BEFORE THE PUBLIC UTILITIES COMMISSION

OF THE STATE OF HAWAIʻI

------ In The Matter Of -----	)	
	)	
PUBLIC UTILITIES COMMISSION	)	DOCKET NO. 2014-0183
	)	
Instituting a Proceeding to Review the Power Supply Improvement Plans for Hawaiian Electric Company, Inc., Hawaii Electric Light Company, Inc., and Maui Electric Company, Limited.	)	

Hawaiian Electric Companies' PSIPs Update Report

Filed December 23, 2016

Book 1 of 4

December 23, 2016

FILED

2016 DEC 23 P 2: 15

PUBLIC UTILITIES COMMISSION

The Honorable Chair and Members of the
Hawai'i Public Utilities Commission
465 South King Street, First Floor
Kekuanaoa Building
Honolulu, Hawai'i 96813

Dear Commissioners:

Docket No. 2014-0183 – Instituting a Proceeding to Review the Hawaiian Electric Companies' Power Supply Improvement Plans ("PSIPs")
Hawaiian Electric Companies' Revised and Supplemented PSIPs

Pursuant to Order No. 33975, as modified by Order No. 34103, the Hawaiian Electric Companies[1] hereby respectfully submit their Revised and Supplemented PSIPs (also referred to as the "PSIP Update Report: December 2016").[2]

Appendix Q of the PSIP Update Report: December 2016 contains confidential and/or proprietary trade secret information and is being filed on a "restricted basis" pursuant to Protective Order No. 33588 issued on March 14, 2016 in the above subject proceeding ("Protective Order"). Accordingly, such confidential information is only provided to the Commission and Consumer Advocate, and will not to be distributed to any other party or participant to this proceeding or its representatives. The disclosure of such confidential information would be harmful to the Companies and could adversely impact the Companies' transactions with customers, adversely impact the Companies' cost of doing business, and result in higher costs to customers. In addition, the uncontrolled disclosure of such information would give providers of competitive services information useful in making their own marketing decisions, without expending the time and money necessary to develop the information, and would allow providers of competitive services to profit or otherwise derive benefits at the expense of the Companies and their customers.

In addition, pursuant to Order No. 34103, the Companies are providing the Commission and the Consumer Advocate each with a set of two CD/DVDs containing a PDF copy of this filing as well as relevant documentation in support of such filing. The files on the CD/DVDs will be saved to the Companies' FTP site for access by the Parties to this proceeding.

[1] The Hawaiian Electric Companies are Hawaiian Electric Company, Inc., Maui Electric Company, Limited, and Hawai'i Electric Light Company, Inc.

[2] Order No. 33975 filed October 17, 2016, as modified by Order No. 34103 filed November 14, 2016, provides that in accordance with the Modified Schedule of Proceedings, by December 23, 2016, the Companies shall file revised and supplemented PSIPs.

In addition, copies of the DVD will be made available to any party or participant in this proceeding upon request directed by email to Marisa Chun at marisa.chun@hawaiianelectric.com.

Sincerely,

for Joseph P. Viola
Vice President
Regulatory Affairs

Enclosure

c: Service List

SERVICE LIST
(Docket No. 2014-0183)

DEAN NISHINA ACTING EXECUTIVE DIRECTOR DEPARTMENT OF COMMERCE AND CONSUMER AFFAIRS DIVISION OF CONSUMER ADVOCACY P.O. Box 541 Honolulu, Hawai'i 96809	2 Copies Via Hand Delivery
DOUGLAS S. CHIN ATTORNEY GENERAL OF HAWAII DEBORAH DAY EMERSON GREGG J. KINKLEY, ESQ DEPUTY ATTORNEY GENERALS DEPARTMENT OF THE ATTORNEY GENERAL STATE OF HAWAII 425 Queen Street Honolulu, Hawai'i 96813 Counsel for DEPARTMENT OF BUSINESS, ECONOMIC DEVELOPMENT, AND TOURISM	1 Copy Electronic Transmission
MOLLY A. STEBBINS CORPORATION COUNSEL WILLIAM V. BRILHANTE, JR. DEPUTY CORPORATION COUNSEL COUNTY OF HAWAI'I 101 Apuni Street, Suite 325 Hilo, Hawai'i 96720 Counsel for the COUNTY OF HAWAI'I	1 Copy Electronic Transmission
PATRICK K. WONG CORPORATION COUNSEL MICHAEL J. HOPPER DEPUTY CORPORATION COUNSEL DEPARTMENT OF THE CORPORATION COUNSEL COUNTY OF MAUI 200 S. High Street Wailuku, Maui, Hawai'i 96793 Counsel for the COUNTY OF MAUI	1 Copy Electronic Transmission
RICK REED DIRECTOR HAWAII SOLAR ENERGY ASSOCIATION 761 Ahua Street Honolulu, Hawai'i 96819	1 Copy Electronic Transmission

SERVICE LIST
(Docket No. 2014-0183)

ERIK KVAM PRESIDENT RENEWABLE ENERGY ACTION COALITION OF HAWAII, INC. 1110 University Avenue, Suite 402 Honolulu, Hawai'i 96826	1 Copy Electronic Transmission
WARREN S. BOLLMEIER II PRESIDENT HAWAII RENEWABLE ENERGY ALLIANCE 46-040 Konane Place, #3816 Kaneohe, Hawai'i 96744	1 Copy Electronic Transmission
RICHARD WALLSGROVE PROGRAM DIRECTOR BLUE PLANET FOUNDATION 55 Merchant Street, 17th Floor Honolulu, Hawai'i 96813	1 Copy Electronic Transmission
COLIN A. YOST, ESQ 1003 Bishop Street Pauahi Tower, Suite 2020 Honolulu, Hawai'i 96813 Counsel for HAWAII PV COALITION	1 Copy Electronic Transmission
TIM LINDL KEYES, FOX & WIEDMAN LLP 436 14th Street, Suite 1305 Oakland, CA 94612 Counsel to THE ALLIANCE FOR SOLAR CHOICE	1 Copy Electronic Transmission
BEREN ARGETSINGER KEYES, FOX & WIEDMAN LLP 401 Harrison Oaks Blvd., Suite 100 Cary, North Carolina 27513	1 Copy Electronic Transmission
ROBERT HARRIS, #7769 THE ALLIANCE FOR SOLAR CHOICE 595 Market Street, 29th Floor San Francisco, CA 94105	1 Copy Electronic Transmission

SERVICE LIST
(Docket No. 2014-0183)

SANDRA–ANN Y.H. WONG ATTORNEY AT LAW, A LAW CORPORATION 1050 Bishop Street, #514 Honolulu, Hawai'i 96813 Counsel for TAWHIRI POWER LLC Counsel for SUNPOWER CORPORATION	1 Copy Electronic Transmission
HENRY Q CURTIS VICE PRESIDENT FOR CONSUMER AFFAIRS LIFE OF THE LAND P.O. Box 37158 Honolulu, Hawai'i 96837	1 Copy Electronic Transmission
THOMAS L. TRAVIS VICE PRESIDENT PUNA PONO ALLIANCE 930 Tahoe Blvd STE 802/387 Incline Village, NV 89451	1 Copy Electronic Transmission
TOM KOBASHIGAWA DIRECTOR, REGULATORY AFFAIRS HAWAI'I GAS 745 Fort Street, Suite 1800 Honolulu, Hawai'i 96813	1 Copy Electronic Transmission
DEAN T. YAMAMOTO CARLITO P. CALIBOSO TYLER P. MCNISH YAMAMOTO CALIBOSO LLLC 1099 Alakea Street, Suite 2100 Honolulu, Hawai'i 96813 Counsel for AES HAWAII, INC. Counsel for PANIOLO POWER COMPANY, LLC Counsel for EURUS ENERGY AMERICA CORPORATION	1 Copy Electronic Transmission
GERALD A. SUMIDA TIM LUI-KWAN ARSIMA A. MULLER CARLSMITH BALL LLP ASB Tower, Suite 2100 1001 Bishop Street Honolulu, Hawai'i 96813 Counsel for ULUPONO INITIATIVE LLC	1 Copy Electronic Transmission

SERVICE LIST
(Docket No. 2014-0183)

ISAAC H. MORIWAKE KYLIE W. WAGER EARTHJUSTICE 850 Richards Street, Suite 400 Honolulu, Hawai'i 96813-4501 Counsel for SIERRA CLUB	1 Copy Electronic Transmission
FIRST WIND HOLDINGS, LLC 1099 Alakea Street, Suite 2440 Honolulu, Hawai'i 96813	1 Copy Electronic Transmission
CHRIS DEBONE ACTING PRESIDENT DISTRIBUTED ENERGY RESOURCES COUNCIL OF HAWAII 99-1350 Koaha Place Aiea, Hawai'i 96701	1 Copy Electronic Transmission

PSIP Update Report: December 2016

23 December 2016

Hawaiian Electric
Maui Electric
Hawai'i Electric Light

Preface

The Hawaiian Electric Companies respectfully submit this revised December 2016 updated Power Supply Improvement Plan (PSIP) to comply with Order No. 33877 issued by the Hawai'i Public Utilities Commission on August 16, 2016 in Docket No. 2014-0183.

Table of Contents

FIGURES

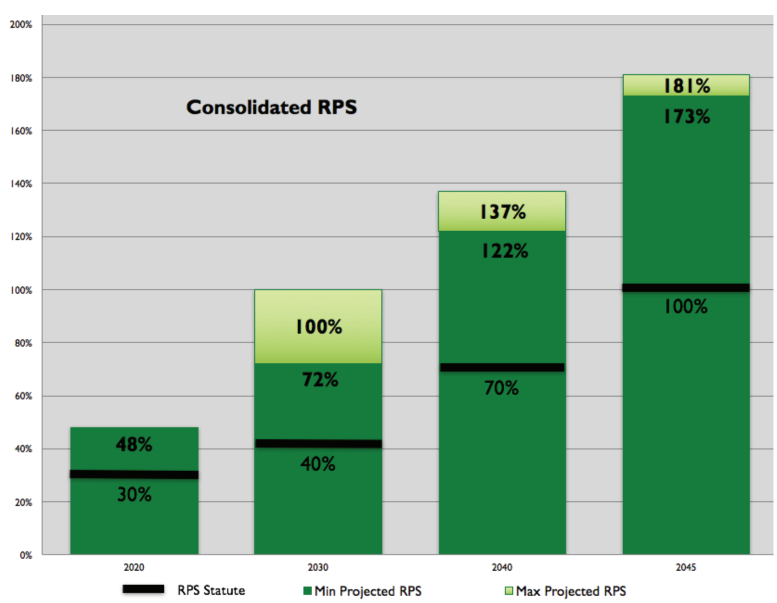
TABLES

Executive Summary

The Hawaiian Electric Companies' 2016 Power Supply Improvement Plan (PSIP) Update outlines a detailed plan charting the specific actions for the years 2017 through 2021 to accelerate the achievement of Hawai'i's 100 percent Renewable Portfolio Standard (RPS) by 2045.

ATTAINING HAWAI'I'S 100% RPS GOAL

By implementing the proposed action plan, we will exceed the 2020 RPS mandate of 30 percent, achieving an estimated 48 percent, and doubling our 2016 RPS. Under multiple longer-term scenarios, our RPS can be at least 72 percent by 2030 and reach at least 100 percent by 2040, ahead of the 2045 deadline.



The Power Supply Improvement Plan (PSIP) places greatest emphasis on the near-term actions that allow us to make strong progress on achieving our clean energy goals. These action plans take advantage of available resources, respond to customer preferences, reduce our dependence on oil and its price uncertainty as quickly as possible, while preserving our flexibility over the longer-term to address changing circumstances, to take advantage of new opportunities that may arise, and to explore emerging technologies.

Our PSIP accelerates the pace on the path to 100 percent renewable energy.
The Action Plans:

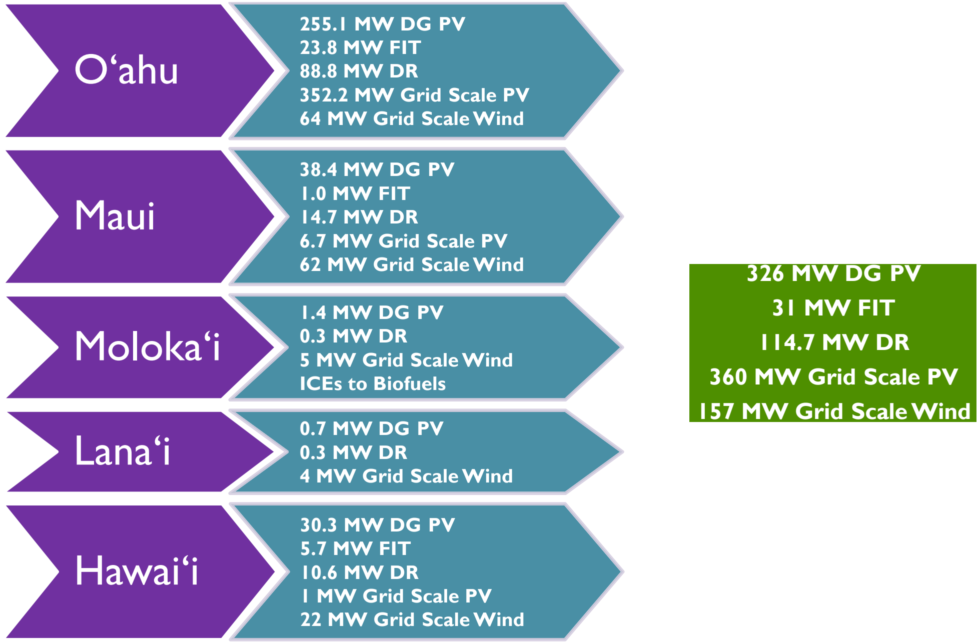
- **Exceed Hawai'i's 2020 Renewable Portfolio Standard (RPS) and achieve a consolidated RPS of 52% over the next five years.**
- **Enable Moloka'i to achieve 100% renewable energy by 2020.**
- **Maximize distributed energy resources—fairly compensated**
- **Make high use of demand response programs.**
- **Aggressively seek grid-scale renewable resources, leveraging federal tax credits.**
- **Pursue grid modernization to enable continued integration of renewable energy.**
- **Preserve long-term flexibility to use emerging technologies and accommodate changing circumstances.**
- **Reduce operations that use fossil fuels and contribute to global warming**

It's important to note that the near-term action plans no longer include liquefied natural gas (LNG), or plans for new combined cycle generation at Kahe. We will continue to evaluate LNG as one alternative in the transition to 100 percent renewable energy.

In the aggregate, our action plans estimate achieving a 52 percent RPS by 2021 by adding 326 megawatts (MW) of rooftop solar, 31 MW of Feed-In Tariff (FIT) solar generation, 115 MW of demand response (DR), 360 MW of grid-scale solar, and 157 MW of grid-scale wind resources across all five islands we serve—an ambitious plan that moves us as a state half-way toward our 100 percent RPS mandate.

Here are the renewable generation and customer demand response additions in our proposed near-term action plans.

2017–2021 Renewable Energy and Demand Response Additions



Achieving the groundbreaking 100 percent goal will require more than a PSIP and the actions of the utility. Rather, it will take *our entire community working together* to make the difficult decisions needed to achieve this clean energy future for our state. All stakeholders—policymakers, government agencies, customers, and private organizations with interests in energy, transportation, agriculture, water use and land use—need to be involved in developing and executing clear policies to guide our choices. Increased energy efficiency, the willingness of communities to accept projects, supportive and adaptive public policies, and partnerships to take advantage of new and improved technology are critical. All of us must support the vision of a future without fossil fuels.

PLAN INFORMS CRUCIAL STATE ENERGY DECISIONS AND ACTIONS

> "Hawai‘i is the Silicon Valley of clean energy. Hawaiian Electric has played a key role in building this reputation and encouraging innovation"
>
> —Brian Ryan, Vector Limited (New Zealand Energy Excelerator Global Partner)

The Hawaiian Electric Companies' mission is to provide innovative energy leadership for Hawai‘i, to meet the needs and expectations of our customers and communities, and to empower them with affordable, reliable, clean energy. Our goal is to create a modern, flexible, and dynamic grid that enables an optimal mix of distributed energy resources (DER—such as customer-generated rooftop solar PV), DR, and grid-scale resources to

Renewable Energy Planning Principles

1. **Renewable energy is the first option.** We plan to aggressively pursue cost-effective renewable resource opportunities that work toward lowering generation costs on the grid. Additional renewable resources can be added cost-effectively, ahead of RPS requirements, as the technology of energy storage matures and costs decline. Removing Hawai'i from the volatility of world energy markets gives future generations a tremendous advantage, and creates a clean energy research and development industry for our state.
2. **The energy transformation must include everyone.** Electricity is essential. Our plans, as well as public policy, should ensure that ratemaking is fair and equitable, and ensure access to affordable electricity—especially those least able to buy self-generation and energy storage.
3. **Today's decisions must not crowd out tomorrow's breakthroughs.** Our plans keep the door open to developments in the rapidly evolving renewable generation market. We must be able to easily accept new, emerging, and breakthrough technologies that are most cost-effective and more efficient when they become commercially viable.
4. **The power grid needs to be modernized.** Energy distribution is rapidly moving to the digital age. We must re-invent our grid to facilitate a 100% renewable energy generation portfolio and enable technologies such as demand response, dynamic pricing, grid-edge devices, and electrification of transportation. Flexible generation is also needed to better integrate renewables.
5. **The lights have to stay on.** Reliability and resiliency of service and quality of power is vital for our economy, for our national security, and for critical societal infrastructure. Our customers expect it, deserve it, and pay for it. All of our plans must maintain or enhance the resiliency of the network—the grid—that delivers energy to the military, businesses, and homes.
6. **Our plans must address climate change.** Power plants are significant producers of greenhouse gas emissions. We have reduced those emissions more than 15% over the past five years through 2015. Still, our plans must go further to reduce the warming of our planet and to minimize the impacts climate change will have on the energy-delivery network—rising sea levels, coastal erosion, increased temperatures, and erratic storm activity.
7. **There's no perfect choice.** No single energy source or technology can achieve our clean energy goals and every choice has an impact, whether it's physical or financial. While we can mitigate those impacts, attaining our 100% renewable energy goal has major implications for our land and natural resources, and the state economy. We seek to make the best choices by engaging with customers, regulators, policy makers, and other stakeholders.

achieve these goals. Our near-term action plans provide the context to inform important pending and future resource and system operation actions.

This is not a plan created in isolation and our state must take a holistic view that considers how energy planning can also influence transportation, economic development, land use and job creation.

In addition to the tactics described in this plan, it's important to note that our planners and engineers continue to evaluate alternatives including pumped storage hydropower, run-of-river hydropower, hydrogen storage and production for potential transportation uses, low-temperature geothermal, ocean-wave technology and the identification of customer loads that when coupled with time-of-use rates can be shifted to times when renewable energy is abundant.

This PSIP adhered to several key Renewable Energy Planning Principles. These Principles, described here, will help to guide us through the complete grid transformation that lies before us over the next 30 years.

Here's a closer look at some of the most significant actions and assumptions in this plan.

Strong Growth in Distributed Energy Resources. We know there is a high level of interest and strong customer participation in our DER programs, especially rooftop solar. Advances in technology continue to drive costs down. Grid-scale renewable resources require large tracts of compatibly-zoned land and community acceptance. To help, we have issued a Request for Information that will help landowners on all islands in our service

territories provide information to potential developers about properties available for grid-scale renewable energy projects. At the same time, we assume high levels of DER penetration and will work to enable the integration of right-sized and right-priced systems. The High DER forecast assumes all single-family residential homes and 20 percent to 25 percent of commercial customers produce the same amount of PV energy as they consume. Over the upcoming months, we will be working with Google's Project Sunroof and Mapdwell's Solar System to provide us with further data on the true potential of DG-PV.

Critical Grid and Generation Modernization. Integrating increasing amounts of customer-supplied DER and grid-scale renewable energy creates a critical need for modernizing the power grid— upgrading and infusing new technologies for our transmission and distribution system utilizing advanced inverters and controls for DER; and judiciously replacing aging, less flexible fossil-fueled units with fast-starting, quick ramping firm generation.

A modernized grid also empowers customer choice where distributed energy resources—solar PV, energy storage batteries, electric vehicles, and demand response resources—can operate at every home.

Modernizing generation means adding fast-starting, quick-ramping flexible units. For example, Waiau unit 8 takes up to four hours to come online; the Schofield generating station currently under construction can provide power to the grid in about one minute and thus can respond to a sudden drop in wind or solar power better than our existing generation fleet. The Schofield Generating Station, strategically located inland and capable of continuing to serve the nearby community in an emergency, is also an example of how the resiliency of the modernized electric system can be bolstered.

Maintaining Reasonable Costs. In developing the action plans, we made concerted efforts to minimize the financial impact on customers. Our near-term action plans include an aggressive deployment of low-cost renewables and a discontinuation of the use of high-carbon dioxide emitting but low-cost coal generation. Despite these renewable additions, the price of oil, the disuse of coal and the cost of modernizing the grid to accept more renewables will move customer bills higher in the near term. However, in the longer term the aggressive pursuit of low-cost renewables will cause customer bills to be flat or slightly declining on a real-dollar basis. The renewable investments in the near-term action plans were selected to minimize the potential for making dead-end decisions and stranding assets. Our approach is to stay flexible to take advantage of breakthrough technologies, especially less expensive ones. A priority is to keep bills manageable as our grid transformation unfolds.

A critical component of affordable bills is rate design. We are exploring options for the evolution of rate design to align with our aggressive transition to more distributed generation and the evolution of the way in which customers provide and receive value from the power network. The rate and bill forecasts in this plan does not yet take these changes into account.

In addition, where military-sited generation is identified in plans, the Company is investigating various ways to reduce the near-term customer bill impacts of these renewable-integrating generators. This could include joint venture arrangements that allow for alternative ownership models while still meeting the electric utility partnership requirements of the military.

Moloka‘i 100% by 2020. Although achieving this potential milestone so quickly may cost a little more, what we learn from Moloka‘i can serve as a blueprint to increase the cost-effective use of renewables for the rest of the state and help us obtain real world experience in running an island grid with 100 percent renewables. Our longer-term plans allow us to apply any insights we learn on Moloka‘i, as well as to take advantage of new and evolving technologies and declining pricing such as for energy storage systems.

We will also continue to collaborate with other island-grid utilities, such as our ongoing working relationship with Okinawa Enetech, Okinawa Electric Power Company, and the National Institute of Advanced Industrial Science and Technology (AIST) to help inform our actions to reach this goal.

Interisland Transmission. Interconnecting the grids on Maui and Hawai‘i Island with O‘ahu could impact the long-term mix and distribution of renewable generation among the islands—more explicitly, reduce renewable development on O‘ahu while increasing it on Maui and Hawai‘i Island.

Over the long term, this could lower generation costs. However, the cost of developing and building such an interisland transmission system must be carefully assessed and factored into a benefit and cost analysis. Given the extreme uncertainty surrounding permitting, feasibility and timing, our near-term action plans do not assume the availability of an interisland transmission system. A thorough evaluation of the benefits and costs of such a system would need to be completed before its future practicability can be assessed.

Paths to 100% RPS in 2045. We operate in an increasingly dynamic environment. Technology, prices, policies, and regulations rapidly change. Our action plans are designed to continue to make strong progress on Hawaiʻi's renewable energy goals while preserving flexibility for multiple long-term energy pathways. The Hawaiian Electric Companies are committed to performing energy planning on a continuous basis. This flexibility will allow us to integrate emerging and breakthrough technologies while adjusting to these changing circumstances.

We operate five separate island grids without the ability to export excess energy or import needed energy. Ensuring that today's choices don't crowd out future technology and potentially lower pricing is imperative to preserve the ability to achieve Hawaiʻi's clean energy goals at reasonable costs for customers.

Electrification of Transportation. Our action plans also provide a solid foundation for the electrification of transportation, including electric vehicles, docks, airports, and warehouses as well as possible hydrogen fuel cell alternatives, reducing further the use of fossil fuels for ground transportation. And again applying a bigger picture view, electrification of transportation can also help integrate more renewable energy, lower total energy costs for customers, and contribute to a lower carbon footprint. Time-of-use rates create incentives for electric vehicle charging, especially when system load is lower, such as during the daytime when excess solar energy is available. Such energy use shifting can also temper the peak electric load in the evening. Electrification of transportation can also influence the sizing of customer-owned generation to recharge batteries and will also increase the opportunity for greater demand response resources to offset utility investments in storage or generation that would otherwise be needed.

Stakeholder Involvement. We analyzed many scenarios and strategies for attaining our RPS goals. These scenarios included multiple long-term energy scenarios developed by Hawaiian Electric and by PSIP stakeholders, including evaluating the hedge value of renewable energy, assessing LNG as a substitute fuel, considering interisland transmission pooling both firm and renewable resources, valuing generation and grid modernization, and evaluating the impact of site-specific data. As part of this evaluation, we collaborated with PSIP stakeholders, thoughtfully considering their suggestions and input. Here is a sampling of scenarios from several stakeholders along with our general assessment of those scenarios:

Ulupono Initiative. Increased LNG costs by 35 percent to account for a natural hedge value that renewables provide. Our results were similar to not considering LNG at all, a situation that allows for an economic incentive to accelerate and interconnect as much tax- advantaged renewable resources as possible before subsidies expire. The result was similar to our analysis for the next five years, with effectively no difference in renewable procurement decisions.

Hawai'i Gas. Assessed Hawai'i Gas's LNG price forecast for O'ahu only, which showed a close similarity to our analysis for the next five years, with effectively no difference in thermal and renewable procurement decisions.

Paniolo Power. Researched the cost-effectiveness of pumped storage hydro as a storage option and wind as a renewable option. We found that wind is a beneficial resource to Hawai'i's portfolio and wind, in conjunction with battery energy storage, is a more cost-effective combined renewable energy/storage option for the island of Hawai'i.

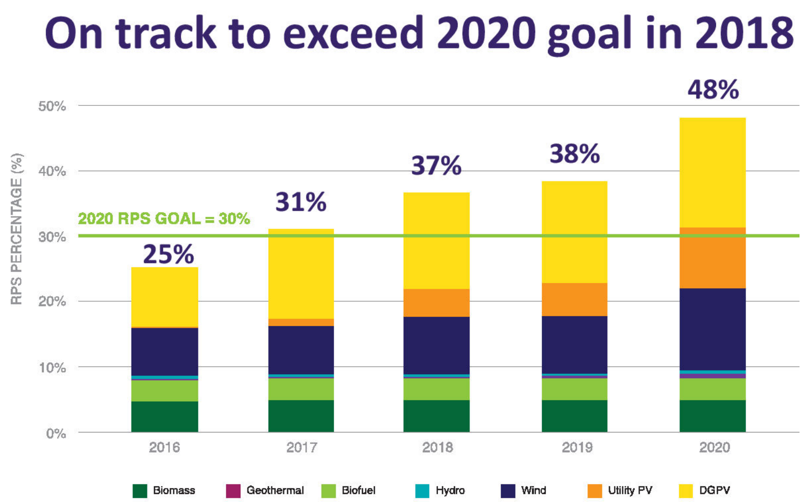
Department of Business, Economic Development and Tourism (DBEDT). Considered DBEDT's proposed five-step methodology regarding the sensitivity of uncertain variables, especially how interisland transmission could change our action plans. Our evaluations showed that using their process served to increase renewable generation on neighbor islands while decreasing the amount of renewable energy generation added on O'ahu. As noted earlier, analysis of interisland transmission is ongoing and will not impact near-term action plans.

Consumer Advocate. Developed a lowest cost plan without regard to resources or RPS attainment. Results showed that the lowest cost plan included LNG and continued use of coal with a market-based DER forecast that didn't meet RPS milestones.

Dr. Matthias Fripp (on behalf of Ulupono and Blue Planet Foundation). Dramatically increased grid-scale solar PV and grid-scale wind resource potential on O'ahu. Results showed a ten-fold increase in early renewable build for wind (assuming no additional development costs per kWh of output and without any land-based constraints, including potential community resistance to siting).

ACHIEVING OUR RPS ENERGY GOALS

Over each of the next four years, we steadily move toward meeting—and exceeding—the 2020 RPS milestone. This increase in renewable energy comprises mainly DG-PV (customer rooftop solar PV), and grid-scale solar PV, and grid-scale wind.



NEXT STEPS

Next, our efforts will be focused on executing the near-term action plans while continuously reviewing long-term directions.

Our long-term planning provides useful directional insights. We have evaluated various long-term portfolios that include diverse sets of resources and input assumptions. For instance, over the upcoming months, we will be working to quantify the technical potential of rooftop solar. As noted earlier, two tools—Google's Project Sunroof and Mapdwell's Solar System—have the potential to provide us with improved data to help us better realize the true potential of DG-PV. We also plan to expand efforts to estimate resource potentials by area and relative proximity to our transmission system.

In this high DER environment, it is also important to develop the appropriate rate design to ensure optimum use of available DER resources and equity for all customers. We look forward to working on this issue under the Commission's guidance.

We plan to maximize integrating DER and DR resources, and begin efforts to procure grid-scale resources. We recently issued a request for information (RFI) to landowners to help inventory potential parcels for renewable energy development. With Commission approval, we would also issue request for proposals (RFPs) for renewable grid-scale solar PV and grid-scale wind installations for all five islands. These RFPs directly flow from the resource acquisitions outlined in our near-term action plans and represent critical steps toward achieving the 100 percent RPS goal.

We plan to initiate additional studies and projects to modernize our grid to allow full and cost-effective integration of distributed and grid-scale resources. Included in this work are the necessary system security upgrades that ensure our transition to 100% renewable energy continues providing our customers with safe and reliable service.

Hawai‘i has the most ambitious renewable energy goals in the entire country. We believe that the proposed near-term action plans are critical to setting our state on a course to achieving those goals. And with all of us working together as a state, we are confident that Hawai‘i will remain a clean energy world leader for the decades to come.

1. Introduction

Throughout the PSIP process, the Commission has stated several strategic objectives for the PSIP.[1] This PSIP describes the planning process and analysis undertaken, and the resulting action plans developed to achieve these strategic objectives.

Achieve state renewable policy goals. The Companies fully embrace the State's 100% renewable policy goals. This PSIP identifies near-term plans for meeting and exceeding the State of Hawai'i's 2020 RPS. It also presents multiple pathways for achieving the State's 2045 100% renewable energy goal, while providing flexibility to respond to changes in technologies and market conditions.

Stabilize and reduce customer bills. The Companies are committed to providing our customers with the most affordable electric energy possible. We are also committed to providing our customers with more options to manage their energy use and costs. In order to inform the Commission and other policy makers of the impacts of policy and investment decisions associated with achieving our 100% renewable energy goal, this PSIP quantifies the impacts on customer bills under several pathways, and discusses the risks associated with those pathways.

Maintain safe and reliable service to customers. The safe and reliable production and delivery of electric energy, and the safe and reliable integration of customer-side energy choices, are vital for the well being of the State's economy. The islanded nature of our electric power systems presents unique planning and operational challenges to achieving safe and reliable service to our customers. This PSIP identifies the measures necessary to meet these challenges and identifies the near term actions that are required to modernize our electric grids to accommodate customer choice and changing technologies.

[1] Docket No. 2014-0183, Order No. 33877 at 2.

This updated 2016 PSIP addresses these objectives. In doing so, this updated PSIP also:

- Specifies realistic and operable near-term action plans for each of our systems that are flexible enough to accommodate alternative long-term pathways presented herein, and to accommodate potential technology changes and changes in market conditions.
- Includes long-term analysis of the integrated grid systems to better inform the specific and prudent near-term capital investments that are part of the near-term action plan.
- Provides context and analysis to inform decision making by illuminating 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.

Achieving our long-term renewable energy policy milestones and providing our customers with an array of affordable, safe and reliable electric service is supported by the near-term actions identified by this update. As circumstances change in the future, we will continue to evaluate the impacts of any changes to the material assumptions used to develop this PSIP, we will seek to improve the planning methodologies, and we will revise our future long-term plans accordingly.

THE DYNAMIC PLANNING ENVIRONMENT

We operate in an environment that is constantly changing. Between the August 2014 and April 2016, the most recent two points in time at which the PSIP was updated, a number of significant changes occurred including: a legislatively mandated increase in Hawai'i's RPS to 100% by 2045, a precipitous decline in the price of oil and associated forecasts of future oil prices, changes with the ownership and in some cases third parties' progress towards development of renewable energy resources in our service areas, the Commission's order capping the net energy metering program, and changes with major customers.[2]

Changes Since April 2016

The pace of changes continues unabated. Since our April 2016 PSIP:

- Solar investment tax credits were ramped down to 10% beginning in 2022 and wind investment tax credits were extended through 2019, after which they are zero.
- Our application to merge with NextEra Energy was dismissed by the Commission, which resulted in the termination of the Hawaiian Electric Companies and NextEra Energy merger agreement.
- EIA published its Annual Energy Outlook (AEO) Early Release report on May 17, 2016.
- The Customer Grid-Supply (CGS) program caps were reached (or nearly so) in each of our service areas. The Commission also issued an Order transferring remaining capacity resulting from withdrawn net energy metering applications to the CGS program.
- The Commission issued Order No. 34206, establishing the issues for Phase II of the DER proceeding (Docket No. 2014-0192).
- NRG Energy acquired the terminated waiver projects previously being developed by SunEdison on O'ahu; we are working to renegotiate the PPAs associated with those projects.
- Hawai'i Electric Light has filed an application to repower the Waiau Hydro project on Hawai'i Island.
- Maui Electric has filed an application to modify its Ma'alaea Dual Train Combined Cycle No. 1 to be able to operate at lower minimum output levels in order to accept more variable renewable energy.

[2] Our April 2016 PSIP highlighted a total of sixteen "changed circumstances" between August 2014 and April 2016.

- Hawaiian Electric has filed an application for approval of the West Loch Solar PV project to provide renewable energy to the U.S. Navy and our other customers.

The Companies also note several accomplishments since April 2016:

- The Commission approved Hawaiian Electric's construction of the 50 MW Schofield Generating Station.
- Hawaiian Electric filed its time-of-use (TOU) retail rate schedule. To date more than 1,000 customers have elected to take advantage of the TOU rate.
- Hawaiian Electric placed its first grid-scale energy storage system into service for a two-year demonstration. The one-megawatt battery from Wyoming-based Altairnano is housed in a large shipping container at Campbell Industrial Park.
- As of September 30, 2016 DG-PV on all five islands totals 561 MW up from 487 MW at the end of 2015.[3]
- As of September 30, 2016, we have attained a consolidated RPS of 24.1%.[4]
- On March 31, 2016, we filed an application with the Commission for the Smart Grid Foundation Project.

In addition to these specific changes in near-term conditions, external market conditions also evolve.

In general, renewable generation technologies continue to improve and drop in costs as implementation increases. Precipitous declines in cost and continued improvements in the performance of energy storage technologies promise to increase the flexibility to utilize these renewable technologies in electric grids, as well as revolutionize the way customers manage their energy costs.

We continually evaluate the status of emerging technologies. In each planning cycle we re-evaluate the energy technologies that should be included as resource options in our long-term planning studies. In particular, as part of this 2016 PSIP update we closely reviewed offshore wind as a possible renewable resource option and we also took a closer look at hydrokinetic technologies, like the small, 18 kilowatt wave power prototype recently deployed by the U.S. Navy in Kaneohe and connected to the Hawaiian Electric grid. We are also in discussions with the Honolulu Board of Water Supply regarding a possible in-line hydro and managed aquifer recharge or pump storage hydro project related to their Nuʻuanu reservoirs.

In making the determination of which resources to include, we balance the need to achieve policy goals and cost effectiveness with the need to protect our customers from risks inherent in new, unproven technologies that may require additional research and

---

3 Includes customer-side Feed-In Tariff projects.

4 https://www.hawaiianelectric.com/about-us/key-performance-metrics/renewable-energy.

testing before becoming commercially available. In this PSIP we have developed near-term action plans for each of our systems that rely on proven and commercially available technologies, while maintaining flexibility in our long-term plans to accommodate inevitable technological change.

In addition to changes that impact our power supply system, we must anticipate and respond to changing conditions and circumstances relating to our customers and their electricity needs. The possibility of electric vehicles replacing gasoline-fueled cars in large numbers will significantly impact the electric grid. As mentioned above, storage technologies may decline in costs allowing customers to locally manage their DERs and take advantage of utility-offerings like demand response and innovative tariffs. This PSIP is based on an assumption that customers will take maximum advantage of DER options in the future, while providing the flexibility of grid-scale resources when needed.

Global market conditions for energy commodities, raw materials and interest rates affect our planning environment, as well as our operating environment. Global energy markets are substantially different today than they were two years ago and therefore the relative benefits of energy alternatives have changed. Prices for raw materials and commodities can affect capital costs for new resources. Interest rate levels affect the borrowing costs of the Companies, and project developers; the low interest rate environment we have enjoyed the last few years may or may not continue. This PSIP reflects the current outlooks for these variables, but changes in future conditions will affect future planning analyses.

Finally, we believe policies will continue to evolve in Hawaiʻi and at the federal level. DER policies, community-based renewable energy policies, RPS applicability for all non-utility generation, grid-scale generation siting policies, rate designs and structures, as well as stable regulatory policies are important if we are to meet the State's energy objectives. Along with the Companies, policy makers must anticipate technological change in order to create the conditions for successful development of emerging resource options like offshore wind. This PSIP anticipates regulatory change, particularly with respect to DER and environmental policies, while also recommending pursuit of a strategy that preserves flexibility to incorporate new technologies and address changing circumstances.

OUR VISION AND STRATEGIC OBJECTIVES

Meeting Our Renewable Generation Goal

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. All of our planning, modeling, analyses, and evaluations are based on this goal.

A Comprehensive Grid Transformation

In order to meet our various objectives around energy policy, customer rates, customer energy options, and reliability, a comprehensive transformation of our energy systems will need to occur. Our near-term action plan contemplates dramatic changes in our systems to accommodate these diverse objectives:

- Our distribution system must be upgraded to accommodate levels of DER that were unimaginable just a few short years ago. These upgrades include better distribution management systems, advanced meters, traditional grid infrastructure, and other smart grid platforms.
- Elements of our transmission systems will need to be upgraded and expanded, not only to accommodate load growth in certain areas (on Maui), but also to accommodate large amounts of variable renewable energy systems (on O‘ahu). Energy storage systems, synchronous condensers, and relay upgrades will augment these transmission improvements.
- Many of our existing generators are approaching the end of their useful lives and lack the flexibility needed to integrate and manage variable renewable resources. We will need to build or acquire flexible firm generation sources to replace decommissioned power plants. Across our island systems, these new resources will be a combination of flexible thermal generation utilizing biofuels, biomass, and in the longer term, geothermal resources.
- We will need new foundational technology platforms to better manage the diverse resource mix, particularly with respect to customer-owned DER and DR technologies. For example, the proposed Demand Response Management System (DRMS) is a very important element in providing the capability to manage and effectively utilize customer-sited options.

Maintaining Safe and Reliable Grids

Integrating variable renewable resources into our systems needs to be accomplished safely and reliably. Improving the flexibility of the generating fleet and limiting the magnitude of contingencies (for example, the sudden loss of generators or transmission lines) are important pieces to integrating larger amounts of variable resources.

System security (the ability of the system to withstand sudden disturbances) and resilience are maintained by operating the system with sufficient reactive power, short circuit current, inertia, fast frequency response, or primary frequency response. To accomplish this, the system operator has historically sacrificed efficiency for reliability by running dispatchable generators at higher minimum levels to maintain adequate reserves.

In this PSIP update, rather than solely relying on these "must-run" generating units, we defined and determined the amount of technology-neutral ancillary services required to meet reliability criteria. This philosophy highlights the opportunity for distributed resources, demand response, and energy storage 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 for the provision of ancillary services.

The grid is also secured by installing new synchronous condensers and by re-purposing decommissioned firm generators as synchronous condensers to ensure sufficient system fault current is available to operate protective relays. Because inverter-based generators cannot provide this fault current, this service has been historically provided by running fossil fueled generating units.

Grid reliability is not optional. Failure to plan for and maintain the security of the grid impedes its ability to withstand sudden disturbances, which can lead to brownouts or blackouts, resulting in significant inconvenience and economic loss to our customers.

REVISED PLANNING PROCESS

For this December 2016 updated PSIP, we revised our planning process for analyzing, modeling, and developing resource plans that form the foundation of our action plans. This process aims to optimize resources across those owned by customers, third parties, and the Companies; to include behind-the-meter DER, demand response and efficiency services, distribution resources, transmission, and centralized renewable generation facilities. This comprehensive planning process is the roadmap for a complete transformation of our power grids.

This revised process employed new tools and new methods, a team of industry-leading consultants partnered with our advanced planning team, to plan for the utility of the future.

Input Assumptions. For our modeling analysis, we began by completely reevaluating our input assumptions from the April filing, modifying virtually all of them with updated information, and verifying them with third-party sources. These sources included the National Renewable Energy Laboratories (NREL), Lazard, Energy Information Administration (EIA), Electric Power Research Institute (EPRI), IHS Energy, Gas Turbine World, and RSMeans. We also included input from the Parties, our internal data and cost estimates, and system interconnection costs.

We coalesced three broad groups of input assumptions for our analysis and modeling process:

Planning Requirements. Fixed parameters of RPS mandates, regulatory and environmental compliance, and overall planning criteria (such as system security, system reliability, loss-of-load probability, service quality, adequacy of supply, and other factors).

Input Assumptions. Metrics driven by market conditions, modeling inputs, or other factors beyond our control. These include fuel price forecasts, resource cost assumptions, resource potential and performance, DR flexible load, DER forecasts, power purchase agreements, and others. DR metrics were independently developed by Black & Veatch using their Adaptive Planning for Production Simulation model. Our Forecasting Department ran the DG-PV Adoption and Customer Energy Storage System models to determine the rate that customers would partake in those energy options.

Planned Assumptions. Metrics that we control: incorporation of the High- or Market-based DER forecasts into the analyses, LNG availability and cost, interisland transmission availability and cost, transmission line limitations and upgrade potential, resource additions (such as military microgrids), and generation modernization scope and cost.

Stakeholder Input. While all Parties submitted extensive commentary about the PSIP process, only a handful of Parties submitted input assumptions for our consideration. We went to great lengths to collaborate with these Parties, to discuss their input, and its relevance to our modeling analysis. To the largest extent possible, we considered, evaluated, and incorporated this input into our PSIP analysis and modeling process.

Modeling Optimization Process. Our analytical approach combined the efforts of two main consultants and their related modeling tools together with a number of Company department teams.

E3 and RESOLVE. Energy and Environmental Economics (E3) employed their RESOLVE capacity expansion modeling tool to conduct the base analysis for our December 2016 PSIP update. RESOLVE used the input assumptions to process a predefined set of core cases (essentially a mix of planned assumptions) to develop a series of theoretical least-cost resource plans. This analytical approach ensures full transparency and is consistent with the resource optimization model suggested by the Parties and orders from the Commission. E3 also completed sensitivity analyses using input received from the Parties to inform development of the near-term action plan.

Ascend Analytics and PowerSimm Planner. Ascend conducted stochastic modeling to validate E3's findings using their PowerSimm Planner modeling tool to evaluate hourly and sub-hourly fluctuations of variable renewable resources. Ascend also developed a companion set of resource plans.

Company Department Teams. Our Advanced Planning Department used PLEXOS for Power Systems to conduct hourly and sub-hourly production simulation modeling analysis of the Core Cases developed by E3; analyzed the impacts of generation modernization for O'ahu; and compared E3's Core Cases against our Post-April PSIP Plan. Our Transmission and Distribution Planning Department ran PSS/E for System Security Analysis to assess the impact of grid resiliency and service reliability.

From this process, we developed a set of Core Cases that served as input for our financial analysis. Our Budgets and Financial Analysis Department ran a Financial Forecast and Rate Impact Model to determine the potential costs and customer rate impacts.

As a result, we developed our near-term action plans based on these overall findings of the analysis and modeling process. Refer to Chapter 4: Analytical Results for details.

DEVELOPING OUR NEAR-TERM ACTION PLANS

Utilizing the results of our optimized planning process, we developed a near-term action plan for each island based on our seven planning principles:

1. Renewable energy is the first option.
2. The energy transformation must include everyone.
3. Today's decisions must not crowd out tomorrow's breakthroughs.
4. The power grid needs to be modernized.
5. The lights have to stay on.
6. Our plans must address climate change.
7. There's no perfect choice.

We also consider and attempt to mitigate risks to our customers. Applying these principles and risk considerations, we developed near-term action plans that:

1. Plans for a High DG-PV future.
2. Fully utilizes DR.
3. Plans for an aggressive build-out of grid-scale renewable energy resources, optimized for each island.
4. Plans for modernization of our grid to incorporate higher levels of DER and grid-scale resources.

SETTING A COURSE FOR OUR RENEWABLE FUTURE

Hawai'i is well on its way to meeting its energy goals. The Hawaiian Electric Companies have exceeded a 24% RPS through September 30, 2016.

Near-Term Action Plans. Our near-term action plans are designed to build on our past successes by integrate increasing amounts of variable renewable energy, while managing variable renewable resources with the provision of grid services from DER, DR and flexible generation. We have developed five action plans, one for each island we serve, which inform and support near-term resource acquisition and system operation decisions. These action plans detail specific initiatives that must be undertaken in the immediate future to take advantage of available renewable resource potential and federal tax incentives (which are phasing out over the next five years). At the same time, the action plan is designed to achieved our near-term RPS milestones, satisfy our customers' desire for more options to manage their energy costs, and take into account the uncertainty in future oil prices.

Longer-Term Energy Planning. Our action plans specify a set of actions that help us continue on the path to 100% renewable energy in 2045. However, our action plan is designed to provide a platform from which any number of potential long-term plans could be designed. Thematically, any of the multiple long-term plans discussed in this PSIP can be launched if our near-term action plan is implemented. However planning is an ongoing activity. As conditions change, we must adjust and re-optimize our long-term plans based on those changes. We anticipate our action plans to be further optimized and adjusted based on changing circumstances in future planning updates to reach our 100% renewable energy goal in other ways.

Next Steps

The near-term action plans detailed in Chapter 7: Near-Term Action Plans are realistic assessments of the actions that need to be taken to continue on our path to 100% renewable energy. If we are to meet our interim RPS milestones, time is of the essence in terms of implementing a plan.

Key actions now include:

- Commission completion of evaluation of this PSIP, including providing direction to the Companies regarding the action plan.

- Continued pursuit of policies and programs to empower our customers with more options for managing their energy use and cost. This includes Phase II of the DER docket and implementation of our demand response programs.
- Commission evaluation of grid modernization initiatives to be submitted to the Commission in the near future for consideration .
- Aggressive pursuit of grid-scale renewable energy resources, including CBRE, to take advantage of waning tax incentives and low interest rates.
- Continued evaluation of fuel options including biofuels to meet RPS requirements and firm, dispatchable generation needs, and LNG as a potential way to reduce customer bills.

