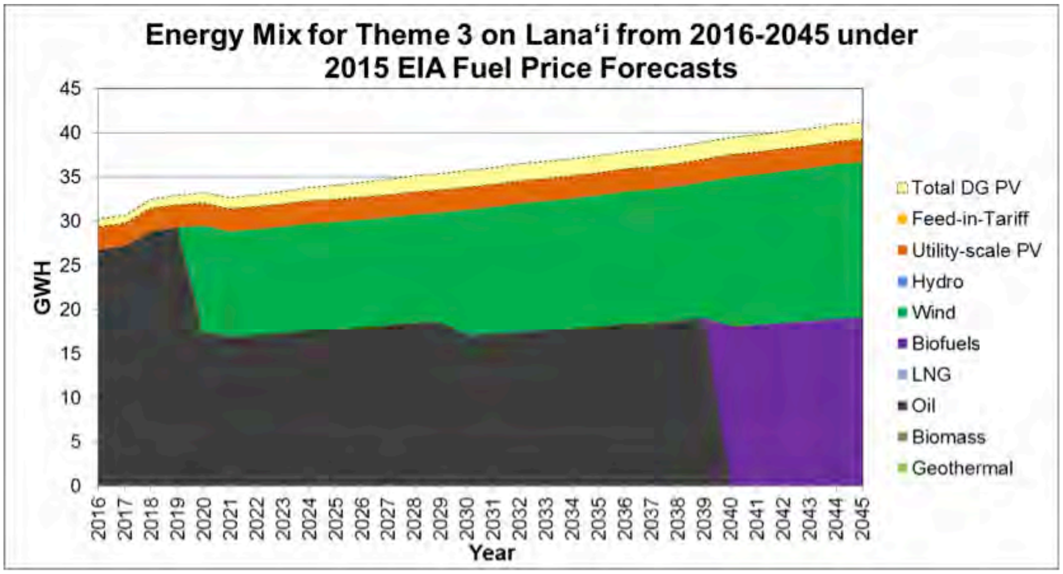


Figure 6-55. Energy Mix for Theme 3 on Lana'i from 2016-2045 under 2015 EIA Fuel Price Forecasts

The generation mix in all themes has increasing levels of renewable energy replacing fossil generation. Renewable energy from distributed PV continues to grow over time and new wind resources are also added to the system. As firm generating units are removed from must-run operation, system security measures will be required. The theme 1 plan provides the most integration of DER over the term of the planning horizon.

PERCENT OVER-GENERATION OF TOTAL SYSTEM OF FINAL PLANS FOR LANA'I

The Lana'i electric system has greatly increased the amounts of variable generation that can be utilized. By eliminating must-run fossil fuel generation along with increasing wind generation and DER, lower levels of curtailment are achieved during low demand periods (which may occur during daytime hours due to influence of DG-PV, as well as during typical night time low load hours). However, even with these improvements, non-firm renewable generation such as wind is occasionally available in quantities that cannot be effectively utilized by the system. Under both the 2015 EIA and February 2016 STEO Fuel Price Forecasts, the total system renewable energy utilization are identical

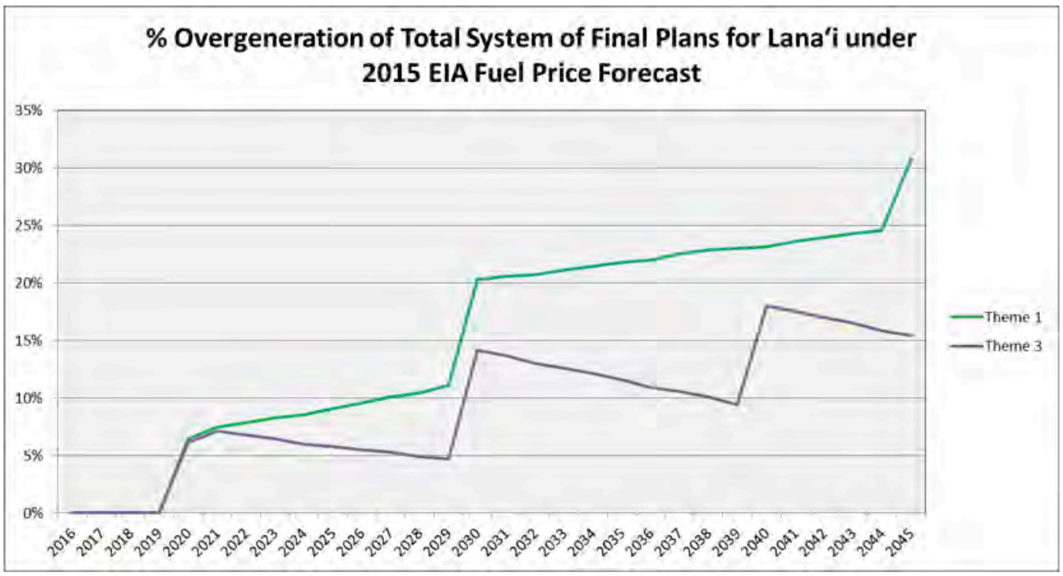


Figure 6-56. Percent Over-Generation of Total System of Final Plans for Lana'i under 2015 EIA Fuel Price Forecast

TOTAL SYSTEM RENEWABLE ENERGY UTILIZED OF FINAL PLANS FOR LANA'I

The extent to which renewable energy can be utilized on Lana'i will depend on factors such as the total system load or energy demand, the amount of downward regulation that must be carried on the system to counteract an unexpected loss of load, the total output from variable generation resources, and the position of the variable generation resource in the curtailment sequence. In all Themes Maui Electric anticipates high utilization of renewable energy on the system to achieve 100% RE. . Under both the 2015 EIA and February 2016 STEO Fuel Price Forecasts, the total system renewable energy utilization are identical.

Theme 1

Renewable Energy Utilization

% RE	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2016-2045
Utilized	100%	100%	100%	100%	93%	91%	91%	91%	90%	90%	89%	89%	88%	88%	86%	86%	86%	86%	85%	85%	85%	85%	84%	84%	84%	84%	84%	83%	83%	78%	85%

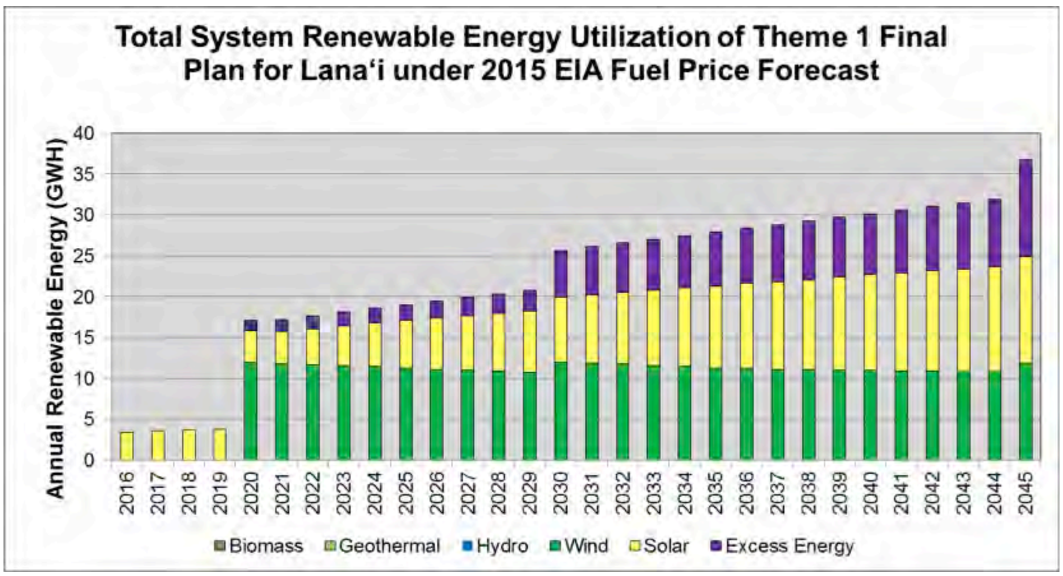


Figure 6-57. Total System Renewable Energy Utilization of Theme 1 Final Plan for Lana'i Under 2015 EIA Fuel Price Forecast

Theme 3

Renewable Energy Utilization

% RE	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Utilized	100%	100%	100%	100%	93%	92%	92%	93%	93%	93%	94%	94%	94%	95%	84%

% RE	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2016-2045
Utilized	85%	86%	86%	87%	87%	88%	88%	89%	90%	88%	89%	89%	89%	90%	90%	90%

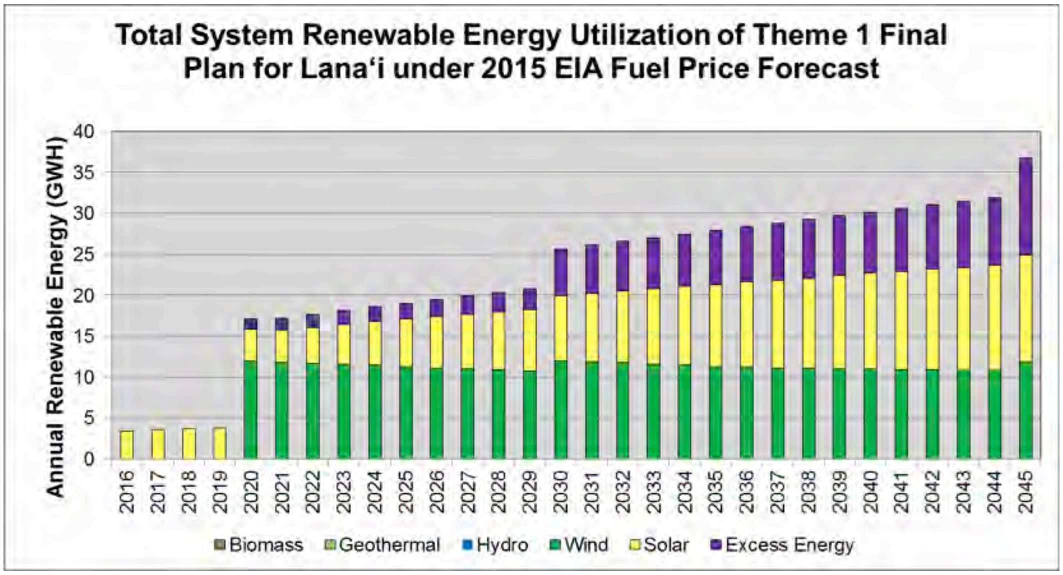


Figure 6-58. Total System Renewable Energy Utilization of Theme 3 Final Plan for Lana‘i Under 2015 EIA Fuel Price Forecast

DAILY ENERGY CHARTS OF FINAL PLANS FOR LANA‘I

The following charts illustrate representative study days on Lana‘i with increasing renewable energy contributions that displace fossil fueled generation over time. These charts show the advantage of a diversified portfolio of resources such, firm dispatchable, variable generation, and demand response to serve our customer’s energy needs.

A noticeable occurrence in each chart is the large contribution of PV energy during daylight hours, and in some instances, an excess of PV generation during daylight hours. During non-daylight hours, customer needs will need to be met by the portfolio of resources other than PV, such as load shifting storage, wind, and firm dispatchable generation.

