U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Lahaina Energy System Context

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National Renewable Energy Laboratory (NREL)

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Photo by Dennis Schroeder, NREL 58000

Overview

- This presentation was developed as part of the Lahaina Energy Partnership (LEP), a multi-year, community-led project to identify and assess energy system options as part of rebuilding Lahaina.
- Lāhainā Strong, Hā Sustainability, and Shake Energy Collaborative facilitate community engagement and co-design for the project. NREL provides strategic guidance and technical assistance with funding from the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy.
- The project will include ongoing energy education to support informed community participation. NREL developed this initial presentation. Local partners will lead development of future educational materials.

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Acknowledgements

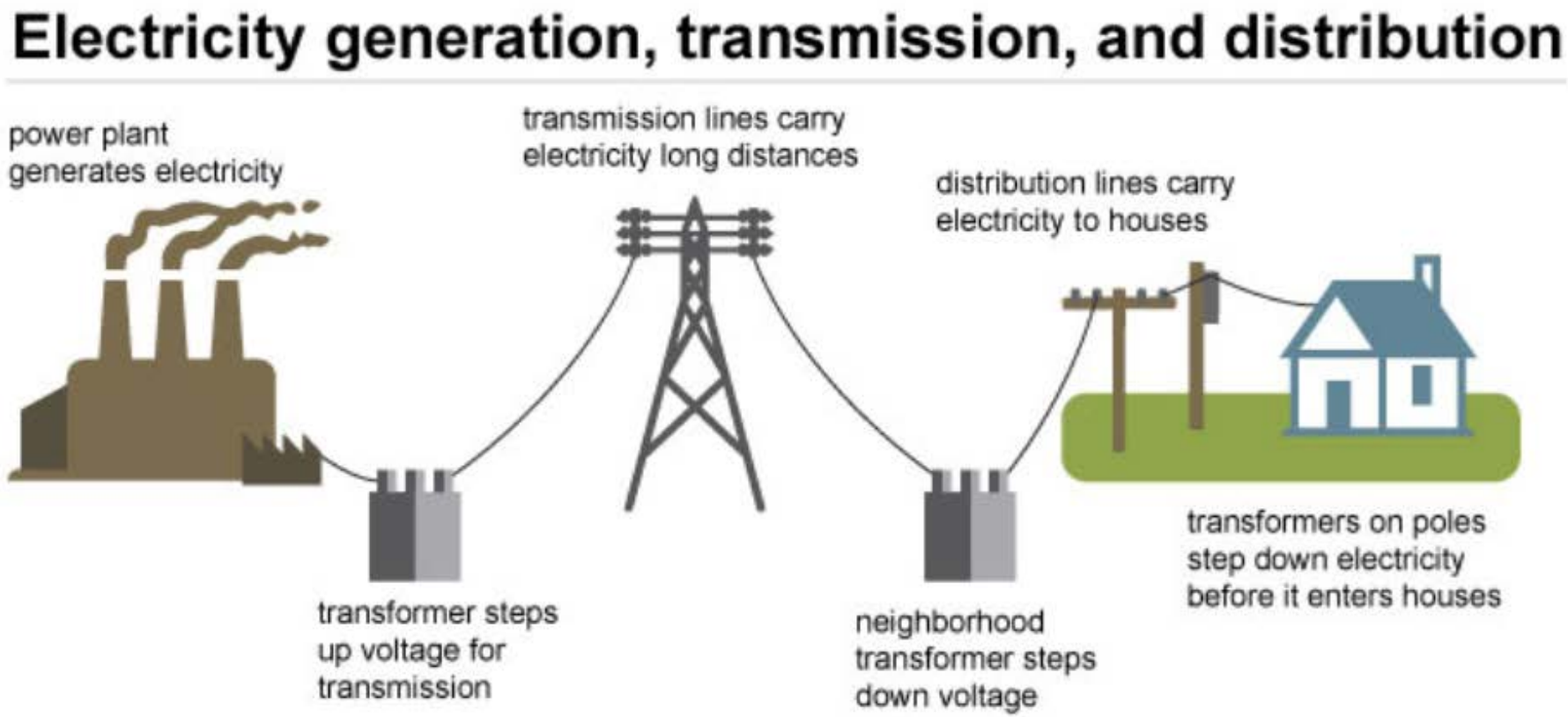
- Contributing authors include Andrew Alberg, Christina Simeone, and Jenny Sumner with NREL, with additional analysis by Eric O'Shaughnessy and Galen Barbose with Lawrence Berkeley National Laboratory.
- Thank you to representatives of LEP partner organizations for their review of this presentation:
  - Hā Sustainability
  - Shake Energy Collaborative
  - Lāhainā Strong
- Thank you also to representatives of Hawaiian Electric and Hawaiʻi State Energy Office for their review.

Topics

- Energy System Basics
- Why Energy Efficiency and Renewable Energy?
- Energy System Reliability and Resilience
- Hawai‘i’s Energy Context
- Hawai‘i’s Renewable Energy and Decarbonization Goals and Progress
- Hawai‘i’s Integrated Grid Plan (IGP) and Preferred Path
- Maui County and Lahaina Energy Context
- NREL Fact Sheet on Rebuilding in Maui and Additional Resources

Energy System Basics: Where We've Been

The electric grid has historically been composed of three phases:



Source: U.S. Energy Information Administration (adapted from National Energy Education Development Project (public domain), https://www.eia.gov/energyexplained/electricity/delivery-to-consumers.php