The Companies stand ready to work with the Commission, Consumer Advocate, state policy makers, the various stakeholders, and most importantly our customers to achieve renewable energy policy goals, customer bill reductions, and continued reliability.

2. Commission Directives

The Companies have reviewed the directives issued by the Commission in each of the previous PSIP-related Orders issued by the Commission. The various directives and issues raised by the Commission constitute a broad and comprehensive set of topics. We have worked diligently and in good faith during the PSIP process to address each and every topic raised by the Commission. This Chapter summarizes the various Commission directives, discusses the Companies' efforts to address the directives, and directs the reader to specific Chapters and Appendices in this report where those directives are addressed in detail.

ADDRESSING THE ISSUES RAISED BY THE COMMISSION

There have been a number of PSIP-related Orders dating back to April 28, 2014. In terms of directives by the Commission, the key Orders are as follows:

- Order No. 32052 issued on April 28, 2014 in Docket 2012-0036 (which included the Commission's "Inclinations" statement).[5]
- Order No. 33320 issued on November 4, 2015 in Docket 2014-0183.
- Order No. 33877 issued on August 16, 2016 in Docket 2014-0183.

These Orders contained a number of instructions, directives, and eight Observations and Concerns (initially outlined in Order No. 33320). Table 5-1 summarizes these issues.

[5] Three Orders were issued in conjunction with Order No. 32052 on April 28, 2014: Order No. 32053 (RSWG – Docket No. 2011-0206), Order No. 32054 (DSM – Docket No. Docket 2007-0341), and Order No. 32055 (Maui Rate Case, Docket No. 2011-0092).

Topic	Order No. 32052	Order No. 33320	Order No. 33877
Near-Term Action Plan	■ Provide key decision points associated with each plan. ■ Provide information to Commission that supports subsequent Commission decisions.	■ Address need for applications for approval of individual capital projects, programs, contracts and RFPs. ■ Present plans that minimize cost-effective renewable energy sources and represent well-reasoned strategies that will lower system costs and maximize use of cost-effective resources. ■ Provide useful context and analysis in the form of well-vetted plans to inform major resource acquisitions. ■ Demonstrate the cost effectiveness of key projects and programs that comprise major near-term investments. Will plan result in unreasonable financial costs for customers?	■ Focus on near-term actions to achieve RPS, reduce rates, maintain safety and reliability. ■ Identify near-term actions that must be taken.
Alternative Resource Portfolios	■ Rank or descriptively prioritize final Resource Plans. ■ Identify common themes, resources, programs, actions that provide greatest value, balance costs and risks, and provide flexibility.	■ Consider alternative strategies to deliver timely benefits to customers. ■ Provide analysis to inform choices and trade-offs between major inter-related and/or mutually exclusive resource strategies. ■ Provide useful context and analysis for meeting state clean energy requirements. ■ Identify changes in circumstances that affected updated plans.	■ Assess trade-offs of alternative portfolios.
Customer Rate & Bill Impacts (Observation and Concern #1)	■ Provide accurate and reliable rate impact analysis. ■ Evaluate impacts of self-generation and energy efficiency on customer who cannot or do not want to take advantage of those opportunities.	■ Demonstrate that cost impacts are reasonable and presented fairly. ■ Provide useful context and analysis to ensure that costs and rates are reasonable.	
RPS Attainment	■ Provide an optimal renewable energy portfolio plan.	■ Address RPS attainment utilizing resources that have reasonable cost, occur at the appropriate point in the planning period, and which have a reasonable probability of successful development.	

Topic	Order No. 32052	Order No. 33320	Order No. 33877
Input Assumptions (Observation and Concern #2: Technical Costs and Resource Availability)	■ What are limits of renewables on O'ahu?	■ Avoid use of resources with higher costs and uncertain feasibility. ■ Demonstrate that low-cost renewable generation resources are included. ■ Provide justification for exclusion of technologies with a CRI Level 4 or below. ■ Provide justification for island resource constraints. ■ Utilize updated new resource cost assumptions. ■ Consider impacts of improvements in technology, reductions in cost, and availability of renewable resources.	■ Clarity and transparency of inputs and assumptions. ■ Incorporate stakeholder input related to fuel prices, resource costs, DER forecasts.
Stakeholder Input	■ Utilize stakeholder input or explain why it was not used. ■ Acknowledge stakeholder input.	■ Stakeholders are encouraged to submit alternative analyses and suggesting analytical methods to assist the Companies.	■ Incorporate stakeholder input related to fuel prices, resource costs, DER forecasts.
Analytical Methods & Models	■ Employ appropriate modeling tools and techniques. ■ Appropriately analyze curtailment amounts, operational characteristics related to increased renewables, ancillary services needs, firm generation amounts, DR.	■ Provide an optimal renewable energy portfolio plan. ■ Ensure the integrity of modeling methods to evaluate ancillary service alternatives. ■ Review all analysis methods, constraints and assumptions for accuracy and provide sufficient analytical tools to support resource plans.	■ Clarity and transparency of resource optimization. ■ Document all methods, models, procedures, and assumptions. ■ Document resource optimization process. ■ Independently verify innovative methods and analyses.
DER Integration (Observation and Concern #3)	■ Impacts of DER on reliability, costs, and curtailment of grid-scale renewable resources.	■ Consider use of all types of distributed resources including DR, energy efficiency, electric vehicles, distributed generation and distributed energy storage. ■ Consider future opportunities for use of DER including use of DER to provide grid services, including those necessary to provide system security. ■ Consider opportunities to upgrade or retrofit existing DER systems to provide grid services. ■ Consider DER strategies that are optimal, reasonable, and cost-effective.	

2. Commission Directives

Addressing the Issues Raised by the Commission

Topic	Order No. 32052	Order No. 33320	Order No. 33877
Fossil Fuel Plant Dispatch and Unit Retirements (Observation and Concern #4)	▪ Provide valid determination of most economical amounts of firm generation. ▪ Provide a Generation Commitment and Economic Dispatch Review to ensure most fuel efficient and cost effective outcome. ▪ Discuss environmental compliance plan. ▪ Generation adequacy analysis. ▪ Fossil Generation Retirement Plan. ▪ Generation Flexibility Plan. ▪ Must Run Generation Reduction Plan. ▪ Environmental Compliance Plan. ▪ Key Generator Utilization Plan. ▪ Optimal Renewable Energy Portfolio Plan. ▪ Generation Commitment and Economic Dispatch Review.	▪ Justify conversion of existing units to burn LNG. ▪ Provide supplemental analysis regarding timing and justification of proposed retirements and replacements of existing fossil-fueled generators. ▪ Provide context and analysis of system operating decisions. ▪ Provide a fossil generation retirement plan and the cost effectiveness of retirements. ▪ Provide a generation flexibility plan and demonstrate that unit modifications can be accomplished and maintained. ▪ Provide a must-run generation reduction plan. ▪ Provide a key generator utilization plan.	

Topic	Order No. 32052	Order No. 33320	Order No. 33877
System Security Requirements (Observation and Concern #5)		■ Justify the basis for system security requirements and costs. ■ Appropriately balance cost with system reliability and risk. ■ Ensure system security requirements do no unreasonably limit utilization of renewable resources. ■ Consider diversity (non-coincidence) of renewable generation output when determining system security requirements, particularly regulation reserve requirements. ■ Rigorously define system security requirements in technology neutral terms over the full spectrum of power system operating domains from cycles to hours. ■ Provide comprehensive cost estimates of the combined capital and operating costs to meet system security requirements. ■ Compare alternatives to demonstrate that proposed requirements are reasonable and cost effective. ■ Demonstrate that the proposed system security requirements constitute a reasonable, cost-effective set of rules for each system.	■ Define ancillary services in technology-neutral terms ■ Optimize deployment of DR, storage, generation, and other options ■ Evaluate various levels of reliability and balance with cost and rate impacts.

Topic	Order No. 32052	Order No. 33320	Order No. 33877
Ancillary Services (Observation and Concern #6)	■ Identify supporting ancillary service needs. ■ Provide comparative analysis of ancillary costs and benefits associated with plans. ■ Demonstrate that Company policies and practices ensure that combined total cost of generating and providing ancillary services are and will continue to be minimized.	■ Consider the potential for DR to meet ancillary service requirements. ■ Explicitly identify ancillary services, need to modify system operations, and costs for integrating renewable resources. ■ Define ancillary services in terms of response speed and amounts required. ■ Identify which technologies currently provide each defined service. ■ Do not exclude technologies from providing ancillary services without clear justification. ■ Demonstrate that contingency BESS resources could not be provided by more economically by alternative means. ■ Examine DR as a source of ancillary services. ■ Examine other sources of ancillary services including wind, ICE, and innovative generation unit operations practices.	■ Define ancillary services in technology-neutral terms. ■ Optimize deployment of DR, storage, generation, and other options.
Transmission and Distribution	■ What are the costs and benefits of smart grid investments? ■ Address needs to interconnect new renewable resources. ■ Comparative analysis of costs and benefits of T&D options.		
Interisland Transmission (Observation and Concern #7)	■ Provide a credible cost/benefit analysis of interisland transmission.	■ Provide a reasonable benefit-cost analysis of interisland transmission options.	■ Complete interisland transmission analysis.
Customer & Implementation Risks (Observation and Concern #8)	■ Identify common themes, resources, programs, actions that provide greatest value, balance costs and risks, and provide flexibility.	■ Evaluate timing and benefits of capital expenditures. ■ Consider risks and uncertainties associated with timing, availability, and pricing of LNG. ■ Consider potential for stranded investment. ■ Consider ability of Company to manage projects and manage a capital intensive resource expansion program. ■ Consider front-loaded capital investment risk.	■ PSIP plans must remain flexible. ■ Analyze customer exit risk. ■ Analyze capital investment risks.

Topic	Order No. 32052	Order No. 33320	Order No. 33877
Company Business Model	■ Consider potential strategies related to the generation system that would lower and stabilize the costs of generation, including high penetrations of lower-cost new utility-scale resources; Modernize the generation system to achieve a future with high penetrations of renewable resources; Exhaust all opportunities to achieve operational efficiencies in existing plants; and pursue opportunities to lower fuel costs in existing power plants.	■ Identify changes required to align the Companies' business model with customers' interests and the state's public policy goals.	■ Align with customer needs and policy goals.

Table 2-1. Summary of Commission Directives Throughout the PSIP Process

We have addressed all Commission directives, placing specific emphasis on the actions directed by Order No. 33877. For this December 2016 updated PSIP, we have:

- Focused on near-term action plans.
- Reviewed and assessed input assumptions, and considered Party input.
- Utilized automated optimization tools for developing longer-term plans.
- Assessed the impacts of alternative portfolios.
- Completed the action items identified in Chapter 9: Next Steps of the April 2016 updated PSIP.

For these Next Steps, we have:

- Updated analyses for new Energy Information Administration *Annual Energy Outlook* (AEO) fuel price forecast.
- Analyzed interisland transmission feasibility.
- Performed further research on offshore wind.
- Performed additional system security analysis.
- Re-optimized the DR portfolio.
- Updated production simulations and cost analyses.
- Completed LNG risk premium analysis.
- Completed sub-hourly analysis[6].
- Updated system-level hosting capacity analysis.

[6] E3 sensitivity analysis as requested by Ulupono.

Finally, while our analysis includes additional and updated evaluations of LNG as a way to stabilize customer rates, reduce use of imported oil, and reduce emissions, we have not included LNG in our near-term action plan.

NEAR-TERM ACTION PLAN

In Order No. 33877, the Commission instructed the Companies to focus on near-term actions that advance achieving the State's 100% renewable energy goal, stabilize and reduce customer rates, and maintain safe and reliable service.[7]

We have prepared the December 2016 PSIP Update with the primary objective of fulfilling this Commission directive. We have not identified a single long-range preferred plan for each island (as in the April 2016 updated PSIP). Rather, the action plans for the near-term (2017–2021) identify implementation needs and strategies that can inform major resource acquisitions, system operation decisions, and other applications that may go before the Commission.

The near-term action plan is designed to aggressively seek new renewable resources, while providing longer-term flexibility to respond to changing market conditions and potential technology changes. The near-term action plan also specifically identifies actions for implementing the plan, including:

- Competitive procurement of new renewable resources, including wind and solar projects for all islands.
- Disposition of pending applications before the Commission (for example, the acquisition of the Hamakua Energy Partners combined-cycle plant).
- Likely new applications for capital investment projects, including reliability-based projects (for example, synchronous condensers and contingency BESS).
- Approvals for power purchase agreement from renewable resource suppliers.
- Customer programs.

The action plan is based on thorough analysis of various new resource alternatives, robust and detailed analytical analysis, review of system operational decisions that must be made to accommodate more renewable resources, and maximum use of customer options including DER, demand response, and time-of-use (TOU) rates.

[7] Docket No. 2014-0183, Order No. 33877 at 2.

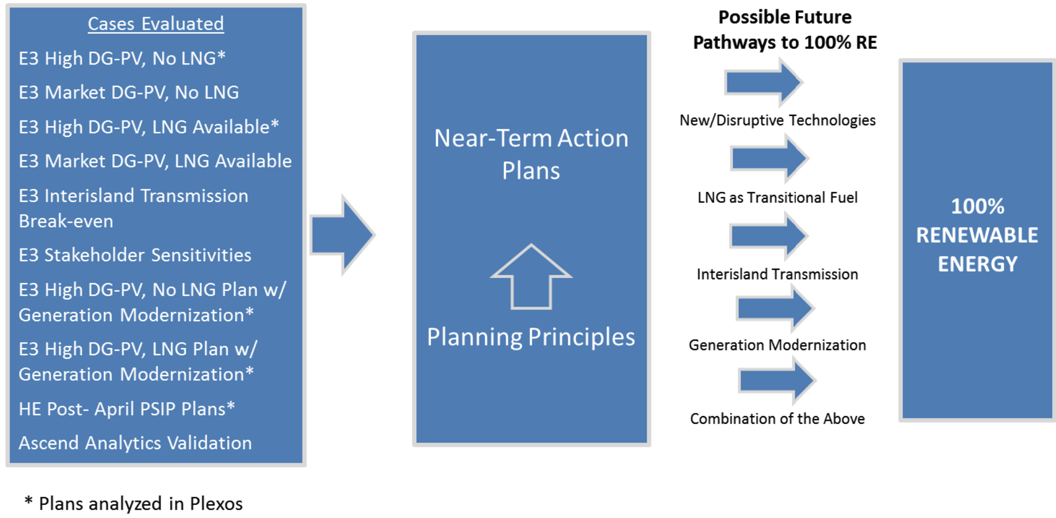


Figure 2-1. Overall Process for Development of the PSIP Action Plan

This flow process in Figure 2-1 should be viewed in conjunction with the overall analytical process described in Chapter 3: Analytical Approach.

The near-term action plan is based on long-term analyses that produced various resource plans through 2045. The near-term action plan focuses on immediate actions; the longer-term views, based on the best information currently available, reflect potential actions over the period beyond 2021.

It is important to note that resource decisions identified for the long term are not committed decisions. Technology changes will likely occur in the future. Customer decisions regarding DER, participation in DR programs, adoption of electric vehicles, increased penetration of air conditioning, and other changes affect future resource decisions. Our near-term action plan is designed to accommodate different futures, while providing a blueprint for immediate action.

The Action Plans for each of the Companies' systems are found in Chapter 7: Near-Term Action Plans.

ALTERNATIVE RESOURCE PORTFOLIOS

This 2016 PSIP update focuses on identifying and supporting the near-term actions, applications, and decisions necessary to effectively meet identified challenges, planning objectives, and the achievement of 100% renewable energy by 2045. We have not provided a Preferred Plan; rather, we present several different resource plans for each island. Each plan is designed to achieve the RPS goals, albeit with a different path. In particular, we have offered plans with and without LNG. These plans are intended to

provide regulators, policy makers, and stakeholders with an objective comparison of potential futures with and without LNG. The action plans presented herein do not include LNG; we have neither predetermined that LNG will be available, nor have we ruled out LNG as a fuel option for the future.

Care was taken to develop these plans by considering stakeholder and Commission input, by utilizing analytical methods and modeling that are replicable utilizing the same tools and assumptions we used (as much as possible, fully documenting the innovative methods and tools employing analyze our unique situation), and by employing a combination of company resources and objective independent consultants.

The Plans presented in this report are summarized below.

Oʻahu Plans

The Oʻahu Plans are as follows:

Post-April PSIP Plan. This plan was developed by the Companies after the filing of the April 2016 PSIP utilizing updates to assumptions that were made after the April 2016 filing.

E3 Plan. This plan is based on an optimized resource portfolio utilizing E3's RESOLVE model, including "optimal" retirements, with adjustments to the plan made to reflect actual resource option sizes and additional modeling using consultant Ascend Analytics' sub-hourly analysis and the Companies' analysis using the PLEXOS sub-hourly model. This plan did *not* include LNG as a potential fuel source.

E3 Plan with LNG. This plan was developed in the same way as the E3 Plan, except LNG was made available as a potential fuel source and the optimization models were allowed to "choose" LNG to the extent it was determined by the model to be the optimum fuel choice.

E3 Plan with Generation Modernization. This plan was developed in the same way as the E3 Plan. However, retirements and replacement generation as recommended by the Companies' Power Supply group were added into the model. LNG was *not* available as a fuel source in this plan.

E3 Plan with LNG and Generation Modernization. This plan is the same as the E3 Plan with Generation Modernization. However, LNG was assumed to be available as a possible fuel source.

Hawai‘i Island Plans

The Hawai‘i Island Plans are as follows:

Post-April PSIP Plan. This plan was developed by the Companies after the filing of the April 2016 PSIP utilizing updates to assumptions that were made after the April 2016 filing.

E3 Plan. This plan is based on an optimized resource portfolio utilizing E3's RESOLVE model, including "optimal" retirements, with adjustments to the plan made to reflect actual resource option sizes and additional modeling using consultant Ascend Analytics' sub-hourly analysis and the Companies' analysis using the PLEXOS sub-hourly model. This plan did *not* include LNG as a potential fuel source.

E3 Plan with LNG. This is the same as the E3 Plan, except that LNG is assumed to be available as a fuel and the optimization model "chose" LNG if it was the optimum fuel or resource option.

Maui Island Plans

The Maui island Plans are as follows:

Post-April PSIP Plan. This plan was developed by the Companies after the filing of the April 2016 PSIP utilizing updates to assumptions that were made after the April 2016 filing.

E3 Plan. This plan is based on an optimized resource portfolio utilizing E3's RESOLVE model, including "optimal" retirements, with adjustments to the plan made to reflect actual resource option sizes and additional modeling using consultant Ascend Analytics' sub-hourly analysis and the Companies' analysis using the PLEXOS sub-hourly model. This plan did *not* include LNG as a potential fuel source.

E3 Plan with LNG. This is the same as the E3 Plan, except that LNG is assumed to be available as a fuel and the optimization model "chose" LNG if it was the optimum fuel or resource option.

Moloka‘i Plans

The Moloka‘i Plans are as follows:

100% Renewable by 2020. Optimized plans developed using the PLEXOS optimization logic for 100% renewable energy in 2020.

100% Renewable by 2030. Optimized plans developed using the PLEXOS optimization logic for 100% renewable energy in 2030.

Lana'i Plans

The Lana'i Plans are as follows:

100% Renewable by 2020. Optimized plans developed using the PLEXOS optimization logic for 100% renewable energy in 2020.

100% Renewable by 2030. Optimized plans developed using the PLEXOS optimization logic for 100% renewable energy in 2030.

These core plans form the basis for development of action plans for each island that are robust under a number of different futures.

The core plans are discussed in Chapter 5: Analytical Results. Documentation of the development of the core plans is discussed in Chapter 3: Analytical Approach, Appendix C: Analysis Methods and Models, Appendix H: Renewable Resource Options for O'ahu , Appendix K: Candidate Plan Data, and Appendix P: Customer Retention Economics.

CUSTOMER RATE AND BILL IMPACTS

See Chapter 5: Financial Impacts and Appendix I: Financial Analysis and Bill Impact Calculations for a detail discussion and results.

RPS ATTAINMENT

Each core case meets or exceeds all statutory RPS requirements.

The near-term action plans presented in this report were informed by the PLEXOS Cases. However, the near-term action plans:

- Do *not* rely on an assumption that LNG or interisland transmission will be available.
- Do *not* rely on resources with as yet unproven feasibility (for example, offshore wind, Maui geothermal, west-side Hawai'i Island geothermal).
- Reflect very aggressive, but realistic, renewable resource additions on all islands (primarily DG-PV, grid-scale wind, grid-scale PV, and DR), provided that action plans are approved by the Commission in a timely manner, so that implementation of the plans can begin.

Discussion of RPS Attainment can be found in the Executive Summary, Chapter 4: Analytical Results, Appendix K: Analytical Steps and Results, and Appendix M: Component Plans.

INPUT ASSUMPTIONS

From the outset of the 2016 PSIP cycle, the Companies have gone to great lengths to research, develop, review, publish, and seek, receive and incorporate input from Stakeholders regarding the various input assumptions that were used to develop the PSIP. The development of many of the input assumptions was coordinated by an outside consultant. The consultant was instructed to develop the input assumptions in as objective of a manner as possible.

As much as possible, we have obtained data from publically available sources that are available to anyone via the Internet. In certain cases, we have relied on proprietary sources of data (that is, data that was developed by a for-profit private expert-entity and made available for a fee to users). In almost every case, the proprietary data is available for purchase by anyone who wishes to pay for it.

We acknowledged the Commission's concerns expressed in Order No. 33320 regarding avoidance of resources with "unproven" feasibility. As explained in our April 2016 PSIP filing, our selection of resource options was based on technologies that are commercially available (which means, among other attributes, that the financing from capital markets is available without the need for subsidies), or which have a reasonable likelihood of achieving commercialization within the foreseeable future.

The April 2016 PSIP Preferred Plan relied heavily on offshore wind as a resource option for O'ahu. Because this technology is still not considered commercially available (among other things it has yet to be tested at full scale), we undertook a more detailed analysis of the potential for offshore wind to become a resource option in the future. Our conclusion is that offshore wind will likely be commercialized within the next five to ten years, but there are many hurdles remaining for offshore wind to be a viable option for Hawai'i, including policy issues that must be sorted out by various State and Federal agencies. All of our new resource capital and operating cost assumptions were reviewed by NREL and found to be reasonable.

Several of the parties suggested that we should include resources such as wave and tidal power and hydrogen energy storage as resource options. In response to those suggestions, we spent time researching such technologies and concluded that, while these types of resources show promise for the future, it is difficult to predict when they will reach commercial status, and at what cost. Therefore, such options were not explicitly considered in this PSIP. To the extent progress is made that would show the commercial availability of such resources, we will consider such options in future planning updates. In addition, we will continue to track these technologies and explore opportunities to pilot and test these and other technologies.

One area that the Commission called into question was our assumptions regarding the resource potential on O'ahu. This is an important consideration because O'ahu has approximately 70% of our customers' electric demand, requiring the most development of renewable resources. However, it is also the most densely populated Hawaiian island, which makes development of those resources potentially more difficult.

To provide a more definitive analysis of the O'ahu resource potential, we engaged NREL to perform an independent analysis of the onshore wind and grid-scale PV potential on O'ahu. NREL's results reflected their estimates of the technical resource potential based on historical wind and solar data, evaluation of land suitable for such development, and thresholds of site capacity factors that would likely be attractive to renewable resource developers.

Several parties took issue with NREL's findings and provided alternative analyses, indicating technical resource potentials that are on the order of double the NREL findings. With an emphasis on near-term actions, we elected to avoid a protracted debate over which analysis is correct, as the near-term action plan includes resource development that is well below either O'ahu resource potential finding (Maui and Hawai'i Island each have abundant solar PV and wind resource potential). We note however, that neither the NREL analysis, nor the alternative analysis put forth by the parties included detailed site-by-site evaluation of site availability, site environmental conditions, community acceptance, or the likelihood of obtaining permits to develop a given site. This lack of practical project development considerations in either analysis suggests that both NREL and the parties' alternative analysis overstate the actual "developable" renewable resource potential on O'ahu. The only way to determine the actual resource potential is to ask the market through competitive procurement processes.

Consistent with interveners' obligation to "…assist in the development of a sound record"[8] and participants' obligation to "… aid the commission by submitting an affirmative case",[9] the Commission in Order No. 33320 asked the Parties to submit "alternative analysis"[10] to assist in the development of the PSIP. In our November 2015 Work Plan, we solicited input from the Parties in Docket 2014-0183 regarding our PSIP input assumptions. During the course of 2016, we presented our resource assumptions at technical conferences and distributed our new resource and energy storage assumptions for comment on two separate occasions. In one case, we sent an "informal data request" to a participant in the proceeding, seeking specific information regarding resources the participant would like to develop. In another case, we provided a detailed list of

[8] Hawai'i Administrative Rules, *Rules and Practice Before the Public Utilities Commission* § 6-61-55 (b) (6)

[9] *Ibid.* § 6-61-56 (c) (6)

[10] Order 33320 at p 136.

questions to better understand a fuel price forecast and to be able to compare that party's forecast to our own sources.

Nonetheless, we received very little input from project developers regarding resource costs reflecting Hawai'i locations, constraints on the availability of sites to locate renewable resources,[11] and the operating parameters we should assume for new renewable resources.[12] This lack of response is likely due to concerns by developers in maintaining their competitive advantage over other developers.

Beginning in September 2016, in response to a Commission's invitation to submit questions and information regarding the PSIP, several parties did begin to provide substantive information. In particular, in late September and October of 2016, we were able to have constructive dialogue with several parties regarding assumptions related to island resource constraints, capital costs and operation assumption for pumped storage hydroelectric and onshore wind, and fuel price forecasts. Where appropriate and within time constraints, we have incorporated such information into this 2016 PSIP update.

In conclusion, we strongly believe that the input assumptions represent a reasonable set of planning assumptions that allow for a fair and unbiased analysis and comparison of alternative resource plans. As part of the ongoing and continuous planning process, we will continue to evaluate and update our input assumptions as appropriate for future planning updates. We continue to encourage and welcome input from all stakeholders in this regard.

The various input assumptions and their development, including stakeholder input, are discussed in Appendix B: Party Commentary and Input, Appendix E: New Resource Options, Appendix F: NREL Reports, Appendix G: Energy Storage Systems, Appendix H: Renewable Resource Options for O'ahu, and Appendix J: Modeling Assumptions Data.

[11] On December 12, 2016, the Companies issued a Request for Information (RFI) seeking information from land-owners and developers regarding specific site availability for renewable resources. The RFI is available at https://www.hawaiianelectric.com/clean-energy-hawaii/producing-clean-energy/selling-power-to-the-utility/land-rfi. Responses to the RFI are due on January 27, 2017.

[12] A notable exception was SunPower, who engaged in detailed conversations with the Companies and provided substantive data and insight regarding solar PV and energy storage cost trends.

STAKEHOLDER INPUT

The Hawaiian Electric Companies have actively sought input from the Participants and Interveners (collectively, the "Parties") to the PSIP proceeding to assist us in updating, supplementing, and amending our initial 2014 PSIPs[13] as directed in Order No. 33320.[14] Our solicitations started with our *Proposed PSIP Revision Plan*[15] that presented a schedule of conferences for just this purpose. Continuing with our *Power Supply Improvement Plan Update Interim Status Report*,[16] we made it clear that we are proactively soliciting input from the Parties, and inviting the Intervenors to our internal planning meetings and engaging in a one-on-one dialogue with most of the Parties. We initially held a stakeholder conference, and proposed another, to engage in direct discourse with the Parties; and participated in two technical conferences held by the Commission to further engage the Parties.

After filing our *PSIP Update Report: April 2016*,[17] we continued to engage the Parties and solicit input through two more stakeholder conferences, more personal invitations to attend our internal planning meetings, numerous impromptu meetings, two technical conferences, four structured stakeholder meetings, and myriad email exchanges. We received commentary and input from the Parties and general public in response to Order No. 33740.[18] We shared all non-confidential information with the Parties through a web interface. We have considered *all* input and commentary. We have incorporated that input where it was relevant, credible and timely.

Appendix B contains a detailed discussion of our solicitation of stakeholder input, the input we received, our analysis of that input, our discussion of stakeholder input with the Parties, and where applicable, our use of stakeholder input.

ANALYTICAL METHODS

In its PSIP-related Orders, the Commission has expressed concerns regarding the tools and analytical methods employed by the Companies, and concerns with the clarity,

[13] Docket 2011-0206: *Hawaiian Electric Power Supply Improvement Plan*; Docket 2011-0092: *Maui Electric Power Supply Improvement Plan*; Docket 2012-2014: *Hawai'i Electric Light Power Supply Improvement Plan*; all instituted on August 26, 2014; and subsequent filing in Docket 2014-0183: *Hawaiian Electric Companies Power Supply Improvement Plan Errata*.

[14] Docket No. 2014-0183, Order No. 33320: *Admitting Interveners and Participants, Identifying Observations and Concerns, Specifying Initial Statement of Issues, and Establishing Schedule of Proceedings*, issued November 4, 2015.

[15] Docket No. 2014-0183, *Hawaiian Electric Companies' Proposed PSIP Revision Plan*, filed November 25, 2015.

[16] Docket No. 2014-0183, *Power Supply Improvement Plan Update Interim Status Report*, filed February 16, 2016.

[17] Docket No. 2014-0183, *Power Supply Improvement Plan Update Report: April 2016*, filed April 1, 2016.

[18] Docket No. 2014-0183, Order No. 33740: *Inviting Comments on the HECO Companies' Power Supply Improvement Plan Update*, issued June 3, 2016.

transparency, and ability to replicate the results generated by the Companies' planning analyses. Throughout the PSIP process, we have worked diligently to improve our analytical methods and tools to appropriately address the complex issues facing the Companies, the Commission and indeed, all stakeholders, so that we can provide affordable and reliable services to our customers in both the near- and long-terms. Issues include, but are not limited to:

- Unprecedented penetration of DG-PV in our systems with a desire to accommodate greater penetrations of distributed resources.
- Substantial increases in variable grid-scale renewable resources are expected.
- The islanded nature of our systems requires us to plan and operate our systems without outside support from other power systems.
- Modernization of our grid is essential to achieve 100% renewable energy and provide safe and reliable service.

There is no single modeling tool that allows for evaluation and optimization of all of the various components that will be necessary to achieve our goals, nor is there a single modeling tool that can evaluate these components across all of the various operational time domains (for example, seconds, sub-hourly, and hourly).

Notwithstanding this challenge, the Companies developed an iterative planning process that was discussed in detail in the April 2016 PSIP filing. Since the April 2016 filing, this process has undergone refinements based on input and feedback from the Commission and stakeholders. Since April 2016, we have worked to improve our internal modeling capabilities through the conversion from P-MONTH to the PLEXOS Integrated Energy Model (which provides sub-hourly analysis capabilities). We have also engaged several external consultants and their modeling tools, including E3 (RESOLVE model), Black & Veatch (Adaptive Planning Model), and Ascend Analytics (PowerSimm Planner model).

Of particular note, the development of resource plans for this 2016 PSIP update started with use of E3's RESOLVE model to create "optimal" theoretical, least-cost resource plans for further analysis in PLEXOS. The use of RESOLVE to automate the selection of "optimum" plans is in direct response to a Commission concern expressed in Order No. 33877 regarding the previously "manual" process for plan selection. Further, Ascend Analytics' PowerSimm Planner model was used to validate analytical results and apply stochastic methods that evaluate inherent risk and future uncertainty around forecast variables and input assumptions used to identify potential improvements. Black & Veatch utilized its Adaptive Planning model to evaluate and optimize demand response resources to provide both capacity and ancillary services within overall optimized plans. Finally, the resources plans were evaluated by our transmission planning group to ensure that they would be operable and reliable in terms of meeting resource adequacy and system security criteria.

These analytical process and models used to develop the updated set of resource plans are described in detail within this report. We have endeavored to make these descriptions as transparent as possible. We are engaged in a continuous effort to improve and refine these modeling methods for future planning efforts. However, we believe that our iterative modeling processes and the refinements we have made in the past few months reflect our good faith efforts to address the complex planning challenges that we face. We continue to welcome and encourage constructive feedback and input from the Commission and stakeholders with respect to our analytical methods and modeling tools.

PSIP analytical methods are discussed in Chapter 3: Analytical Approach, Appendix C: Analysis Methods and Models, and Appendix P: Consultant Reports.

DER INTEGRATION

In the April 2016 PSIP filing, DER resource amounts 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 levelized cost of energy for DG-PV, value of storage to the system for distributed storage, value to the system for DR).

Several parties expressed concern that the resulting forecast of DG-PV resources understated the likely potential for DG-PV in our systems. In this 2016 PSIP update, we continued to refine our market DG-PV forecasting, and updated the market uptake of DG-PV based on the updated core plans. However, for purposes of developing our near-term action plans, we selected the High DER case to drive those action plans. If this high DG-PV forecast does not materialize, grid-scale renewable resources will be substituted.

Multiple strategies are necessary to integrate high-levels of DG-PV. These DG-PV integration strategies and costs are more fully described in Appendix N.

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.

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 (DRMS) 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.

DER integration is discussed in Appendix N: Integrating DG-PV On Our Circuits.

FOSSIL FUEL PLANT DISPATCH AND UNIT RETIREMENTS

To date, five Commission Orders have directed the Companies create a series of Component Plans. These Component Plans first appeared in Order No. 32053 for Hawaiian Electric, Order No. 31758 for Hawai'i Electric Light, and Order No. 32055 for Maui Electric. Order No. 33320 and Order No. 33870 reiterated this directive.

These Component Plans are:

- Fossil Generation Retirement Plan: This component plan addresses the opportunities and needs regarding existing fossil generation.
- Generation Flexibility Plan
- Must-Run Generation Reduction Plan
- Environmental Compliance Plan
- Key Generator Utilization Plan
- Optimal Renewable Energy Portfolio Plan
- Generation Commitment and Economic Dispatch Review

Integrated throughout our planning and analysis, the Companies have worked toward satisfying the Commission's requirements for each of the Component Plans.

The various fossil fuel plants related plans are presented in Appendix M: Component Plans.

SYSTEM SECURITY REQUIREMENTS

Since filing our 2014 PSIPs, we have updated and revised our system security requirements and analysis, which can be found in Appendix O. Our analysis identified new concepts to provide operating reliability for the grid now and into the future.

Operating reliability (or system security), is the ability of the electric system to withstand sudden disturbances such as electric short circuit faults or unanticipated loss of system components. We will integrate large quantities of variable wind and solar into our island grids, displacing traditional conventional central station generation. Although DER, to a certain extent, can reduce losses and loading constraints, the de-committing of conventional generation offsets those benefits because the system loses voltage control, short circuit availability, inertia, and primary frequency response services. Conventional generators provide multiple grid services that secure the gird; replacing these services with multiple assets will require innovative planning and operations.

Frequency support is required to stabilize frequency on the synchronized grid and to maintain continuous load and resource balancing by deploying automatic response functions in response to frequency deviations. Under pre- and post-contingency conditions, system operators must have the ability to raise or lower generation or load, automatically or manually. Alternatively, we can carefully deploy autonomously responding resources that are not under the visibility and control of the utility to maintain the balance of the grid, while not compromising system security.

Voltage support and short circuit availability is required to maintain system level voltages on the grid within established limits, under pre- and post-contingency situations, thus preventing voltage collapse, system instability, or delayed fault clearing. The increased voltage support and short circuit current will strengthen the grid making it better able to withstand disturbances.

Some of the Companies' technical strategies for operating reliability are included in our near-term action plan, and are described in Table 2-2.

Issue	Current Methods	Future Methods
Frequency Support	■ Inertia is the stored rotating energy in a power system provided by online synchronous and induction generation operating at least their minimum power output level. ■ Primary frequency response (droop) is the automatic corrective response of the system, typically provided by synchronous generation, to react or respond to a change in system frequency. ■ Spinning reserve is typically provided by synchronous generation that is ready to ramp up or down in response to a frequency deviation. ■ Demand response is the reduction of load to balance loss of generation triggered at a predetermined frequency set point and limited by program participants. ■ Under frequency load shed scheme is the automatic disconnection of blocks of load to re-balance the system during a frequency disturbance.	■ Synchronous condensers and flywheels to provide inertia ■ Fast frequency response resources such as batteries, flywheels, curtailed PV and wind energy that can respond in cycles, upwards, by injecting energy into the grid. ■ Demand Response resources (with fast frequency response characteristics) that can respond within a specified time adequate to correct frequency imbalances. This can be reductions in load or injection of real power from DER aggregated into a controllable and quantifiable program to respond to under frequency events, or a fast injection of controllable load in response to an over-frequency event. ■ Autonomous downward response of inverter based DER resources configured with the advanced inverter frequency-watt function to respond to an over-frequency event.
Voltage Support/Short Circuit Availability	■ Reactive power supply and voltage control provided by synchronous generating facilities, excitation systems, and capacitors. ■ Protective relay schemes designed to isolate faults within cycles. ■ Fault current supplied by synchronous generators. ■ Dynamic reactive power capability of synchronous generators and static var compensators.	■ Synchronous condensers to provide reactive power support and short circuit current. Repurposing de-activated generators as condensers. ■ Storage systems such as battery storage, electric vehicles, flywheels, and thermal storage to provide quick and flexible energy sources to stabilize system balancing.

Table 2-2. Strategies for Maintaining Operating Reliability

See Appendix O: System Security Analysis for an extensive discussion of system security.

ANCILLARY SERVICES

In the April 2016 PSIP 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 were 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 revised DR Program Portfolio.

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. At the Commission’s Technical Conference for DR in Docket No. 2015-0412 held on September 1, 2016,[19] the Companies clarified that while the April 2016 PSIP update presented DR as a resource under the FFR2 service category, this was intended to serve as an example of an FFR2 resource. The intent was not to preclude DR as a resource option for delivery other services such as FFR1 or PFR.

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

[19] Docket No. 2015-0412, For Approval of Demand Response Program Portfolio Tariff Structure, Reporting Schedule, and Cost Recovery of Program Costs through the Demand-Side Management Surcharge.

Technology-neutral definitions and requirements are discussed in Appendix A: Glossary and Acronyms and Appendix O: System Security, the Must-Run Generation Reduction Plans and Generation Flexibility Plans are included in Appendix M: Component Plans.

TRANSMISSION AND DISTRIBUTION

In Commission Order No. 32052 (Docket No. 2012-0036), the Commission instructed the Companies to provide information regarding transmission and distribution improvements, including the Companies' smart grid plans.

Integration of distributed and grid-scale renewable energy resources to achieve 100% renewable energy require modernization of our transmission and distribution systems. Consistent with Hawai'i's grid modernization statute (Hawai'i Revised Statute §269-145.5), the Companies will take actions, in support of the PSIP resource plans, that, (1) maximize cost-effective interconnection of distributed energy resources and grid-scale resources, (2) maintain and enhance grid operating reliability and safety, (3) seek improved efficiencies in grid operations and interoperability, and (4) create an integrated grid through advanced planning, forecasting and operations.

The costs and benefits of smart grid investments are covered in detail in the Companies' application in Docket No. 2016-0087.

The issues relative to integration of DER and its ramifications on our distribution systems are discussed in Appendix N: Integrating DER on Our Circuits.

INTERISLAND TRANSMISSION

In response to the Commission's directives, we have completed additional analysis of the feasibility of interisland transmission.

Our conclusion is that pursuit of interisland transmission is not an option at this time and should not be a part of the action plan. Our findings are generally consistent with previous analysis in the 2013 Integrated Resource Plan and the 2014 PSIP: O'ahu could benefit from lower cost renewable energy produced on the neighbor islands. However, this analysis quantified the aggregated benefit of combining all resources where the neighbor islands benefit from thermal resources on O'ahu as well.

While interisland transmission is not in our near-term action plans, the option to pursue interisland transmission in the future should be preserved as a possibility for meeting our renewable energy objectives in the long term.

The analysis and results of interisland transmission is discussed in Chapter 3: Analytical Approach and in Appendix P: Consultant Reports. The rationale for not including the interisland transmission in the near-term action plans are discussed in Chapter 6: Planning and Analysis Considerations.

CUSTOMER & IMPLEMENTATION RISKS

The Commission expressed concerns that the extensive capital investment strategies we proposed in the April 2016 PSIP filing appear to entail risks that could ultimately be borne by our customers. As noted in our Motion for Clarification, we withdrew the applications for approval of an LNG fuel supply agreement and for approvals related to a proposed Kahe combined cycle project to be fueled primarily with natural gas. Consistent therewith, we made clear that the near-term action plans that will be developed from the revised PSIPs will no longer include LNG or a 3x1 Kahe combined cycle project. Instead, resources will be selected as determined by the E3 RESOLVE capacity expansion analysis.

In future planning updates, we will continue to evaluate fuel alternatives to lower costs for customers, including considering LNG as a cleaner transition fuel towards the State's 100% renewable energy goal. Similar to other long-term options, LNG will be analyzed to determine its impact in stabilizing and lowering costs for customers ,while aiding in the effective integration of more renewable energy. This is consistent with the Commission's Inclinations.

Note that the updated optimization process and the evaluation of multiple PLEXOS Cases resulted in a near-term action plan that requires considerable development of new renewable resources. Whether borne by Independent Power Producer (IPP) project developers or the Companies, substantial capital will be required to implement the near-term action plans. This capital will ultimately be recovered through customer rates in either case. These capital expenditures are unavoidable if we are to transition through the various RPS milestones towards the ultimate 100% goal.

Further, with respect to the renewable resource additions, there are substantial development risks that could delay or even preclude the completion of those resources. Many of these risks are not within the control of the Companies, and may require policy initiatives to mitigate these risks and thereby create an environment conducive to project development. The Companies take their obligations to protect the interests of their customers very seriously. As we seek to implement the action plan, we will continue to carefully evaluate the merits of proposed projects and the qualifications and track records of project developers. Further, our power purchase agreements are designed to

properly balance risks between the Companies (acting on behalf of our customers) and project developers. We will not hesitate to enforce our rights under our agreements with project owners and developers to shield our customers from the risks associated with project development activities.

Longer term, the alternative plans in this PSIP constitute several different resource portfolios with multiple pathways to 100% renewable energy. The longer-term resources included in these plans may change in future planning cycles based on technology changes, load growth, and other factors. The near-term action plan is designed to maximize flexibility and accommodate different long-term pathways (a "least regrets" action plan).

The Commission has expressed concerns with potential customer exit. The Companies share these concerns: higher rates drive load or grid defection, and increasing defection decreases the customer base and revenue, thereby resulting in higher rates. Thus, maintaining reasonable rates is critically important as the transition to higher levels of renewable energy is achieved over time. For this December 2016 PSIP update, we have provided an analysis of customer exit economics in Appendix Q: Customer Retention Economics.

Customer and implementation risks are discussed in Chapter 6: Panning and Analysis Considerations, Appendix E: New Resource Options, Appendix H: Renewable Resource Options for Oʻahu, Appendix I: Financial Analysis and Bill Impact Calculations, and Appendix Q: Customer Retention Economics.

COMPANY BUSINESS MODEL

In Commission Order 33877, the Commission reiterated that:

> "… the PSIPs should address the Commission's Inclinations on the Future of Hawai'i's Electric Utilities ("Commission's Inclinations"), which summarized several of the Commission's broader perspectives on aligning the HECO Companies' business model with customer needs and the State's public policy goals".[20]

Background

The entire electric utility industry is in the midst of unprecedented uncertainty and change. The bar is even higher in Hawaiʻi with its isolated grids, 100% RPS, the proliferation of new market entrants, and the many parties involved in influencing

[20] Docket No. 2014-0182, Order No. 33877, page 3.

Hawai'i's energy future. The Companies' transformation is imperative for the Companies to meet the needs and expectations of customers and remain competitive in a rapidly changing market.

Many utilities across the country are trying to define the utility of the future, but there is no "silver bullet." The continuously changing energy market forces, such as customer preferences, new technologies, public policy, regulation, and the cost of renewables, cause this dynamic environment and uncertain future. Thus, no one can predict the next five to ten years, much less the next thirty years. Critical to the business strategy are flexibility, the ability to pivot and adjust as markets and circumstances change, while continuing to fulfill the utility's "obligation to serve."

As the Companies progress toward Hawai'i's 100% RPS, we will continue to focus on our regulated, core responsibilities and business, while also pursuing new opportunities.

The Companies will continue to fulfill our obligation to serve as a regulated utility by providing a reliable and resilient grid for all customers, and by delivering electrons to customers when customers choose or need to buy energy from the utility. The Companies will modernize this offering through investments in an intelligent grid that will enable us to: integrate more renewables and distributed resources, obtain access to more data and visibility to the grid edge to more efficiently operate the system, better understand customers' needs, provide more customer options (for example, DR programs), and better serve both full-service and partial-service customers (or customers that are both consumers and producers of energy and grid services).

The modernized utility grid ensures that all customers have access to and can leverage the value realized from a diversified and integrated mix of resources connected to the grid. It allows customers the option to offer resources and grid services that are cost-effective to all customers. This may come in the form of customer-sited generation supplied to the grid, other grid services enabled by customer-sited equipment, and/or demand response, all of which are important components of the Companies' long-term plans to achieve 100% renewable energy. The grid also enables all customers to access the reliability and resiliency achieved through operating a diverse portfolio of resources—diversity in location, size, technology, source, and timing of supply and/or demand—as a cost-effective, integrated system. Such affordable, reliable, and resilient energy services are critical to the economy, energy security, and overall well-being of Hawai'i.

All of the above must be balanced with ensuring that the Companies' value proposition remains competitive with other customer options, particularly off-grid options, which will hinder Hawai'i's collective ability to transition to 100% RPS, and therefore risk its achievement. Alignment of stakeholders, markets, public policy, and rate design in concert with each other, is imperative for working toward 100% RPS.

In addition to focusing on our core business, the Companies will seek new opportunities that are closely aligned with, or adjacent to, our core business. We will pursue new markets, such as transportation and products and services that increase the customer value proposition and generate new sources of earnings and/or offset costs of the core business to remain competitive.

In order to execute our strategies, the Companies must focus on both an external and internal transformation. External transformation requires a transformation in the way the Companies engage with external stakeholders to align interests, resources, policy, and regulation for the public good and for achieving Hawai'i's 100% RPS goal. The Companies are also focused on an internal transformation, which includes the Companies' culture, organizational structure, capabilities, and skills to align with our changing business.

These efforts are encompassed in the Companies' Strategic Transformation Plan. This is an active plan that is regularly monitored, measured, evaluated, and updated. Our plan will and should continue to evolve for our success within the dynamic market environment.

Strategic Transformation Plan Overview

The Companies' strategy is focused on two overarching outcomes: (i) top-ranking customer satisfaction, and (ii) achieving 100% renewable energy by 2045, exceeding but aligned with the State's nation-leading energy policy requirement of 100% RPS.

Customer satisfaction requires a reliable and resilient electric system, quality customer service, affordable bills and value-add product and service options, among other things. Customer satisfaction is vital, as the "utility of the future" must provide a competitive value proposition relative to emerging off-grid options. Grid connected customers are essential to an integrated grid and transitioning to 100% renewable energy in a manner that is cost-effective and that does not leave any customer segment behind.