Hawaiian Electric
Maui Electric
Hawai‘i Electric Light

Theme 1

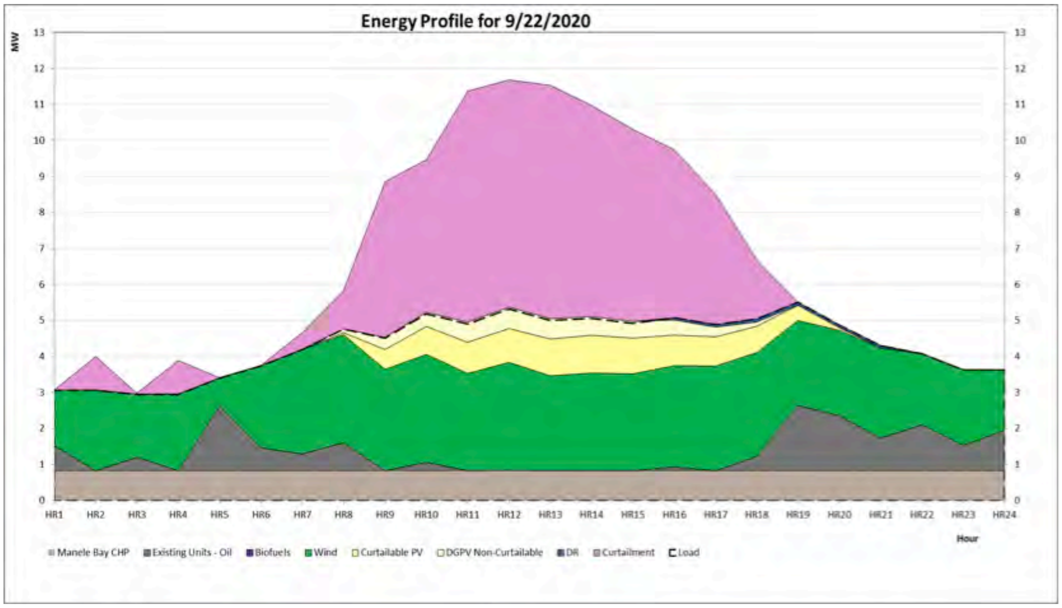


Figure 6-59. Theme 1 Max PV Day 9/22/20

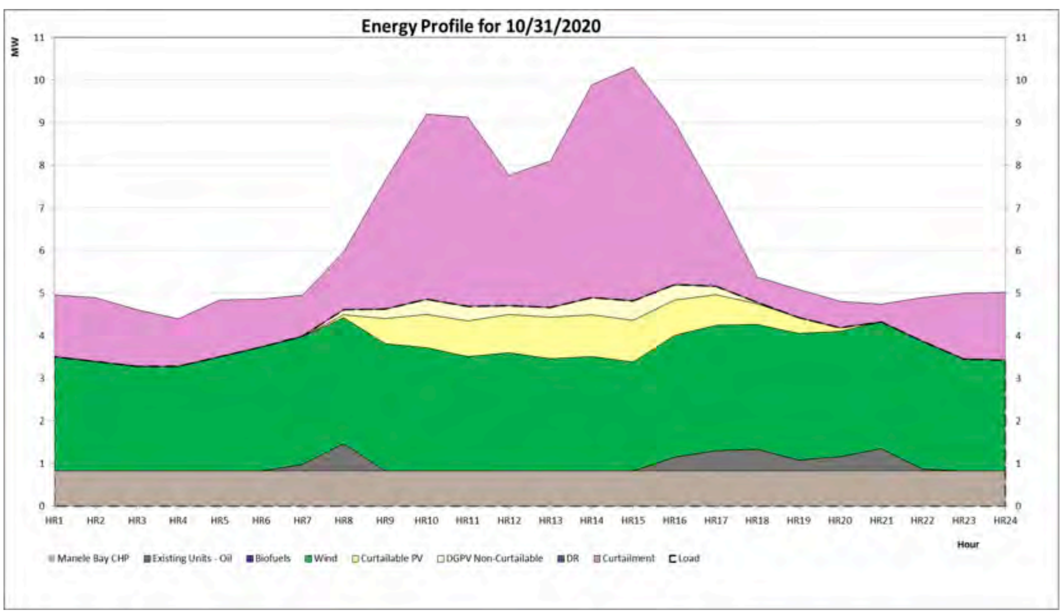


Figure 6-60. Theme 1 Max Wind and PV Day 10/31/20

6. Maui Electric Preferred Plan

Daily Energy Charts of Final Plans for Lanaʻi

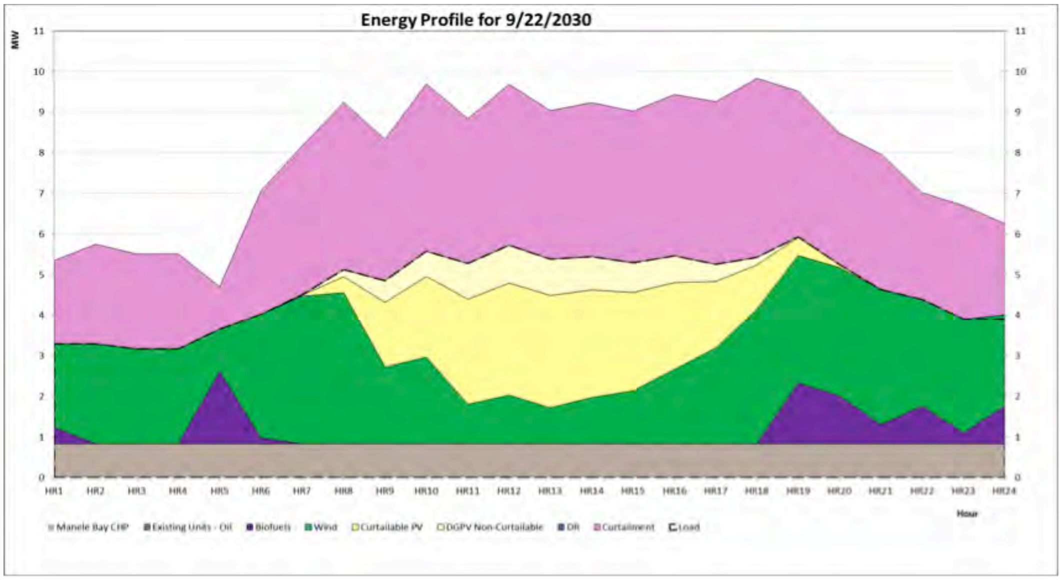


Figure 6-61. Theme 1 Max PV Day 9/22/30

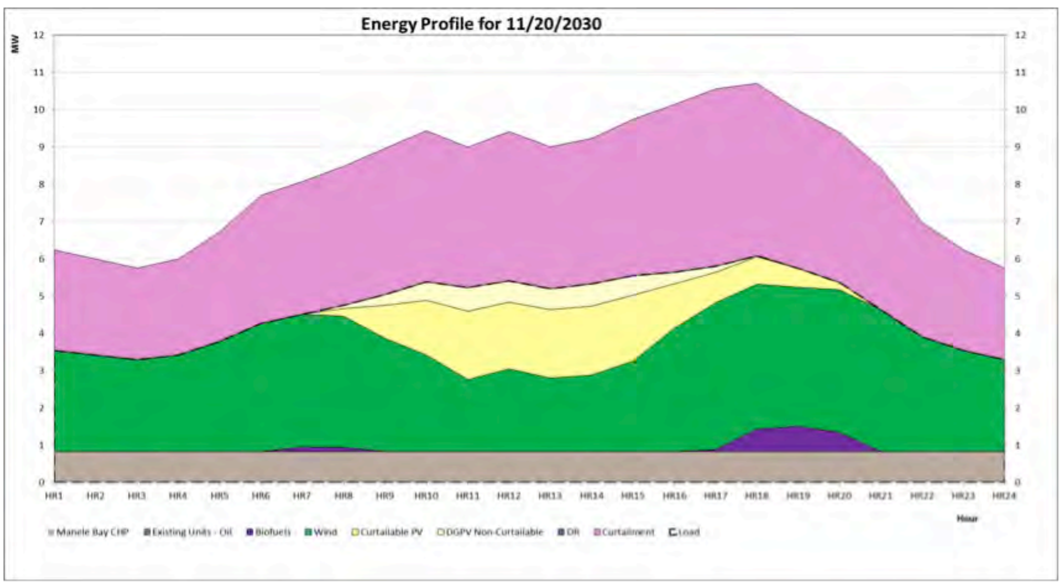


Figure 6-62. Theme 1 Max Wind and PV Day 11/20/30

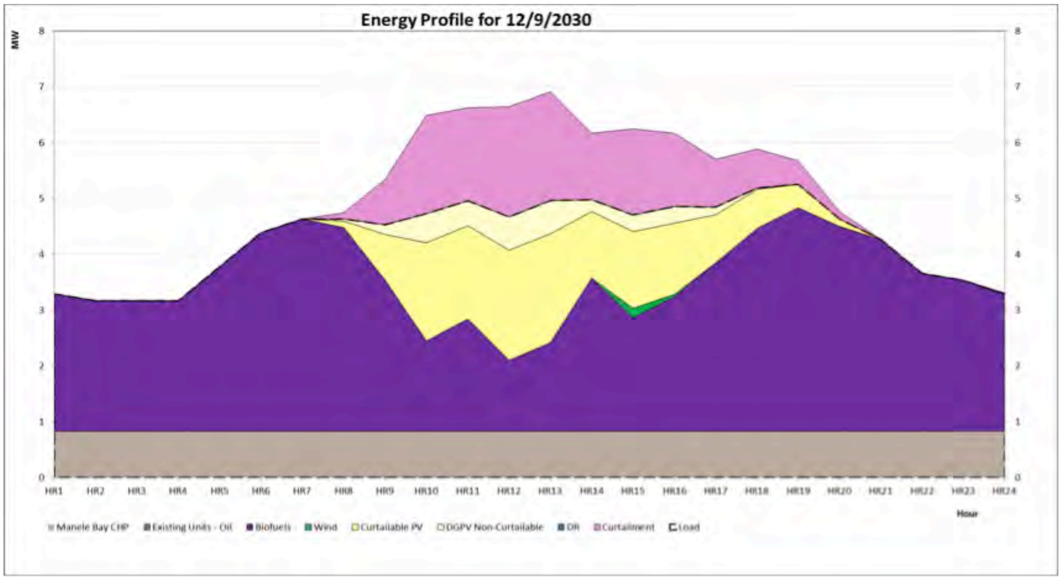


Figure 6-63. Theme 1 Least PV and Wind Day 12/9/30

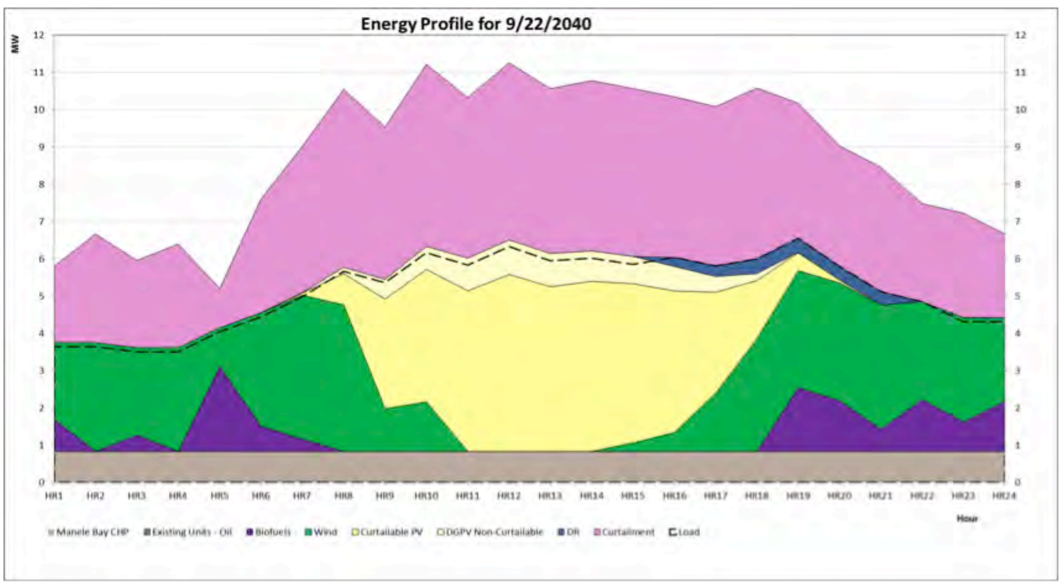


Figure 6-64. Theme 1 Max PV Day 9/22/40

Theme 3

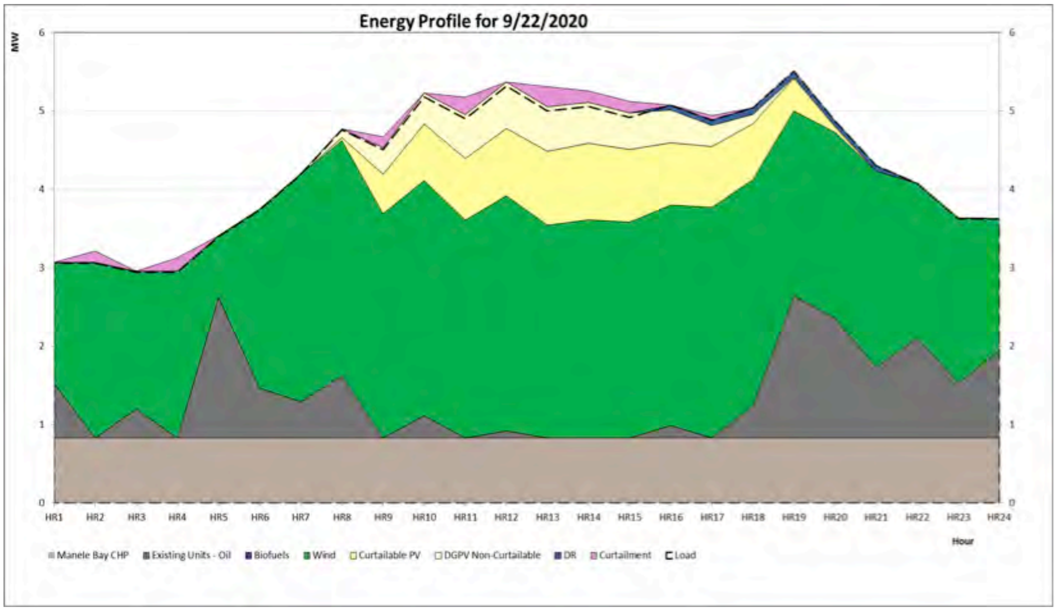


Figure 6-65. Theme 3 Max PV Day 9/22/20

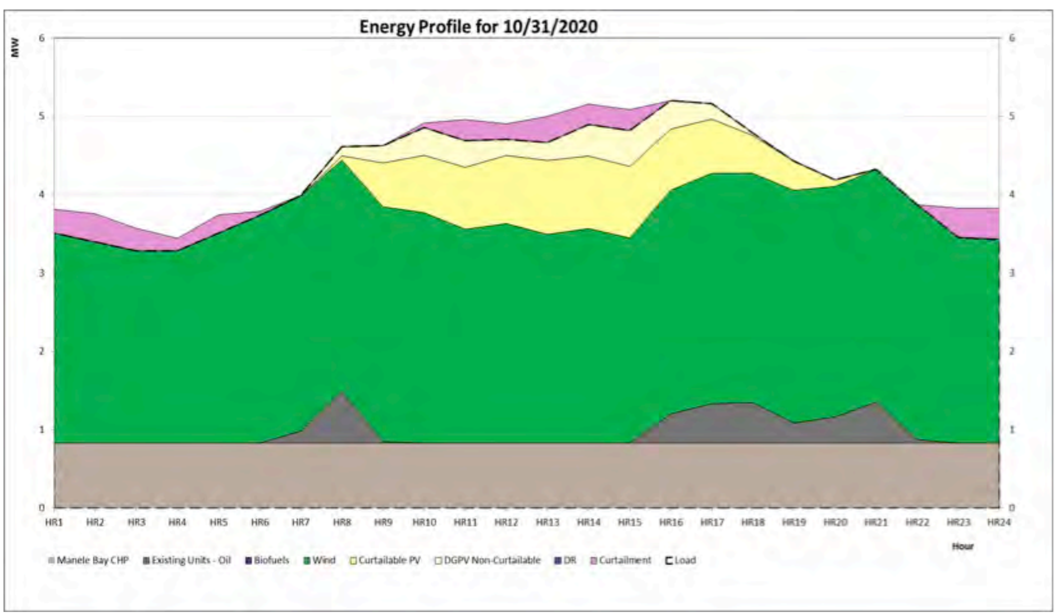


Figure 6-66. Theme 3 Max Wind and PV Day 10/31/20

Hawaiian Electric
Maui Electric
Hawai'i Electric Light

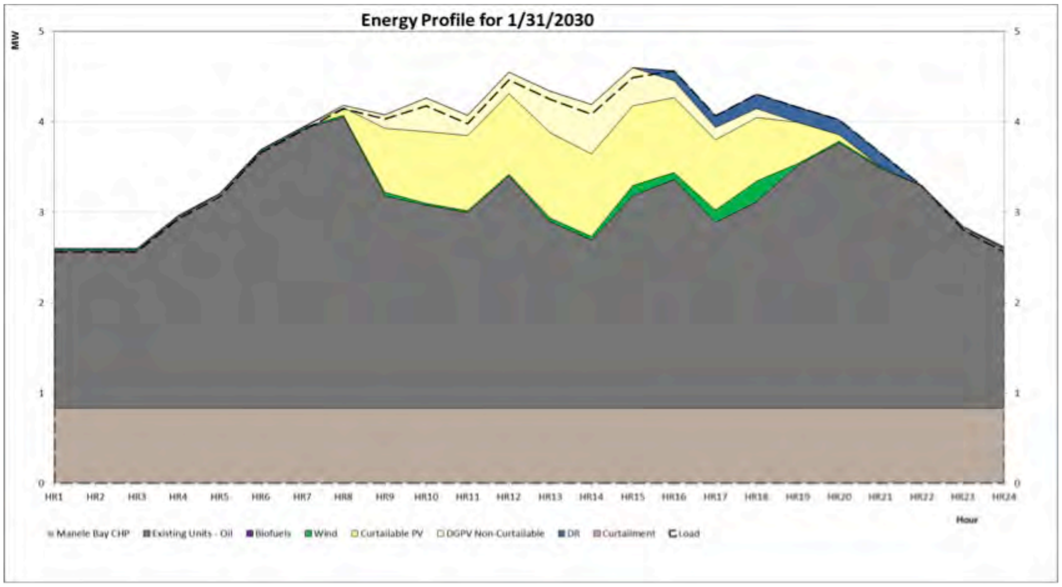


Figure 6-67. Theme 3 Max PV Day 1/31/30

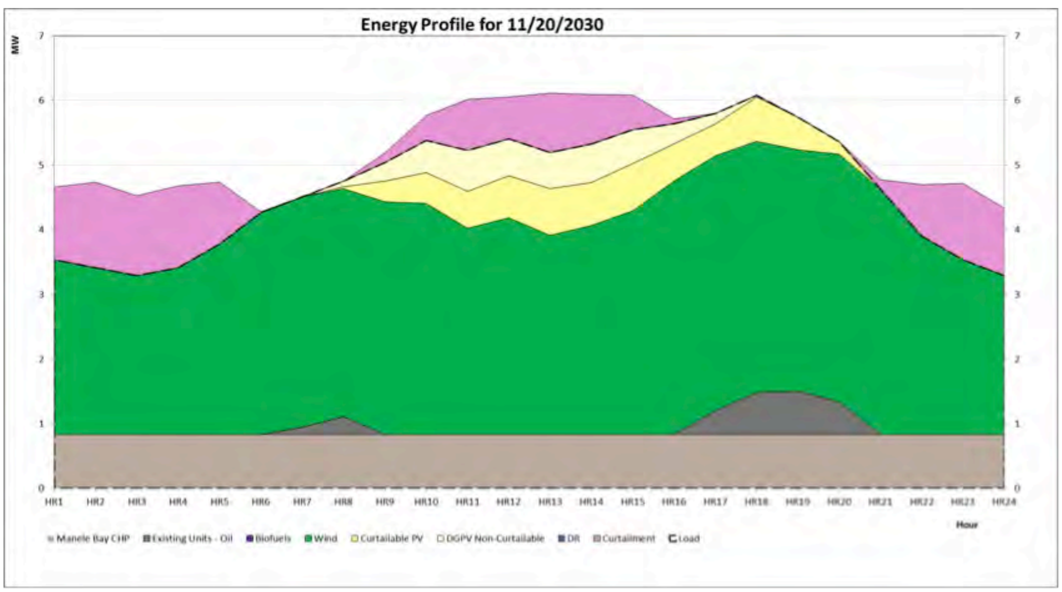


Figure 6-68. Theme 3 Max PV and Wind Day 11/20/30

6. Maui Electric Preferred Plan

Daily Energy Charts of Final Plans for Lana'i

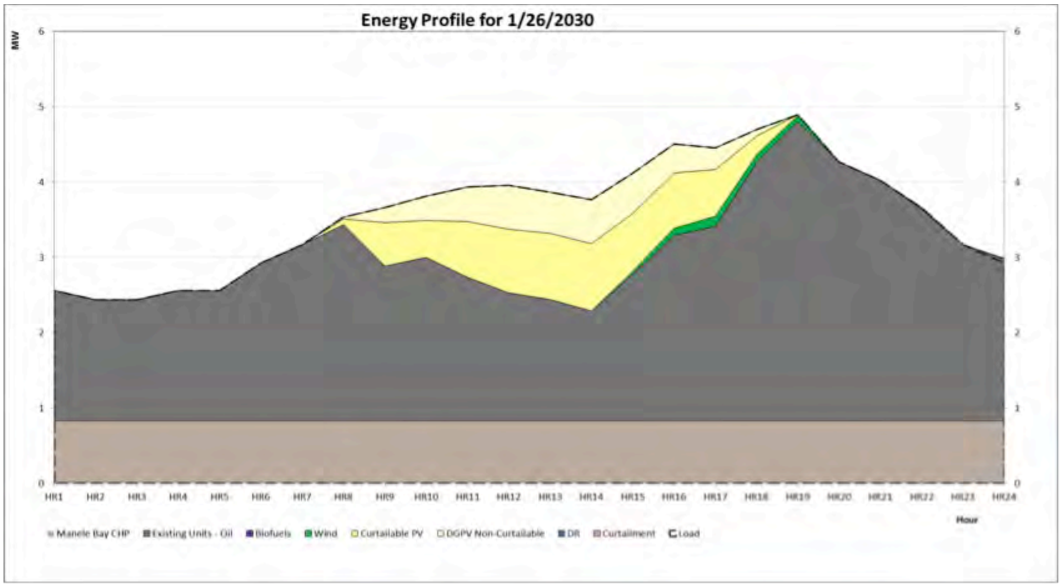


Figure 6-69. Theme 3 Least PV and Wind Day 1/26/30

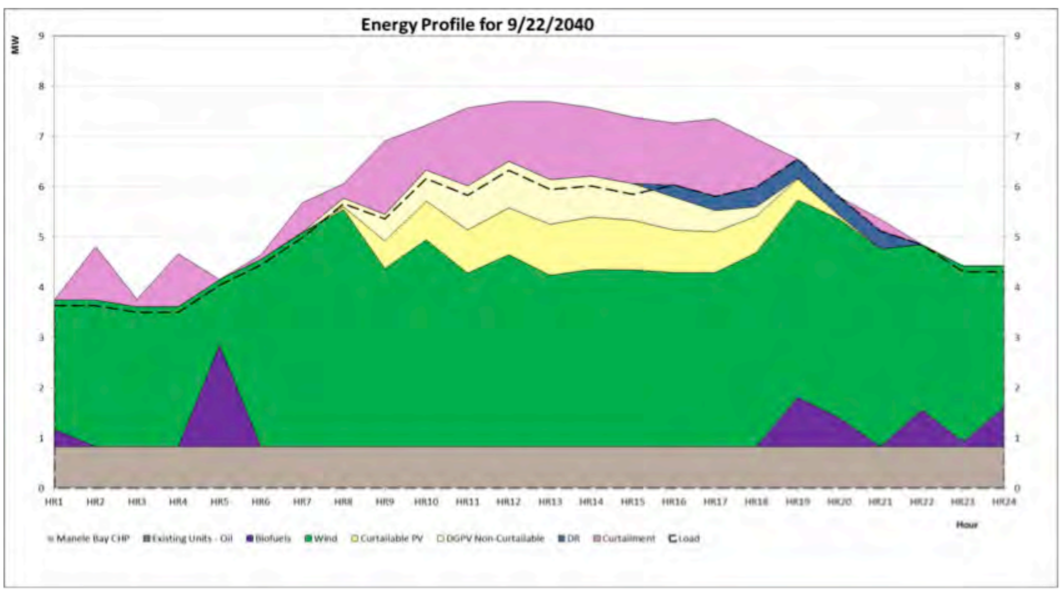


Figure 6-70. Theme 3 Max PV Day 9/22/40

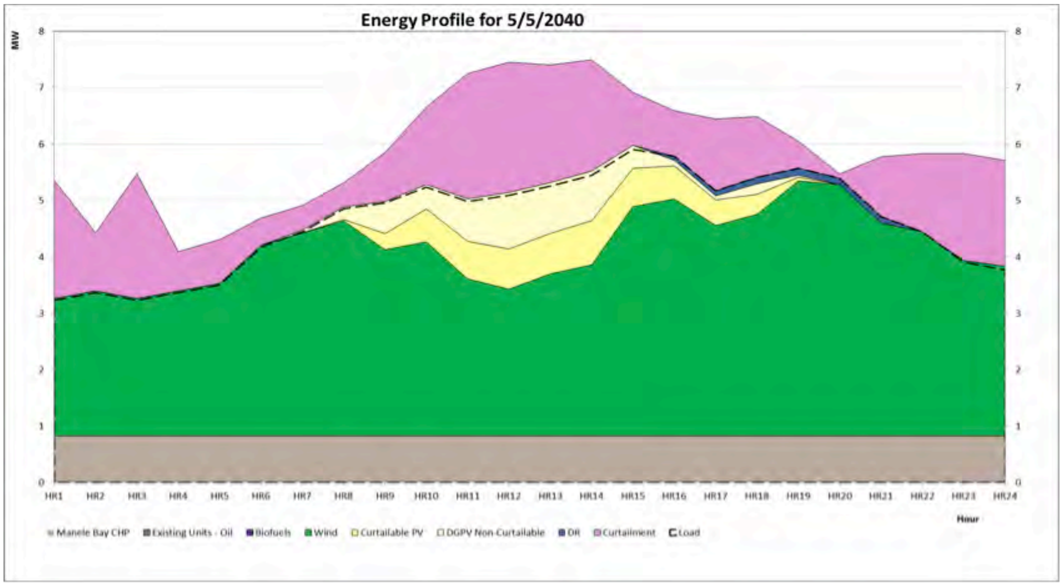


Figure 6-71. Theme 3 Max PV and Wind Day 5/5/40

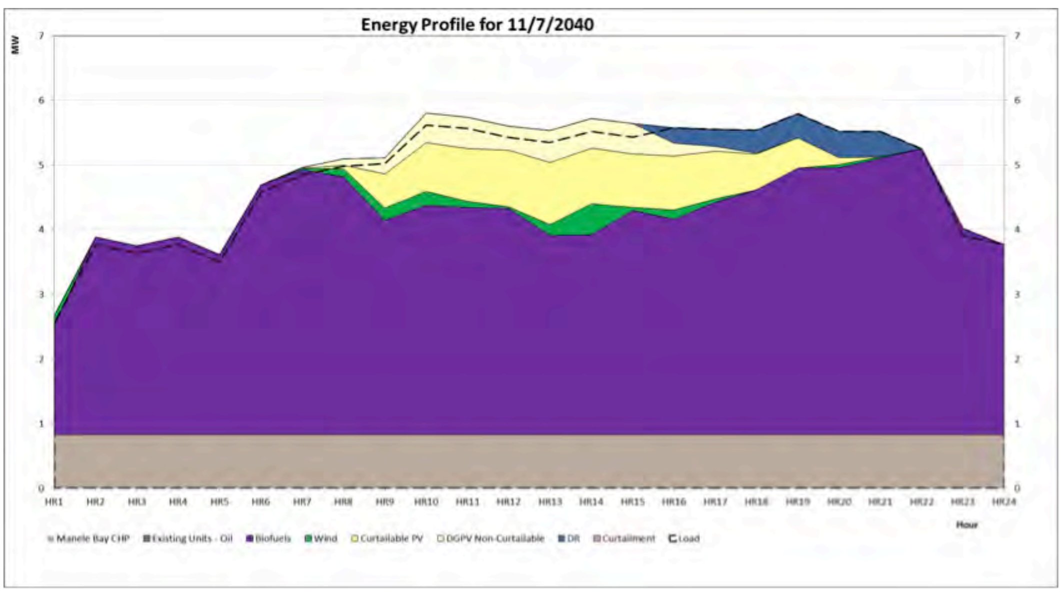


Figure 6-72. Theme 3 Least PV and Wind Day 11/7/40

LANA'I SELECTION OF THEME 1

Theme 1 will add significant amounts of variable renewable generation in conjunction with the removal of "must-run" conventional generation upon installation of system security measures. Lana'i will achieve 100% renewable energy by 2030.

Case Name	Preferred Plan
Case Label	
DER Forecast	High DG-PV
Fuel Price	2015 EIA Reference
2016	
2017	
2018	
2019	Install two - 5 MVA Synchronous Condenser (10 MVA Total)
2020	3 MW Wind
2021–2029	*No additions 2021–2029*
2030	1 MW Wind
2031–2034	*No additions 2031–2034*
2045	1 MW Wind

Table 6-3. Lana'i Preferred Plan

Hawaiian Electric
Maui Electric
Hawai'i Electric Light

7. Hawai'i Electric Light Preferred Plan

Hawai'i Electric Light developed this Preferred Plan for transforming the system from current state to a future vision of the utility in 2045 that is consistent with the Commissions Observations and Concerns.

Implementation of this Preferred Plan would safely transform the electric system and achieve unprecedented levels of renewable energy production. The electric system of the future would integrate a balanced portfolio of renewable energy resources, thermal generation, energy storage, and demand response.

This Preferred Plan transforms the electric system to provide the appropriate characteristics to accommodate high levels of both variable and dispatchable renewable technologies. This transformation includes the addition of new renewable dispatchable generating units and energy storage for cost effective and reliable operations. The plans also incorporate systematic retirement of existing steam generating units as their value to the system has diminished. This transformation allows for the incorporation of unprecedented amounts of renewable generation on the electric system, above levels that are already the highest in the nation.

Through adding the identified resources to the electric system, the Hawai'i Electric Light Preferred Plan exceeds the mandated RPS at every interim year by a substantial margin, decreases reliance on imported fossil fuels, improves costs, and preserves system operability.

ENERGY MIX OF FINAL PLANS

As discussed in Chapter 3, different paths to achieving 100% renewable energy in 2045 were analyzed. Figure 7-1 summarizes the annual RPS for each year. Theme 1 accelerates the RPS targets while Themes 2 and 3 strategically achieves the RPS targets.

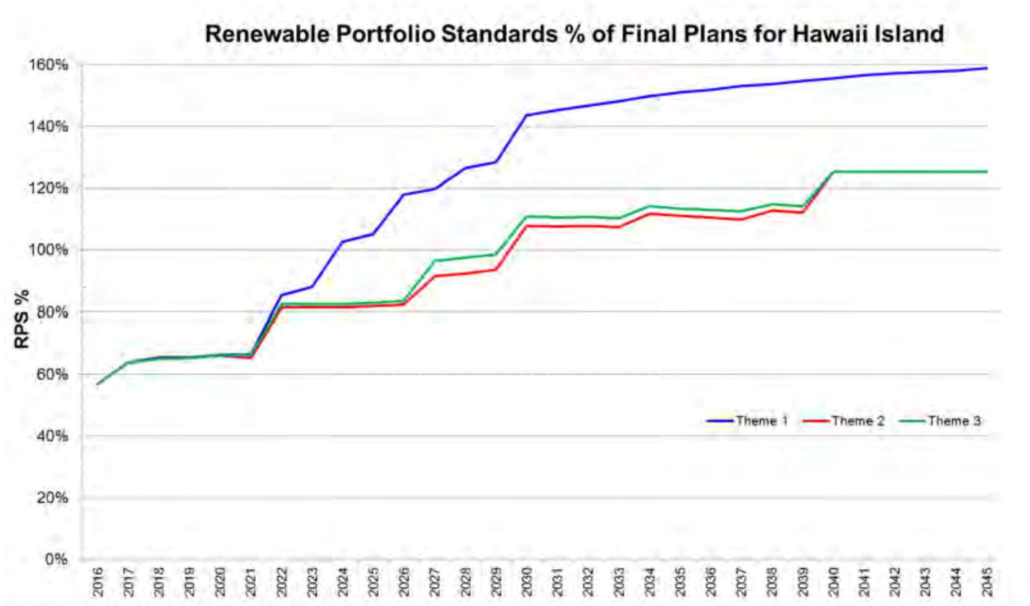


Figure 7-1. Renewable Portfolio Standards of Final Plans for Hawai‘i Island

The Hawai‘i Electric Light Preferred Plan includes the conversion of the islands two combined cycle units to LNG and incorporate greater amounts of renewable energy out to 2045. The figures that follow show how the resource mix of the three Hawai‘i Island themes vary in generation and transform over time.

The annual energy served by resource type is shown in Figure 7-2 for the Theme 1 final plan under the 2015 EIA Reference Fuel Price Forecasts. The transition to renewable wind, biomass, and geothermal can be easily seen as the fossil fuel (oil and diesel) significantly decreases over time.