Energy System Basics: Where We've Been

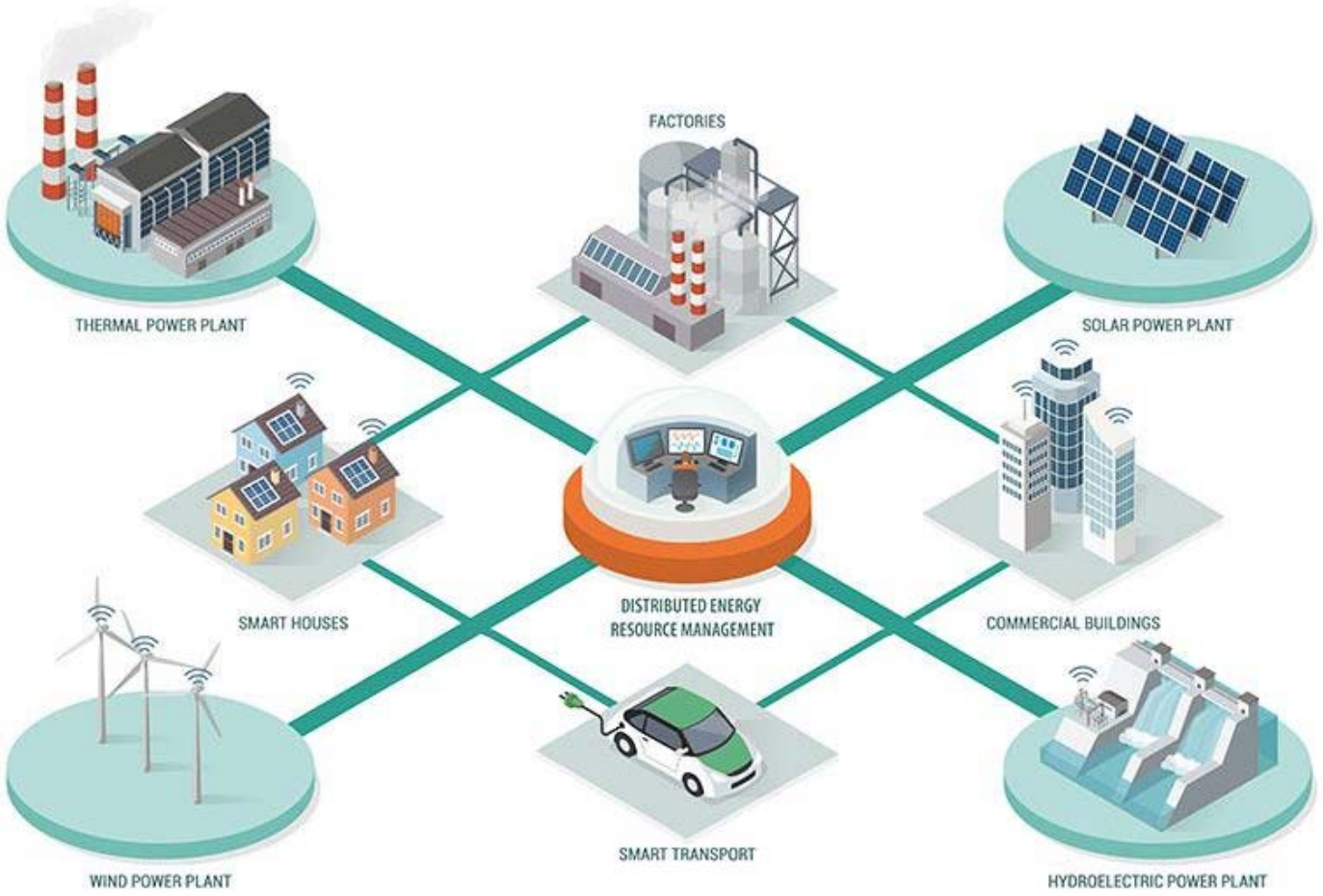
The electric grid has historically been composed of three phases:

1. **Generation** – Electricity generation typically fits into two categories:
    1. "Firm" or "dispatchable" power can be generated and injected into the grid as needed. Sources include combustion of coal, methane natural gas, petroleum fuel oil, biofuels, as well as nuclear and geothermal energy, hydrogen, and hydroelectric dams. Battery storage and pumped-storage hydro are also dispatchable.
    2. "Variable" or "intermittent" electricity is generated when available and not necessarily when called upon. Sources include solar, wind, and run-of-river hydroelectric generators. Pairing variable generation with storage enables dispatchability of these sources.
2. **Transmission** delivers electric power to users over long distances.
3. **Distribution** carries lower-voltage electricity short distances to homes and businesses.

Energy System Basics: Options for the Future

The electric grid is transitioning toward one that is more:

- Renewable
- Distributed
- Interactive.



Source: National Renewable Energy Laboratory (NREL), Distributed Energy Resource Management Systems, https://www.nrel.gov/grid/distributed-energy-resource-management-systems.html

Energy System Basics: Options for the Future

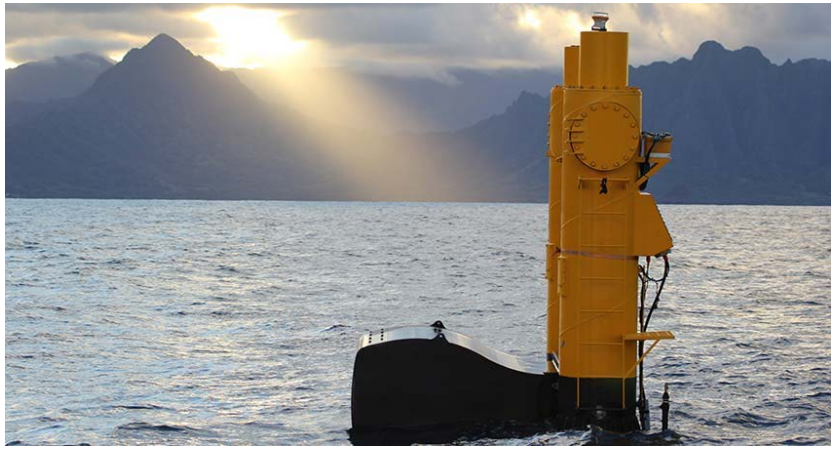
The electric grid is transitioning toward one that is more:

1. **Renewable** – Renewable energy generation facilities, such as utility-scale solar, wind, marine, hydro, and geothermal energy, and other technologies are replacing fossil-fueled power plants.
2. **Distributed** – Distributed generation, such as rooftop solar on homes and businesses, as well as energy storage systems, smart appliances, and electric vehicles, provides electricity locally and allows consumers to participate in the energy system as “prosumers.”
3. **Interactive** – Grid interactivity, in the form of advanced communications and controls, enables participation of distributed resources resulting in a grid that is also more flexible, reliable, and resilient.

Why Energy Efficiency and Renewable Energy?

