RHODIUM GROUP

Transcending Oil

Hawaii's Path to a Clean Energy Economy

Prepared for Elemental Excelerator

April 2018

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Foreword

Aloha,

Every year, our Elemental Excelerator team combs through applications — this year almost 500 — from amazing entrepreneurs around the globe. We learn about solar robots, spinning batteries, even vertically-integrated cows (in case you're wondering, that's a cow that goes from farm to table right here in Hawaii, without a mainland detour for finishing). To learn as much as we can about each new idea, we bring in community members and ask: Which solutions are most likely to positively impact people's lives? What ideas will be most fruitful for our islands?

We invite community members to help select companies because we're an unusual type of accelerator. As a non-profit organization with a mission to support companies that will speed Hawaii's transition from oil to clean energy, we optimize for impact, not for financial return. And, in order to uncover the most creative thinking and attract the best solutions for our clean energy transition, we work to understand the resources and needs here at home. Our curiosity to learn more led us on a quest to refresh the data about exactly how Hawaii has progressed in our transition, and what's possible moving forward.

We share it with you in the spirit of collaboration, with the intention of informing rich conversations and supporting collective action (and with the not-so-secret hope that it may inspire you to jump in and start a company with an idea that just might change the world).

WHERE WE'VE BEEN

The idea for Elemental Excelerator was borne out of a landmark partnership called the Hawaii Clean Energy Initiative. In 2008, this partnership aligned state, federal, utility, business, and non-profit organizations that agreed we no longer needed to burn oil in an island chain with abundant natural resources.

We've made enormous progress — going from 6% renewable generation in 2008 to over 25% in Hawaii today. Just a decade ago, solar energy and electric vehicles were virtually nonexistent here. Now, in 2018, we have the most rooftop solar and the second most electric cars per capita in the nation. Hawaiian Electric, Kauai Island Utility Cooperative, Hawaii Energy, government agencies, and the private sector have implemented renewable energy and energy efficiency that has reduced greenhouse gas emissions totaling 2.5 million metric tons. That amounts to taking 160,000 cars off the road for a year. So, while it may not always feel like it, change is happening, and happening fast.

WHERE WE'RE GOING

After this decade of acceleration, we recognized the need to explore what the increasing pace of technological and economic change will mean for Hawaii's future. We commissioned independent energy and transportation analysts to dig into the numbers, gather insights from our community members, and assess what is possible.

We don't think that one report can provide all the answers, but it can help inform our thinking and deepen our collective conversations. We learned that, contrary to conventional wisdom, Hawaii can save money by accelerating the transition off of oil. Here are two insights we found particularly interesting:

1. **It's cheaper to go faster than to stick with our current targets.** The analysis shows that it's possible to generate between 58% and 84% of our electricity from renewable sources by 2030 — and it's cheaper than not doing it. This is compared to our current target of 40% renewable energy by 2030.

2. **Transitioning from oil earlier creates good-paying jobs.** The transition can create as many as 3,500 more jobs in Hawaii compared to what would occur by just meeting current targets (for scale, there are 2,700 auto mechanics in Hawaii). Clean energy jobs pay $3-7 per hour more than Hawaii's median wage of about $20 per hour.

WHAT'S NEEDED NOW?

We have all the right ingredients, but artificial barriers stand in our way. For electricity, this includes misaligned financial incentives that keep utilities from benefitting from clean energy, outdated rules and systems that limit data access and transparency, and a lack of options for renters and residents of limited means who want greener choices. For transportation, the numbers show that we're farther behind in getting off of oil. We will need to design neighborhoods that give families the freedom to get around without cars; increase choices for public transit, shared rides, electric vehicles, and biking; and work with other states and call on the federal government to uphold and strengthen vehicle efficiency standards.

Rather than being surprised by or unprepared for the changes to come, we have an opportunity now to take collective action and transition by design, not by default.

WHY DOES THIS MATTER?

We embarked on this quest because we love our home. This is a place where people value long-term impact over short-term gain, treat neighbors as ohana rather than as strangers, and willingly embrace their kuleana to care for our islands that in turn care for us. We can be a beacon for the world and prove that it's possible to decarbonize our economy. Technology and policy will play important roles, but what we've learned from the past decade is that it will take people working together even when they don't always agree, organizations redesigning incentives to facilitate change, and leaders taking chances on innovative and unfamiliar ideas.

A 10-year-old already lives in a cleaner Hawaii today than she would have had we not started this journey in 2008. And she will work in a more prosperous Hawaii if we work together to accelerate toward clean energy over the next ten years.

As we learned as teenagers, the best way to gain control through the curves is to accelerate through them. The time is now.

Aloha,

Dawn Lippert & the EEx team

CEO, Elemental Excelerator

ELEMENTAL EXCELERATOR

***Elemental Excelerator** is a non-profit that helps startups change the world, one community at a time. Each year, we find 15-20 companies that best fit our mission and fund each company up to $1 million to improve systems that impact people's lives: energy, transportation, water, agriculture, and beyond. To date, we have awarded over $22 million to 63 companies. For more information, please visit elementalexcelerator.com.*

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About the Authors

Elemental Excelerator commissioned Rhodium Group, in partnership with Smart Growth America to assess the pace and impact of clean energy deployment in Hawaii since the launch of the Hawaii Clean Energy Initiative in 2008, and the prospects for accelerating that progress in the years ahead. The research was performed independently, and the results presented in this report reflect the views of the authors and not necessarily those of Elemental Excelerator.

RHODIUM GROUP

Rhodium Group is an independent research provider combining economic data and policy insight to analyze global trends. Rhodium's Energy & Climate team analyzes the market impact of energy and climate policy and the economic risks of global climate change. This interdisciplinary group of policy experts, economic analysts, energy modelers, data engineers and climate scientists supports decision-makers in the public, financial services, corporate, philanthropic and non-profit sectors. More information is available at www.rhg.com.

John Larsen is a Director at Rhodium Group and leads the firm's US power sector and energy systems research. John specializes in analysis of national and state clean energy policy and market trends. Previously, John worked for the US Department of Energy's Office of Energy Policy and Systems Analysis where he served as an electric power policy advisor.

Shashank Mohan is Director of Quantitative Analysis at Rhodium Group. He leads the development and management of Rhodium's suite of economic models and other quantitative tools.

Whitney Herndon is a Research Analyst at Rhodium Group focused on US energy markets and policy. She employs a range of energy and economic models to analyze the impact of policy proposals on the US electricity sector, energy market, and macroeconomy.

Peter Marsters is a Research Analyst at Rhodium Group and draws on an interdisciplinary background in economics, engineering, and public policy to analyze the latest energy and environmental trends.

Hannah Pitt is a Research Analyst at Rhodium Group. She focuses on analyzing energy markets and policy, and on quantifying the impacts of climate change on human systems.

SMART GROWTH AMERICA

Smart Growth America works with elected officials, real estate developers, chambers of commerce, transportation and urban planning professionals, governors, and leaders in Washington to improve everyday life for people across the country through better development. More information is available at https://smartgrowthamerica.org/

Beth Osborne is Vice President for Transportation at Smart Growth America (SGA), leading the organization's work in transportation policy, advocacy and technical assistance. Previously, Beth worked for the US Department of Transportation as Deputy Assistant Secretary and then Acting Assistant Secretary for Transportation Policy, where she managed the TIGER Discretionary Grant program, worked on the fuel economy standards and ran the Secretary's livability initiative.

Dr. Eric Sundquist is director of the State Smart Transportation Initiative (SSTI), a project of SGA and the University of Wisconsin. He works with state DOTs and other large transportation departments on sustainable transportation policy and practice. Prior to launching SSTI, Eric worked on building-energy policy at UW.

Dan Levine is a Policy Associate with Smart Growth America, leading efforts on state and local transportation policy. He launched the organization's State Transportation Advocacy, Research and Training (START) network to aid legislators, advocates, and local stakeholders in advancing legislation to boost funding and empower local initiatives.

Dr. Chris McCahill is a researcher at SSTI, where he also works with DOTs on sustainable transportation policy and practice. Prior to joining SSTI, he worked on the Project for Transportation Reform at the Congress for New Urbanism.

Acknowledgments

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Finally, the authors are grateful for the feedback received by the following individuals who reviewed an earlier version of this analysis including: Colton Ching, Hawaiian Electric; Murray Clay and Kyle Datta, Ulupono Initiative; Makena Coffman, Matthias Fripp, Michael Roberts, University of Hawaii, Manoa; Kristina Currans, University of Arizona; Jose Dizon, Parker Ranch; Scott Glenn, Hawaii Office of Environmental Quality Control; Deron Lovaas, Natural Resources Defense Council; Ernest Moniz, Energy Futures Initiative; Amy Myers Jaffe, Council on Foreign Relations; Francis O'Sullivan, Massachusetts Institute of Technology Energy Initiative; Alison Silverstein, Silverstein Consulting; Ron Whitmore, County of Hawaii and Chris Yunker, Hawaii State Energy Office.

Executive Summary

An ocean apart from the US mainland's electric supply, Hawaii has embarked on an ambitious effort to wean itself off imported fossil fuels. Dependence on oil has been a defining feature of Hawaii's energy system since before its 1959 statehood. As a result, Hawaii's electricity prices have been among the highest and most volatile in the nation. Over the past 15 years, the people of Hawaii have paid 260% more for electricity than the US average, while gasoline prices consistently hover close to $1-per-gallon higher.

Hawaii has already begun to usher in a new era of energy independence. It is the only state in the nation with a mandate to reach 100% renewable electricity in place, with a deadline of 2045. The last ten years have seen steady progress toward that goal. In 2008, the Hawaii Clean Energy Initiative, a partnership between the State of Hawaii and the US Department of Energy (DOE), launched with the goal of transforming Hawaii's energy ecosystem. Innovators in Hawaii, seeking to mitigate climate change and make the state more resilient, have created opportunities for new clean energy technologies and novel business models to thrive in the state.

Elemental Excelerator commissioned Rhodium Group, in partnership with Smart Growth America, to conduct an independent analysis of Hawaii's clean energy transition. To do this, we leveraged state-of-the-art energy system and economic modeling tools, state and federal datasets, existing literature and nearly 200 hours of interviews and meetings with Hawaii stakeholders and experts. This is not a plan; rather, this report presents a quantitative assessment of accomplishments to date and describes the future potential of clean energy deployment in Hawaii's electric power sector and on-road transportation.

THE PATH AHEAD: CHEAPER TO GO FASTER

What does the future hold for Hawaii? We find it is cheaper to accelerate the clean energy transition than cruise toward the 2045 renewables targets. After considering a range of energy sector cost projections, we find Hawaii's most cost-effective pathway would source from 58 to 84% of its electricity from renewable energy by 2030 (Figure ES.1). That could amount to double the mandate of Hawaii's current Renewable Portfolio Standard, which calls for 40% renewable energy by 2030. Supplying a full 100% of the state's electricity from renewable sources as early as 2030 would be more expensive than this 58 to 84% range, but cheaper than the current energy mix or current RPS under most oil price and renewable energy cost futures.

Why is this the case? Innovation and scaled deployment have slashed the cost of renewables so much that they are cheaper than oil in many applications. Recent clean power purchase agreements prices are lower than the price of conventional power plant fuels (Figure ES.2).

Accelerating the clean energy transition will bring real economic and environmental benefits including:

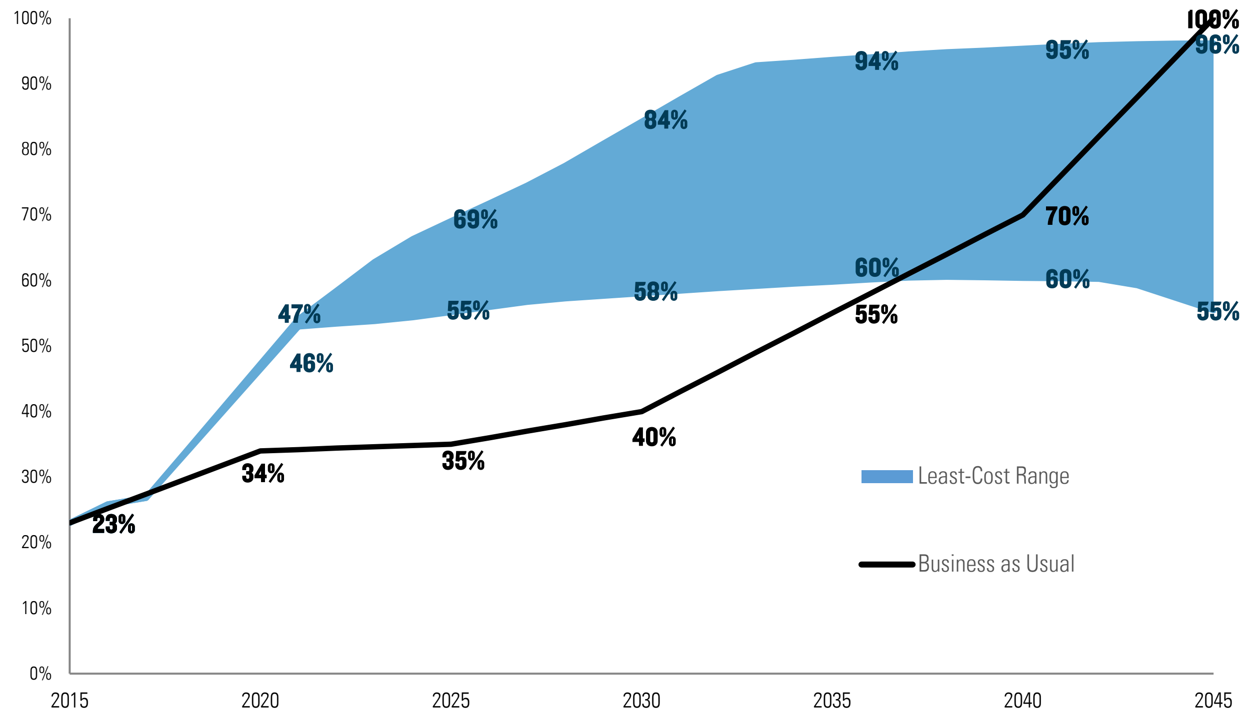
- ***Increasing investment in clean energy up to an additional $2.9 billion.*** Accelerating clean energy deployment from 2020 to 2030 will bring new investments and will reduce the amount of money sent offshore for imported oil.

- ***Adding thousands of new good-paying jobs.*** New investment brings employment opportunities across the state. Hawaii could see a net increase in average annual statewide employment of 1,522 jobs from new clean energy investment (Figure ES.3). Energy cost savings could increase yearly average employment by an additional 500 to 2,000 jobs.

- ***Creating a strong platform for innovation.*** More innovation will be necessary to achieve a 100% renewable energy future. Hawaii has an opportunity to position itself at the forefront of energy innovation and compete globally for talent and investment.

- ***Meeting Hawaii's Paris Commitment.*** While Hawaii is on track to meet its share of America's 2025 target under the Paris Agreement, under a "business-as-usual" scenario the state is not on a path to reduce emissions to levels consistent with the Paris Agreement's long-term temperature targets. Hawaii needs to accelerate its clean energy transition and address its oil dependence in both the electric and the ground transportation sectors if it is going to maintain progress towards these goals (Figure ES.4).

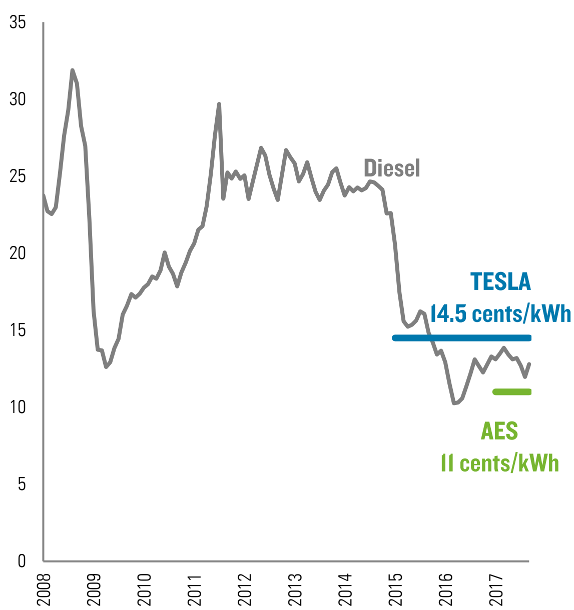
Figure ES.1: State-wide renewable share of total generation, 2015-2045



Source: Rhodium Group analysis

Figure ES.2: Kauai Island Utility Cooperative solar-plus-storage contracts and diesel fuel costs

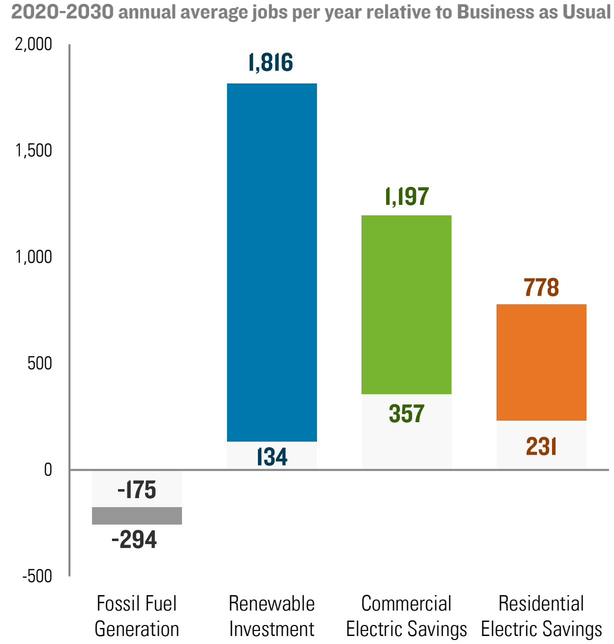
2016 Cents/kWh



Source: Kauai Island Utility Cooperative (KIUC), Hawaii Department of Business, Economic Development and Tourism (DBEDT), Rhodium Group analysis

Figure ES.3: Change in employment driven by investment and cost savings from accelerated clean energy deployment

2020-2030 annual average jobs per year relative to Business as Usual



Source: Rhodium Group analysis

THE ROAD AHEAD: DOUBLING DOWN ON MOBILITY

The pace of the transportation clean energy transition has been slower than in electric power. While Hawaii has taken steps to expand mobility options across the state, total transportation demand is increasing. Federal standards have helped to keep oil consumption flat despite growth in travel demand. The state ranks second in the nation in electric vehicles per capita fueled in part by state and county incentives and $10,000 rebates offered by Hawaiian Electric. Hawaiian Electric's Electrification of Transportation roadmap projects that 55% of cars on the road in 2045 will be electric. Last year, each county in Hawaii proclaimed a goal of 100% renewable ground transportation by 2045.

Looking to the future, we find that transportation demand will continue to increase without new efforts to expand mobility and improve the prevalence of dense, mixed-use development. By coupling these actions with accelerated sales of EVs, in line with the county-level proclamation, Hawaii could cut its oil dependence in the ground transportation sector to zero by 2045. This can be achieved while still capturing the benefits of accelerating clean energy in the electric power sector.

NEW ACTION IS NEEDED

Hawaii has a strong track record of setting ambitious goals in electricity and transportation, but to capture the benefits of accelerating the clean energy transition new action by the state, counties, communities, and individuals are required. These actions can improve existing policy frameworks and create new ones that provide certainty for businesses, opportunities for new technologies and incentives to make an accelerated clean energy transition a reality. These actions fall into three categories:

Phase out fossil fuels:

- ***Accelerate renewable energy targets.*** Revise Hawaii's renewable energy mandate to align with current clean energy economics. Our analysis shows that it is cheaper to use less oil in the electric sector than current policy mandates require through at least 2037.

- ***Adopt Zero Emission Vehicle standards.*** Join nine other states in adopting California's ZEV standards to require more EVs be sold in the state by 2025.

- ***Follow through and build on clean transportation commitments.*** Hawaii's mayors have pledged to electrify public vehicle fleets by 2035. Meeting these goals and extending them to private fleets, and possibly automated vehicles will accelerate EV deployment in the state.

Realign incentives with clean energy goals:

- ***Revise utility regulatory frameworks to create an open grid.*** Change utility regulations to let the utility profit from cutting oil consumption. Lift limits on distributed energy and establish fair compensation for those resources, especially rooftop solar, so these technologies can deliver all the system benefits they have the potential to provide.

- ***Create an open data environment.*** Encourage the creation of open data between the utility and government, which will enable more efficient markets and attract local and global innovators.

- ***Engage now in a multi-sector, long-term integrated energy plan.*** Proactively engaging all stakeholders in the development of a comprehensive energy plan for the state will give public and private sector actors needed certainty for investment decisions. Identifying and working through tradeoffs between land-use, energy production priorities and community needs should be a central focus of this process.

- ***Put a price on carbon.*** A carbon tax could generate revenue that stays in Hawaii. That funding stream can serve for a variety of purposes such as dividend payments to local residents, clean energy development and other projects that combat the harmful impacts of climate change.