In support of the Companies' overarching customer satisfaction and renewable energy goals, the Strategic Transformation Plan is organized around three core strategies to drive value for customers.

Quality customer experience and innovative energy solutions. Delivering a competitive value proposition is influenced by the customer experience and the availability of effective products and services. The strategic plan seeks to improve customer experience at every touch point and to strengthen the Companies' role as a trusted energy partner. With improved customer relationships, the Companies can design better processes, products, and services tailored to customers' unique needs and

interests. The Companies will partner with others to pursue innovations that create value for our customers.

Modern grid and technology platform. A modern, intelligent grid is necessary to operate an integrated system, support more renewables, optimize DER resources, and enable new products and services that provide value to customers. From this platform, technologies such as smart meters, energy storage, distribution automation, and energy management products can be leveraged to enhance the Companies' system and give their customers more insight, service options, and control of their energy usage.

Cost-effective, clean energy portfolio. The PSIP efforts define near-term action plans to put the State on a course to 100% renewable energy. The Companies will achieve a diversified mix of low cost, fixed price renewable resources. In pursuit of this goal, the Companies will provide customers with more options to enjoy the benefits of DER (including DG-PV) and support the growth of DER in a manner that is sustainable and equitable for all customers.

Business Model vs. Ownership Model

The Commission's Inclinations seek alignment between the Companies' business model with customer needs. However, many have confused the concept of "business models" with the concept of "ownership models." There is an important distinction between the two. Ownership model refers to the utility's ownership structure (for example, an investor-owned utility vs. a cooperative). A business model refers to the utility's value proposition—the products and services offered, the targeted customer segments, and the revenue model (that is, how the utility is compensated to sustainably provide it's offering).

The Companies' Strategic Transformation Plan described above represents the Companies' business model, founded in a customer-centric design to ensure alignment with the interest of all of our customers. This PSIP provides detailed analysis and action plans that forms a critical component of, and informs other components of, our Strategic Transformation Plan.

3. Analytical Approach

Hawai‘i faces a unique challenge: we must undertake a comprehensive electric grid transformation in order to attain 100% renewable generation by 2045. Planning for this electric power systems future is a complex process, representing uncharted territory for formulating viable resource plans.

In order to address the challenge, the Companies have completely revised the analytical approach for developing this December 2016 updated PSIP. Our goal is to fulfill the Commission’s directive "… to produce final PSIPs that focus on near-term actions that the HECO Companies plan to take to advance the achievement of the State’s 100% renewable energy goal, to stabilize and reduce customer rates, and to maintain safe and reliable service."[21]

This updated PSIP focuses on near-term actions, consistent with the Commission’s directive. In addition, our detailed analysis and modeling centers on a near-term action plan period and a long-term optimization that was fulfilled through capacity expansion modeling.

INPUTS AND ASSUMPTIONS

Since we began the process of updating our PSIP in November 2015, one of our core goals was to ensure that we provide clarity and transparency regarding our inputs and assumptions, and our analytical approach. We understand that this measure of openness was critical to establish confidence with our analysis and results among the Parties.

[21] Docket No. 2014-0183, Order No. 33877 at 2, filed August 16, 2016.

As a result, we explained and distributed our inputs and assumptions, analyses, and progress on numerous occasions. We held three conferences to engage the Parties, share information, and obtain additional information. We actively participated and explained our PSIP work during four Commission-sponsored technical conferences. Our Interim Status Report and our Work Plan outlined our planning and progress.

To establish better communication with the Parties, we created a WebDAV ftp site. This allowed for two-way communication between the Companies and the Parties to electronically share information. On that site, we posted resource cost assumptions, fuel price forecasts, and Party submissions. We invited the Intervenors to attend our scheduled planning meetings, then solicited and welcomed their suggestions in our discussions and to our decision-making.

We worked with consultants and other organizations to develop verifiable foundational input assumptions: resource costs, renewable generation potential, and fuel prices. HD Baker and Company developed resource cost assumptions using publicly available information, which NREL independently reviewed and verified. NREL also analyzed and provided resource potentials and aggregated power time series for PV and wind resources. The Energy Information Administration (EIA) published its *Annual Energy Outlook* (AEO) Early Release report, which provided the fuel price forecasts used in our analyses. We made all of this information available to the Parties through our WebDAV site.

The vast majority of input received throughout the development of the PSIP focused on our analytical approach. We held four additional working meetings with the Parties in the fall of 2016.

And we collaborated with certain Parties who submitted input. We worked with SunPower to compare PV and BESS input assumptions. We discussed site-specific input assumptions for wind and PSH with Paniolo Power (many of which Paniolo agreed should be aligned with the Companies' own assumptions for PSH and wind). We discussed our LNG fuel price forecast with Hawai‘i Gas. We vetted our resource potentials for O‘ahu with Dr. Matthias Fripp, consultant to Ulupono and Blue Planet. We agreed to have E3 complete sensitivity analyses using these input assumptions. (Appendix B: Party Commentary and Input details our interactions with the Parties for the duration of this PSIP proceeding.)

Fuel Price Forecasts

We updated our fuel price forecasts based on the EIA AEO Early Release report, published on May 17, 2016. We emailed these updated fuel price forecasts to the Parties on June 27, 2016[22] to prepare for our Third Stakeholder Conference, and posted the forecasts on our WebDAV site.

Our Motion for Clarification[23] noted that our near-term action plans will not include LNG. However, consistent with the Commission's Inclinations, we will continue to evaluate cleaner fuel alternatives, including LNG, over the longer term to lower costs for our customers and better meet environmental mandates. LNG was included in our fuel price forecasts and resource plans with the assumption that LNG will not be available in the near-term.

Resource Cost Assumptions and Resource Potential

We also re-evaluated and adjusted some resource costs, and distributed this information to the parties via email on June 24, 2016[24] and via postings on the WebDAV site, in advance of the third Stakeholder Conference. We also posted Appendix J: Modeling Assumptions Data, that included updated fuel price forecasts, updated resource cost assumptions, and other input assumptions.

After our third Stakeholder Conference, we collaborated with Dr. Matthias Fripp (consultant for Ulupono and Blue Planet) and SunPower to jointly decide that our PV and energy storage cost assumptions are reasonable for use in our PSIP update.[25]

Based on Dr. Fripp's input, we adjusted the resource potential screening criteria for grid-scale PV on O'ahu, increasing from an up-to-5% developable slope to the aggressive up-to-10% developable slope, increasing the potential for grid-scale PV from 793 MW to 2,756 MW. We did not adjust the resource cost assumptions associated with an increase in the slope. No such adjustments were made for Maui or Hawai'i Island as their PV potentials at a 5% slope are substantial enough to meet their energy needs. NREL, at our request, reran their corresponding study using this increased slope, which resulted increased resource potential for grid-scale PV on O'ahu. (Appendix F: NREL Reports contains this updated study; Appendix H: Renewable Resource Options for O'ahu discusses the results of the study in great detail.)

22 Email from Todd Kanja on behalf of Colton Ching, Vice President of Energy Delivery, sent on June 27, 2016 at 7:42 PM, with the subject line "re: Hawaiian Electric PSIP Stakeholder Conference".

23 Companies' Motion for Clarification of Order No. 33877, filed August 26, 2016, at 11–12.

24 Email from Todd Kanja on behalf of Colton Ching, Vice President of Energy Delivery, sent on June 24, 2016 at 6:35 PM, with the subject line "Hawaiian Electric PSIP Stakeholder Conference".

25 Companies' Motion for Clarification of Order No. 33877, filed August 26, 2016, at 14.

The DG-PV Adoption model uses a levelized market-based cost-of-energy for grid-scale PV to determine export pricing for DG-PV. We updated this DG-PV Adoption model to include the revised cost assumptions for grid-scale PV. We also developed a DG-PV plus storage forecast to represent the Customer Self-Supply (CSS) option as a refinement to the DER and DR iteration analysis.

As a result of the dismissal of the proposed merger with NextEra Energy, we withdrew our applications for a LNG fuel supply agreement and a proposed 3x1 Kahe combined-cycle project to be fueled primarily with natural gas (both were contingent on approval). As a result, our near-term action plans do not include LNG or the 3x1 Kahe combined-cycle project. However, we did include an LNG fuel price forecast (both ours and Hawai‘i Gas’) and the use of LNG in some of the long-term scenarios. The modernization of O‘ahu’s generation fleet now considers the smaller resources (listed in Appendix J: Modeling Assumptions Data).

TRANSPARENCY OF THE ANALYTICAL APPROACH

The Companies have revised the analytical approach for developing our December 2016 updated PSIP. A fundamental goal of this revised analytical approach was to demonstrate that our analysis and modeling results are based on credible, transparent, and objective methods. Further, in order to ensure a transparent, well-defined and reproducible approach, we used RESOLVE, an optimizing capacity expansion model, to quantitatively determine a least-cost resource portfolio according to standard, documented, and vetted methods. We explained this revised analytical approach at Technical Conference #1 (September 21, 2016) and Technical Conference #2 (October 3, 2016).

The simplified diagram in Figure 3-1 depicts the various models and tools involved in the overall analytical process used to develop and evaluate resource plans. For the inputs to these models, we further developed and refined the datasets used in the April 2016 PSIP update based on updated forecast information and input from stakeholders.

Using information from these datasets, E3 used the RESOLVE model to develop:

- Optimal resource portfolios from 2020 to 2045 that meet the RPS objectives while minimizing costs.
- Reference case portfolios using a set of base case assumptions (developed by the Companies) as well as several sensitivities (using stakeholder input and Company assumptions).
- An upper bound estimate of the benefits that interisland transmission could provide.

- A starting point for the PLEXOS analysis (from RESOLVE reference portfolios) that incorporated more detailed operational and transmission constraints on the system.

The Companies used PLEXOS for all hours within each year of the plan, to both validate and identify any additional resource needs (beyond the RESOLVE portfolios) to ensure reliable system operation.

Ascend used their PowerSimm model to validate the PLEXOS results, as well as to test the least-cost portfolio RESOLVE findings. This validation confirmed the general findings of RESOLVE and PLEXOS, including early storage build-outs, the need for and value of storage, and cost-effective renewable procurement above RPS to take advantage of federal tax incentives before they expire.

These resulting portfolios were then run through financial modeling to determine the forecasted rate impact and develop the near-term action plan.

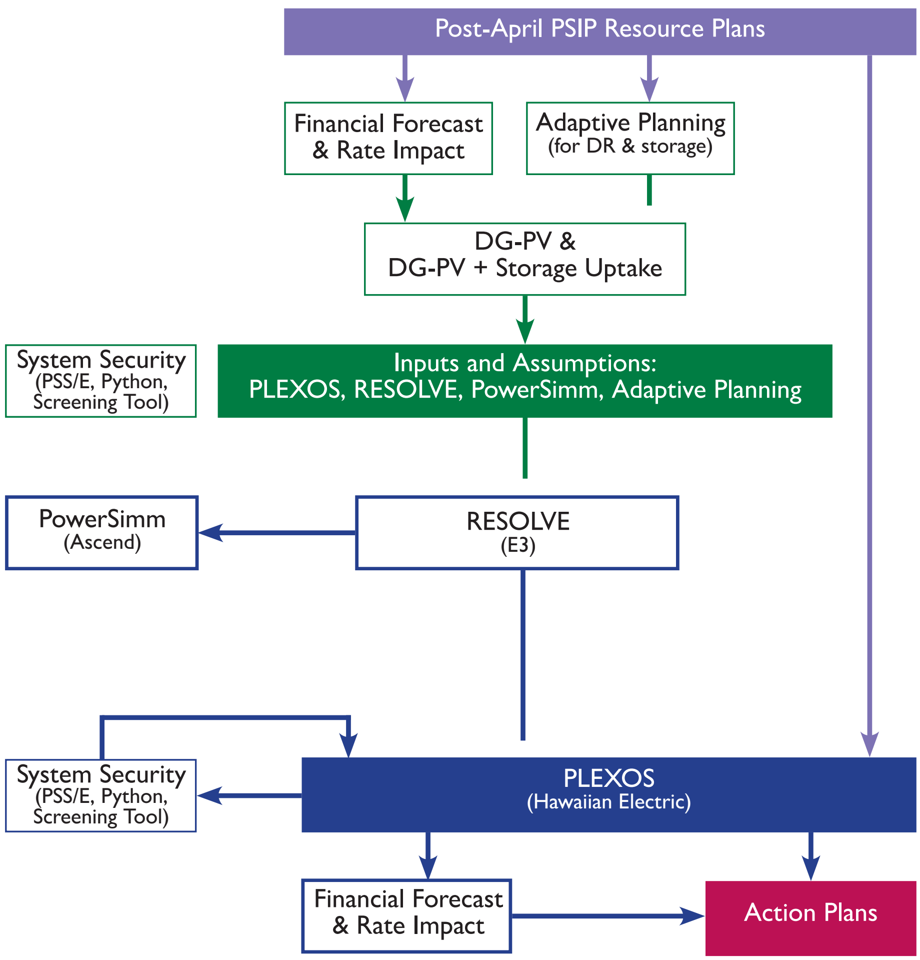


Figure 3-1. Overall PSIP Modeling Process

Revised PSIP Optimization Process

To ensure additional transparency in the modeling and resource selection process, we used E3's RESOLVE capacity expansion model to develop a theoretically lowest-cost resource plan. (Using the RESOLVE model addressed the concerns of manually developing cases and down-selecting process, therefore, the Decision Matrix wasn't used for this update.) The Companies believe that the RESOLVE outputs and resulting resource plans can be used to address many questions regarding the resources selected for the near-term action plans and provide the required context and analytical support to inform important pending and future resource acquisition and system operation decisions.

RESOLVE by itself, however, is not able to complete the analysis required to fully develop near-term action plans because it lacks the sub-hourly granularity needed to evaluate sub-hourly variability of intermittent renewable resources and it does not account for pricing sensitivity of customer adoption of DER and DR programs. RESOLVE relies on a sample of hourly net loads to determine hourly dispatch as opposed to use of annual hourly or 15-minute net loads used by PLEXOS and other models. Accordingly, RESOLVE is useful for developing longer-term expansion plans over a wide range of input scenarios and assumptions but the RESOLVE least cost plans must be validated to ensure that they are indeed lowest cost, robust under a range of future uncertainties, and maintain reliability at the sub-hourly level. In order to refine the RESOLVE results, we used a combination of PLEXOS, our revenue requirements forecasting models, and Ascend's PowerSimm Planner. This combined analysis provided additional insight of hourly and sub-hourly operations.

RESOLVE's results provide optimal new resource block sizes without considering the practical consideration of discreet block size availability for certain resources (for example, combined-cycle plants). Therefore, a critical step in the process of developing a practical and implementable 5-year plan was to adjust the RESOLVE resource block sizes to match the resource options that were included for consideration in this PSIP. These adjusted block sizes were then used in our PLEXOS analysis. We ran production simulations for both the Post-April PSIP Plan and for those produced by RESOLVE. We also used PLEXOS together with its own revenue requirements models to conduct hourly and sub-hourly production simulations to validate that: (1) all capacity planning criteria is satisfied in all years; (2) system energy costs are accounting for sub-hourly variability of generation and dynamic regulation requirements; and (3) costs of production are appropriately captured for the rates and bills analysis. In addition, we analyzed the impacts of generation modernization for O‘ahu, including an assessment of the risks of continuing to operate existing generation through 2045.

As a critical input to each of the simulation and planning models, we used the DG-PV Adoption model results and the Black & Veatch Adaptive Planning for Production Simulation (AP) model results to determine DER and DR adoption. Because RESOLVE cannot fully model optimized hourly output with DR, AP-developed DR hourly profiles and RESOLVE resource plans served as inputs for PLEXOS. In turn, the results of PLEXOS were then used as inputs to the Financial Model for the rates and bills analysis.

E3 RESOLVE MODELING

In addition to developing plans for each island system under a range of individual island cases, E3's modeling also looked at the potential cost savings from a resource plan that might be enabled by a series of interisland cables.

Individual Island Plans

E3 first developed theoretical least-cost plans for O‘ahu, Maui, and Hawai‘i Island without any interisland interconnection (and without LNG). Since RESOLVE selected LNG as part of the theoretical least-cost plan, E3 also ran a second case without LNG—the E3 Plan. These initial cases incorporated the Market DG-PV forecast as an external input to the plans.

The theoretical least-cost plans for the case without LNG resulted in a build out of large amounts of renewables in 2020. This was an unconstrained case that did not consider physical limits of the existing transmission and distribution system in the near term. Subsequent to this initial finding, T&D Planning assessed the possible constraints on the systems if the renewable resources were located as identified in the NREL potential maps (Appendix F: NREL Reports). Appendix N: Integrating DG-PV on Our Distribution Circuits describes the analysis performed to estimate the amount of available capacity available to interconnect and integrate grid-scale resources by 2020 without having to perform conductor upgrades.

E3 reproduced the RESOLVE modeling to develop plans with and without LNG available with the 2020 constraints identified for interconnecting grid-scale renewable resources. This was done for both the Market DG-PV forecast and the High DG-PV forecast. The details of the different cases and results are fully described in E3's report in Appendix P: Consultant Reports.

Since the RESOLVE modeling analyzes total resource cost and not the cost to the utility, the high DG-PV plans were found to be higher in cost in comparison to the market DG-PV plans. Not surprisingly, E3 also found that optimized resource plans for the

market DG-PV plans included more grid-scale renewable resources in comparison to the high DG-PV plans. This PSIP assumes that future DG-PV will be through the Companies' tariffed programs (pending legacy NEM, SIA, grid-supply to cap, self-supply and potential future grid-supply). The potential future grid-supply program assumes that energy exported to the grid would be compensated at utility-scale PV LCOE. Thus, the cost of exported energy is the same to the utility. Considering these factors and strong customer interest and participation in our programs, it was decided that planning for the High DG-PV forecast is a reasonable assumption. Accordingly, the E3 Plan (without LNG available) and the E3 Plan with LNG, using the High DG-PV forecast were the cases that were exported and evaluated in the PLEXOS production simulation model.

Table 3-1 lists the resources selected by the RESOLVE model for Oʻahu. Some resources are forecasted (like DER) or are planned for retirement (such as AES in 2022). New renewable energy resources have a 20-year lifetime; thus solar and wind built in 2040 and 2045 partly replace retiring resources that were selected for builds in 2020, 2022, and 2025. Inputs into RESOLVE (like the DG-PV forecast) that are not model decisions, are not represented in these tables.

Year	E3 Plan	E3 Plan with LNG
2020	300 MW new grid-scale solar	173 MW new grid-scale solar
2022	48 MW new grid-scale solar 426 MW new battery	285 MW new battery 679 MW of LNG conversion of existing thermal resources
2025	143 MW new offshore wind 193 MW new grid-scale solar 29 MW new battery	73 MW new battery
2030	72 MW new offshore wind 165 MW new battery	No new thermal or renewable build as model decisions
2035	51 MW new offshore wind 168 MW new battery	
2040	581 MW new grid-scale solar 875 MW new battery	297 MW new offshore wind 356 MW new grid-scale solar 723 MW new battery
2045	71 MW new biodiesel (additional to fuel-switching of various resources) 30 MW new onshore wind 150 MW new offshore wind 1,400 MW new grid-scale solar 1,700 MW new battery	58 MW new biodiesel (additional to fuel-switching of various resources); 30 MW new onshore wind 1,500 MW new grid-scale solar 2,000 MW new battery

Table 3-1. E3 Plans for Oʻahu

Table 3-2 lists the resources selected by the RESOLVE model for Hawai'i Island.

	E3 Plan	E3 Plan with LNG
2022	50 MW new wind	15 MW new wind
2025	12 MW new battery	13 MW new battery
2030	41 MW new battery	29 MW new battery
2040	56 MW new battery 19 MW new wind 20 MW of fuel-switches to biodiesel	43 MW new battery 17 MW of fuel-switches to biodiesel
2045	115 MW new battery 82 MW new wind 90 MW of fuel-switches to biodiesel	133 MW new battery 101 MW new wind 93 MW of fuel-switches to biodiesel

Table 3-2. E3 Plans for Hawai'i Island

Table 3-3 lists the resources selected by the RESOLVE model for Maui.

Year	E3 Plan	E3 Plan with LNG
2020	54 MW new onshore wind	38 MW new onshore wind
2022	40 MW new biomass 32 MW new battery	20 MW new biomass 26 MW new battery
2025	43 MW new battery	58 MW new battery
2030	–	26 MW new battery
2035	14 MW new battery	16 MW new battery
2040	107 MW new battery 37 MW new geothermal	20 MW new biomass 120 MW new battery
2045	241 MW new battery 3 MW new geothermal 57 MW biodiesel engine fuel-switching 122 MW new grid-scale solar	227 MW new battery 40 MW new geothermal 57 MW biodiesel engine fuel-switching 122 MW new grid-scale solar

Table 3-3. E3 Plans for Maui

Upon receiving the individual island resource plans presented in Table 3-1 through Table 3-3, it was noted that partial units were removed from service until 2045 and then converted to biofuel in 2045. Adjustments were made to correct partial sized units into for whole unit sizes, and cases were reanalyzed in RESOLVE. These resulting plans were then used as the basis for Companies' PLEXOS analyses.

Table 3-4 lists the resources selected by the RESOLVE model for O'ahu after preventing partial removal of units until 2045.

Year	E3 Plan	E3 Plan with LNG
2020	300 MW new grid-scale solar	173 MW new grid-scale solar
2022	48 MW new grid-scale solar 426 MW new battery	285 MW new battery 679 MW of LNG conversion of existing thermal resources
2025	143 MW new offshore wind 193 MW new grid-scale solar 29 MW new battery	73 MW new battery
2030	72 MW new offshore wind 165 MW new battery	No new thermal or renewable build as model decisions
2035	51 MW new offshore wind 167 MW new battery	
2040	581 MW new grid-scale solar 875 MW new battery	297 MW new offshore wind 361 MW new grid-scale solar 688 MW new battery
2045	71 MW new biodiesel (additional to fuel-switching of various resources) 30 MW new onshore wind 150 MW new offshore wind 1,400 MW new grid-scale solar 1,700 MW new battery	58 MW new biodiesel (additional to fuel-switching of various resources); 30 MW new onshore wind 1,500 MW new grid-scale solar 2,000 MW new battery

Table 3-4. Corrected E3 Plans for O'ahu

Table 3-5 lists the resources selected by the RESOLVE model for Hawai'i Island after correcting for partial unit removal until 2045, when units are fuel-switched to biofuel.

	E3 Plan	E3 Plan with LNG
2022	50 MW new wind	16 MW new wind
2025	9 MW new battery	10 MW new battery
2030	39 MW new battery	22 MW new battery
2040	58 MW new battery 19 MW new wind 20 MW of fuel-switches to biodiesel	27 MW new battery 15 MW of fuel-switches to biodiesel
2045	114 MW new battery 82 MW new wind 90 MW of fuel-switches to biodiesel	126 MW new battery 101 MW new wind 95 MW of fuel-switches to biodiesel

Table 3-5. Corrected E3 Plans for Hawai'i Island

Table 3-6 lists the resources selected by the RESOLVE model for Maui after correcting for partial unit removal until 2045, when units are fuel-switched to biofuel.

Year	E3 Plan	E3 Plan with LNG
2020	60 MW new onshore wind	34 MW new onshore wind
2022	36 MW new biomass	20 MW new biomass 16 MW new battery
2025	2 MW new biomass	6 MW new battery
2030	28 MW new battery	2 MW new battery
2035	2 MW new biomass 18 MW new battery	4 MW new battery
2040	56 MW new battery 31 MW new geothermal	3 MW new onshore wind 20 MW new biomass 78 MW new battery
2045	176 MW new battery 9 MW new geothermal 118 MW biodiesel fuel-switching 70 MW new grid-scale solar	279 MW new battery 40 MW new geothermal 57 MW biodiesel fuel-switching 120 MW new grid-scale solar

Table 3-6. Corrected E3 Plans for Maui

Interisland Transmission Copper-plate Plans

E3 first developed theoretical least-cost plans for Oʻahu, Maui, and Hawaiʻi Island without any interconnection. Then, using the same input assumptions, E3 conducted the interisland transmission analyses. Since RESOLVE selected LNG as part of the theoretical least-cost plan, E3 ran a second case without LNG.

E3 then developed theoretical least-cost plans without transmission line restrictions for interisland connections (assumed to be a "copper-plate" or bus-bar connections) between Oʻahu, Maui, and Hawaiʻi Island, both with and without LNG. The difference between the theoretical copper-plate plan cost and the combined cost of the theoretical least-cost plans of the individual islands is the breakeven cost of the interisland transmission configuration.

Table 3-7 lists the resources RESOLVE selected for the copper-plate O'ahu plans. Some resources (such as batteries) are location agnostic across islands. While all batteries are listed as being built on O'ahu, their physical distribution can be varied across islands to optimize local transmission and other usage constraints.

Year	E3 Copper-plate Plan	E3 Copper-plate Plan with LNG
2020	–	–
2022	365 MW battery	163 MW battery 679 MW LNG fuel-switching
2025	86MW battery	89 MW battery
2030	–	–
2040	685 MW battery	355 MW battery
2045	1,485 MW battery 26 MW offshore wind	1,817 MW battery 3 MW offshore wind

Table 3-7. E3 Copper-plate Plans for O'ahu

Table 3-8 lists the resources RESOLVE selected for the copper-plate Hawai'i Island plans. The copper-plate case is unconstrained by resource feasibility beyond 2020, influenced by factors such as siting, timing, and transmission. The island specialization shown in these results is unrealistic, although they indicate the economic choices that would benefit interconnected islands.

Year	E3 Copper-plate Plan	E3 Copper-plate Plan with LNG
2020	20 MW wind	20 MW wind
2022	795 MW wind	322 MW wind 113 MW LNG fuel-switching
2025	78 MW wind	–
2030	–	–
2040	347 MW wind 73 MW biodiesel fuel-switching	258 MW wind 48 MW biodiesel fuel-switching
2045	122 MW geothermal 58 MW biodiesel fuel-switching 40 MW biomass 536 MW onshore wind	208 MW geothermal 83 MW biodiesel fuel-switching 40 MW biomass 461 MW wind

Table 3-8. E3 Copper-plate Plans for Hawai'i Island

Table 3-9 lists the resources RESOLVE selected for the copper-plate Maui plans.

Year	E3 Copper-plate Plan	E3 Copper-plate Plan with LNG
2020	113 MW onshore wind 44 MW utility-scale solar	130 MW wind
2022	–	–
2025	–	–
2030	–	–
2040	–	–
2045	570 MW utility-scale solar 107 MW biodiesel fuel-switching	570 MW solar 13 MW biodiesel fuel-switching 40 MW biomass

Table 3-9. E3 Copper-plate Plans for Maui

Sensitivity Analyses

E3 also conducted numerous sensitivities to incorporate stakeholder input. At the Technical Conferences and Stakeholder Meetings, the Parties agreed that, because of time constraints, E3 would perform the sensitivity analysis independent from the Companies' more detailed analyses. Together, the parties and the Companies agreed on these sensitivities:

1. Hedge value of renewables (per Ulupono input)
2. Least cost plan without any RPS requirements (per Consumer Advocate input)
3. LNG fuel prices for O‘ahu (per from Hawai‘i Gas input)
4. Wind and pumped storage hydro for Hawai‘i Island (per Paniolo Power input)
5. Higher potential for on-island renewable resources for O‘ahu (per Dr. Matthias Fripp input on behalf of Ulupono and Blue Planet)
6. DG-PV as an endogenous decision in the model (that is, not an input)
7. Military generation projects on O‘ahu as an endogenous decision in the model (that is, not an input)

Details on the sensitivities are described in Appendix P: Consultant Reports. Here is a brief summary of the key insights gleaned from the RESOLVE cases.

- In almost all fuel price and fuel type options, regardless of DG-PV forecast, the short term renewable build is constrained by transmission and interconnection limits before the model hits economic limits.

- The RESOLVE model confirms that least-cost pathways to achieving 100 percent renewable energy in Hawai'i must take maximum advantage of federal tax subsidies before they phase out completely in the early 2020's.
- In the longer term, while each of the sensitivities illustrates different pathways towards the 100% RPS goal in 2045, the resulting build in 2045 is similar across cases. The mix of renewable resources varies based on resource potentials and resource cost and performance characteristics, but in general the value of renewable energy sources over thermal sources rises as the real capital cost for renewable resources consistently drop as forecast in our new resource capital cost assumptions. This trend results in RESOLVE renewable build patterns with high builds for the next five years, and with deferred or increased builds at the back end of the plans. When we include economic selection of DG-PV resources in RESOLVE, fewer DG-PV systems are built, however in large part these are replaced in the plans with grid scale solar PV on O'ahu.
- LNG, given the EIA fuel price forecasts, is a forecasted as a lower cost fuel resource compared to fossil fuel cost forecasts. Utilization of thermal plants in the LNG case is significantly higher than utilization of thermal plants in the non-LNG case because of this price forecast difference. Higher cost fuel oil in the non-LNG case drives earlier adoption of renewables compared to the LNG case, pushing the portion of energy sales attributable to renewables significantly above statutory RPS milestones on all islands. Even with LNG, renewables sales are above the statutory RPS requirements on Maui and Hawai'i Island. However, LNG competes favorably against renewables on Oahu where the RPS is only slightly exceeded in the early years, and then met and not exceeded in later years. In general, higher fossil fuel prices drive earlier adoption of renewables. The same effect is seen to a lesser extent in the fuel price hedge cases.
- Renewables are a valuable resource to the islands even without the statutory RPS requirements. Even when renewable resource selection is not forced by the RPS requirements, RESOLVE makes significant investment in renewables in the No-LNG Market DG-PV case, from 72% energy sales from renewables on O'ahu in 2045, to 95% on Hawai'i Island. This number is significantly lower on O'ahu in the LNG Market DG-PV case at 45%, but remains 85% on Hawai'i Island and 87% on Maui in 2045. The competitiveness of renewables on Hawai'i Island and Maui comes from the better wind resources (relative to wind resources on O'ahu) competing against more expensive thermal generator alternatives.
- The maximum value of an interisland cable is sufficiently large enough to justify further analysis of the feasibility, configuration and cost effectiveness of interisland interconnections. The present value benefit of the cable was found to be three billion dollars[26]. This is an upper bound that will be refined when cable operating constraints

---

[26] This represents present value of the gross benefits of interisland interconnections, *not* the *net* present value (NPV) feasibility of interisland interconnections. The overall feasibility of interisland cables must include the capital costs,

and adjusted system operating constraints are developed through more detailed study.

MULTIPLE PATHWAYS TO 100 PERCENT RENEWABLE ENERGY

For our December 2016 PSIP update, we examined multiple pathways for achieving 100% renewable energy. For this analysis, we considered DER, DR, grid-scale resources, generation modernization, and interisland transmission, all utilizing updated input assumptions (independently verified) and Party input. Using this information, Company planning teams and selected independent consultants developed a set of cases (referred to as the "PLEXOS cases") that formed the foundation of our analysis. From these analyses we determined a near-term action plan that defines a path of least regrets, one in which shorter term actions do not preclude us from pursuing a particular longer term path that may be warranted in the future, based on changing market conditions and potentially, new technologies.

Below, we summarize by island the PLEXOS Cases that were examined. While the basic PLEXOS Cases are the same, the costs and resource availabilities differ by island. These PLEXOS Cases form the basis for developing robust action plans for each island under a number of different futures.

Oʻahu PLEXOS Cases

Here are the Oʻahu PLEXOS Cases (adjusted for costs and available resources):

Post-April PSIP Plan. The Companies developed this plan after the filing of the April 2016 PSIP using updated input assumptions.

E3 Plan. E3's RESOLVE model defined this plan based on an optimized resource portfolio, including optimal retirements. The plan was adjusted to reflect actual feasible resource option sizes and additional modeling using sub-hourly modeling conducted by Ascend's PowerSimm and our use of PLEXOS. This plan did *not* include LNG as a potential fuel source.

E3 Plan with LNG. This plan was developed using the same method as the E3 Plan, except that LNG was included as a potential fuel source. The optimization models chose LNG as the optimum fuel choice.

operating costs and system integration costs and considerations related to the interisland cable in order to definitively determine economic and operational feasibility.

E3 Plan with Generation Modernization. This plan was developed in response to the Commission's Inclinations[27] using the same renewable build-out as the E3 Plan with retirements and replacement generation (as recommended by our Power Supply Department) forced into the model. LNG was *not* available as a fuel source in this plan.

E3 Plan with LNG and Generation Modernization. This plan was developed in response to the Commission's Inclinations[28] and is the same as the E3 Plan with Generation Modernization, except LNG was assumed available as a potential fuel source.

Hawaiʻi Island PLEXOS Cases

Here are the Hawaiʻi Island PLEXOS Cases (adjusted for costs and available resources):

Post-April PSIP Plan. This plan was developed by the Companies after the filing of the April 2016 PSIP using updated input assumptions.

E3 Plan. This plan is based on an optimized resource portfolio using E3's RESOLVE model, including optimal retirements. The plan was adjusted to reflect actual feasible resource option sizes and additional modeling using sub-hourly modeling conducted by Ascend's PowerSimm and our use of PLEXOS. This plan did *not* include LNG as a potential fuel source.

E3 Plan with LNG. This plan was developed using the same method as the E3 Plan, except that LNG was included as a potential fuel source. The optimization models chose LNG as the optimum fuel choice.

Maui Island PLEXOS Cases

Here are the Maui island PLEXOS Cases (adjusted for costs and available resources):

Post-April PSIP Plan. The Companies developed this plan after the filing of the April 2016 PSIP using updated input assumptions.

E3 Plan. This plan is based on an optimized resource portfolio using E3's RESOLVE model, including optimal retirements. The plan was adjusted to reflect actual feasible resource option sizes and additional modeling using sub-hourly modeling conducted by Ascend's PowerSimm and our use of PLEXOS. This plan did *not* include LNG as a potential fuel source.

---

[27] Docket 2012-0036, Order No. 32052; *Regarding Integrated Resource Planning: Commission's Inclination on the Future of Hawaiʻi's Electric Utilities*, at 6.

[28] *Ibid.*

E3 Plan with LNG. This plan was developed using the same method as the E3 Plan, except that LNG was included as a potential fuel source. The optimization models chose LNG as the optimum fuel choice.

Moloka‘i PLEXOS Cases

Here are the Moloka‘i PLEXOS Plans (adjusted for costs and available resources):

100% Renewable by 2020. This plan was developed using PLEXOS optimization logic for attaining 100 percent renewable energy in 2020.

100% Renewable by 2030. This plan was developed using PLEXOS optimization logic for attaining 100 percent renewable energy in 2030.

Lana‘i PLEXOS Cases

Here are the Lana‘i PLEXOS Plans (adjusted for costs and available resources):

100% Renewable by 2020. This plan was developed using PLEXOS optimization logic for attaining 100 percent renewable energy in 2020.

100% Renewable by 2030. This plan was developed using PLEXOS optimization logic for attaining 100 percent renewable energy in 2030.

SYSTEM SECURITY ANALYSIS

A thorough system security analysis over the 30-year planning period requires extensive modeling, which takes several months to complete, and can only commence *after* the resource plans have been optimized with DER and DR, and then validated. Additional iterations are necessary if system security requirements with a given resource plan are cost prohibitive, thus possibly requiring alternate plans to be developed and analyzed.

Our detailed analysis and modeling focused on the near-term, with lesser importance placed on long-term optimization of system security requirements. First, we performed voltage stability and frequency stability analyses using the Siemens PTI PSS/E model on the Post-April PSIP Plan without DR to identify technology neutral system security requirements to inform the development of DR programs. Then we completed analyses on the Post-April PSIP Plan with DR incorporated.

We performed voltage stability (QV) analysis to determine if resource plans meet the system's reactive power requirements; and performed a screening analysis to ensure minimum fault current requirements are met. Detailed power flow analyses to determine

if the existing transmission infrastructure can support resource plans cannot be completed until new resource sites are identified, which will affect voltage stability.

We performed frequency response analysis on the Post-April No DR Plan to define Fast Frequency Response 1 (FFR1), Fast Frequency Response 2 (FFR2), and Primary Frequency Response (PFR) requirements. Contingencies that were analyzed include loss of generation, normally cleared faults, and delay clearing faults. Results were used to inform the development of DR programs. Frequency stability analysis was performed on plans with DR to determine the FFR1 and PFR requirements. Assessing the optimized plans helps determine if a revised system security analysis is required.

After we completed our system security analysis on the Post-April PSIP Plan, we compared them to the E3 Plans. Given the similarities of the near-term resource plans, we conducted screening analyses of the E3 Plans to identify differences in resource requirements. The Oahu analysis and assessment focused on two resource plans developed by E3 using RESOLVE and modeled in PLEXOS to obtain hourly dispatch models: (i) E3 Plan, and (ii) E3 Plan with Generation Modernization. The screening analysis found similar requirements to the analysis performed on the Post-April PSIP Plan for O‘ahu. For Maui and Hawai‘i, the analysis focused on the E3 Plan. See Appendix O: System Security Analysis for details.

ADDITIONAL ENHANCEMENTS TO THE MODELING PROCESS

As part of our PSIP, we looked at regulation and ramping requirements, load shifting energy storage, and DR and DER modeling.

Regulation and Ramping Requirements

High levels of variable, intermittent renewable distributed and grid-scale resources pose significant operational challenges. Weather variations result in continual production variations and uncertainty in production capacity of variable renewable resources at any given point in time. Load changes are more predictable, but still dynamic. As our systems transition to higher levels of variable, intermittent renewable resources, operating our systems to continuously balance capacity and load becomes increasingly challenging, with regulation and ramping requirements becoming increasingly demanding.

The April 2016 updated PSIP resources plans utilized regulating reserve assumptions as noted in Appendix J: Modeling Assumptions Data. In addition, we are working with EPRI to investigate a new method for determining operating reserve requirements (see

Appendix L: EPRI Reserve Determination). Initial results, however, are not expected until mid-2017.

Because there are numerous approaches, we employed various methods to determine an estimated range of regulation and ramping requirements. General Electric-HNEI for O'ahu and EPS for Maui and Hawai'i both developed methods for determining regulation and ramping requirements (as described in Appendix J). We ran sub-hourly modeling in PLEXOS; Ascend Analytics independently used 1-minute data to determine these requirements. The Ascend model determined flexible resource requirements as a function of the renewable resource mix to determine requirements for regulation, ramps, and daily changes in gradient (changes in the slope of load following). Insufficient time prevented us from fully analyzing these requirements, so we couldn't justify modifying the GE and EPA methods.

There is no industry standard for estimating regulation reserve requirements for the high level of variable generation needed to achieve 100% renewable energy. We will continue to investigate the different methods we tried for future PSIP updates, as well as any new findings from industry or locations with high renewable energy penetration.

Load Shifting Energy Storage

Since the April 2016 PSIP update, Ascend and the Companies have been evaluating the economics of load shifting energy storage (versus curtailment). E3's RESOLVE was able to model energy storage and found that load shifting energy storage could be economical in the future. Ascend's work validates this finding. Cost effective energy storage depends on the resource mix, cost of energy storage, and cost of energy resources on the system.

Load shifting energy storage with variable renewable energy such as wind and solar can have an important role in the 100% renewable energy future. Conventional thermal generating resources will still be required to meet the load during seasonal low renewable energy production or unpredicted weather-related events (such as the 6 weeks of consecutive rainy days in 2006). Ascend Analytics used their tools to validate and assess the resource adequacy of the E3 plans in greater detail by accounting for the uncertainty in weather, load, and renewable energy availability.

DR and DER Modeling

For the December 2016 PSIP update, we separated the DER forecasts into three components: NEM, customer self-supply, and future grid export.

Customer self-supply consists of residential customers, together with small and medium commercial customers, utilizing DG-PV with distributed energy storage. The future grid export program does not include storage, representing DG-PV as a single resource. The

DG-PV Adoption model was used to develop the Market DER forecast. The High DER forecast, not based on customer economics, represents the theoretical potential for all single–family homes and some commercial customers (assumed to be 20 to 25% of commercial sales due to limitations of rooftop space) to be net zero.

For the December 2016 PSIP update, DR (as determined by Black & Veatch) was incorporated as flexible load and utilized as a resource by E3 to optimize the resource plans. Production simulations of the E3 resource plans used the hourly profile developed by the Adaptive Planning model, which fully integrates DR and the DER forecast.

4. Analytical Results

The Companies performed a comprehensive analyses in PLEXOS of the different paths for achieving 100% renewable energy by 2045 for all five islands we serve. In addition to evaluating the E3 Plan and E3 Plan with LNG, the Companies also evaluated its Post-April PSIP Plans, which are refinements to the plans from the April 2016 PSIP Update, and for Oahu, the impacts of generation modernization. Considerations related to use of the High DG-PV forecast are discussed in Chapter 6, Planning and Analysis Considerations. From that analysis, we arrived at some key results that led to our near-term action plans.

O'AHU ANALYTICAL RESULTS

Using updated input assumptions, we investigated and incorporated into our PLEXOS cases:

- High DG-PV forecast.
- Demand response.
- System security resources.
- Regulation and ramping requirements.
- Load-shifting energy storage.
- High-levels of grid-scale PV.

O'ahu E3 Plan Comparison

The original E3 Plan was developed using RESOLVE (see Chapter 3: Analytical Approach). The Companies then adjusted the original E3 Plan shown in Chapter 3 for use in the PLEXOS production simulations and Finance model as follows:

- Because the RESOLVE model allows incremental 1 MW blocks of new generation options, generation resource sizing was adjusted to correspond to the block sizes that the resource costs were based on (see Appendix J: Modeling Assumptions Data).
- Since the first year E3 modeled was 2020, adjustments were also made to account for planned and proposed projects that would be in-service prior to 2020. An example is the 20 MW West Loch PV Project in which an application was submitted to the PUC. The E3 Plan shown in Chapter 3 includes 300 MW of new grid-scale PV in 2020. This 300 MW was reduced by 20 MW for the West Loch PV Project and other planned and proposed projects that would be in-service prior to 2020, and the difference was added in 2020.
- The original E3 Plan produced by RESOLVE did not choose to keep Kalaeloa online in 2045. For the production simulations in PLEXOS, Kalaeloa remained in service throughout the planning period and converted to biodiesel in 2045, given the flexible nature of this combined cycle plant and its ability to provide firm power at times when solar, wind and storage is not available to fully serve system demand.
- The E3 plans relied heavily on battery storage for firm capacity needs. The RESOLVE model is not able to fully take into account the uncertainty in weather, particularly in the longer timeframes, and associated reliability risk of not being able to serve load if there isn't enough renewable energy to charge the batteries and there is no thermal generation as backup. This situation could occur when there are long periods of rainy days and low solar production. The hourly and sub-hourly results from PLEXOS (see Appendix K: Analytical Steps and Results) illustrate the potential generation shortfalls to serve load. Therefore, generation modernization benefits were evaluated using the E3 Plans. The same renewable energy build-outs from the E3 Plan and E3 Plan with LNG were used to create two additional cases for evaluation in PLEXOS, the E3 Plan with Generation Modernization and the E3 Plan with LNG and Generation Modernization, respectively. The cases with generation modernization incorporate Hawaiian Electric's Fossil Generation Retirement Plan (Appendix M: Component Plans) which removes from service all existing steam units by the year 2039. Replacement generation consists of reciprocating engines and proxy 151 MW single-train combined cycle units to provide fast-start and fast-ramping generation.
- Comparing the E3 Plan versus the E3 Plan with Generation Modernization, there is a significant reduction in the amount of unserved energy (see Appendix K: Analytical Steps and Results) in the E3 Plan with Generation Modernization. Ascend Analytics' analyses (see Appendix P: Consultant Reports) also illustrate the need for thermal

generation to provide backup during periods where there is not enough excess energy available to store for future use. The seasonality of available variable renewable resources is illustrated in Appendix K: Analytical Steps and Results for select years. Despite high amounts of grid-scale PV and grid-scale wind included in the E3 Plans, there are still periods where the load exceeds the available resources in 2045. Seasonal load-shifting storage or firm renewable generation would be necessary to bridge this gap.

Table 4-1 shows the adjusted E3 plans that were evaluated using the PLEXOS model.