- Many firm generators combust fossil fuels such as coal, methane gas, or liquid fuels to produce electric power, which emit greenhouse gases (GHGs) including carbon dioxide, nitrous oxide, and methane that cause climate change and affect local air quality and public health.
- Deploying **energy efficiency measures** such as energy-efficient appliances and **renewable energy technologies** such as wind energy, solar energy, bioenergy, geothermal energy, hydropower, and marine energy can:
  - Reduce GHG emissions.
  - Improve air quality by reducing airborne pollutants.
  - Reduce costs of power system operation and monthly electric bills.
  - Reduce reliance on imported fuels.
  - Increase resilience.

Rooftop solar on a home in Hawai'i. Photo by Deb Lastowka, NREL 54445.



Wave energy device at U.S. Navy's Wave Energy Test Site near Kaneohe Bay, Oahu, Hawai'i. Marine energy technology is in an early stage of development. Photo from Northwest Energy Innovations, NREL 46297.

Sources: U.S. Environmental Protection Agency, "Clean Air Power Sector Programs" (https://www.epa.gov/power-sector) and U.S. Department of Energy (DOE), "Why Clean Energy Matters" (https://www.energy.gov/eere/why-clean-energy-matters)

Energy System Reliability and Resilience

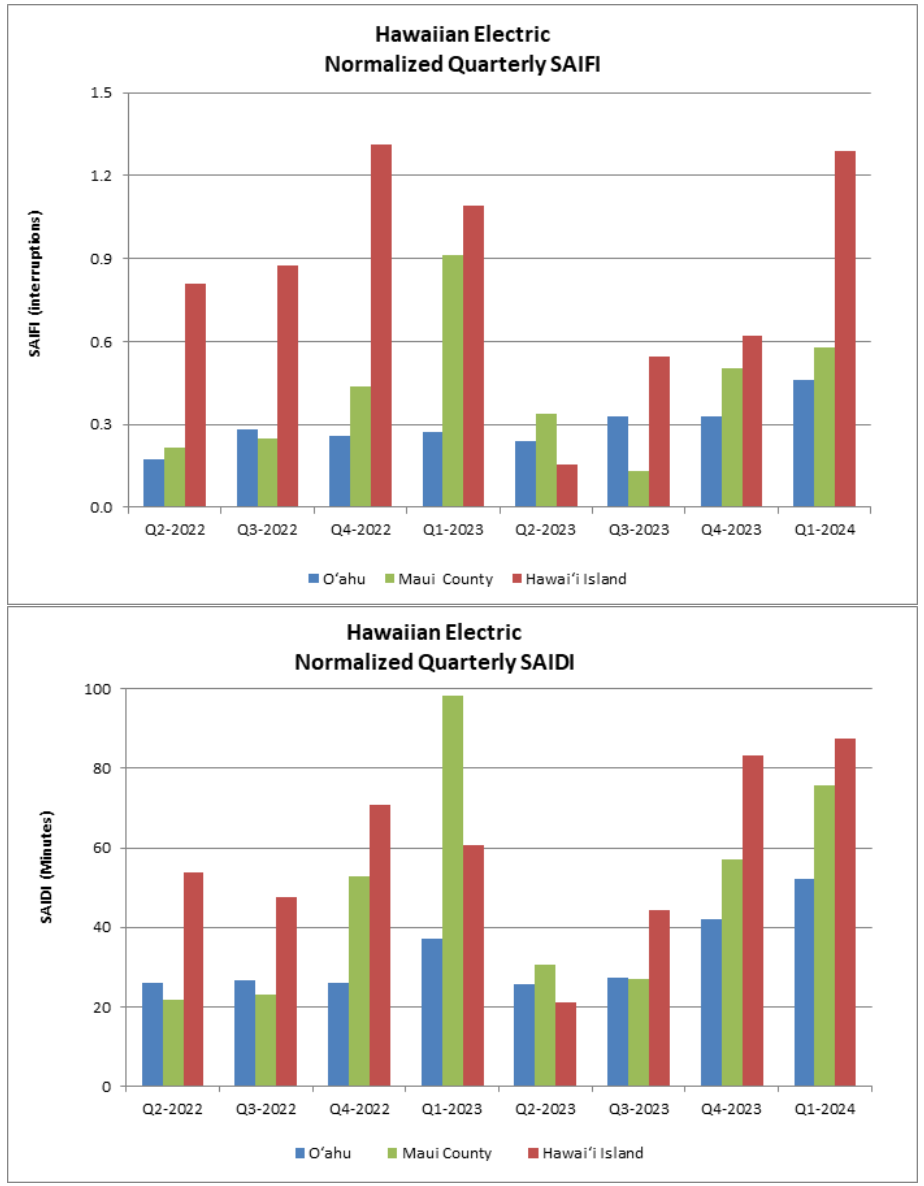
Reliability is focused on delivering power to consumers, and ***resilience*** deals with preparation and response to issues on the electric grid arising internally and externally such as equipment failures or extreme weather events.

- **Reliability** is, “the ability of a power system to withstand instability, uncontrolled events, cascading failures, or unanticipated loss of system components.”
- **Resilience** is, “the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions to the power sector through adaptable and holistic planning and technical solutions.”

Sources: DOE, “Energy Reliability,” https://www.energy.gov/eere/energy-reliability;” Resilient Energy Platform, “Glossary,” https://resilient-energy.org/about/glossary

Energy System Reliability

- Reliability is measured by frequency and duration of outages,* among other metrics.
- Hawaiian Electric uses industry standard metrics for reliability, and service reliability is regulated by the Hawai‘i Public Utilities Commission.
- Maui County’s electric service is, on average, slightly less reliable than on O‘ahu but more reliable than on Hawai‘i Island (figures at right).



Reliability of Hawai‘i’s electric service measured by frequency (top) and duration (bottom) of outages, 2022–2024

*System Average Interruption Frequency Index (SAIFI) and System and Average Interruption Duration Index (SAIDI) are two key reliability metrics.