Tackle transportation demand

- ***Revise state and county land use and transportation policies to incentivize multimodal mobility and disincentive car ownership.*** Revising subdivision ordinances and zoning to improve mobility options, incentivize land-uses and enhance connectivity can reduce transportation demand growth.

- ***Price the full cost of parking and driving.*** Half the VMT reductions considered in our analysis come from pricing mechanisms. Parking management plans should be established, and minimum parking requirements in new developments should be removed, as they add to housing costs and incentivize personal vehicle ownership. Congestion charges potentially coupled with VMT charges tailored to reward ride-sharing could be useful in shoring up lost gasoline tax revenue while also reducing transportation demand.

- **Design public streets for everyone.** Public streets are the most underutilized public asset. Future road maintenance and new road construction should support a multimodal system of transportation including pedestrian, bicycle lanes, bike share, car share, ride-hailing, bus, rail, and EV charging.

HAWAII IS ALREADY REAPING THE REWARDS OF THE CLEAN ENERGY TRANSITION

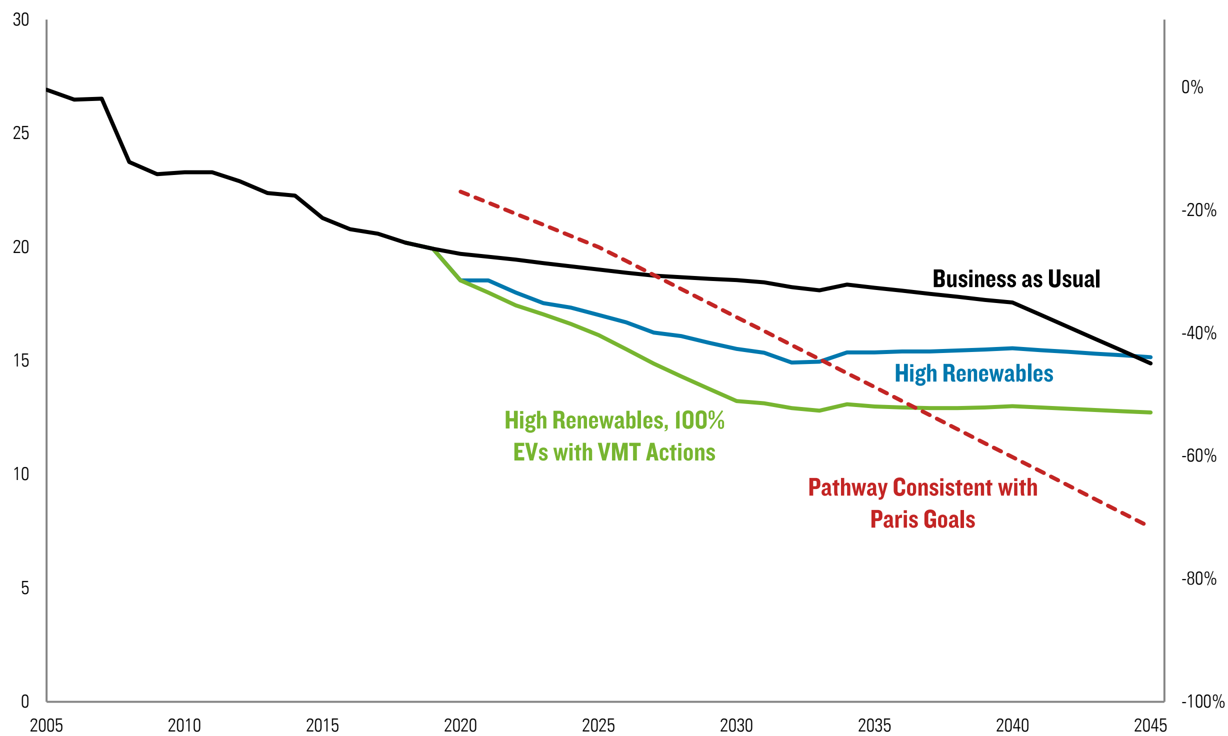
Since 2008, clean energy has surged in Hawaii due to falling costs, policy leadership, and innovation. Renewable energy now makes up 25% of all the power generated in Hawaii up from 6% in 2008 (Figure ES.5). Nearly one thousand gigawatt hours of electricity savings have been captured through energy efficiency investments. That is almost enough electricity to power the Big Island for one year. Hawaii committed to accelerate this transition and put the state on track to do its part in meeting long-term US greenhouse gas (GHG) emission reduction goals, with a commitment to achieve 100% renewable energy by 2045. These combined achievements have produced real benefits including:

- **Hawaii now has nearly 16,000 clean energy jobs.** There are twice as many people working as rooftop solar installers, energy efficiency contractors, and renewable fuel producers than people employed in fossil energy. Energy jobs on average pay $3- to $7-per-hour better than the median wage, so this growth in clean energy employment has helped support living wages in Hawaii.

- **Hawaii saved over 2.5 million metric tons of GHG emissions from 2010 to 2015.** The state has cut total emissions by 20% from 2005 levels, outperforming the US as a whole.

Figure ES.4: Hawaii economy-wide greenhouse gas emissions, 2005-2045

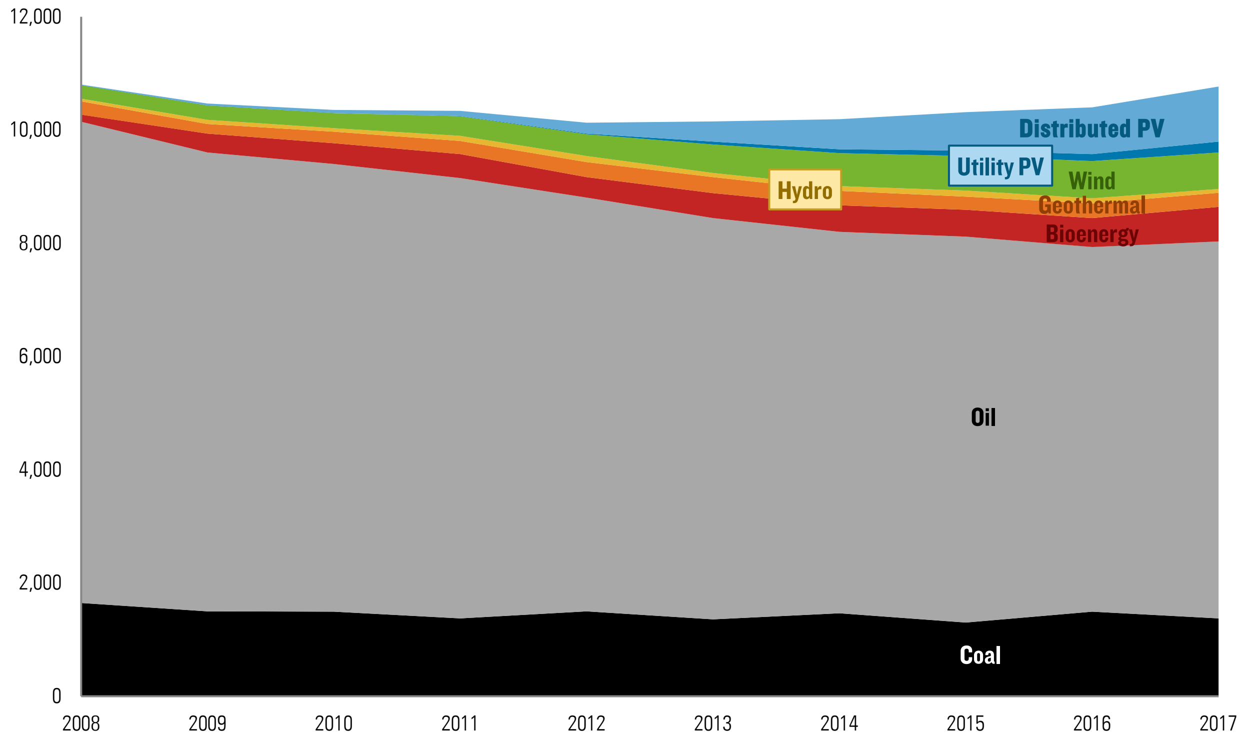
Million metric tons carbon dioxide equivalent (left axis), % change from 2005 (right axis)



Source: Rhodium Group analysis. "Pathway Consistent with Paris Climate Goals" assumes a straight-line path from a 26-28% reduction below 2005 levels in 2025 (the official US target under the Paris Agreement) to a 83% reduction in 2050, the long-term goal put forward by the US at the Copenhagen climate conference. It is possible, depending on the actions taken by other countries, climate sensitivity, post-2050 action and other factors, that a greater than 83% reduction in 2050 would be required by the US to meet the Paris Agreement's long-term temperature stabilization target.

Figure ES.5: Hawaii electric generation by fuel and technology, 2008-2017

Gigawatt hours



Source: Energy Information Administration, Hawaii Public Utilities Commission, Rhodium Group analysis. Note: Generation includes utility scale and distributed generation. Bioenergy includes biomass, biodiesel and municipal solid waste. Hydro includes conventional and run-of-river technologies.

CHAPTER I

Introduction

Like the rest of the US, Hawaii has a dynamic and thriving economy. The state's robust military presence, strong tourism industry, and diverse commercial base have helped deliver a vigorous recovery from the Great Recession. Indeed, Hawaii today has the lowest unemployment rate in the country, at 2.1%.[i] Hawaii's economy has a unique vulnerability. Since before becoming a state in 1959, Hawaii's energy system has been almost exclusively dependent on imported oil.

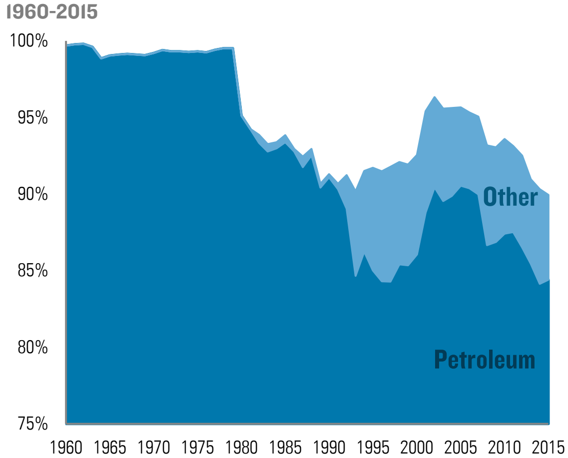
OIL DEPENDENCE, AND ITS CONSEQUENCES

Hawaii's heavy reliance on imported oil for nearly all the state's energy needs is a result of its isolation, 2,500 miles from the nearest neighboring state, and until recently a lack of cost-effective local alternatives. Until 1980, nearly 100% of all energy used in Hawaii was imported petroleum (Figure 1.1). Just as on the mainland, oil is used to fuel cars, trucks, and airplanes. Unlike the mainland, Hawaii has also relied on oil to provide electricity to the state's growing population.

Some diversification towards biomass and other local energy sources began in the 1980s. Hawaii also started importing coal for electric power generation in the 1990s. Still, the share of imported energy used in Hawaii hovered around 90-95% for the past 25 years while for the US as a whole, net energy imports declined to 8% in 2017.[ii]

Figure 1.1: Shares of Hawaii energy consumption from imports

1960-2015



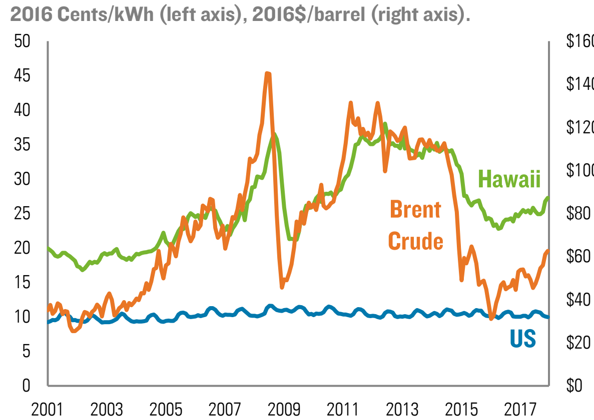
Source: Energy Information Administration (EIA), Rhodium Group analysis. Note: Petroleum includes imported ethanol.

Among the highest electricity prices in the country

There are several consequences of Hawaii's high level of oil dependence. One of the most tangible is the inextricable link between electricity prices and oil prices. Oil is a global commodity traded in an open and liquid market. Hawaii, like all oil importers, is forced to pay whatever the going oil price is on a given day. The oil price paid by the state's power generators is passed along to households and businesses in the price they pay for electricity. Because oil is one of the most expensive sources of energy for power generation, Hawaii has among the highest electricity prices in the country. Over the past 15 years, the people of Hawaii have paid 260% more for electricity per kilowatt hour (kWh) than the US average (Figure 1.2).[iii] Oil market dependence also makes electric prices far more volatile in Hawaii than elsewhere in the US, making it difficult for households and businesses to plan and invest.

Figure 1.2: Hawaii and US average electric rates and Brent crude prices 2001-2017

2016 Cents/kWh (left axis), 2016$/barrel (right axis).



Source: Department of Business, Economic Development & Tourism, EIA, Rhodium Group analysis

Hawaii's cost of living leads the nation

High electricity prices have contributed to Hawaii becoming the most expensive state to live in the nation.[iv] Most goods, including oil, must be shipped either from the mainland or abroad, leading to significantly higher prices than the rest of the US. The cost of homeownership is third-highest in the country due to land constraints and high demand from seasonal residents.[v] Hawaii's gasoline prices are consistently close to $1 per gallon higher than the US average.[vi] Meanwhile, almost every dollar spent on imported energy sends money out of state that could otherwise be spent in the local economy.

Contributing to climate change

Hawaii's dependence on oil also produces carbon dioxide (CO_2) emissions that contribute to global climate change. The average person in Hawaii was responsible for 14 metric tons of global warming pollution in 2015.[vii] While lower than the US average, that is still higher than 85% of the countries on Earth, including Germany, France, Japan, China, and India. Successfully addressing climate change requires all states and countries take action. Global efforts to reduce emissions and avoid the worst impacts of climate change are particularly important for Hawaii, where sea level rise could fundamentally change the landscape, threaten critical infrastructure, and destroy valuable real estate. The Hawaii Climate Change Mitigation and Adaptation Commission estimates that sea level rise of 3.2 feet by the end of this century would displace over 20,000 residents in Hawaii, flood 25,800 acres of land and compromise over 6,500 structures with a current value of $19 billion.[viii] Recent research suggests that if past emissions trends continue there is a greater than 90% chance of that much sea level rise occurring this century.[ix]

HAWAII CAN AND IS CHANGING COURSE

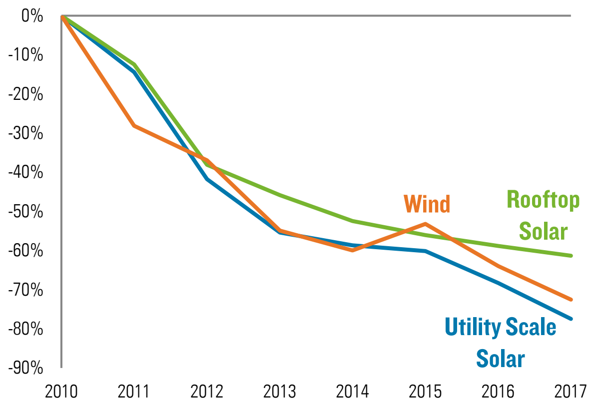
Hawaii has already begun to chart a course away from oil. In 2008 the Hawaii Clean Energy Initiative (HCEI), a partnership between the State of Hawaii and the US Department of Energy (DOE), was launched with the goal of leading Hawaii towards energy independence. Complementing HCEI's efforts, innovators in Hawaii seeking alternatives to expensive imported energy have created opportunities for new clean energy technologies and novel business models to thrive in the state.

Clean energy transition is underway

As a testament to these developments, 25% of the electricity generated in Hawaii now comes from renewable energy, up from 9% in 2010.[x] The average cost of wind and solar generating technologies in the US has dropped by 60-77% during that time (Figure 1.3).[xi] Recent utility procurement deals for renewable energy register well below the cost of oil, reflecting this increasingly compelling economics.[xii] Still, more than 70% of Hawaii's electricity and nearly all of its transportation fuel currently comes from fossil fuels. Leaving Hawaii, its economy, and its people vulnerable to the whims of global oil markets in a way that most Americans are not.

Figure 1.3: Change in renewable energy costs

US national average



Source: National Renewable Energy Laboratory, Lawrence Berkeley National Laboratory, Rhodium Group analysis. Note: Both solar data series reflect installed system costs. Wind data reflects agreement prices.

THE PURPOSE OF THIS STUDY

Elemental Excelerator commissioned Rhodium Group, in partnership with Smart Growth America, to conduct an independent analysis of Hawaii's clean energy transition. The goal of this work is to assess the impact of the transition since 2008, when HCEI was born, and explore potential pathways in the decades to come. To do this, we leveraged state-of-the-art energy system and economic modeling tools, state and federal datasets, existing literature and nearly 200 hours of interviews and meetings with Hawaii stakeholders and subject matter experts. This report presents our results. It describes the progress and potential of clean energy deployment in Hawaii's electric power sector and on-road transportation, with a focus on energy consumption and costs, employment, investment, technology, and pollution. Our report is not intended to be an energy plan for Hawaii. Instead, we aim to provide a quantitative assessment of accomplishments to date and what is possible going forward.

Structure of the report

The report consists of five parts. This introduction is followed by Chapter 2 where we review developments in Hawaii's clean energy transition since the creation of HCEI and quantify the impact to date. Chapter assesses how fast Hawaii could move as it continues its clean energy transition and the implications of acceleration. In Chapter 4 we present key findings and policy recommendations. A separate technical appendix containing additional details of how we conducted our analysis is available at:

https://rhg.com/research/transcending-oil-hawaii-clean-energy-economy

CHAPTER 2

A Decade of Clean Energy Progress

At the beginning of 2008, Hawaii was on the verge of the financial crisis and Great Recession along with the rest of the nation. Record high oil prices that year particularly burdened the state's economy, with consequently record high electric rates and gasoline prices. Energy spending equaled roughly 10% of the state's GDP in 2008.[xiii] Not since the late 1970s, had the economic ramifications of Hawaii's outsized dependence on imported oil been so pronounced, and so painful.

In response, the State and the US DOE signed a Memorandum of Understanding (MOU) to create HCEI, a unique federal-state collaboration intended to diversify Hawaii's energy system and steer the state towards energy independence.[xiv] In this chapter, we draw on approximately 200 hours of stakeholder interviews and meetings, state and federal data and an array of literature to document the most consequential energy events since HCEI's creation, the pace of the clean energy transition over the past decade, and its implications.

HCEI PROCESS AND GOALS

HCEI initiated a collaborative process that brought together a diverse set of stakeholders to find innovative and broadly supported actions to reduce the state's oil dependence. The first round of HCEI goal-setting primarily focused on electric power supply and demand. Analysis conducted for HCEI at the time suggested up to 70% of Hawaii's electricity needs by 2030 could be met with local renewable energy and energy efficiency resources. By harnessing these resources, Hawaii could substantially cut its dependence on oil while fostering local economic development.

In interviews for this report, people who took part in the HCEI stakeholder process lauded the initiative for its inclusiveness and collaborative nature. Most agreed that HCEI enabled members of the Hawaii energy and business community to recognize the urgency of confronting the state's oil dependence. The process also helped to create a consensus that local, affordable, clean energy resources are available to substitute for oil in the electric power sector.

HCEI sets goals and codifies them into law

Supported by analysis, a series of charrettes, and ongoing stakeholder engagement, HCEI set its first set of goals for Hawaii in 2008. Among these goals were three key targets: 1) saving 4,300 gigawatt hours (GWh) of electricity, equal to roughly 30% of projected 2030 electric demand, through energy efficiency; 2) meeting 40% of Hawaii's electric demand with renewable energy by 2030; and 3) transitioning to 100% renewable energy on Molokai and Lanai. That same year, the state entered into an agreement with Hawaiian Electric, the state's largest electric utility, to achieve these targets. The agreement also included a commitment to pursue key regulatory reforms, such as decoupling electric revenues from rates. Hawaiian Electric also agreed to pursue procurement of up to 1,000 megawatts (MW) of renewable energy, including the possible development of large wind facilities on neighbor islands to deliver power to Oahu via undersea cables.[xv]

Hawaii codified HCEI's goals in statute. In 2009 an Energy Efficiency Portfolio Standard (EEPS) was enacted. It created a third-party administrator, Hawaii Energy, charged with meeting the 4,300GWh savings goal with funding from an existing system benefits charges on customer bills.[xvi] The same statute increased the state's renewable portfolio mandate to 25% in 2020, from 20%, and set a new requirement of 40% renewables by 2030.[xvii]

HCEI expands focus to transportation

Building on this policy action in the electric power sector, HCEI's board, and what would become its steering committee, turned their focus to transportation. To break its oil dependence, Hawaii would have to address transportation consumption, which represents 62% of total petroleum consumption.[xviii] In 2011, HCEI set new ground transportation goals including:

- Reduce ground transportation vehicle miles traveled (VMT) 4% below 2011 levels by 2020.
- 40,000 electric vehicles (EVs) on the road by 2020.
- Blend 50 million gallons per year of renewable fuel into the fuel mix by 2020.
- Reduce ground transportation petroleum consumption by 70% by 2030.