Year	E3 Plan	E3 Plan with LNG	E3 Plan with Generation Modernization	E3 Plan with LNG and Generation Modernization
2017				
2018	50 MW SGS 24 MW Na Pua Makani Wind Project Install 109.6 MW Replacement Waiver PV Projects Install 15 MW Grid-Scale PV (CBRE) Install 10 MW Wind (CBRE)	50 MW SGS 24 MW Na Pua Makani Wind Project Install 109.6 MW Replacement Waiver PV Projects Install 15 MW Grid-Scale PV (CBRE) Install 10 MW Wind (CBRE)	50 MW SGS 24 MW Na Pua Makani Wind Project Install 109.6 MW Replacement Waiver PV Projects Install 15 MW Grid-Scale PV (CBRE) Install 10 MW Wind (CBRE)	50 MW SGS 24 MW Na Pua Makani Wind Project Install 109.6 MW Replacement Waiver PV Projects Install 15 MW Grid-Scale PV (CBRE) Install 10 MW Wind (CBRE)
2019	Install 70 MW Contingency Battery 20 MW West Loch PV Project	Install 70 MW Contingency Battery 20 MW West Loch PV Project	Install 70 MW Contingency Battery 20 MW West Loch PV Project	Install 70 MW Contingency Battery 20 MW West Loch PV Project
2020	Install 180 MW Grid-Scale PV Waiau 3 & 4 Removal From Service Waiau 5 Removal From Service	Install 60 MW Grid-Scale PV Waiau 3 & 4 Removal From Service Waiau 5 Removal From Service	Install 180 MW Grid-Scale PV	Install 60 MW Grid-Scale PV
2021	Convert H8 & H9 to Synchronous Condenser	Convert H8 & H9 to Synchronous Condenser	Convert H8 & H9 to Synchronous Condenser	Convert H8 & H9 to Synchronous Condenser
2022	Install 426 MW 4-hour Load-Shift Battery Install 40 MW of Grid-Scale PV Kahe 1-4, Waiau 5–8 Removal From Service AES deactivated, 9/2022 Install 100 MW JBPHH Plant	Convert Kahe 1-6, KPLP to LNG Install 285 MW 4-hour Load-Shift Battery Waiau 5–8 Removal From Service AES deactivated, 9/2022 Install 100 MW JBPHH Plant	Install 426 MW 4-hour Load-Shift Battery Install 40 MW of Grid-Scale PV AES deactivated, 9/2022 Install 100 MW JBPHH Plant	Convert Kahe 1–6, KPLP to LNG Install 285 MW 4-hour Load-Shift Battery AES deactivated, 9/2022 Install 100 MW JBPHH Plant
2023	Install 54 MW KMCBH Plant	Install 54 MW KMCBH Plant	Waiau 3 & Waiau 4 Removal From Service Install 54 MW KMCBH Plant	Waiau 3 & Waiau 4 Removal From Service Install 54 MW KMCBH Plant
2024				

Year	E3 Plan	E3 Plan with LNG	E3 Plan with Generation Modernization	E3 Plan with LNG and Generation Modernization
2025	Install 200 MW of Grid-Scale PV Install 29 MW 4-hour Load-Shift Battery Install 200 MW of Offshore Wind	Install 72 MW 4-hour Load-Shift Battery	Install 200 MW of Grid-Scale PV Install 29 MW 4-hour Load-Shift Battery Install 200 MW of Offshore Wind	Install 72 MW 4-hour Load-Shift Battery
2026			Install 151 MW CC Waiau 5 & 6 Removal From Service	Install 151 MW CC Waiau 5 & 6 Removal From Service
2028			Install 151 MW CC Kahe 5 & 6 Removal From Service	Install 151 MW CC Kahe 5 & 6 Removal From Service
2030	Install 165 MW 4-hour Load-Shift Battery		Install 165 MW 4-hour Load-Shift Battery	
2031			Waiau 7 & 8 Removal From Service	Waiau 7 & 8 Removal From Service
2032			Install 302 MW CC (2 x 151 MW)	Install 302 MW CC (2 x 151 MW)
2035	Install 168 MW 4-hour Load-Shift Battery		Install 168 MW 4-hour Load-Shift Battery Kahe 1 & 2 Removal From Service	Kahe 1 & 2 Removal From Service
2039			Kahe 3 & 4 Removal From Service	Kahe 3 & 4 Removal From Service
2040	Install 280 MW of Grid-Scale PV Install 420 MW 4-hour Load-Shift Battery	Install 180 MW of Grid-Scale PV Install 366 MW 4-hour Load-Shift Battery Install 300 MW of Offshore Wind	Install 280 MW of Grid-Scale PV Install 420 MW 4-hour Load-Shift Battery	Install 180 MW of Grid-Scale PV Install 366 MW 4-hour Load-Shift Battery Install 300 MW of Offshore Wind
2045	Install 1180 MW of Grid-Scale PV Install 1525 MW 4-hour Load-Shift Battery Install 68 MW ICE (4 x 17 MW) Install 30 MW Wind K1-6, Removal From Service CIP CT-1, Waiau 9 & 10, Airport DSG, Schofield, 154 MW Military Generation biodiesel conversion KPLP biodiesel conversion	Install 1520 MW of Grid-Scale PV Install 2013 MW 4-hour Load-Shift Battery Install 51 MW ICE (3 x 17 MW) Install 30 MW Wind K1-6, Removal From Service CIP CT-1, Waiau 9 & 10, Airport DSG, Schofield, 154 MW Military Generation biodiesel conversion KPLP biodiesel conversion	Install 1180 MW of Grid-Scale PV Install 1525 MW 4-hour Load-Shift Battery Install 68 MW ICE (4 x 17 MW) Install 30 MW Wind K1-6, Removal From Service CIP CT-1, Waiau 9 & 10, Airport DSG, Schofield, 154 MW Military Generation biodiesel conversion KPLP biodiesel conversion	Install 1520 MW of Grid-Scale PV Install 2013 MW 4-hour Load-Shift Battery Install 51 MW ICE (3 x 17 MW) Install 30 MW Wind K1-6, Removal From Service CIP CT-1, Waiau 9 & 10, Airport DSG, Schofield, 154 MW Military Generation biodiesel conversion KPLP biodiesel conversion

Table 4-1. O'ahu E3 Plan Comparison (DG-PV additions not shown)

O'ahu Post-April PSIP Plan Comparison

The Companies continued to refine the plans filed in the April 2016 PSIP which led to the development of the Post-April PSIP Plan.

For O'ahu, notable revisions include higher levels of DG-PV, higher potential of and accelerated adoption of grid-scale PV, the addition of load-shifting energy storage, and a regulation/ramping battery.

As mentioned in Chapter 3, the resource potentials were re-evaluated and the grid-scale PV potential was increased on O'ahu. Although NREL provided resource potential groupings based on developable slope and capacity factor, for our analysis, there was no distinction made in costing the different potentials. The same cost was applied for all available grid-scale solar. It should be noted, however, that projects developed on land with higher slopes would likely have higher cost. Higher resource potential available for grid-scale PV along with the updated resource costs (see Appendix J: Modeling Assumptions Data) enabled grid-scale PV to become more cost-effective at higher levels and earlier in the planning period than previously. Thus, the Post-April PSIP Plan increased the amount of grid-scale PV added in the near-term.

Continued analysis by the Companies and Ascend Analytics following the April 2016 PSIP explored the potential benefits of load-shifting energy storage. The cost-effectiveness of load-shifting energy storage is highly dependent upon several factors such as the capital cost of the energy storage, the cost of the energy charging the storage, and the cost of the energy displaced when discharging the storage. As further described in Appendix P, Ascend Analytics' analysis found load-shifting energy storage beneficial in a range of years, depending upon the resources available. The Post-April PSIP Plan for O'ahu includes a 300 MW/1200 MWh load-shifting battery in 2030. The Companies will continue to evaluate the sizing and timing of load shifting storage as storage costs evolve and additional renewable resources are added to the system.

Generation modernization was incorporated to the Post-April PSIP Plan. As further described in Appendix M, the benefits of replacement generation was evaluated to address our aging fleet of generating units and to provide fast-start and fast-ramping capabilities. The Post-April Plan removes from service all existing steam units by 2034 and includes replacement generation from reciprocating engines and proxy 151 MW single-train combined cycle units.

Table 4-2 compares our three April 2016 PSIP plans to the Post-April PSIP plan created for the December 2016 PSIP update.

Year	April PSIP O'ahu Theme 1 Plan	April PSIP O'ahu Theme 2 Plan	April PSIP O'ahu Theme 3 Plan	O'ahu Post April PSIP Plan
2017				
2018	50 MW SGS 24 MW Na Pua Makani Wind Project Install 109.6 MW Replacement Waiver PV Projects Install 15 MW Grid-Scale PV (CBRE) Install 10 MW Wind (CBRE)	50 MW SGS 24 MW Na Pua Makani Wind Project Install 109.6 MW Replacement Waiver PV Projects Install 15 MW Grid-Scale PV (CBRE) Install 10 MW Wind (CBRE)	50 MW SGS 24 MW Na Pua Makani Wind Project Install 109.6 MW Replacement Waiver PV Projects Install 15 MW Grid-Scale PV (CBRE) Install 10 MW Wind (CBRE)	50 MW SGS 24 MW Na Pua Makani Wind Project Install 109.6 MW Replacement Waiver PV Projects Install 15 MW Grid-Scale PV (CBRE) Install 10 MW Wind (CBRE)
2019	90 MW Contingency Battery Convert Honolulu 8 & 9 to Synchronous Condensers	90 MW Contingency Battery Convert Honolulu 8 & 9 to Synchronous Condensers	90 MW Contingency Battery Convert Honolulu 8 & 9 to Synchronous Condensers	Install 70 MW Contingency Battery 20 MW West Loch PV Project
2020	Install 30 MW Wind Install 200 MW of Grid-Scale PV	Install 100 MW JBPHH Plant, 12/2020 Kahe 1, 2, 3 Removal From Service, 12/2020 Install 30 MW of Wind Install 60 MW of Grid-Scale PV	Install 30 MW of Wind Install 60 MW of Grid-Scale PV	Install 30 MW Wind Install 180 MW Grid-Scale PV Install 100 MW 1-hour Regulation/Ramping Battery
2021		Install 27 MW KMCBH Plant, 6/2021 Install 3x1 CC, 6/2021		Install 100 MW Grid-Scale PV Convert H8 & 9 to Synchronous Condenser
2022	Install 100 MW JBPHH Plant AES Deactivated 9/2022 Install 200 MW of Grid-Scale PV	AES Deactivated 9/2022 Waiau 3 & 4 Removal From Service Kahe 4 Removal From Service Kahe 1, 2, 3 converted to Synchronous Condenser	Install 100 MW JBPHH Plant AES Deactivated 9/2022	AES PPA Expires, 9/2022 Install 100 MW JBPHH Plant Install 80 MW Grid-Scale PV
2023	Install 54 MW KMCBH Plant Waiau 3 & 4 Removal From Service Waiau 3 & 4 converted to Synchronous Condenser		Install 54 MW KMCBH Plant Waiau 3 & 4 Removal From Service Waiau 3 & 4 converted to Synchronous Condenser	Install 54 MW KMCBH Plant Waiau 3 & 4 Removal From Service Install 60 MW Grid-Scale PV
2024	Install 220 MW of Grid-Scale PV	Waiau 5 & 6 Removal From Service		Install 40 MW Grid-Scale PV
2025	Kahe 6 Removal From Service Kahe 6 converted to Synchronous Condenser		Kahe 6 Removal From Service Kahe 6 converted to Synchronous Condenser	Kahe 6 Removal From Service Install 151 MW CC Install 10 MW-6hr PSH Install 40 M W Grid-Scale PV
2026				Install 40 MW Grid-Scale PV
2027				Install 40 MW Grid-Scale PV Install 151 MW CC Kahe 1 & 2 Removal From Service

Year	April PSIP O'ahu Theme 1 Plan	April PSIP O'ahu Theme 2 Plan	April PSIP O'ahu Theme 3 Plan	O'ahu Post April PSIP Plan
2028				Install 40 MW Grid-Scale PV
2029				Install 20 MW Grid-Scale PV
2030	Waiau 5 & 6 Removal From Service Install 200 MW of Offshore Wind	Waiau 7 & 8 Removal From Service, 1/2030 Install 100 MW of Grid-Scale PV Install 200 MW of Offshore Wind	Waiau 5 & 6 Removal From Service Install 100 MW of Grid-Scale Solar Install 200 MW of Offshore Wind	Waiau 5 & 6 Removal From Service Kahe 5 Removal From Service Install 151 MW CC Install 300 MW 4hr Load-Shift Battery Install 20 MW Grid-Scale PV
2031				Install 20 MW Grid-Scale PV
2032	Install 200 MW of Offshore Wind			Install 151 MW CC Waiau 7 & 8 Removal From Service Install 20 MW Grid-Scale PV
2033				Install 20 MW Grid-Scale PV
2034	Install 200 MW of Offshore Wind			Install 20 MW Grid-Scale PV Install 151 MW CC Kahe 3 & 4 Removal From Service
2035				Install 20 MW Grid-Scale PV
2036	Install 200 MW of Offshore Wind			Install 20 MW Grid-Scale PV
2037				Install 20 MW Grid-Scale PV
2038				Install 20 MW Grid-Scale PV
2039				Install 20 MW Grid-Scale PV
2040		Install 200 MW of Grid-Scale PV Install 200 MW of Offshore Wind	Install 200 MW of Grid-Scale PV Install 200 MW of Offshore Wind	Install 400 MW Offshore Wind Install 20 MW Grid-Scale PV
2045		Install 300 MW of Grid-Scale PV Install 400 MW of Offshore Wind	Install 300 MW of Grid-Scale PV Install 400 MW of Offshore Wind	Install 400 MW Offshore Wind

Table 4-2. O'ahu April PSIP Plans and Post-April PSIP Plan Comparison (DG-PV additions not shown)

O'ahu System Security Analysis Results

System security analysis was performed to bring the resource plans into compliance with TPL-001 and results are available in Appendix O. Based on the analysis for the Post-April DR plan, the following resources are required in the next five years.

An FFR1 resource of 70 MW is required in 2019 to supplement capacities of FFR2 demand response reserves to stabilize system frequency for a Kahe Unit 5 trip at full output.

Conversion of Honolulu 8 and 9 to synchronous condensers (128.5 MVAR total) is required in 2021 for reactive power/voltage support and to provide fault current.

Analysis was performed to determine the system impacts of electrical faults on the transmission system through the five-year action plan. Results indicate that the system is susceptible to collapse on normally cleared three-phase faults in 2019. Selected sensitivity analyses were performed for normally cleared faults to stabilize system frequency and bring the system into compliance with TPL-001. Strategies that were analyzed include 1) mitigate the loss of generation with the addition of PFR at 1% droop response, and 2) limit transient voltage impact by committing Waiau 7 and 8 in VPO. Both of these strategies improve system performance but more extensive analysis is required to determine the optimal strategy to maintain system stability.

Furthermore, additional analysis is required to determine an optimal strategy to mitigate system impacts from electrical faults.

After the system security analysis on the Post-April PSIP Plans was completed, the plans were compared to the E3 Plans. Given the similarities of the near term resource plans, we conducted a screening analyses of the E3 plans to identify differences in resource requirements. The O'ahu analysis and assessment focused on two resource plans developed by E3 using RESOLVE and modeled in PLEXOS to obtain hourly dispatch models: (1) E3 Plan, and (2) E3 Plan with Generation Modernization. The screening analysis found similar requirements to the analysis performed on the Post-April PSIP Plan for O'ahu. Any differences are attributed to the unit commitment and dispatch schedules which were different from the Post-April PSIP Plan in the PLEXOS production simulation; further review of the dispatch models is required.

Regulating Reserve Analysis Results

With increasing levels of variable, intermittent resources in the future, such as distributed and grid-scale solar and grid-scale wind, there will be insufficient regulating resources on the system to maintain system frequency on a minute by minute basis and to cover large ramping events. The near-term O'ahu resource plan shown in Chapter 6: Planning and Analysis Considerations includes 695 MW of additional distributed and grid-scale resources, all of which are variable, intermittent resources. Ascend Analytics' System Flexibility Software utilizes historical minutely data to determine regulating and ramping requirements, as described in Appendix P. Using the System Flexibility Software, we identified approximate regulation requirements up to 500 MW and

15-minute maximum ramp requirements up to 650 MW during day-time hours which is largely due to increasing distributed and grid-scale solar.

Additional analysis by Ascend, described in Appendix P, identified a regulation requirement of 167 MW and a maximum ramp requirement of 688 MW in 2020 during day-time hours. The increase in regulation requirements as solar and wind generation increases is also shown in Appendix P, with solar having a much larger impact on regulation requirements. As an initial step to meeting these increasing requirements, a 100 MW 1-hour regulation/ramping battery was included in the Post-April PSIP Plan in 2020. The Companies will continue to evaluate the regulation and ramping requirements necessary to address increasing levels of variable resources.

O'ahu Plan Emissions

The CO_2 emissions of the O'ahu plans were estimated and shown in Figure 4-1. Emissions for the all the plans decrease over time as more renewables are added to the system to reach 100% renewable energy in 2045. The E3 plans with LNG have the highest emissions until the 2040 timeframe. However, starting in 2040, the E3 Plan with LNG has lower emissions than the E3 Plan and the E3 Plan with LNG and Grid Modernization has lower emissions than the E3 Plan with Generation Modernization.

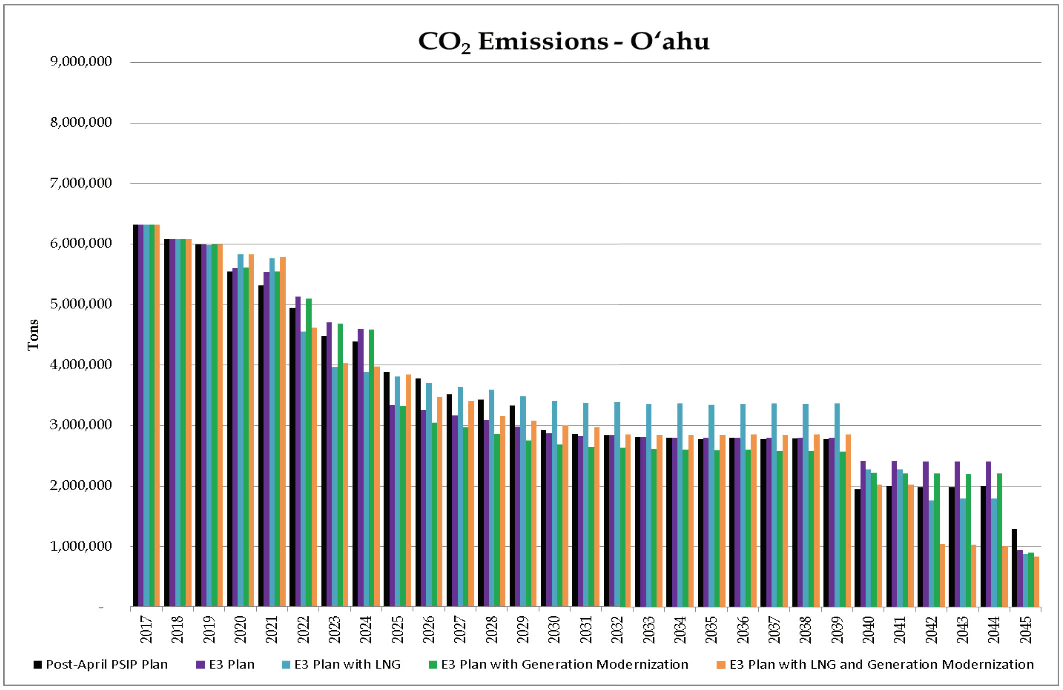


Figure 4-1. Estimated CO_2 Emissions of the O'ahu Plans

O'ahu Plan Key Results

Although the plans evaluated have different paths to achieving 100% renewable energy by 2045, the near-term resources and customer costs are very similar. Some key findings from the analyses are:

- Large amounts of grid-scale PV is cost-effective in the near term.
- Although the E3 plans did not include pursuing grid-scale wind in 2020, the Post-April PSIP Plan did and through confirmation in production simulation modeling, lowers plan costs in the near-term.
- The Post-April PSIP Plan included a regulating/ramping battery in 2020 that could also lower cost and support integrating higher levels of variable, intermittent generation.
- The E3 Plans with LNG were lower in cost than the E3 Plans that did not include LNG.
- Generation modernization to support grid-connected microgrids on military installations in the near-term reliably serves load and increases flexibility to integrate variable renewable generation. In combination with the AES PPA expiration in 2022, the military units provide replacement capacity and increase the system hosting capacity by reducing must-run generation on the system.
- Plans with generation modernization were slightly higher cost than the plans without generation modernization. However, modernization includes benefits such as fast-starting and fast-ramping capabilities to assist in integrating high levels or variable, intermittent generation that are not fully valued and accounted for in current modeling methods.
- Initial steps to facilitate the build out of new transmission to future grid scale renewable resources that are beyond the five year action plan period. Such new transmission will be site specific, dependent upon the specific location and size of a future grid scale resource.

MAUI ANALYTICAL RESULTS

Using updated input assumptions, we investigated and incorporated into our post-April PSIP plan:

- High DG-PV forecast.
- Demand response.
- System security resources.
- Regulation and ramping requirements.
- Load-shifting energy storage.
- High-levels of grid-scale PV and grid-scale wind.

Maui E3 Plan Comparison

The original E3 Plan was developed using RESOLVE (see Chapter 3: Analytical Approach). The Companies then adjusted the original E3 Plan shown in Chapter 3 for use in the PLEXOS production simulations and Finance model as follows:

- Because the RESOLVE model allows incremental 1 MW blocks of new generation options, generation resource sizing was adjusted to correspond to the block sizes that the resource costs were based on (see Appendix J). For example, RESOLVE added approximately 30.6 MW of geothermal in 2040 and another 9.4 MW in 2045 for the E3 Plan. The block size and timing of the geothermal addition was adjusted to reflect 40 MW in-service in 2040 for the PLEXOS model.

The E3 plans economically relied heavily on battery storage for firm capacity needs. The E3 model did not take into account the uncertainty in weather and associated reliability risk of not being able to serve load if there isn't enough renewable energy to charge the batteries and there is no thermal generation as backup. This situation could occur when there are long periods of rainy days and low solar production. The seasonality of available variable renewable resources is illustrated in Appendix K: Analytical Steps and Results for select years. Despite high amounts of renewable resources such as grid-scale PV and grid-scale wind included in the E3 Plans, there are still periods where the load exceeds the available resources in 2045. Seasonal load-shifting storage or firm renewable generation would be necessary to bridge this gap.

Table 4-3 shows the E3 plans that were evaluated using the PLEXOS model.

Year	E3 Plan	E3 Plan with LNG
2017	5.74 MW of PV Projects	5.74 MW of PV Projects
2018	Install 1 MW Grid-Scale PV (CBRE) Install 2 MW Wind (CBRE)	Install 1 MW Grid-Scale PV (CBRE) Install 2 MW Wind (CBRE)
2019	9 MW Contingency Battery	9 MW Contingency Battery
2020	Install 60 MW Wind Install 30 MVA Synchronous Condensers on 69 kV System	Install 40 MW Wind Install 30 MVA Synchronous Condensers on 69 kV System
2021		
2022	Install 40 MW Biomass Install Two 9 MW NTA ICE	Install 16 MW 4hr Load-Shift Battery 106 MW Ma'alaea CCs Convert to LNG Install Two - 9 MW NTA ICE Install 20 MW Biomass
2023		
2024	33 MW Kahului Planned Retirement	33 MW Kahului Planned Retirement
2025	Install 4 MW 4-hour Load-Shift Battery	Install 6 MW 4-hour Load-Shift Battery
2030	Install 28 MW 4-hour Load-Shift Battery	Install 2 MW 4-hour Load-Shift Battery
2035	Install 18 MW 4-hour Load-Shift Battery	Install 4 MW 4-hour Load-Shift Battery
2040	Install 52 MW 4-hour Load-Shift Battery Install 40 MW Geothermal	Install 56 MW 4-hour Load-Shift Battery Install 20 MW Biomass
2045	Install 70 MW Grid-Scale PV Install 149 MW 4-hour Load-Shift Battery Two 9 MW NTA ICE biodiesel conversion Ma'alaea 4–9 Removal From Service Ma'alaea 10–13 Removal From Service Ma'alaea X1–3 biodiesel conversion 106 MW Ma'alaea CC biodiesel conversion	Install 120 MW Grid-Scale PV Install 277 MW 4-hour Load-Shift Battery Install 40 MW Geothermal Two 9 MW NTA ICE biodiesel conversion Ma'alaea 10–11 Removal From Service Ma'alaea 4–9 Removal From Service Ma'alaea 12–13 biodiesel conversion Ma'alaea X1–3 biodiesel conversion 106 MW Ma'alaea CC biodiesel conversion

Table 4-3. Maui E3 Plan Comparison (DG-PV additions not shown)

Maui Post-April PSIP Plan Comparison

The Companies continued to refine the plans filed in the April 2016 PSIP which led to the development of the Post-April PSIP Plan.

For Maui, notable revisions include higher levels of DG-PV, grid-scale PV, and grid-scale wind as well as an accelerated adoption of grid-scale wind and grid-scale PV. With the updated resource costs (see Appendix J: Modeling Assumptions Data), it was found that adding large amounts of grid-scale wind earlier in the planning period was cost-effective. However, due to transmission constraints between the areas in which there are grid-scale wind resources available and the location of the load centers, the amount of additional grid-scale wind included in the plan was limited to 90 MW in the near-term. With the limited addition of grid-scale wind, grid-scale PV was also added in the near-term and found to be cost-effective although not as cost-effective as grid-scale wind.

Table 4-4 compares our three April 2016 PSIP plans to the Post-April PSIP plan created for the December 2016 PSIP update.

Year	April PSIP Maui Theme 1 Plan	April PSIP Maui Theme 2 Plan	April PSIP Maui Theme 3 Plan	Maui Post April PSIP Plan
2017	5.74 MW of PV Projects	5.74 MW of PV Projects	5.74 MW of PV Projects	5.74 MW of PV Projects
2018				Install 1 MW Grid-Scale PV (CBRE) Install 2 MW Wind (CBRE)
2019				9 MW Contingency Battery
2020	Install 30 MW Wind	Install 60 MW Wind	Install 60 MW Wind	Install 90 MW Wind (Kaheawa) Install 80 MW Grid-Scale PV Install 30 MVA Synchronous Condensers on 69 kV System
2021				
2022	Install 30 MW Pumped Storage Hydro Install 20 MW Biomass Install 20 MW 1hr Regulation/Contingency Battery for South Maui Non-Transmission Alternative Install two 30 MVA Synchronous Condenser (Maʻalaea)	Install Two 9 MW ICE, Install 20 MW Biomass Install 20 MW 4-hour Load-Shift Battery Install 20 MW 1hr Regulation/Contingency Battery for South Maui Non-Transmission Alternative Install two 30 MVA Synchronous Condenser (Maʻalaea)	Install Two 9 MW ICE Install 20 MW Biomass Install 30 MW Wind Install 20 MW 4-hour Load-Shift Battery Install 20 MW 1hr Regulation/Contingency Battery for South Maui Non-Transmission Alternative Install two 30 MVA Synchronous Condenser (Maʻalaea)	Install Two 9 MW NTA ICE Install 20 MW Biomass Install 20 MW 4-hour Load-Shift Battery Install 20 MW 1hr Regulation/Contingency Battery for South Maui NTA Install 20 MW 1hr Regulation Battery
2023	Convert K1, K2, K3, K4 to Synchronous Condensers	Convert K1, K2, K3, K4 to Synchronous Condensers	Convert K1, K2, K3, K4 to Synchronous Condensers	Convert K1, K2, K3, K4 to Synchronous Condensers
2024				
2025			Install 30 MW Wind	
2030	Install 40 MW Geothermal Install 40 MW Biomass			Install 40 MW Geothermal
2037		Replace 20 MW 4-hour Load-Shift Battery with a 30 MW 6-hour Load-Shift Battery	Replace 20 MW 4-hour Load-Shift Battery with a 30 MW 6-hour Load-Shift Battery	Replace 20 MW 4-hour Load-Shift Battery with a 30 MW 6-hour Load-Shift Battery
2040	Install 30 MW Wind	Install 20 MW Biomass Install 40 MW Geothermal Install 120 MW Wind Install 40 MW 1-hour Battery for Regulation	Install 20 MW Biomass Install 40 MW Geothermal Install 60 MW Wind Install 40 MW 1-hour Battery for Regulation	Install 40 MW Biomass
2045	Install 30 MW Wind Install 60 MW 1-hour Battery for Regulation	Install 30 MW Wind Install 40 MW Grid-Scale PV	Install 30 MW Wind Install 40 MW Grid-Scale PV	

Table 4-4. Maui April PSIP Plans and Post-April PSIP Plan Comparison (DG-PV additions not shown)

Maui System Security Analysis Results

System security analysis was performed to bring the resource plans into compliance with TPL-001 and results are available in Appendix O. Based on the analysis for the Post-April DR plan, the following resources are required in the next five years.

An FFR1 resource of 9 MW is required in 2019 to stabilize system frequency for a KWP I trip at full output.

A new 16 MVA synchronous condenser is required in 2019 to provide reactive power/voltage support and fault current for the 23 kV system level if the must-run constraint is removed from Kahului 3 and 4. Otherwise, this resource is required in 2022 prior to retirement of the Kahului Plant in 2024. An additional 30 MVA synchronous condenser at the 69 kV system level is required in 2020.

Like O‘ahu, Maui is susceptible to collapse for a normally cleared fault in 2019. Selective sensitivity analyses were performed for normally cleared faults to stabilize system frequency and/or bring the system into compliance with TPL-001. Strategies that were analyzed include 1) mitigate the loss of generation with the addition of PFR at 1% droop response, and 2) reduce the fault clearing time to 5-cycles improves system performance. This can be accomplished by installing dual pilot or dual differential relay schemes.

More analysis is required to determine an optimal strategy to mitigate system impacts from electrical faults.

After the system security analysis on the Post-April PSIP Plans was completed, the plans were compared to the E3 Plans. Given the similarities of the near-term resource plans, we conducted a screening analyses of the E3 plans to identify differences in resource requirements. For Maui, the analysis focused on the E3 Plan. The loss of generation screening results showed degraded system performance, more hours where frequency response resources are required, than the Post-April DR plan. The FFR and PFR capacities required are similar to the Post-April DR plan. The 69 kV fault analyses identified more unstable conditions than the Post-April DR plan. Most of these differences are attributed to the unit commitment and dispatch differences between the Post-April PLEXOS production simulation and E3 plans and further review of the dispatch models are required.

Regulating Reserve Analysis Results

With increasing levels of variable, intermittent resources in the future, such as distributed and grid-scale solar and grid-scale wind, there will be insufficient regulating resources on the system to maintain system frequency on a minute by minute basis and to cover large ramping events. This will require continuous review and study of historical changes in the actual performance of intermittent resources and the ability of current regulating resources to balance the system. Evaluation of historical data and performance will be used to determine whether there are sufficient resources available to integrate the increasing levels of intermittent generation and if not, what resources are required in the future.

Maui Plan Emissions

The CO_2 emissions of the Maui plans were estimated and shown in Figure 4-2. Emissions for the all the plans decrease over time as more renewables are added to the system to reach 100% renewable energy in 2045. The Post-April PSIP has the lowest emissions since that plan has the highest amounts of renewables added. The E3 Plan with LNG has the highest emissions until 2045 since that plan had the lowest amount of renewables added.

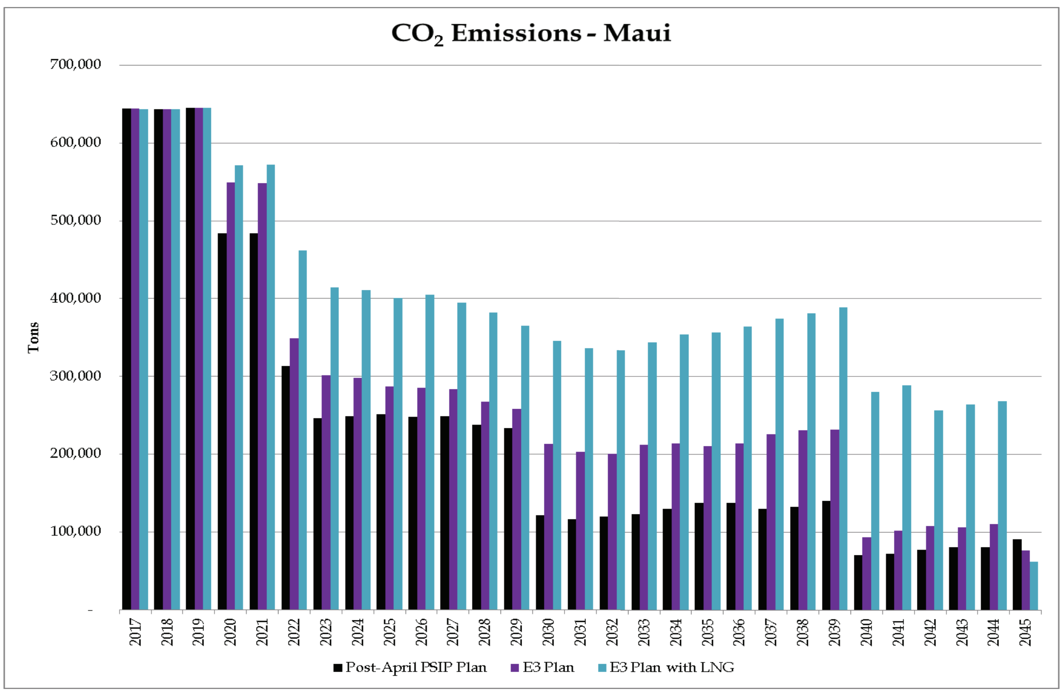


Figure 4-2. Estimated CO_2 Emissions of the Maui Plans

Hawaiian Electric
Maui Electric
Hawai'i Electric Light

Maui Plan Key Results

Although the plans evaluated have different paths to achieving 100% renewable energy by 2045, the near-term resources are very similar. Some key findings from the analyses are:

- Large amounts of grid-scale wind is cost-effective in the near term.
- The E3 Plan with LNG was marginally lower cost than the E3 Plan that did not include LNG.
- Replacement dispatchable generation is required to replace generation capacity lost with the retirement of Kahului Power Plant. Upgrades to the Central Maui transmission is necessary to provide the voltage support currently provided by the Kahului Power Plant.
- Initial steps to facilitate the build out of new transmission to future grid scale renewable resources that are beyond the five year action plan period. Such new transmission will be site specific, dependent upon the specific location and size of a future grid scale resource.

MOLOKA‘I ANALYTICAL RESULTS

Using updated input assumptions, we investigated and incorporated into our Post-April PSIP plan:

- High DG-PV forecast.
- Demand response.
- System security resources.
- High-levels of grid-scale wind.

Moloka‘i 100% Renewables Plan Comparison

The Companies continued to refine the plans filed in the April 2016 PSIP which led to the development of the Post-April PSIP Plan. For the first time, in this December filing, PLEOXS's capacity expansion module was used to optimize the future resource installations for the island of Moloka‘i. PLEXOS optimized resource plans included between 5 MW of grid-scale wind in 2020 and 1 MW grid-scale wind installed in later years, depending on the 100% renewable energy target date (that is, 2020, 2030). Despite adding 5 MW of grid-scale wind and higher levels of DG-PV, a fair amount of biofuel is still utilized (see Appendix K).

To validate the optimal solution that PLEXOS's capacity expansion module recommended and reduce and/or eliminate biofuels, subsequent analyses were performed with manual adjustments to resource plans. Manual adjustments included overbuilding wind, adding PV, and adding energy storage systems. All of the subsequent analyses were higher in total cost in comparison to the PLEXOS optimized resource plans and still included the need for biofuels. This provided assurance that PLEXOS's has the capability of providing a least-cost solution.

Table 4-5 compares our two April 2016 PSIP plans to the two 100% renewable PLEXOS cases created for the December 2016 PSIP update.

Year	April PSIP Moloka'i Theme 1 Plan	April PSIP Moloka'i Theme 3 Plan	100% Renewables by 2020	100% Renewables by 2030
2017				
2018	Install two 5 MVA Synchronous Condenser	Install two 5 MVA Synchronous Condenser		
2019			2.75 MW Contingency Battery Install 2.75 MVA Synchronous Condensers	2.75 MW Contingency Battery Install 2.75 MVA Synchronous Condensers
2020	Install 5 MW Wind	Install 5 MW Wind	Install 5 MW Wind Convert to biodiesel	Install 5 MW Wind
2021				
2022				
2023				
2024				
2025				
2030				Convert to biodiesel
2040				
2045		Install 1 MW Wind		

Table 4-5. Moloka'i April PSIP Plans and 100% Renewables Plans Comparison (DG-PV additions not shown)

Moloka'i System Security Analysis Results

The Moloka'i system is a nominal 12 kV radial distribution system that does not fall under the jurisdiction of TPL-001. Therefore, the reliability criterion that was used for the frequency response analysis is to prevent system collapse and to maintain acceptable stability margin. Based on the analysis for the Post-April DR plan, the following resources are required in the next five years.

- An FFR1 resource of 2.75 MW is required in 2019 to stabilize system frequency for a Pala'au 9 diesel generator trip at 2.2 MW.
- A new 2.75 MVA synchronous condenser is required in 2019 to provide reactive power/voltage support and fault current.

Distribution fault analysis indicates the system is stable.

Regulating Reserve Analysis Results

With increasing levels of variable, intermittent resources in the future, such as distributed solar and grid-scale wind, there will be insufficient regulating resources on the system to maintain system frequency on a minute by minute basis and to cover large ramping events. This will require continuous review and study of historical changes in the actual performance of intermittent resources and the ability of current regulating resources to balance the system. Evaluation of historical data and performance will be used to determine whether there are sufficient resources available to integrate the increasing levels of intermittent generation and if not, what resources are required in the future.

Moloka'i Plan Key Results

Although the plans had different target dates of achieving 100% renewable energy, the analysis yielded the same near term goal. Some key findings from the analysis are:

- 5 MW of grid-scale wind is cost-effective in the near term.
- Some biofuel is utilized to achieve 100% renewable energy.
- Accelerating the target date for 100% renewable energy raises costs due to the earlier substitution of more expensive biodiesel for diesel fuel

LANA‘I ANALYTICAL RESULTS

Using updated input assumptions, we investigated and incorporated into our Post-April PSIP plan:

- High DG-PV forecast.
- Demand response.
- System security resources.
- High-levels of grid-scale wind.

Lana‘i 100% Renewables Plan Comparison

The Companies continued to refine the plans filed in the April 2016 PSIP which led to the development of the Post-April PSIP Plan. For the first time, in this December filing, PLEOXS’ capacity expansion module was used to optimize the future resource installations for the island of Lana‘i. PLEXOS optimize resource plans included between 3 MW–4 MW of grid-scale wind in 2020 and 1 MW–3 MW of grid-scale PV installed in later years, depending on the 100% renewable energy target date (that is, 2020, 2030). Despite adding 4 MW of grid-scale wind and higher levels of DG-PV, a fair amount of biofuel is still utilized (see Appendix K).

To validate the optimal solution that PLEXOS’s capacity expansion module recommended and reduce and/or eliminate biofuels, subsequent analyses were performed with manual adjustments to resource plans. Manual adjustments included overbuilding wind, adding PV, and adding energy storage systems. All of the subsequent analyses were higher in total cost in comparison to the PLEXOS optimized resource plans and still included the need for biofuels This provided assurance that PLEXOS’s has the capability of providing a least-cost solution.

Table 4-6 compares our two April 2016 PSIP plans to the two 100% renewable PLEXOS cases created for the December 2016 PSIP update.

Year	April PSIP Lana‘i Theme 1 Plan	April PSIP Lana‘i Theme 3 Plan	100% Renewables by 2020	100% Renewables by 2030
2017				
2018				
2019	Install two 5 MVA Synchronous Condenser	Install two 5 MVA Synchronous Condenser	1.25 MW Contingency Battery Install 2.75 MVA Synchronous Condensers	1.25 MW Contingency Battery Install 2.75 MVA Synchronous Condensers
2020	Install 3 MW Wind	Install 3 MW Wind	Install 4 MW Wind Convert to biodiesel	Install 4 MW Wind
2021				
2022				
2023				
2024				
2025				
2030	Install 1 MW Wind	Install 1 MW Wind		Convert to biodiesel
2040		Install 1 MW Wind		
2045	Install 1 MW Wind			

Table 4-6. Lana‘i April PSIP Plans and 100% Renewables Plans Comparison (DG-PV additions not shown)

Lana‘i System Security Analysis Results

The Lana‘i system is a nominal 12 kV radial distribution system that does not fall under the jurisdiction of TPL-001. Therefore, the reliability criterion that was used for the frequency response analysis is to prevent system collapse and to maintain acceptable stability margin. Based on the analysis for the Post-April DR plan, the following resources are required in the next five years.

- An FFR1 resource of 1.25 MW is required in 2019 to stabilize system frequency for a Miki Basin 7 diesel generator trip at 1.24 MW.
- A new 2.75 MVA synchronous condenser is required in 2019 to provide reactive power/voltage support and fault current.

Distribution fault analysis indicates the system is stable.

Regulating Reserve Analysis Results

With increasing levels of variable, intermittent resources in the future, such as distributed solar and grid-scale wind, there will be insufficient regulating resources on the system to maintain system frequency on a minute by minute basis and to cover large ramping events. This will require continuous review and study of historical changes in the actual performance of intermittent resources and the ability of current regulating resources to balance the system. Evaluation of historical data and performance will be used to determine whether there are sufficient resources available to integrate the increasing levels of intermittent generation and if not, what resources are required in the future.

Lana'i Plan Key Results

Although the plans had different target dates of achieving 100% renewable energy, the analysis yielded the similar resource plans. Some key findings from the analysis are:

- 4 MW of grid-scale wind is cost-effective in the near term.
- Some biofuel is utilized to achieve 100% renewable energy.
- Accelerating the target date for 100% renewable energy raises costs due to the earlier substitution of more expensive biodiesel for diesel fuel..

HAWAI'I ISLAND ANALYTICAL RESULTS

Using updated input assumptions, we investigated and incorporated into our Post-April PSIP plan:

- High DG-PV forecast.
- Demand response.
- System security resources.
- Regulation and ramping requirements.
- Load-shifting energy storage.
- High-levels of grid-scale PV and grid-scale wind.

Hawai'i Island E3 Plan Comparison

The original E3 Plan was developed using RESOLVE (see Chapter 3). The Companies then adjusted the original E3 Plan shown in Chapter 3 for use in the PLEXOS production simulations and Finance model as follows:

- Because the RESOLVE model allows incremental 1 MW blocks of new generation options, generation resource sizing was adjusted match block sizes that the resource costs were based on (see Appendix J). For example, RESOLVE added 16 MW of grid-scale wind in 2022. The block size of the grid-scale wind was adjusted to 15 MW for the PLEXOS model.
- The original E3 Plan produced by RESOLVE did not choose to keep the Keahole DTCC online in 2045. For the production simulations in PLEXOS, Keahole remained in-service to provide voltage support throughout the entire planning period and converted to biodiesel in 2045.

The E3 plans economically relied heavily on battery storage for firm capacity needs. The E3 model did not take into account the uncertainty in weather and associated reliability risk of not being able to serve load if there isn't enough renewable energy to charge the batteries and there is no thermal generation as backup. This situation could occur when there are long periods of rainy days and low solar production. The seasonality of available variable renewable resources is illustrated in Appendix K for select years. Despite high amounts of grid-scale wind included in the E3 Plans, there are still periods where the load exceeds the available resources in 2045. Seasonal load-shifting storage or firm renewable generation would be necessary to bridge this gap.

Table 4-3 shows the E3 plans that were evaluated using the PLEXOS model.

Year	E3 Plan	E3 Plan with LNG
2017		
2018	Install 1 MW Grid-Scale PV (CBRE) Install 2 MW Wind (CBRE)	Install 1 MW Grid-Scale PV (CBRE) Install 2 MW Wind (CBRE)
2019		
2020	Install 20 MW Wind Install 12 MW 4-hour Load-Shift Battery Puna Steam, Hill 5&6 Removal From Service 9 MW Contingency Battery Install 25 MVA Synchronous Condensers	Install 20 MW Wind Install 14 MW 4-hour Load-Shift Battery Puna Steam, Hill 5&6 Removal From Service 9 MW Contingency Battery Install 25 MVA Synchronous Condensers
2021		
2022	Install 50 MW Wind	Install 15 MW Wind Keahole CC Converted to LNG
2023		
2024		
2025	Install 9 MW 4-hour Load-Shift Battery	Install 10 MW 4-hour Load-Shift Battery
2030	Install 39 MW 4-hour Load-Shift Battery	Install 22 MW 4-hour Load-Shift Battery
2035	Install 21 MW 4-hour Load-Shift Battery	Install 13 MW 4-hour Load-Shift Battery
2040	Install 48 MW 4-hour Load-Shift Battery CT1 biodiesel conversion CT2 Removal From Service	Install 42 MW 4-hour Load-Shift Battery CT1 biodiesel conversion CT2 Removal From Service
2045	Install 30 MW Wind Install 74 MW 4-hour Load-Shift Battery Keahole CC biodiesel conversion HEP biodiesel conversion CT3 biodiesel conversion Small diesels biodiesel conversion	Install 65 MW Wind Install 104 MW 4-hour Load-Shift Battery Keahole CC biodiesel conversion HEP biodiesel conversion CT3 biodiesel conversion Small diesels biodiesel conversion

Table 4-7. Hawai'i Island E3 Plan Comparison (DG-PV additions not shown)

Hawai'i Island Post-April PSIP Plan Comparison

The Companies continued to refine the plans filed in the April 2016 PSIP which led to the development of the Post-April PSIP Plan.

For Hawai'i Island, notable revisions include higher levels of DG-PV and additional grid-scale wind in the near-term, added in 2020 to leverage benefits of tax incentives prior to expiration of those programs. Adding grid-scale wind in the near-term delayed the timing of additional geothermal. With the updated resource costs (see Appendix J), it was found that adding considerable amounts of grid-scale wind earlier in the planning period was cost-effective due to taking advantage of the tax incentives. However, due to transmission constraints between the areas in which there are grid-scale wind resources available and the location of the load centers, the amount of additional grid-scale wind included in the plan was limited to 20 MW. Additional expansion of wind may be feasible if procured near certain transmission system locations that can accommodate higher levels; potentially as high as 70 MW.

Table 4-7 compares our three April 2016 PSIP plans to the Post-April PSIP Plan created for the December 2016 PSIP update.

Year	April PSIP Hawai'i Island Theme 1 Plan	April PSIP Hawai'i Island Theme 2 Plan	April PSIP Hawai'i Island Theme 3 Plan	Hawai'i Island Post April PSIP Plan
2017				
2018				Install 1 MW Grid-Scale PV (CBRE) Install 2 MW Wind (CBRE)
2019	15 MW Contingency BESS	15 MW Contingency BESS	15 MW Contingency BESS	
2020				Install 20 MW Wind 9 MW Contingency Battery Install 25 MVA Synchronous Condensers
2021				
2022	Install 20 MW Geo Puna Steam Removal From Service	Install 20 MW Geo Puna Steam Removal From Service	Install 20 MW Geo Puna Steam Removal From Service	
2023	Conversion to 15.6 MVA Synchronous Condensers			
2024	Install20 MW Biomass Hill 5 Removal From Service Install 45 MVA Synchronous Condensers	Install 75 MVA Synchronous Condensers	Install 75 MVA Synchronous Condensers	
2025				Install 20 MW Geothermal Puna Steam Removal From Service
2026	Install20 MW Geo Hill 6 Removal From Service Conversion to 27.5 MVA Synchronous Condensers			
2027		Install 20 MW Biomass Hill 5 Removal From Service Conversion to 15.6 MVA Synchronous Condensers	Install 20 MW Biomass Hill 5 Removal From Service Conversion to 15.6 MVA Synchronous Condensers	Install 20 MW Biomass Hill 5 Removal From Service
2028	Install 30 MW Wind			
2030	Install 30 MW/6hr Load-Shift Battery, Install 30 MW Pumped Storage Hydro, Biofuel	Install 20 MW Geo Hill 6 Removal From Service	Install 20 MW Geo Hill 6 Removal From Service	Install 20 MW Wind Install 20 MW Geothermal Hill 6 Removal From Service
2034		Install 20 MW Wind	Install 20 MW Wind	
2038		Install 20 MW Wind	Install 20 MW Wind	
2040		Biofuel	Biofuel	
2045				

Table 4-8. Hawai'i Island April PSIP Plans and Post-April PSIP Plan Comparison (DG-PV additions not shown)

Hawai'i Island System Security Analysis Results

Hawai'i has the most miles of transmission lines of any major island so the exposure to system impact from electrical faults is high. Initial system security analysis was performed and results are available in Appendix O. Based on the analysis for the Post April DR plan, the following resources are required in the next 5 years. Additional resources may be required to mitigate system impacts pending further investigation of additional base cases and other types of events.

An FFR1 resource of 9 MW is required in 2019 to stabilize system frequency for a HEP Trip in STCC mode at 28.7 MW.

A new 25 MVA synchronous condenser to provide reactive power/voltage support and fault current is required in 2019.

Hawai'i Island is susceptible to collapse for a normally cleared fault in 2019. Selective sensitivity analyses were performed for normally cleared faults to stabilize system frequency and/or bring the system into compliance with the planning standard TPL-001. Strategies that were analyzed include 1) mitigate the loss of generation with the addition of PFR at 1% droop response, and 2) installation of synchronous condensers. Delayed clearing faults were analyzed but mitigation sensitivities were not performed. More analysis is required to determine the impact of delayed clearing faults and to determine an optimal strategy to mitigate system impacts from electrical faults.