Source: Hawaiian Electric, “Service Reliability,” https://www.hawaiianelectric.com/about-us/performance-scorecards-and-metrics/service-reliability

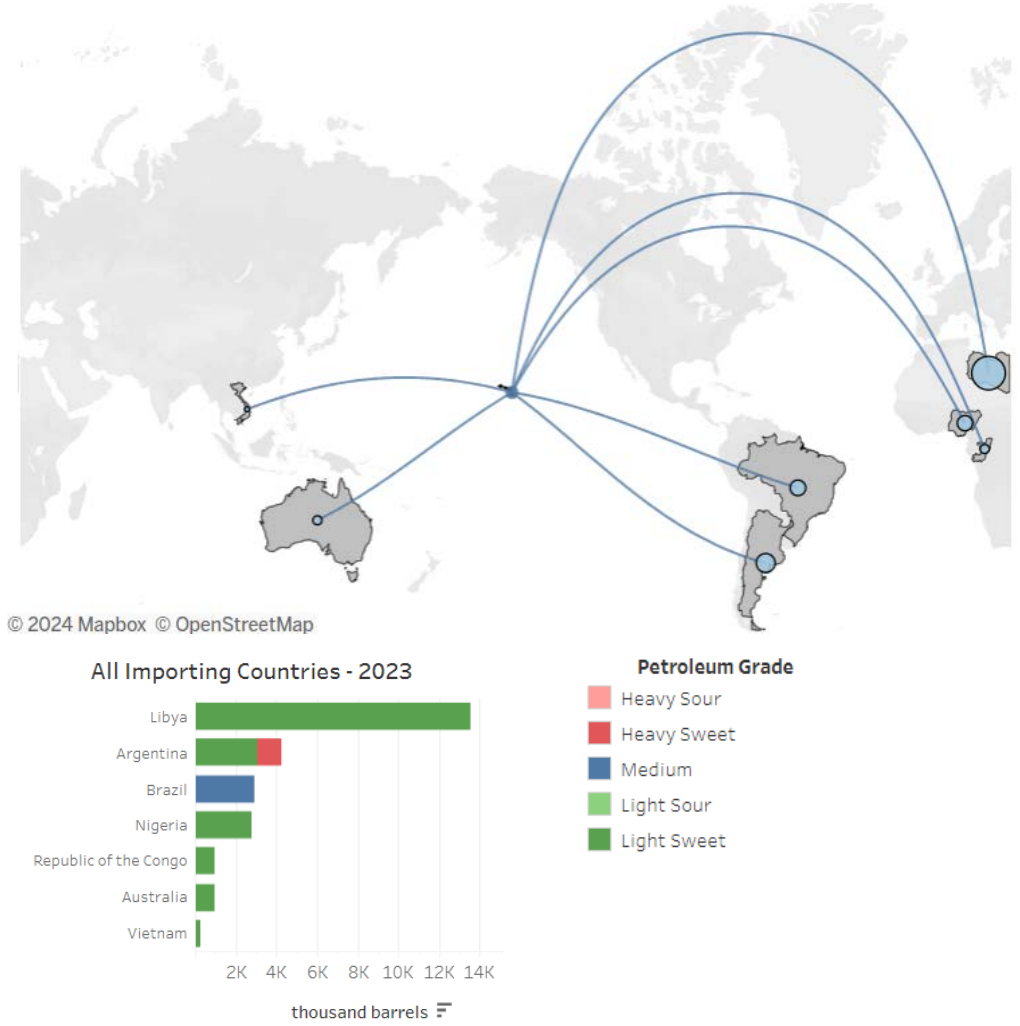
Energy System Resilience

- Energy system hazards in Hawai‘i include:
  - Tropical storms
  - Floods
  - Earthquakes
  - Tsunamis
  - Volcanic activity
  - Wildfires
  - Infrastructure failures
  - Physical and cyber attacks.
- Mitigating hazards and improving energy system resilience reduces vulnerability to these hazards. Examples include:
  - Resilience planning and preparedness
  - Capacity building
  - Grid hardening and wildfire safety
  - Improving local resilience through distributed solar and storage, islandable community microgrids, and resilience hubs.
- Hawaiian Electric is making investments aimed at improving resilience through wildfire safety, system maintenance and upgrades, disaster recovery, and planning.
- In February 2024, the energy commission approved Hawaiian Electric’s 5-year, $190 million *Climate Adaptation Transmission and Distribution Resilience Program* application.
  - A $95 million federal grant would cut cost to customers in half, to less than 50 cents a month.
  - Wildfire safety actions are a key element of program.
  - 2,100 poles on critical circuits to be strengthened, replaced.

Sources: Hawaii State Energy Office, “Energy Assurance, Resilience, And Security In Hawai‘i,” “Performance Based Regulation (PBR) Scorecards and Metrics, Resilience;” NREL, “Energy System Resilience;” Hawaiian Electric press release, “Regulators approve 5-year grid resilience plan”

Hawai‘i’s Energy Context: Fuel Sources

- Fossil-fueled power plants in Hawai‘i, including Kahului and Ma‘alea on Maui, are powered by liquid petroleum products.
  - Hawai‘i’s last coal-fired power plant, on O‘ahu, was retired in 2022.
- Liquid fossil fuels are primarily imported to Hawai‘i from foreign countries, transported across the ocean, and offloaded on O‘ahu before being refined if needed and barged to other islands.
  - In 2023, Hawai‘i imported fuel primarily from Libya, Argentina, Brazil, and Nigeria (figure at right).

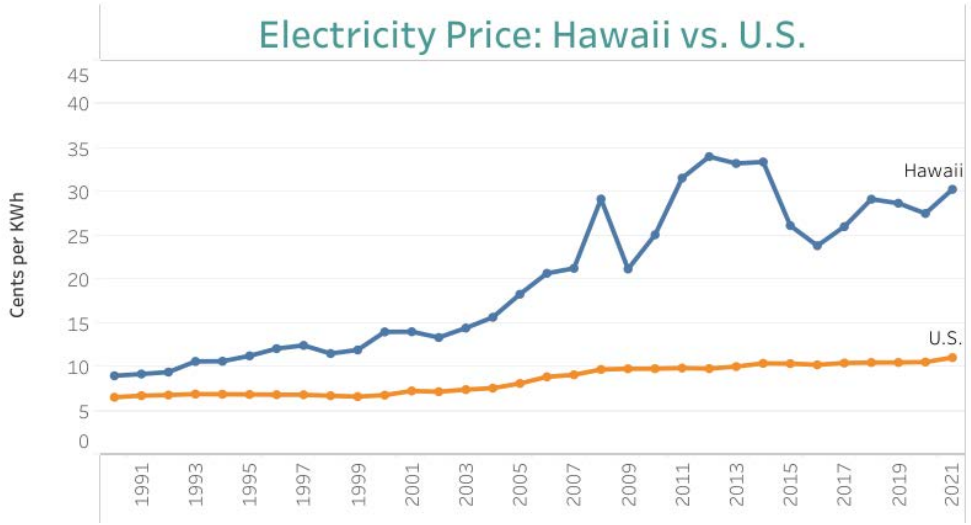


Hawai‘i foreign crude oil imports, 2023

Source: Hawaii State Energy Office, “Non-renewable Energy Sources,” https://energy.hawaii.gov/what-we-do/energy-landscape/non-renewable-energy-sources/