That same year, the state approved a study to explore how to expand biofuel production in Hawaii, with the view that local, sustainably-produced biofuels could reduce import dependence and create new economic development opportunities. Five years later, the state established a renewable fuels production tax credit.

Strengthening cooperation and looking forward

In 2014, the State of Hawaii and DOE reaffirmed their collaborative commitment through a new MOU and set out to establish a long-term vision for Hawaii's clean energy transition.[xix] Under the new MOU, the state reinvigorated its stakeholder engagement with a continued focus on tackling transportation oil consumption. A two-year community engagement effort commenced with a series of charrettes. Each focused on a different component of transportation energy demand. The effort culminated in a report that outlined a series of recommendations for reducing transportation demand and boosting renewable fuel production and use.[xx]

Electric power remained a top priority for HCEI in 2014. Policymakers set out a new long-term renewable energy goal of 100% by 2045. The following year, the state amended its renewable portfolio mandate by increasing the 2020 target to 30% and adopting HCEI's long-term target. Hawaii became the first and only state in the nation to establish a 100% renewable electricity mandate.[xxi]

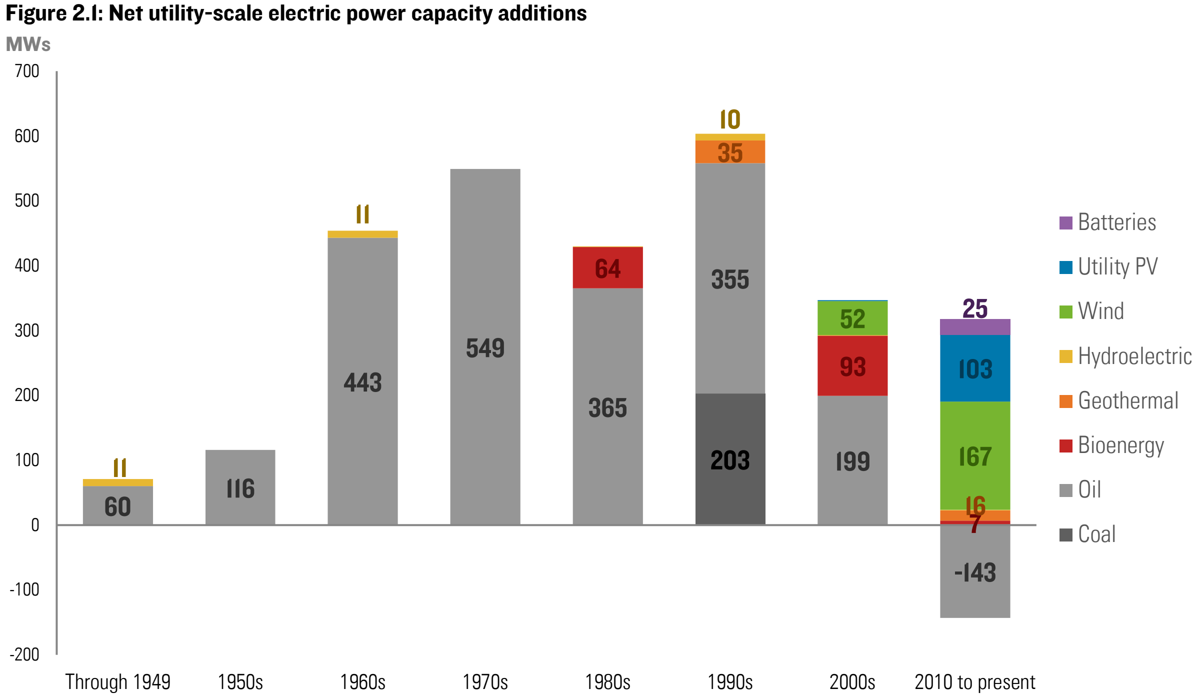
HCEI AND HAWAII'S CLEAN ENERGY TRANSITION

HCEI set Hawaii on a path away from oil, towards locally sourced renewable energy. The policies put in place over the past decade established the state as a national clean energy leader, especially in the electric power sector. In this section, we examine the changes that occurred in the electric and ground transportation sectors and discuss major events beyond the policy reforms outlined above that drove the shift.

Electric power transition

Hawaii's electric power sector moved quickly towards embracing renewable energy, though perhaps not along the course that policymakers expected at HCEI's 2008 inception. After decades of building almost exclusively oil-fired generating capacity, the state's utilities changed course in the 2000s (Figure 2.1). The first large wind projects broke ground in 2006 on Hawaii Island and Maui. Since 2010, wind capacity has tripled, and over 100 MWs of utility-scale solar has been installed. Additionally, the state now has 25 MWs of battery storage in place with more on the way.

Figure 2.1: Net utility-scale electric power capacity additions

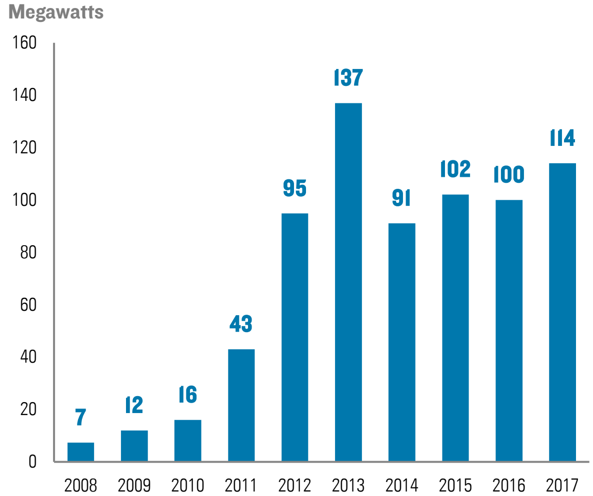


Source: EIA, Rhodium Group analysis

While these changes in the bulk power system mark a significant departure from the past, shifts in the distribution system represent more impressive progress. Customer-owned rooftop distributed solar photovoltaic (PV) capacity additions took off in 2012. The ascent of distributed PV was driven by a combination of historically high oil prices, federal and state tax incentives, rapidly falling technology costs, and Net Energy Metering (NEM) rules that required the utility to pay customers retail electric rates for self-generated power sold to the grid. From 2010 through 2017, Hawaii installed over 600 MWs of rooftop PV capacity - more than all utility-scale renewable energy capacity additions combined. Distributed PV growth accelerated with the emergence of solar companies with innovative business models that allowed customers to get solar systems with little to no money down for a fixed price of electricity.

The quick surge of rooftop solar eroded the sales base of incumbent utilities and began to cause stress on the distribution grid. Like elsewhere around the country, Hawaii's distribution systems were never designed to handle two-way flows of electricity. To accommodate these new resources, Hawaiian Electric implemented a variety of technological and operational changes to its systems and has now integrated more distributed generation than almost any other utility in the nation. Even as it adapted to these changes, the utility expressed concerns that rooftop PV owners were forcing upgrades to distribution systems without any mechanism to get those users to cover the costs. In response, the Hawaii Public Utilities Commission made several changes to interconnection and NEM rules. This resulted in regulatory uncertainty over the past decade that slowed the pace of capacity additions. By 2015, new rooftop solar customers could no longer select NEM as a rate option. The latest regulatory framework incentivizes the use of distributed storage in combination with solar to use more, if not all, the electricity generated on-site. Tracking annual distributed PV capacity additions over the decade, the effect of these changing rules is apparent (Figure 2.2).

Figure 2.2: Annual distributed PV capacity additions



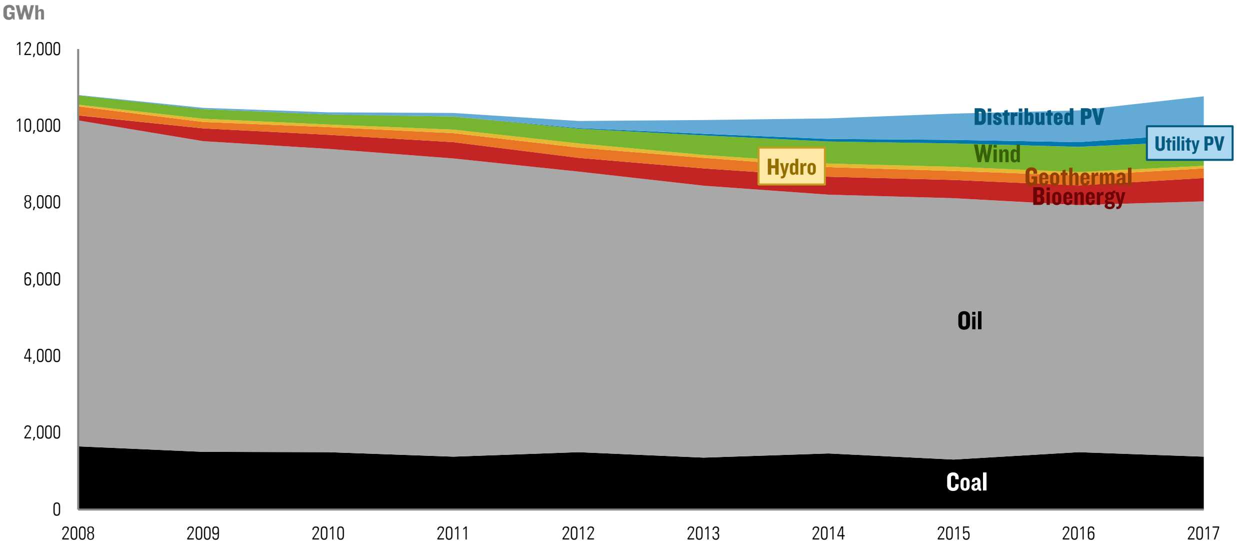
Source: EIA, Hawaiian Electric, Rhodium Group analysis

The current rules reduce stress on the distribution system, but increase the total cost, putting distributed generation systems further out of reach for low-income customers. Customers in multi-family dwellings also miss out on the opportunity for lower cost energy from distributed generation since they often rent and don't have permission to develop their roofs. New initiatives and frameworks may need to be pursued if all the people of Hawaii are going to benefit from distributed generation. Meanwhile, the new regulations have driven a fresh round of distributed generation capacity additions. On Oahu over 760 residential battery or battery combined with PV projects were permitted in 2017, compared to just 15 projects in 2015.[xxii]

These developments promoted distributed PV to the single largest source of renewable generation in Hawaii last year, followed by wind (Figure 2.3).[1] Bioenergy, geothermal and hydroelectric remained steady over the last decade. Utility-scale PV is also beginning to play a role. Solar electricity began the decade providing almost none of Hawaii's electricity and now, as a whole provides over 10% of total generation.

[1] Throughout this report the term generation includes utility scale and distributed generation unless otherwise specified.

Figure 2.3: Hawaii electric generation by fuel and technology, 2008-2017



Source: EIA, Hawaii Public Utilities Commission, Rhodium Group analysis. Note: Generation includes utility scale and distributed generation. Bioenergy includes biomass, biodiesel and municipal solid waste. Hydro includes conventional and run-of-river technologies.

Energy efficiency efforts also increased over the past decade, led by Hawaii Energy's electric savings programs and a push to update building codes. Hawaii Energy, as well as demand-side management programs undertaken by Kauai Island Utility Cooperative (KIUC), invested money into rebate and building retrofit programs that save customers electricity and money. By 2014, an independent assessment found the combination of efforts underway across the state put Hawaii on track to achieving its 2030 goal of 4,300 GWh savings, though only if program funding continued.[xxiii] Critically, the assessment found that one-third of the goal could be reached through adoption and implementation of updated building codes established in 2009, plus new appliance standards. In 2015, Hawaii further updated its building codes to match the latest federal guidelines. Counties are now taking steps to implement these changes. Together, these developments make the 2030 goal even more achievable and open up the prospect of pushing for higher levels of energy savings. The 2014 assessment estimated that Hawaii's economic energy efficiency potential could be as high as 6,210 GWhs by 2030, 44% greater than the current goal. Meanwhile, implementing energy savings programs for eight years has helped Hawaii Energy achieve 973 GWh of first-year savings, nearly a quarter of the EEPS goal.

Perhaps the most surprising outcome of the electric power transition over the past decade is what didn't happen. The initial agreement between the state and Hawaiian Electric envisioned procurement of over a gigawatt of utility-scale generation. An important component of the plan was to pursue large wind projects on Lanai and Molokai that would serve Oahu through one-way undersea transmission cables. The wind projects met overwhelming local opposition in part because residents of these islands did not want to be home to projects that were perceived to only benefit residents on Oahu. Subsequent plans were explored to connect Maui, Oahu, and perhaps Hawaii Island with a two-way transmission cable. A two-way cable provides added reliability benefits by pooling grid resources between connected islands, as opposed to a one-way cable that simply sends power from one island to another. The legislature put in place a regulatory framework to support the effort.

While nearly a gigawatt of capacity did get built over the decade, more than half of that ended up being customer-sited distributed solar instead of utility-scale generation. Stakeholders suggested regulatory incentives are not sufficient to drive Hawaiian Electric to conduct rapid and cost-effective procurement of energy resources.

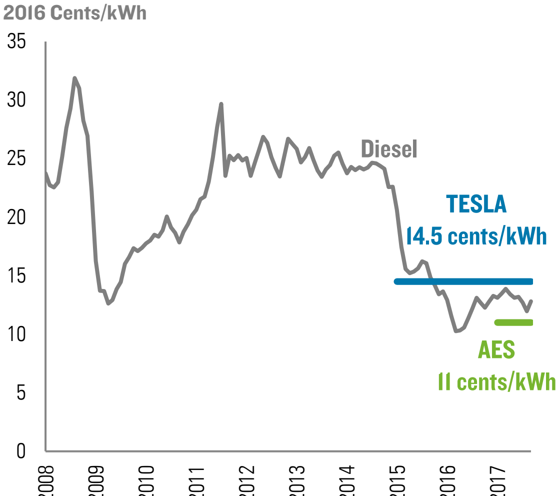
During this same timeframe, NextEra Energy proposed to buy Hawaiian Electric, a move that effectively froze any major new initiatives, while both the utility and the Hawaii Public Utilities Commission (PUC) considered the merger proposal. After two years of deliberations, the PUC denied the merger in July 2016 on the grounds that it would not benefit Hawaii ratepayers.

Since then Hawaiian Electric has put forward, and the PUC has accepted, a new Power Supply Improvement Plan (PSIP) and approved a plan for grid modernization.[xxiv] The combination of these two plans represents Hawaiian Electric's near and long-term strategy to exceed the state's current renewable energy targets. Following through on these plans, Hawaiian Electric this year issued the largest RFP for renewable energy procurement in the state's history with a request for up to 300 MW of new capacity installed on Oahu, Maui, and Hawaii Island through 2022.[xxv]

The recent procurement deals executed by KIUC provide on-the-ground evidence that renewable energy is now cheaper than oil in Hawaii. The cooperative secured its 2015 solar-plus-storage PPA with Tesla Energy at the cost of 14.5 cents per kWh. In 2017 KIUC's second solar-plus-storage contract, this time with AES Corporation, came in at 11 cents per kWh. At the time the PPA's were signed, the cost of electricity from each project was cheaper than the cost of diesel fuel used in oil-fired power plants on Kauai (Figure 2.4).[xxvi]

Figure 2.4: KIUC solar-plus-storage PPAs and diesel fuel costs

2016 Cents/kWh

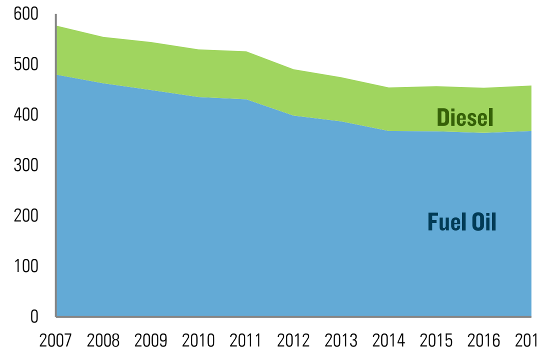


Source: KIUC, DBEDT, Rhodium Group analysis

Growth in renewable energy and energy efficiency in Hawaii over the past decade has resulted in a 21% reduction in the amount of petroleum consumed in power generation (Figure 2.5). Compared to 2007, that translates into 120 million gallons per year of avoided oil consumption. Still, Hawaii's power sector remains far more dependent on oil than electric power generation in any other state. Indeed, 50% of all the petroleum burned for electricity in the US in 2017 was burned in Hawaii.[xxvii]

Figure 2.5: Petroleum use in power generation

Million gallons per year



Source: EIA

The ground transportation transition

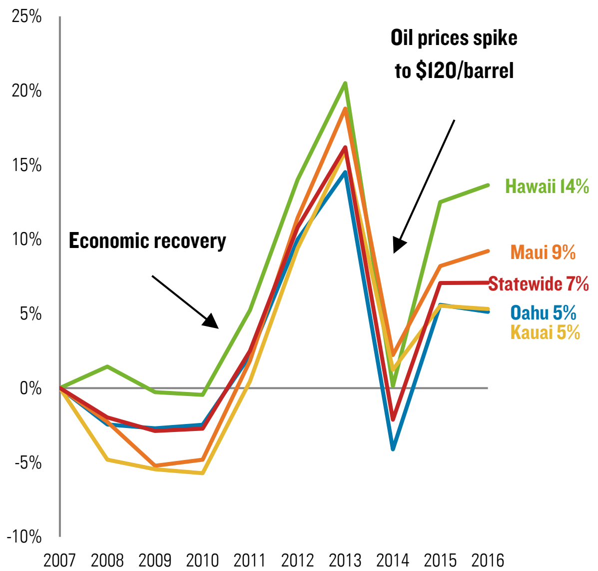
The pace of change in the transportation over the past decade has not been nearly as swift as in power generation. Unlike electric power, there are no central utilities with control over much of the transportation system. Hawaii's Department of Transportation and county governments do influence infrastructure decisions. However, individual users of the transportation system decide how to use it, often while lacking reasonable, convenient alternatives to their cars for mobility services. This creates a different set of challenges to reducing oil demand -- challenges that are an ongoing focus of HCEI.

Three key ways to reduce oil consumptions in transportation are to 1) reduce demand for single occupancy vehicles through coordinated land use and mobility options; 2) increase use of alternative fuels such as electricity and biofuels; or 3) increase the efficiency of vehicle energy use.

Hawaii lacks the kind of long-distance car and truck travel that is a major feature of transport-related oil demand on the mainland. The state's overall level of motor vehicle travel, as measured in vehicle-miles traveled (VMT) per person, is 23% lower than the national average. However, as in the rest of the country, Hawaii's total VMT inclusive of military and tourism activity is growing. Since 2007, VMT has increased by 7% (Figure 2.6) posing a challenge to the state as it strives to reduce GHG emissions and its oil dependence. Much of Hawaii's built environment is similar to other parts of the country that experienced rapid growth in the last 70 years, in that it is highly auto-centric. Land uses are segregated, street networks circuitous, walking facilities (both sidewalks and crossings) often missing, transit robust in a few areas but mostly not.[xxviii] Therefore, many residents and visitors have little choice but to drive to meet their needs. Development patterns like these make streets unsafe for anyone not in a car, resulting in Hawaii having a pedestrian fatality rate 27% higher than the national average.[xxix]

Figure 2.6: Change in vehicle miles traveled

Percent change from 2007



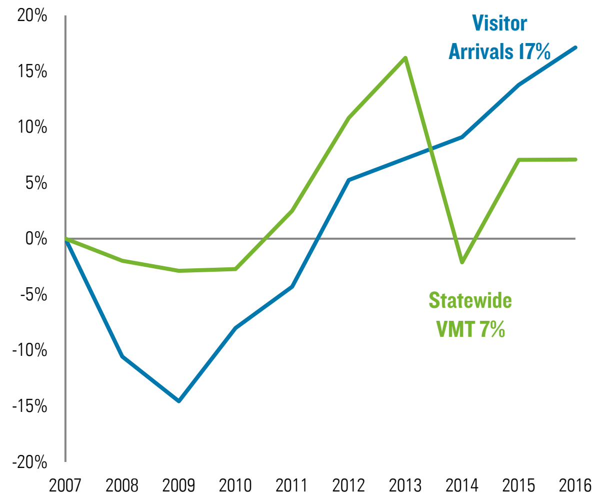
Source: DBEDT, SGA, Rhodium Group analysis

The state pioneered land use districts, established in 1961 and administered by the State Land Use Commission, which serve as growth boundaries and over which county zoning lies. Outside of urban centers, high-VMT development is more or less required, and in the urban areas, it is permitted. These are the areas where most people live, and most development is occurring. Some new residential areas on Oahu are fairly dense, but driving is still a necessity due to the distance to jobs and amenities.