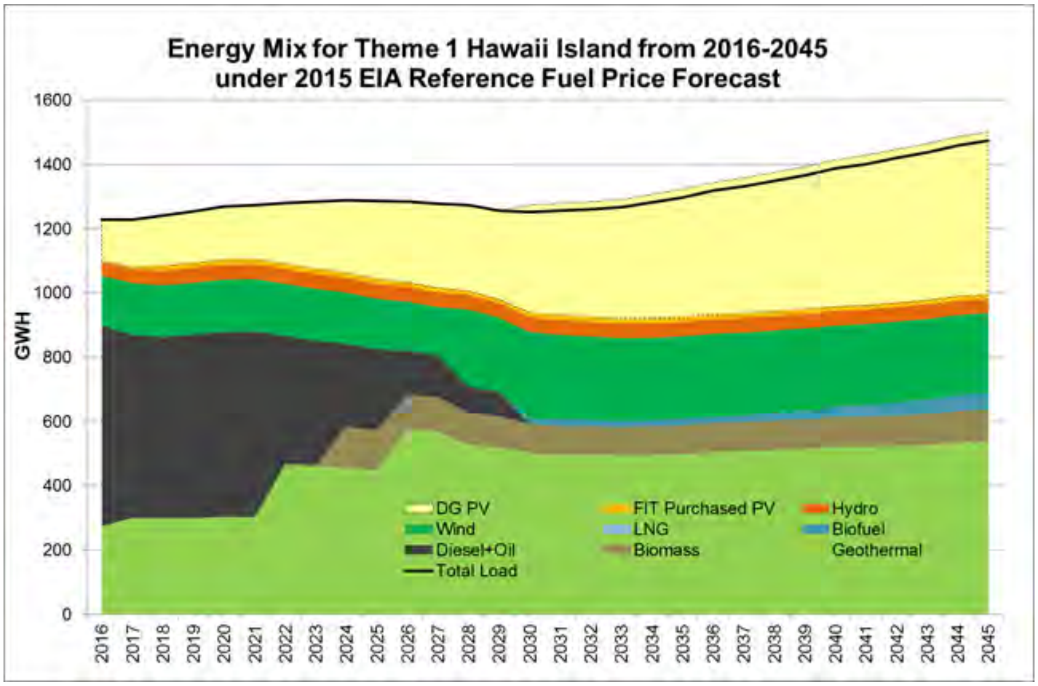


Figure 7-2. Energy Mix for Theme 1 on Hawaiʻi Island from 2016-2045 under 2015 EIA Fuel Price Forecast

Each final plan was evaluated under a range of fuel prices and Figure 7-3 shows the energy mix of Theme 1 under the February 2016 EIA STEO Fuel Price Forecasts. The lower fuel prices did not noticeably change the energy mix

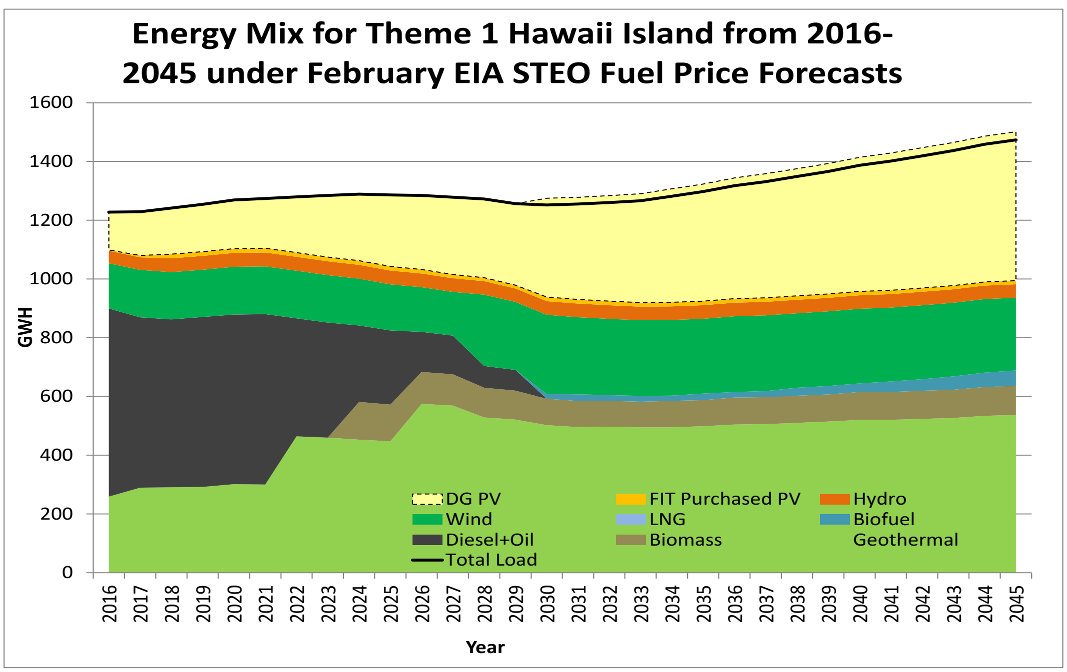


Figure 7-3. Energy Mix for Theme 1 on Hawaiʻi Island from 2016-2045 under February 2016 EIA STEO Fuel Price Forecast

The Theme 2 final plan uses LNG as a transitional fuel from oil to increasing levels of renewable energy. Renewable energy is added to meet intermediate RPS targets as it moves towards 100% renewable in 2040. The energy mix for Theme 2 under the 2015 EIA Reference Fuel Price Forecasts is shown in Figure 7-4.

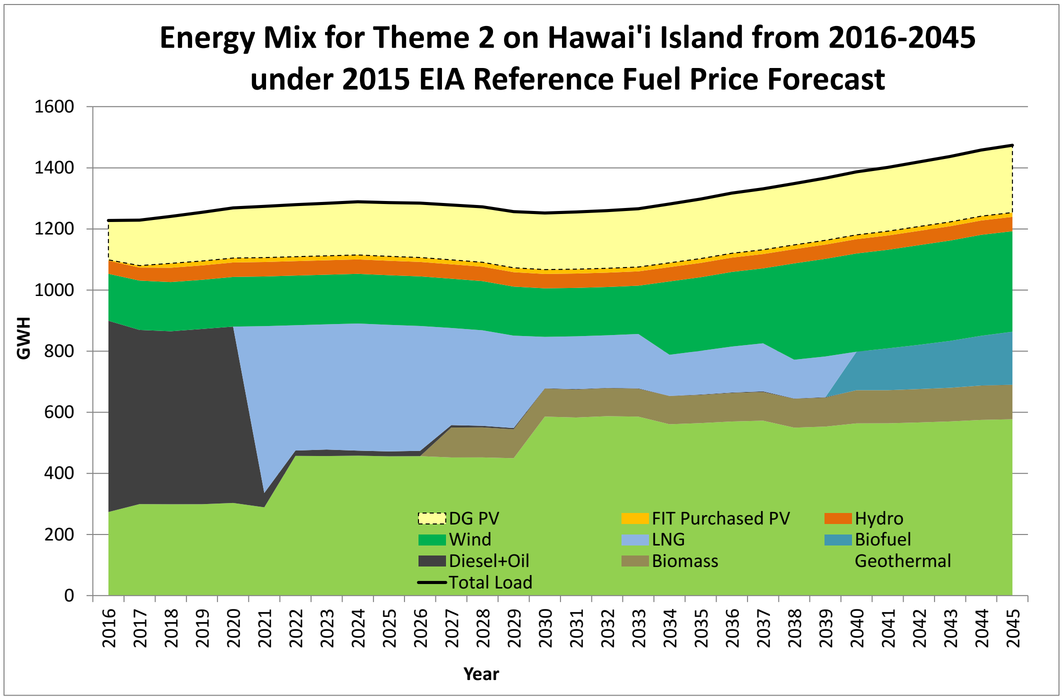


Figure 7-4. Energy Mix for Theme 2 on Hawai'i Island from 2016-2045 under 2015 EIA Reference Fuel Price Forecast

The energy mix of Theme 2 under the February 2016 EIA STEO Fuel Price Forecasts did not noticeably change under the lower fuel prices as shown in Figure 7-5.

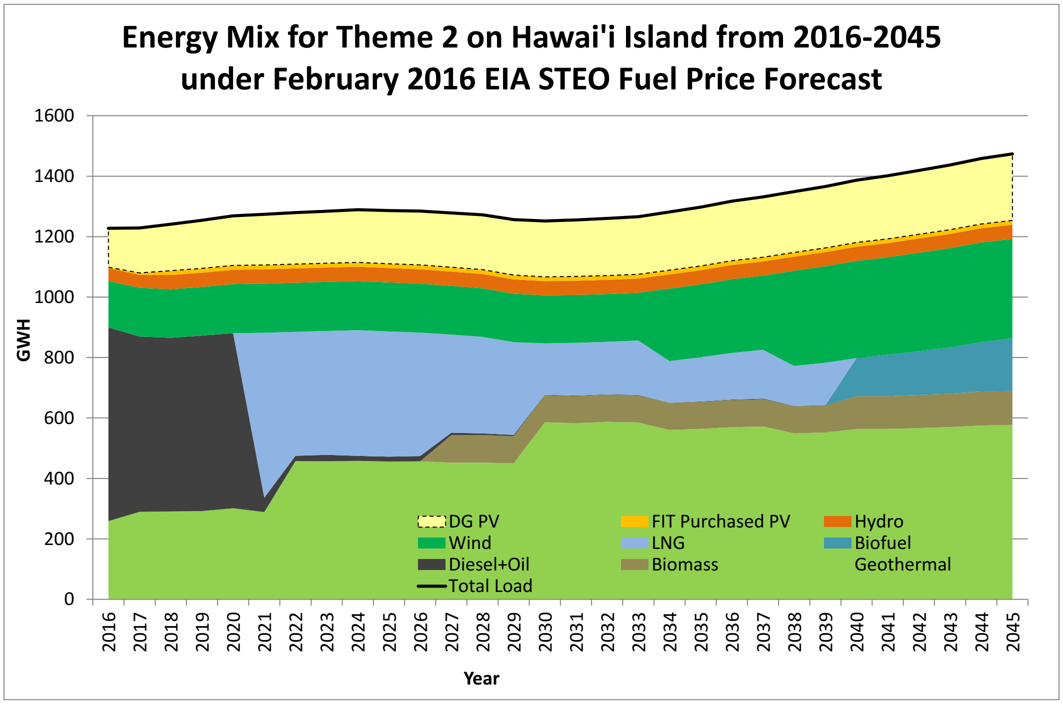


Figure 7-5. Energy Mix for Theme 2 on Hawai'i Island from 2016-2045 under February 2016 EIA STEO Fuel Price Forecasts

The final plan for Theme 3 does not include the use of LNG and strategically increases renewable energy to meet the intermediate RPS targets as in Theme 2. Figure 7-6 illustrates the energy mix under the 2015 EIA Reference Fuel Price Forecasts.

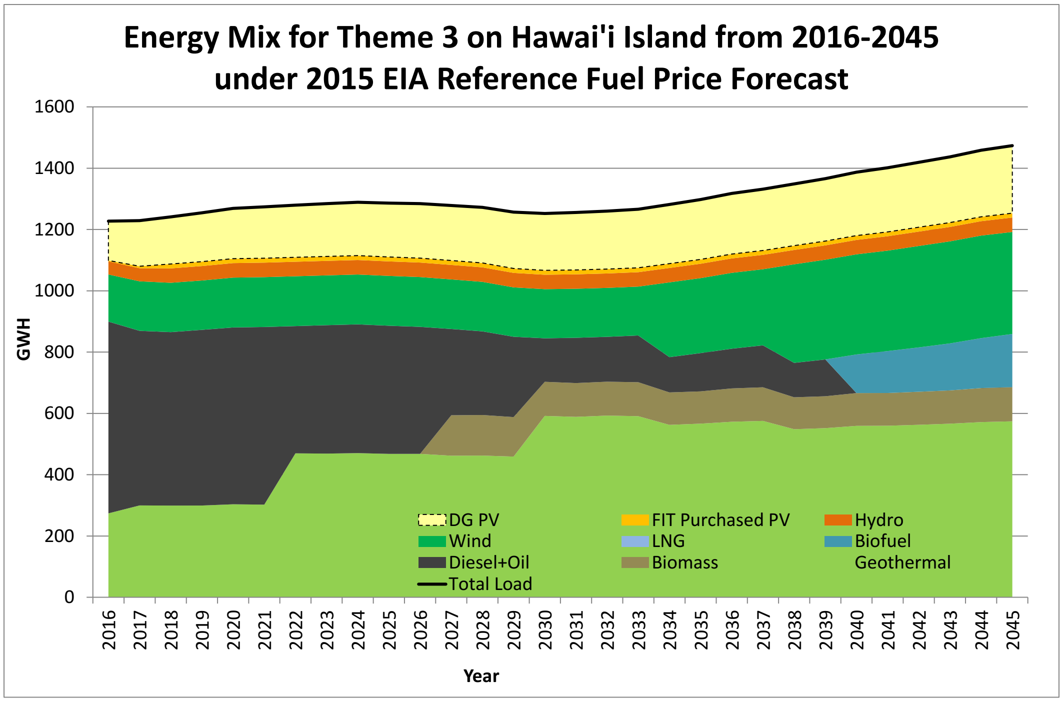


Figure 7-6. Energy Mix for Theme 3 on Hawai'i Island from 2016-2045 under 2015 EIA Fuel Price Forecasts

Similar to the final plans in Themes 1 and 2, the energy mix of Theme 3 under the February 2016 EIA STEO Fuel Price Forecasts did not noticeably change under the lower fuel prices as shown in Figure 7-7.

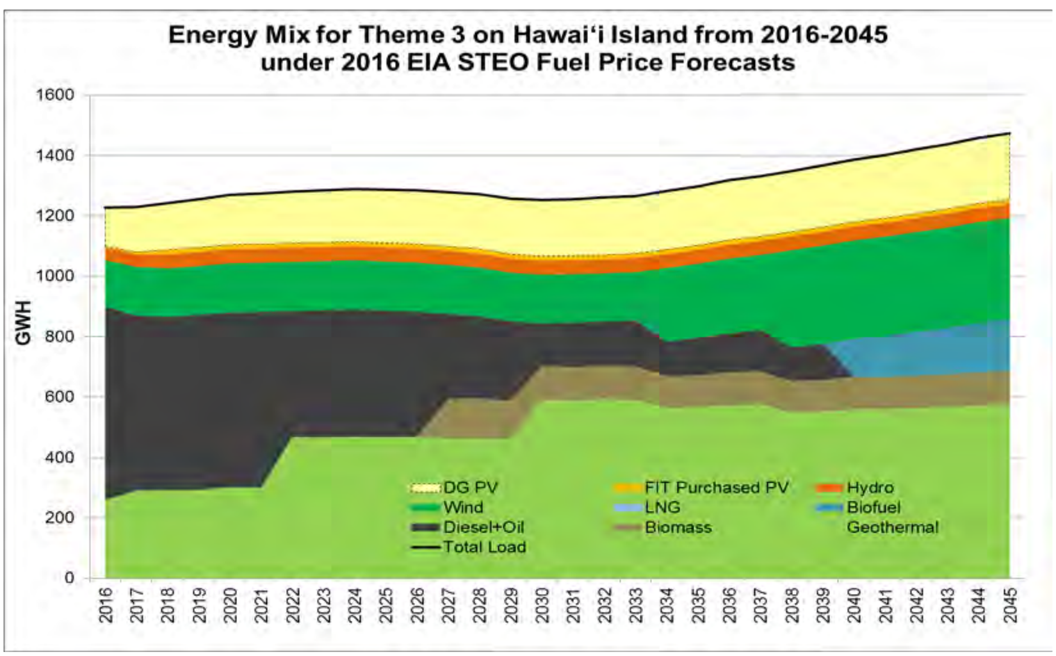


Figure 7-7. Energy Mix for Theme 3 on Hawai'i Island from 2016-2045 under February 2016 EIA STEO Fuel Price Forecasts

The generation mix in all themes has increasing levels of renewable energy replacing fossil generation. Renewable energy from distributed PV continues to grow over time and new wind and geothermal are also added to the system. As new flexible firm generation is added to the system, firm fossil-fuel generating units are displaced. The different paths of Themes 1, 2, and 3 to achieving 100% renewable energy is clearly displayed in the figures above.

OVER-GENERATION OF TOTAL SYSTEM OF FINAL PLANS

The Hawai'i Island electric system currently has a large share of energy generated by renewable resources. The addition of new flexible firm renewable generation along with increasing wind generation, provide the path to 100% renewable energy generation. There must be available renewable energy in excess of demand to ensure adequacy of supply (from renewable resources) under a 100% renewable energy case. Further, with nearly all resources being renewable, both variable and renewable resources must adjust output to balance with demand – which at lower renewable penetration was borne primarily by dispatchable fossil generation. As a result, variable renewable generation such as wind and PV will occasionally be available in quantities that cannot be fully utilized by the system.

However, situations of over-generation provide opportunities, coupled with appropriate controls systems, to use wind and solar generation as regulation resources in addition to use as a reserve resource. This provides more value than a resource providing energy only. In combination, wind and solar used for energy and some level of regulation and reserve appear to be cheaper than the alternative of additional storage, at least at moderate over-generation levels. For the purposes of this PSIP update, we include the full cost of the utility scale variable generation resources in cost calculations, regardless of over-generation levels and provides a simplified accounting for other services from these resources.

As the islands evolve to ever increasing levels of renewable energy, grid management capabilities, such as dispatch control to balance demand, frequency response, and voltage regulation, will be increasingly required from both variable and firm renewable resources as the systems are transformed to economically and reliably serve the energy needs of the future with 100% renewable energy. This increasing contribution to grid management will require changes to both procurement terms and technical and operational capabilities of all renewable resources, including distributed and variable energy resources.

Figure 7-8 provides estimates of the percent oversupply from variable resources over-generation of the total system annual energy for the final plans under the 2015 EIA Reference Fuel Price Forecasts. Since Theme 1 integrates greater amounts of variable renewable energy than Themes 2 and 3, the percent over-generation increases significantly and much earlier than in Themes 2 and 3. The charts do not show available capacity from dispatchable renewable resources that are not utilized to follow demand and/or accommodate variable energy resources. In 100% renewable energy systems, variable and firm dispatchable resources will compete to serve demand. The actual allocation of energy between variable and dispatchable should be done in a manner to decrease overall system costs and manage system security, considering the relative costs and capabilities of all resources to provide energy and grid services.

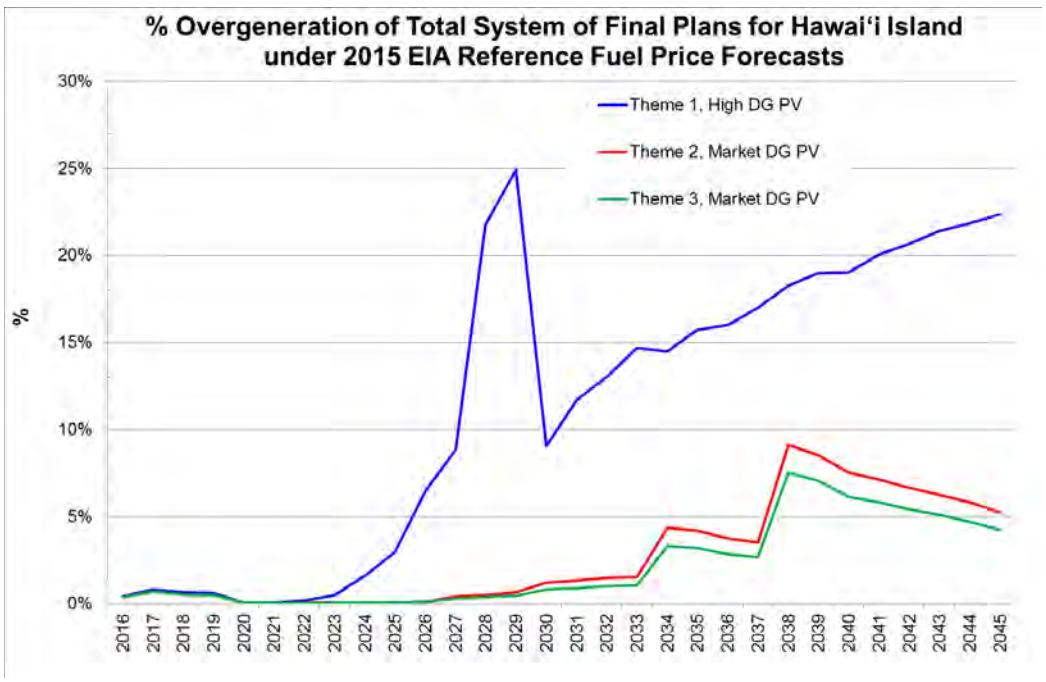


Figure 7-8. Percent Over-Generation of Total System of Final Plans for Hawai'i Island under 2015 EIA Reference Fuel Price Forecasts

Similar estimates of the percent over-generation for the final plans under the February 2016 EIA STEO Fuel Price Forecasts is in Figure 7-9. Again, there isn't a visible difference between the two fuel price forecasts.

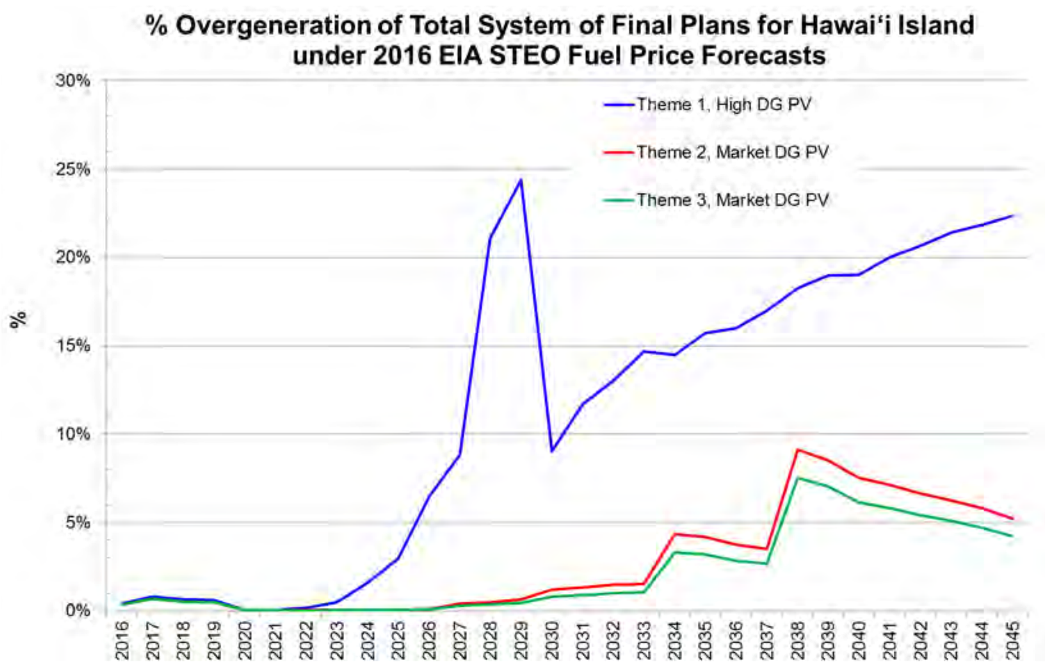


Figure 7-9. Percent Over-Generation of Total System of Final Plans for Hawai‘i Island under February 2016 EIA STEO Fuel Price Forecasts

TOTAL SYSTEM RENEWABLE ENERGY OF FINAL PLANS

The extent to which renewable energy can be utilized on Hawai‘i Island will depend on factors such as the total system load or energy demand, the amount of downward regulation that must be carried on the system to counteract an unexpected loss of load or increase in variable generation, and the total output from variable generation resources. In all Themes, Hawai‘i Electric Light anticipates there is increasingly more renewable energy than can be utilized, as resources are added to ensure cost-effective adequacy of supply using 100% renewable energy.