Hawai‘i’s Energy Context: Electricity Price

- Hawai‘i has the highest electricity prices in the United States (~3x national average) (right). Average residential price as of April 2024 year-to-date was (cents/kilowatt-hour [kWh]):
  - U.S.: 16.19
  - Hawai‘i: 44.65
- Electricity prices in Hawai‘i vary by island. Average residential prices in 2023 were (cents/kWh):
  - O‘ahu: 43.22
  - Maui: 43.31
  - Moloka‘i: 51.74
  - Lanai: 52.49
  - Hawai‘i Island: 46.52
  - Kaua‘i: 37.54
- Due to reliance on liquid petroleum products for electricity generation in Hawai‘i, the price of electricity is tied to the fluctuating price of crude oil.



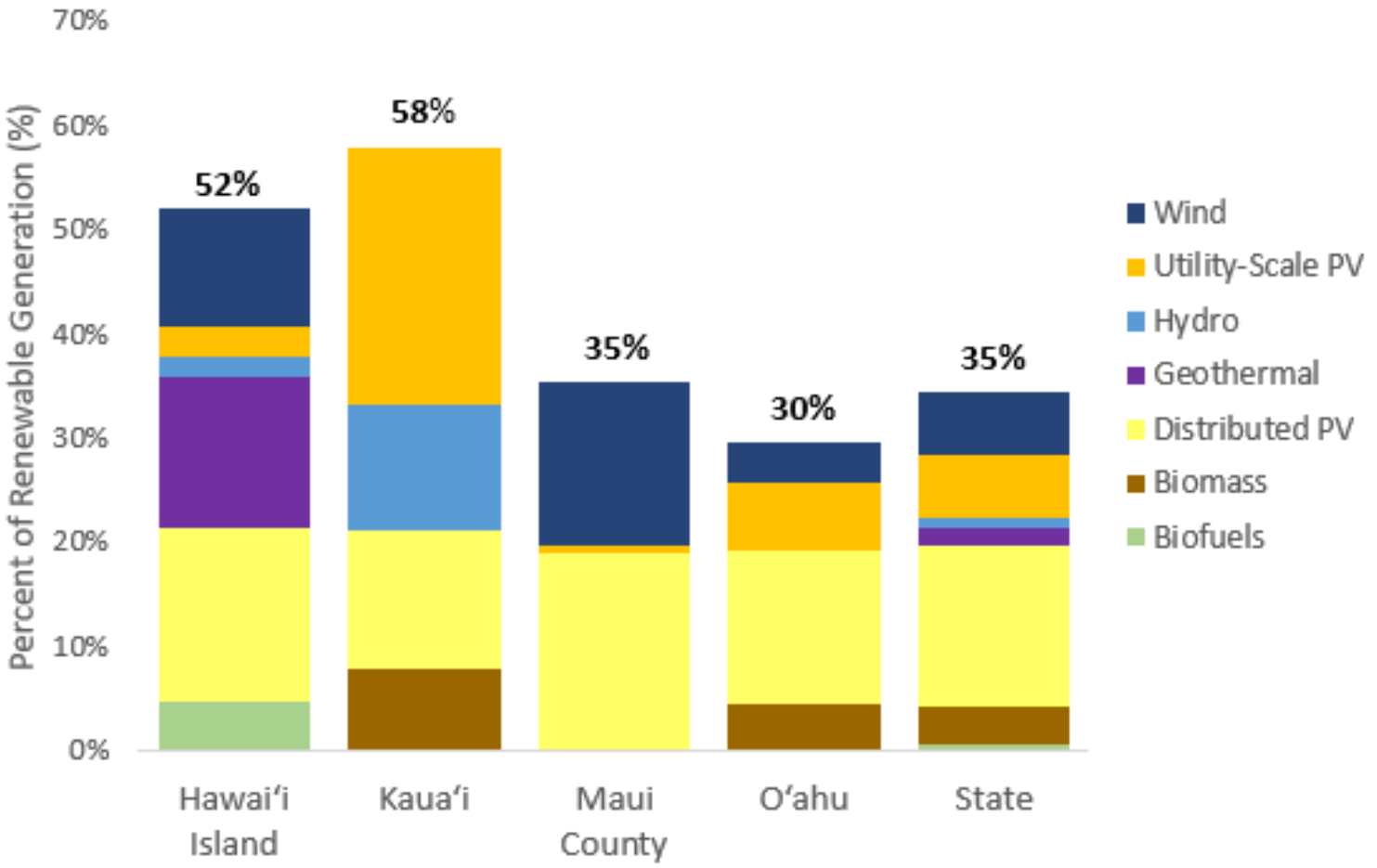
Sources: U.S. Energy Information Administration, Electric Power Monthly; Hawaiian Electric, “Average Price of Electricity;” Hawaii State Department of Business, Economic Development, and Tourism (DBEDT), “Economic Data Warehouse.” Hawaii State Energy Office, “Energy Dashboard/ Electricity” (figure above); DBEDT, “Monthly Energy Trends;”

Hawaii State Energy Office notes that on Kaua‘i, the high penetration of renweable energy, specifically utility-scale solar, has contributed to both stabilizing and lowering electricity prices on that island.

Hawai‘i’s Renewable Energy and Decarbonization Goals

- 100% of electricity sales to come from renewable energy by 2045 (Act 97, 2015).
- Public and private ground transportation powered by 100% renewable fuel sources by 2045 (Mayoral proclamation, 2017).
- Net-negative carbon emissions by 2045 (Act 15, 2018) and greenhouse gas emissions at least 50% below 2005 levels by 2030 (Act 238, 2022).
- Climate emergency declaration and commitment to a just transition toward a decarbonized economy (Senate Concurrent Resolution (SCR) 44, 2021).