We see these dynamics in uneven VMT growth across the islands, a testament to growing demand in less congested parts of the state. At 14% growth over 2007 levels, Hawaii Island VMT increased by twice as much as the state average while growth on Oahu was slower at 5%. The volatility of VMT change over the decade is due to several factors. The surge in VMT growth between 2010 and 2013 coincides with the recovery, a period of relatively cheap oil prices and an increase in annual visitors of one million, or 16% over 2010 levels (Figure 2.7).[xxx] Then oil prices shot up to over $110 per barrel, increasing the cost of road travel across the state and the cost of air travel for tourists. As a result, VMT dropped and tourism growth slowed in 2014. As oil prices have declined and the economy continues to grow VMT has recently rebounded. For the time being it appears that the HCEI goal of 4% below 2011 levels by 2020 is currently out of reach without additional action.

Figure 2.7: Change in statewide VMT and visitor arrivals

Percent change from 2007

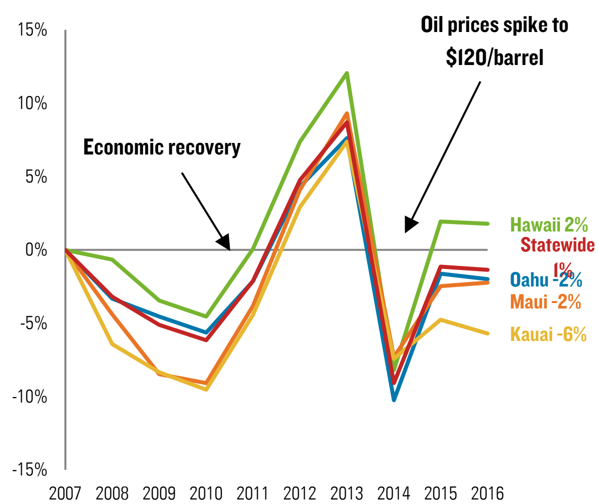


Source: DBEDT, SGA, Rhodium Group analysis

Hawaii's growing population also drives changes in total VMT. While VMT growth was positive on all islands relative to 2007, VMT per capita declined statewide and on all islands except Hawaii (Figure 2.8). People are driving slightly less, but there are more people and more tourists on the state's roads overall.

Figure 2.8: Change in vehicle miles traveled per person

Percent change from 2007



Source: DBEDT, SGA, Rhodium Group analysis

A key strategy for reducing VMT is to coordinate land use and transportation decisions and provide convenient alternatives that allow people to get out of their cars. Coordination is also essential because, unlike the power sector, no central actor can control energy use within each island's transportation system.[xxxi] Public transit, walkable neighborhoods and bike-friendly options provide alternatives to vehicle use. Hawaii's public transit offerings include a public bus and paratransit system in each county. TheBus, the bus transit system operated in Honolulu, has some of the highest ridership per capita in the US.[xxxii] Still, ridership has declined by 5% from 2007 through 2016. One recent transit development was the launch of Biki Bikeshare in Honolulu in 2017 which brought new transportation choices for residents and visitors in the city's downtown and along Waikiki. In its first six months, the service logged over 360,000 rides. [xxxiii]

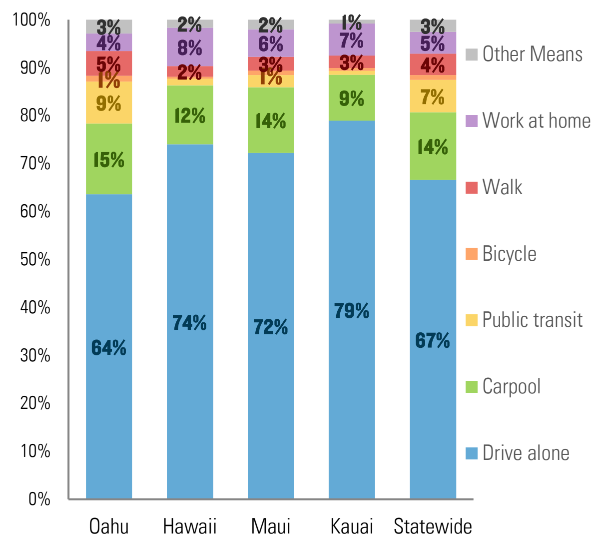
While all part of an integrated mobility network, one system with the potential to deliver additional reductions in VMT is Honolulu Rail Transit, a 20-mile fully automated heavy metro system with 21 stations, estimated to provide 119,000 passenger trips per day in 2030. After years of legal challenges and delays, the project is now under construction with the first phase connecting Kapolei and Aloha Stadium expected to be complete by late 2020. Phase 2, to be completed in 2025, will extend the line to Ala Moana Center. Once complete the project will increase transportation options and offer service from Kualakai station in Kapolei to downtown Honolulu in 35 minutes, and Ala Moana Center in 42 minutes, regardless of road congestion.

In 2009, the state adopted Complete Streets, adding another policy tool to increase mobility options and reduce VMTs.[xxxiv] Complete Streets requires that a transportation facility be planned, designed, operated, and maintained to provide safe mobility for all users, including bicyclists, pedestrians, transit riders, movers of freight, and motorists. Complete Streets also mandates that highway and infrastructure funds encourage compact development that accommodates these multiple transportation modes and improves safety. Each of Hawaii's counties adopted implementation resolutions by 2012 paving the way for safer sidewalks and crosswalks and new bike lanes around the state. As evidence of this Kauai received a $13 million federal grant in 2015 that is funding an expansion of mobility options in the center of Lihue.[xxxv] In 2016, Maui created a Metropolitan Planning Organization to conduct comprehensive transportation planning on the island.[xxxvi]

Complete Streets is an important tool in a state where two-thirds of all commutes are in single occupancy vehicles, contributing to some of the worst traffic congestion in the US (Figure 2.9). It is also important on the neighbor islands where as many as 79% of commutes are by single occupancy vehicles and public transportation currently plays a much smaller role. The state has initiated new efforts to foster development near transit.[xxxvii] Several efforts are underway in the City and County of Honolulu to plan for new development around Honolulu Rail Transit stations.[xxxviii] Hawaii's population is getting older. People age 65 or older made up 14% of the population in 2010 and are expected make up nearly 20% by 2020.[xxxix] Expanding mobility options can provide improvements to the quality of life for people in this demographic should car travel becomes less practical.

Figure 2.9: Share of commutes by mode

2016, % of total commutes



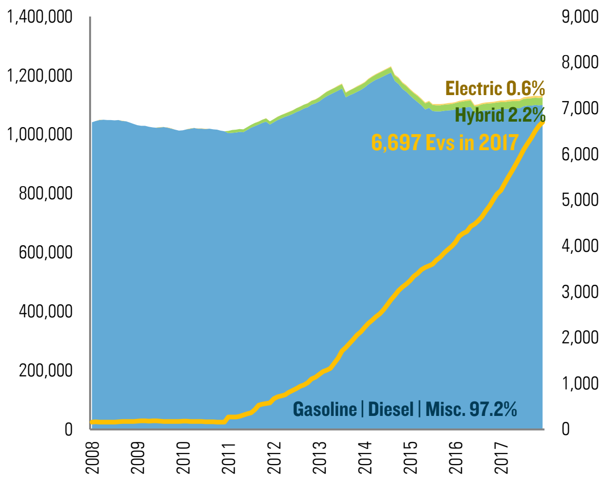
Source: American Community Survey, SGA, Rhodium Group analysis

In addition to reducing VMT through coordination of land use, transportation planning, and increased mobility options, a transition to alternative fuels like electricity or biofuels can reduce oil consumption. Clean technology deployment in Hawaii's on-road vehicle fleet has not moved as quickly as it has in the electric power sector. Of the 1.1 million vehicles registered in the state, 6,697 were electric or plug-in hybrid, and another 25,000 were hybrids as of the end of 2017 (Figure 2.10).[xl] Hybrids represented 2.2% of all vehicles and electrics represented 0.6%. While these numbers are not large, Hawaii is ranked second in the nation, after California, in EV adoption per capita.[xli]

To reach HCEI's goal of 40,000 EVs by 2020, Hawaii residents will have to buy 11,100 EVs on average each year for the next three years. This represents increasing EV sales by a factor of seven compared to 2017 sales of 1,565 vehicles. The state and counties have put in place free parking and High Occupancy Vehicle lane access for EVs,[xlii] though it is unclear if they are sufficient to achieve this goal. More than 400 public charging stations have been installed across the islands, and the State Energy Office provides a free app to help drivers locate the nearest charger.[xliii] Hawaiian Electric has published a roadmap to support accelerating EV deployment.[xliv] Outreach efforts such as Drive Electric Hawaii and Sustainable Transportation Coalition of Hawaii (STCH) are working to educate consumers on the benefits of EVs.[xlv]

Figure 2.10: Registered vehicles by type

Number of vehicles on the road, share of 2017 total, total EVs (RHS)



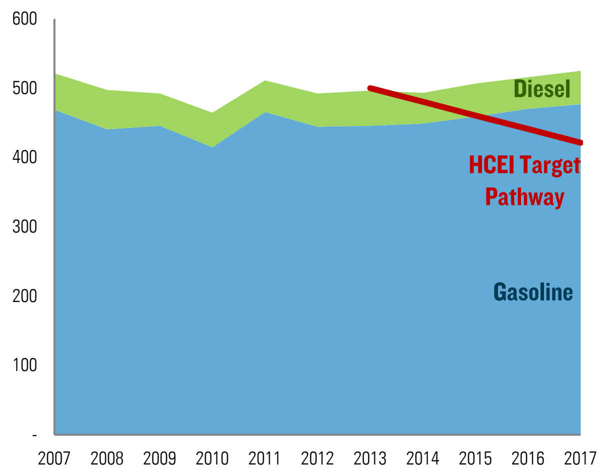
Source: DBEDT, SGA, Rhodium Group analysis. Note: Electric vehicles include plug-in hybrids

Combined gasoline and diesel consumption in 2017 was near 2007 levels at 525 million gallons per year (Figure 2.11). To stay on a straight line toward meeting HCEI's goal of a 70% reduction in petroleum demand by 2030, Hawaii ground transportation oil consumption would need to be 100 million gallons lower than it was in 2017. Improvements in vehicle efficiency, driven by federal fuel economy standards, have offset growth in VMT but were not enough to deliver meaningful reductions in absolute oil consumption levels.

The state has also focused its efforts on developing local renewable fuel supply in Hawaii as an alternative to petroleum. The fuel consumption numbers above do include imported ethanol and domestically produced biodiesel, though both fuels played a small role in total sales. Hawaii in 2006 put in place a 10% ethanol blend mandate in the hopes of spurring local production, but the mandate was met primarily with imports. As a result, it was repealed in 2015. Pacific Biodiesel is the single in-state biofuel producer. With operations on Maui and Hawaii Island, the company is using energy crops and waste oils to produce sustainably certified fuel. Currently, its production capacity is 5.5 million gallons per year - roughly 1% of total current statewide on-road petroleum fuel consumption. Pacific Biodiesel's fuels are sold at fuel stations around the state, and recently the company entered into a supply agreement with Hawaiian Electric to fuel some of its electric generators.[xlvi]

Figure 2.11: Ground transportation petroleum consumption

Million gallons per year



Source: DBEDT, Dashboard.Hawaii.gov, Rhodium Group analysis. Note: 2017 value is the 12-month total from 12/2016 through 11/2017. Diesel includes biodiesel and gasoline includes ethanol, together they are 1% of the total.

County mayors come together to raise the bar

In December 2017, Hawaii's four county mayors all adopted a proclamation that set new renewable energy goals for ground transportation in the state.[xlvii] In declaring their goals, the mayors cited the success of HCEI in electric power and conceded that the transport sector is not on track to meet petroleum reduction goals. Tackling GHG emissions from the sector is essential, the mayors acknowledged, if counties and the state are going to meet their GHG reduction targets. The mayors each set a goal of fueling 100% of private and public ground transportation with renewable energy by 2045, through biofuels, EVs powered by renewable electricity, or a combination of both. Most mayors also pledged to lead by example and fuel public fleet vehicles with 100% renewable energy by 2035. For these goals to succeed, new policies will be required.

THE BROADER BENEFITS OF CLEAN ENERGY

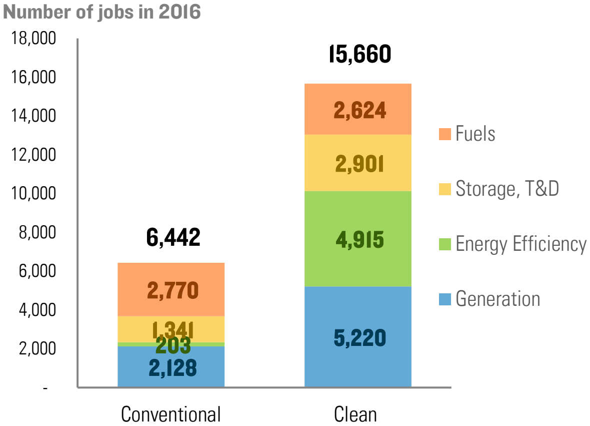
Much has changed in Hawaii ten years into the transition towards clean energy, in a relatively short period of time. This shift has already delivered broader cross-cutting benefits for people in Hawaii and the global climate.

Emergence of good-paying clean energy jobs

New markets for energy efficiency and renewable energy create employment opportunities for people in Hawaii. Due to the growth of clean energy since 2008, Hawaii now has more than twice as many people working in the clean energy sector as work in conventional energy. Rooftop solar installers, energy efficiency retrofit contractors, renewable fuels producers and more totaled over 15,000 jobs in 2016 (Figure 2.12). Energy jobs on average pay $3- to $7-per-hour better than the median wage in Hawaii (Figure 2.13). In a state with the highest cost of living in the US, clean energy is helping more people in Hawaii make ends meet.

Figure 2.12: Hawaii energy employment

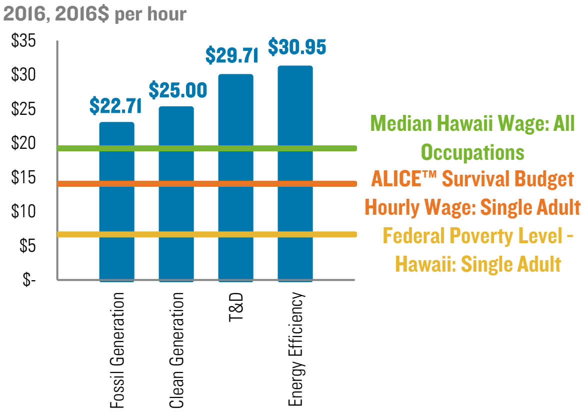
Number of jobs in 2016



Source: US DOE, Rhodium Group analysis

Figure 2.13: Average energy job wages

2016, 2016$ per hour



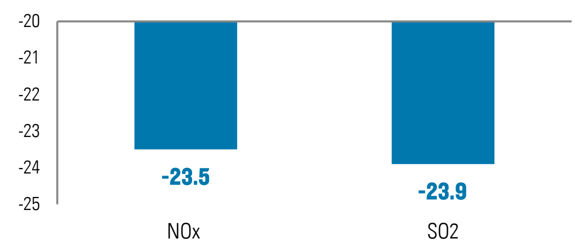
Source: DOE, Bureau of Labor Statistics, Aloha United Way, Health and Human Services, Rhodium Group analysis. Note: ALICE stands for Asset Limited, Income Constrained, Employed.

Pollution benefits

Reductions in oil consumption in the electric power sector also reduce the amount of pollution released into the atmosphere. We estimate that between 2008 and 2016 nitrogen oxide (NOx) and sulfur dioxide (SO_2) pollution, which can cause smog and acid rain, each declined by 24 metric tons on a cumulative basis (Figure 2.14). That sum is roughly equal to all the pollution emitted by power plants in Hawaii in 2008. Between 2010 and 2015 cumulative CO_2 reductions from clean energy totaled 2.8 million metric tons.[xlviii] That amounts to taking 160,000 cars off the road for a year.

Figure 2.14: Cumulative conventional pollution reductions from clean energy deployment

2010-2015, metric tons

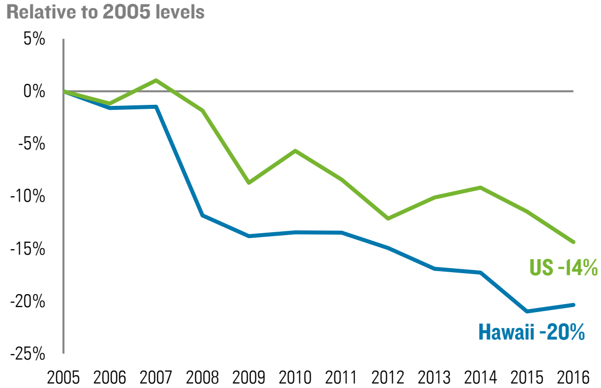


Source: Rhodium Group analysis

Hawaii has adopted and codified in statute the Paris Agreement US climate goal of a 26-28% reduction in GHG emissions by 2025 relative to 2005 levels, and long-term reductions consistent with keeping global average temperature increases to less than 2 degrees Celsius. Thanks to the clean energy transition of the past decade, Hawaii has outperformed the nation by reducing its GHG emissions by 20% between 2005 and 2016 compared to 14% for the US overall (Figure 2.15). In chapter 3 we consider whether Hawaii is on course to meet long-term climate goals.

Figure 2.15: Change in GHG emissions

Relative to 2005 levels



Source: Rhodium Group US Climate Service

CHAPTER 3

Accelerating Hawaii's Clean Energy Transition

The last ten years represent major change in Hawaii's energy system and the first big steps away from oil. Where does the state go from here? Can Hawaii accelerate its clean energy transition and achieve HCEI's goal of freeing the state from its dependence on oil once and for all? Predicting the future is hard, particularly when it comes to energy markets. Global oil prices are volatile, renewable energy costs are falling dramatically, and technological innovation is always difficult to anticipate. To help Hawaii chart its path forward, we model potential clean energy futures under a range of assumptions about fuel price and technology cost.

OUR APPROACH

The purpose of this analysis is to inform discussions in Hawaii around how to design policy and markets to facilitate a clean energy transition that meets the state's goals at the lowest cost to the system and consumers. To do that, we model least-cost pathways for supplying electricity in each of Hawaii's four major electric systems, representing 99% of total demand under a range of energy costs and developments in the electric power sector.[2] We also analyze the implications for the power sector of meeting the mayors' proclamation of 100% renewable energy for ground transportation by 2045.

Analytical approach and tools

For this analysis, we leverage several state-of-the-art modeling tools, input from nearly 200 hours of stakeholder conversations and the latest data from Hawaii's electric utilities and government agencies. To simulate the electric power system, we use RHG-SWITCH, an open source optimization modeling platform known as "SWITCH" that has been customized by Rhodium Group for this analysis.[xlix] RHG-SWITCH contains detailed representations of the electric power systems for the islands of Oahu, Hawaii, Maui, and Kauai. We use RHG-SWITCH to determine the most cost-effective mix of generation, capacity expansion, and energy storage based on fuel and technology costs, with specific policy constraints. The optimization ensures there are sufficient resources in place on each island to maintain key bulk power grid services including operating, contingency and planning reserves. For a further description of RHG-SWITCH as well as the assumptions and inputs we used in this analysis, please see the Technical Appendix that accompanies this report.

To estimate the implications of changes in the ground transportation sector, we use the EnergyPATHWAYS,[l] a stock accounting model maintained by Evolved Energy Research, that has been licensed and calibrated to Hawaii by Rhodium Group. EnergyPATHWAYS allows us to estimate energy demand and GHG emissions under different EV penetration and VMT scenarios. Finally, we use the Economic Impact Analysis for Planning (IMPLAN) model to assess the employment implications of changes in the electric power system.[li] IMPLAN is licensed by Rhodium Group and uses county-level economic data for Hawaii. Figure 3.3 reflects the interaction between the various inputs and tools used in this analysis.

Fuel and technology cost assumptions

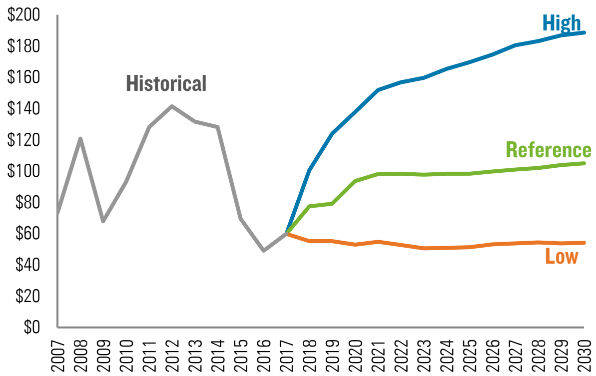
The relative costs of renewable energy technologies and petroleum fuels have played a major role in setting the pace of the clean energy transition in the electric power sector over the past decade. For this analysis, we made specific assumptions about how those relative costs would evolve in the years ahead.