Theme 1 is utilizing nearly 100% of the variable renewable energy in the near-term and slowly decreases to about 90% after 2040. The results shown in Figure 7-10 is the same under both fuel price forecasts.

Theme 1 2015 EIA Reference Fuel Price Forecast

% RE Utilized	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	99.8%	99.6%	99.6%	99.7%	100.0%	100.0%	99.9%	99.8%	99.3%	98.7%	97.3%	96.2%	91.2%	89.7%	96.1%

% RE Utilized	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2016-2045
	94.8%	94.1%	93.3%	93.3%	92.6%	92.4%	91.8%	91.1%	90.7%	90.6%	90.0%	89.6%	89.1%	88.9%	88.6%	93.5%

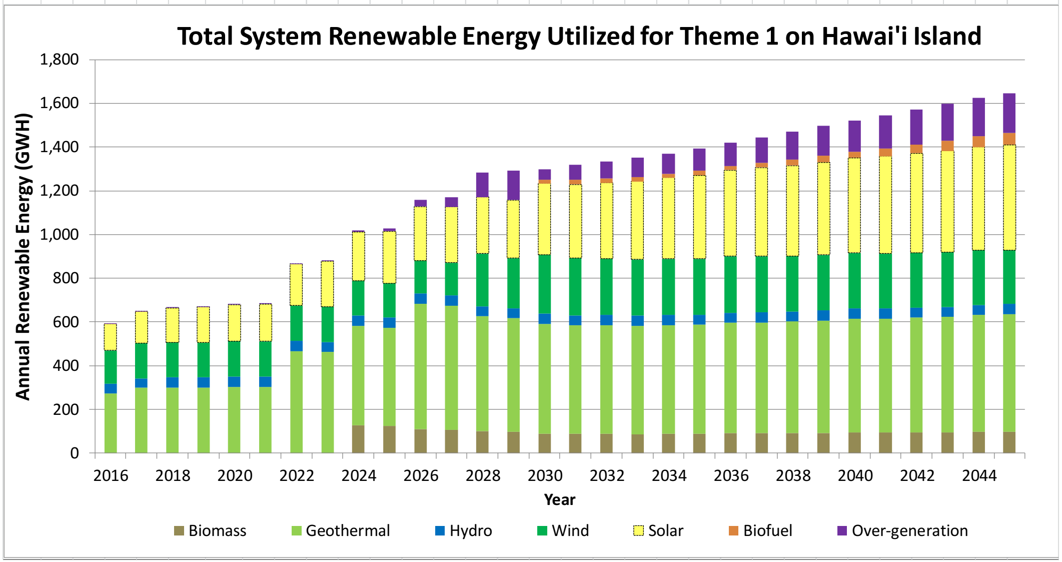


Figure 7-10. Total System Renewable Energy Utilized for Theme 1 on Hawai'i Island

As revealed in Figure 7-11, Theme 2 is utilizing 100% of the variable renewable energy available until about 2030. The lowest amount utilized is about 97%. The results shown in Figure 7-11 is the same under both fuel price forecasts.

% RE Utilized	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	99.8%	99.6%	99.7%	99.7%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.8%	99.8%	99.7%	99.5%

% RE Utilized	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2016-2045
	99.5%	99.4%	99.4%	98.3%	98.4%	98.6%	98.7%	96.7%	96.9%	97.4%	97.5%	97.7%	97.8%	98.0%	98.2%	98.8%

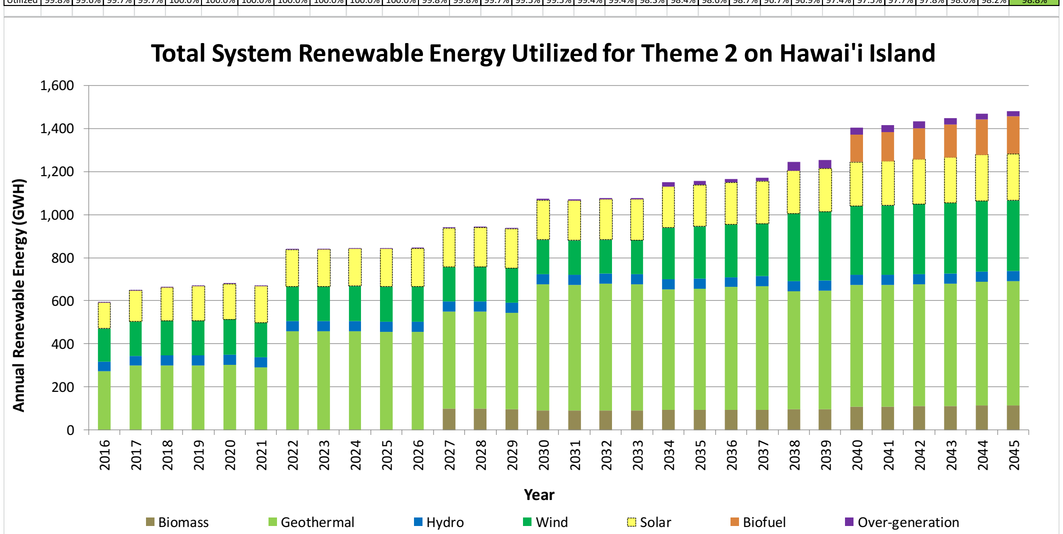


Figure 7-11. Total System Renewable Energy Utilized for Theme 2 on Hawai'i Island

Theme 3 has the same levels of renewable energy as Theme 2 and has very similar utilization of the energy. Figure 7-12 indicates that Theme 3 is utilizing 100% of the renewable energy available until about 2030. The lowest amount utilized is about 97%. The results shown in Figure 7-12 is the same under both fuel price forecasts.

% RE	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Utilized	99.8%	99.6%	99.7%	99.7%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	99.8%	99.8%	99.7%

% RE	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2016-2045
Utilized	99.6%	99.6%	99.6%	98.7%	98.8%	98.9%	99.0%	97.3%	97.5%	97.8%	97.9%	98.1%	98.2%	98.3%	98.5%	99.0%

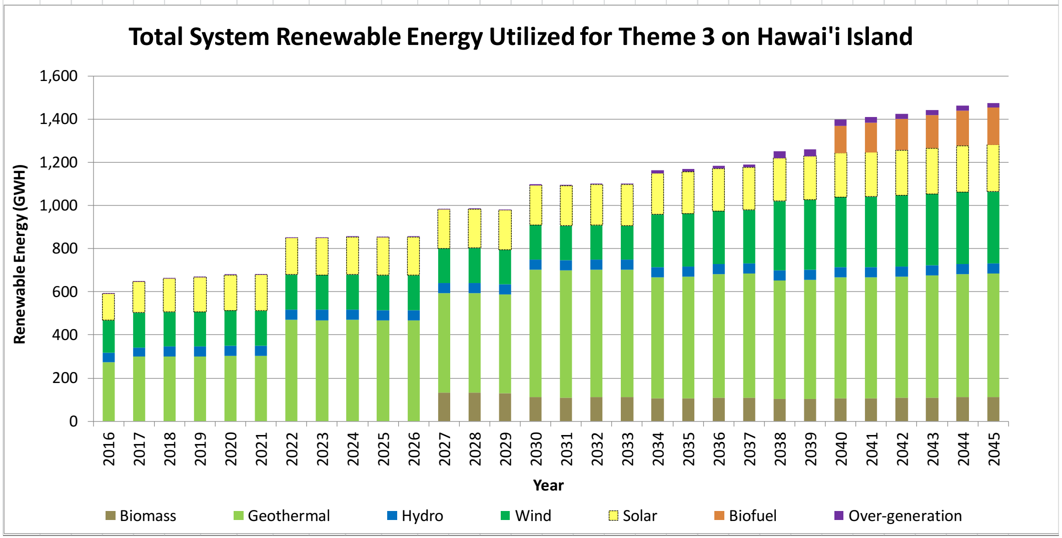


Figure 7-12. Total System Renewable Energy Utilized for Theme 3 on Hawai'i Island

DAILY ENERGY CHARTS OF FINAL PLANS

The following charts illustrate representative study days on Hawai'i Island with increasing renewable energy contributions that displace fossil fueled generation over time. These charts show the advantage of a diversified portfolio of resources such as, firm dispatchable, variable generation, demand response, and load shifting storage to serve our customer's energy needs.

A noticeable occurrence in each chart is the large contribution of PV energy during daylight hours, resulting in potential oversupply of PV generation. During hours without PV production, beyond daylight or cloudy/low irradiance days, customer needs will need to be met by the portfolio of resources other than PV, including storage, wind, and firm dispatchable generation.

Theme 1

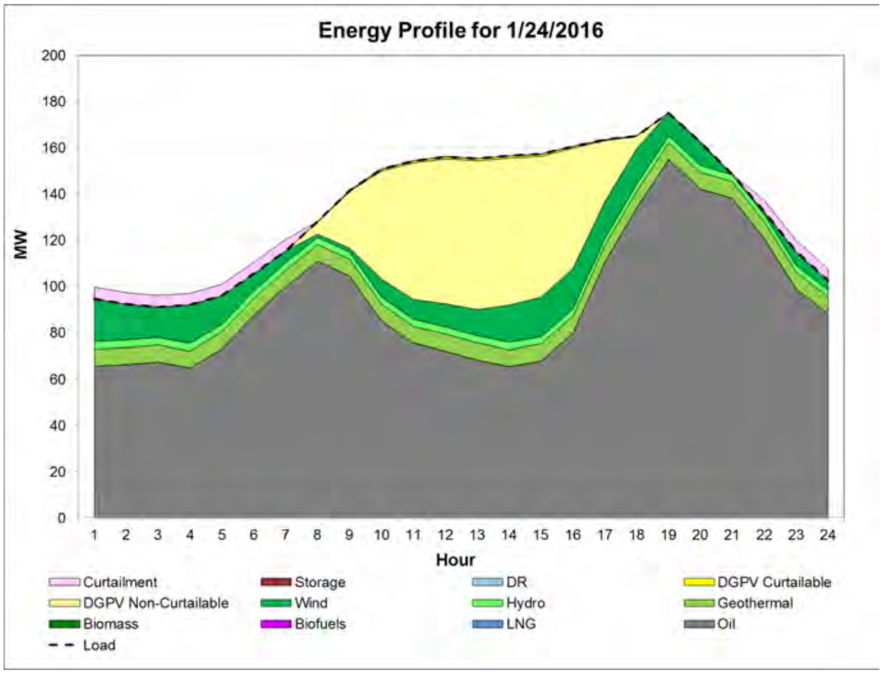


Figure 7-13. Modeled Energy Profile for January 24, 2016 of the Final Plans

Based on the modeling assumptions, the day with the highest penetration of PV energy is January 24, 2016. Figure 7-13 provides the view of the PV energy being accepted together with other renewable and non-renewable resources for Theme 1. Since the assumptions between Theme 1 – 3 are the same in 2016, this chart is representative of all the three themes.

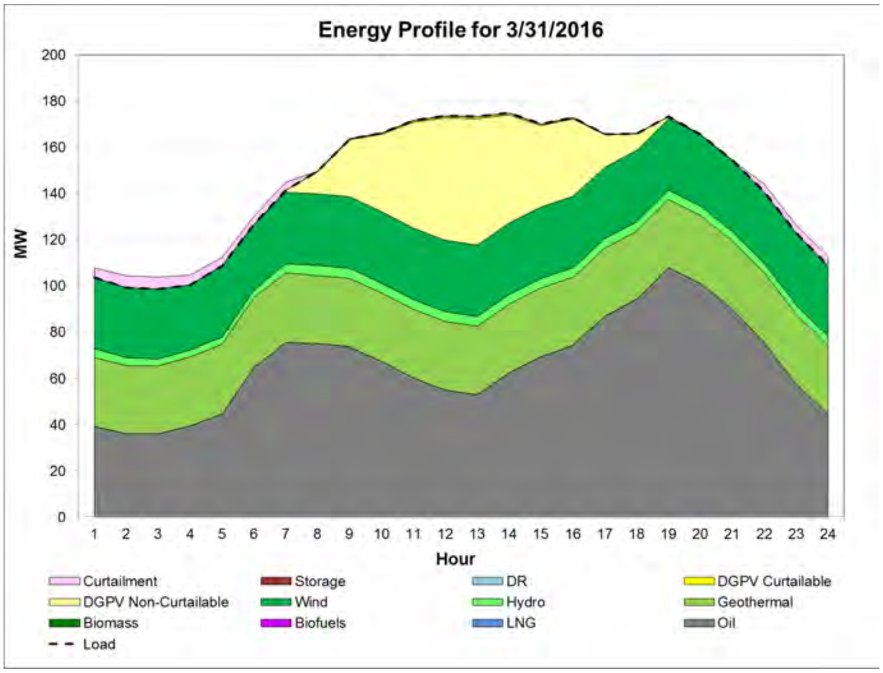


Figure 7-14. Modeled Energy Profile for March 31, 2016 of the Final Plans

Based on the modeling assumptions, the day with the highest penetration of wind energy is March 31, 2016. Figure 7-14 provides the view of the wind energy being accepted together with other renewable and non-renewable resources. Since the assumptions between Theme 1–3 are the same in 2016, this chart is representative of all the three themes.

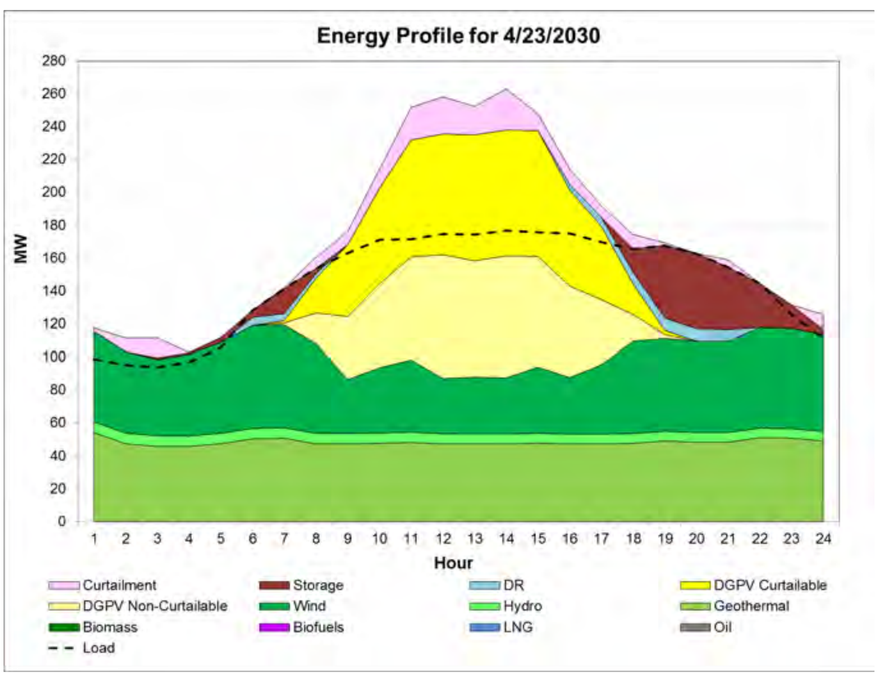


Figure 7-15. Modeled Energy Profile for April 23, 2030 of the Final Plans

Figure 7-15 above illustrates the day with highest available energy from PV and wind in 2030 for Theme 1. As can been seen from the graph, in 2030 the system is 100% renewable as only renewable generating resources serve the daily load. The chart also illustrates the excess generation from wind and PV during day and night hours due to high levels of energy from wind and PV resources. Furthermore, the figure illustrates the use of DR and storage resources.

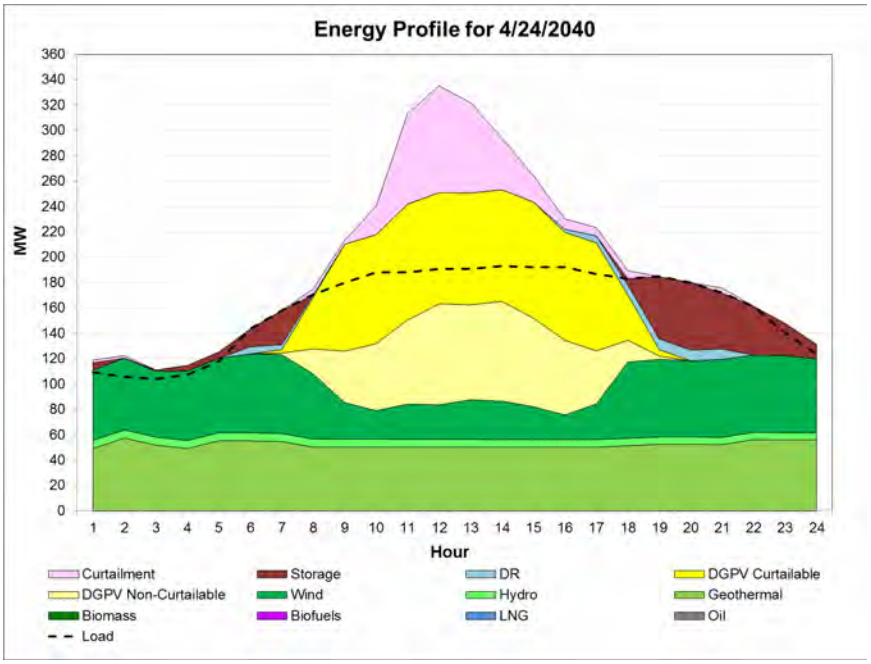


Figure 7-16. Modeled Energy Profile for April 24, 2040 of the Final Plans

Figure 7-16 above illustrates the day with the highest available energy from PV and wind in 2040 for Theme 1. The system is 100% renewable.

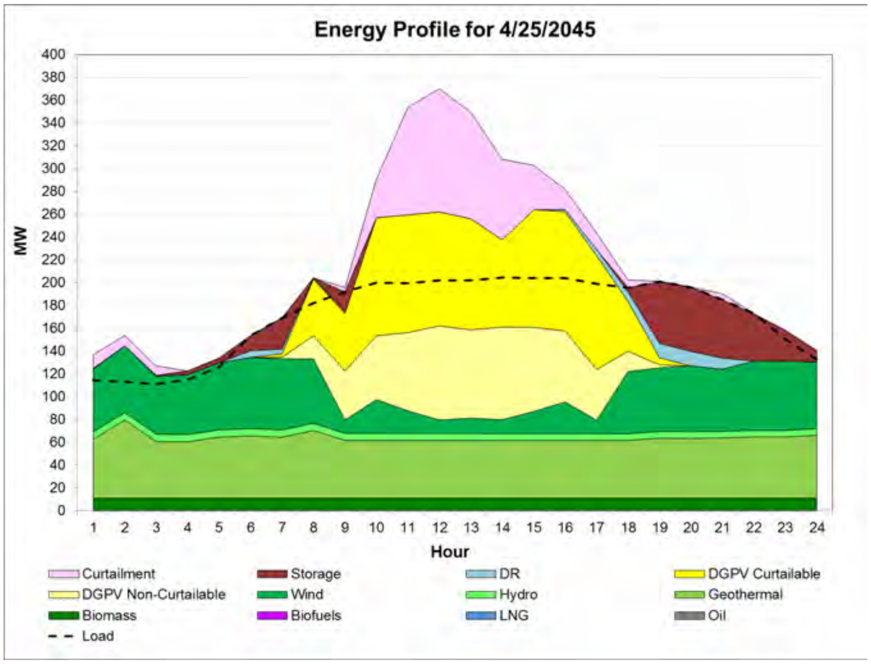


Figure 7-17. Modeled Energy Profile for April 25, 2045 of the Final Plans

Similar to the figure before, Figure 7-17 illustrates the day with highest available energy from PV and wind in 2045 for Theme 1. The system is 100% renewable.

Theme 2

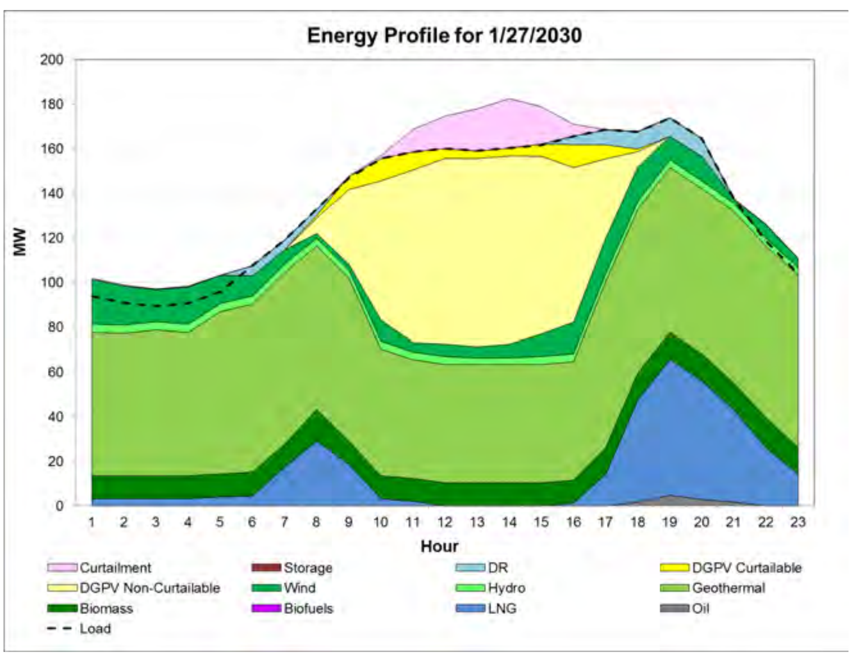


Figure 7-18. Modeled Energy Profile for January 27, 2030 of the Final Plans

Figure 7-18 above illustrates the day with the highest penetration of PV in 2030. There is some excess energy during the day for Theme 2. Most oil generation has been replaced by LNG fuel. A small amount of generation is produced by oil resources to serve the energy during the peak hours.

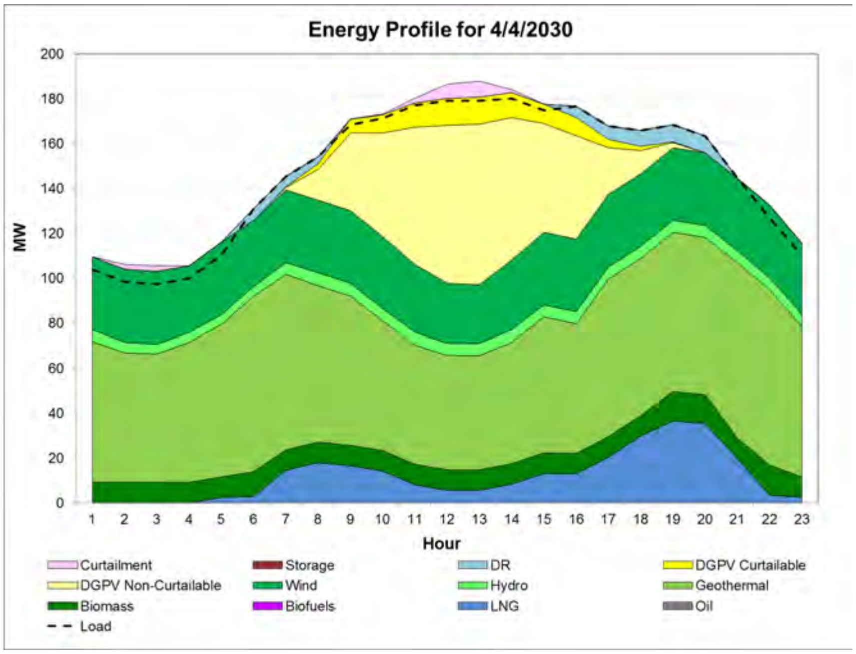


Figure 7-19. Modeled Energy Profile for April 4, 2030 of the Final Plans

Figure 7-19 illustrates the day with the highest penetration of wind in 2030. All of the oil generation is replaced by LNG. High availability of wind and PV resource reduces the use of LNG and oil generation.