After the system security analysis on the Post-April PSIP Plans was completed, the plans were compared to the E3 Plans. Given the similarities of the near term resource plans, we conducted a screening analyses of the E3 plans to identify differences in resource requirements. For Hawai'i island, the analysis focused on the E3 Plan. The short circuit screening identified more synchronous condensers were required to meet the minimum fault current requirement in 2022. The loss of generation screening found degraded system performance starting in 2020 and more hours where additional frequency response resources are required. Most of these differences are attributed to the unit commitment and dispatch schedules which were different from the Post-April PLEXOS production simulation so further review of the dispatch models are required.

Regulating Reserve Analysis Results

With increasing levels of variable, intermittent resources in the future, such as distributed solar and grid-scale wind, there will be insufficient regulating resources on the system to maintain system frequency on a minute by minute basis and to cover large ramping events. This will require continuous review and study of historical changes in the actual performance of intermittent resources and the ability of current regulating resources to balance the system. Evaluation of historical data and performance will be used to determine whether there are sufficient resources available to integrate the increasing levels of intermittent generation and if not, what resources are required in the future.

Hawai'i Island Plan Emissions

The CO_2 emissions of the Hawai'i Island plans were estimated and shown in Figure 4-3Figure 4-1. Emissions for the all the plans decrease over time as more renewables are added to the system to reach 100% renewable energy in 2045.

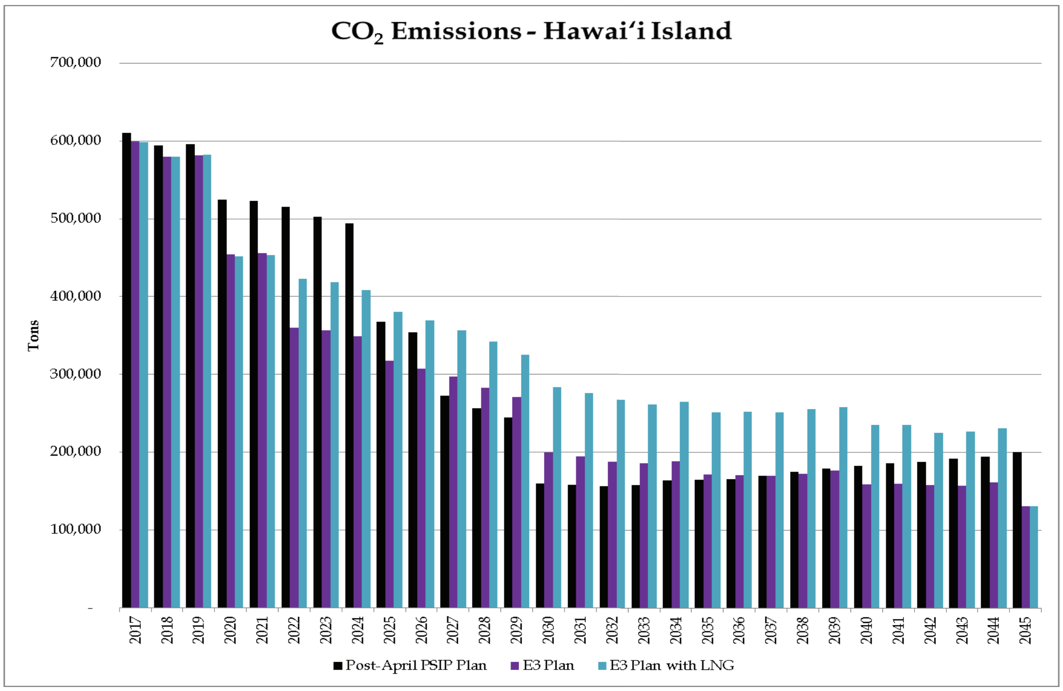


Figure 4-3. Estimated CO_2 Emissions of the Hawai'i Island Plans

Hawai'i Island Plan Key Results

Although the plans had different target dates of achieving 100% renewable energy, the analysis yielded the same near term goal. Some key findings from the analysis are:

- Large amounts of grid-scale wind is cost-effective in the near term.
- The E3 Plan with LNG was marginally higher cost than the E3 Plan that did not include LNG given the relatively low volumes of LNG.
- Grid-scale wind additions in the near-term were limited to transmission constraints. Increasing the limits in the near-term could further reduce costs depending on interconnection costs.
- Initial steps to facilitate the build out of new transmission to future grid scale renewable resources that are beyond the five year action plan period. Such new transmission will be site specific, dependent upon the specific location and size of a future grid scale resource.

ASCEND ANALYTICS VALIDATION RESULTS

Ascend, through its PowerSimm model, validated the following PLEXOS modeling of the following cases:

- Oahu, Post-April PSIP Plan
- Oahu, E3 Plan
- Oahu E3 Plan with LNG
- Hawai‘i Island, Post-April PSIP Plan
- Hawai‘i Island, E3 Plan
- Maui, Post-April PSIP Plan
- Maui, E3 Plan

Ascend Analytics’ analysis yielded similar trends as the Companies evaluation of the E3 plans and Post-April PSIP Plans in general. A summary is provided below and further details of Ascend’s analysis are provided in Appendix P.

Overall, the cost comparisons of the E3 Plan and the Post-April PSIP Plan for O‘ahu, Maui, and Hawai‘i Island were directionally similar and relatively consistent with the Company’s findings which are discussed in Chapter 5.

E3 Plan Percent Cost Differentials to Post April PSIP Plan with PLEXOS and PowerSimm

O‘ahu E3 Plan	–0.1%	+1.4%
O‘ahu E3 Plan with LNG	–7.6%	–11.2%
Maui E3 Plan	–7.0%	–8.2%
Hawai‘i E3 Plan	–9.4%	–2.4%

- Comparison of evaluation of plans by PLEXOS and PowerSimm
- Ascend also found that the use of LNG could provide significant savings on O‘ahu.
- Similar to the results of E3’s RESOLVE model, PowerSimm simulations resulted in acceleration of adding grid-scale renewables and load-shifting storage and further optimization may be possible.
- Ascend found the addition of flexible thermal units beneficial to assisting with integrating higher levels of variable, intermittent generation. Without the flexible thermal fleet, production costs will be higher because a considerable amount of steam generators will be compelled to come online for a relatively short duration during

peaking conditions, and then remain running at minimum generation for a substantial block of hours when their generation is no longer necessary.

- Both regulation batteries and flexible batteries provide savings in operating costs immediately upon their introduction to the energy system, and these battery savings grow over time.
- Since the E3 plans rely heavily upon load shifting battery storage for capacity, the system is susceptible to potential energy shortfalls when there are consecutive days with low over-generation available for storage. Even if thermal generation is rarely utilized at high capacities, the guarantee of dispatchable energy in periods with low intermittent renewable generation is essential for meeting load reliably. Though load-shifting batteries mitigate the need for thermal generation, they do not completely eliminate this need. Similar findings are discussed further in Appendix K.

Load-shifting energy storage was found to be cost-effective as the levels of renewable generation increases, especially with the increase in available solar generation. This is consistent with the E3 plans developed for O‘ahu, Maui, and Hawai‘i Island. Without load-shifting batteries, there would be insufficient renewable energy resources at night, thus requiring thermal generation to meet customer demand. Not only would this thermal generation in 2045 require burning expensive biofuels, but it would also require expensive plant startups or running power plants at a sub-optimal generation level to prevent startups and shutdowns.

5. Financial Impacts

This chapter provides the financial analyses of the updated December 2016 PSIP. It presents the capital requirements over the period for each Company and the residential customer electricity rate and bill impacts for each of the different plans. 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 planning to provide context to inform important pending and future resource acquisition and system operation decisions. Actual values could vary significantly with changes in assumptions including resource costs, new renewable technologies, fuel prices, energy efficiency, tax policy, fiscal policy, and other factors.

This chapter is divided into three sections, one for each Company. For each Company, the following information is provided:

- Revenue requirements
- Capital expenditures
- Residential customer rate and bill impacts
- Total costs to achieve 100% renewable energy

Revenue Requirements

The revenue requirement calculations include both the power supply and non-power supply cost structure. The calculations include operating and maintenance costs, taxes other than income and public benefits fund, return on and of existing utility asset investments, and return on and of future utility asset investments.

Capital Expenditures

Capital expenditure projections for power supply, Smart Grid, ERP, and all other utility capital expenditures (referred to as "balance-of-utility business capital expenditures") are included in the analysis.

- Power supply capital expenditures include major investments in additional utility-owned generation and LNG unit modifications, if applicable.
- Smart Grid and ERP capital expenditures represent specific expenditures for those major projects.
- Balance-of-utility capital expenditures represent grid modernization expenditures such as T&D upgrades, energy storage and synchronous condensers as well as all other utility investments.

As described in detail in Appendix I: Financial Analysis and Bill Impact Calculations, the balance-of-utility business capital expenditures and significant major projects are adjusted in order to manage the impact on rates and to stay within reasonable financing limits. Some exceptions are made for the lumpy nature of significant major projects that may go into rates (for example, new generating stations and grid-scale batteries).

The lumpy rate increases inherent with traditional rate base treatment of major capital projects are a challenge. The Companies will continue to explore options to smooth out the rate impact of significant major capital investments through use of levelized cost recovery (similar to Power Purchase Agreements) or request inclusion of the Construction Work in Progress (CWIP) to be included in rate base as the project progresses.

Residential Customer Bill and Rate Impacts

The overall impact on a residential customer's bill is the combination of usage and rates. Over the planning period, usage per residential customer is expected to decline, consistent with the Energy Efficiency Portfolio Standard goals,[29] providing an offset to the increase in rates.

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 rise over the planning period, except in cases with LNG, where fuel savings provide an offset.

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

However, with these investments, 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 affordable.

Total Investments to Achieve 100% Renewable Energy

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. As Hawai‘i selects the best path to achieve its renewable energy future, the total cost of electricity is an important consideration. For this analysis, the total 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.

HAWAIIAN ELECTRIC FINANCIAL IMPACTS

The data and analyses presented in this section cover all of Hawaiian Electric's service territory and customers. For O'ahu, the E3 Plan with LNG and E3 Plan with LNG and Generation Modernization, show the lowest overall revenue requirements over the 2017 to 2045 planning period. The E3 Plan is the lowest non-LNG scenario and the E3 Plan with Generation Modernization is the highest cost scenario.

Revenue Requirements

Table 5-1 shows the Net Present Value of the annual revenue requirements for each Plan.

Net Present Value of Revenue Requirements	000)	Increase from Lowest Cost Plan
Post-April PSIP Plan	$26,526,206	6%
E3 Plan	$26,294,804	5%
E3 Plan with LNG	$24,938,940	–
E3 Plan with Generation Modernization	$26,562,410	7%
E3 Plan with LNG and Generation Modernization	$25,743,019	3%

Table 5-1. Net Present Value of Revenue Requirements: Hawaiian Electric

The annual revenue requirements are presented in real dollars and nominal dollars in Figure 5-1 and Figure 5-2.

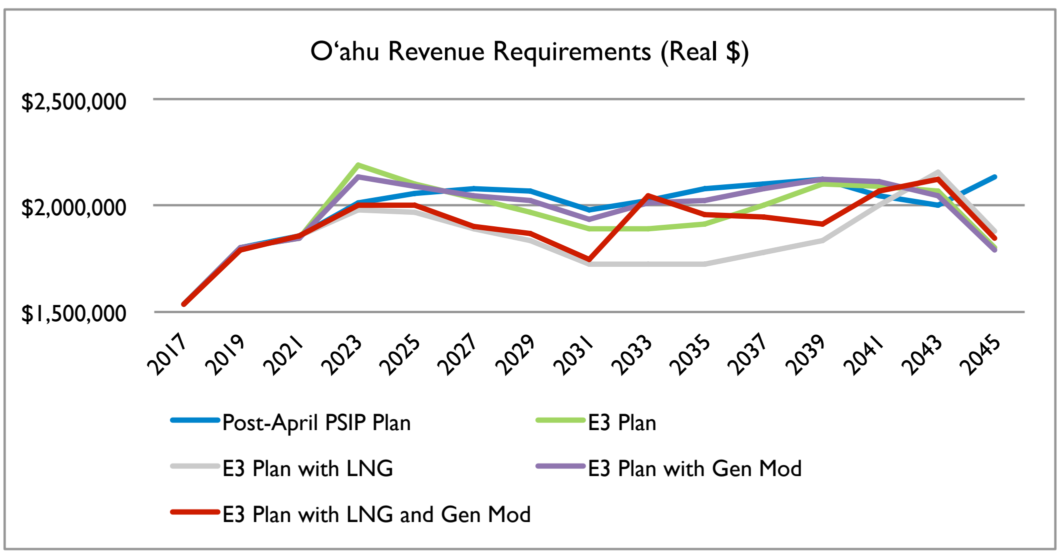


Figure 5-1. Revenue Requirement (Real $): O'ahu

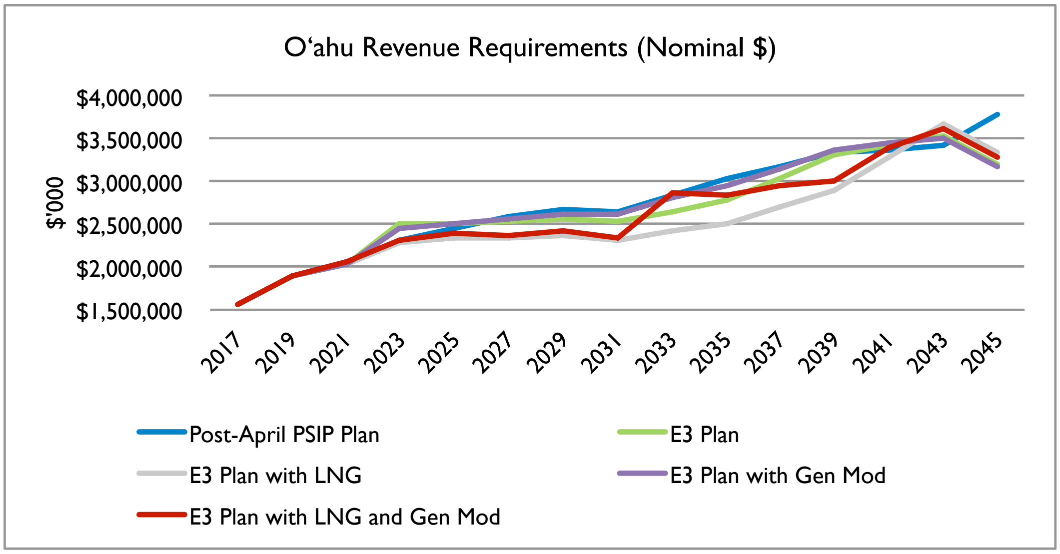


Figure 5-2. Revenue Requirements (Nominal $): O'ahu

Capital Expenditure Projections

The Power Supply capital expenditures range from a low of $2.4B ($1.0B in the first nine years) for the Post-April PSIP Plan to a high of $6.8B ($1.7B in the first nine years) for the E3 Plan, consistent with the mix and timing of resource additions and retirements.

Table 5-2 through Table 5-6 summarize the capital expenditures by category for each plan.

Post-April PSIP Plan

Under this resource plan, $2.4B (nominal) of capital will be invested by the utility in Power Supply assets over the 29 year planning period, with $1.0B (nominal) of this investment occurring in the first nine years of the period.

000)	2017 2021	2022 2025	2026 2030	2031 2035	2036 2040	2041 2045	Total
Power Supply	$294,800	$209,937	$24,779	$20,064	$15,749	$7,182	$572,511
Smart Grid	$90,910	$11,855	$9,062	$7,021	$5,543	$0	$124,391
ERP	$47,747	$0	$0	$0	$0	$0	$47,747
Balance-of-utility business	$1,290,835	$958,637	$1,725,726	$1,357,979	$1,374,708	$1,955,370	$8,663,255
Total	$1,724,292	$1,180,429	$1,759,567	$1,385,064	$1,396,000	$1,962,552	$9,407,904

Table 5-2. Hawaiian Electric Capital Expenditures (Nominal $): Post-April PSIP Plan

E3 Plan

Under this resource plan, $6.8B (nominal) of capital will be invested by the utility in Power Supply assets over the 29 year planning period, with $1.7B (nominal) of this investment occurring in the first nine years of the period.

000)	2017 2021	2022 2025	2026 2030	2031 2035	2036 2040	2041 2045	Total
Power Supply	$294,800	$208,531	$24,779	$20,064	$15,749	$196,629	$760,552
Smart Grid	$90,910	$11,855	$9,062	$7,021	$5,543	$0	$124,391
ERP	$47,747	$0	$0	$0	$0	$0	$47,747
Balance-of-utility business	$1,181,899	$1,702,267	$1,420,076	$1,820,671	$2,755,169	$4,111,374	$12,991,456
Total	$1,615,356	$1,922,653	$1,453,917	$1,847,756	$2,776,461	$4,308,003	$13,924,146

Table 5-3. Hawaiian Electric Capital Expenditures (Nominal $): E3 Plan

E3 Plan with LNG

Under this resource plan, $6.6B (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 nine years of the period.

000)	2017 2021	2022 2025	2026 2030	2031 2035	2036 2040	2041 2045	Total
Power Supply	$550,877	$225,381	$24,779	$20,064	$15,749	$156,565	$993,415
Smart Grid	$90,910	$11,855	$9,062	$7,021	$5,543	$0	$124,391
ERP	$47,747	$0	$0	$0	$0	$0	$47,747
Balance-of-utility business	$1,153,396	$1,686,429	$1,181,793	$1,677,800	$2,573,340	$4,612,373	$12,885,131
Total	$1,842,930	$1,923,665	$1,215,634	$1,704,885	$2,594,632	$4,768,938	$14,050,684

Table 5-4. Hawaiian Electric Capital Expenditures (Nominal $): E3 Plan with LNG

E3 Plan with Generation Modernization

Under this resource plan, $6.7B (nominal) of capital will be invested by the utility in Power Supply assets over the 29 year planning period, with $1.7B (nominal) of this investment occurring in the first nine years of the period.

000)	2017 2021	2022 2025	2026 2030	2031 2035	2036 2040	2041 2045	Total
Power Supply	$294,800	$209,937	$24,779	$20,064	$15,749	$7,182	$572,511
Smart Grid	$90,910	$11,855	$9,062	$7,021	$5,543	$0	$124,391
ERP	$47,747	$0	$0	$0	$0	$0	$47,747
Balance-of-utility business	$1,265,110	$1,864,526	$1,489,556	$1,846,125	$2,610,541	$4,111,374	$13,187,232
Total	$1,698,567	$2,086,318	$1,523,397	$1,873,210	$2,631,833	$4,118,556	$13,931,881

Table 5-5. Hawaiian Electric Capital Expenditures (Nominal $): E3 Plan with Generation Modernization

E3 Plan with LNG and Generation Modernization

Under this resource plan, $6.4B (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 nine years of the period.

000)	2017 2021	2022 2025	2026 2030	2031 2035	2036 2040	2041 2045	Total
Power Supply	$550,877	$226,787	$24,779	$20,064	$15,749	$7,182	$845,438
Smart Grid	$90,910	$11,855	$9,062	$7,021	$5,543	$0	$124,391
ERP	$47,747	$0	$0	$0	$0	$0	$47,747
Balance-of-utility business	$1,236,608	$1,686,882	$1,214,528	$1,534,633	$2,361,388	$4,666,661	$12,700,700
Total	$1,926,142	$1,925,524	$1,248,369	$1,561,718	$2,382,680	$4,673,843	$13,718,276

Table 5-6. Hawaiian Electric Capital Expenditures (Nominal $): E3 Plan with LNG and Generation Modernization

Residential Customer Bill and Rate Impacts

Declines in estimated residential usage through energy efficiency provide an offset to rate increases for needed new investments. Significant upfront expenditures for new generation facilities and batteries in the first seven years of all plans contribute to the increase in bills through 2023. With these investments, 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 affordable.

The E3 Plan with Generation Modernization is the lowest cost plan and the Post-April PSIP is the highest cost plan.

Average Annual Bill Increase 2017 2045)	Real $	Nominal
Post-April PSIP Plan	0.34%	2.28%
E3 Plan	(0.20)%	1.72%
E3 Plan with LNG	(0.05)%	1.88%
E3 Plan with Generation Modernization	(0.22)%	1.71%
E3 Plan with LNG and Generation Modernization	(0.11)%	1.82%

Table 5-7. Average Annual Residential Bill Increases: Hawaiian Electric

The residential customer bill impact for the five Plans are presented in real dollars and nominal dollars in Figure 5-3 and Figure 5-4.

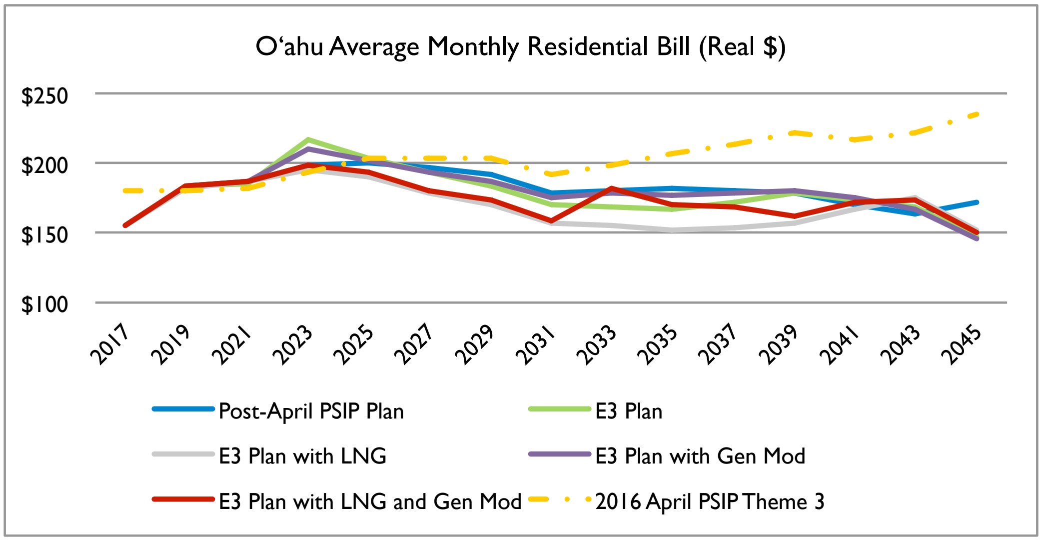


Figure 5-3. Average Monthly Residential Bill (Real $): O'ahu

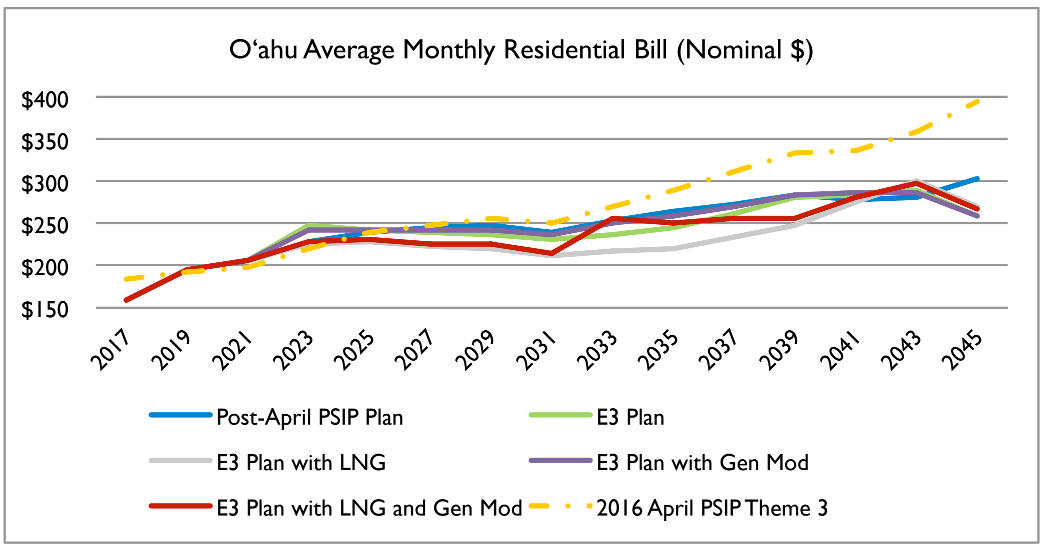


Figure 5-4. Average Monthly Residential Bill (Nominal $): O'ahu

As a result of an increasing revenue requirement in combination with declining sales, residential customer rates, in real 2016 $, rise over the planning period for all plans. Significant upfront expenditures in new generation facilities and batteries in the first seven years of all plans contribute to the increase in rates through 2023. In 2023, the E3 Plan with LNG and Generation Modernization increases due to additional PPA costs. Starting in 2044, all E3 plans decrease due to reductions in PPA costs. The E3 Plan with LNG and the E3 Plan with LNG and Generation Modernization are generally the lowest rate plans. The Post-April PSIP and E3 Plan with Generation Modernization are the highest rate plans.

The residential customer rates are presented in real dollars and nominal dollars in Figure 5-5 and Figure 5-6.

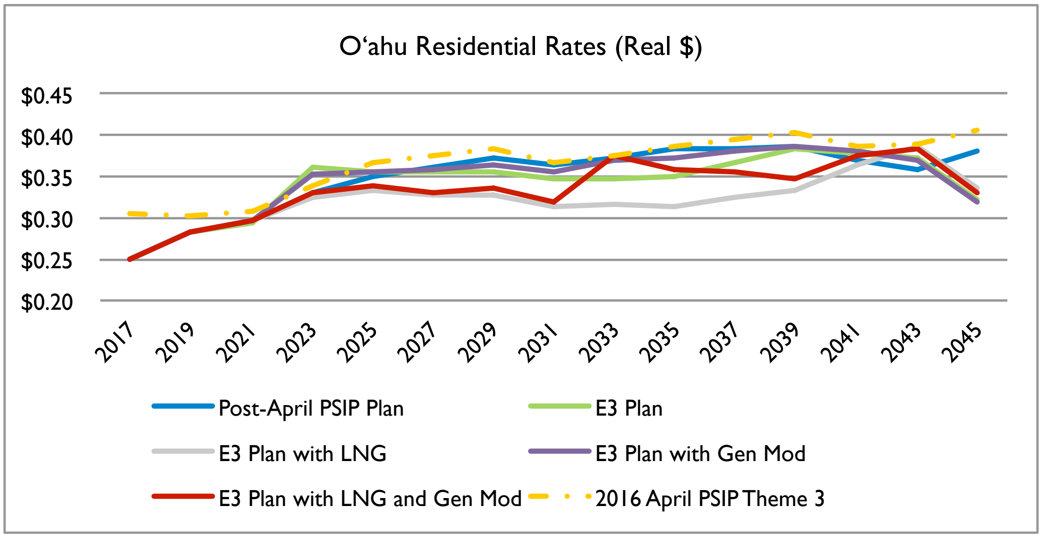


Figure 5-5. Residential Rates (Real $): O'ahu

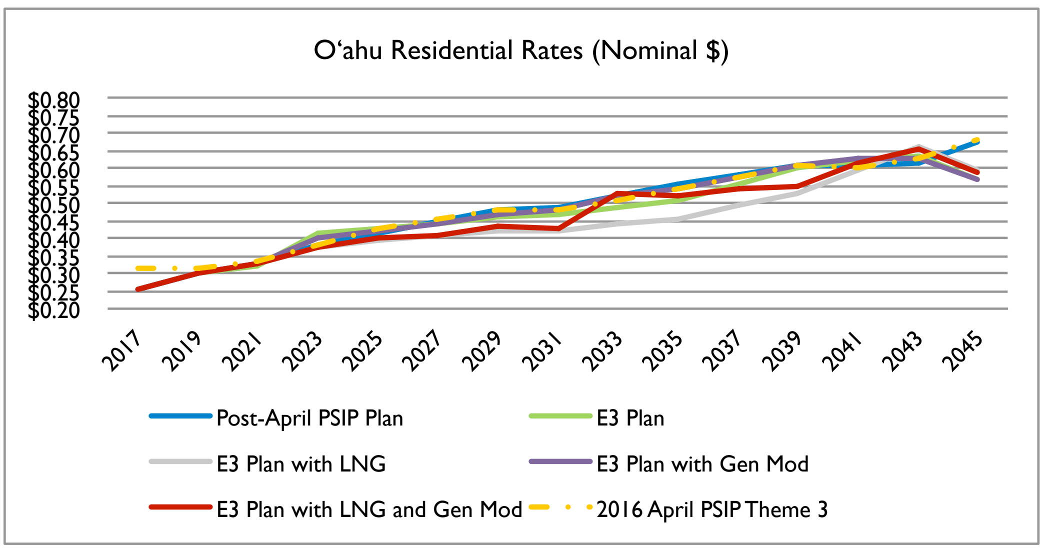


Figure 5-6. Residential Rates (Nominal $): O'ahu

Total Costs to Achieve 100% Renewable Energy

Total 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.

Figure 5-7 provides, by Plan, the Net Present Value of this cost stream over the period 2017 through 2045.

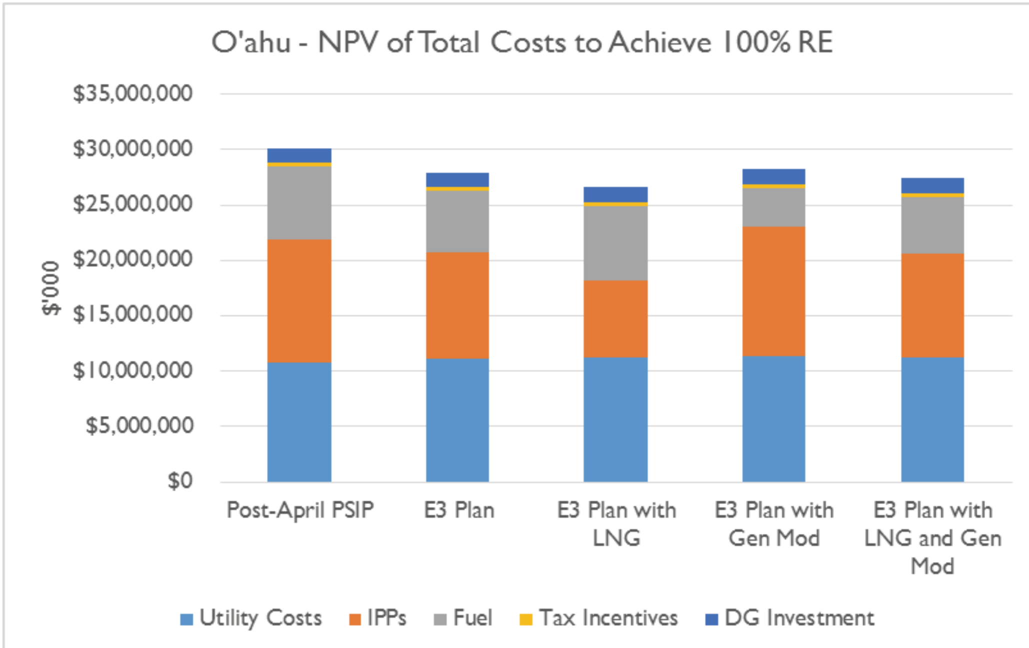


Figure 5-7. Total Costs of the Plans 2017–2045: Hawaiian Electric

MAUI ELECTRIC 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 approximating estimations were made to break these islands out individually as well. For Maui, the E3 Plan with LNG shows the lowest overall revenue requirements over the 2017 to 2045 planning period. The Post-April PSIP Plan is the highest cost plan.

Revenue Requirements

Table 5-8 shows the Net Present Value of the annual revenue requirements for each Plan.

Net Present Value of Revenue Requirement 000)	000)	Increase from Lowest Cost Plan
Post-April PSIP Plan	$5,287,079	6%
E3 Plan	$5,048,805	1%
E3 Plan with LNG	$4,982,469	–

Table 5-8. Net Present Value of Revenue Requirements: Maui Electric

The annual revenue requirements are presented in real dollars and nominal dollars in Figure 5-8 through Figure 5-13.

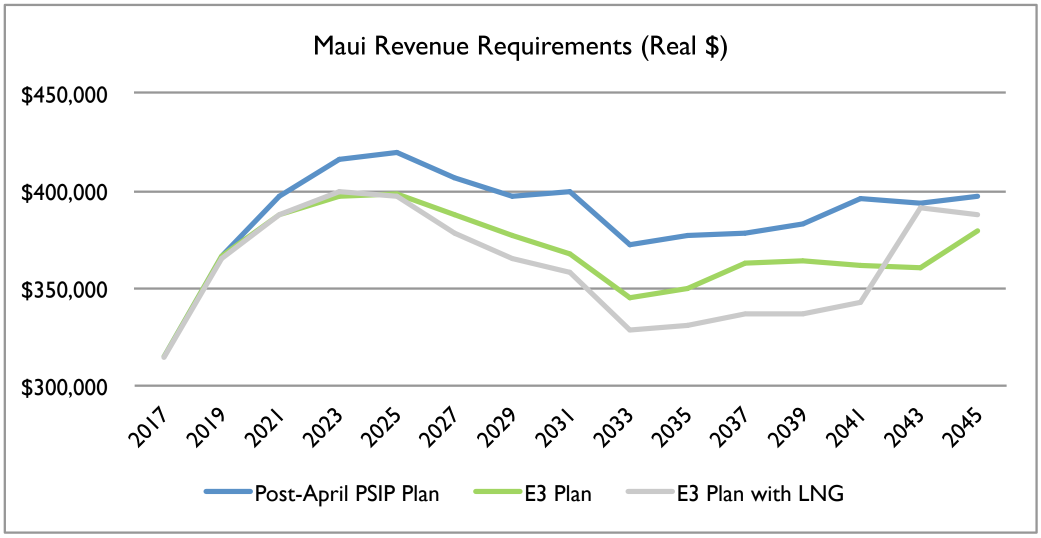


Figure 5-8. Revenue Requirements (Real $): Maui

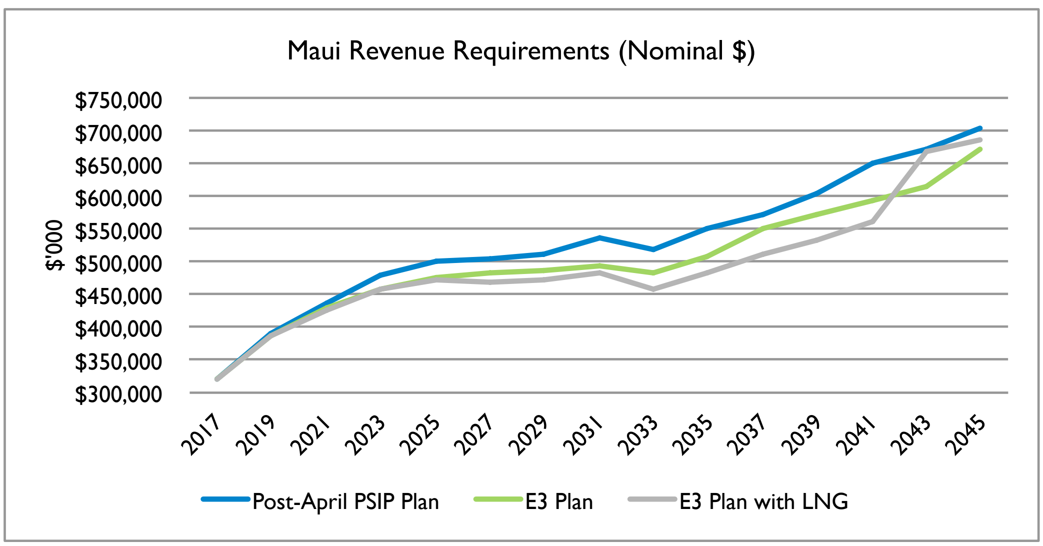


Figure 5-9. Revenue Requirements (Nominal $): Maui

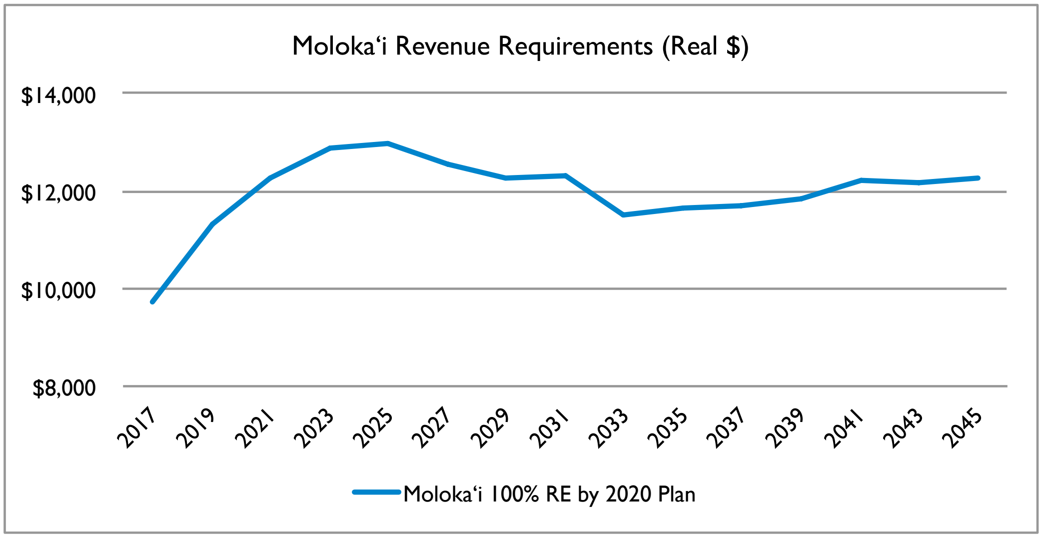


Figure 5-10. Revenue Requirements (Real $): Moloka'i

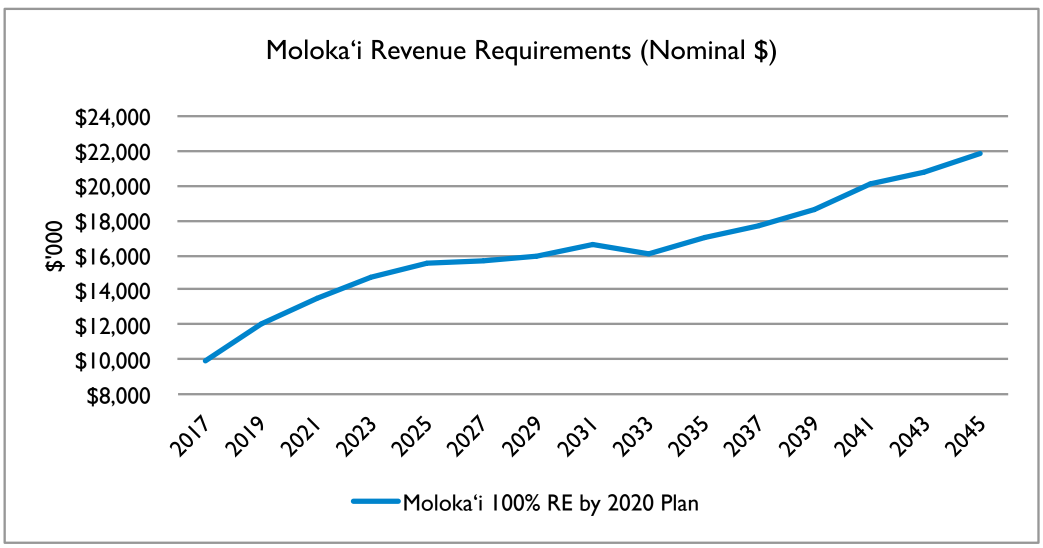


Figure 5-11. Revenue Requirements (Nominal $): Moloka'i

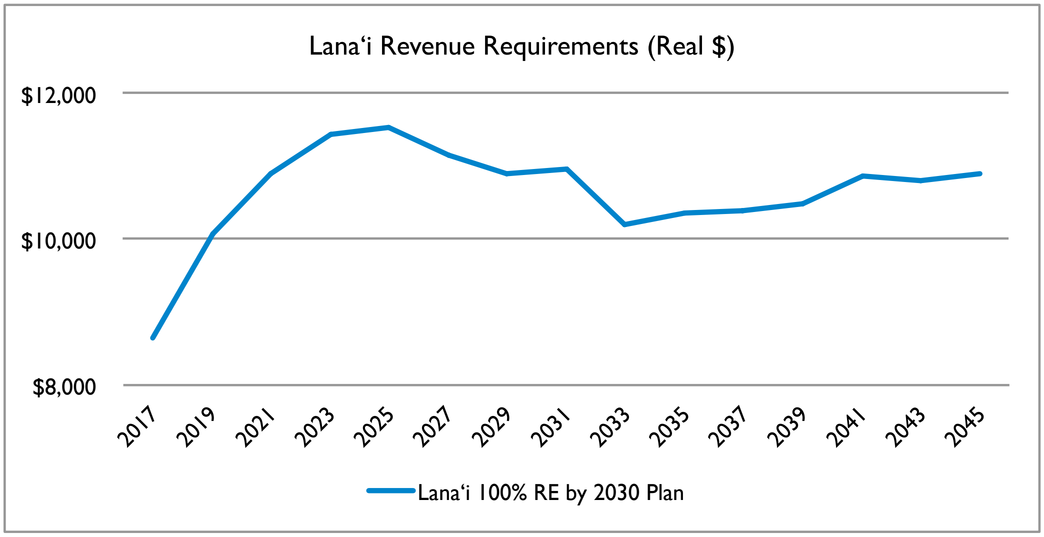


Figure 5-12. Revenue Requirements (Real $): Lana'i

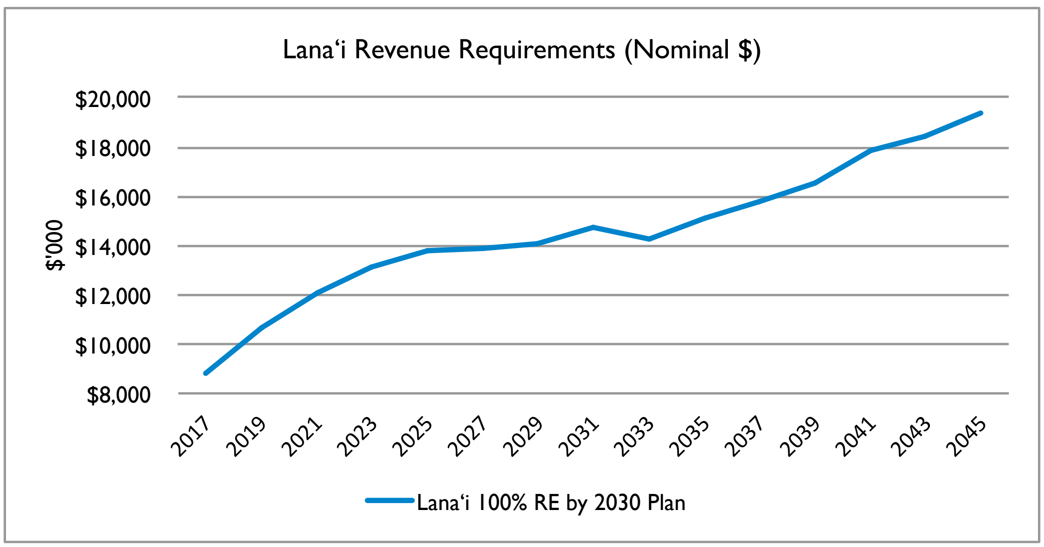


Figure 5-13. Revenue Requirements (Nominal $): Lana'i

Capital Expenditure Projections

The Power Supply capital expenditures range from a low of $0.6B ($0.3B in the first nine years) for the Post-April PSIP Plan to a high of $1.2B ($0.3B in the first nine years) for the E3 Plan with LNG, consistent with the mix and timing of resource additions and retirements.

Table 5-9 through Table 5-17 summarize the capital expenditures by category for each Plan, for all three islands, as well as Moloka'i and Lana'i separately.

Hawaiian Electric
Maui Electric
Hawai'i Electric Light

Post-April PSIP Plan

Under this 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 nine years of the period.

000)	2017 2021	2022 2025	2026 2030	2031 2035	2036 2040	2041 2045	Total
Power Supply	$0	$0	$0	$0	$0	$0	$0
Smart Grid	$17,559	$1,626	$1,639	$1,634	$1,153	$0	$23,611
ERP	$8,667	$0	$0	$0	$0	$0	$8,667
Balance-of-utility business	$297,473	$258,944	$226,080	$247,797	$287,706	$251,280	$1,569,280
Total	$323,699	$260,570	$227,719	$249,431	$288,859	$251,280	$1,601,558

Table 5-9. Capital Expenditures (Nominal $): Post-April PSIP Plan – Maui

000)	2017 2021	2022 2025	2026 2030	2031 2035	2036 2040	2041 2045	Total
Power Supply	$0	$0	$0	$0	$0	$0	$0
Smart Grid	$0	$0	$0	$0	$0	$0	$0
ERP	$0	$0	$0	$0	$0	$0	$0
Balance-of-utility business	$4,864	$106	$114	$3,915	$116	$67	$9,182
Total	$4,864	$106	$114	$3915	$116	$67	$9,182

Table 5-10. Capital Expenditures (Nominal $): Post-April PSIP Plan – Moloka‘i

000)	2017 2021	2022 2025	2026 2030	2031 2035	2036 2040	2041 2045	Total
Power Supply	$0	$0	$0	$0	$0	$0	$0
Smart Grid	$0	$0	$0	$0	$0	$0	$0
ERP	$0	$0	$0	$0	$0	$0	$0
Balance-of-utility business	$3,778	$416	$646	$3,008	$0	$0	$7,848
Total	$3,778	$416	$646	$3,008	$0	$0	$7,848

Table 5-11. Capital Expenditures (Nominal $): Post-April PSIP Plan – Lana‘i

E3 Plan

Under this resource plan, $0.9B (nominal) of capital will be invested by the utility in Power Supply assets over the 29 year planning period, with $0.2B (nominal) of this investment occurring in the first nine years of the period.

000)	2017 2021	2022 2025	2026 2030	2031 2035	2036 2040	2041 2045	Total
Power Supply	$0	$0	$0	$0	$0	$0	$0
Smart Grid	$17,559	$1,626	$1,639	$1,634	$1,153	$0	$23,611
ERP	$8,667	$0	$0	$0	$0	$0	$8,667
Balance-of-utility business	$245,947	$232,471	$276,967	$267,898	$339,170	$561,463	$1,923,916
Total	$272,173	$234,097	$278,606	$269,532	$340,323	$561,463	$1,956,194

Table 5-12. Capital Expenditures (Nominal $): E3 Plan – Maui

000)	2017 2021	2022 2025	2026 2030	2031 2035	2036 2040	2041 2045	Total
Power Supply	$0	$0	$0	$0	$0	$0	$0
Smart Grid	$0	$0	$0	$0	$0	$0	$0
ERP	$0	$0	$0	$0	$0	$0	$0
Balance-of-utility business	$4,864	$106	$114	$3,915	$116	$67	$9,182
Total	$4,864	$106	$114	$3,915	$116	$67	$9,182

Table 5-13. Capital Expenditures (Nominal $): E3 Plan – Moloka‘i

000)	2017 2021	2022 2025	2026 2030	2031 2035	2036 2040	2041 2045	Total
Power Supply	$0	$0	$0	$0	$0	$0	$0
Smart Grid	$0	$0	$0	$0	$0	$0	$0
ERP	$0	$0	$0	$0	$0	$0	$0
Balance-of-utility business	$3,778	$416	$646	$3,008	$0	$0	$7,848
Total	$3,778	$416	$646	$3,008	$0	$0	$7,848

Table 5-14. Capital Expenditures (Nominal $): E3 Plan – Lana‘i

E3 Plan with LNG

Under this resource plan, $1.2B (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 nine years of the period.