Oil price forecasting is particularly challenging. Over the past decade, global crude oil prices have ranged from $30 per barrel to $140 per barrel. The Energy Information Administration's 2018 Annual Energy Outlook includes residual fuel price scenarios for 2030 that range from $50- to $190-per-barrel in current dollars (Figure 3.1). There are plausible oil market narratives that could produce either extreme. Given the volatility of the past couple decades, Hawaii's energy policymakers and utility companies would be well-advised to plan for a wide range of potential futures. We use a high oil price scenario and a low oil price scenario adjusted to the upper and lower bounds of electric power sector diesel and residual fuel oil prices between 2006 and 2017 for each island.

[2] We consider the islands of Molokai and Lanai separately from our modeling and assume both to be supplied by 100% renewable electricity no later than 2025 following Hawaiian Electric's plan for Molokai described in its December 2016 PSIP.

Figure 3.1: Historical and projected residual fuel prices

2016$/barrel for use in electric power sector

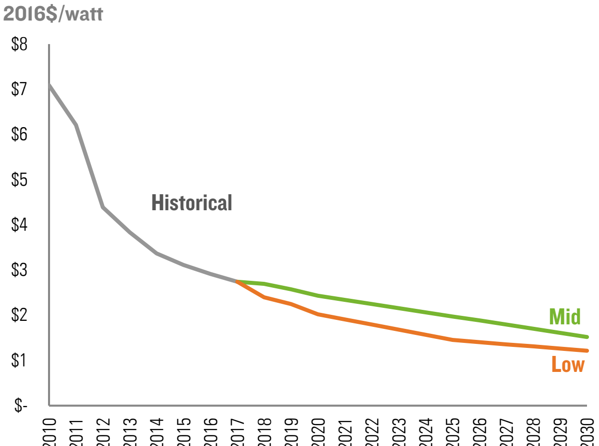


Source: DBEDT, EIA, Rhodium Group analysis. Note: Historical values are annual average residual fuel oil costs for Hawaii utilities. Projections are electric power sector delivered prices for the Pacific census region.

For renewables, all analysts expect costs will continue to decline. They differ on how fast prices will fall and by how much. The National Renewable Energy Lab (NREL), for example, projects in their mid-cost case that average rooftop solar generation costs in the US will decline by 45% between now and 2030 or decline by 56% over the same time period in their low-cost case. That means rooftop PV costs could be as low as $1.20-per-watt, compared to the $2.80-per-watt today (Figure 3.2). NREL projects utility-scale solar will follow a similar path, while more mature renewable energy sources such as wind and geothermal may see more modest cost declines.[lii] For our analysis, we start with renewable energy costs assumed by Hawaiian Electric in its December PSIP. We then scale those prices to projections from NREL's mid-cost and low-cost scenarios and incorporate all applicable state and federal incentives.

Figure 3.2: US average rooftop PV system costs

2016$/watt



Source: NREL, Rhodium Group analysis. Note: NREL does include a high projected cost, but it assumes current costs hold constant. Given the unlikely event of no further cost declines, this analysis does not present that pathway.

Scenario analysis

To capture the fastest and least-costly path for Hawaii to reduce its oil dependence further, we constructed Business as Usual scenarios that include relevant current policies and measures in place in the state. These scenarios assume that Hawaiian Electric and KIUC build or procure all under-construction or planned generation and then only enough renewable energy is developed to meet the current renewables mandate of 40% by 2030, 70% by 2040 and 100% by 2045. For the transportation sector in these scenarios, we use ground transportation VMT and EV penetration forecasts provided by SGA which assume no changes in policy. SGA assumes that VMT increases based on current development trends with no changes in policy, leading to a total statewide increase of 17% over 2016 levels by 2045 (Figure 3.4). SGA projects that up to 1% of all vehicles on the road in Hawaii are electric by 2020, increasing to 10% by 2045. We do not assume Hawaii meets the goals of the mayors' transportation proclamation in this scenario. We consider two versions of the Business as Usual scenarios: one with high oil prices and cheap renewables costs; another with low oil prices and expensive renewables costs.

To identify the least cost range of renewable energy penetration in the electric power sector we remove the current renewables mandate constraint from the two Business as Usual scenarios described above and consider a "High Renewables" scenario and a "Low Renewables" scenario. This change allows RHG-SWITCH to solve for the least-cost pathway to operate each of Hawaii's electric systems, within a range bounded by fuel and technology costs.

We consider two additional scenarios to assess Hawaii's clean energy transition if the state meets the goals of the mayors' ground transportation proclamation. First, we take our High Renewables scenario and incorporate the additional electricity demand associated with meeting the proclamation through complete electrification of ground transportation by 2045. Second, we model the same scenario and include policy bundles by state and local government that reduce VMT (Figure 3.4). These policies were identified by SGA and include shifting new development to higher density locations, parking management, as well as congestion charges and road use pricing. SGA estimates that the total impact of these actions would reduce VMT by 21% below the business as usual scenario and 7% below 2016 levels in 2045. Table 1 provides a summary of the scenarios analyzed in this report

Figure 3.3: Analytical tools and process

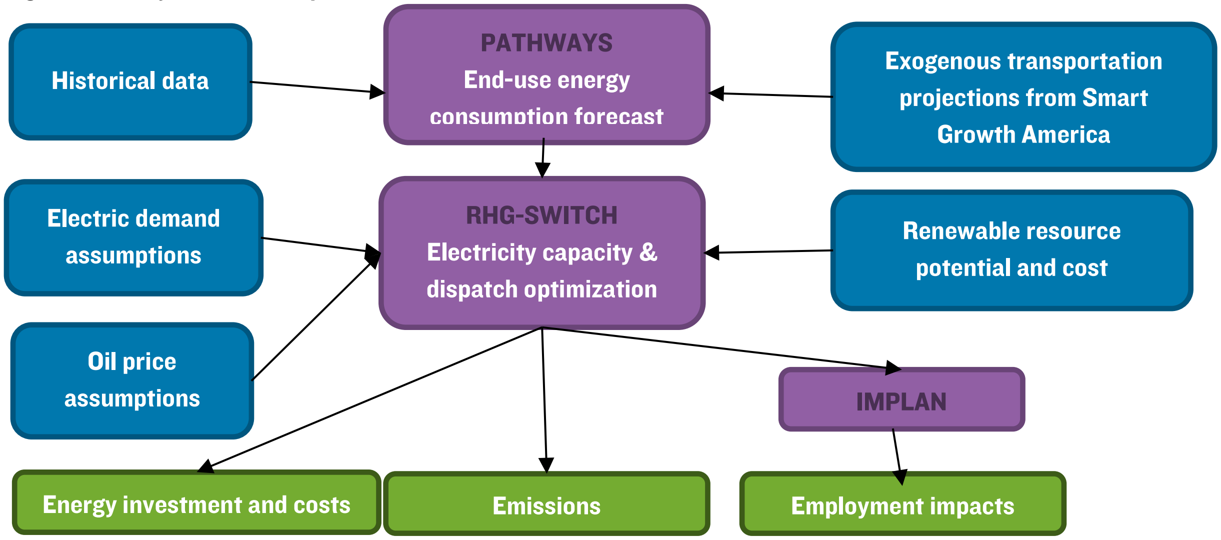
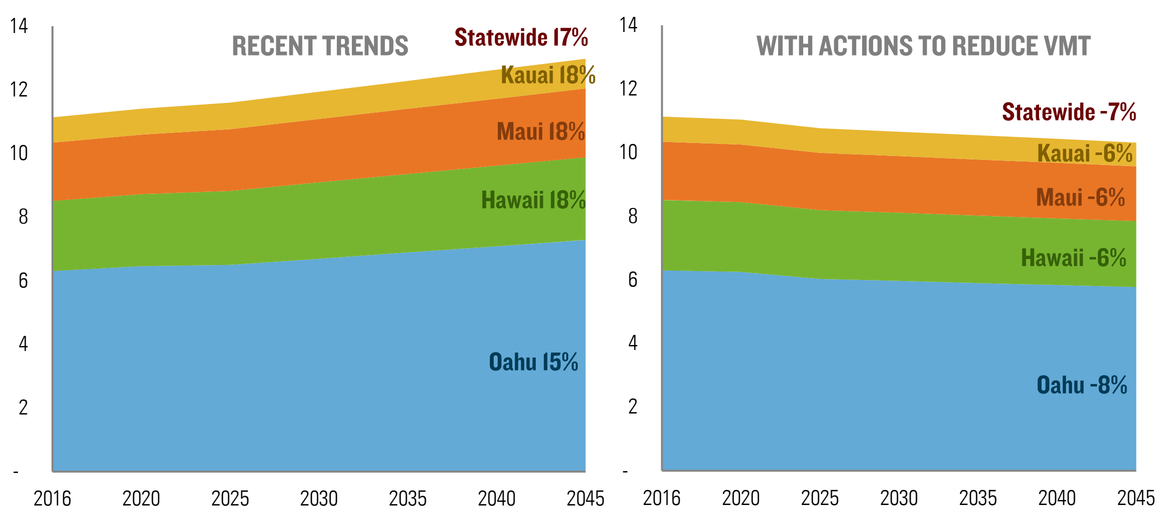


Figure 3.4: VMT projections by county, 2016-2045

Billion miles traveled



Source: SGA

Table 1: Scenario summary

Scenario	Renewables Deployment	Renewables Costs	Fuel Costs	EV Deployment	Transportation Demand
Business as Usual High Oil Price	Current Renewable Portfolio Targets	Low	High	11% by 2045	Follows recent trends
Business as Usual Low Oil Price	Current Renewable Portfolio Targets	High	Low	11% by 2045	Follows recent trends
High Renewables	Least-Cost	Low	High	11% by 2045	Follows recent trends
Low Renewables	Least-Cost	High	Low	11% by 2045	Follows recent trends
High Renewables 100% EVs	Least-Cost	Low	High	100% by 2045 (Mayors' Proclamation)	Follows recent trends
High Renewables 100% EVs+VMT Actions	Least-Cost	Low	High	100% by 2045 (Mayors' Proclamation)	Actions taken to reduce VMT

What else we considered in this analysis

In all scenarios, we assume that Hawaii's EEPS are met and that additional energy savings accrue from building codes, appliance standards, and programs after 2030 in line with Hawaiian Electric PSIP. Renewable resources available for each island are largely derived from the PSIP and rely on third-party assessments when PSIP values are not available. Additional balancing resources such as battery storage and demand response (DR) are also included. RHG-SWITCH runs with 24-hour, 20 day-per-year resolution with days statistically selected to make sure the projected electric system on each island is capable of meeting load even on days and hours when renewable resources are relatively scarce, and demand is relatively high.

We do not consider changes in energy demand that could occur with climate change in this analysis. In previous analyses, we found that in the most extreme warming scenario, nationwide electric demand would likely increase by 3-9% by 2040 relative to historic climate conditions.[liii] We also do not consider the impacts of climate change on renewable resource availability because comprehensive projections of local weather changes in a warming world are not available.

We included the costs of distribution system upgrades to accommodate additional distributed PV generation, as well as the cost associated with interconnecting utility-scale generation into the bulk power system. We did not include distribution system upgrade costs to accommodate high penetration of EVs because cost estimates specific to Hawaii were not available. Our analysis does not consider electric power price implications of avoided cost power contracts held by utilities in Hawaii, or distribution system ancillary services. We would need proprietary utility data that are not publicly available to consider these last components.

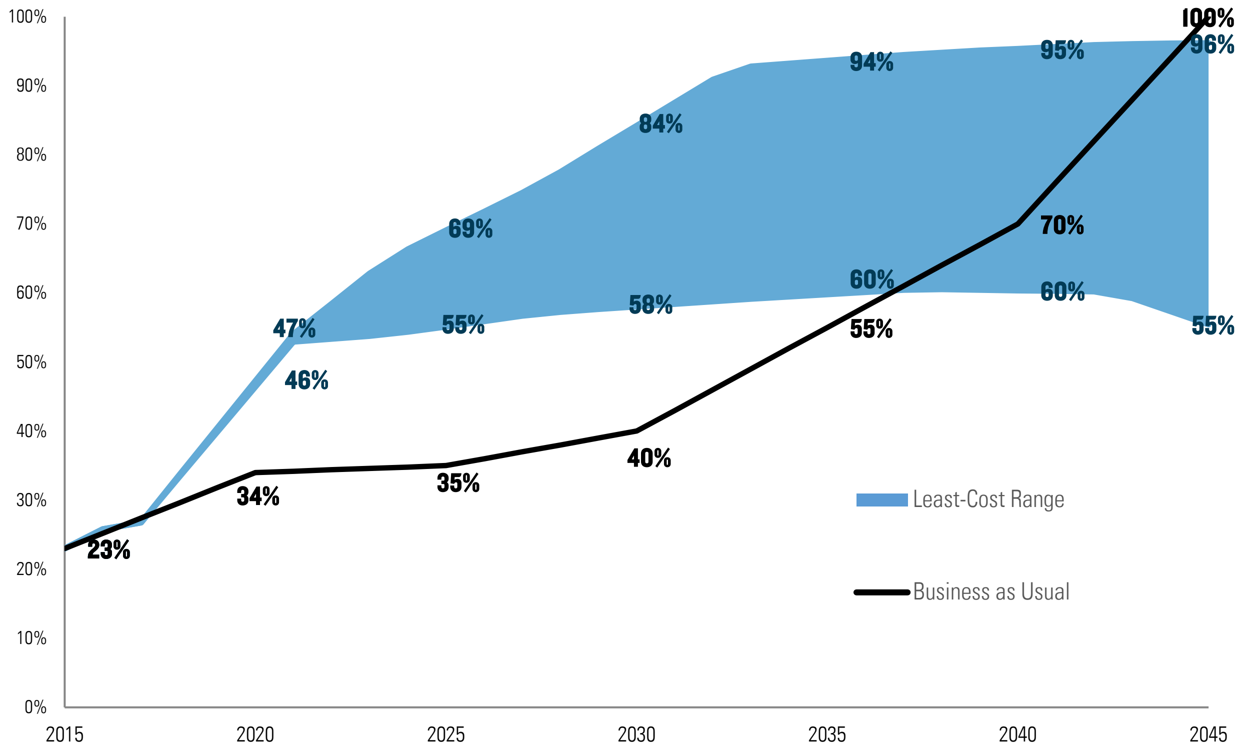
As part of this analysis, we do not model a scenario where an interisland transmission cable connects the electric systems of any of the islands. The costs and timetable for such a cable are highly speculative. We found that each island has enough resources available to meet demand, making a cable less necessary if those resources are successfully developed. We also do not consider the possibility of building new liquified natural gas (LNG) regassification facilities to supply future power plants because it is not included in the current PSIP action plan. Doing so would potentially impact our findings.

We constructed projections of Hawaii's energy future based purely on economic considerations, without considering any social costs or hedge values. Including one or more estimates of the social cost of carbon (SCC) in our scenarios would effectively increase fuel prices and make renewable energy more competitive. Assigning a benefit to reduced oil dependence would have a similar effect. Both factors are important and have substantial value. For example, the latest central estimate of the SCC for 2020 is roughly $50 per metric ton of CO_2.[liv] That translates into $21.50-per-barrel of crude oil. EPA has previously found that the national average hedge value of avoided oil consumption is $11-28 per barrel.[lv] If policymakers in Hawaii assign a value to these additional factors, new policy actions could be pursued to reflect these costs in the state's energy systems. Without such policies in place, we focus on the cheapest pathways to operate the state's electric power systems.

THE LEAST-COST ELECTRICITY PATHWAY FOR HAWAII

Across the full range of oil price and renewable energy cost futures considered in this analysis, we find that the least-cost path forward for Hawaii's electric power system includes more renewable generation than the state's current mandates require through 2030 (Figure 3.5). In our Low Renewables scenario, with relatively cheap oil prices and expensive renewables, renewable sources provide 58% of the state's electricity in 2030. That is 18% more market share than the 40% required that year in the current RPS. In our High Renewables scenario, with relatively expensive oil and cheap renewables, renewables provide 84% of Hawaii's total electricity in 2030. These findings point in a similar direction to Hawaiian Electric's PSIP, which concluded that over compliance with the renewables mandates would be the best pathway for ratepayers.[lvi]

Figure 3.5: State-wide renewable shares of total generation



Source: Rhodium Group analysis. Note: Generation includes utility scale and distributed generation.

100% requires innovation

Over the next 20-25 years, Hawaii can deploy renewable energy at a faster rate than called for in the current state RPS, and at lower cost to ratepayers. Under the range of oil prices and renewable energy costs considered in this analysis, however, a least-cost electricity pathway for Hawaii never quite reaches the state's ultimate goal of 100% renewables. In 2045, renewable generation ranges from 55% of total generation in our Low Renewables scenario to 96% in our High Renewables case. We find that it is technically possible for Hawaii to close the gap and achieve 100% renewables, but at a higher cost to ratepayers relative to a least-cost pathway. This finding is consistent with conclusions from current renewable modeling literature: meeting the last 10-20% of electricity demand is the hardest to serve with renewable energy alone, as it typically requires large capital outlay for resources that are used for only a few hours per year.[lvii]

While more expensive than the least-cost pathways analyzed in this report, we find that achieving 100% renewables as early as 2030 would still be cheaper for Hawaii's ratepayers than both the current energy mix and the current RPS under most oil price and renewable energy cost futures.

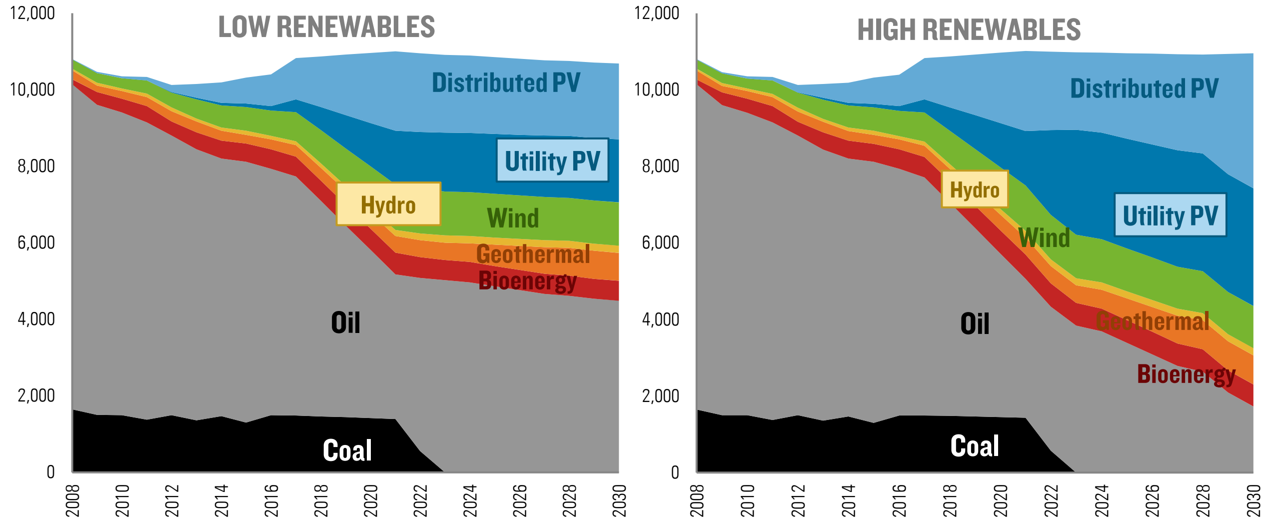
Innovation also has the potential to reduce the cost of very high levels of renewable energy penetration, through technologies such as advanced storage, high levels of demand response (DR), electric vehicle-to-grid technologies, hydrogen production coupled with fuel cells and virtual power plants. Affordable sustainably produced solid and liquid biofuels can also play an important role as a dispatchable resource.

Acceleration calls for a mix of resources

Accelerating renewable energy deployment along will require an array of renewable resources (Figure 3.6). Utility-scale and rooftop solar play the most prominent roles in our analysis, with a combined 34% of total generation in the Low Renewables scenario and 60% of total generation in the High Renewables scenario. On a capital cost basis, utility-scale solar is the cheapest technology available. However, we find wind, geothermal and biofuels also factor in important ways. Each island has its unique mix of resources and constraints, as we discuss later in this chapter.