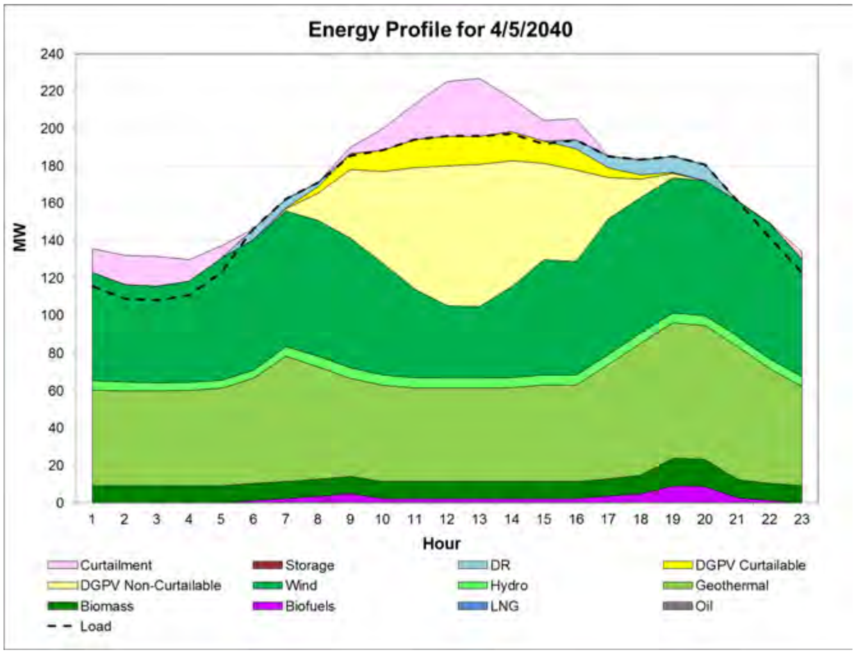


Figure 7-20. Modeled Energy Profile for April 5, 2040 of the Final Plans

Figure 7-20 above illustrates a day in 2040 with high PV and wind generation for Theme 2. The system is 100% renewable. The majority of renewable energy is provided by firm and variable generation renewable resources. A small portion of generation is provided by biofuels. Over-generation occurs during the day and night hours due to high availability of wind and PV resources.

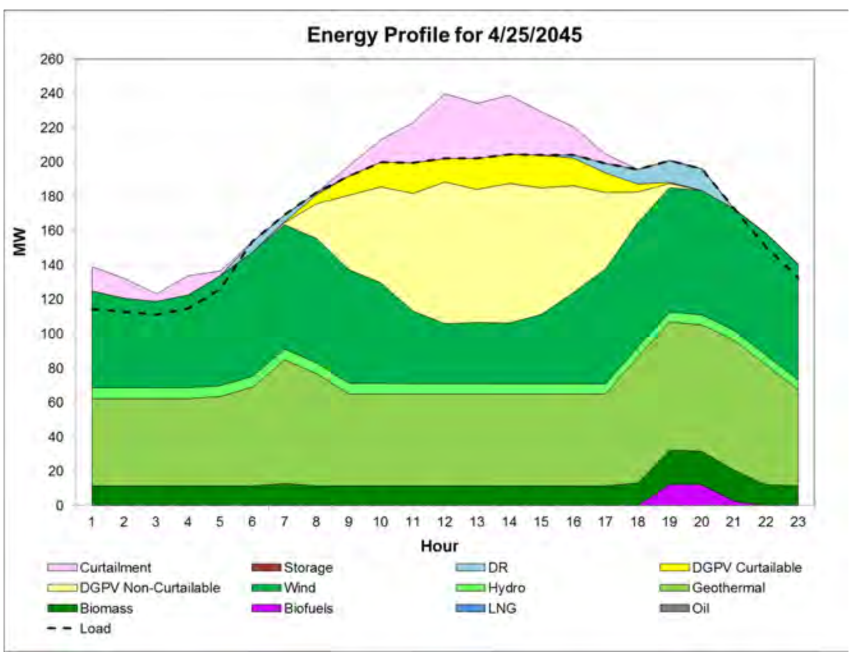


Figure 7-21. Modeled Energy Profile for April 25, 2045 of the Final Plans

Figure 7-21 above illustrates a day in 2045 with high PV and wind generation.

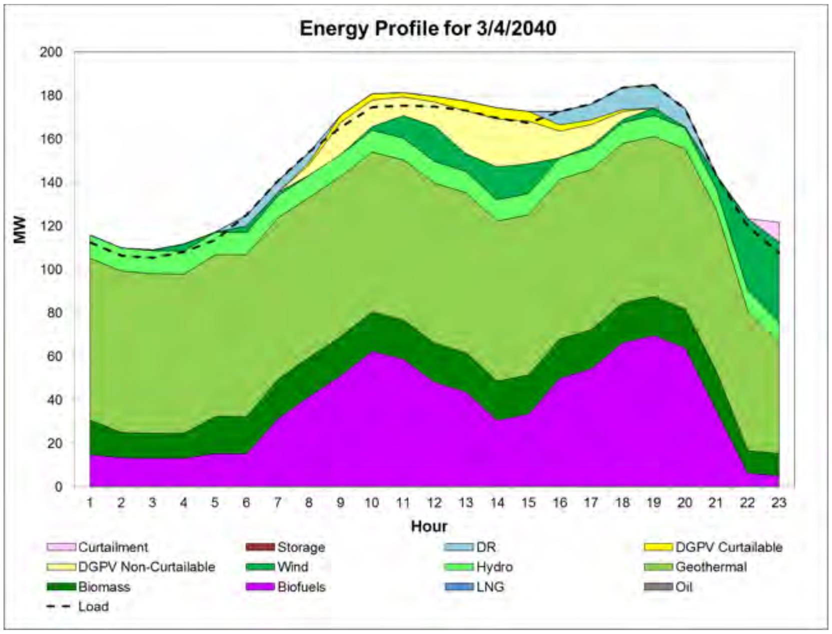


Figure 7-22. Modeled Energy Profile for March 4, 2040 of the Final Plans

Figure 7-22 above illustrates daily generation with minimum availability of both wind and PV. In this case, there is minimum excess generation during this day. However, for the system to reliability meet the daily load, it relies heavily on firm dispatchable renewable resources and thermal generators using biofuels. This situation will occur during the days when PV and wind energy resources are unavailable or minimally available.

Theme 3

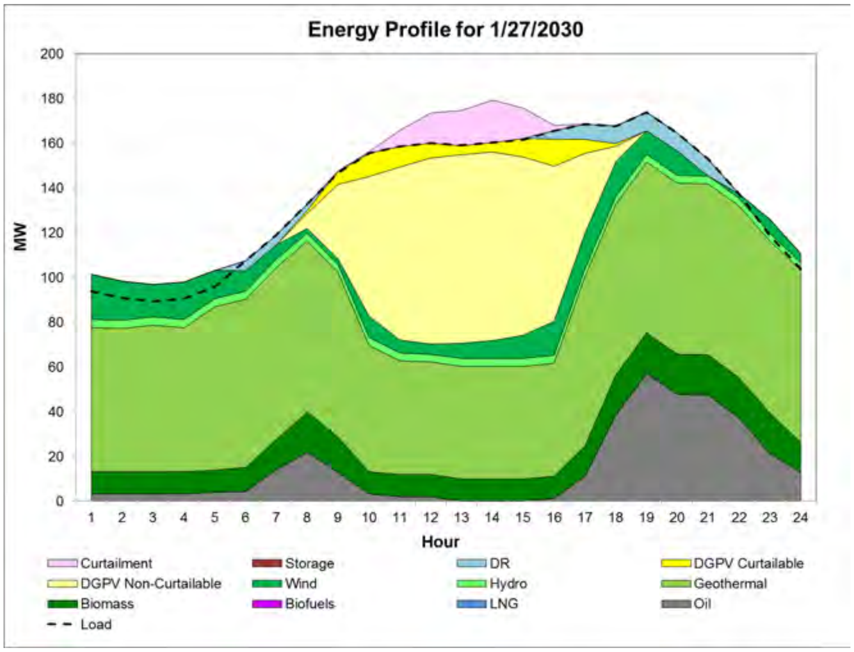


Figure 7-23. Modeled Energy Profile for January 27, 2030 of the Final Plans

Similarly to Theme 2, Figure 7-23 above illustrates the daily generation with high penetration of PV. Unlike Theme 2, the system does not switch to LNG.

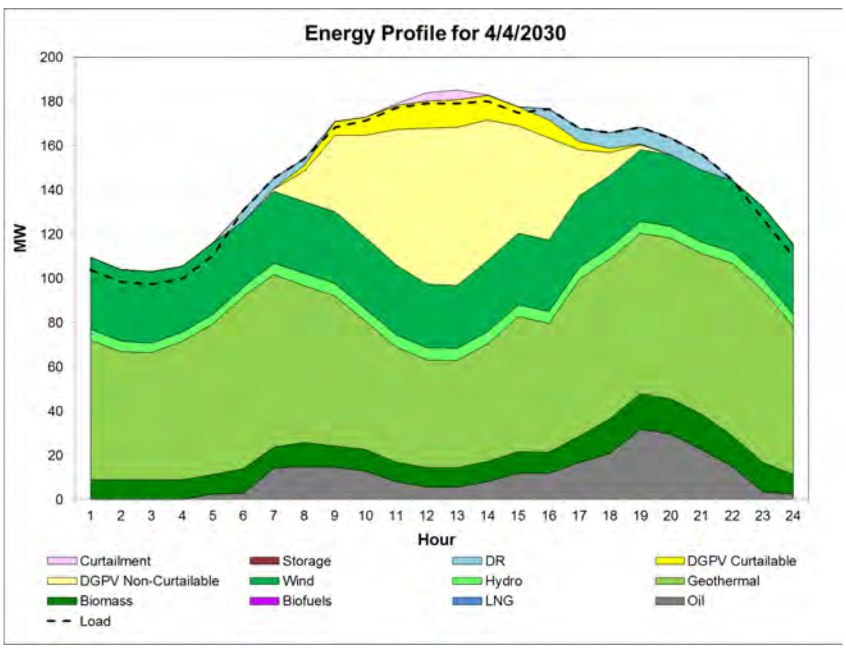


Figure 7-24. Modeled Energy Profile for April 4, 2030 of the Final Plans

Figure 7-24 above illustrates a day with high wind generation. Unlike Theme 2, the system does not switch to LNG.

Emissions of Final Plans for Hawai'i Island

The CO2 emissions of the final plans were estimated and are shown in the figure below. Theme 3 has the highest projected emissions among the three final plans since some generating units remain on fossil fuel until 2039. Theme 2 has lower emissions with the switch to LNG. Theme 1 has the lowest projected emissions due to the increasing levels of renewables displacing fossil fuels.

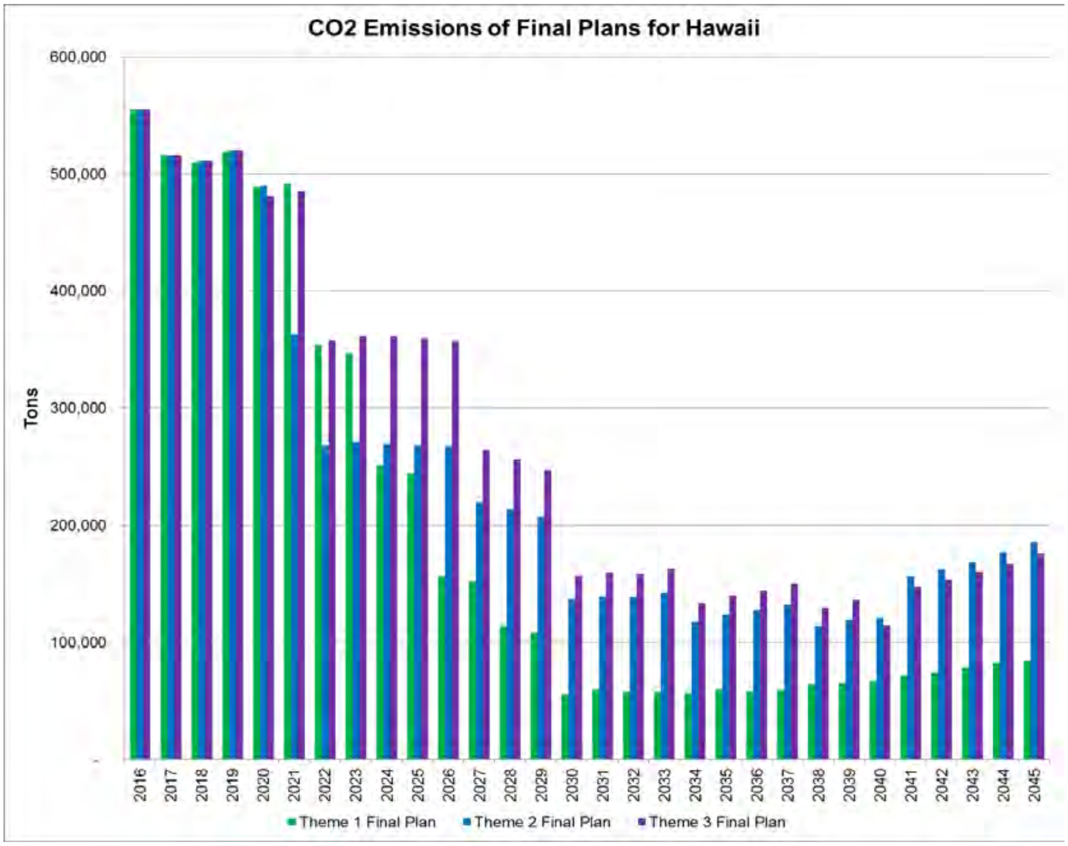


Figure 7-25. CO2 Emissions of Final Plans for Hawai'i

Hawaiian Electric
Maui Electric
Hawai'i Electric Light

HAWAI‘I ISLAND SELECTION OF THEME 2

The rigorous long-term analyses of the three themes provided insights on the different strategies for achieving 100% renewable energy by 2040. They provide directional guidance to inform the risks and the level of "no regrets" in short- term actions, particularly as you compare long-term resources across multiple themes. Although the steps along the paths to 2045 are different among the final plans, the starting point is the same. The purpose of the Preferred Plan is to inform the evaluation of specific near-term actions that are implementable based on the direction that the longer-term view of the plan provides. The Preferred Plan will balance technical, economic, environmental, and cultural considerations.

Based on the results of the analyses, Theme 2 will add a substantial amount of flexible, firm generation that will allow for the retirement of older generating units, incorporate significant amounts of variable renewable generation, and lower and stabilize customer bills by using lower cost fuel in the transition to 100% renewable.

7. Hawai'i Electric Light Preferred Plan

Hawai'i Island Selection of Theme 2

Case Name	Preferred Plan
DER Forecast	Baseline
Fuel Price	Feb 2016 EIA STEO or 2015 EIA Reference
2016	
2017	
2018	
2019	15 MW Contingency battery
2020	
2021	
2022	20 MW Geothermal Puna Steam Deactivated
2023	
2024	
2025	
2026	
2027	20 MW Biomass Hill 5 Deactivated
2028	
2029	
2030	20 MW Geothermal Hill 6 Deactivated
2031	
2032	
2033	
2034	20 MW Wind
2035	
2036	
2037	
2038	20 MW Wind
2039	
2040	Biofuels
2041	
2042	
2043	
2044	
2045	

Table 7-1. Hawai'i Island Preferred Plan

8. Five-Year Action Plans

This Five-Year Action Plan details a set of actions that must be taken to continue the transformation of our electric systems, and to continue on the path of reaching our 100% renewable energy goal. This Action Plan focuses on the near-term 2016 to 2020 period and includes those activities that must be done within this period to accomplish goals that are beyond that period. For example, acquiring new, firm capacity resources may take anywhere from five years to ten years or more, depending on the type of resource. Actions, such as initiating a competitive procurement process, will need to be taken within the Action Plan period in order to have the resource in service by the date needed.

COMPANY-WIDE

Achieving the RPS

The Preferred Plans across our territories exceed the requirements of the RPS law as shown in Figure 8-1.

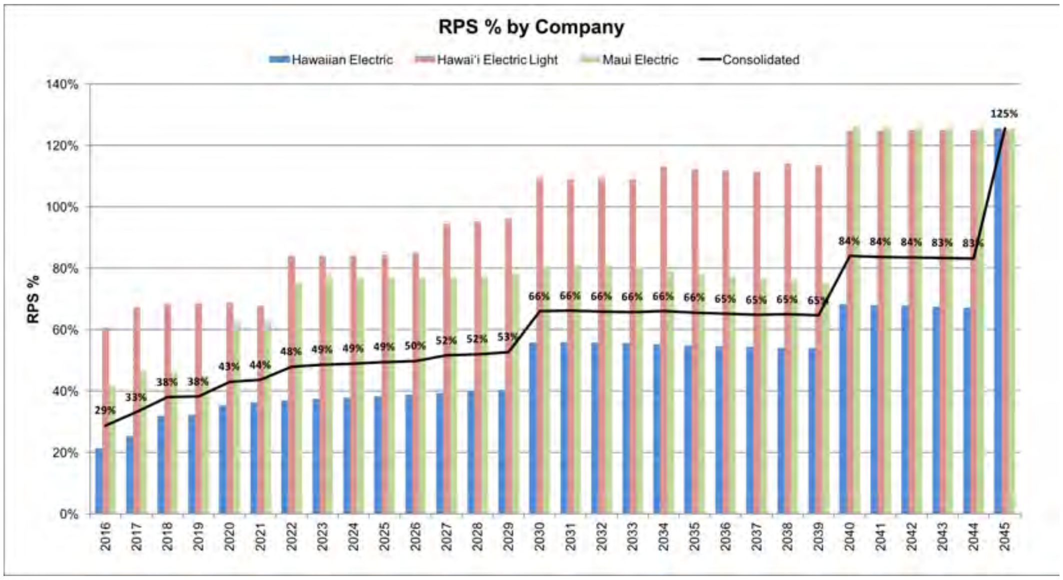


Figure 8-1. Renewable Portfolio Standards Compliance of Preferred Plans

The calculation of the RPS per the law does result in values over 100%. To emphasize that we are committed to achieving 100% renewable energy in 2045, Figure 8-2 shows the renewable energy as a percent of total energy including customer-sited generation.

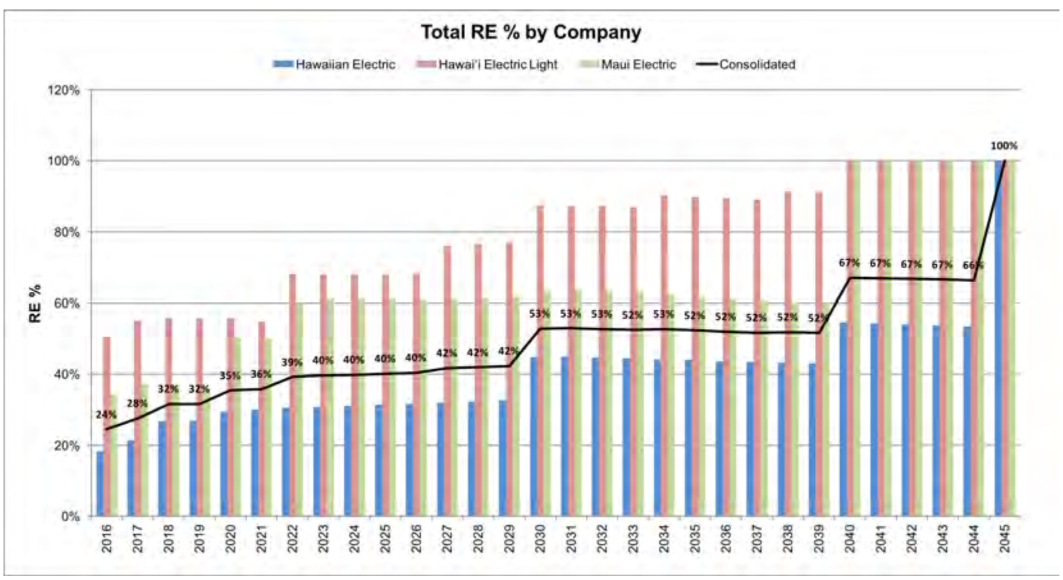


Figure 8-2. Total Renewable Energy Percent of Preferred Plans

Figure 8-1 and Figure 8-2 provides a long-term view of a path towards 100% renewable in 2045. Figure 8-3 shows the total capacity of renewable energy included in the Preferred Plans on a consolidated basis. By 2045, the total capacity of renewable energy on the systems is more than double the total of the system peaks to be served.

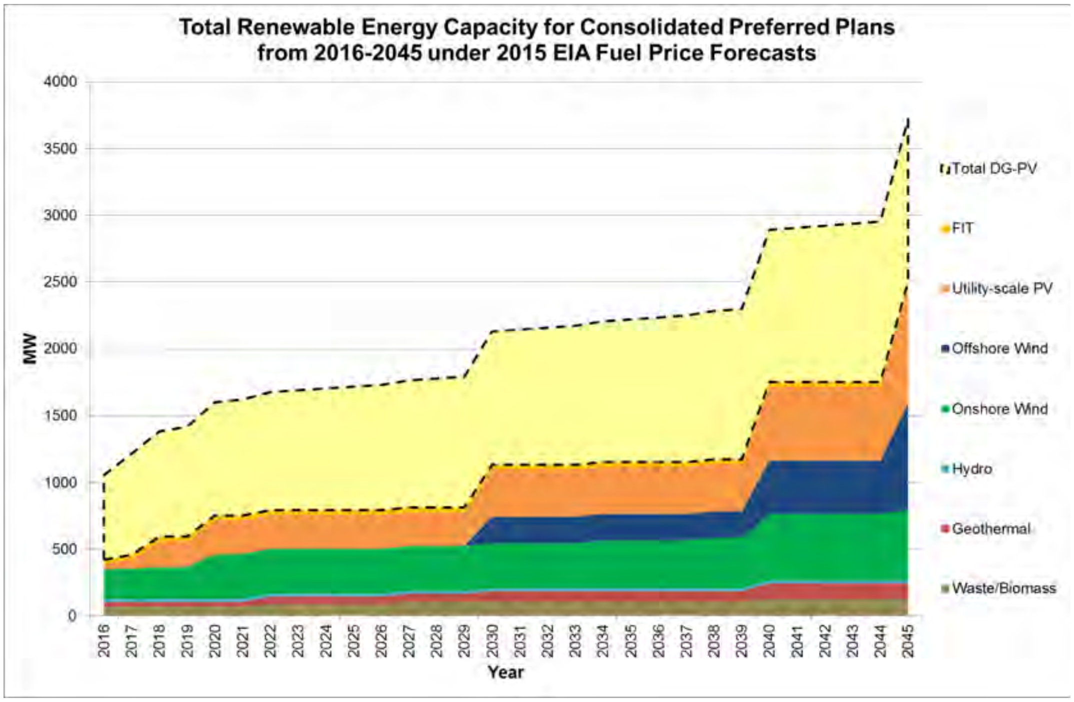


Figure 8-3. Total Renewable Energy Capacity for Consolidated Preferred Plans from 2016-2045 under 2015 EIA Fuel Price Forecasts

The energy mix for the Preferred Plans on a consolidated basis, including the all the renewable energy capacity shown in Figure 8-4.