000)	2017 2021	2022 2025	2026 2030	2031 2035	2036 2040	2041 2045	Total
Power Supply	$73,083	$3,847	$0	$0	$0	$0	$76,930
Smart Grid	$17,559	$1,626	$1,639	$1,634	$1,153	$0	$23,611
ERP	$8,667	$0	$0	$0	$0	$0	$8,667
Balance-of-utility business	$255,846	$257,029	$229,715	$248,898	$371,970	$740,213	$2,103,671
Total	$355,155	$262,502	$231,354	$250,532	$373,123	$740,213	$2,212,879

Table 5-15. Capital Expenditures (Nominal $): E3 Plan with LNG – Maui

000)	2017 2021	2022 2025	2026 2030	2031 2035	2036 2040	2041 2045	Total
Power Supply	$0	$0	$0	$0	$0	$0	$0
Smart Grid	$0	$0	$0	$0	$0	$0	$0
ERP	$0	$0	$0	$0	$0	$0	$0
Balance-of-utility business	$4,864	$106	$114	$3,915	$116	$67	$9,182
Total	$4,864	$106	$114	$3,915	$116	$67	$9,182

Table 5-16. Capital Expenditures (Nominal $): E3 Plan with LNG – Moloka‘i

000)	2017 2021	2022 2025	2026 2030	2031 2035	2036 2040	2041 2045	Total
Power Supply	$0	$0	$0	$0	$0	$0	$0
Smart Grid	$0	$0	$0	$0	$0	$0	$0
ERP	$0	$0	$0	$0	$0	$0	$0
Balance-of-utility business	$3,778	$416	$646	$3,008	$0	$0	$7,848
Total	$3,778	$416	$646	$3,008	$0	$0	$7,848

Table 5-17. Capital Expenditures (Nominal $): E3 Plan with LNG – Lana‘i

Residential Customer Bill and Rate Impacts

Declines in estimated residential usage through energy efficiency provide an offset to rate increases for needed new investments. Significant upfront expenditures in battery storage in the first eight to nine years of all plans contribute to the increase in bills through 2024–2025. With these investments, 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 affordable.

The E3 Plan is the lowest cost plan. The Post-April PSIP is the highest cost plan.

Average Annual Bill Increase (2017 2045)	Real $	Nominal $
Post-April PSIP Plan	(0.14)%	1.78%
E3 Plan	(0.31)%	1.61%
E3 Plan with LNG	(0.25)%	1.68%

Table 5-18. Average Annual Residential Bill Increases: Maui Electric

The residential customer bill impact for the three Plans are presented in real dollars and nominal dollars in Figure 5-14 through Figure 5-19.

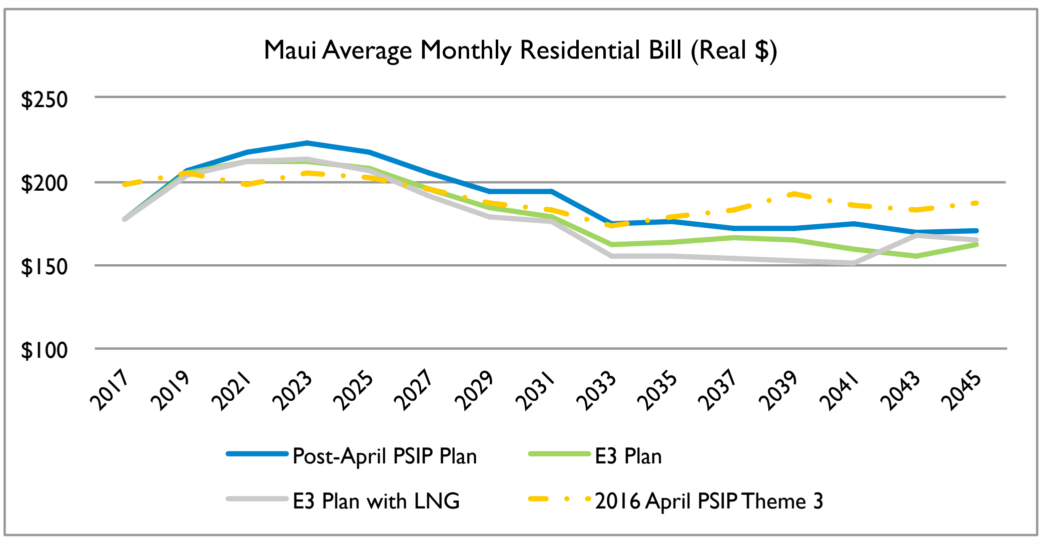


Figure 5-14. Average Monthly Residential Bill (Real $): Maui

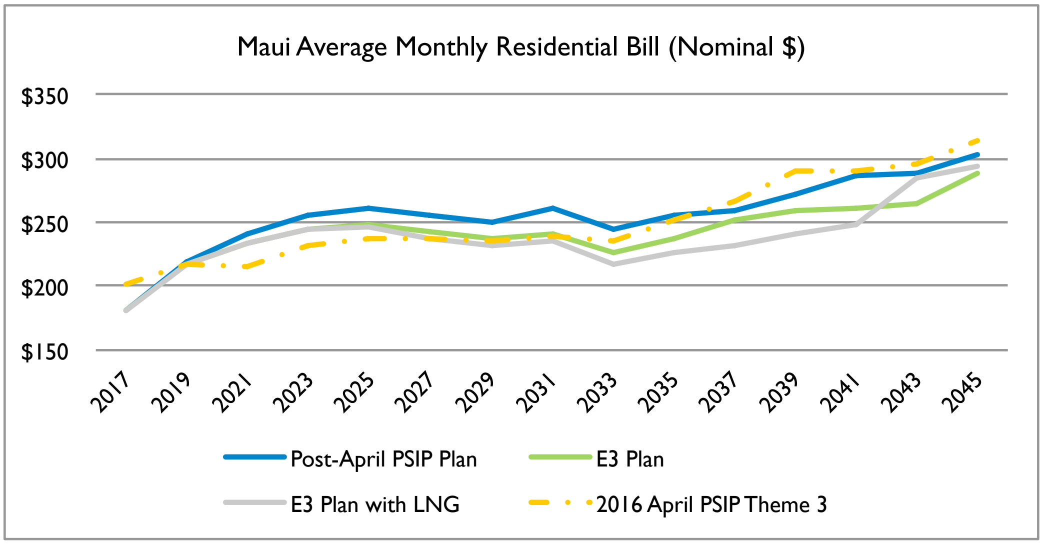


Figure 5-15. Average Monthly Residential Bill (Nominal $): Maui

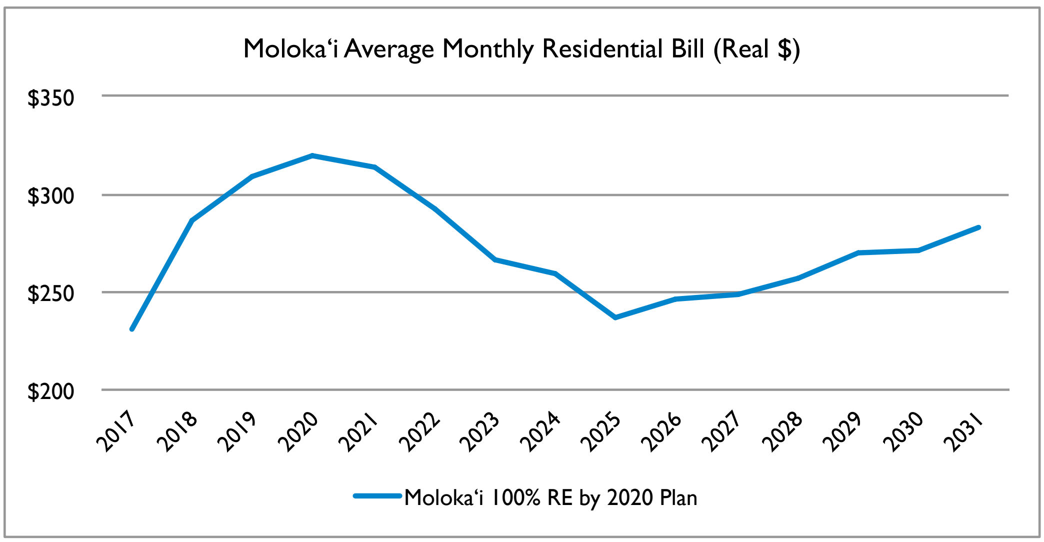


Figure 5-16. Average Monthly Residential Bill (Real $): Molokaʻi

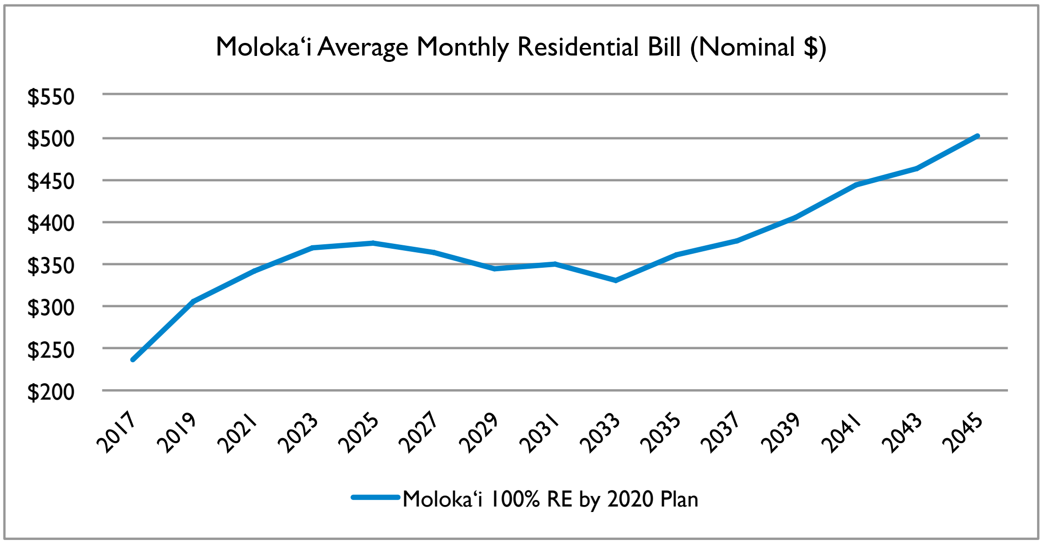


Figure 5-17. Average Monthly Residential Bill (Nominal $): Moloka'i

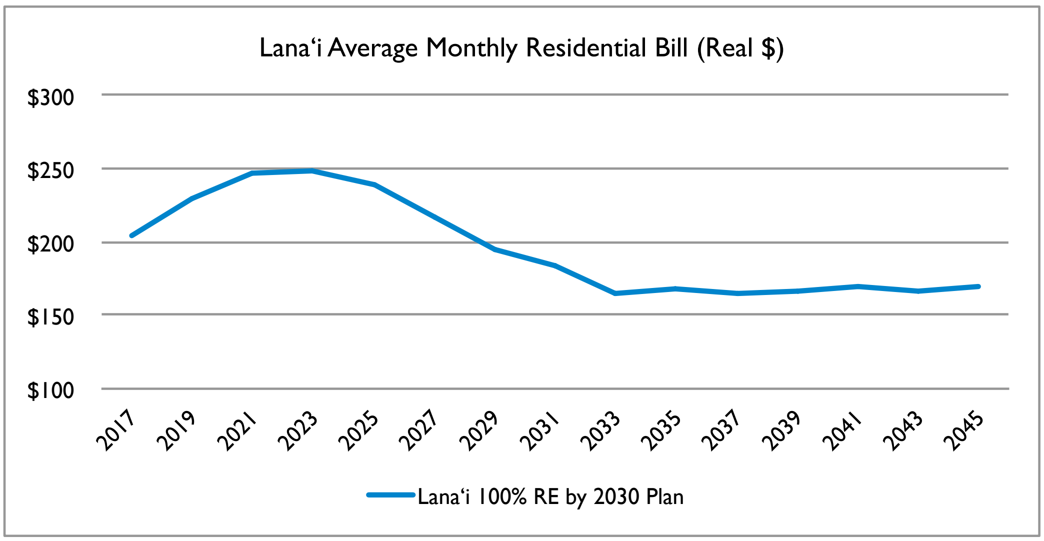


Figure 5-18. Average Monthly Residential Bill (Real $): Lana'i

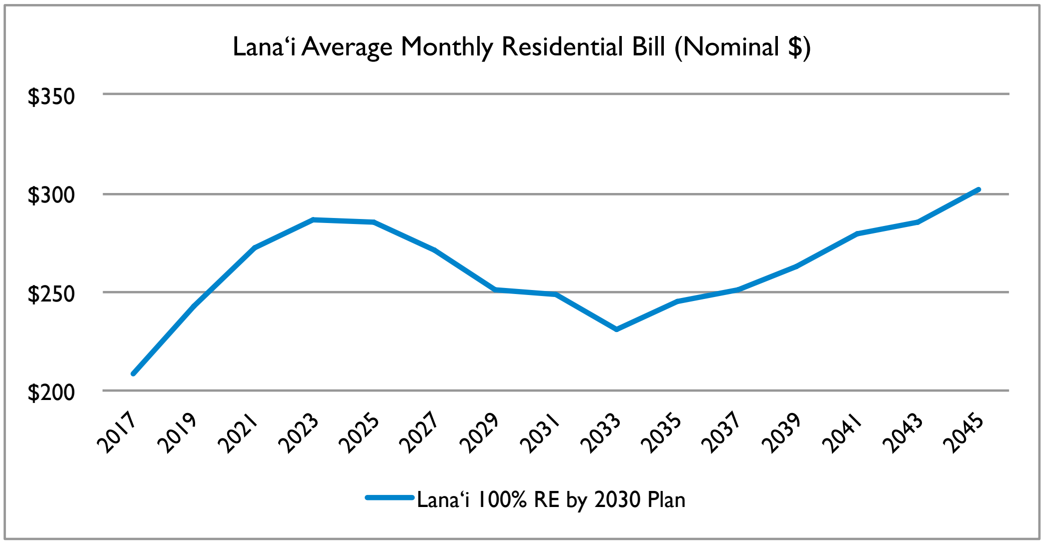


Figure 5-19. Average Monthly Residential Bill (Nominal $): Lana'i

As a result of an increasing revenue requirement in combination with declining sales, residential customer rates, in real 2016 $, rise over the planning period for all plans. The significant upfront expenditures in battery storage in the first eight to nine years of all plans contribute to the increase in rates through 2024–2025. The increase in rates in 2031 is driven by the addition of load shifting batteries. The decrease in rates in 2033 is driven by lower PPA costs. The increase in E3 Plan with LNG in 2042 is driven by a shift in fuel type. The E3 Plan with LNG is the lowest rate plan. The Post-April PSIP is the highest rate plan.

The residential customer rates are presented in real dollars and nominal dollars in Figure 5-20 through Figure 5-25.

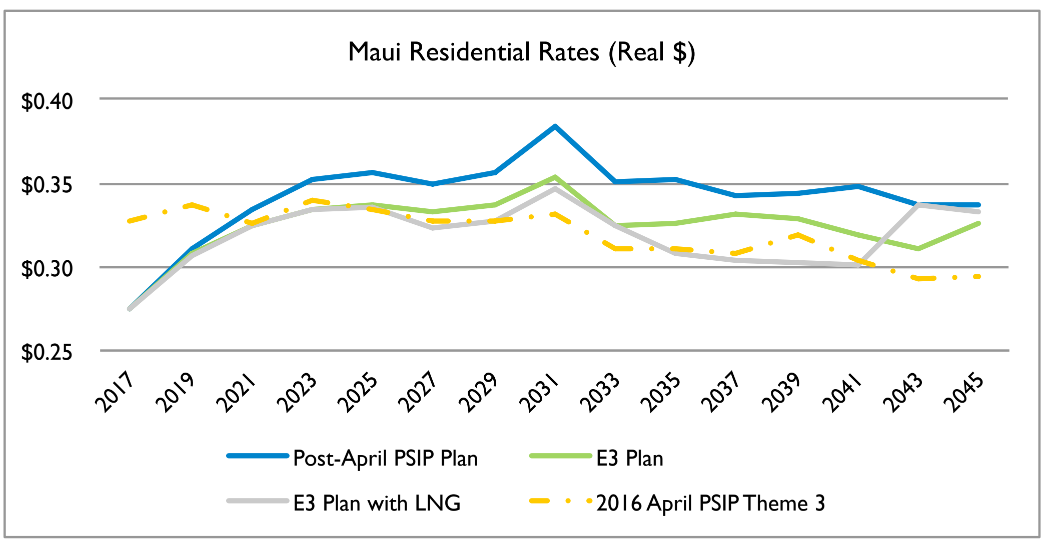


Figure 5-20. Residential Rates (Real $): Maui

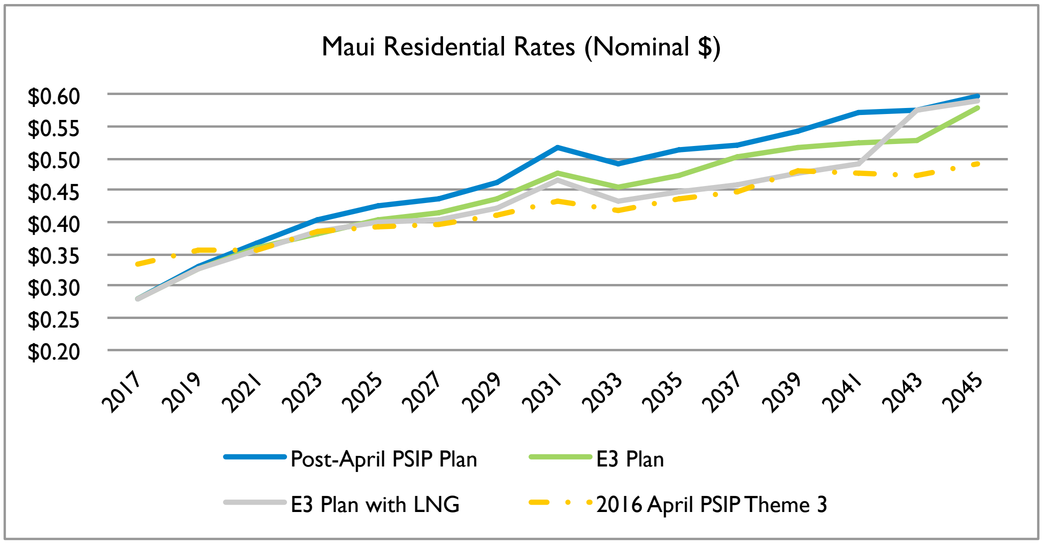


Figure 5-21. Residential Rates (Nominal $): Maui

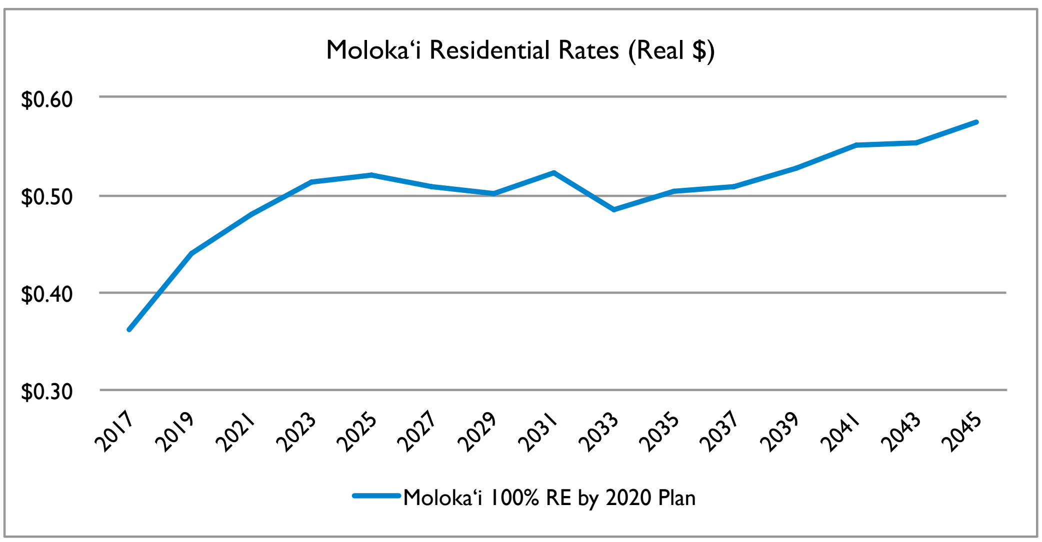


Figure 5-22. Residential Rates (Real $): Moloka‘i

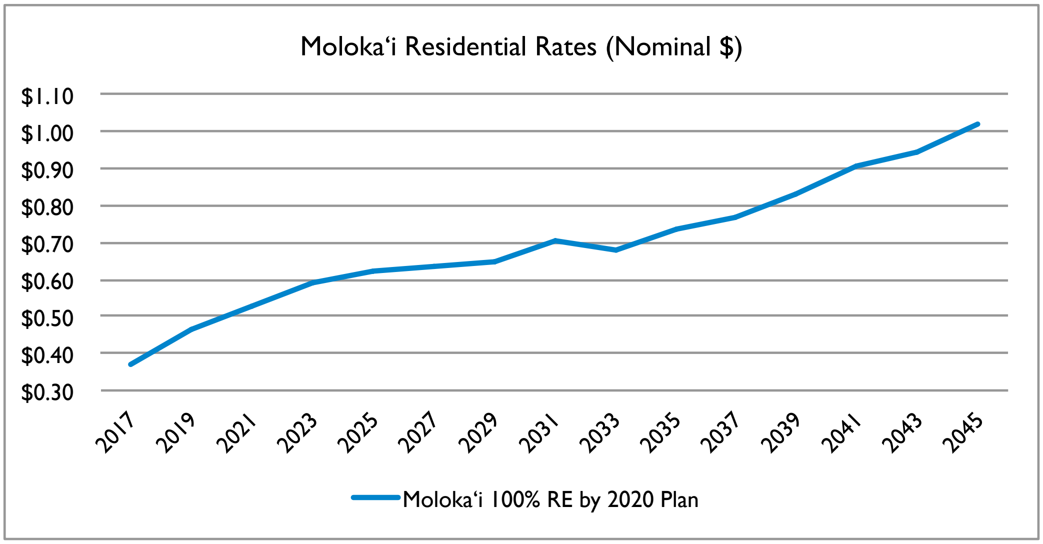


Figure 5-23. Residential Rates (Nominal $): Moloka'i

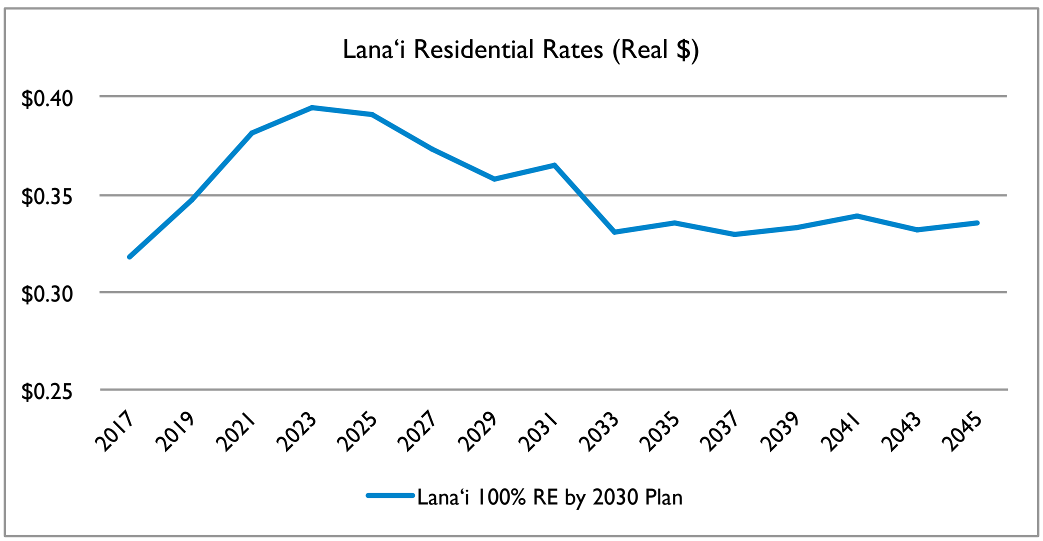


Figure 5-24. Residential Rates (Real $): Lana'i

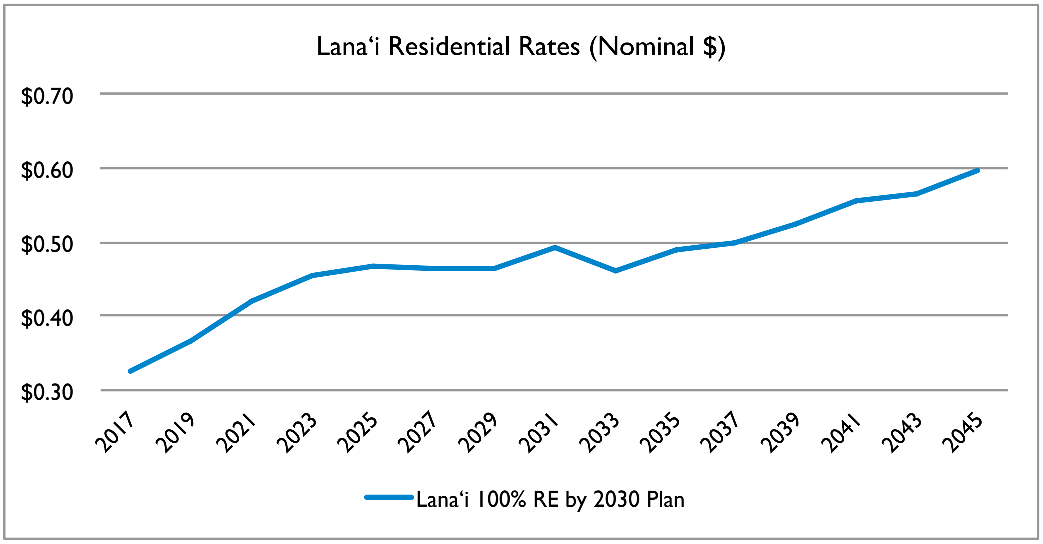


Figure 5-25. Residential Rates (Nominal $): Lana'i

Total Costs to Achieve 100% Renewable Energy

Total 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.

Figure 5-26 provides, by Plan, the Net Present Value of this cost stream over the period 2017 through 2045.

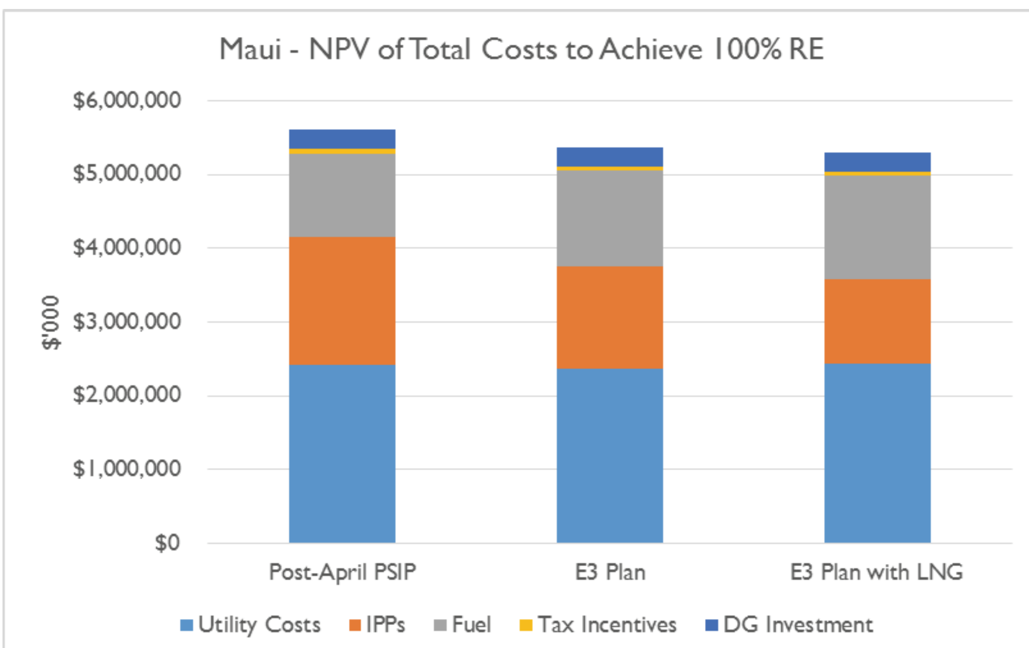


Figure 5-26. Total Costs of the Plans 2017–2045: Maui Electric

HAWAI'I ELECTRIC LIGHT FINANCIAL IMPACTS

The data and analyses presented in this section cover all of Hawai'i Electric Light's service territory and customers. For Hawai'i Island, the E3 Plan shows the lowest overall revenue requirements over the 2017 to 2045 planning period. The Post-April PSIP Plan is the highest cost plan.

Revenue Requirements

Table 5-19 shows the Net Present Value of the annual revenue requirements for each Plan.

Net Present Value of Revenue Requirement 000)	000)	Increase from Lowest Cost Plan
Post-April PSIP Plan	$5,036,269	6%
E3 Plan	$4,743,167	–
E3 Plan with LNG	$4,838,515	2%

Table 5-19. Net Present Value of Revenue Requirement: Hawai'i Electric Light

The annual revenue requirements are presented in real dollars and nominal dollars in Figure 5-27 and Figure 5-28.

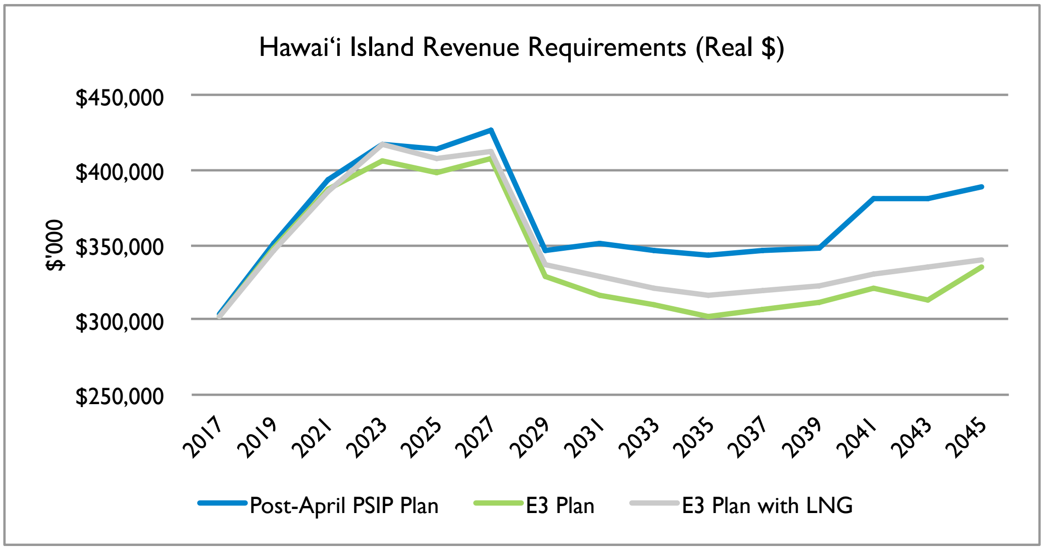


Figure 5-27. Revenue Requirements (Real $): Hawai'i Island

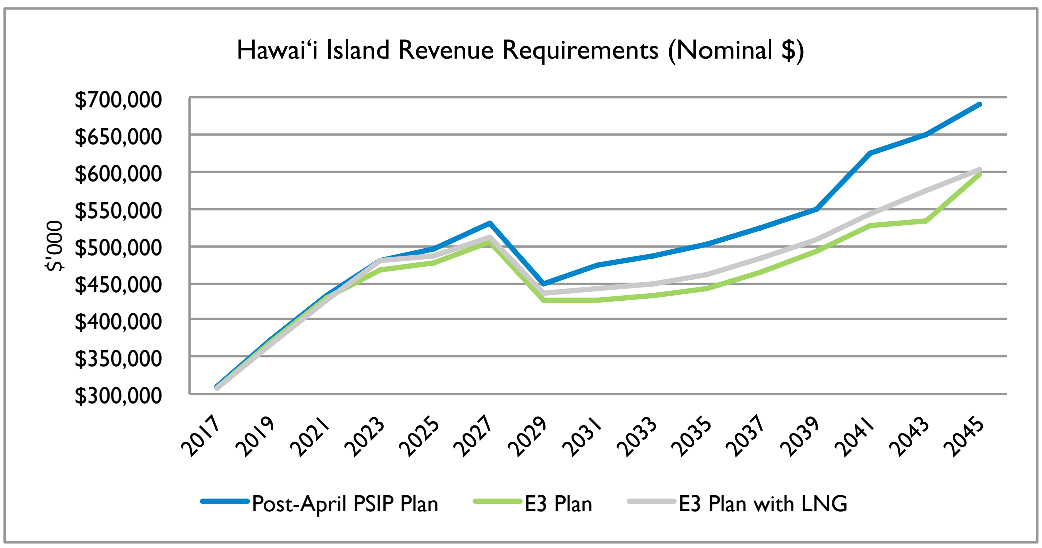


Figure 5-28. Revenue Requirements (Nominal $): Hawai'i Island

Capital Expenditure Projections

The Power Supply capital expenditures range from a low of $0.2B ($0.1B in the first nine years) for the Post-April PSIP Plan to a high of $0.7B ($0.2 B in the first nine years) for the E3 Plan with LNG, consistent with the mix and timing of resource additions and retirements.

Table 5-20 through Table 5-22 summarize the capital expenditures by category for each Plan, for all three islands.

Post-April PSIP Plan

Under this resource plan, $0.2B (nominal) of capital will be invested by the utility in Power Supply assets over the 29 year planning period, with $0.1B (nominal) of this investment occurring in the first nine years of the period.

000)	2017 2021	2022 2025	2026 2030	2031 2035	2036 2040	2041 2045	Total
Power Supply	$92,425	$0	$0	$0	$0	$0	$92,425
Smart Grid	$21,948	$2,139	$2,201	$2,054	$1,429	$0	$29,771
ERP	$9,173	$0	$0	$0	$0	$0	$9,173
Balance-of-utility business	$345,908	$227,694	$332,901	$350,397	$370,337	$393,456	$2,020,693
Total	$469,454	$229,833	$335,102	$352,451	$371,766	$393,456	$2,152,062

Table 5-20. Hawai'i Electric Light Capital Expenditures (Nominal $): Post-April PSIP Plan

E3 Plan

Under this resource plan, $0.7B (nominal) of capital will be invested by the utility in Power Supply assets over the 29 year planning period, with $0.2B (nominal) of this investment occurring in the first nine years of the period.

000)	2017 2021	2022 2025	2026 2030	2031 2035	2036 2040	2041 2045	Total
Power Supply	$92,425	$0	$0	$0	$0	$0	$92,425
Smart Grid	$21,948	$2,139	$2,201	$2,054	$1,429	$0	$29,771
ERP	$9,173	$0	$0	$0	$0	$0	$9,173
Balance-of-utility business	$295,443	$244,845	$403,779	$408,356	$469,830	$591,482	$2,413,735
Total	$418,989	$246,984	$405,980	$410,410	$471,259	$591,482	$2,545,104

Table 5-21. Hawai'i Electric Light Capital Expenditures (Nominal $): E3 Plan

E3 Plan with LNG

Under this resource plan, $0.7B (nominal) of capital will be invested by the utility in Power Supply assets over the 29 year planning period, with $0.2B (nominal) of this investment occurring in the first nine years of the period.

000)	2017 2021	2022 2025	2026 2030	2031 2035	2036 2040	2041 2045	Total
Power Supply	$138,820	$2,442	$0	$0	$0	$0	$141,262
Smart Grid	$21,948	$2,139	$2,201	$2,054	$1,429	$0	$29,771
ERP	$9,173	$0	$0	$0	$0	$0	$9,173
Balance-of-utility business	$297,665	$246,815	$372,883	$397,818	$461,123	$614,264	$2,390,568
Total	$467,606	$251,396	$375,084	$399,872	$462,552	$614,264	$2,570,774

Table 5-22. Hawai'i Electric Light Capital Expenditures (Nominal $): E3 Plan with LNG

Residential Customer Bill and Rate Impacts

Declines in estimated residential usage through energy efficiency provide an offset to rate increases for needed new investments. Significant upfront expenditures in battery storage in the first eight to nine years of all plans contribute to the increase in bills through 2024–2025. With these investments, 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 affordable.

The E3 Plan is the lowest cost plan. The Post-April PSIP is the highest cost plan.

Average Annual Bill Increase 2017 2045)	Real $	Nominal
Post-April PSIP Plan	(0.28)%	1.65%
E3 Plan	(0.87)%	1.05%
E3 Plan with LNG	(0.82)%	1.10%

Table 5-23. Average Annual Residential Bill Increases: Hawai'i Electric Light

The residential customer bill impact for the three Plans are presented in real dollars and nominal dollars in Figure 5-29 and Figure 5-30.

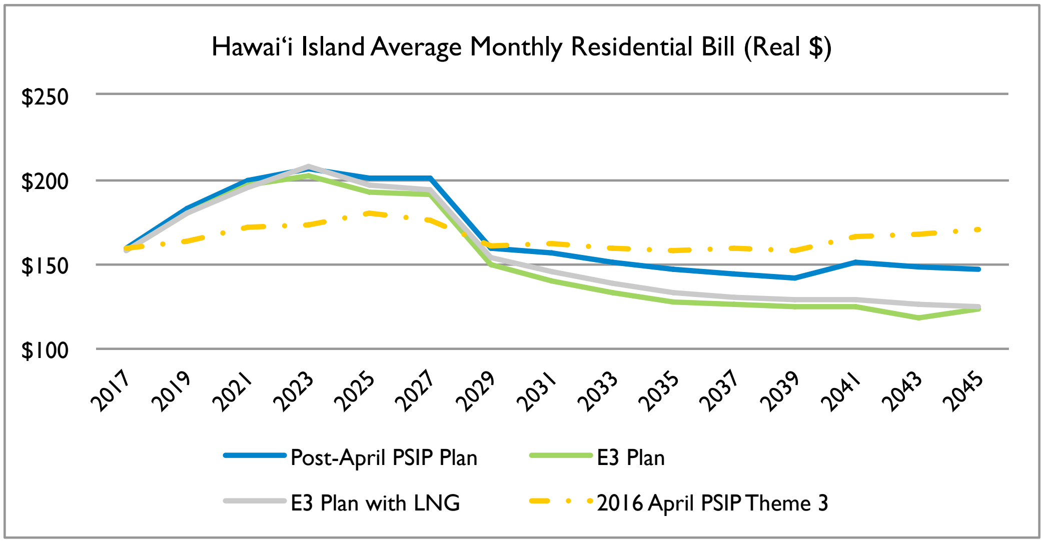


Figure 5-29. Average Monthly Residential Bill (Real $): Hawai'i Island

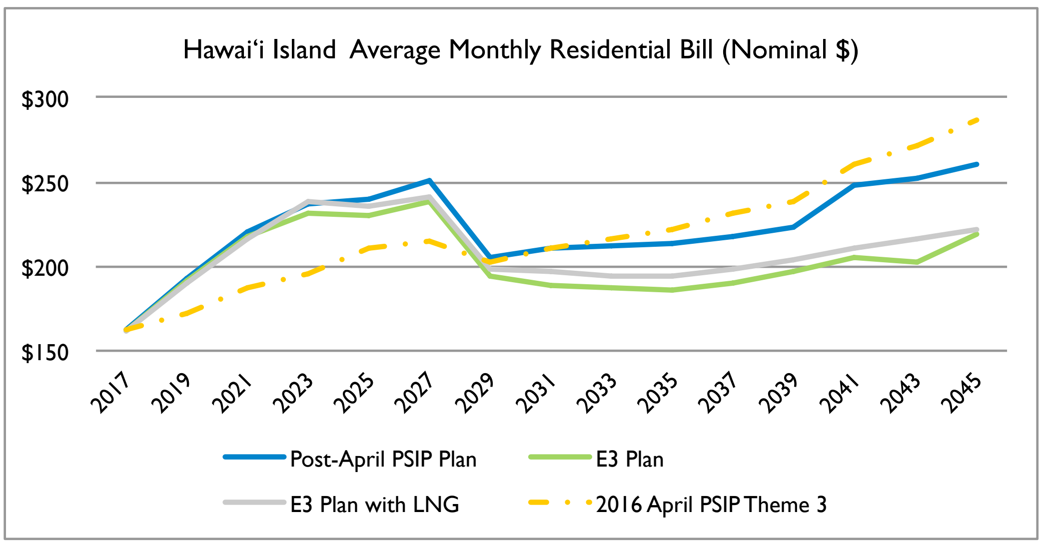


Figure 5-30. Average Monthly Residential Bill (Nominal $): Hawai'i Island

As a result of an increasing revenue requirement in combination with declining sales, residential customer rates, in real 2016 $, rise over the planning period for all plans. The significant upfront expenditures in battery storage in the first eleven years of all plans contribute to the increase in rates through 2027. The decrease in 2030 is driven by lower diesel costs. The increase in Post-April PSIP Plan in 2040 is driven by a shift in fuel type. The increase in E3 Plan in 2041 is driven by the addition of load shifting batteries. The E3 Plan is the lowest rate plan. The Post-April PSIP is the highest rate plan.

The residential customer rates are presented in real dollars and nominal dollars in Figure 5-31 and Figure 5-32.

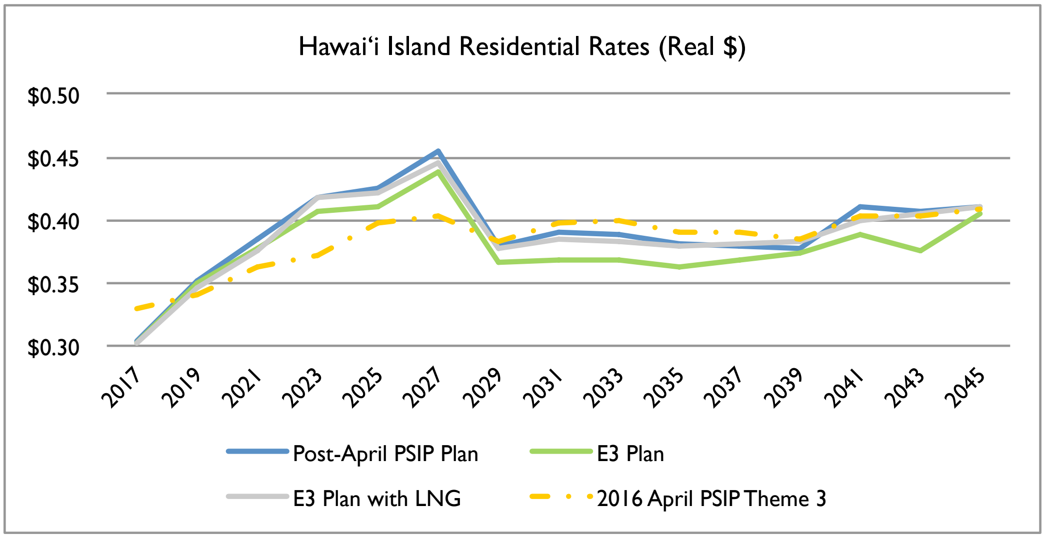


Figure 5-31. Residential Rates (Real $): Hawai'i Island

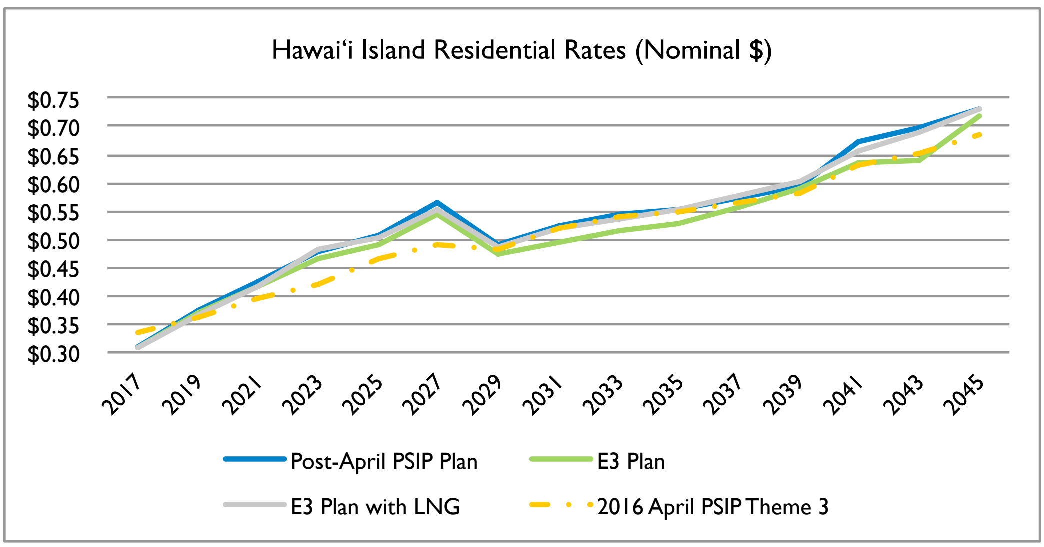


Figure 5-32. Residential Rates (Nominal $): Hawai'i Island

Total Costs to Achieve 100% Renewable Energy

Total 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.

Figure 5-33 provides, by Plan, the Net Present Value of this cost stream over the period 2017 through 2045.