Hawai‘i’s Renewable Energy Progress



Renewable energy generation by source, 2023

Source: Data compiled by the Hawai‘i State Energy Office from Public Utilities Commission Docket 2007-0008, Renewable Portfolio Standards (RPS) Annual Reports, https://puc.hawaii.gov/reports/energy-reports/renewable-portfolio-standards-rps-annual-reports/

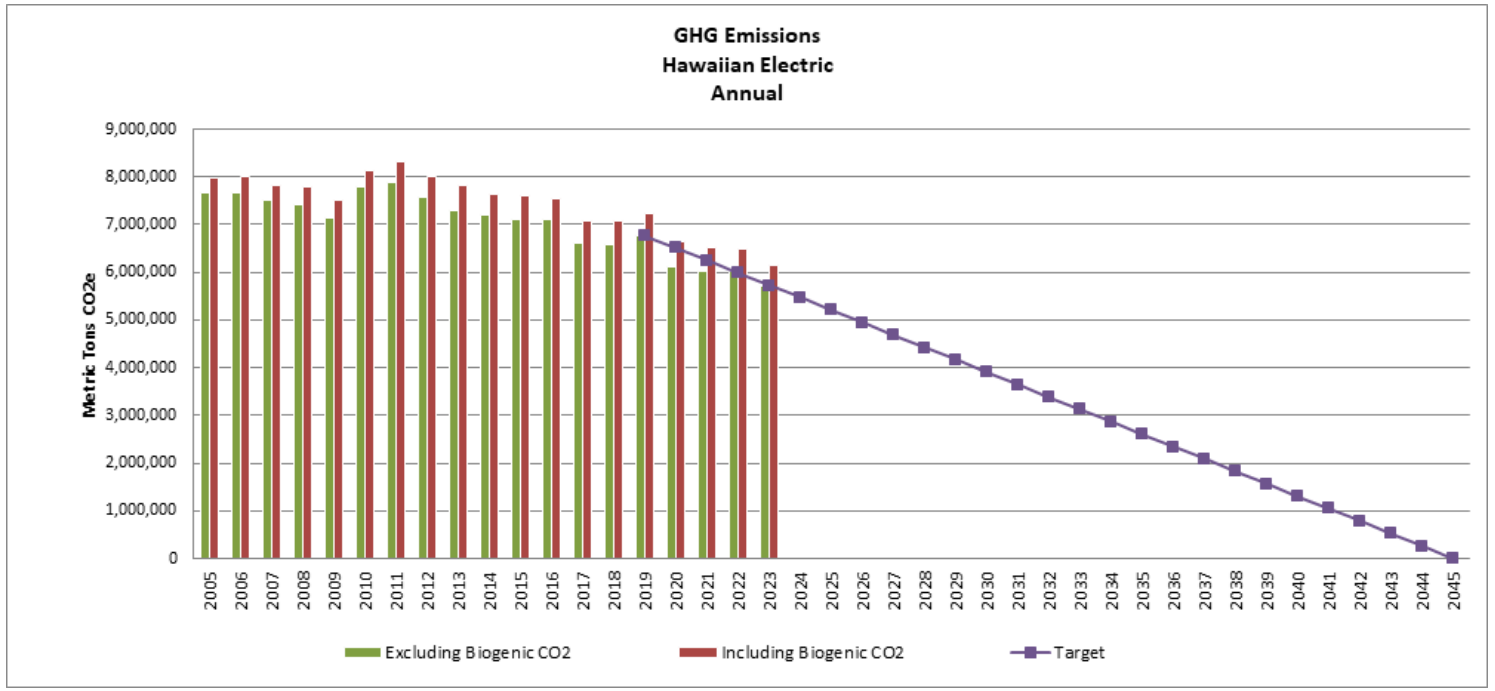
Hawai‘i’s Renewable Energy Progress

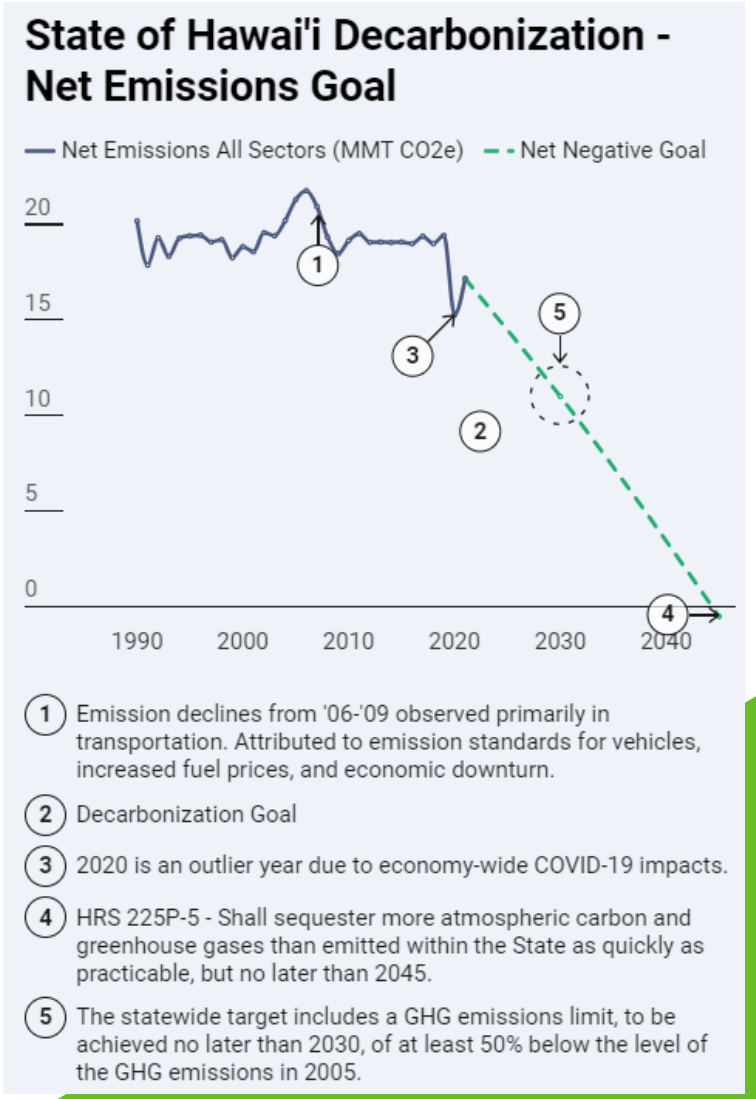
- In 2023, Hawai‘i achieved 33% total renewable energy statewide:
  - Hawai‘i Island, 52%
  - Maui County, 35%
  - O‘ahu, 30%.
- Maui County had the highest percentage of customer-sited distributed energy resources (DER) (primarily rooftop solar at 19%, compared with 16% statewide).
- The other major renewable energy source on Maui is wind (16%).
- Geothermal energy is the second-largest renewable energy generation source for Hawai‘i Island (14%).