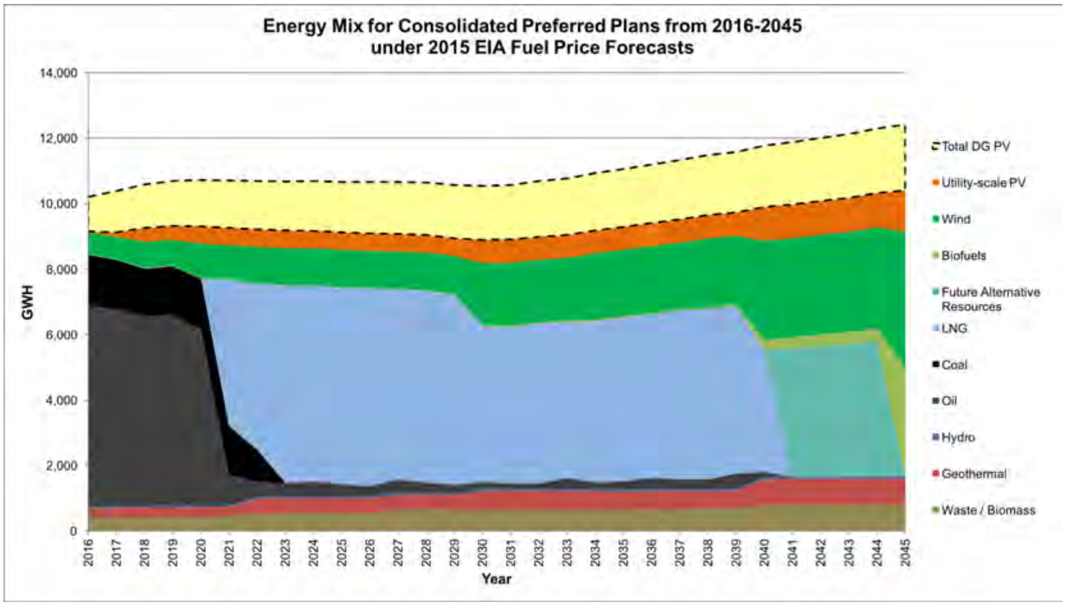


Figure 8-4. Energy Mix for Consolidated Preferred Plans from 2016-2045 under 2015 EIA Fuel Price Forecasts

Future Alternative Fuels: During the last intervening years in the transition to 100% renewable energy, potential fuels at this time could include biofuels, LNG, oil, other renewable options or a mix of options. Given rapidly evolving energy options and technology, the exact fuel mix is difficult to predict today.

The near-term action plan items will strategically grow the level of renewable energy on our systems to allow for the flexibility to transition to even greater levels on the course to 100% renewable. The longer-term perspective provided by the Preferred Plans will help guide actions and decisions in the near-term to achieve our commitment to 100% renewable energy.

Demand Response

Distributed Energy Resources (DER) is a major component to achieving the state's goal of a 100% RPS by 2045. The Companies fully support and promote next generation DER programs that can provide grid benefits that can be realized by all of Hawai'i. Following Commission Order No. 33258 on October 12, 2015 resolving Phase I issues in Docket No. 2014-0192, the net energy metering program was closed to new participants. Pursuant to Order No. 33258, two new DER programs, Customer Grid-Supply and Customer Self-Supply were launched.

In the meantime, the Companies have successfully met all of their commitments to clear the 2,749 customers within the queue of existing net energy metering (NEM) projects as described in the Companies' Plan to "Clear the Queue," filed on October 31, 2014.

In Phase II of Docket 2014-0192, the Companies will continue to collaborate with the customer and industry stakeholders, including solar contractors, inverter manufacturers, and external organizations such as NREL to develop innovative technical solutions and program policies that ensure fair and safe interconnection to the grid, while providing the same reliability that all customers have come to expect.

Building a "Smart Export" DER environment of the future that is fully integrated, able to contribute when needed, and supportive of the grid, will require visibility, controllability, and the extensive use of advanced inverters for all DER systems and programs.

As we increase our understanding of both the circuit and system limits for each island grid it is important that we establish annual Hosting Capacity limits as a methodology to manage future interconnections. This will allow us to plan, communicate, and coordinate the integration of DER in a way that benefits all customers. Integrating annual Hosting Capacity limits into an automated end-to-end tool that screens and processes DER applications will greatly facilitate interconnection and positively impact customer experience. This integration is expected to be completed in the 4th quarter of 2016.

DR Programs/DR Tariffs

The Interim DR Program Application was filed with the Commission on December 30, 2015 in Docket No. 2015-0412. The two major requests in the application are for approval of the Tariff Structure and the cost recovery methodology. A final DR Program Application will be filed after filing of this PSIP Update. The final DR Application will present the cost effective DR programs that will be pursued specific to each of the island based on the updated analyses. Hawaiian Electric is targeting initiation of the DR programs by early 2017, depending on the timing of Commission approval. The Companies will also investigate whether location-specific DR programs can be developed to mitigate circuit level issues to integrate DER resources.

One of the envisioned DR Programs, Real-Time Pricing, requires the approval of the Smart Grid project, and therefore is expected to start in 2020 in the unmerged scenario of the Smart Grid project but could start as early as 2018 in the merged Smart Grid scenario.

The Preferred Plans for each island includes DR in the early years consistent with the DR Programs/DR Tariffs contained in the Action Plan.

Demand Response Management System (DRMS)

The DRMS Application was filed with the Commission on December 30, 2015 in Docket No. 2015-0411. Currently, contract negotiations with the selected vendor, Omnetric, are in progress. We plan to file a signed contract with Omnetric at the Commission by mid-year 2016.

While awaiting Commission approval of the Companies' cost recovery proposal for the DRMS project, Hawaiian Electric will continue to develop integration requirements for the DRMS. The Hawaiian Electric team will also work with projects, such as Sustainable and Holistic Integration of Energy Storage and Solar PV (SHINES), to develop state-of-the-art capability that could potentially be incorporated directly into the DRMS if approved by the Commission. Hawaiian Electric is targeting initiation of the DRMS project by late 2016 to early 2017, depending on the timing of Commission approval.

The DRMS is required to enable the DR resources that are included in the Preferred Plans.

Time–of–Use (TOU) Rates

The Companies proposed revised residential TOU rates in the Distributed Energy Resources Docket No. 2014-0192 and they are before the Commission for consideration and approval. The Companies indicated in that docket that they plan to propose revised commercial TOU rate options as part of Phase 2 of the proceeding. The Companies noted that Phase 2 would offer an avenue for collaboration with other parties in the docket and allow for a better analysis of the appropriate price signals that would be beneficial to the grid while enhancing customer choices and giving consideration to the appropriate form of recovery of fixed generation, transmission, and distribution costs.

Community-Based Renewable Energy (CBRE)

A phased approach will help to implement the CBRE Program in a sustainable manner, in-line with the market demand, while respecting the technical limitations of the electric grid. The first phase ("Phase One") is envisioned to last two years commencing upon Commission approval. Findings from the Phase One will inform the planning process for Phase Two. The planning process for Phase Two of CBRE will begin 18 months after Commission approval of Phase One.

Below is a chart outlining by island, technology, and size of project, the capacity allocation for Phase One CBRE (Tier 1 projects are less than or equal to 250 kW_{AC}, Tier 2 projects are 250kW_{AC} to less than or equal to 1MW_{AC}, and Tier 3 projects are greater than 1MW_{AC}):

	Solar (MW_{AC})		Wind (MW_{AC})	
	Tier 1 and 2	Tier 3	Tier 1 and 2	Tier 3
O'ahu	5	10	0	10
Hawai'i Island	1	0	0	2
Maui	1	0	0	2
Moloka'i	0	0	0.5	0
Lana'i	0	0	0.5	0
Total	7	10	1	14
Phase 1 Total	32			

Table 8-1. CBRE Island Technology

Distributed Energy Storage

As the Companies increase the amount of renewable energy production, energy storage will play a role in distributing that energy throughout the day to coincide with demand, and to provide grid services such as fast-frequency response or contingency reserves. The Companies are supportive of energy storage as a customer option and have prepared the following guiding principles to assist in enacting policies that benefit all customers:

- Energy storage policies should promote or enable renewable energy production to help Hawai'i achieve the state's goal of 100% RPS by 2045.
- Energy storage policies should provide overall cost effective grid benefits to all customers, including those who do not choose to install batteries on their property.
- Should the state choose to enact policy to promote energy storage through investment tax credits (ITC) or rebates to customers who install energy storage, these customers should remain connected to the electric system for the life of the storage system to support the societal benefit for which these ITCs or rebates are intended i.e. integrating more cost-effective renewable energy that contributes to the state's renewable energy goals.

The Companies have a number of pilot projects that are evaluating various energy storage technologies that could potentially provide grid services. These pilot projects include, but are not limited to, partnerships with innovative start-ups such as Stem[19] and Shifted Energy[20]. Our findings from these pilot projects may help us develop additional distributed energy programs that leverage distributed energy storage resources.

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19 Stem is an energy storage provider that has deployed a pilot project aimed at demonstrating how distributed storage can help the utility affordably integrate more renewable energy onto the system.

20 Hawaiian Electric is working with a company called Shifted Energy to deploy 499 grid interactive water heaters at the Kapolei Lofts development project (housing in Kapolei developed by Forest City) for the demand response program. See http://www.greentechmedia.com/articles/read/hawaii-to-test-smart-water-heaters-as-grid-resources.

Curtailment Policy Review

The Companies are researching new curtailment policies that will provide flexibility in contracting renewable resources and support the reliable operation of the grid as an alternative to the current practice of allocating curtailments in reverse chronological order. New contract terms will be included as part of RFPs for future resources and adopted as new power purchase agreements are negotiated.

Smart Grid

On March 31, 2016, the Companies filed an application for approval of the Smart Grid Foundation Project. Pending a favorable Commission decision, the Companies plan to implement the following from 2017-2021.

- Advanced Metering Infrastructure (AMI) across all islands that the Companies serve, which automates meter reading and provides a communication network to control service end points.
- Meter Data Management System to automate billing by 15–minute increments.
- Conservation Voltage Reduction which controls voltage from substations to service endpoints for enhanced power quality and conservation.
- Customer Facing Solution that provides customers with a seamless integrated mobile and web energy portal.
- Direct Load Control to replace existing 1-way load control switches on O‘ahu with switches that have 2-way communication and control.
- Outage Management System expansion that improves reliability and customer outage information.
- Enterprise Service Bus for efficient data interchange.
- Enterprise Data Warehouse to promote data collection, sharing and analytics.
- As part of the smart grid project application, the Companies have filed an update to the Smart Grid Roadmap describing additional activities planned for the Smart Grid expansion, including leveraging the Advanced Metering Infrastructure for Distribution Automation (DA) and endpoint control.

Environmental Compliance

Mercury and Air Toxics Standards (MATS)

Hawaiian Electric’s Waiau units 5 to 8 and Kahe units 1 to 6 will demonstrate compliance with MATS by meeting emission limits for filterable particulate matter (fPM) and fuel moisture content. Hawaiian Electric received a one-year extension of the MATS Rule compliance date to April 16, 2016. The compliance strategy must be in place by this date and initial compliance must be demonstrated within 180 days, or no later than October 13, 2016. Kahe and Waiau will each demonstrate compliance using a site-wide emissions average of all units to calculate a 30-day rolling average value that will be reported to the EPA. Results from periodic monitoring of stack emissions from the steam units at Kahe and Waiau will be used as input into the facility-wide emissions average calculation.

Hawaiian Electric has determined through extensive emissions testing that careful control of boiler operation and fuel specifications are sufficient to achieve compliance with the MATS 0.03 pound per MMBtu fPM emission standard when using 100% LSFO fuel in all units. Hawaiian Electric's fuel supplier has also certified that the fuel will satisfy the moisture limit.

Waiau units 3 and 4 have annual capacity factors of less than 8% and will be classified in the limited-use subcategory. These units will not be subject to MATS emissions standards, but must comply with work practice standards. Honolulu units 8 and 9 are currently deactivated. MATS requirements will not apply to them until they are reactivated.

The boilers operated by Maui Electric and Hawai'i Electric Light are not subject to MATS because they generate less than 25 MW.

National Ambient Air Quality Standards (NAAQS)

The NAAQS requirements may require reductions in SO2 emissions at Kahe and Waiau by the use of lower sulfur fuels. Compliance with the SO2 NAAQS requires that facilities demonstrate through either modeling or monitoring that offsite impacts are below the standard and will be in attainment with the standard. Hawaiian Electric plans to monitor ambient SO2 concentrations in the area of Kahe and Waiau for at least three years beginning no later than January 1, 2017 through December 31, 2019. Following the collection of ambient SO2 monitoring data, the EPA, by December 31, 2020, will issue its final attainment or nonattainment designation for Kahe and Waiau. If reductions in SO2 emissions at Kahe and Waiau are required, the Companies currently believe the worst-case scenario would be blending 40% LSFO with 60% ultra–low sulfur diesel no later than December 31, 2024 to achieve the December 31, 2025 attainment deadline.

Greenhouse Gases (GHG)

To meet new Hawai'i Department of Health (DOH) requirements that took effect in mid-2014, the Hawaiian Electric Companies submitted a GHG Emissions Reduction Plan (EmRP) to DOH on June 30, 2015. This EmRP commits the Hawaiian Electric Companies to reducing aggregate GHG emissions from their eleven (11) affected facilities by 16% from 2010 levels by January 1, 2020. That reduction will be accomplished by replacing fossil-fueled power generation with more power from renewable sources. Importantly, it will not require expensive emissions controls or fuel switches. Adherence to this PSIP will be enough to assure that the GHG reduction targets are met.

As part of a negotiated amendment to the Power Purchase Agreement (PPA Amendment No. 3) between AES Hawai'i and Hawaiian Electric, Hawaiian Electric has agreed to include the AES Hawai'i coal-fired power plant as a partner in the Companies' EmRP. Similarly, with the planned acquisition of the Hamakua Energy Partners (HEP) facility by Hawai'i Electric Light, the GHG emissions from the HEP facility will also be addressed in the Companies' EmRP. Both the AES PPA amendment and the HEP acquisition are subject to Commission approval, so the inclusion of these facilities in the Companies' EmRP is also subject to Commission approval. Hawaiian Electric is working closely with the DOH on the timing of the EmRP modifications to address these changes in the partnership.

The EPA's Clean Power Plan (CPP) rule was published on August 3, 2015 to govern emissions of GHG from existing steam electrical generating units (EGUs). The CPP did not establish GHG emissions limits for Hawai'i, but left that to be worked out later because the state's circumstances are so much different from the mainland. The U.S. Supreme Court on February 6, 2016 stayed the CPP pending further action by EPA and federal courts. The timing for establishing federal GHG emission reduction requirements that could affect the Companies' EGUs power plants is uncertain.

Clean Water Act / National Pollution Discharge Elimination System (NPDES)

2016 -2018: Renew Hawaiian Electric NPDES Permits

The NPDES permits for Honolulu, Waiau and Kahe all expire in 2017. Permit renewal applications must be submitted to the DOH at least six months prior to the expiration dates. The permit expiration dates and renewal application due dates are shown in the Table 8-2.

Facility	Permit Expiration Date	Application Due Date
Honolulu Plant	May 31, 2017	November 30, 2016
Waiau Plant	June 28, 2017	December 28, 2016
Kahe Plant	October 24, 2017	April 24, 2017

Table 8-2. Hawaiian Electric NPDES Permit Dates

Although the Honolulu Power Plant is currently deactivated, its NPDES is being renewed to allow the plant to be reactivated if necessary in the future.

Negotiate §316(b) compliance with DOH during renewal process (Hawaiian Electric only).

The NPDES permit renewal applications will include cooling water intake fish protection reports for each plant, as required by the Clean Water Act (CWA) Section 316(b). The fish protection reports will be submitted with the permit renewal applications. We plan to negotiate 316(b) best technology available (BTA) options with the DOH, and the outcome of negotiations could include a requirement for affected facilities to install fish protection technology on the cooling water intake systems within the next five years. The specific requirements and compliance dates will be determined during permit negotiations with the DOH.

Obtain new NPDES permits for Honolulu, Kahe and Waiau

New permits will include 316(b) requirements and are also likely to include additional water quality standards.

2019 – 2022

Possible installation of fish protection technology at Waiau and Kahe

If required, fish protection technology (e.g., fish friendly traveling screens, barrier nets, or closed cycle cooling) will be installed at Waiau and Kahe. The specific compliance dates will be determined during permit negotiations with the DOH.

Renew Maui Electric NPDES Permits

Maui Electric's NPDES permits for Ma'alaea and Kahului expire in December 2019 and May 2020, respectively. Permit renewal applications must be submitted at least six months prior to the expiration dates. The 316(b) requirements are not applicable to Maui Electric's facilities. The permit expiration dates and renewal application due dates are shown in Table 8-3.

Facility	Permit Expiration Date	Application Due Date
Ma'alaea	December 15, 2019	June 14, 2019
Kahului	May 13, 2020	November 13, 2019

Table 8-3. Maui Electric NPDES Permit Dates

Kahului Plant Retirement/NPDES Compliance Plan

The Kahului NPDES permit that was effective on June 1, 2015 contains a compliance schedule that includes cessation of operations at the Kahului Plant no later than November 30, 2024. Maui Electric's current plans include the scheduled retirement of the Kahului Plant on December 31, 2022.

Advanced Inverter Functionality

The Hawaiian Electric Companies are working with leading equipment manufacturers from the Advanced Inverter Technical Working Group (AITWG) and the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) to test selected capabilities of advanced inverter functionality that would accelerate the implementation of solar PV and distributed energy storage systems (collectively referred to as DER Systems) that can provide grid-supportive benefits to the Companies' grids. On December 15, 2015, the Hawaiian Electric Companies filed a proposed Advanced Inverter Test Plan and have since been aggressively pursuing the execution of the Commission's directives to test advanced inverters.[21] The results of this initial phase of testing are expected to be available by the beginning of the third-quarter and will be used by the Companies to propose the activation of new advanced inverter functions.

The near-term goal for the Advanced Inverter Test Team, which comprises engineers and research scientists from the inverter manufacturing industry, NREL and the Hawaiian Electric Companies, is to implement the highest priority Advanced Inverter functions that can be implemented as soon as the national certification standards from Underwriter Laboratories, Inc. (UL) are issued. In Hawaiʻi, as well as in California, the utilities are requiring that advanced inverters be capable of meeting UL 1741 Supplement A standards within 12-months after UL's final publication of the new standard, now expected to be issued in the May-June 2016 timeframe.

The Hawaiian Electric Companies are proactively working with the inverter manufacturers to test advanced inverter functions ahead of the formal adoption of UL 1741 Supplement A so that the manufacturing industry can implement DER Systems that better support Hawaiʻi's new Customer Self-Supply, Customer Grid-Supply, and other DER programs.

The Companies are currently working with the Advanced Inverter Test Team to collaboratively develop an implementation plan, including the timeline for activation of voltage regulation advanced inverter functions. The intent of the Hawaiian Electric Companies' advanced inverter implementation plan will be to require the mandatory activation of the selected voltage regulation functions sooner than required on the mainland. The staged implementation of multiple advanced inverter voltage regulation functions to actively manage the impact of high-level of PV penetration is needed in order for Hawaiʻi to continue to aggressively pursue the interconnection of DER Systems and to mitigate the negative impacts of existing PV-Systems ("Legacy PV") that do not provide grid support capabilities.

[21] Docket No. 2014-0192, Decision and Order No. 33258, Compliance Filing – Advanced Inverter Test Plan.

As noted in the Companies' February 11, 2016 response to the Commission's supplemental information request regarding the Technical Conference on the Companies' Advanced Inverter Test Plan held January 28, 2016, the Companies' strategy for implementing advanced inverters is a multi-facet approach that extends beyond the hardware testing of advanced inverter equipment. The Companies are also working with other industry partners to form a consortium to fund a broader research and development program to address the system-level functions and capabilities of DER Systems. The Hawaiian Electric Companies are members of the Grid Modernization Lab Call (GMLC) Hawai'i Regional Partnership, which recently received a $1 million grant from the U.S. Department of Energy to address the research, development and testing of grid frequency support advanced inverter functions.

This GMLC Project 15 – Grid Frequency Support for Distributed Inverter-Based Resources in Hawai'i – will comprehensively evaluate the merits of various Fast Frequency Service control methods, including the Frequency-Watt Advanced Inverter function. This comprehensive approach for addressing the bulk-power system level issues, with the ability to leverage the fast response capabilities of power electronics from PV inverters and battery energy storage systems, requires innovation to develop advanced inverter capabilities that are not yet adopted on a widespread basis across the industry.

The GMLC Project 15 will take a holistic approach to go beyond the scope of what is currently being pursed in the Advanced Inverter Test Plan by developing new bulk-power system models, time domain modeling, simulation and controls development, and field testing and demonstration that is not within the limited budget and schedule afforded to the Advanced Inverter Test Plan. When attempting to address the resiliency of the grid with high levels of non-firm, non-dispatchable, DER Systems, a more sophisticated and comprehensive approach is needed. The Companies recognize the need to pursue this parallel track of research, development and demonstration and will be pursuing the Advanced Inverter testing of the selected system-level advanced inverter functions to complement the GMLC Project 15 statement of work

Circuit-Level Improvements on All Islands

The growth levels of DG-PV studied in this PSIP will require distribution circuit level improvements to further integrate these systems onto the grid. At the present time, more than 46%of the circuits on O'ahu have DG-PV penetration levels that exceed 100% of the daytime minimum load, and on Maui 38% of the circuits exceed 100% of the daytime minimum load. To support the continued integration of DG-PV, even with the continued development of functionality from advanced inverters, the Companies will need to make improvements to its distribution circuits to accommodate the changes to the load flow on circuits due to Customer Self Supply, Customer Grid Supply, grandfathered NEM, SIA, Community Based Renewable Energy, and any future DER programs.