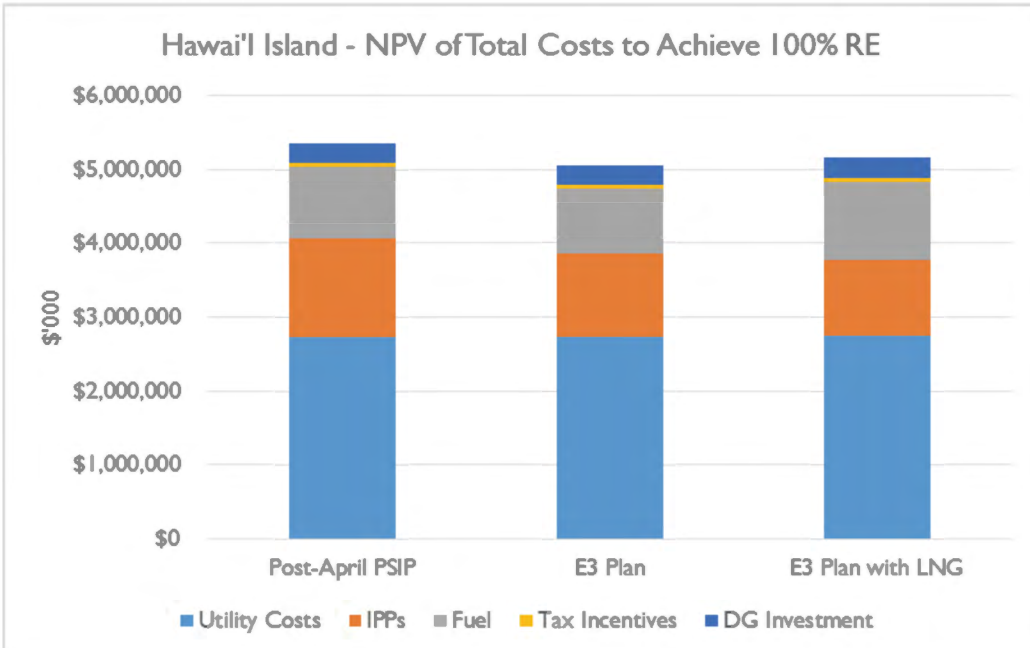


Figure 5-33. Total Costs of the Plans 2017–2045: Hawai'i Electric Light

EMERGING FACTORS AFFECTING FINANCIAL FORECASTS

A number of emerging factors, discussed below, may have an impact on the analyses performed in this chapter. Future plans will incorporate these emerging items as additional information is known or as policy decisions are made.

Statewide Rates

The above analysis was performed and presented on a Company and island specific basis. However, with the potential need to allocate 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.

Electric Vehicles

Additional incentives for the purchase of EVs, as well as expansion of the charging infrastructure, could drive significant adoption of electric vehicles in the State. This could further accelerate the implementation of renewable energy and storage options, while driving down the total cost of energy for all customers.

Tax Policy

Federal and state tax credits have been a major driver for renewable energy deployment across the State. Changes or expansion of these tax credits could result in significant changes to these forecasts.

President-Elect Trump

President-Elect Trump has taken strong positions on pro-business policies, such as reducing the corporate tax rate and funding infrastructure development. The final form of these policy changes could result in significant changes to these forecasts.

6. Planning and Analysis Considerations

PLANNING AND ANALYSIS CONSIDERATIONS

The focus of the December PSIP Update is on near term actions to advance the achievement of the State's 100% renewable energy goal, to stabilize and reduce customer rates, to maintain safe and reliable service and provide context to inform important pending and future longer-term resource acquisition options and system operation decisions.[30]

The PSIP addresses the uncertainty inherent in long-term forecasts and projections by maximizing long-term flexibility to accommodate integration of new emerging technologies and changing circumstances. In addition, the Companies have further improved the Analytical Methodology and incorporated E3's analysis using RESOLVE to identify theoretical least-cost plans that utilized unbiased, objective modelling while maximizing transparency. Furthermore, Ascend Analytics' PowerSimm modeling tool duplicated and validated the production simulation analyses performed by the Companies. In addition to completing analysis of long-term resources such as LNG or interisland transmission, we invested substantial time and effort in working with the Parties to obtain feedback on input assumptions and define sensitivity cases to test the robustness of the overall analyses. The Companies, with E3's assistance, completed sensitivity analyses around input received from the Parties.

As described in Chapter 3: Analytical Approach, E3 evaluated multiple cases that considered the impacts of significant, long-term decisions such as LNG and Interisland Transmission, and developed optimized resource plans for each case.

[30] Docket No. 2014-0183, Order No. 33877 at 2.

Our Renewable Energy Planning Principles

Translating the analytical results into near-term action plans requires the application of planning principles that focus on fulfilling the objective of this PSIP. Our renewable energy planning principles are as follows:

1. **Renewable energy is the first option.** We plan to aggressively pursue cost-effective renewable resource opportunities that work toward lowering generation costs on the grid. Additional renewable resources can be added cost-effectively, ahead of RPS requirements, as the technology of energy storage matures and costs decline. Removing Hawaiʻi from the volatility of world energy markets gives future generations a tremendous advantage, and creates a clean energy research and development industry for our state.

2. **The energy transformation must include everyone.** Electricity is essential. Our plans, as well as public policy, should ensure that ratemaking is fair and equitable, and ensure access to affordable electricity—especially those least able to buy self-generation and energy storage.

3. **Today's decisions must not crowd out tomorrow's breakthroughs.** Our plans keep the door open to developments in the rapidly evolving renewable generation market. We must be able to easily accept new, emerging, and breakthrough technologies that are most cost-effective and more efficient when they become commercially viable.

4. **The power grid needs to be modernized.** Energy distribution is rapidly moving into the digital age. We must re-invent our grid to facilitate a 100% renewable energy generation portfolio and enable technologies such as demand response, dynamic pricing, grid-edge devices, and electrification of transportation. Flexible generation is also needed to better integrate renewables.

5. **The lights have to stay on.** Reliability and resiliency of service and quality of power is vital for our economy, for our national security, and for critical societal infrastructure. Our customers expect it, deserve it, and pay for it. All of our plans must maintain or enhance the resiliency of the network—the grid—that delivers energy to the military, businesses, and homes.

6. **Our plans must address climate change.** Power plants are significant producers of greenhouse gas emissions. We have reduced those emissions more than 15% over the five years ending on December 31, 2015. Still, our plans must go further to reduce the warming of our planet and to minimize the impacts climate change will have on the energy-delivery network—rising sea levels, coastal erosion, increased temperatures, and erratic storm activity.

7. **There's no perfect choice.** No single energy source or technology can achieve our clean energy goals and every choice has an impact, whether it's physical or financial. While we can mitigate those impacts, attaining our 100% renewable energy goal has major implications for our land and natural resources, and the State's economy. We seek to make the best choices by engaging with customers, regulators, policy makers, and other stakeholders.

Reducing Risk to Customers

Our action plans also seek to minimize the risks to our customers. We therefore have developed our near-term action plans around managing the following 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. We believe our action plans set forth a realistic, "least regrets" path forward.

Technology Risk. Renewable technologies have various levels of commercial readiness and availability. We did not base our action plans on technologies that are unproven or have unknown feasibility. To do so would expose our customers to risks that are not appropriate for them to bear.

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 the Companies, IPPs, and customers to 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. We have operated in a low interest rate environment for a number of years. There are no assurances that such low interest rates will be sustained. Tax incentives that have underwritten renewable energy projects in the past are phasing out. It is therefore important that we deliberately pursue our modernization and renewable energy initiatives in order to take advantage of the current environment.

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 near-term action plans on projects that have little chance of being constructed.

Stranded Costs. Consideration must be given to minimizing or eliminating 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.

Operational Risk. Any plan must be operable so that our customers enjoy continuous and reliable electric service. Our action plan was developed to provide our customers with continued reliability in a cost effective manner.

DEVELOPING THE NEAR-TERM ACTION PLANS

Figure 7-1 depicts the developmental flow of our near-term action plans.

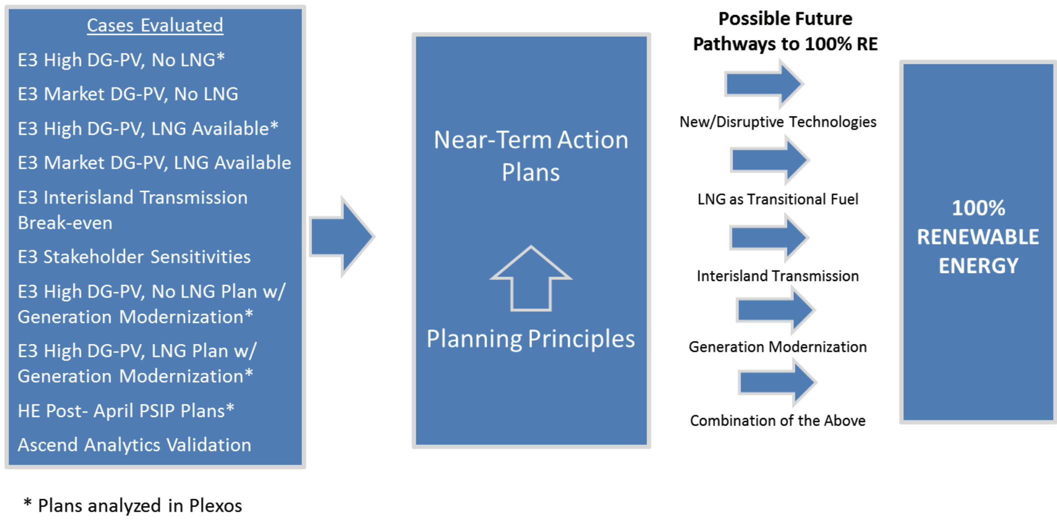


Figure 6-1. Development of the Near-Term Action Plans

Liquefied Natural Gas (LNG)

Although the analysis clearly indicates the cost benefits of LNG, procurement of LNG requires a long-term commitment, with substantial financial considerations. Furthermore, with lower energy costs, the build-out of renewables is less aggressive compared to cases where energy costs are higher. Additionally, the Governor has expressed concerns about LNG being a distraction to the State's efforts to achieve its renewable energy goals. For these reasons, development of LNG in the near–term is highly improbable.

Accordingly, in the Companies' Motion for Clarification of Order No. 33877, the Companies stated: "… That in light of the Companies' withdrawal of their applications for approval of a liquefied natural gas ("LNG") fuel supply agreement and for approvals related to a proposed Kahe combined cycle project to be fueled primarily with natural gas, consideration of LNG will not be part of the Companies' five-year action plans, but similar to other longer term options, LNG as a potential transition fuel for long-term planning towards the State's 100% renewable energy goals will be analyzed to determine its impact in stabilizing and lower costs for customers and in lowering emissions, while

aiding in the effective integration of renewable energy in a manner consistent with Order No. 33877 and the Commission's Inclinations."[31]

Considering all factors, the Near-Term Action Plan does not include LNG. This assumption results in a more aggressive build-out of renewables. The risks of an aggressive build-out of renewable energy, if cost-effective, are very limited.

Distributed Photovoltaic Generation (DG-PV)

Customer participation in DG-PV continues to be strong, as evidenced by the response to the CGS program. Realization of the High DG-PV forecast will offset some grid-scale renewable resources but does not eliminate any future pathway. It will also require policy decisions to support achieving the levels forecasted, which is under discussion in Docket No. 2014-0192. Achieving high levels of equitable DER will be especially beneficial if grid-scale resources are difficult or take longer to develop, or if there is a shortfall of developable onshore resources. For these reasons, the 2017–2021 Resource Plans plan for and incorporate the High DG-PV forecast and assume full implementation of DR programs.

Planning for the High DG-PV forecast carries little risk. This approach positions our systems to be better equipped to accommodate any future new technologies. If customer participation in DG-PV does not meet expectations, we will have the option to pursue more grid-scale renewables.

Interisland Transmission

E3 found that the "Copper-Plate" Interisland Transmission case substantially increases the renewable builds on the neighbor islands and substantially reduces the renewable build out on Oʻahu. The resulting build out of renewable resources on Oʻahu in the 2020–2022 timeframe would be reduced from 348 MW to zero; Maui would increase from 96 MW to 217 MW; and Hawaiʻi would increase from 70 MW to 814 MW. E3 notes that these are unrealistic build amounts given both the near-term timing and the assumption of unlimited transmission capacity on each island system.

In the near–term, the resource decisions in the interisland cable case compared to the individual island cases do not change drastically because the renewable build is constrained by interconnection limitations. However, given the extreme uncertainty around the cable permitting, feasibility and timing, a risk mitigating strategy would be to procure resources in the next 5 years without a presumption that an interisland cable

[31] Docket 2014-0183, Order No. 33877: *Hawaiian Electric Companies' Motion for Clarification of Order No. 33877*, filed August 26, 2016.

will be in place. This is also a prudent step given RPS requirement to achieve 30% RPS in 2020.

More impactful differences in resource decisions start to occur in 2022. These should be analyzed in further detail along with more development of the cost assumptions and operational constraints of the cable options as well as consideration of the 40% RPS requirement in 2030. A near-term build out that optimizes the renewable resources on each island does not eliminate any future pathway, including interisland transmission.

Generation Modernization

To address the Commission's Inclinations to modernize the generation system and to address risks of continuing to operate existing generation through 2045, we analyzed the impacts of generation modernization for O'ahu.[32]

The Joint Base Pearl Harbor Hickam (JBPPH) Power Barge and Marine Corp Base Hawai'i (MCBH) projects build on the benefits provided by the Schofield Generation project. Older, less flexible generation (Waiau 3 and 4 and AES) is replaced with new flexible generation needed to facilitate the integration of variable renewable generation, allowing for much higher levels of renewable energy, and the elimination of coal. While E3's sensitivity analysis did not choose to build these units in this timeframe, E3's analysis does choose to build new dispatchable generation later in 2045.

It should be noted that the RESOLVE model does not investigate detailed contingencies or system security constraints and uses a simplified capacity adequacy determination based solely upon reserve margins, rather than the capacity planning criterion and guidelines used for each island. This simplification might be adequate for large connected systems, but needs to be augmented with specific capacity adequacy models for Hawai'i's island systems. E3 also clarifies that RESOLVE assumes that beyond 2020 there are no interconnection limits or land use issues to constrain the grid in absorbing further renewable energy installations and that all resources will be developed as needed, without consideration of the consequences of delayed availability of required resources (that is, perfect foresight).

Hourly production simulation analyses results from PLEXOS and Ascend indicate that a capacity shortfall exists in the early 2020s with the retirements of Waiau 3 and 4 in 2020 and PPA expiration of AES in 2022. If distributed and/or grid-scale renewable energy resources take longer to develop, the capacity shortfall will be intensified. Incremental, measured, modernization with flexible generation will help mitigate these risks and reduce concerns over stranded assets, as investments are made earlier as opposed to

[32] Docket 2012-0036, Order No. 32052; *Regarding Integrated Resource Planning: Commission's Inclination on the Future of Hawai'i's Electric Utilities*, at 6.

later. The increased generation flexibility and improved efficiency will facilitate integration of more variable renewable energy resources and reduce fuel cost.

Depending on the location and configuration, the JBPPH Power Barge and MCBH projects could also help to improve grid resiliency by distributing generating resources and potentially allow for critical infrastructure to operate as a microgrid if the need arises. For these reasons, the 2017–2021 Resource Plan for O'ahu incorporates the JBPHH and MCBH projects.

Other Considerations

RESOLVE does not investigate detailed contingencies or system security constraints, and there are reliability benefits to keeping thermal projects online that RESOLVE is not considering.

Furthermore, the RESOLVE analysis does not account for the risks of future environmental compliance requirements under New Source Performance Standards (NSPS) or New Source Review (NSR), nor does it account for regulatory changes that could result in substantial cost impacts to keeping existing generation online or possibly require the closure of older generation. These are not shortfalls of the E3 RESOLVE model, but rather real–world possibilities that no resource optimization model is able to simulate.

While our existing generating assets on O'ahu have served us well for many years, a methodical, measured retirement/replacement strategy that is designed to facilitate the transition to 100% renewable energy is a prudent, risk reducing measure over the longer term. The need for flexible generation will increase as higher levels of variable renewable energy are achieved. We have analyzed two slightly different approaches in the Post-April PSIP Plan and the E3 Plan with Generation Modernization. While our generation modernization analysis in PLEXOS did not demonstrate cost-effectiveness relative to the E3 Plan without Generation Modernization, it did not account for the risks of future environmental compliance requirements under NSPS or NSR, other mandated changes, or reliability issues that we may encounter as we operate our units in ways for which they were not originally designed. The costs to add pollution control equipment, which may be required at some point to continue operation of existing units, were not included in our analysis. Prior estimates for these improvements are approximately $900M for Kahe and Waiau.

The same modeling limitations described for O'ahu apply for the Maui and Hawai'i systems, although in different degrees. As the resource mixes change, reliability concerns may require changes to the characteristics to existing generation or require supplemental and/or new resources. Maui Electric must retire Kahului Power Plant (KPP) in 2024 to

comply with mandatory NPDES requirements. This will result in a shortfall of dispatchable capacity despite the addition of new variable renewable generation in 2020. Both the E3 Plans and Post-April PSIP Plan for Maui indicate a need for new dispatchable generation due to a capacity shortfall resulting from the retirement of KPP. KPP not only supplies power to meet demand, but it also provides voltage support for the central Maui area, and fault current for the 23 kV system.

Since any replacement generation will be relocated from KPP, upgrades to the Central Maui transmission line must be in place and a synchronous condenser must be installed on the 23 kV system before KPP is retired. In addition to the new dispatchable generation and Central Maui transmission upgrades, the Near-Term Action Plan for Maui includes 18 MW of internal combustion engine (ICE) generation as a non-transmission alternative to new transmission lines to South Maui.

Moloka‘i and Lana‘i have existing generation that is sufficiently flexible to meet current and future needs.

While increasing flexibility is required from firm generation as variable resources increase on the system and larger conventional plants are displaced from operation, Hawai‘i Electric Light has a significant amount of flexibility with its existing fast start diesels and simple-cycle combustion turbines. The diesels and simple-cycle units initially provided fast-starting replacement reserves to restore under–frequency load-shed customers, and to support short-term energy needs. These units have proven useful in managing system balancing with a high penetration of variable renewable resources. Therefore, it is not a near-term priority to add new flexible generation to accommodate variable renewable generation.

RESOURCE PLANS (2017–2021)

Resource plans spanning the years of 2017 to 2021 were developed for each island, applying the Planning Principles and Risk Considerations described above. The resource size and timing are not absolute and are subject to change, depending on specific conditions at the time applications are submitted to the Commission for approval and upon obtaining Commission approval.

O‘ahu Resource Plan (2017–2021)

O‘ahu’s 2017–2021 Resource Plan incorporates elements of the E3 Plan and Post-April Plan. Both plans incorporate High DG-PV, and are similar in terms of cost and customer rates. The primary differences are that the Post-April Plan incorporates 30 MW of additional grid-scale onshore wind and 100 MW/1hr regulation BESS in 2020 and 100 MW of PV in 2021. The 100 MW of PV in 2021 exceeds the transmission capacity constraint for O‘ahu and will need to be studied further after the amount and location of the grid-scale PV in 2020 is specified through the RFP process. The 30 MW of additional grid-scale onshore wind in combination with the 100 MW per one-hour regulation battery appears to provide cost benefits and increases the amount of renewable capacity that can be interconnected. Since the federal tax credit for wind projects will expire at the end of 2019, it is prudent to seek proposals for potential developable resources as soon as possible. Additionally, sub-hourly analysis in PLEXOS and regulation analysis by Ascend Analytics identifies the need for regulating resources in addition to the resources provided by DR.

System security requirements include an FFR1 resource of 70 MW in 2019 to supplement capacities of FFR2 demand response resources to stabilize system frequency for a Kahe Unit 5 trip at full output, and conversion of Honolulu 8 and 9 to synchronous condensers (128.5 MVAR total) in 2021 to provide reactive power/voltage support and fault current. Additional resources may be required to mitigate system impacts from normally cleared and delayed clearing faults pending further investigation.

Table 6-1. outlines the resource plan for O‘ahu.

ear	O‘ahu Resource Plan
2017	72.3 MW DG-PV
2018	41.2 MW DG-PV 6 x 8.14 MW Schofield Plants 24 MW Na Pua Makani Wind 109.6 MW Grid-Scale PV 10 MW Grid-Scale Wind (CBRE) 15 MW Grid-Scale PV (CBRE)
2019	45.5 MW DG-PV 70 MW Contingency FFR1 20 MW West Loch PV
2020	40.5 MW DG-PV 30 MW Grid-Scale Wind 180 MW Grid-Scale PV 100 MW 1-hour Regulation BESS
2021	55.6 MW DG-PV Convert H8 & H9 to synchronous condenser

Table 6-1. O‘ahu Near-Term Resource Plan

The O‘ahu near–term resource plan will add 695 MW of distributed and grid-scale renewable energy capacity to the system, increasing the total renewable energy capacity to 1,299 MW. The percent RPS and percent renewable energy will increase to 45% and 37%, respectively.

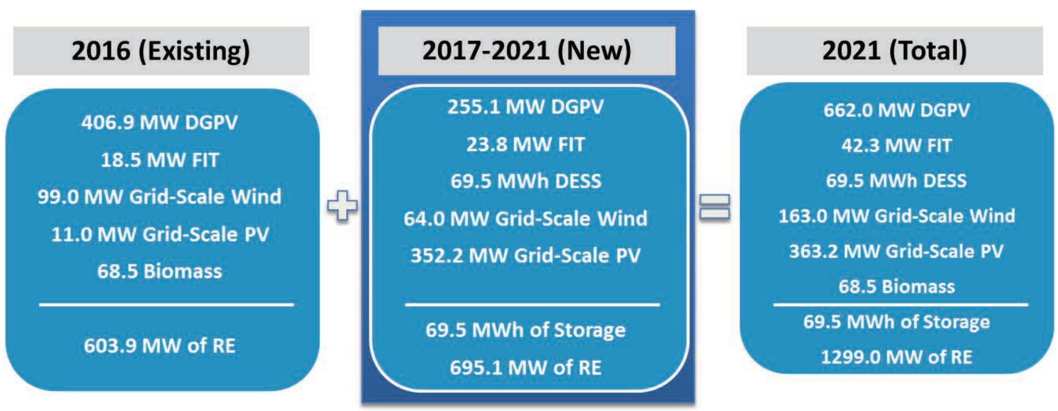


Figure 6-2. O‘ahu Renewable Energy Resource Summary

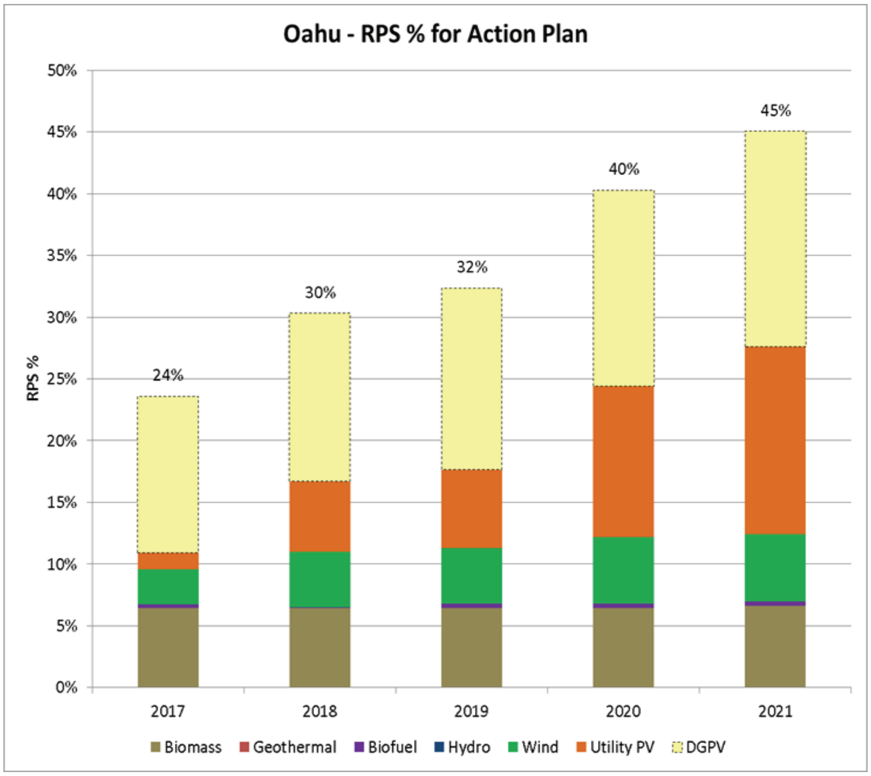


Figure 6-3. RPS Percent for O‘ahu Action Plan

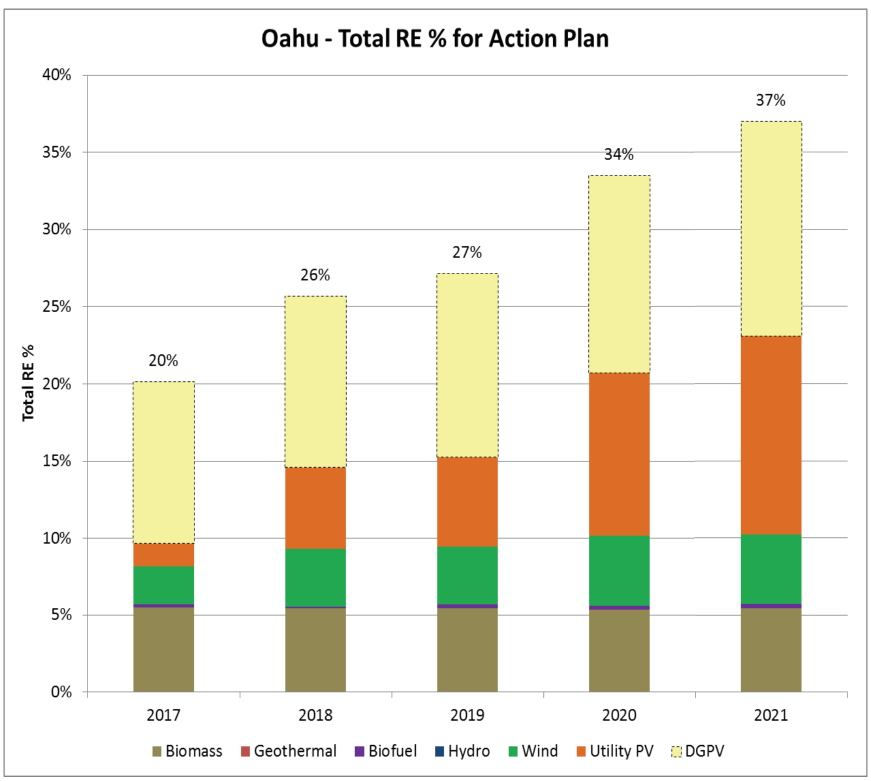


Figure 6-4. Total Renewable Energy Percent for O‘ahu Action Plan

Maui Resource Plan (2017-2021)

Maui's 2017–2021 Resource Plan incorporates all resources from the E3 Plan, which includes High DG-PV. The E3 Plan resulted in a lower overall total cost and lower customer rates in comparison to the Post-April PSIP Plan.

System security requirements include an FFR1 resource of 9 MW in 2019 to stabilize system frequency for a KWP I trip at full output, a new 30 MVA synchronous condenser in 2019 to provide reactive power/voltage support and fault current, and a new 16 MVA, 23 kV synchronous condenser in 2022, before Kahului Power Plant is retired in 2024. Additional resources may be required to mitigate system impacts from normally cleared faults pending further investigation.

Table 6-2 outlines the resource plan for Maui.

ear	Maui Resource Plan
2017	17.1 MW DG-PV 5.74 MW Grid-Scale PV
2018	3.5 MW DG-PV 2 MW Grid-Scale Wind (CBRE) 1 MW Grid-Scale PV (CBRE)
2019	6.8 MW DG-PV 9 MW Contingency FFR1
2020	6.7 MW DG-PV 60 MW Grid-Scale Onshore Wind New 30 MVA Synchronous Condenser (69 kV)
2021	4.3 MW DG-PV

Table 6-2. Maui Near-Term Resource Plan

The Maui near–term resource plan will add a total of 108 MW of distributed and grid-scale renewable energy capacity to the system, increasing the total renewable energy capacity to 284 MW. The percent RPS and percent renewable energy will increase to 63% and 50%, respectively.

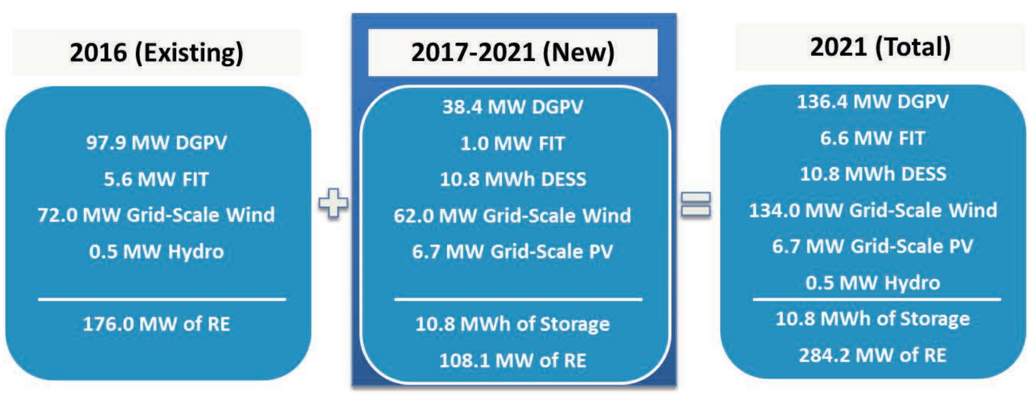


Figure 6-5. Maui Renewable Energy Resource Summary

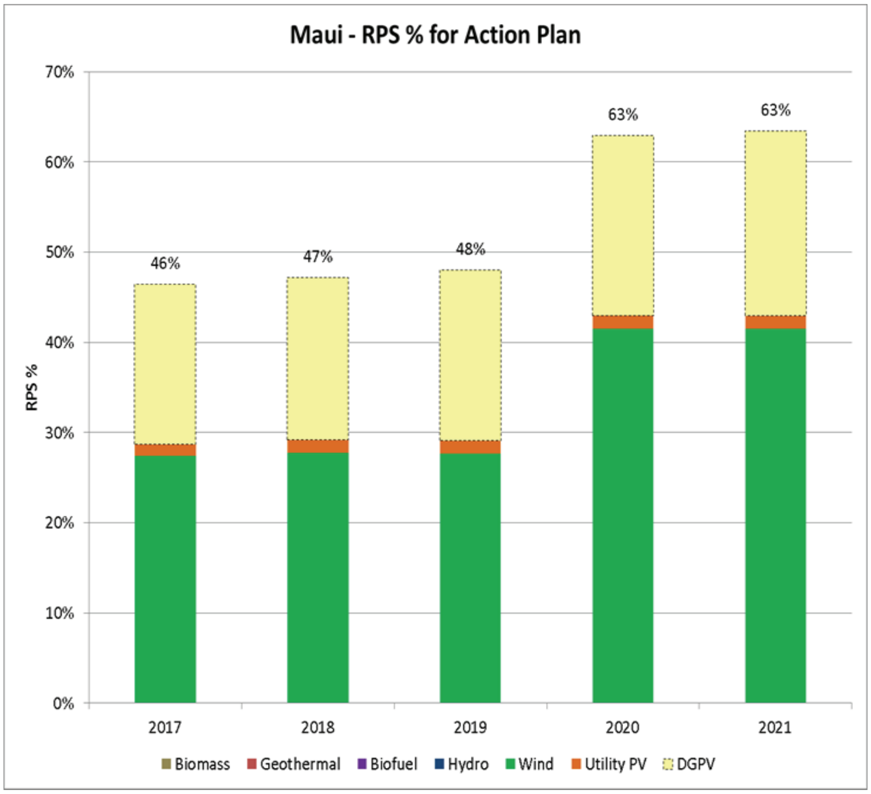


Figure 6-6. RPS Percent for Maui Action Plan

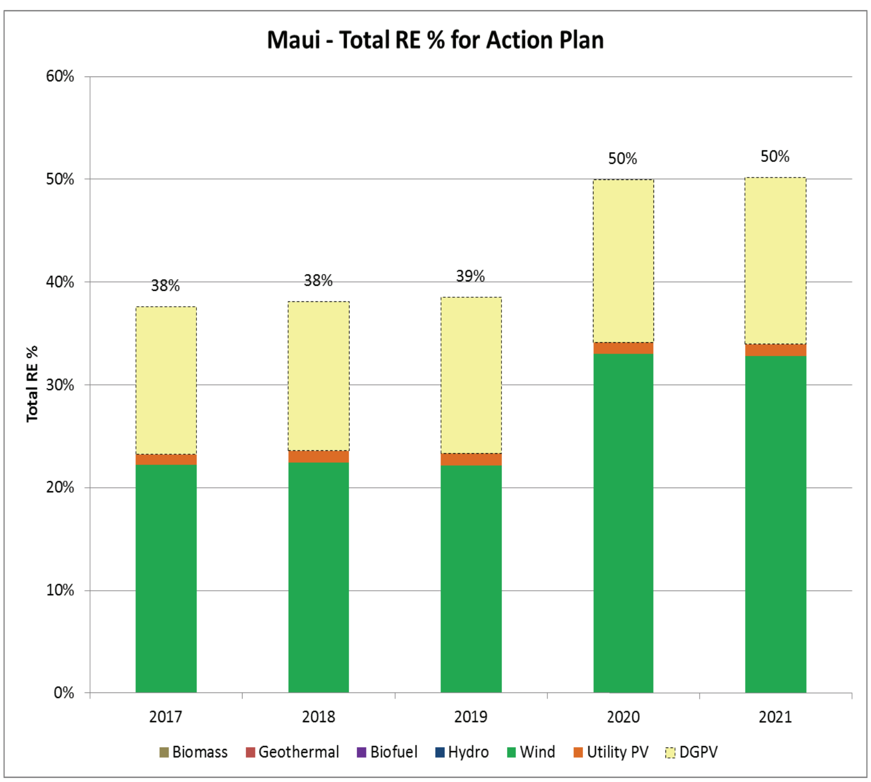


Figure 6-7. Total Renewable Energy Percent for Maui Action Plan

Moloka'i Resource Plan (2017-2021)

Moloka'i's near–term resource plan incorporates high DG-PV and required renewable resources to achieve 100% renewable energy in 2020. As discussed in Chapter 4, multiple plans were evaluated, including plans optimized using the PLEXOS optimization tool. Although the analysis achieved 100% renewable energy in 2020 through the use of biofuels to replace the diesel fuel consumed when the renewable energy is unavailable, we will continue to investigate other options, taking advantage of new and evolving technologies, and declining prices for renewable resources.

Moloka'i will serve as a blueprint to increase the cost-effective use of renewables for the remainder of the state and help us obtain real–world experience in running an island grid with 100% renewable energy.

System security requirements include an FFR1 resource of 2.75 MW in 2019 to stabilize system frequency for a Pala'au 9 diesel generator trip at 2.2 MW and a new 2.75 MVA synchronous condenser in 2019 to provide reactive power/voltage support and fault current.

Table 6-3 outlines the resource plan for Moloka'i.

ear	Moloka'i Resource Plan
2017	0.37 MW DG-PV
2018	0.65 MW DG-PV
2019	0.09 MW DG-PV 2.75 MW FFR1 2.75 MVA Synchronous Condenser
2020	0.17 MW DG-PV 5 MW Grid-Scale Wind
2021	0.12 MW DG-PV

Table 6-3. Moloka'i Near-Term Resource Plan

The Moloka‘i near term resource plan will add 6.4 MW of distributed and grid-scale renewable energy capacity to the system, increasing the total renewable energy capacity to 8.5 MW. The percent RPS and percent renewable energy will increase to 142% and 100%, respectively.

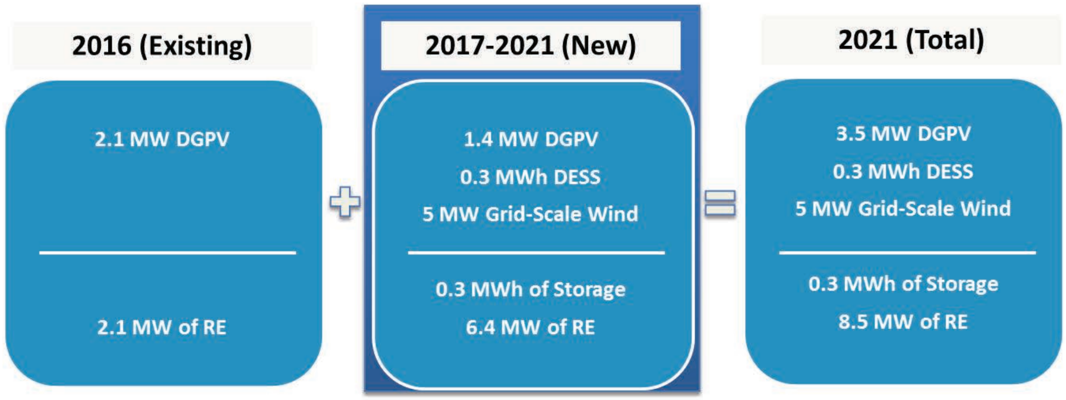


Figure 6-8. Moloka‘i Renewable Energy Resource Summary

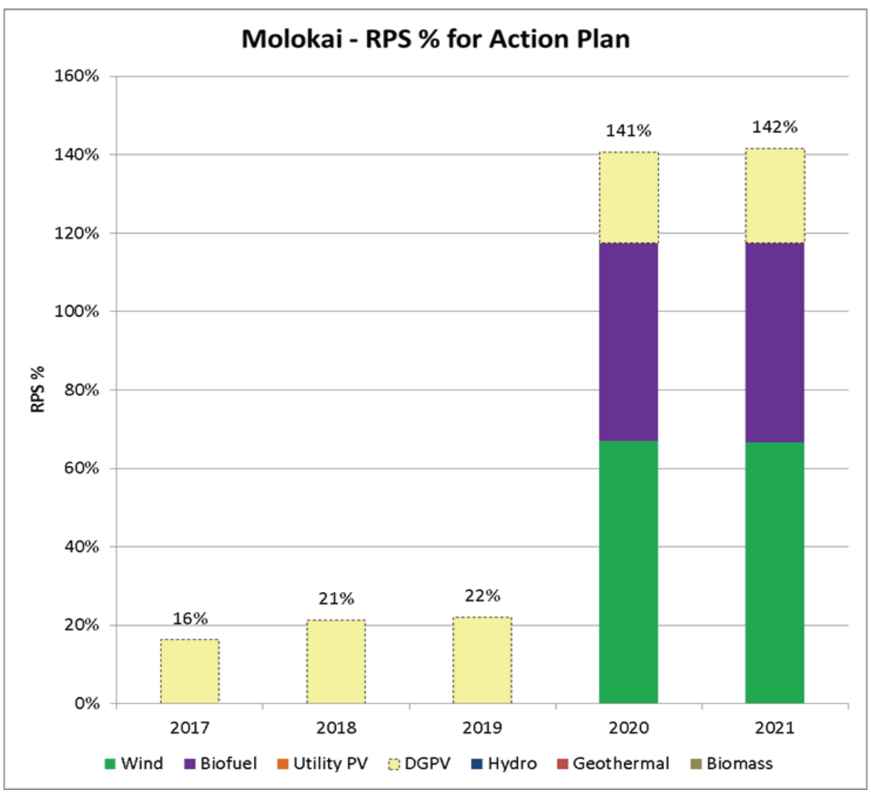


Figure 6-9. RPS Percent for Moloka‘i Action Plan

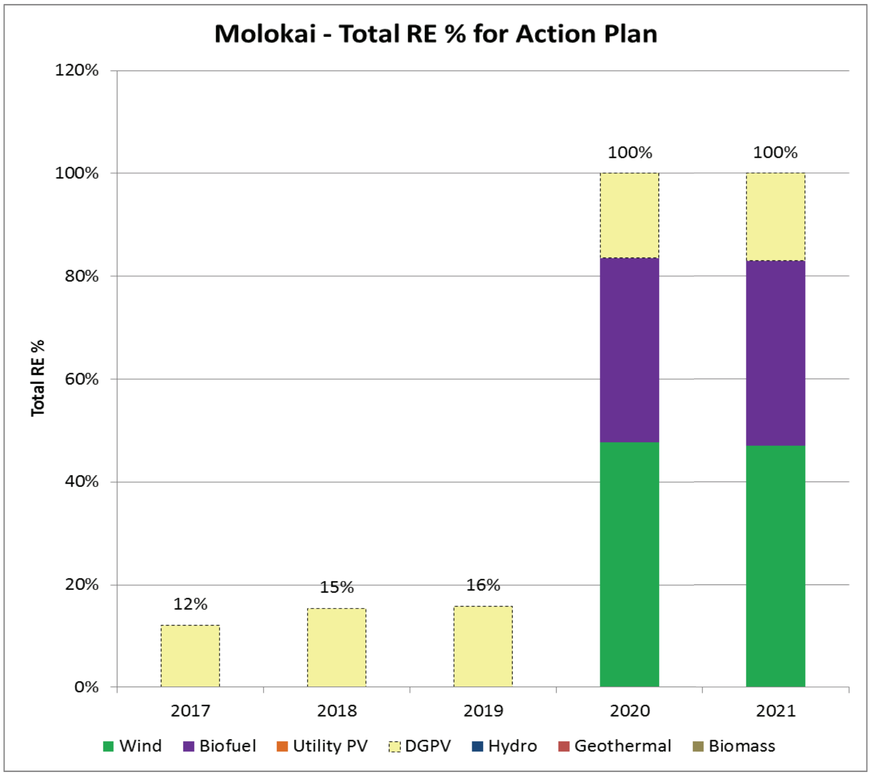


Figure 6-10. Total Renewable Energy Percent for Moloka'i Action Plan

Lana'i Resource Plan (2017-2021)

Lana'i's near–term resource plan incorporates high DG-PV and required renewable resources to achieve 100% renewable energy in 2030. As discussed in Chapter 4, multiple plans were evaluated, including plans optimized using the PLEXOS optimization tool. Although the analysis achieved 100% renewable energy in 2030 through the use of biofuels to replace the diesel fuel that is consumed when the renewable energy is unavailable, we will continue to investigate other options, take advantage of new and evolving technologies, and declining prices for resources.

System security requirements include an FFR1 resource of 1.25 MW 2019 to stabilize system frequency for a Miki Basin 7 diesel generator trip at 1.24 MW and a new 2.75 MVA synchronous condenser in 2019 to provide reactive power/voltage support and fault current.

Table 6-4 outlines the resource plan for Lana‘i.

ear	Lana‘i Resource Plan
2017	0.43 MW DG-PV
2018	0.13 MW DG-PV
2019	0.04 MW DG-PV 1.25 MW FFR1 2.75 MVA Synchronous Condenser
2020	0.09 MW DG-PV 4 MW Grid-Scale Wind
2021	0.02 MW DG-PV

Table 6-4. Lana‘i Near-Term Resource Plan

The Lana‘i near term resource plan will add a total of 4.7 MW of distributed and grid-scale renewable energy capacity to the system, increasing the total renewable energy capacity to 6.7 MW. The percent RPS and percent renewable energy will increase to 59% and 52%, respectively.

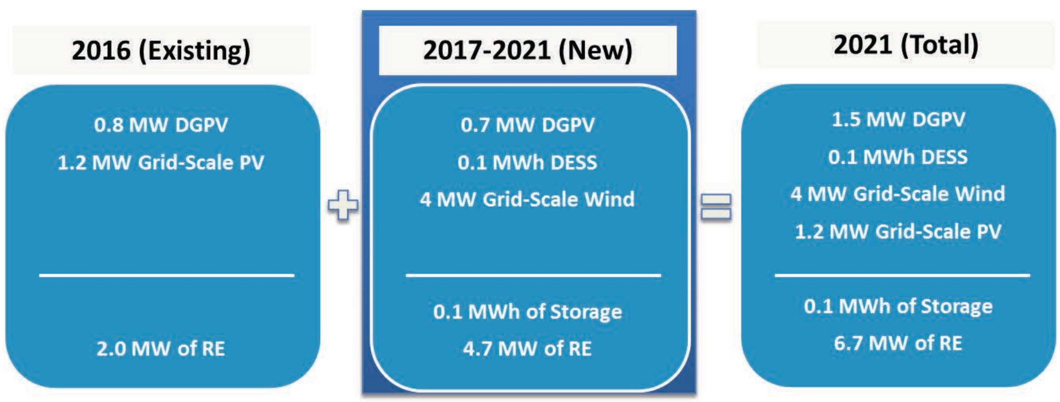


Figure 6-11. Lana‘i Renewable Energy Resource Summary

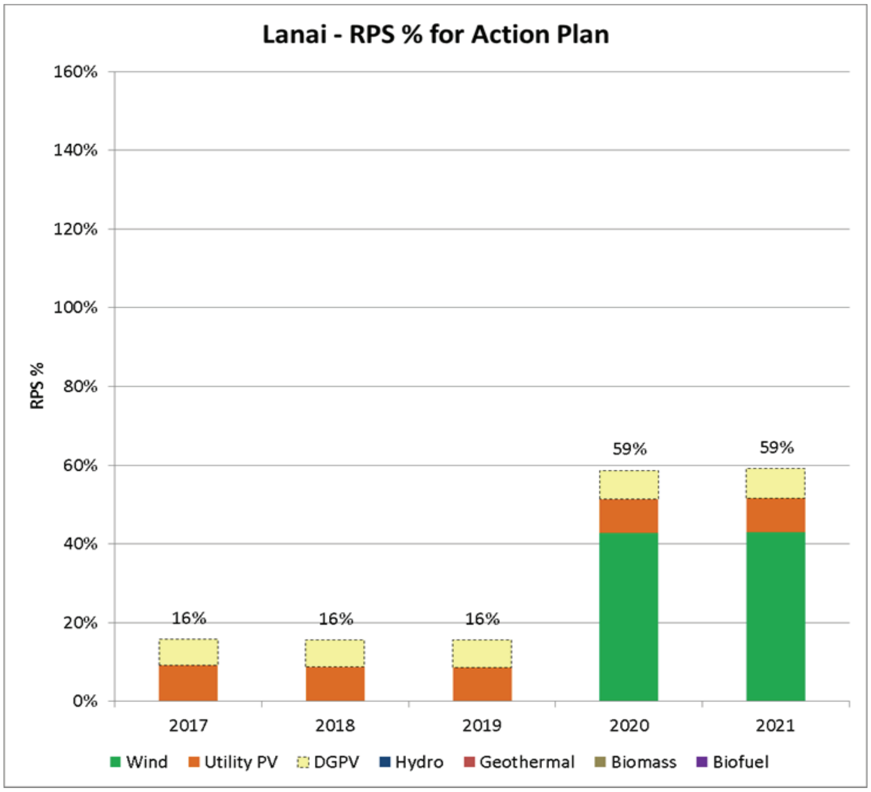


Figure 6-12. RPS Percent for Lana‘i Action Plan

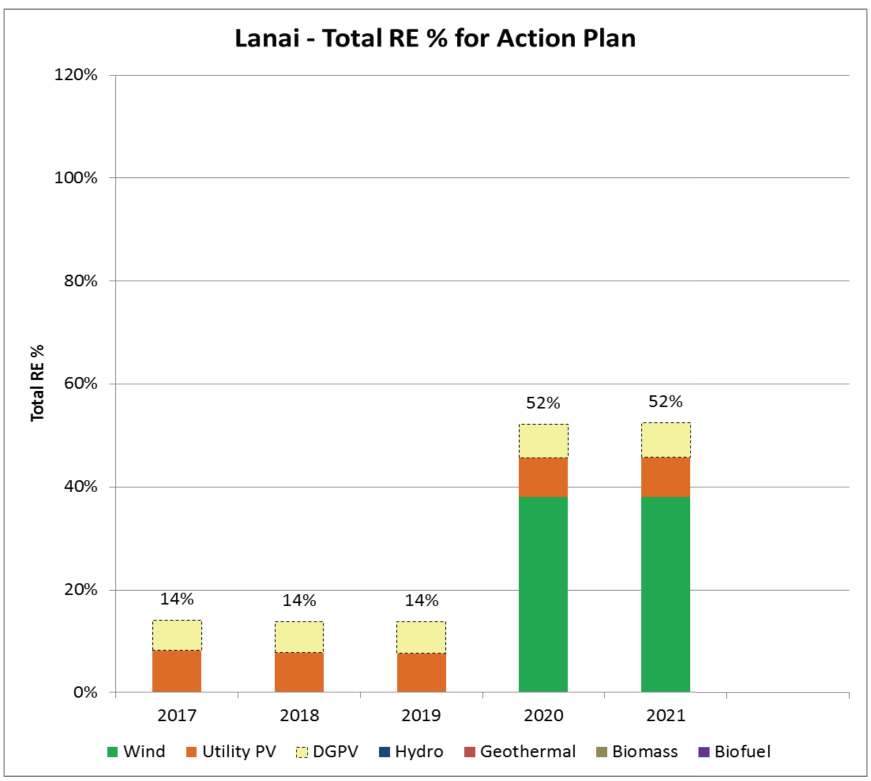


Figure 6-13. Total Renewable Energy Percent for Lana‘i Action Plan

Hawai‘i Resource Plan (2017-2021)

Hawai‘i’s near term resource plan utilizes all of the resources from E3 Plan. The E3 Plan resulted in a lower overall total cost and lower customer rates. Although the analysis limited the 2020 interconnection of wind to 20 MW, it may be possible to interconnect as much as 70 MW at the Waimea substation. Procurement efforts in the near term action plan should seek up to 70 MW to determine if projects are able to interconnect at Waimea.