Figure 3.6: Hawaii electric generation by fuel and technology, 2008-2030

GWh



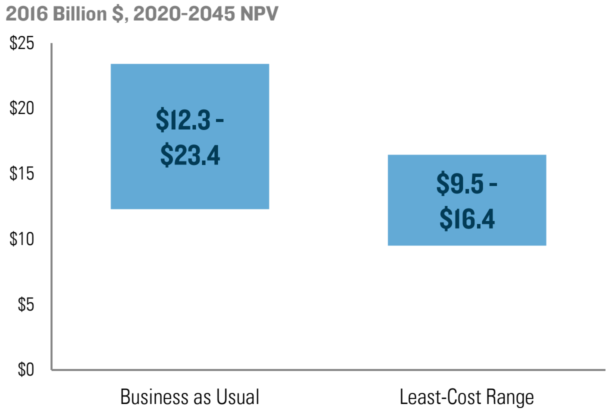
Source: Rhodium Group analysis. Note: Generation includes gross utility scale and distributed generation before storage is engaged.

More renewables could save billions in power system costs

In the Business as Usual scenario, we estimate that operating Hawaii's four electric power systems from 2020 through 2045 will cost $12.3-$23.4 billion in net present value terms (NPV) (Figure 3.7). The range represents differences in fuel prices and renewable energy costs. We find generating more power from renewables in Hawaii would reduce system costs dramatically - to $9.5-16.4 billion on a net present value basis between 2020 and 2045. That represents a savings of $3 to $7 billion over this time frame. While Business as Usual includes the costs of reaching 100% renewables in 2045 it also includes the cost of higher oil consumption. It's the latter that largely explains the difference in costs between Business as Usual and the least-cost range.

Figure 3.7: Total electric power system costs

2016 Billion $, 2020-2045 NPV



Source: Rhodium Group analysis

Accelerating electric sector renewables could slash oil dependence

Currently, oil is the dominant fuel used to generate electricity in Hawaii. Under a Business as Usual scenario, Hawaii's power sector consumes 357 million gals on oil in 2030. Under our least-cost scenarios, electricity-related oil consumption drops 75-257 million gallons per year by 2030 as renewable generation displaces oil (Figure 3.8). Oil consumption increases in the early 2020s to make up for the retirement of the AES coal plant on Oahu, then declines from current levels. Through at least 2036, we find oil consumption is lower in our least-cost scenarios than under the current RPS.

To accelerate, each island needs unique resource mix

In this analysis, we capture each island's unique mix of renewable resource potential and electric demand requirements. Our generation capacity projections reflect this diversity in both the Low Renewable and High Renewable (Figure 3.9) least-cost bounding scenarios.

Solar plays a dominant role across islands in our analysis, both utility-scale and distributed. But the importance of wind, geothermal and bioenergy varies significantly across islands due to differences in each islands' resource base. Supporting high levels of renewables penetration requires additional energy storage across all islands. Hawaii needs up to two GWs of lithium-ion battery or functionally equivalent storage in 2030 state-wide in our least-cost range.

DR is also an important component of our analysis. We assume a share of non-EV electric load responds to real-time electric prices and can shift to lower system costs. This share starts at 2% and rises to 10% of the non-EV load by 2045. Without DR, we would expect batteries to play an even larger role in our results and somewhat lower renewable energy penetration overall.

Embracing distributed energy resources is essential

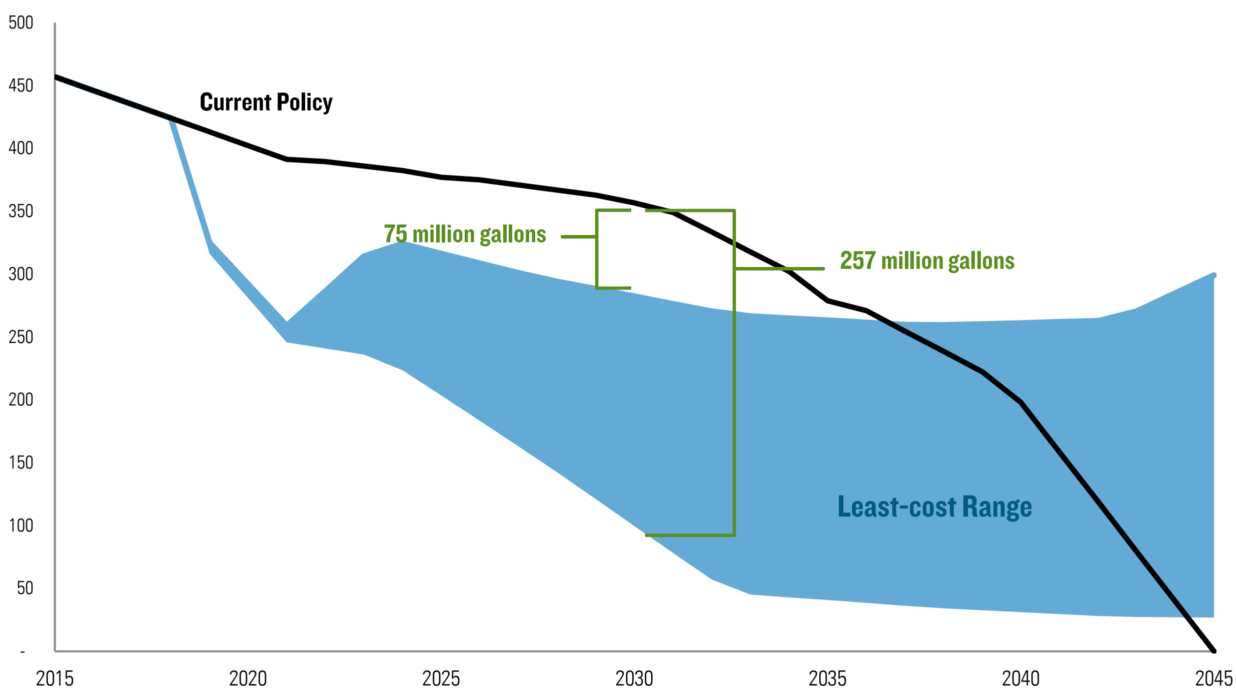
A least-cost electricity future for Hawaii includes a continuation of recent rooftop solar trends. By 2030, we find distributed PV is Oahu's largest generating technology on a capacity basis across our scenarios, ranging from 936 MWs to 1,379 MWs. Indeed, due to land and other resource constraints discussed later in this section, continued development of rooftop solar is critical to accelerating renewable energy deployment on Oahu. However, current rate tariffs limit the amount of distributed energy resources (DERs) that can be added to Oahu, Maui, and Hawaii's electric systems or require the customer to use all the electricity generated onsite. Our analysis suggests restrictions on capacity additions will need to be lifted and distribution systems upgrades will be required for Oahu to unlock its renewable energy potential.

Embracing DERs and capturing the benefits of DR will also require smart grid technology. Advanced metering infrastructure (AMI) allows for two-way information flows across distribution systems. This enables real-time pricing, better renewable energy integration, and increased system resilience. KIUC has already deployed AMI across its service territory, and Hawaiian Electric has initiated more limited strategic deployment of AMI in select portions of its territory.

Customers will need fair compensation for electricity and other grid services sold to the electric system to allow rooftop solar to provide all potential system benefits. Our analysis suggests new utility regulatory frameworks and business models may be required to support these efforts. The State Energy Office is sponsoring a study to explore possible alternative frameworks.[lviii] On Oahu, fossil generators have traditionally provided most of the ancillary services needed to keep the electric grid running. As these resources are retired and replaced with rooftop solar, we find energy market frameworks need to be established for grid service provision. Without such frameworks, maintaining high levels of system reliability may become challenging. Our modeling assumes that these markets, technologies, and frameworks in place.

Figure 3.8: Electric power sector oil consumption

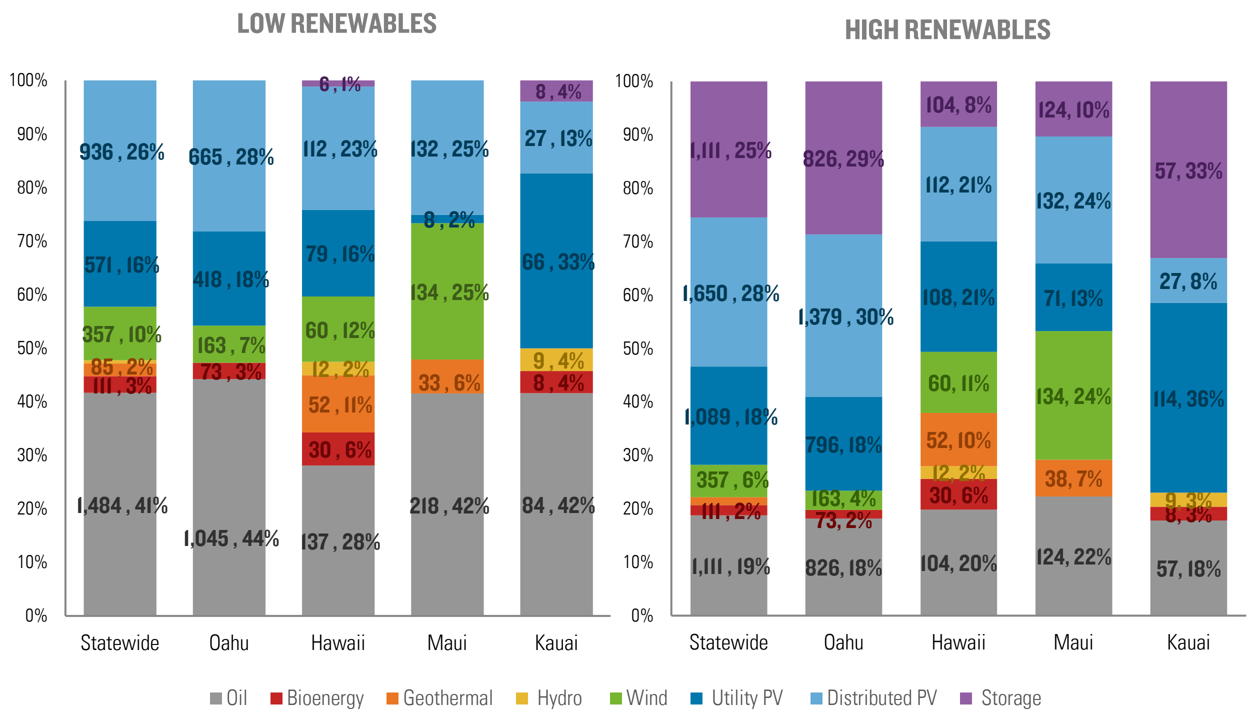
Million gallons



Source: Rhodium Group analysis

Figure 3.9: Hawaii electric generating capacity in 2030

Megawatts, % of total



Source: Rhodium Group analysis

The further proliferation of DERs provides new opportunities to make Hawaii's electric systems more resilient. Microgrid technologies allow a building or set of facilities to maintain electric service through a network of DERs that operate independently of the larger grid in emergencies.[lix] While not explicitly modeled in this analysis, microgrids are entirely compatible with our results. Military facilities, hospitals, schools, public safety infrastructure and other important facilities could be targets for microgrid deployment. The technology holds considerable promise considering recent natural disasters. We point to the devasting impact Hurricane Maria had on Puerto Rico in 2017, causing the worst blackout in American history.[lx]

Microgrids can keep the lights on for key infrastructure and allow communities to rebound far more quickly from a crisis. Given Hawaii's remote location, our analysis suggests the pursuit of microgrid deployment in the context of accelerating clean energy deployment makes much sense. Hawaii is now home to several microgrid projects, including one on Molokai and another at Camp Smith.[lxi] These projects and others can help inform how best to pursue microgrids going forward.

Acceleration could drive billions in new investment

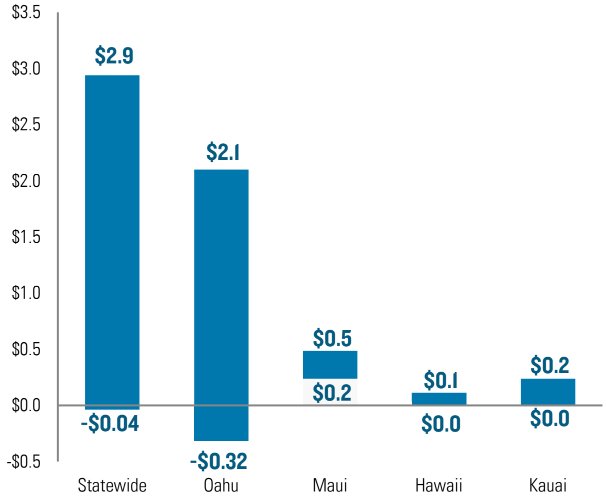
We find substantial new investment will be required to get Hawaii onto the least-cost generation electricity pathway. From 2020 to 2030, cumulative investment in new generation, storage, and system upgrades ranges from zero in the Low Renewables scenario to $2.9 billion in the High Renewables scenario in real 2016 dollars (Figure 3.10). These values represent an investment that would not occur by 2030 to meet the current renewable mandate. For each island, the amount of new investment needed varies, depending on current system resources and what kinds of new resources get built.

Investment, cost savings spur thousands of new jobs

We project these investments in Hawaii's island economies would drive the creation of new, good-paying energy sector jobs. Those positions stimulate the creation of additional jobs, as high-wage earners spend their money in local economies. Electric system cost savings produced by accelerating clean energy deployment would result in lower electric bills for residents and businesses. This frees up money that can be spent on other goods and services in local economies, creating additional jobs.

Figure 3.10: Cumulative incremental electric power system investment

Least-cost range relative to Business as Usual, 2020-2030, billion 2016$

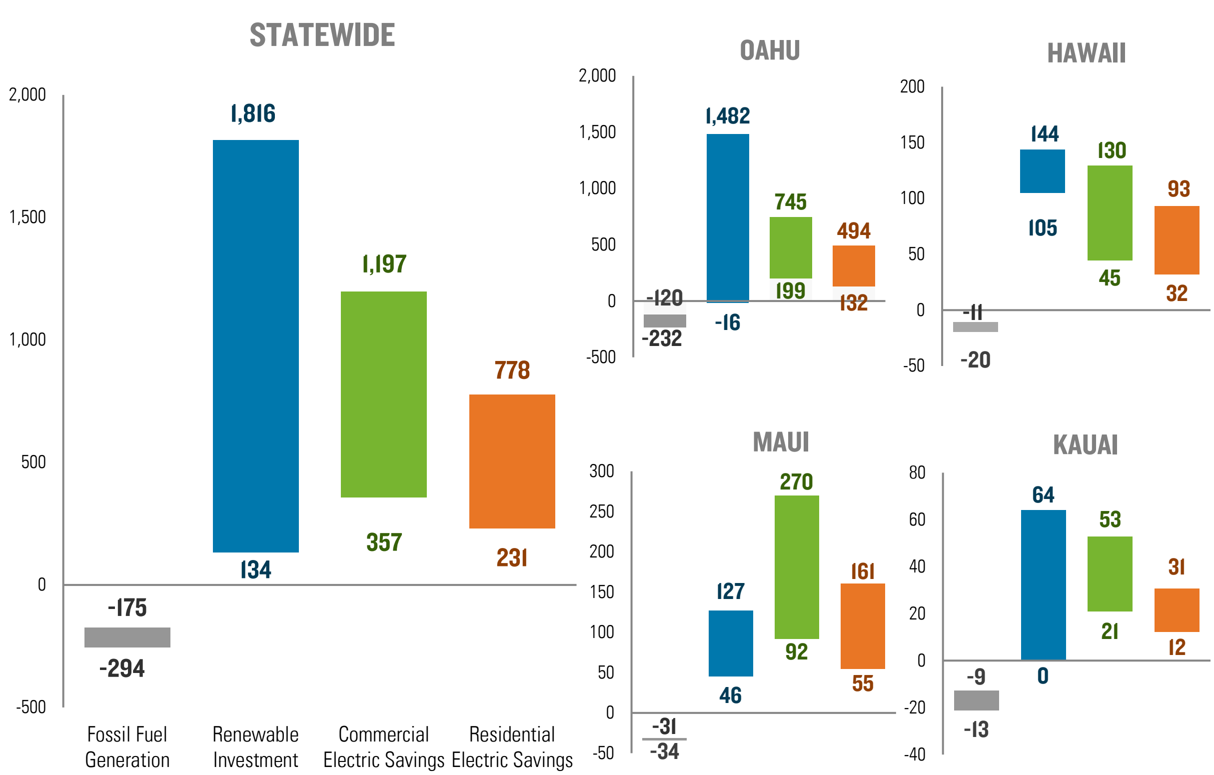


Source: Rhodium Group analysis

When looking at average annual statewide employment between 2020 and 2030, we estimate that accelerating clean energy deployment could create 1,522 additional jobs in our High Renewables scenario (Figure 3.11). This is the net impact over the course of the decade of 1,816 new jobs from more renewable energy investment and 294 fewer jobs due to lower fossil fuel demand. These include direct, indirect and induced effects of changes in energy-sector investment and production due to accelerated renewable energy deployment. In the Low Renewables scenario, we find energy sector investment would spur a small net reduction in employment. We estimate that energy cost savings for business and households could significantly impact average annual employment across Hawaii's economy, adding 588 to 1,975 jobs between 2020 and 2030. It is important to note that these investment and jobs estimates do not account for general equilibrium effects like higher interest or wage rates across the state due to increased renewable energy investment. Such effects would likely diminish net state-wide employment gains shown in Figure 3.11, particularly given Hawaii's currently low unemployment rate.

Figure 3.11: Change in employment from electric sector investment and electricity cost savings

2020-2030 annual average relative to current policy, range of potential



Source: Rhodium Group analysis

JUMPSTARTING TRANSPORT TRANSFORMATION

We find that accelerating the power sector clean energy transition would be cheaper and provide more economic benefits than meeting the current renewables mandate. With the 100% renewable energy proclamation by Hawaii's mayors as the focal point, we now consider what accelerating the ground transportation clean energy transition could look like and how it might interact with acceleration in the electric sector.

The starting point

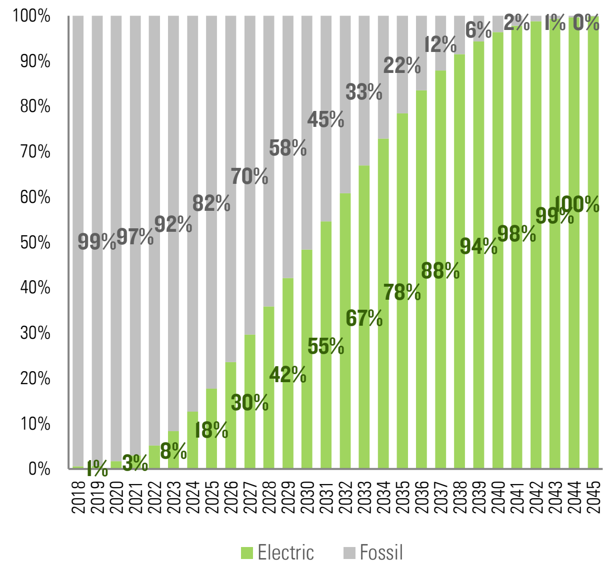
While Hawaii has the second-highest ownership of electric vehicles per capita in the nation, EV's account for fewer than 1% of its total vehicles. In 2016, less than 3% of total vehicles sold in the state were EVs. Consistent with these trends and recent projections of EV penetration, SGA constructed a projection which estimates that by 2045 EVs will make up 10% of all vehicles on the road in Hawaii without additional policy action. For comparison, EIA's latest outlook and projections published by the Hawaii Natural Energy Institute at the University of Hawaii estimate that by 2040 EV penetration could reach 5 to 15% of vehicle stock.[lxii] Alternatively, in its Electrification of Transportation Roadmap submitted to the PUC in March 2018 and currently under review, Hawaiian Electric considers several EV deployment scenarios including one where new policy action leads to 55% of the light-duty vehicle fleet being electric or plug-in hybrid by 2045 on the island of Oahu.[lxiii] Together, these studies project EV adoption could be as low as 6% or as high as 55% for light-duty vehicles. The range represents considerable market, technology and policy uncertainty. The Business as Usual scenario in this analysis operates under SGA's projection that by 2045 EVs will make up 10% of all vehicles on the road.

To estimate the maximum grid impact of vehicle electrification, we also model a 100% EV penetration scenario that aligns with the mayors' proclamation for 100% clean ground transportation by 2045. While the proclamation allows for biofuels, we consider a fully-electrified pathway to capture the full potential impact on electric demand. This 100% EV scenario allows us to quantify the pace of change required in the transport sectors if Hawaii chooses an EV-centric strategy for meeting the mayors' target, as well as assess the potential implications of doing so for Hawaii's electric power sector.

The average age of a car on the road in the US is 12 years. As a result, to fully electrify Hawaii's passenger vehicle fleet by 2045, EVs would need to account for 95% of total vehicle sales within ten years. By 2030, all vehicles sold in Hawaii would need to be electric to allow enough time for the technology to penetrate 100% of total vehicle stock by 2045, absent a massive vehicle retirement and replacement program (Figure 3.12). Fleet vehicles drive far more than personally owned vehicles, so for this segment stock-turnover is meaningfully faster.