In the near-term, the circuit level improvements will include the following:

- Overhead and underground conductor upgrades to address power flow conditions where energy may overload conductors past 100% of their thermal rating. This can be resolved by upgrading the conductor size to create additional capacity.
- Voltage regulator installations or other voltage adjusting or correcting devices to address voltage quality issues, where analyses show that neighborhoods or sections of circuits may experience high and/or low voltage caused by the reverse power flow generated from PV systems.
- Distribution (service or secondary) transformer replacements or transformer modification when the transformers are overloaded if the aggregate PV connected to a transformer divided by the transformer rating exceeds 200%. In other cases, secondary high voltage will necessitate an upgrade of secondary conductors in addition to the replacement of the distribution transformer.
- Reconfiguring circuits to resolve the loss of operational flexibility when it has been determined that the PV or DER penetration exceeds the operational limit of the circuit.
- Substation upgrades if operational flexibility is lost where the reverse power generated by DG-PV systems loads the substation transformer to more than 50% of its highest transformer rating, or with advanced inverter control of DG-PV resources reverse power flow loads the substation transformer to more than 100% of its highest transformer rating.
- Distributed Battery Energy Storage Systems will be deployed behind or in front of the meter to relieve distribution system congestion and maintain operational flexibility. Strategically located storage can avoid conductor overloads, while simultaneously maintaining operational flexibility at the circuit or system level.
- VAR compensation devices will be considered and used when available and found to be cost effective in mitigating voltage issues. These devices leverage modern power electronics to provide fast acting reactive power to reduce voltage fluctuations, and regulate circuit voltages to avoid the high voltage effects of high DG-PV penetration. These devices come in many different forms: advanced inverters, low voltage static VAR compensators, fast switching capacitors, and inline power regulators. These types of devices, located on the secondary part of the distribution system, can potentially provide more cost-effective and efficient regulation to mitigate voltage quality impacts and displace traditional, slower acting equipment such as capacitor banks and voltage regulators. This distributed voltage regulation technique represents a departure from traditional industry methods of voltage regulation. While we have started to demonstrate and assess these innovative devices, the technology is a

relatively recent development and has yet to achieve widespread adoption across the industry.

Controlling PV / Advanced Inverters

The Companies' ability to control customer-sited DG-PV with advanced inverter capabilities will depend on the implementation of foundational infrastructure such as an advanced distribution management system, a distributed energy resource management system, and advanced metering infrastructure. The Companies recently revised interconnection Rule 14H to include functional requirements for remote configurability and controllability features however no single industry standard or protocol has been identified for implementation).

The Companies' plan to implement Advanced Inverter requirements for remote configurability and controllability will depend in most part on the hardware and software standards that are under development in California's Smart Inverter Working Group Phase 2 proceedings. There are several emerging open protocol communications standards that show great promise for the DER industry stakeholders to align new product capabilities that will allow the utilities to interconnect through non-proprietary control systems. In the interim, the Companies plan to request Commission approval to activate other autonomous Advanced Inverter functions that do not depend on proprietary control systems to implement remote communications and controls as the newer open standards are further developed.

In addition, policies and programs, including pricing programs that stipulate the parameters within which control of a distributed energy resource may be administered, will need to be in place. These policies and programs are expected to be captured jointly between current DR program filings and the anticipated efforts within the DER Phase II proceedings.

Ideally, to lower the cost of communications functionality, the Companies will explore the use of a single, secure Company-owned communications network to exercise DER control along with other grid modernization devices, DA devices, and AMI. However, the Companies' Advanced Meter Infrastructure is not currently expected to be deployed until after 2018. Based on discussions with aggregators and providers of distributed energy resources, the Companies expect that these aggregators will provide near-term communications sufficient for the preliminary stage of DG control and the associated feedback loop.

Currently, only a limited number of inverter manufacturers are able to provide aggregation services for their legacy PV inverters and many do not provide any form of communications hardware or software capability at all. All of the inverter manufacturers that provide communications to their legacy PV inverters today are reliant on the public internet services provided by their customers' internet service providers to maintain the reliable connection to perform remote communications services for software system upgrades and activation of new functionality. There may be cybersecurity issues associated with internet service platforms that will need to be addressed. The ability of the customer to disconnect their internet service to the DER Systems has hampered the ability of the Companies to remotely configure, upgrade and active new functions in the existing fleet of legacy inverters. These are the real-life examples that inverter manufacturers and the Companies will have to jointly solve in order to achieve the stringent communications infrastructure requirements for "always-on" connectivity that will ensure the necessary high-level reliability control functions that are envisioned by the Companies' DER systems operational model in the future.

Renewable Acquisition

The Preferred Plans for each island identify various types and sizes of renewable energy resources that should be added at various times in order to achieve long-term objectives, including reaching 100% renewable energy by 2045. The Hawaiian Electric Companies plan to procure these new renewable resources through a competitive procurement process to ensure the best value for the customers. There may be exceptions as allowed in the Commission's Competitive Bidding Framework that will need to be evaluated and justified.

From time to time, the Companies may receive unsolicited proposals for renewable energy projects outside of a competitive procurement cycle. In such cases, the Companies will review the merits of those proposals in accordance with established rules and practices.[22]

Legacy PV

Much work has already been done to improve the performance of existing PV systems. For example, in December 2014, Enphase remotely reprogrammed many of the existing Enphase inverters to upgrade the inverters' ability to ride through voltage and frequency upset conditions to prevent disconnections that could exacerbate the effects of system disturbances. This was done no cost to the Companies or to their customers.

A substantial number of existing inverters cannot be remotely reprogrammed. Reprogramming these inverters would require that a person visit each site to either upgrade the inverter software or replace the inverter. Performing this work on all remaining legacy inverters would result in a very high cost. Rather than replacing

[22] For example, see Docket No. 2015-0224 (PPA with Ku'ia Solar, LLC) and 2015-0225 (PPA with South Maui Renewable Resources LLC) for the evaluation methodologies used.

inverters or reprogramming them on-site at a high cost, the Companies' plan is to upgrade the distribution circuits and equipment on the system to account for the potential effects of legacy PV remaining in place for the next 15 to 20 years.

LNG Procurement

Given the cost-effectiveness of LNG, the Companies plan to submit an application for approval of an LNG fuel supply agreement and General Order No. 7 requests for LNG-related dual fuel unit conversions to receive, store, and regasify LNG and utilize natural gas at the designated generation facilities and procurement of International Standard Organization intermodal cryogenic containers for the transport of the LNG, which will enable the Companies to procure a lower cost and cleaner fuel.

As noted earlier, LNG is included in plans under a scenario where the Hawaiian Electric Companies merge with NextEra Energy. In the event the merger is not approved by the Commission, the Companies will explore pursuing LNG under a different contract.

Research, Development and Demonstration Activities

The Hawaiian Electric Companies are engaged in numerous RD&D and pilot projects, including technology testing, to address numerous technical needs, operational applications, and customer engagement options that will help facilitate the increasing integration of renewable energy. These RD&D and pilot projects include those in the area of Grid Management (voltage and frequency), Visualization and Operation Tool Development, Distributed Energy Resources (DER) functionality, and control, Customer Solutions and Options, Demand Response, and Electrification of Transportation. The Hawaiian Electric Companies will continue its RD&D efforts to find innovative ways to integrate more renewable energy.

Interisland Cable

Analysis of the economic attractiveness of an interisland cable from O'ahu to one or more of the neighbor islands will continue. Analyses could not be completed in time for this filing. Please see Chapter 9 for the next steps for this analysis.

O'AHU ACTION PLAN

Utility-Scale Energy Storage for Contingency Reserve

Recognizing the need to secure the grid with contingency reserves that meet the requirements of our changing power system, Hawaiian Electric issued a technology neutral energy storage system request for proposal in April 2014 that would provide 60-200 MW of power for a duration of 30 minutes. The request for proposal intended to procure an energy storage system(s) to meet the following technical objectives:

- Provide an additional resource to help manage system frequency by absorbing or discharging energy on a minute-to-minute basis to help maintain system frequency at 60 Hz.
- Provide energy for a short duration during the recovery period after a sudden loss of generation until a quick starting generator can be brought online.
- Provide an immediate injection of a large amount of energy for a short duration in the event of a sudden loss of generation to decrease the need to utilize load shedding blocks.
- Provide Hawaiian Electric with grid operational flexibility to reasonably manage distributed, intermittent generation with the island electrical load.

Hawaiian Electric received over sixty (60) proposals that included one or more of the following technologies: battery energy storage, demand side management, flywheel energy storage, flywheel-battery hybrid storage systems, pumped storage hydro, pumped thermal with compressed air storage, and ice storage combined with demand side management. After a thorough evaluation of all proposals, battery energy storage emerged as the preferred technology to suit the Company's requirements.

The 2014 PSIP identified a 200 MW contingency battery energy storage system. We expect to reduce the previous capital requirement by seizing upon lower resource costs and by optimizing the size of the battery to the 90 MW size range after more detailed sizing analyses are conducted. To meet the full contingency reserve requirement, the utility-scale battery will be supplemented by demand response programs.

As part of the updated sizing analyses, Hawaiian Electric will identify Fast Frequency Response 1 (FFR1)[23], FFR2[24], and Primary Frequency Response (PFR) requirements. FFR1 can be satisfied by utility scale energy storage, curtailed energy from central station PV, or curtailed energy from wind plants. FFR2 can be satisfied by demand response

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[23] Technologies that are responsive within 12 cycles.

[24] Technologies that are responsive within 30 cycles.

programs. The acquisition of technically qualified FFR resources can further reduce the utility-scale size requirement.

The optimized battery size will make this investment resistant to changing contingency requirements. The battery energy storage system will help to meet near-term contingency requirements (a trip of AES and legacy PV), remain flexible to meet future contingency requirements as in the case of the Preferred Plan (e.g., the trip of a Kahe Combined Cycle Unit, or a trip of a cable that interconnects offshore wind), and maximize the value of this investment by also functioning as a frequency regulating resource.

The Company intends to submit an application for approval to commit funds towards the procurement of the final optimally sized contingency battery energy storage system later this year.

System-Level Improvements

Fossil Generation Retirement Plan

Hawaiian Electric's Preferred Plans identify generating units that are planned to be deactivated or decommissioned. Its Preferred Plan for Theme 2 (merged scenario) shows that Kahe Units 1 to 4 and Waiau Units 3 to 8 will be deactivated or decommissioned over time as the generating system is modernized. The final Theme 3 (no LNG scenario) shows that Waiau Unit 3 to 6 and Kahe Unit 6 will be deactivated over time as the generating system is modernized.

Generation Flexibility Plan / Must-Run Generation Reduction Plan

Hawaiian Electric is improving the operational flexibility of its steam units to help facilitate the integration of variable renewable generation. Much has been accomplished but more will be done.

- Modify procedures and test operations to achieve minimum loads of 5 MW-gross (near zero net-to-system).
- Review and improve procedures to facilitate cycling of units that previously have not typically been cycled, while minimizing deleterious long-term effects on the units.
- Develop processes to enable units to ramp at higher ramp rates.

Testing has already been conducted on most of the 90 MW reheat units and three of the six units are already available for low load operation. All of the 90 MW reheat units will be ready for low load operation by the third quarter of 2016.

It has already become necessary to operate at very low outputs on the steam units. On multiple occasions one or more units has been dispatched to the new, lower outputs.

The ability of the steam units to achieve lower operating levels is reflected in the PSIP modeling effort.

It is expected that ramp rate improvements will be completed by the third quarter of 2016. Ramp rate improvements will result from improved control system logic. Hawaiian Electric control engineers and its controls consultants have identified effective solutions for improving ramp rates. Testing is in progress.

A number of projects have been identified to help improve and support low load operation and/or cycling of the steam units.

- Steam Atomization Projects: K1-4 and W7-8 have or will have their mechanical atomization systems replaced with steam atomization. The main purpose of these projects was for improvements in emissions associated with MATS compliance. However, a secondary benefit is significantly improved turndown capability on the burners resulting in improved flexible operations and better startup processes.
- Pilot variable speed drives on K1 Boiler Feed Pumps: Project supports more efficient low load and cycling operations. Project is being evaluated and benefits to cost are being considered.
- Automated Air Ejector/Gland Seal Steam: This is currently a manual process that does not change during normal operation. During low load operation, this requires moderate operator attention. Projects will improve the reliability of low load operation.
- Turbine Hood Spray: Hood spray keeps the low pressure turbine hood at proper temperatures. At low load and during startup, there is risk of overheating the turbine hood. Units that cycle and operate at low load should have turbine hood sprays for safe operations.
- Other Projects such as turbine bypass systems and cross feeding systems will be considered based on the cycling and retirement plans. These projects are not necessary to begin cycling but will provide increased reliability if the units will cycle often and for many years.

Generation Commitment and Economic Dispatch

Hawaiian Electric is in the process of determining the appropriate timeframe to transition to new operating reserve policies, such as the General Electric / Hawai'i Natural Energy Institute regulating reserve formula for generation commitment purposes.[25] It is anticipated that as significant levels of utility-scale and/or distributed variable renewable generation are added to the O'ahu grid, operating with regulating reserves as

[25] See page 4-21 of the Companies Power Supply Improvement Plan Update Interim Status Report for a description of the GE-HNEI formula.

an explicit component of the system reserve requirements will be needed to maintain system stability and reliability.

Hawaiian Electric also presently requires frequency response controls on any new utility-scale renewable generation and will likely require such controls on future distributed generation, when such capabilities become available. Frequency response controls will allow these future renewable resources to supply downward reserves (for overfrequency mitigation) in lieu of carrying such reserves on conventional generators and storage devices. This will allow the conventional generation to operate at lower minimum levels and the O'ahu grid to host higher levels of renewable generation sooner and/or reduce the amount of energy storage needed.

Dependable demand response resources with the proper operating characteristics as discussed in the Companies' Integrated demand response Portfolio Plan (IDRPP)[26] also have the potential to reduce the reserve requirements that has to be carried by the system's online generation resources and storage devices.

Hawaiian Electric continues to refine and improve the approach to determining its reserve requirements. In particular, Hawaiian Electric is currently engaged with the Electric Power Research Institute (EPRI) in a study exploring the use of stochastic methods for determining operating reserve requirements. Stochastic methods with modern forecast techniques could help to optimize the regulating reserve requirements and potentially, also optimize the total reserve requirements. A final report is anticipated to be completed in December 2016.

Within the constraints of meeting the system reserve requirements and other operating consideration, and fulfilling the regulatory and contractual obligations, Hawaiian Electric will continue to economically commit and dispatch the dispatchable generation.

Renewable Acquisition

Replacement of Waiver Projects

Hawaiian Electric is reviewing all of its options and is considering pursuing a transparent and competitive effort to procure resources that may provide viable alternatives to replace the terminated waiver project PPAs, to provide similar benefits to its customers at the earliest timeframe possible. Hawaiian Electric has been considering various options for a competitive procurement process in compliance with the Commission's Framework for Competitive Bidding.

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[26] See the Companies filings, dated September 23, 2015 and November 6, 2015, in Docket No. 2007-0341.

Offshore Wind

Hawaiian Electric is aware of two unsolicited offshore wind energy lease requests received by the US Department of the Interior's Bureau of Ocean Energy Management (BOEM). The proposed projects are approximately 400 MW each in size and include plans for floating offshore wind turbines with undersea cables to various points on O'ahu. Hawaiian Electric will monitor the BOEM lease process for these projects and any other offshore wind project development activities that occur, as Hawaiian Electric will openly consider all energy technologies in order to meet Hawai'i's RPS requirements.

Generation Modernization

Hawaiian Electric plans to install, own and operate the following new and replacement generation assets: a 3x1 combined cycle unit at the Kahe generating station (only under a merged scenario); a reciprocating engine station at Marine Corps Base Hawai'i (both merged and unmerged scenarios); and a reciprocating engine station at Joint Base Pearl Harbor Hickam or a power barge at the Waiau Generating Station (both merged and unmerged scenarios). Approval from the Commission for each of these options is envisioned to be completed via separate competitive bidding waiver requests and General Order No. 7 applications.

As noted earlier, the 3x1 combined cycle unit is part of Theme 2, where the Hawaiian Electric Companies are merged with NextEra Energy. In the event the merger is not approved by the Commission, Hawaiian Electric does not plan to pursue the installation of the 3x1 combined cycle unit.

Underfrequency Load Shed Scheme

Under frequency load shed (UFLS) schemes are designed to stabilize system frequency for severe contingency events and ultimately prevent a system collapse for a cascading contingency. The UFLS scheme is used as a last resort safety net. The schemes are coordinated such that increasing capacities of load are shed in blocks depending on the severity of the event. Typically, the initial blocks (e.g., UFLS blocks 1 – 3) are shed at the 12 kV distribution circuit level to target non-critical residential loads while Blocks 4 & 5 are at the sub-transmission level to shed a large capacity of load to prevent system collapse. Distributed PV will reduce the UFLS capacities of Blocks 1-3 during the day while demand response could reduce UFLS capacities of all blocks at any given hour. Coordination of demand response programs with UFLS will be challenging because over shedding can be more problematic than under shedding. Hawaiian Electric will be conducting a long term UFLS study to specify how its current UFLS scheme should be redesigned to accommodate the changes to the system due to DER resources, DR programs, and projects to automate the distribution system. This study is expected to be completed in mid-2017.

On O'ahu, we have already seen a deterioration of load during the day that affects the current load shed scheme due to DG–PV on our circuits. In 2016, we will be revising the UFLS scheme by rearranging and adding circuits that are part of the UFLS scheme to replace the approximately 10 MW of load lost during the day from Blocks 1 and 2.

MAUI ACTION PLAN

Utility-Scale Energy Storage

The Company will complete a BESS sizing study by the end of 2016 to support submittal of an application for approval to expend funds for a BESS system that will provide Fast Frequency Reserves 1 to make up any shortfall in Fast Frequency Reserves or Primary Frequency Reserves that demand response programs cannot provide to meet the system security requirements identified in the PSIP and subsequent system security studies. The size of this resource is expected to be in the 3 MW to 11 MW size range, a significant reduction in size from the 60 MW BESS that was contemplated in the 2014 PSIP. Further analysis is needed to determine the optimal size needed. The BESS will supplement DR-provided Fast Frequency Response 2 resources to arrest frequency decay caused by events such as the sudden loss of a large generating unit. The Company will conduct an RFP for development of the BESS.

System-Level Improvements

Fossil Generation Retirement Plan

Maui Electric plans to retire Kahului Power Plant (KPP) in 2022 to comply with stringent NPDES requirements. A reserve capacity shortfall of at least 40 MW will result from the retirement of KPP if no new firm capacity is added. In addition, as previously described in Maui Electric's 2014 PSIP, not only does KPP supply power to meet demand, it also provides voltage support for the central Maui area 23 kV system. Upgrades to the Central Maui transmission line must be in place before KPP is retired.

Non–transmission alternatives were considered as options to the transmission upgrades. Options such as utilization of internal combustion engine distributed generation (ICE DG), PV, BESS, DR, synchronous condensers, and capacitor banks were evaluated as options to address the transmission line need.

Additionally, due to the anticipated 40 MW reserve capacity shortfall following the retirement of KPP, Maui Electric does not anticipate retiring any additional generating assets over the planning period of this PSIP. As variations in load occur over the years, units may be deactivated and reactivated, as needed to serve the capacity need.

Over the long term and in future PSIP updates, the need for conventional generation to serve as backup to 100% renewable energy generation needs to be assessed.

Generation Flexibility Plan

Maui Electric has implemented many changes in our generation fleet to increase flexibility and renewable acceptance. These have previously been described in our System Improvement and Curtailment Reduction Plan (SICRP) and subsequent annual updates and included:

- Implementation of the Maui Operational Measures
- Reduction in the number of base loaded units
- Deactivation of KPP units 1 and 2
- Lowering of the minimums on KPP units 3 and 4
- Study and implementation of new regulating reserve requirements
- Automation of curtailment though our Automatic Generation Control (AGC) system

In addition to the above actions that were already completed, Maui Electric will seek Commission approval as necessary to make modifications to our Dual Train Combined Cycle #1 (DTCC1) that will allow operation at lower minimum loads. Going forward, Maui Electric will seek to procure replacement generation for KPP that will have flexible attributes more likely to allow increased renewable resource penetration over a wide variety of potential futures.

Must-Run Generation Reduction Plan

The major actions summarized above to reduce the online megawatts associated with must-run generation and described in the SICRP are listed in more detail below.

The PSIP modeling assumed no fossil-fueled must-run units on Maui after 2022.

Task	Description	Current Target Implementation Date	Actual Implementation Date	Current Status
1	HSIS[27] Regulating Reserve Policy Implementation	10/16/13	10/16/13	Completed
2	K1and K2 Deactivation	2/1/14	2/1/14	Completed
3	DTCC2 Operational Changes – Simple Cycle Operation Enabled	5/1/14	5/24/14	Completed
4	DTCC1 Low Load Modifications – File Capital Project Application with Commission	1/1/2017	NA	In Progress

Table 8-4. SICRP Milestone Metrics Status Update

Additionally, after the retirement of KPP in 2022, it is anticipated that fossil-fueled replacement generation will not be base loaded, thereby further reducing must-run generation.

Generation Commitment and Economic Dispatch

Our current unit commitment and dispatch decisions are based upon wind resource availability, maintenance schedules, costs, system security, and generator operating characteristics which determine contribution to security and adequacy of supply, as constrained by contractual requirements. The system, which utilizes an Automatic Generation Control (AGC) system to improve efficiency in managing firm and variable renewable resources, is already designed to accept variable renewable resources as a priority. The System Generation Operator uses information from the Energy Management System and AGC, operational plans, resource forecasts, planning studies, and relative resource costs to facilitate secure and cost-effective operation of the power system. Throughout the day, the system regulating reserves are monitored for quick response to system load changes. The amount of online reserves carried is currently based on the Hawaiʻi Solar Integration Study (HSIS) reserve policy as described in the SICRP.

To build upon the steps that were taken to prepare the system to accommodate more renewable resources, Maui Electric commits to the following actions:

- Continue Modernizing our Generation Fleet – Maui Electric will continue modernizing our generation fleet to minimize base loaded generation so that more renewable energy can be accommodated on our system. Maui Electric will seek Commission approval as necessary to make modifications to our Dual Train

[27] Hawaiʻi Solar Integration Study.

Combined Cycle units to allow operation at lower minimum loads to reduce base loaded generation and allow the system to utilize more renewable energy.