Source: Hawaiian Electric, *2023 Renewable Portfolio Standard Status Report*, “Key Performance Metrics, Renewable Energy”

Hawai‘i’s Decarbonization Progress

- Energy accounted for 86.7% of Hawai‘i’s GHG emissions in 2021, 27% of which comes from the production of electricity.
- GHG emissions from electricity generation (excluding biogenic carbon dioxide [CO2], such as from incineration of municipal solid waste and some fuel blending) are declining (left).
- Net emissions from all sectors including transportation held steady from 2010 until the COVID-19 pandemic, dropped steeply, then climbed back up until 2020 (right).





Sources: Hawaii State Department of Health, *Hawai‘i Greenhouse Gas Emissions Report for 2020 and 2021;* Hawaiian Electric, “Greenhouse Gas (GHG) Reduction” (figure at left), *Hawaii Pathways to Net Zero* (2023); Hawaii State Energy Office, “Decarbonization” (figure at right)

Hawai‘i’s Integrated Grid Plan (IGP) and Preferred Path

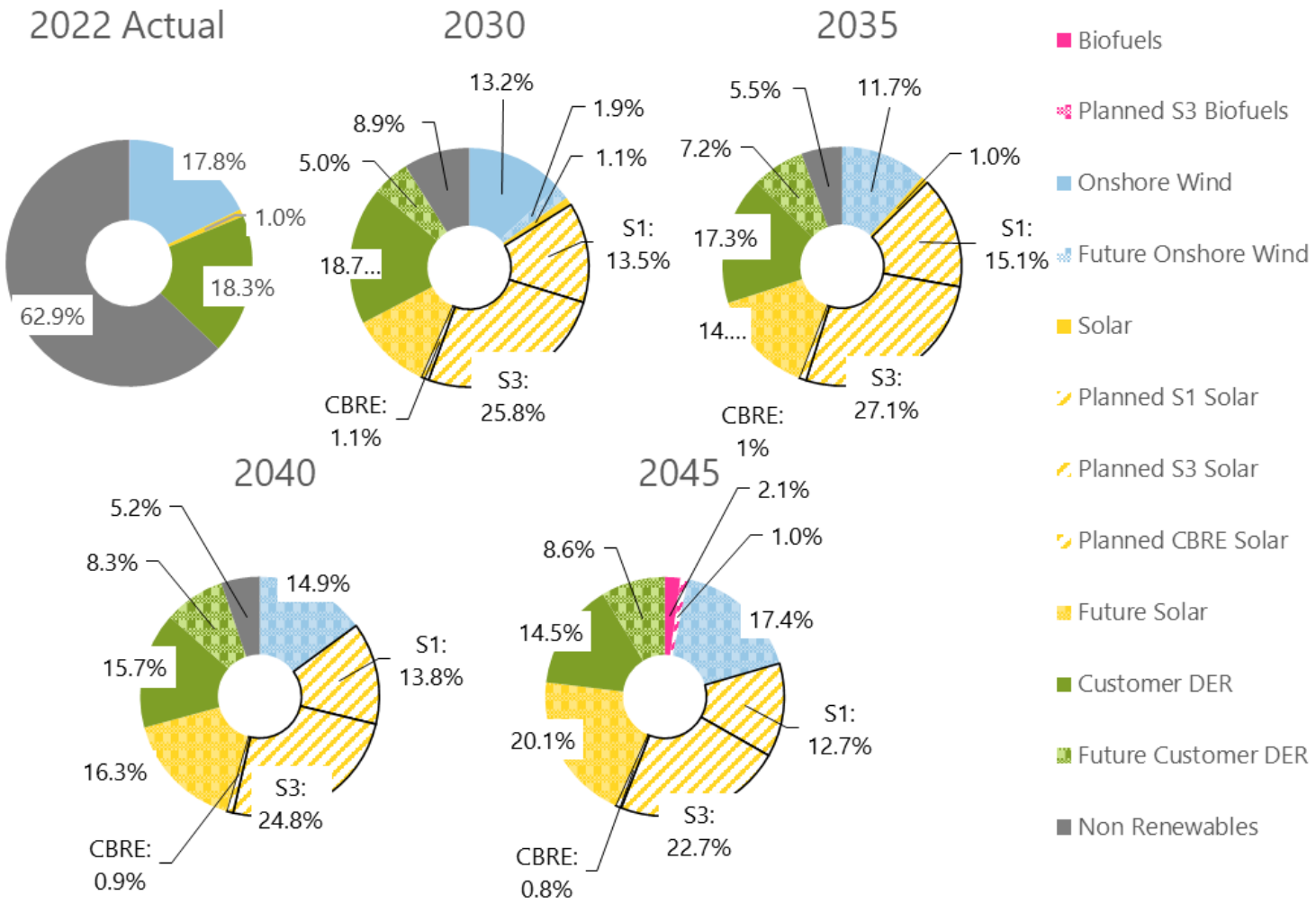
- Hawaiian Electric developed an Integrated Grid Plan, with stakeholder and community participation, which proposes actionable steps to decarbonize the electric grid on the state of Hawai‘i’s timeline. In was approved by the Public Utilities Commission in March 2024.
- The plan:
  - Is based on a forecast of future energy needs.
  - Highlights four high-level actions in next five years:
    - Stabilize utility rates and advance energy equity
    - Grow the marketplace for customer-scale and large-scale renewables
    - Create a modern and resilient grid
    - Secure reliability through diverse energy sources and technologies.
  - Recognizes distinct energy planning contexts on Moloka‘i and Lana‘i.
  - Includes Preferred Plans for each island.