Figure 3.12: Share of vehicle stock in 100% EV scenario

Percent of total



Source: Rhodium Group analysis

We note this sector is entering a period of disruptive change. Automated vehicles, though not currently permitted to operate in Hawaii, hold the potential to completely change vehicle-based mobility in the state and influence ownership models in ways that could help accelerate EV deployment. Some automotive industry executives view fleets of automated vehicles as the way forward to a new mobility future that is fully electric.[lxiv] However, automated transportation is not required or guaranteed to be electric.

Absent clear policy direction; technology has the potential to boost or curtail VMT. For instance, owners of automated vehicles could opt to have their cars circle a block for hours while they go out to dinner or attend a play instead of paying for parking. In contrast, properly incentivized platforms for automated vehicle ride-hailing could lead to a reduction in VMT by increasing carpooling and ridesharing. Recent research has found that ride-hailing services attract people away from biking and transit use, potentially boosting VMT.[lxv] Other research suggests that the best path towards sustainable vehicle transportation and away from dependence on oil is to embrace both electrification and automation while establishing policies and price mechanisms that maximize the use of ride-sharing.[lxvi] Implementing these "three revolutions" could cut congestion in Hawaii while accelerating EV deployment, putting the mayors' clean ground transportation goal within reach. However, we did not consider these revolutions in our scenarios due to uncertainty surrounding their likelihood, pace, and level of disruption. We note the same infrastructure investments, policies, pricing and development patterns that encourage ride-sharing today would be necessary to encourage ride-sharing in an automated, electric world as well.

EVs increase electric demand, but VMT actions can make this growth more manageable

The 100% EV deployment path described above would lead to an increase in electric demand, as all of Hawaii's on-road vehicles transitioned away from oil. Though slow at first, by 2045 this rise in demand from EVs adds 33% to conventional load from buildings and industry in our analysis (Figure 3.13). Meeting this demand would require additional resources and investment in electric power generation.

State and county governments could take actions to reduce VMT through the pursuit of policies that foster connected, compact, mixed-use development, with improved facilities for non-auto travel. Planning, zoning requirements, and subdivision ordinances can encourage connectivity with all modes of transport as well as mixed-uses and density. Investments in walking and transit options – not just in the densest part of Honolulu – can reduce VMT. Parking management, subdivision, and transit-oriented development planning, and incentives can further influence VMT trends. Together, such measures drive half the VMT reductions included in this analysis. Congestion and road charges that increase the cost of single-occupant vehicle travel account for the other half. Together, SGA estimates that these actions could reduce VMT 7% below 2016 levels by 2045, leading to a 27%, instead of 33%, increase in electric demand from vehicle electrification. Chapter 4 contains additional details on specific policy actions that could reduce VMT to the levels considered here.

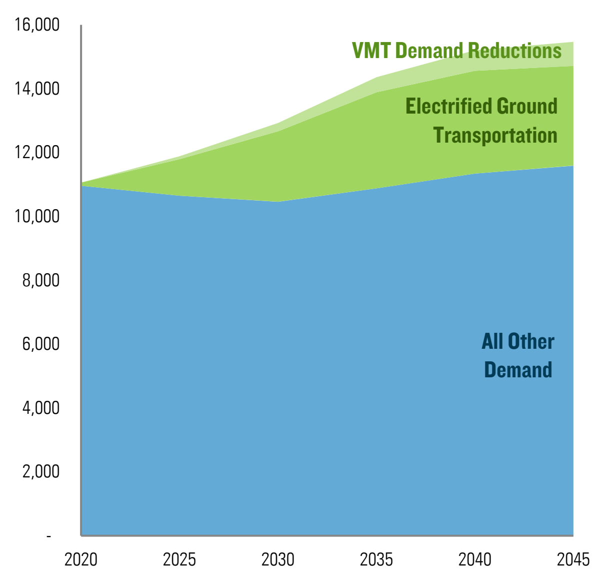
These development patterns deliver savings to both government and taxpayers. In prior research, SGA studied the cost and revenues from various development patterns. Findings indicated that upfront infrastructure for high density, smart growth development costs one-third less, saves municipalities 10%, on average, on continuous delivery of public services, and generates tenfold more tax revenue per acre than sprawling non-dense developments.[lxvii] Additionally, people spend less on transportation in places where they can reach jobs and amenities both in and out of a car. [lxviii]

Renewable energy deployment in a 100% EV Hawaii

What does all the additional EV driven electric demand mean for accelerating renewable energy deployment? Using our High Renewables assumptions, we find deployment slows to 64% by 2025 in a least-cost systems approach, compared to 69% without 100% EV penetration (Figure 3.14). In the long run, renewables penetration roughly matches the initial High Renewables scenario. Even with substantially more demand, we find renewables still provide the cheapest path to operating the electric system. EVs can act as a source of flexible load, allowing cheaper and easier balancing of variable renewables, resulting in a similar level of penetration. This reduces the need for battery storage. We assume 50% of EVs respond to real-time electric prices by charging when electricity is cheapest and renewable generation is plentiful. If electric regulatory frameworks are not put in place to enable and incentivize optimal EV charging behavior, renewable penetration would be lower than we show here.

Figure 3.13: Statewide electric demand

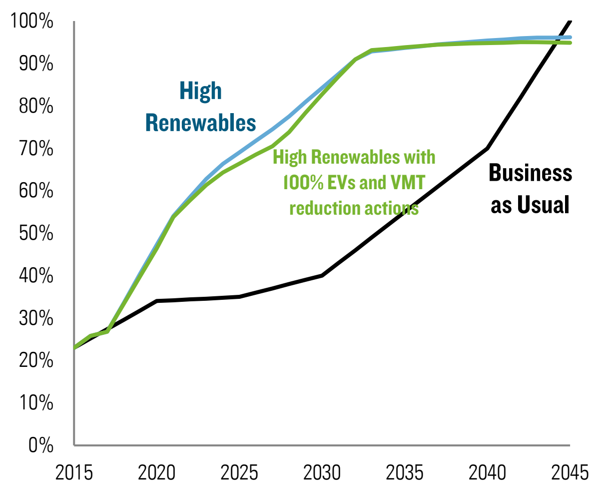
GWh



Source: Rhodium Group analysis. Note: Demand includes both retail sales and demand served by distributed generation.

Figure 3.14: Renewable share of power generation with low renewable costs and high fuel costs

Percent of total



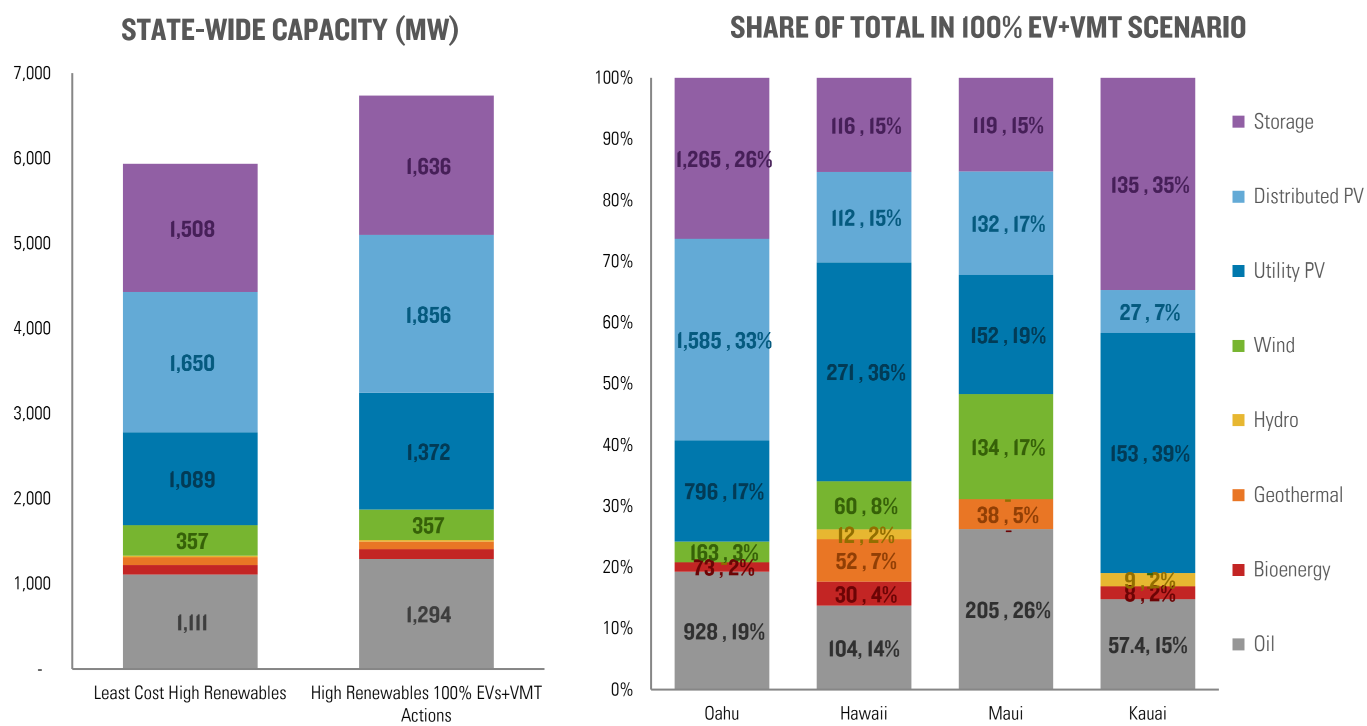
Source: Rhodium Group analysis. Generation includes utility scale and distributed generation.

The renewable energy mix in a 100% EV Hawaii

On all islands, we find that meeting the additional demand associated with 100% EVs requires additional capacity, even with actions to reduce VMT (Figure 3.15). In 2030, solar is the primary technology built to serve EV load (Figure 3.16). Other options could be considered if decision makers or community members on any of these islands preferred a different generation mix. For example, Hawaii island community members may favor, due to cultural sensitivities, not to pursue additional geothermal energy development. The island could choose to pursue additional utility solar and battery storage capacity instead. If Kauai stakeholders oppose utility solar power plants, the island could make additional energy efficiency investments to reduce demand and remove the need for some of that generation. If decision-makers on Maui prefer to avoid a further build-out of wind power they could more aggressively pursue DR or biodiesel.

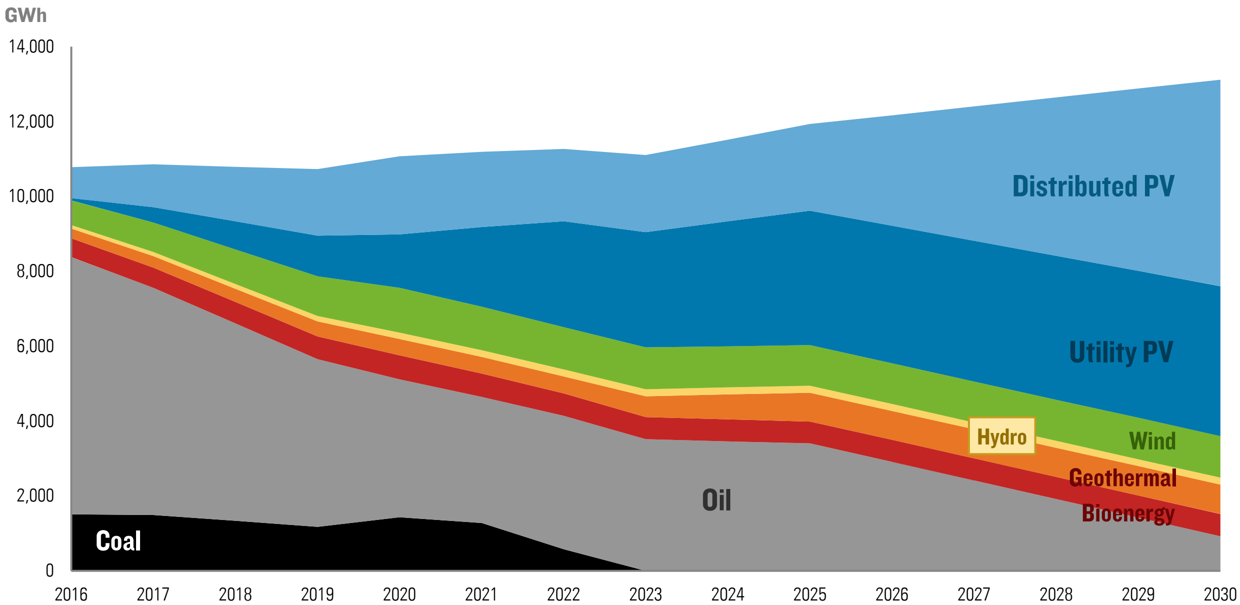
Figure 3.15: Renewable capacity by island in 2030 in 100% EV/VMT reduction scenario

Megawatts (left axis) and percent of total (right axis)



Source: Rhodium Group analysis

Figure 3.16: Hawaii electric generation by fuel and technology in High Renewables, 100% EV/VMT Reduction scenario, 2008-2030



Source: Rhodium Group analysis. Note: Generation includes gross utility scale and distributed generation before storage is engaged.

On Oahu, we find constraints on resource potential raise larger questions about alternatives and tradeoffs that could have statewide implications. In a scenario with ground transportation fully electrified by 2045, our least-cost scenario utilizes all rooftop and utility solar potential. That means every single rooftop with good solar exposure on the island is equipped with solar panels in 2045. It also means utility-scale solar panels are installed on approximately 10 square miles of open land, roughly 2% of the island's total area. Floating offshore wind farms 12 miles off the coast become economic in this scenario.

Achieving high levels of renewable penetration in Oahu will require both fully exploiting the island's renewable energy resources and reducing demand through efficiency, VMT reductions, and DR programs wherever possible. This will require extensive and proactive community outreach and engagement. Stakeholders will need a clear understanding of the relationship between energy efficiency, DR and VMT reduction policies and the extent to which solar and wind resources need to be developed and the cost of doing so for Oahu ratepayers.

Another option is an interisland transmission cable connecting Oahu with one or more neighbor islands. Instead of meeting Oahu's electric demand completely with on-island resources, neighbor islands' resources could help meet demand. Molokai, Lanai, Maui and Hawaii Island all have more renewable resources than they require to meet demand. Interconnecting these separate island electric systems could increase renewable energy development on neighbor islands and reduce the possibility of friction and conflicts on Oahu. However, the experiences of the past decade suggest neighbor island communities may prefer to not be suppliers of large utility-scale renewables for Oahu's benefit. A two-way interisland cable has the potential to improve grid flexibility, reliability, and resilience for all the islands it connects. These benefits may be enough to persuade stakeholders who opposed previous cable proposals, depending on how project costs are allocated. Ultimately the costs and availability of renewable resources on Oahu will drive whether a cable makes economic sense. In its latest PSIP, Hawaiian Electric found that the viability of an interisland cable project will require further analysis.[lxix]

Technological innovation could also ease Oahu's resource constraints. More efficient solar PV panels could make it possible to generate more electricity from the same number of rooftops (or the same amount of electricity from fewer roofs) and utility-scale projects. Floating solar technologies could allow for deployment of offshore solar plants relieving the pressure from land use conflicts. Hawaii has a long history of investments in ocean thermal energy conversion and ocean kinetic technologies.[lxx] These technologies have yet to become commercially competitive though they have the potential to help address Oahu's resource constraint challenges.

With more capacity comes more investment

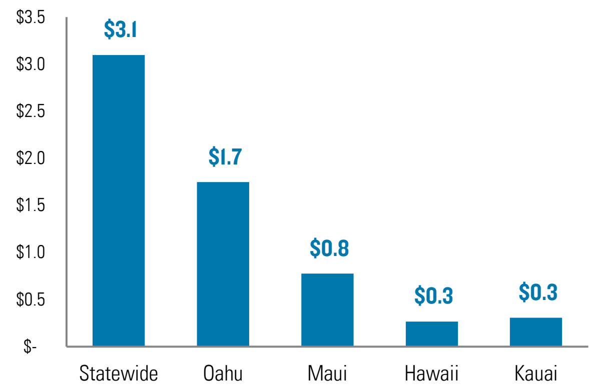
To meet the energy demand associated with 100% EVs with VMT actions in the High Renewables scenario nearly $3.1 billion in cumulative investment will be required statewide by 2030 (Figure 3.17). This is new investment relative to Business as Usual without achievement of the goal of the mayors' proclamation. While most of this new investment occurs on Oahu, there is a substantial investment on the neighbor islands. We do not consider the employment implications of these investments because such an estimate would have to account for possible changes in employment outside the electric power sector due to electrification of transportation, which was outside the scope of this report.

HCEI oil reduction goals could be within reach

In our Business as Usual scenario, oil consumption in the power and transportation sectors declines from 964 million gallons in 2015 to 726 million gallons in 2030 (Figure 3.18). If Hawaii pursues a power sector pathway consistent with our High Renewables scenario while electrifying transportation and reducing VMT, oil consumption in the state will drop much more quickly – to 322 million gallons in 2030, and a mere 45 million gallons by 2045. Hawaii would be on track to meet the HCEI 2030 oil reduction goals and come within striking distance of eliminating oil in these sectors.

Figure 3.17: Additional investment in high renewables 100% EV plus VMT scenario

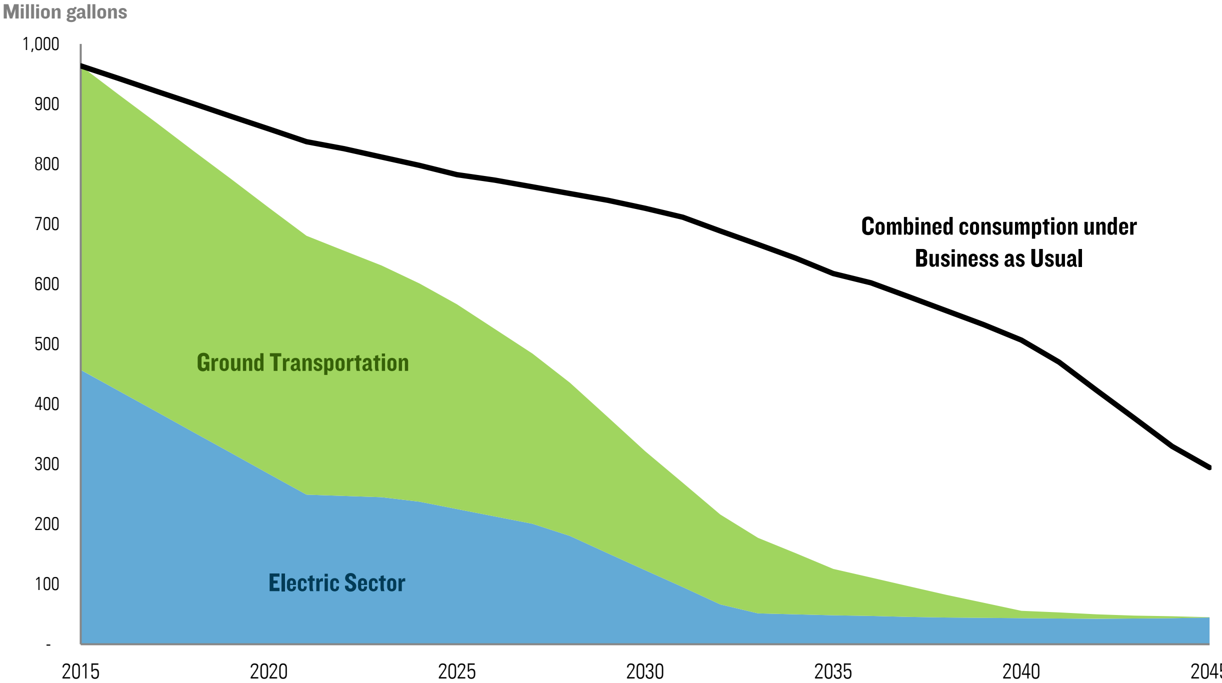
Cumulative, 2020-2030, billion 2016$



Source: Rhodium Group analysis.