- Further evaluation of Wind, Solar, and Load Forecasts into Dispatch – Maui Electric will continue to evaluate the process of incorporating wind, solar, and load forecasts into our generation commitment and economic dispatch process and will continue to explore improvement opportunities. The Hawaiian Electric Companies are currently working with AWS Truepower to help us develop forecasting tools that can be integrated with our EMS. As we implement our action plan, we will continue to refine and adapt our process to reflect changes in daily dispatch and commitment requirements from new resources, changes in operational modes of existing resources, and changes in demand and distributed generation.
- Further Evaluation of Regulating Reserve Requirements – With the current renewable resources on the system the HSIS assumptions are presently at their study limits and, as such, new regulating reserve criteria may need to be studied.
- Maui Electric will continue to refine and improve the approach to determining its reserve requirements. As stated above, Hawaiian Electric is currently engaged with EPRI in a study exploring the use of stochastic methods for determining operating reserve requirements. Based on the study results, Maui Electric may adopt similar reserve requirements
- Using Curtailed Energy for Reserve – Maui Electric is exploring whether curtailed energy can serve as regulating reserve in order to further minimize our thermal generation. The curtailment and un-curtailment of power from as-available generation resources will allow these resources to act in the same manner as conventional thermal units and facilitate the integration of other generating assets. If curtailed energy can be used as regulating reserve, it would potentially reduce the minimum thermal generating levels, allowing the system to accept additional generation from as-available renewable resources.
- Integrating Demand Response Resources into Operations – The proposed DR portfolio is focused on technology agnostic solutions to provide system reliability. When DR resources are obtained, we will work to safely integrate DR resources into the operations on each island, where available, to contribute to system reliability.

Transmission and Distribution System Upgrades

The Central Maui Transmission Line Upgrade Project is being driven by the retirement of the Kahului Power Plant.

The Central Maui Transmission Line Upgrade Project will consist of the following:

- Maʻalaea – Puʻunene Substation reconductoring
- Maʻalaea to Waiʻinu Substation 69 kV reconductoring

- Waiʻinu to Kanaha 23 kV to 69 kV upgrade

Non–transmission alternatives were considered as options to the transmission upgrades. Options such as utilization of ICE DG, PV, BESS, DR synchronous condensers, and capacitor banks were evaluated as options to address the transmission line need.

Additionally, transmission line upgrades in South Maui are required to accommodate the projected growth in the South Maui area as well as to maintain the required voltage should something interfere with the transmission of energy from the Maʻalaea Power Plant. A portfolio of non-transmission alternatives was considered as an option to offset the need for this transmission line work. Being responsive to community feedback opposing the transmission line upgrades, Maui Electric plans to solicit proposals for generation in the South Maui area in conjunction with a competitive procurement process to replace the generating capacity of KPP by 2022.

Maui Electric will explore opportunities for aggregated DR to provide location-specific benefits, particularly in the case of non-transmission alternatives. A cornerstone of the DR program portfolio is the effective aggregation of DR resources. All of the proposed DR services utilize various DER technologies to achieve this aggregation philosophy. Furthermore, the DERMS that will be sued to deliver the DR services through the intelligent management and optimization of groups of DERs has been specified to allow for the attribution, selection and dispatch of these resources across various zones. These zones map to the physical topography of the various islands' systems and span from the system level at the highest level down to the individual circuit at the lowest level. As such, the current architecture and system design of the DR portfolio implementation allows for targeted deployment of DERs, which is suitable and appropriate as a tool for helping to address distribution or transmission level constraints such as those being considered by non-transmission alternatives in South Maui.

Replacement Capacity in 2022

Maui Electric is actively working to procure additional firm dispatchable capacity consistent with the PSIP for the island of Maui utilizing the Commission's Framework for Competitive Bidding. Additional generation capacity is needed on the island of Maui to address anticipated retirement of the generating units at KPP at the end 2022, load growth, constrained South Maui transmission capability, and Hawaiian Commercial & Sugar (HC&S) ceasing operations.

Underfrequency Load Shed Scheme

In 2016, Maui Electric will be conducting an UFLS study to verify the performance of the current system under typical underfrequency events and to propose mitigation measures in the event that the current system performance does not meet planning and operating criteria. Due to the increasing amount of renewable generation being added to the Maui Electric system, the dynamic performance of Maui's current system under generation loss contingencies has changed. These changes could potentially impact the reliability of the Maui system. Based on the results of the study, changes to the Maui underfrequency load shedding scheme may be required.

MOLOKAʻI ACTION PLAN

Energy Storage

Distributed Energy Storage

To address the near-term challenges resulting from the high level of DG–PV currently interconnected and waiting to interconnect to the Molokaʻi grid, the minimal impact system is a viable option. A minimal impact system would utilize the energy generated by the PV system solely to charge a storage system during the PV producing hours. The energy stored in the battery would be used to meet the customers nighttime energy needs. Maui Electric will offer customers the option to interconnect minimal impact systems subject to Commission approval.

Utility-Scale Energy Storage

An Altairnano/HNEI 2MW/333KWh Lithium-Ion BESS will be installed second quarter 2016. This BESS is a research project with the Companies partnering with Hawaiʻi Natural Energy Institute to determine applications for batteries in high solar PV penetration scenarios.

Maui Electric is in discussions with Molokaʻi Island Energy (MIE) for a large scale PV and energy storage project. Maui Electric will continue discussion with MIE and will perform more detailed analyses based on the specific parameters proposed.

Maui Electric submitted a High Energy Cost Grant application to the USDA, Rural Utilities Service, in December 2015 to install a proposed utility-owned 100 kW photovoltaic (PV) system with a 500 kW/2 MWh battery energy storage system. To avoid contributing to the excess energy situation on Molokaʻi, the PV system will not export energy to the grid directly. The PV energy would charge the batteries and only the batteries would be connected to the grid and provide energy at peak times or as needed.

System-Level Improvements

Fossil Generation Retirement Plan

Maui Electric does not anticipate retiring any Molokaʻi generating assets over the planning period of this PSIP. As variations in load occur over the years, units may be deactivated (and reactivated) as needed.

Generation Flexibility Plan

Molokaʻi has a centralized generating station with nine (9) diesel internal combustion units and one (1) diesel combustion turbine with capacity to generate 12.0 MW (gross) of power. Maui Electric applied for and received approval from the Department of Health (DOH) for modifications to the air permit that would allow lower minimum operating levels on the base loaded units to accommodate the addition of more renewables to the system. Additionally, generator control upgrades are planned to enable remote monitoring and operation of the generating units.

Must-Run Generation Reduction Plan

Maui Electric currently runs with a minimum number of base loaded units on Molokaʻi – typically two. Maui Electric applied for and received approval from the DOH for modifications to the Palaʻau power plant's air permit that allow lower minimum operating levels on the base loaded units.

Generation Commitment and Economic Dispatch

Maui Electric currently operates with two base loaded units on Molokaʻi because this is the lowest number of base loaded units that satisfy our single contingency criteria. When additional units are needed, they are committed in the most economical order given operational constraints. The Molokaʻi system does not have AGC and therefore the demand for electricity is shared equally between the online units in an isochronous mode of operation.

E-Gear Energy Management Control (EMC) and Storage Technology Pilot Project

In partnership with E-Gear LLC, the Hawaiian Electric Companies will launch a pilot program designed to allow more customers to interconnect rooftop PV systems on Molokaʻi.

E-Gear will install their specialized EMC and storage technology, which will be paid for by the utility, alongside 10 existing rooftop PV systems that have been waiting to be connected to the grid. This equipment can be monitored and controlled by utility system operators, potentially improving the interaction of rooftop PV systems with the grid and reducing the chance these systems will undermine reliable service and power quality for all Moloka'i customers. The Hawaiian Electric Companies will evaluate the performance of these systems and determine whether similar systems can be used to integrate more solar power in areas with high concentrations of rooftop PV systems.

E-Gear is currently evaluating their EMC-equipped PV systems—designed to minimize the grid impact of rooftop PV systems on a small, highly saturated grid like Moloka'i's—in partnership with the EPRI.

Renewable Acquisition

Moloka'i Island Energy Proposal

Maui Electric is actively investigating and considering adoption of an alternative curtailment mechanism and intends to submit its report to the Commission on May 18, 2016 as required by the Commission's Decisions and Orders in Docket Nos. 2015-0224 and 2015-0225.[28] Since Maui Electric anticipates that the results of the investigation will fundamentally modify the structure of all future as-available PPAs, it is deferring the negotiations on a PPA with MIE until after the report has been filed and the Commission and Consumer Advocate have had the opportunity to comment. Maui Electric does not anticipate that the results of the report will adversely affect the ongoing MIE Interconnection Requirements Study.

LANA'I ACTION PLAN

Utility-Scale Energy Storage

Maui Electric will continue to explore the merits of utility-scale variable generation coupled with utility-scale energy storage to increase the renewable energy percentage on Lana'i.

System-Level Improvements

Fossil Generation Retirement Plan

Maui Electric does not anticipate retiring any Lana'i generating assets over the planning period of this PSIP. As variations in load occur over the years, units may be deactivated (and reactivated) as needed.

[28] Docket No. 2015-0224, For Approval of PPA for Renewable As-Available Energy with Ku'ia Solar, LLC, Decision and Order No. 33541, dated February 22, 2016, pages 68-69. Docket No. 2015-0225, For Approval of PPA for Renewable As-Available Energy with South Maui Renewable Resources LLC, Decision and Order No. 33537, dated February 18, 2016, pages 67-68.

Generation Flexibility Plan

The Lanaʻi grid includes a centralized generating station with nine (9) diesel units with 10.4 MW of firm capacity. Generator control upgrades were completed in 2015 to enable remote monitoring and operation of the generating units. Maui Electric also has an agreement to operate a Combined Heat and Power (CHP) unit that is expected to return to service in 2017. The CHP unit will replace one (1) of the two (2) diesel units that provide base load power for the system at Miki basin.

Maui Electric applied for, and is awaiting, approval from DOH for modifications to our air permit that allow lower minimum operating levels on the base loaded units to accommodate the addition of more renewables to the system.

Must-Run Generation Reduction Plan

Maui Electric currently runs with a minimum number of base loaded units on Lanaʻi – typically two. Maui Electric applied for, and is awaiting approval from DOH for modifications to the Miki Basin power plant's air permit that allow lower minimum operating levels on the base loaded units to accommodate the addition of more renewables to the system.

Generation Commitment and Economic Dispatch

Maui Electric currently operates with two base loaded units on Lanaʻi because this is the lowest number of base loaded units that satisfy our single contingency criteria. The CHP base load non-regulating operation is required to fulfill the contractual heat requirement of the customer. When additional units are needed, they are committed in the most economical order given operational constraints. The Lanaʻi system does not have AGC and therefore the demand for electricity is shared equally between the online units in an isochronous mode of operation (excluding the CHP).

HAWAI'I ISLAND ACTION PLAN

Utility-Scale Energy Storage

The Company will provide a BESS sizing study to support submittal of an application for approval to expend funds on a BESS system in 2016. The storage will be designed to provide acceptable system reliability. The sizing of the resource will consider other available cost–effective resources, including demand response. The size of this storage is expected to be 16 MW, with the predominant factor in size being the amount of DER systems that trip at 60.5 Hz. The Company will conduct an RFP for development of the BESS.

Circuit-Level Improvements

Service Transformer Upgrades

Transformer upgrades and new installations are necessary to maintain reliable service with increasing amounts of DER integrated onto the grid. Hawai'i Electric Light will continue to upgrade service transformers as the transformers become overloaded and will also install new transformers to mitigate voltage issues.

Circuit Improvements

Hawai'i Electric Light will use Synergi models, analysis, and field measurements to identify other circuit improvements needed with DER installations. This may include reconductoring, load tap changer setting adjustments, voltage regulator installations, and other equipment upgrades and installations.

System-Level Improvements

Fossil Generation Retirement Plan

While there are no fossil-fueled generating units scheduled to be retired within the five-year Action Plan Period, Hawai'i Electric Light's Preferred Plan shows future dates when certain resources could be removed from service based upon the identified new firm renewable energy additions. Such dates may be adjusted based on further optimization, including actual fuel costs and resource availability at the time of the decision, and on the timing of proposed renewable energy additions which provide capacity and operational benefits similar to the potentially displaced resources.

Units are considered for retirement when all of the below are true:

- They cannot economically serve bulk demand;
- They are not required for adequacy of supply;
- They are not required for system security and reliability reasons, such as offline reserves, fast-start, system restoration, or other critical function, or are not the most economic means of meeting system security and reliability (where other resources may compete).

If retirement is enabled through addition of a new resource, a period of time for the new resource to become reliable and proven will be accommodated before retirement. Typically, a resource would be used for replacement capacity for a period of time before retirement.

As new, firm capacity renewable resources are added to the system, as shown in Hawai'i Electric Light's Preferred Plan, Hawai'i Electric Light will retire existing fossil-fueled generating units when the above conditions are met.

Must-Run Generation Reduction Plan

In the PSIP plans, the value of dispatchable renewable energy resources has been identified as providing value by displacing maximum amount of fossil fuels through the high capacity factor. The acquisition of these resources will include design and operational requirements to leverage the ability for renewable resources to provide grid services similar to displaced fossil generation. This will enable renewable energy to provide all the reliability that fossil-fueled must-run units provide, with a minimum of supplemental resource additions.

Additional analyses based on planning criteria will be performed to identify additional system security constraints beyond the PSIP, which may identify additional cost-effective resource options to address operational constraints.

Prior to altering operational requirements based on system security, the system operators will be provided with resources and operating criteria to ensure acceptable system security based on the through planning analysis.

Generation Commitment and Economic Dispatch

To facilitate operation, state-of-the art forecasting tools have been integrated into the control room. There remains, however, a great deal of uncertainty in the forecast, which can lead to under or over committing the generation. Under committing occurs when production is lower or a down-ramp occurs, and may lead to a generation shortfall and need for supplemental or emergency generation.

For supplemental and emergency purposes, Hawai'i Electric Light will increasingly rely on fast-start resources for start-failure of cycled units and short-term generation needs caused by forecast error. The availability of these units allows the operator to adjust generation quickly in response to changes in net demand. They are also used to restore under frequency load-shed. Further work is being done to improve controls for reliable startup, and allow for stable low-load operation at the steam units.

Hawai'i Electric Light has integrated its state-of-the art wind and PV forecasting into the control room, which is used for the daily unit commitment decisions. Additional projects are in progress to further integrate the forecasting services into the Energy Management System and provide additional visibility and control of DER. This includes EMS cyber security enhancement for migration to the MPLS communications to enable smart-grid technologies and additional integration of distributed networks and transmission components into the EMS control room. This path is in accordance with the telecommunications migration plan. The first stage will be completed in 2016.

Transmission and Distribution System Upgrades

6800 Line Reconductor, Phases 2 to 4

This project pertains to the 69 kV transmission line that runs from Keamuku switching station to Keahole switching station. This project is needed to replace 21 miles of aged and deteriorated transmission poles, insulators and hardware along Mamalahoa highway to improve the reliability of the aging infrastructure. The reconductoring work is targeted for the period 2016 to 2017. Phases 2-4 have been approved by the Commission.

Kilauea 3400, Phases 1 and 2

This project pertains to the 34 kV transmission line that runs from Puna Power Plant to Kilauea switching station. This project is needed to replaced aged and deteriorated sub-transmission poles, insulators and hardware along Hawai'i Belt road to improve the reliability of the aging infrastructure. The replacement work is targeted for the period 2016 to 2017.

New 9400 Transmission Line, Phases 1 and 2

This project pertains to a new 69 kV transmission line that will run from Waimea/Ouli area to North Kohala. It will help facilitate the eventual rebuild of the 3300 line which is presently a radial line. The new transmission line reconductoring work is targeted for the period 2019 to 2020. An application seeking Commission approval to commit funds to this project is planned to be will be submitted in 2017.

6200 Transmission Line Rebuild

This project pertains to the 69 kV transmission line that runs along the saddle road from Kaumana Switching station to Keamuku Switching station. This project is needed to improve reliability of critical cross-island transmission line, as well as to potentially support additional East Hawai'i generation. The reconductoring work is targeted for 2018. An application seeking Commission approval to commit funds to this project will be submitted in 2016.

Underfrequency Load Shed Scheme

Hawai'i Electric Light is implementing a Dynamic UFLS project that is scheduled to be completed by the end of 2016. The scheme adaptively assigns circuits to each stage of the underfrequency load-shed scheme to ensure adequate system protection for loss of generation contingencies under varying net demand levels and levels of distributed generation. The project includes an application on the EMS system, which will calculate the required load shed for each stage based on net demand, and a communication to circuit relaying to assign circuits to a particular under frequency stage.

The project includes upgrades and installations of equipment at 41 substations. These upgrades include installing Real Time Automation Controllers (RTAC), upgrading Supervisory Control and Data Acquisition (SCADA) equipment and electromechanical feeder relays at some locations, and SCADA master station upgrade. With the increasing amounts of uncontrolled and unmonitored rooftop PV, the daily net loading of feeders can change dramatically throughout the day and is no longer predictable. In order to maintain the proper load in each stage of UFLS to meet the system protection targets, the UFLS system must now monitor feeder loads in real-time and adjust the amount of load in each stage of the UFLS according to the actual measured load on that feeder at that time. The dynamic UFLS scheme will allow for automated allocation of feeders to UFLS settings based on actual system load and feeder loads at the time. This allows the UFLS scheme to adapt to changing system and feeder conditions dynamically and continue to provide the necessary protection for the utility grid.

In addition to adding dynamic functionality to the UFLS scheme, frequency rate of change relaying (df/dt) on feeder breakers will be used to speed up sensing time for the first stage of load shedding. The df/dt functionality reduces the possibility of over shedding thereby stabilizing frequency faster, which is necessary to accommodate existing distributed resources connected with the original IEEE 1547 fast-trip requirements during off-normal voltages and frequencies. Reducing over shedding: (a) reduces the chances of "legacy PV" tripping (PV that trips at 59.3 Hz) reducing the overall amount of load that must be shed for stability; and (b) reduces the chances of the frequency rebounding to higher than 60.5 Hz which can cause a large amount of PV to trip, causing the frequency to drop again, triggering additional load shedding and effecting many more customers than necessary.

Renewable Energy Restoration – Waiau Hydro Repowering and Rehabilitation

Hawai'i Electric Light plans to rehabilitate Unit 1 and repower Unit 2 at its Waiau Hydroelectric Power Plant, which is about 96 years old. Rehabilitation and repowering of the aging equipment is expected to increase renewable energy production from the facility. Hawai'i Electric Light plans to submit an application for approval from the Commission to commit funds to this project once project details have been worked out.

9. Next Steps

Given the scope of the Commission's directives and its accompanying limited timeframe, we have completed a thorough analysis, and produced an actionable PSIP that includes Preferred Plans and their attendant Five-Year Action Plans that can be implemented in the short-term.

Over the following months, we will be continuing our analysis to widen the scope and assess additional considerations and constraints to refine our Preferred Plans and make clearer the subsequent 25 years until 2045.

Update Analyses for New EIA AEO Fuel Price Forecast

Two of the foundations of our analysis is the fuel price forecast for both LNG and petroleum-based fuels. The U.S. Energy Information Administration (EIA) issues updated fuel price forecasts generally mid-year. After we receive these new fuel price forecasts, we will perform additional analysis based on those updated forecasts.

Because of this reliance, we will file an addendum to our 2016 updated PSIP either by August 1, 2016 or within two months after these fuel price forecasts are published.

Analyze Inter-Island Transmission

Given the findings of this updated PSIP that O‘ahu will likely need a substantial amount of off–island renewable resources to meet a 100% renewable energy goal in 2045, Hawaiian Electric plans to reassess the scope and requirements for inter-island transmission. As a follow-up action, Hawaiian Electric plans to assess inter-island transmission configurations that might benefit the furthering of our renewable energy goals; assess the costs, integration challenges, and operational considerations inherent in the configurations; and identify the benefits of inter-island transmission relative to alternatives and mixes of alternatives.

Perform Further Research on Offshore Wind

Hawaiian Electric plans to further evaluate the viability of offshore wind resources. This will include assessing, in greater depth, the resource’s potential, possible onshore interconnection configurations, risks factors (such as permitting, community acceptance, natural hazards, and hazards from human activity), resource development and installation costs, and the feasibility of acquiring and implementing offshore wind projects. These evaluations will be performed in conjunction with our planned analysis of an inter-island cable system.

Perform Additional System Security Analysis for the Preferred Plans

The system security analysis focused on N-1 loss of generation contingency events that affect frequency stability. Further analysis is required to ensure system security. These analyses include:

- A protection coordination study to determine the fault current requirements at the sub-transmission system level to ensure distribution protection schemes can operate. Simulations will be performed to maintain system MVA requirements for fault current.
- System MVAR requirements and voltage stability.
- Rotor angle stability.
- Load flow analysis, distribution to transmission.
- Low inertia system analysis.
- Under frequency load shed, an islanding scheme, or both.

Re-Optimize the DR Portfolio for the Preferred Plans

As of the ongoing iterations, we will rerun the Adaptive Planning model to identify the optimal DR portfolio for the final resource plans. This effort will subsume additional iterations between the DR portfolio valuing and the econometric model that optimizes the addition of more distributed storage resources. Once the iterations converge on the value and amounts of distributed storage resources, we will then optimize the final DR model run by incorporating the updated potential study with new storage uptake amounts and new assumptions, optimized DR services by highest benefit cost ratio of each program; and all rules for DR service prioritization.

When the modeling has been completed, we will develop the avoided cost from the optimized DR portfolio. The portfolio costs will also be developed based on the maximum MW in the optimized portfolio (in accordance with the bottom-up methodology described in Appendix J). With avoided costs and costs finalized, we will then perform tests to determine the final cost effective portfolio by island.

The resulting portfolio will be filed in the final DR Program portfolio application in the summer of 2016.

Update Production Simulations and Cost Analyses

Reflect Findings from System Security Analyses

The system security analyses performed in the PSIP defined the system requirements to maintain system reliability for providing frequency and voltage regulation and satisfying the our planning criteria TPL-001. The next step in the process (which could not be completed in time for this filing) is to determine the most economical means to satisfy the requirements.

For example, for the Maui analyses, production simulations were performed and plans were evaluated without must-run fossil-fueled generation after 2022. This assumes that other resources (such as demand response and energy storage: batteries, PSH, or flywheels) will provide cost-effective ancillary services (frequency response and frequency regulation) and other options (such as synchronous condensers) could provide voltage regulation, in lieu of a must-run unit, to accept more renewable energy. Analyses will need to be performed to determine the most economical means to provide the required ancillary services.

Reflect Updated Demand Response Impacts and Costs

The DR program impacts will be re–optimized. This information will be integrated into our updated analyses.

Complete LNG Risk Premium Analysis

We plan to complete risk premium analyses—the monetized value of resource cost volatility—using Ascend Analytics' modeling tools and techniques to define the risk associated with LNG and oil prices for the Preferred Plans.

Complete Sub-Hourly Analysis

We plan to perform additional analysis to optimize the operation of energy storage, including sub-hourly analyses to provide additional insights into the operation of energy storage resources.

Update System–Level Hosting Capacity Analysis

The analysis will determine the extent the system–level hosting capacity will change as a result of updates to the PSIP.