System security requirements include an FFR1 resource of 9 MW in 2019 to stabilize system frequency for a HEP Trip in STCC mode at 28.7 MW and a new 25 MVA synchronous condenser to provide reactive power/voltage support and fault current in 2020. Additional resources may be required to mitigate system impacts from normally cleared faults pending further investigation.

Table 6-5 outlines the resource plan for Hawai‘i Island.

ear	Hawai‘i Island Resource Plan
2017	15.0 MW DG-PV
2018	3.6 MW DG-PV 2 MW Grid-Scale Wind (CBRE) 1 MW Grid-Scale PV (CBRE)
2019	4.1 MW DG-PV
2020	3.9 MW DG-PV 20 MW Grid-Scale Onshore Wind 12 MW Load Shifting Energy Storage 9 MW FFR1 25 MVA Synchronous Condenser
2021	3.8 MW DG-PV

Table 6-5. Hawai‘i Island Near-Term Resource Plan

The Hawai‘i near term resource plan will add a total of 59.0 MW (and possibly higher) of distributed and grid-scale renewable energy capacity to the system, increasing the total renewable energy capacity to 235.3 MW. The percent RPS and percent renewable energy will increase to 80% and 63%, respectively.

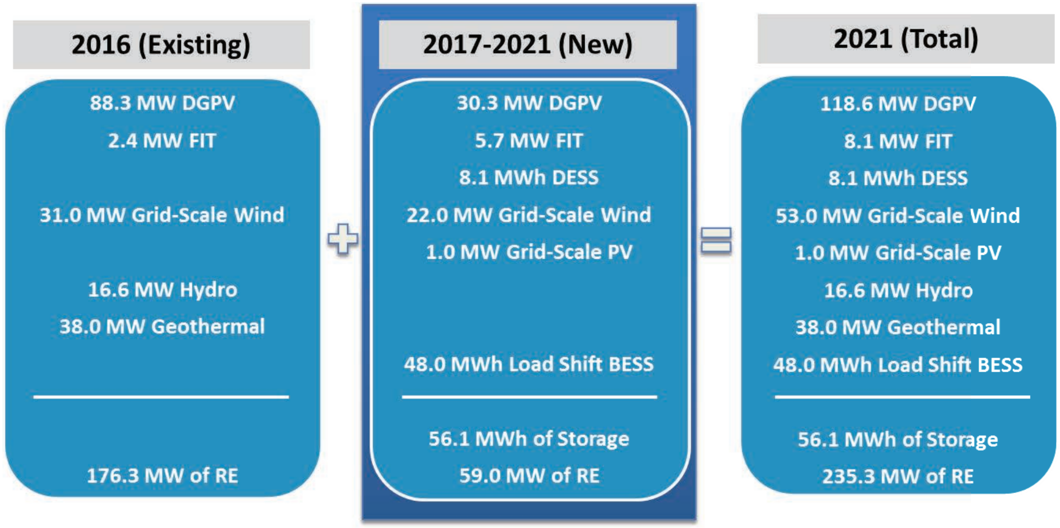


Figure 6-14. Hawai'i Island Renewable Energy Resource Summary

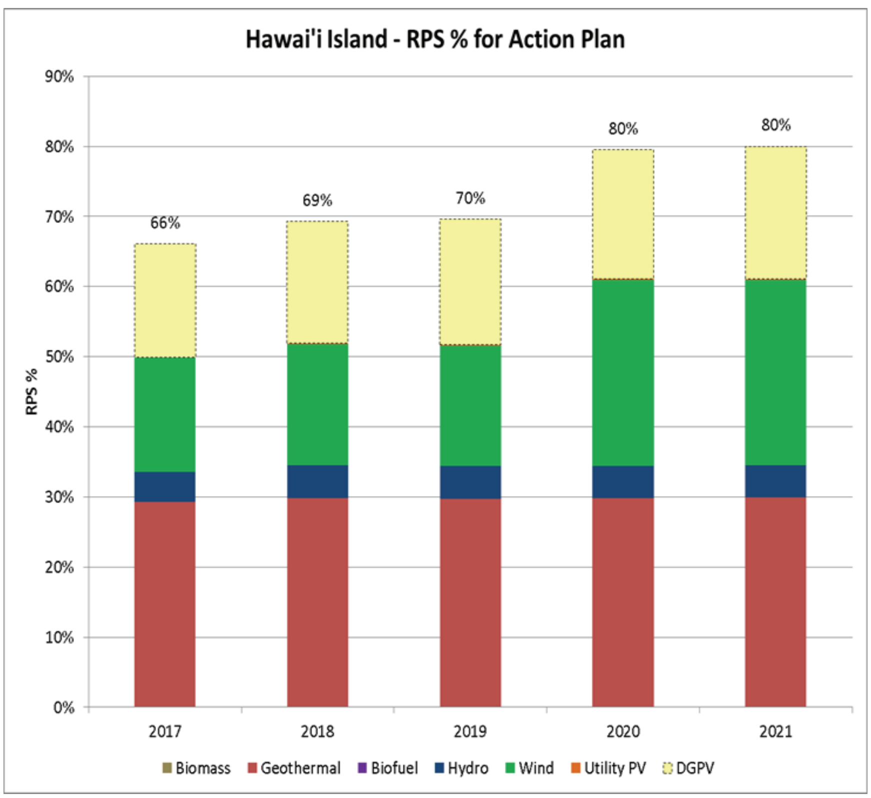


Figure 6-15. RPS Percent for Hawai'i Island Action Plan

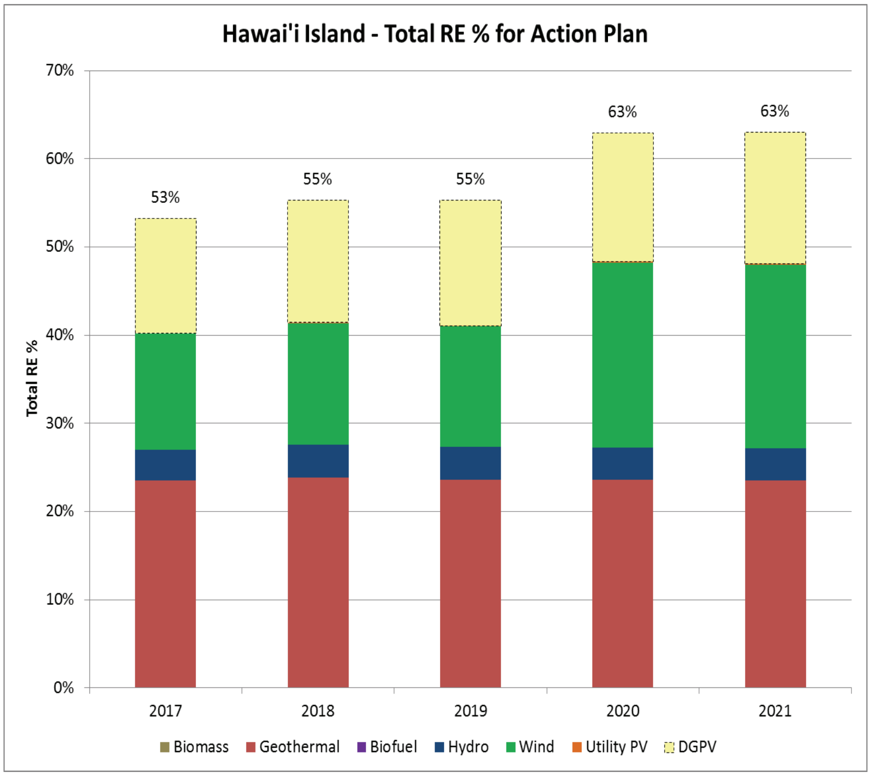


Figure 6-16. Total Renewable Energy Percent for Hawai'i Island Action Plan

7. Near-Term Action Plans

This Near-Term Action Plan details a set of actions that must be taken to continue on the path of reaching our 100% renewable energy goal. This Action Plan focuses on the near-term 2017 to 2021 period and includes those activities that must be done within this period to accomplish goals that are beyond that period.

We have created Company-Wide Action Plans and action plans for each island we serve.

COMPANY-WIDE ACTION PLANS

The Companies' Resource Plans (2017–2021) incorporate High DG-PV, full implementation of DR, and maximizing cost-effective grid-scale renewable energy resources. LNG and Interisland Transmission are not included in the near-term resource plans, but will continue to be evaluated as alternatives in the transition to 100% renewable energy. Described below are the proposed Near-Term Action Plans (2017–2021) that help achieve significant progress toward Hawai'i's 100 percent renewable energy goal preserving our flexibility over the longer-term to address changing circumstances, leverage new opportunities, and explore new emerging technologies.

Figure 7-1 depicts the Companies' consolidated RPS % for the proposed near-term action plans.

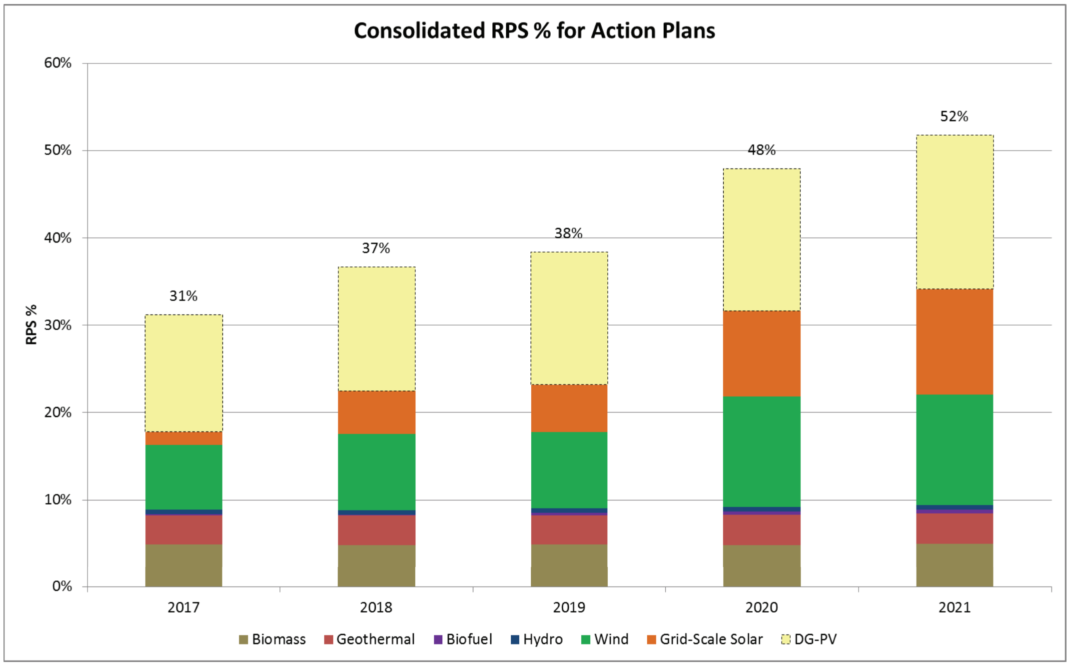


Figure 7-1. Consolidate RPS % for Action Plans

Renewable Acquisition Action Plan

The Near-Term Resource 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.

We will seek to procure least-cost grid-scale resources.

The Hawaiian Electric Companies plan to procure these new renewable resources through a competitive procurement process to ensure the best value for customers. There may be exceptions as allowed in the Commission's Competitive Bidding Framework that will need to be evaluated and justified, especially when considering the expiring and decreasing federal tax credits. The timeframes in our Near-Term Resource Plans are aggressive, and to procure those amounts of energy will require the collaboration with and support of regulatory, state, and county agencies.

The Companies will seek the most cost effective resources that meet the necessary requirements for each island. These future RFPs will be designed to be technology agnostic, that is, to allow different renewable technologies to compete to provide the best value for all customers. This method will require the Companies to evaluate each potential resource as it is added to the Companies' portfolios.

The Companies are researching new contracting methods that will provide necessary dispatch flexibility for variable renewable resources and support the reliable operation of the grid. This contracting method will be structured to provide measures needed to encourage new projects while moving away from treating variable resources as must-take energy sources with excess energy reductions done in reverse chronological order of the source procurement date. New contract terms will be included as part of RFPs for future resources and adopted when new power purchase agreements are negotiated.

In addition to these efforts, the Companies have engaged existing renewable energy providers to actively explore opportunities for their facilities to increase contribution to system reliability, increase utilization of renewable energy, and provide more benefits to customers.

We will seek cost-effective, diverse Community-Based Renewable Energy (CBRE) as part of our renewable portfolios.

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 M AC		ind M 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 7-1. CBRE Island Technology

Grid Modernization Action Plan

Consistent with Hawai'i's grid modernization statute (Hawai'i Revised Statute §269-145.5), the Companies will take actions, in support of the PSIP resource plans, that, (1) maximize cost-effective interconnection of distributed energy resources and grid-scale resources, (2) maintain and enhance grid operating reliability and safety, (3) seek improved efficiencies in grid operations and interoperability, and (4) create an integrated grid through advanced planning, forecasting and operations.

We will propose the activation of new advanced inverter functions as part of Docket 2014-0192.

On December 13, 2016, the Companies filed the first phase of our advanced inverter testing work. The report, entitled, *Hawaiian Electric Advanced Inverter Grid Support Function Laboratory Validation and Analysis,* prepared and published by the National Renewable Energy Laboratory (NREL), contains performance testing of several models of advanced inverters for seven of the highest priority grid support functions that are required to support DER integration on Hawai'i's grids. Through this work, we will set forth our Source Requirements Document to provide manufacturers detailed requirements pertaining to our highest priority advanced inverter functions, which will enable manufacturers to begin certifying their equipment to the approved Underwriter Laboratory 1741 Supplement A test standard as required by Rule 14H by September 2017. Finally, we will seek approval to implement mandatory functions such as Volt-Watt, which may allow safe interconnection of additional DER while grid modernization upgrades continue over the near-term.

We plan to complete the next phase of our advanced inverter voltage function research in the third quarter of 2017.

In response to the feedback from the members of Hawai'i's Smart Inverter Technical Working Group, the Companies have proactively undertaken this new study with NREL to analyze the operational strategies that best mitigate primary and secondary voltage impacts of DER integration. We believe the results of this work will be informative to the parties in Docket 2014-0192 as we find solutions to increase distribution circuit hosting capacities.

We expect to develop ways in which advanced inverter-based distributed resources can support grid frequency by September 2017.

Through the Grid Modernization Lab Call, together with NREL, Sandia National Laboratories, and inverter manufacturers, the Companies will investigate, develop, and validate ways that distributed PV and storage can support grid frequency stability on the fastest time scale, starting a few cycles after a contingency event. The expected outcomes include, (1) grid frequency support capabilities for presently-available PV and storage inverters based on simulations of the actual dynamics of O‘ahu’s transmission and distribution system, (2) develop and validate new control methods that improve inverter based frequency support capabilities and performance (that is, Frequency-Watt/droop), (3) field validation of developed functions, and (4) models and modeling methods for evaluating DER-based frequency support functions. Advanced inverters on PV systems with the Frequency-Watt function activated would be able to autonomously reduce the output of PV systems during excess energy conditions and help to balance the frequency of the system.

We plan to propose communication, monitoring, and reporting requirements for DER by 2019.

Monitoring, configurability, visibility, and appropriate command and control of DER assets, whether through direct or aggregated communication, are a key component in the PSIP Resource Plans and Grid Modernization efforts. The Companies have taken the first step by revising Rule No. 14, Paragraph H, on October 21, 2015 to include remote connect/disconnect and configurability functionality for advanced inverters, in a signal to the manufacturing industry of our intent to require that functionality in the near future. Since that time, the Companies have engaged in several efforts to implement these requirements.

1. Submitted an application for approval of Smart Grid Foundation Project under Docket No. 2016-0087 to enable real-time visibility and control of DER through advanced metering infrastructure.

2. Submitted an application for approval of a Demand Response Management System (DRMS) under Docket 2015-0411 to increase the dispatchability of customer loads and generation resources.

3. Starting in 2017, we plan to pilot a plug-in collar device that is integrated with the standard utility meter slot called ConnectDER that through cellular communications (with capability to accommodate other communication protocols, including the Company’s proposed Smart Grid Foundational Project network) can provide remote monitoring, visibility, configurability and on/off control of PV systems. Pilot is leveraging federal grant funding from US DOE and Energy Excelerator.

4. Plans to develop autonomous advanced inverter control for excess energy conditions. Through the Grid Modernization Lab Call, we are studying if frequency-watt functionality can be developed and configured to mitigate excess energy conditions without the need for remote communication and control. We expect to complete this study work in September 2017.

5. Participation in the working group charged with revising IEEE Standard 1547, *Standard Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interface,* which will include interoperability, monitoring, cybersecurity, and communication protocol requirements for all DER.

6. Continue collaboration with Siemens, Alstom, AWS Truepower, Referentia Systems, DNV GL, Apparent Inc., Stem, Gridco, Western Balancing Authority, and Utilities Advisory Team under the US DOE grant-supported System to Edge-of-Network Architecture and Management (SEAMS) for SHINES (Sustainable and Holistic Integration of Energy Storage and Solar PV) project. Deployment of standardized communication and control infrastructure can provide system-level benefits of enhanced utility visibility and control of distributed systems and edge-of-network electrical resources thus providing grid-informed support services and monitoring.

7. Maui Electric and Hawaiian Electric will also continue its collaboration with Hitachi, Maui Economic Development Board (MEDB), County of Maui, HNEI, DBEDT, and the New Energy and Industrial Technology Development Organization (NEDO) on the Hitachi JUMPSmart Pilot Project on Maui. In Phase 2, DMS-based aggregation and control of the distributed resources are being evaluated to assess this functionality to manage high renewable energy penetration and to demonstrate a “virtual power plant” concept. The project leverages over $50 million from NEDO and supported by numerous international and local stakeholders. A key component of the project is the aggregation and control of distributed resources, including electric vehicles. About 12 months of data collection has occurred under Phase 1 with Phase 2 pilot testing scheduled to occur until February 2017.

We will evaluate volt-var optimization schemes as a way to increase circuit-level hosting capacities.

The Companies will continue to evaluate traditional and non-traditional solutions to maintain proper operating voltages, conducive to integrating higher levels of DER. Deployment of volt-var optimization schemes using emerging distributed technologies represent an innovative way to solving voltage impacts caused by rooftop PV. The following innovative technologies are being evaluated and implemented:

1. Hawaiian Electric is currently conducting a pilot program using Varentec's ENGO (edge of network grid optimizer) and GEMS (grid edge management system) a reactive power compensating system on two distribution feeders to test the capability of this technology to improve voltage performance on both the primary and secondary portions of circuits highly penetrated by older, legacy PV and inverter systems. Initial results of the pilot are promising and show tightening of the voltage range which will facilitate increased circuit hosting capacities. Final results are expected by the end of the first quarter of 2017.

2. We continue piloting Gridco's In-line Power Regulator (IPR) units on select high PV penetrated circuits. Installed on the secondary side of the distribution feeder, the Gridco IPRs provide real-time voltage monitoring and control. The power electronics-based IPR provides the utility with active voltage regulation on secondary feeders downstream of the device to maintain stable voltage levels, and is being investigated as a limited solution to mitigate both high and low voltage problems on selected high PV penetrated feeders. To date, five IPRs been installed and more installations are planned on Maui, O‘ahu, and Hawai‘i Island in 2016–2017.

3. We will evaluate advanced inverter volt-var capability as part of the next phase of our advanced inverter voltage function research with NREL, with expected completion by the third quarter of 2017.

We will continue execution of distribution system improvements to raise hosting capacities to accommodate near-term DER forecasts.

Appendix N: Integrating DG-PV on Our Circuits has identified a mix of solutions to resolve near-term PV impacts – high and low voltage, conductor and equipment capacity overloads, and operational flexibility. The Companies continue to execute various solutions to solve these problems; for example, we have completed over 64 load tap changer upgrades, voltage regulator installations, LTC setting optimizations, and numerous secondary conductor and transformer upgrades. We have scheduled conductor upgrades, 4 kV conversions, and voltage regulator installations to increase hosting capacities on circuits with continued high customer demand for PV interconnection.

Pending the outcome of Docket 2014-0192, Phase II discussions of Appendix N, the Companies' hosting capacity work, and its policy implications, the Companies are prepared to make grid investments on a proactive basis to increase capacities to accommodate near-term DER programs (future grid-export, CBRE, and remaining CGS for example).

The Company is in discussions with Google and Mapdwell to quantify the technical potential of rooftop PV using advanced satellite imagery and 3D modeling for the islands of O‘ahu, Maui, and Hawai‘i. This information will allow us to develop long-range plans for a possible future where every rooftop is equipped with DG-PV.

We plan to procure fast frequency response contingency resources for all island systems by the end of 2019.

In addition to acquired Demand Response Programs, which will also provide Fast Frequency Response (FFR) resources, the Companies plan to procure supplemental fast frequency response contingency reserve storage systems to mitigate the largest loss of generation as expected in the 2019 resource mix of the system. This resource is slated for installation in 2019 or sooner because the grids are currently operating with reduced reliability.

Mitigation for primary and secondary faults, and for additional probable system events and system configurations beyond those studied, could increase these requirements.

Each application submitted for approval to commit funds towards procurement will include the finally optimal sized FFR contingency resource. The following lists the expected Fast Frequency Response contingency resource capacities:

- O‘ahu: 70 MW to supplement the expected FFR 2 DR resources, expected operation in 2019.
- Maui: 8 MW expected operation in 2019.
- Moloka‘i: 2.75 MW expected operation in 2019.
- Lana‘i: 1.25 MW expected operation in 2019.
- Hawai‘i Island: 9 MW expected operation by 2020 or sooner.

We plan to procure synchronous condensers for all island systems by the end of 2018.

All islands will require synchronous condensers to provide reactive power for voltage support and short circuit capacity for proper protective relay scheme operation. Over the next two years (2017–2018) the Companies intend to submit applications for approval to commit funds towards the procurement of synchronous condensers with the following capacities:

- O‘ahu: 128.5 MVA required operation in 2021 – conversion of Honolulu 8 and 9 generators.
- Maui: 30 MVA required operation in 2021.
- Moloka‘i and Lana‘i: 2.75 MVA required operation in 2019.
- Hawai‘i Island: 25 MVA required operation in 2020.

We will evaluate expanding on-island transmission infrastructure to increase capacity for interconnection of grid-scale resources.

New transmission lines are site specific and dependent upon the specific location and size of a future grid-scale resource. In the near term, the Companies will take the initial steps to facilitate the build out of new transmission to interconnect future grid scale renewable resources beyond the five-year action plan period on all islands. We expect that during the action plan period the O‘ahu sub-transmission system will reach its capacity for interconnecting grid-scale resources based on the sites NREL has identified in its renewable potential analysis. As part of this evaluation, we will weigh this decision against alternatives such as co-location of energy storage and interisland transmission. Other uncertainties such as the practicality of maximizing the NREL stated resource potentials, and the future system load and its shape will affect this decision. Transmission expansion is expected to take between 10-15 years to complete, given the many permitting, routing, and community issues associated with such infrastructure projects. Since development of transmission, lines require substantial lead-time, initiation of transmission work may likely need to precede the development of renewable resources, similar to what was done in Texas and California.

We will continue to evaluate interisland transmission to enable long-term resource integration.

E3’s copperplate analysis determined that an interisland cable has the potential to provide sufficiently large benefits related to procurement and energy capacity savings and that more detailed analysis is justified. E3 estimated that the benefits a large cable system interconnecting each island could have benefits as large as $ 3 billion not including the cost of the cable. However, given the extreme uncertainty around the cable permitting, feasibility and timing, the Near-Term Action Plan incorporates a risk mitigating strategy to procure resources without a presumption that an interisland cable will be in place. This is also a prudent step given our RPS requirement to achieve 30% RPS in 2020 and 40% in 2030. Given the potential value of interisland transmission, the

Companies plan to advance our analysis into a Phase 2 study of the interisland cable that would break down the copper plate case into scenarios that would include (1) specific transmission project costs as well as design requirements and operating limitations, and (2) assumptions about the feasibility, timing, and cost constraints of significantly expanded renewable resources on Maui and Hawai‘i.

We will continue research, development, and demonstration activities valued at over $30M to find innovative technologies beneficial for Hawai‘i's grids.

From 2009–2016, the Companies undertook renewable transformation project initiatives valued at over $30 million of total project funding, including the leveraging of over $20 million of external grant and partnership funding to execute innovative projects supporting renewable integration. The Companies view collaboration with technology entities and stakeholders as a critical part of technology innovation.

We 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.

Pending Commission approval, we plan to execute our Smart Grid Foundation Project to benefit DER integration.

On March 31, 2016, the Companies filed an application for approval of the Smart Grid Foundation Project. We expect to realize the following DER-related benefits from the implementation of the Smart Grid Foundation Project:

- Provide customers access to energy use and information.
- Enables time-of-use and real-time pricing programs.
- Provides system operators and planners needed visibility to grid operations and power quality at DER point of interconnection.
- Enables two-way communication and control of smart home appliances and devices.
- Facilitate integration and management of DR and DER and their associated grid services otherwise provided by the utility.
- Improved grid operations and flexibility through aggregation services, load and curtailment forecasting.

Pending a favorable Commission decision, the Companies plan to implement the following from 2017–2021.

1. Advanced Metering Infrastructure (AMI) across all islands that the Companies serve, which includes a multi-purpose communication network to support automated meter reading, remote control of service endpoints, and communications to DER devices.
2. Meter Data Management System to automate billing by 15–minute intervals.
3. Conservation Voltage Reduction which controls voltage from substations to service endpoints for enhanced power quality and conservation.
4. Customer Facing Solution that provides customers with a seamless integrated mobile and web energy portal.
5. Direct Load Control to replace existing one-way load control switches on Oʻahu with switches that have two-way communication and control.
6. Outage Management System expansion that improves reliability and customer outage information.
7. Enterprise Service Bus for efficient data interchange.
8. Enterprise Data Warehouse to promote data collection, sharing and analytics.
9. 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.

Pending Commission approval, we plan to implement a Demand Response Management System (DRMS).

The DRMS Application was filed with the Commission on December 30, 2015 in Docket No. 2015-0411. Executed contracts with the selected vendor, Omnetric, were filed with the Commission on September 2, 2016. Following the procedural schedule agreed by the parties and approved by the Commission, the Companies filed a Reply Statement of Position on December 21, 2016.

While awaiting Commission approval of the Companies' DRMS project, the Companies will continue to develop integration requirements for the DRMS. We will also work with projects, such as System to Edge-of-Network Architecture and Management (SEAMS) for Sustainable and Holistic Integration of Energy Storage and Solar PV (SHINES), to develop state-of-the-art edge-of-network control capability that could potentially be incorporated directly into the DRMS if approved by the Commission. Hawaiian Electric is targeting initiation of the DRMS project in early 2017.

The DRMS will enable the Companies to manage DR resources and other distributed energy resources through a single integrated system, facilitating the flow of information between the Companies' operational systems and residential, commercial, and industrial customer resources, thereby allowing the Companies to manage and control the dispatch of DR resources to be included in the DR Portfolio. At its core, the DRMS will offer system operators a single view of measureable, actionable, and verifiable, DR resources for system-wide dispatch, while allowing the Companies' DR program managers to perform a range of functions from program design to tracking, settlement, and measurement and verification (M&V).

We plan to implement the first phase of our online DER application web portal in April 2017 to improve the interconnection process for customers.

The Companies are currently in the process of implementing Qado Energy's GridUnity platform for customers, which will have the following capabilities:

- Contractor and customer user accounts
- Ability to submit and view application status online
- Improved work flow management—automated communication issued via email, automated tracking of compliance timelines, automated workflow handoffs, limited automation and data integration with Initial Technical Review
- Consistent application process across the Hawaiian Electric Companies
- Consolidated input of DER projects to serve as input to modeling efforts

Forthcoming implementation phases will include accommodations for future DER programs.

We will evaluate additional foundational technologies that support the DER integration.

In addition to the smart grid foundation project, the DRMS, and the online customer portal, the Companies are in the process of evaluating an advanced distribution management system (ADMS) and substation and distribution automation (DA) technologies. Together these foundational technologies will improve grid efficiencies, outage planning and operations, increase operator situational awareness, and improve reliability for customers as well as DER resources. These technologies will be enabled through a modern communications network that combines local wireless field networks with fiber optics equipped with the bandwidth to support the transmission of system SCADA data, intelligent field device control, DER command and control, AMI real-time data, and smart home device control.

Distributed Energy Resources (DER) Policies Action Plan

We will seek innovative DER programs that benefit all customers.

The Companies fully support and promote next generation equitable DER programs that can provide grid benefits that can be realized by all of Hawai'i. In Phase II of Docket 2014-0192, the Companies will continue to collaborate with customer and industry stakeholders, including solar contractors, inverter manufacturers, and external organizations such as NREL to develop innovative technical solutions and program policies that enable a High DER environment through fair and safe interconnection to the grid, while providing the same reliability that all customers have come to expect.

We will seek DR programs that fairly compensate customers and service providers for grid services.

The Near-Term Resource Plans for each island include DR consistent with full and timely implementation of the DR Programs. For example, DR resources will play a key role in the system security on O'ahu by providing fast frequency response capabilities.

The Companies filed their DR Program Portfolio Application with the Commission on December 30, 2015 in Docket No. 2015-0412. The two major requests in the application are for approval of the proposed tariff structure and the cost recovery methodology. Under the current procedural schedule in Docket No. 2015-0412, a revised DR portfolio will be filed on February 10, 2017 after filing of this PSIP Update. The revised DR portfolio will present the cost effective DR programs that will be pursued specific to each of the island based on the updated analyses. The Companies are targeting initiation of the DR programs in 2017, subject to Commission approval and its timing of a decision. 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 smart meter and other grid improvements.

We will continue our time–of–use (TOU) pilot to inform future efficient rate structures.

As directed by the Commission in Order No. 33976 and Clarifying Order No. 33923 in the Distributed Energy Resources Docket No. 2014-0192, Interim Time-of-Use tariffs are now available for residential customers. The Companies will use the learnings from the interim Time-of-Use tariffs to identify broader Time-of-use rates to reduce peak demand and shift energy use to times of the day when more renewable generation is available.

We will continue to evaluate and pursue distributed energy storage systems (DESS) to benefit DER integration.

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 exploring energy storage as a value-adding customer option and have prepared the following guiding principles to assist in enacting policies that benefit all customers:

1. Energy storage policies should promote or enable renewable energy production to help Hawaiʻi achieve the state's goal of 100% RPS by 2045.

2. 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 (that is, integrating more cost-effective renewable energy that contributes to the state's renewable energy goals).

The Companies have a number of projects that are evaluating various energy storage technologies and applications that could potentially provide grid services. These projects include, but are not limited to, partnerships with the University of Hawaiʻi's Hawaiʻi Natural Energy Institute (HNEI) and Energy Excelerator, and innovative companies such as Stem,[33] Shifted Energy,[34] E-Gear, and Amber Kinetics.[35] The Companies have developed demonstration projects[36] to identify and mitigate potential technology, operational, and market risks associated with the delivery of grid services by energy storage. Our findings from these demonstration projects will inform and refine the implementation of additional distributed energy programs that leverage distributed energy storage resources.

[33] 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.

[34] 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.

[35] Amber Kinetics is developing long-duration flywheel technology which will be tested by Hawaiian Electric in 2017.

[36] See RFP Addendum No 1, Filed under Docket No. 2015-0412 on September 13, 2016.

Environmental Compliance Action Plan

We will comply with greenhouse gas (GHG) reduction commitments through the implementation of our PSIPs.

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’ EmRPwill be done following Commission approval. Hawaiian Electric is working 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.

We will continue to monitor and comply with New Source Review (NSR) and New Source Performance Standards (NSPS)

NSR and NSPS are CAA programs that may have an impact on the future operation of fossil based generation at Hawaiian Electric, Maui Electric, and Hawaiʻi Electric Light. These programs specifically target older, fossil fuel burning units because they generate more air pollution. EPA and DOH require modern pollution control and monitoring equipment to be added to an existing stationary unit if it undergoes certain changes in operation or there is a major modification to the unit.

The NSR program requires existing facilities to improve emission control performance as technology improves over time as older equipment needs to be modified and results in a significant emissions increase. NSR requires the entity to go through a permitting process with EPA and DOH to, among other things, identify the best available control technology that will be used to reduce and monitor emissions. The NSPS program establishes limits for how much of a regulated pollutant can be emitted from new or recently modified units in certain source categories, such as boilers, combustion turbines, and stationary compression ignition and reciprocating internal combustion engines. The NSPS emission limits apply to existing units where there is a physical change or change in the method of operation that increases the amount of an air pollutant currently emitted or that adds emissions from a new air pollutant.

Some of the major projects required to continue to run older units at Hawaiian Electric, Maui Electric and Hawaiʻi Electric Light could require add-on pollution control to ensure the units emit fewer emissions as they age. The costs associated with emissions control programs will be considered, as units require major modifications to continue to operate in the future.

O‘AHU ACTION PLAN

Renewable Acquisition

Replacement of Waiver Projects

Hawaiian Electric is in discussions with NRG, the new owners of the former SunEdison projects (which transfer resulted from SunEdison’s bankruptcy proceedings), to determine the status of these projects and whether they may continue to be viable options for Hawai‘i.

New Grid-Scale Resources

With Commission approval, Hawaiian Electric will be pursuing a transparent and competitive effort to procure cost-effective renewable resources as identified in the Near-Term Resource Plan. Hawaiian Electric is considering various options for a competitive procurement process in compliance with the Commission’s Framework for Competitive Bidding. From time to time, Hawaiian Electric may receive unsolicited proposals for renewable energy projects outside of a competitive procurement cycle that provide clear benefits to customers. In such cases, Hawaiian Electric will review the merits of these proposals in accordance with established rules and practices.

Offshore Wind

Hawaiian Electric is aware of three unsolicited offshore wind energy lease requests from two developers 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 has been working collaboratively with BOEM by providing planning information to assist with BOEM’s lease process and will continue to monitor the BOEM’s 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.

System-Level Improvements

Regulating/Ramping Battery Energy Supply System in 2020

Hawaiian Electric has identified a need for installing and operating a 100 MW, 1-hr regulation/ramping battery energy storage system in 2020 to provide needed ramping to augment DR program capabilities and avoid the need for must-run generation to provide

ramping through conventional means. In order to keep costs as low as possible, the Company is looking at the possibility of dual-purposing a single energy storage project to provide this regulation/ramping function as well as the separate function of providing fast frequency response for contingency reserve mentioned earlier in this chapter.

Replacement Capacity in 2022–2023

Hawaiian Electric plans to propose installing and operating a reciprocating engine station at Marine Corps Base Hawai'i. As the concepts involved with this project will be very similar to the Schofield Generating Station, the Company envisions requesting approval from the Commission via a competitive bidding waiver request and General Order No. 7 application.

The Company will also seek the installation of 100MW of firm, dispatchable, flexible generation, likely through an RFP process that comports with the Competitive Bidding Framework. However, a competitive bid waiver request may be requested to attain this resource if it serves specific government needs. For example, a Waiau Power Barge that would normally serve the O'ahu grid, but that also is intended to provide civil defense emergency services to neighbor islands or energy security to the Navy following natural disasters events such as tsunamis or hurricanes.

The Company is also investigating various ways to reduce the near term rate and bill impact to customers of these generators, including joint venture arrangements that allows for alternative ownership models while still maintaining utility operational control to meet the partnership requirements of the military.

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 (for example, UFLS blocks 1–3) are shed at the 12 kV distribution circuit level to target non-critical residential loads while Blocks 4 and 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. In order to revise the current UFLS scheme to accommodate the changes to the system due to DER resources, projects to automate the distribution system to provide visibility and control of load, DER, and DR resources will need to be implemented. The project development work to support this will begin in 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. The UFLS scheme was revised in late 2016 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.

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. 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 1-hour SO_2 NAAQS may require reductions in SO_2 emissions at Kahe and Waiau by the use of lower sulfur fuels. Implementation of the 2010 1-hour SO_2 NAAQS requires that air agencies identify sources around which further characterization of the air quality is required to determine through either modeling or monitoring if the area around these source are below the standard. Hawaiian Electric has installed air quality monitoring stations for Kahe and Waiau, which will be integrated into the Hawai'i Department of Health's state and local air quality monitoring network to monitor ambient SO_2 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 SO_2 monitoring data, the EPA, by December 31, 2020, will issue its final attainment or nonattainment designation for Kahe and Waiau. If reductions in SO_2 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.

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 7 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 7 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 (for example, 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.

MAUI ACTION PLAN

Renewable Acquisition

New Grid-Scale Resources

Maui Electric will be pursuing a transparent and competitive effort to procure cost-effective renewable resources as identified in the Near-Term Resource Plan. Maui Electric is considering various options for a competitive procurement process in compliance with the Commission's Framework for Competitive Bidding. From time to time, the Companies may receive unsolicited proposals for renewable energy projects outside of a competitive procurement cycle that provide clear benefits to customers. In such cases, the Companies will review the merits of these proposals in accordance with established rules and practices.

System-Level Improvements

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 internal combustion distributed generation (DG), battery energy storage system (BESS), demand response (DR), and synchronous condensers 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. A request to open such a docket was filed with the Commission in May 2016.

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 pursued 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.

Fault Clearing Time Reduction

Reducing fault clearing times reduces the level of imbalance created by a transmission line fault. Maui Electric will continue to work to reduce fault clearing times on the 69kV transmission system. Maui Electric has already added dual differential protection to a majority of the 69kV lines and replaced a majority of the 69kV breakers with 3 cycle SF6 breakers in an effort to reduce fault clearing times. The final two 69kV transmission lines are due to have the protection upgraded in 2017 and the final 69kV circuit breakers will be replaced in 2018. Maui Electric also has plans for upgrades to all of the 23kV line protection, 69kV bus protection, and transformer protection over the next decade.

Underfrequency Load Shed Scheme

In 2016, Maui Electric started 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.

Replacement Capacity in 2022

In May 2016, Maui Electric filed a request with the Commission for a docket to be opened, facilitating the acquisition of replacement capacity for the planned retirement of KPP in 2022. In addition to replacing the capacity that will be lost with KPP's retirement additional generation capacity is needed on the island of Maui to address anticipated load growth, constrained South Maui transmission capability, and Hawaiian Commercial & Sugar (HC&S) ceasing operations. As a temporary near term measure, Maui Electric has begun the procurement of DG just under 5 MW in size to be located at the Kuihelani Substation in central Maui. An application for approval for the DG units was submitted to the Commission in September 2016. Additionally, Maui Electric filed an application with the Commission to expand the existing Fast Demand Response (DR) Pilot Program on Maui from 200 kW to 5.0 MW as a complementary potential near-term capacity strategy.

Environmental Compliance

Clean Water Act / National Pollution Discharge Elimination System (NPDES)

Renew Maui Electric NPDES Permits

Maui Electric's NPDES permits for Maʻalaea 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 7 3.

Facility	Permit Expiration Date	Application Due Date
Maʻalaea	December 15, 2019	June 14, 2019
Kahului	May 13, 2020	November 13, 2019

Table 7 3. Maui Electric NPDES Permit Dates

Kahului Power Plant Retirement/NPDES Compliance Plan

The Kahului Power Plant (KPP) NPDES permit that was effective on June 1, 2015 contains a compliance schedule that includes cessation of operations at KPP no later than November 2024. Maui Electric's current plans include the scheduled retirement of the KPP in 2022.

MOLOKA'I ACTION PLAN

Renewable Acquisition

New Grid-Scale Resources

Maui Electric will be pursuing a transparent and competitive effort to procure cost-effective renewable resources as identified in the Near-Term Resource Plan to achieve 100% Renewable Energy in 2020. Maui Electric is considering various options for a competitive procurement process in compliance with the Commission's Framework for Competitive Bidding. From time to time, Maui Electric may receive unsolicited proposals for renewable energy projects outside of a competitive procurement cycle that provide clear benefits to customers. In such cases, Maui Electric will review the merits of these proposals in accordance with established rules and practices.

Biofuel Procurement

To achieve 100% renewable energy in 2020, some biofuels will be required. We plan to solicit proposals for the procurement of biofuels in 2018.

System-Level Improvements

100% Renewable Energy by 2020

Many parallel efforts to achieve 100% renewable energy for Moloka'i are focused on collaborating with the community, seeking to make necessary investments in our infrastructure, expanding the choices we provide our customers, and seeking alternate sources of financial assistance to keep energy costs affordable. Ongoing research includes: developing control algorithms for battery project, monitoring device/recorder installations, monitoring TripSaver installations, and monitoring and regulating devices.

E-Gear Energy Management Control (EMC) and Storage Technology Pilot Project

In partnership with E-Gear LLC, the Hawaiian Electric Companies have launched a pilot program designed to allow more customers to interconnect rooftop PV systems on Moloka'i.

In this pilot project, E-Gear will install their specialized EMC and storage technology, which will be paid for by the utility, alongside 10 rooftop PV systems that have been waiting to be connected to the grid. Utility system operators can monitor and control this equipment, which can potentially improve the interaction of rooftop PV systems with the

grid. This equipment can also act as a virtual minimal impact system by absorbing grid energy during the day and not contributing to the excess energy situation on Molokaʻi. This configuration will be tested for its ability to address the impact additional DGPV systems have on the small island grid and enable Maui Electric to continue to provide reliable service and power quality for all Molokaʻi customers. The Companies will evaluate the performance of these systems and determine whether similar systems and in what manner of deployment can be used to integrate more solar power in areas with high concentrations of rooftop PV systems.

As of December 2016, 7 of the 10 systems locations have been identified and Maui Electric is working with these customers on coordinating the construction of customer PV systems with the utility's E-Gear system.

E-Gear is evaluating their EMC-equipped PV systems—designed to minimize the grid impact of rooftop PV systems on a small, highly saturated grid like Molokaʻi's—in partnership with the EPRI.

Other Initiatives

Utility-Scale Energy Storage

An Altairnano/ Hawaiʻi Natural Energy Institute (HNEI) 2MW/333KWh Lithium-Ion BESS was installed in 2016. This BESS is a research project with the Companies partnering with HNEI to determine applications for batteries in high solar PV penetration scenarios. Work continues on developing the algorithms needed to speed up the response

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. The awards have not yet been made for this grant as of this filing.

LANA'I ACTION PLAN

Renewable Acquisition

New Grid-Scale Resources

Maui Electric will be pursuing a transparent and competitive effort to procure cost-effective renewable resources as identified in the Near-Term Resource Plan to achieve 100% Renewable Energy in 2030 or possible sooner. Maui Electric will consult with Pulama Lana'i and engage the community to better understand the priorities of the community. Maui Electric is considering various options for a competitive procurement process in compliance with the Commission's Framework for Competitive Bidding. From time to time, Maui Electric may receive unsolicited proposals for renewable energy projects outside of a competitive procurement cycle that provide clear benefits to customers. In such cases, Maui Electric will review the merits of these proposals in accordance with established rules and practices.

HAWAI‘I ISLAND ACTION PLAN

Renewable Acquisition

New Grid-Scale Resources

Hawai‘i Electric Light will be pursuing a transparent and competitive effort to procure cost-effective renewable resources as identified in the Near-Term Resource Plan. Although the current analysis assumes 20 MW of grid-scale wind in 2020, and greater amounts may be possible pending further evaluation of system constraints and resource availability. Analysis will be updated and adjustments made to resource plans through the Companies continuous planning process. Hawai‘i Electric Light is considering various options for a competitive procurement process in compliance with the Commission’s Framework for Competitive Bidding. This will incorporate a new contract model for variable resources, to provide necessary flexibility for energy dispatch and provision of the operational and technical capabilities to support reliable, cost-effective grid operation.

From time to time, Hawai‘i Electric Light may receive unsolicited proposals for renewable energy projects outside of a competitive procurement cycle that provide clear benefits to customers. In such cases, Hawai‘i Electric Light will review the merits of these proposals in accordance with established rules and practices. In addition to these efforts, we have engaged existing renewable energy providers to actively explore opportunities for their facilities to increase contribution to system reliability, increase utilization of renewable energy, and provide more benefits to customers. These discussions and any resulting agreements follow requirements of contractual terms, established rules and practices.

System-Level Improvements

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 has submitted an application for approval from the Commission to commit funds to this project.

6800 Line Reconductor, Phases 2 through 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 and the project was approved by the Commission. Phase 2 and 3 were completed in 2016, phase 4 will be completed in 2017.

Kilauea 3400, Phases 1 through 4

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 Hawaiʻi Belt road to improve the reliability of the aging infrastructure. The replacement work is targeted for the period 2016 to 2017. Phase 1 will be in 2017, phases 2 and 4 in 2018, and phase 3 in 2019.

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, but may be adjusted after discussions with the community. 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 Hawaiʻi generation. The reconductoring work was previously targeted for 2018 but has been moved out to 2020–2021 due to the environmental and regulatory studies required.

Underfrequency Load Shed Scheme

Hawaiʻi Electric Light is implementing a Dynamic UFLS project that is in progress and will begin testing in the first quarter of 2017. 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. In January 2015, the UFLS scheme on Hawai'i island was modified to have smaller size blocks in order to avoid overshedding and result in overfrequency tripping of PV systems. An adaptive load-shed scheme is being installed for HELCO and commissioning is planned for 1Q 2017.