Figure 3.18: Combined electric and ground transportation oil consumption High Renewables 100% EV plus VMT actions scenario

Million gallons



Source: Rhodium Group analysis

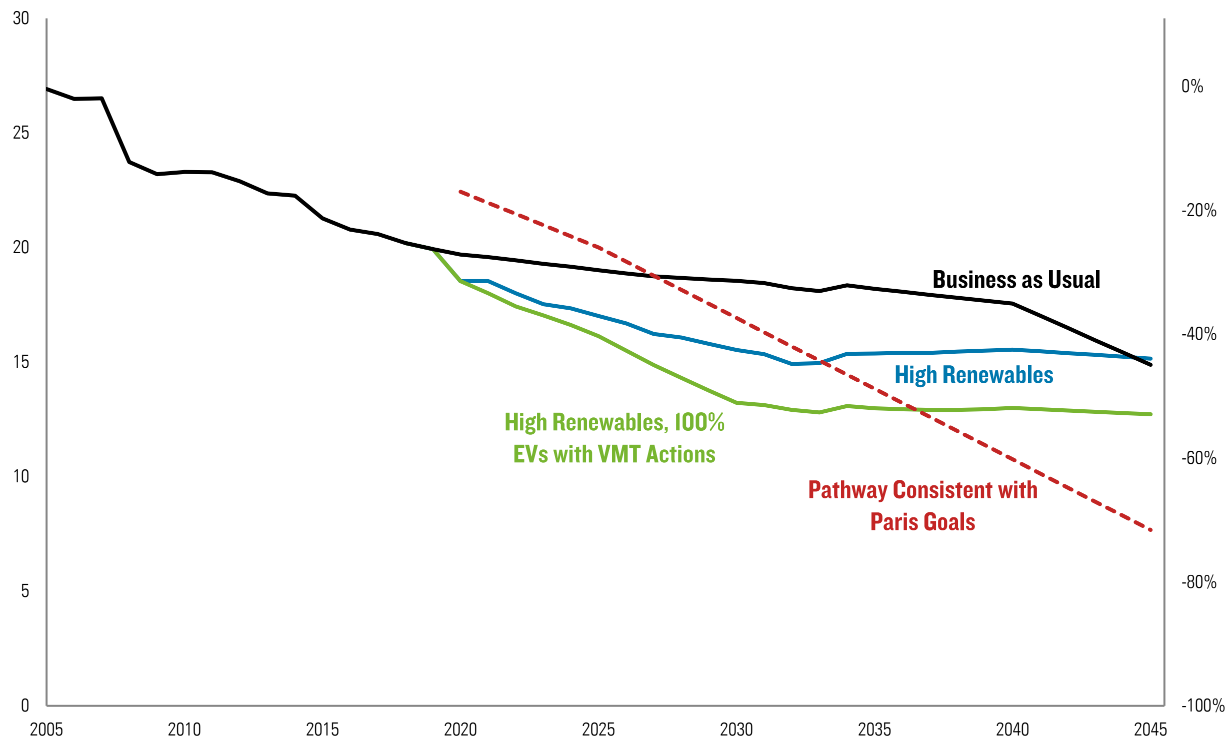
THE GHG IMPLICATIONS OF AN ACCELERATED TRANSITION

Accelerating Hawaii's clean energy transition would also put the state closer to a pathway that meets its share of US long-term GHG reduction goals as part of a global solution to combating climate change. In 2017, the state enacted a statute binding it to fulfill its share of the US Paris Accord commitment.[lxxi] Each of Hawaii's counties did the same. The goals include reducing total GHG emissions 26-28% below 2005 levels by 2025 and contributing to keeping global average temperature increases below 2 degrees Celsius relative to pre-industrial levels. What kind of long-term US emissions pathway is consistent with that 2-degree target depends on what actions other countries take, post-2050 emissions reductions, and the sensitivity of the global climate to changes in GHG concentrations. The most recent long-term target put forward by the US government is an 83% reduction in GHG emissions by 2050 relative to 2005 levels. We draw a straight line from the low end of the 2025 goals to that 2050 target in Figure 3.19 as an illustrative pathway consistent the goals of the Paris Agreement.

Under Business as Usual, Hawaii's total GHG emissions reductions exceed the Paris goals in 2025 (Figure 3.19). However, by 2030 Hawaii is off track, and by 2045 emissions are only 45% below 2005 levels. To be on a straight-line path to an 83% reduction by 2050, emissions would need to be 72% below 2005 levels in 2045. Under our High Renewables scenario, GHG emissions reductions exceed Paris goals until 2033 but also come up short in 2045, at only 44% below 2005 levels. If Hawaii pursues an electric power pathway similar to our High Renewables scenario while also electrifying transportation and reducing VMT, the state would far exceed mid-term Paris targets – cutting emissions in half between 2005 and 2030 – and stay below Paris-consistent levels until the late 2030s. Remaining emissions from aviation and non-energy consumption sources such as agriculture will need to be addressed if Hawaii is to get all the way to the long-term goal.

Figure 3.19: Hawaii economy-wide GHG emissions, 2005-2045

Million metric tons CO2e (LHS), % change from 2005 (RHS)



Source: Rhodium Group analysis. "Pathway Consistent with Paris Climate Goals" assumes a straight-line path from a 26-28% reduction below 2005 levels in 2025 (the official US target under the Paris Agreement) to an 83% reduction in 2050, the long-term goal put forward by the US at the Copenhagen climate conference. It is possible, depending on the actions taken by other countries, climate sensitivity, post-2050 action and other factors, that a greater than 83% reduction in 2050 would be required by the US to meet the Paris Agreement's long-term temperature stabilization targets.

NEW OPPORTUNITIES, AND NEW CHALLENGES

Shifting Hawaii's electric power and ground transportation systems to renewable energy brings with it new opportunities and challenges. The transition is unlikely to be seamless but proactive measures could make things smoother. While we cannot anticipate all the opportunities that may arise, we chose to highlight the following areas based on the results of our analysis and input from stakeholders.

State taxation and revenue in the transition

Like most states, Hawaii funds investment, operations, and maintenance of its transportation infrastructure through an excise tax on fuels. The counties have their liquid fuel taxes on top of the state tax. The state also funds environmental, energy and agricultural programs through a "barrel tax" on fossil fuels.[lxxii] In 2017, the state brought in a total of $221 million in revenue from these taxes.[lxxiii] This sum, 3% of total revenue, represents the lion's share of funding for the state and county highway funds. If the goal of the mayors' transportation proclamation is entirely met through electrification, revenue from the liquid fuels tax is eliminated 2045 and barrel tax revenue would be a fraction of what it is today.

On the expenditure side, Hawaii offers tax incentives for renewable energy deployment to residents and businesses. Over the past decade, cumulative tax credit claims totaled over $800 million.[lxxiv] In our analysis, we assume these incentives remain in place over the entire study period. For most renewable technologies, the tax credit does not make a material difference in total capital cost except for DG PV where a 10kw system receives $5,000 in tax incentives. In our highest DG PV deployment case we estimate that the state would receive nearly $1 billion in additional tax credit claims between 2017 and 2030 for this technology alone. We find the tax credit represents approximately 17% of the cost of DG PV in 2030. We, therefore, expect that without the tax credits DG-PV generation and overall RE penetration would be lower than in our projections.

If Hawaii moved to accelerate its clean energy transition, certain tax revenue and expenditure issues would need to be addressed. The state may need to shift taxation away from fossil fuels to other sources revenue sources. Options include a tax on the carbon content of fossil fuels used in the economy or an increase in Hawaii's barrel tax. Hawaii could also put in place pricing mechanisms like congestion charges in urban areas, mileage-based road pricing and other road user fees. These strategies fill revenue gaps and provide the added benefit of reducing VMT. Pricing mechanisms are most effective when the costs are incurred directly, as with congestion pricing or tolling, rather than being rolled into weekly, monthly or annual fees. Half of the reductions in transportation demand contained in SGA's VMT reduction policy projections come from pricing mechanisms that on net increase the cost of driving by 50%.

Education and workforce opportunities

To help ensure that the local population fills the jobs created during the clean energy transition, Hawaii would likely need to make new investments in education and training. Currently, Hawaii leads the nation in careers that require post-secondary school education and training, but less than half the working-age population has these skills.[lxxv] New curricula and programs at the high school, college and university level could be constructed to teach technical and problem-solving skills needed to be useful across the clean energy economy. Additional programs may be required to assist workers that currently hold conventional energy jobs, such as refining and oil-fired power plant operations, as these sectors play a diminished role in meeting energy demand in the state. Equipping more people with these skills could spread the economic benefits projected to result from Hawaii's clean energy transition.

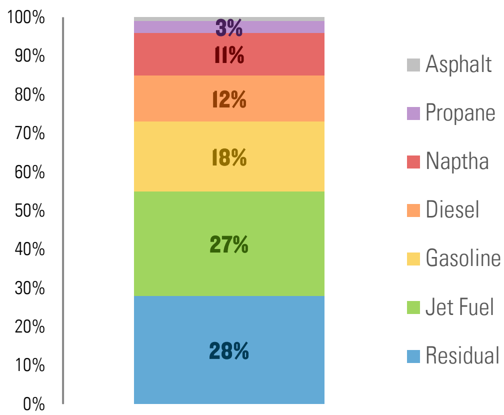
The implications of the clean energy transition on petroleum fuels

A typical barrel of crude oil imported in Hawaii gets transformed into a variety of products at one of two refineries in the state. Hydrocarbon chemistry dictates that all refined products get made in roughly consistent proportions, regardless of whether there is a market in Hawaii for a given fuel. The refineries convert 28% of each barrel of imported crude into residual fuel oil, the primary fuel currently used in most of Hawaii's electric power systems (Figure 3.21). Jet fuel, used to serve aviation between islands and overseas, represents 27% of a typical barrel, and gasoline represents 18%.

Accelerating the clean energy transition in electric power and ground transportation will eventually eliminate gasoline demand and most of the state's residual fuel demand. Meanwhile, projected increases in Hawaii's tourism industry and population would drive additional aviation and jet fuel demand.[lxxvi] These dynamics have two major implications. First, the increasing mismatch between refined fuel production and domestic demand could lead to the export of residual fuel and other products to overseas markets. The cost of exports would be passed to consumers, as the price of other fuels sold in Hawaii increased. Second, demand for refined fuels could drop to a level at which one or both of Hawaii's refineries are not economically viable. Hawaii would then need to import refined products from other refineries around the world. Workers at these facilities would require transition assistance. A complete petroleum fuel market analysis is beyond the scope of this paper, but our analysis suggests decisionmakers should engage in discussions on how to manage this aspect of the clean energy transition.

Figure 3.21: Petroleum fuels refined in Hawaii

Percent of each barrel of crude



Source: Hawaiian Electric

Biofuels and resource competition

One potential solution to the fuel market challenge is to increase production of locally sustainable biofuels. This has long been a focus of HCEI and policymakers. Electricity generated from biofuels and used in conventional power plants can count towards Hawaii's renewable electricity mandate. Biofuels could also help meet the mayors' ground transportation proclamation. Due to a lack of clean alternatives, SGA found that aviation and shipping may be the best applications of biofuels if Hawaii is to reduce its imported oil dependence further.

The design of existing aircraft and engine technology limits the amount of bio-based fuel that can be incorporated into the fuel mix. Fuel blends including 50 percent bio-based fuel are certified to "drop in" to the fuel supply. They can substitute for petroleum-based fuels with no modification to supply infrastructure or the engines that combust the fuel. Planes departing Hawaii airports filled up with 542 million gallons of fuel in 2014.[lxxvii] SGA projects that amount to increase to 607 million gallons in 2045. Meeting half of that demand with locally-produced biofuel would require an enormous amount of agricultural land to be devoted to fuel production. A Hawaii Natural Energy Institute study estimated the potential of Hawaii's agricultural land to produce products to be converted to biofuel and found that if all available land were cultivated up to 422 million gallons per year of bio jet fuel could be produced. Based on this finding, we estimate that meeting 50% of projected jet fuel demand in 2045 with locally sources biofuels would require approximately three-quarters of the state's agricultural land.[lxxviii]

This outcome may be untenable if Hawaii aims to have a robust local food economy as well as a clean energy economy. It also illustrates a tension with demand for biofuels outside of aviation and energy production on open lands in the state. In our analysis we limit biofuel use in the electric power sector to a total of 5.5 million gallons per year, matching current in-state production capacity. If biofuel demand increases beyond this amount across the economy, Hawaii may either turn to imports, as the state has done in the past or increase production capacity.[lxxix] Trading imports of petroleum fuels for biofuels may not provide as much economic benefit to the state. Meanwhile, utility-scale solar and wind electricity production would have to occur on open land in Hawaii to accelerate renewable energy deployment. In this analysis, we assume that Hawaii class A land as well as 90% of class B and C land is not available for utility-scale PV. Still, conflicts could arise between food producers, fuel producers and electricity producers for scarce land resources in the future. Establishing a process for mediating these disparate interests could represent an important step in managing these issues.

CHAPTER 4

Key Findings and Steps to Catalyze Acceleration

Hawaii's historical dependence on imported petroleum has put the state's economy in a precarious position and resulted in some of the highest energy prices in the nation. Fortunately, the declining cost of renewable electricity and other oil alternatives is allowing Hawaii to chart a new course. This report has highlighted the important progress the state has made over the past decade in transitioning away from oil towards locally-produced renewable energy, as well as the work that remains.

Combining state-of-the-art modeling tools, state and federal data and input from almost 200 hours of stakeholder interviews and meetings, we find the past decade of transition has reduced energy costs for households and businesses, supported local job creation and economic activity, and reduced pollution. We also find that Hawaii has the potential to expand these benefits by accelerating the pace of transition in the years ahead.

ELECTRIC POWER IS THE LEADING EDGE

Renewable energy generation in Hawaii grew from 6% to 25% of total generation over the past decade led by the proliferation of distributed PV solar. As clean energy gained momentum so did the ambition of Hawaii's clean energy goals leading to the nation's first 100% renewable energy mandate by 2045. Energy efficiency programs achieved nearly a 1,000 GWh of first-year savings. As part of this transition, oil consumption has declined by 21%, and over 2 million metric tons of CO_2 emissions were avoided. Clean energy now employs twice as many people in Hawaii as conventional energy production.

The pace of change has been slower in ground transportation, where oil consumption has remained roughly flat over the decade despite improved vehicle efficiency. Each person in Hawaii drives slightly fewer miles, but population and tourism growth are increasing overall vehicle transportation demand. Transit ridership has dropped slightly, but new Complete Streets developments and bikesharing are providing new mobility options. The state's mayors have established new ambitious goals for moving to 100% renewable fuels for vehicles (through both electrification and biofuels) that, if met, will transform transportation in the state.

IT IS CHEAPER TO GO FASTER THAN TO STICK WITH CURRENT TARGETS

Under a range of oil prices and renewable energy costs, it is cheaper for Hawaii to accelerate the clean energy transition than to stay on Business as Usual trajectory. In our modeling, the cheapest pathway shows renewable generation providing between 58% and 84% of all electricity generation in the state by 2030 compared to the current mandate of 40%.

Accelerating the transition could reduce oil consumption by 85 to 267 million gallons and spur as much as $2.8 billion additional cumulative investment by 2030, compared to Business as Usual. It could also create up to 1,500 net new jobs per year, on average, between 2021 and 2030. To realize these outcomes, we find Hawaii will need to build a more efficient and open electric grid equipped with AMI and implement regulatory frameworks that allow distributed PV, DR, and other flexible resources to provide an array of grid services. Increased energy efficiency investments can make the acceleration more attainable. Data sharing and transparency can make sure all of these resources and frameworks operate efficiently and cost-effectively.

TACKLING TRANSPORTATION REQUIRES A MULTI-PRONGED APPROACH

The slow pace of vehicle stock turnover and increasing transportation demand present challenges to accelerating the clean energy transition in ground transportation. Dramatic acceleration of the pace of renewable-powered EV deployment coupled with actions to reduce VMT will be required for the state to have a chance of meeting its long-term Paris commitments.

Our least-cost scenarios in the power sector combined with achieving 100% EV penetration by 2045 in line with the mayors' proclamation could put Hawaii on track to reduce economy-wide oil consumption by up to 415 million gallons per year by 2030. Moving to 100% renewable energy in ground transportation will not, however, address Hawaii's worst-in-the-nation traffic congestion. Our analysis finds it will also add substantial new electric load and require considerably more renewable power generation to meet the new load. Aggressive VMT reduction strategies can make a meaningful dent in load growth while reducing road congestion and making Hawaii's communities more livable.

POLICY RECOMMENDATIONS FOR CONSIDERATION

Based on our analysis and findings we put forward the following action items that could be pursued to accelerate the clean energy transition in Hawaii in line with our projections. These recommendations fall into three themes:

1. **Phase out fossil fuels**
2. **Realign incentives with clean energy goals**
3. **Tackle transportation demand**

Phase out fossil fuels

Our analysis shows that it is economic to phase out fossil fuels in the electric power sector to a greater degree than current RPS mandates require. It also shows a significant gap between Business as Usual in the ground transportation sector, and emissions reduction necessary maintain progress towards meeting Hawaii's long-term Paris Commitments. The following actions can help move both sectors along this path.

- ***Follow through and enforce current clean energy policies.*** Our projections assume current statutory energy efficiency mandates, as well as building codes and standards, are fully funded and implemented. Delayed implementation, exemptions, and funding reductions will make it harder to accelerate the clean energy transition. The cost will be higher, and the full benefits of the transition will not be realized.
- ***Accelerate renewable energy targets.*** While Hawaii's current 100% renewables mandate leads the nation, our analysis shows that more ambition in the near- and medium-term is cost effective and will further reduce oil consumption. Our analysis justifies setting the 2030 target at least as high as 58% and as much as 84% based solely on the relative cost of oil and renewable energy. Accelerating these goals will bring billions in new investment and new good-paying jobs.
- ***Adopt and implement California's Zero Emissions Vehicle (ZEV) standards.*** Nine states have adopted California's ZEV mandates which effectively require 8% of vehicles sold in 2025 to be electric, plug-in hybrid or fuel cell vehicles. The Clean Air Act allows California to enforce its own vehicle emissions rules and allows any other state to adopt California's standards in place of federal standards. Adopting the California standards requires an act by the state legislature. A ZEV mandate sends a signal to auto manufacturers to increase their EV offerings in the Hawaii market. It represents one of the most straightforward regulatory levers for accelerating EV sales.
- ***Follow through and build on mayors' clean transportation commitments*:** Hawaii could make significant near-term progress towards renewable energy use in ground transportation by requiring that certain types of vehicles be electric. Aggressive ZEV requirements for rental cars, hotel and private bus fleets, municipal vehicles, and other fleets could accelerate deployment state-wide. Likewise, requiring all automated vehicles to be fully electric helps ensure this technology results in less oil consumption, not more vehicle usage. Lawmakers in the California State Legislature recently proposed similar requirements.

Realign incentives with clean energy goals

Accelerating the clean energy transition will require all participants in Hawaii's energy system to receive and respond to incentives that drive decision-making in line with acceleration of the clean energy transition. Currently, that is not the case, but reforms could make a big difference.

- ***Revise utility regulatory frameworks to create an open grid.*** Current regulatory frameworks constrain clean energy technologies such as distributed PV and DR that are essential to accelerate the clean energy transition. Utilities receive no reward for meeting current goals more quickly, and customer-sited systems are prevented from providing or getting compensated for all the grid services they can offer. Rewriting the rules to open up the grid, expand energy service markets, and streamline procurement is essential. Regulatory dockets now open with the PUC and other efforts are an important starting point to generate momentum.
- ***Engage now in a multi-sector, long-term integrated energy plan.*** Proactively engaging all stakeholders in the development of a comprehensive energy plan for the state will give public and private sector actors needed certainty for investment decisions. Identifying and working through tradeoffs between land-use, energy production priorities, and community needs should be a central focus of this process.

- ***Create an open data environment.*** Encourage utilities and government to create open data, which will enable more efficient markets and attract local and global innovators.

- ***Put a price on carbon.*** A reasonably high carbon price functions similarly to high oil prices and would encourage faster renewable energy deployment in the electric power sector. An appropriate tax rate could also reduce VMT and speed up sales of EVs if coupled with other land use and transportation policies. Unlike renewable deployment growth driven by oil prices, which transfers money from Hawaii ratepayers to non-Hawaii oil producers, a carbon tax generates revenue that stays in Hawaii. These funds can be used to further accelerate clean energy deployment through biofuel development, EV incentives, and other activities to help meet Hawaii's Paris commitments. They can also be returned directly to the people of Hawaii to help offset the state's high living costs or to fund education and transition assistance for displaced workers.

Tackle transportation demand

Transportation remains Hawaii's most challenging clean energy quagmire because it requires coordination between land use and transportation across federal, state, local, and private entities. Phasing out fossil fuels in the transportation sector is critical to meet the state's long-term Paris commitment. It should be complemented with policies to reduce vehicle usage through more compact and less car-centric development.

- ***Revise state and county land use and transportation policies to incentivize multimodal mobility and compact, walkable development.*** Subdivision ordinances and zoning should be changed to improve mobility options, incentivize mixed land-uses, and improve neighborhood connectivity. These actions can be complemented by directing new development towards transit and multiple mobility options.

- ***Price the full cost of parking and driving.*** Half the VMT reductions considered in our analysis come from pricing mechanisms. Parking management plans should be established, and minimum parking requirements in new developments should be removed, as they add to housing costs and incentivize personal vehicle ownership. Congestion charges potentially coupled with VMT charges tailored to reward ride-sharing could be useful in shoring up lost gasoline tax revenue while also reducing transportation demand.

- ***Design public streets for everyone.*** Public streets are the most underutilized public asset. Future road maintenance and new road construction should support a multimodal system of transportation including pedestrian, bicycle lanes, bike share, car share, ride-hailing, bus, rail, and EV charging.

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