Source: Integrated Grid Plan: A pathway to a clean energy future (2023) and Integrated Grid Plan Preferred Plans and Next Steps (2023) available on “Integrated Grid Plan,” Hawaiian Electric, https://hawaiipowered.com/igpreport/

Hawaiian Electric Integrated Grid Plan: Preferred Plan for Maui

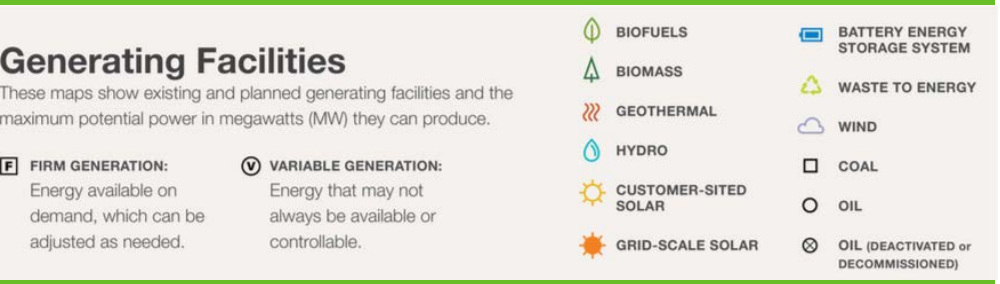
- The IGP includes a proposed renewable energy portfolio for each island through 2045.

Preferred Plan generation mix for Maui

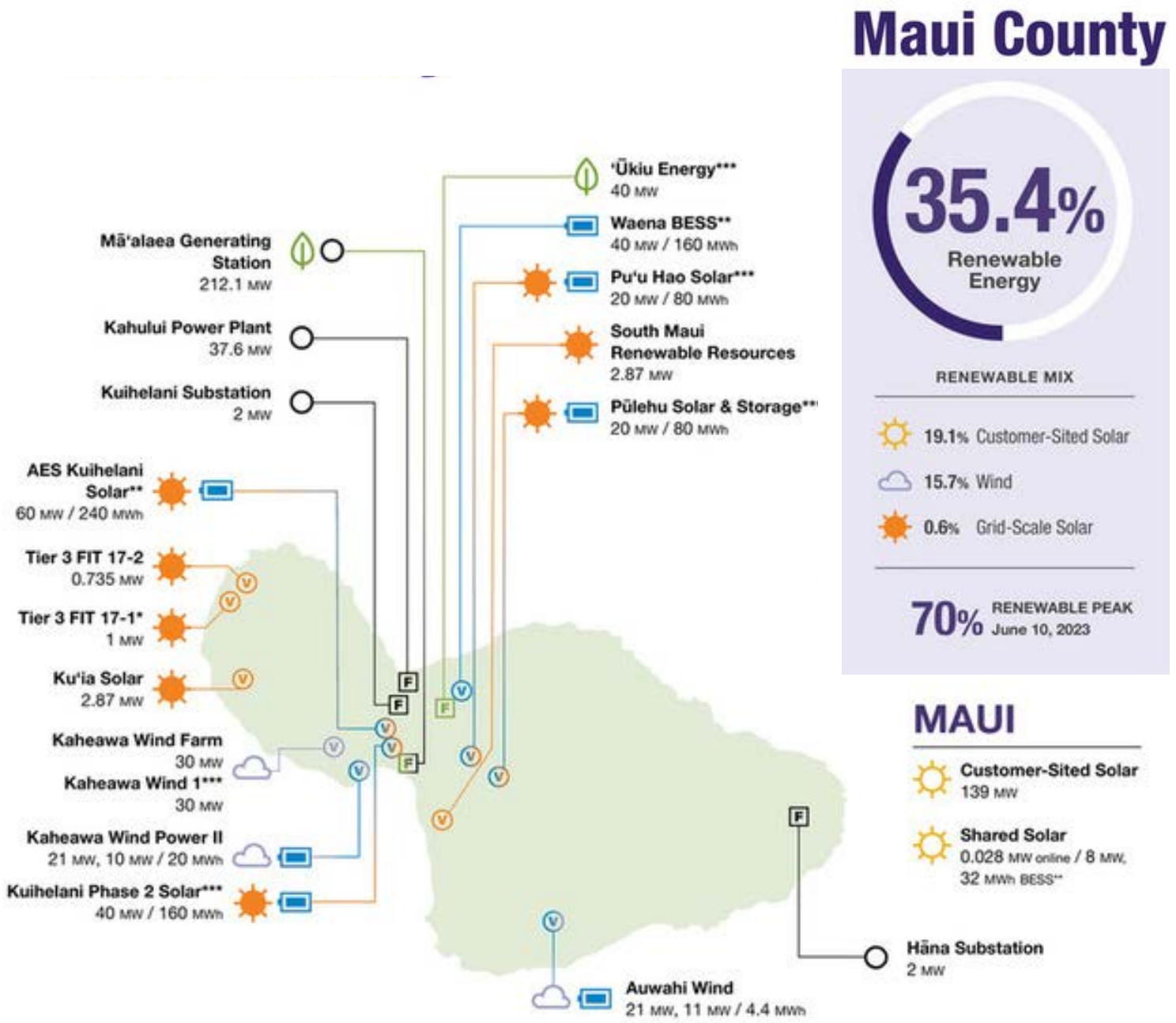


Source: Integrated Grid Plan Preferred Plans and Next Steps (2023), https://hawaiipowered.com/igpreport/IGP_SupplementalResponse_Nov-14-2023.pdf

Maui County Energy Mix



* Awaiting approval
** In progress
*** In negotiation



Source: 2023 Sustainability Maps, Hawaiian Electric (2024), https://www.hawaiianelectric.com/clean-energy-hawaii/sustainability-report-and-maps

Maui County Energy Profile

Maui County's annual electricity generation is about 36% renewable as of 2024,
with renewables hitting 70% of generation during peak hours.

Maui County's renewables come almost entirely from wind and solar.
The island of Maui has the highest annual and peak levels of wind and solar generation for any interconnected power system over 100 megawatts (MW) in size.

Most of Maui County's solar generation comes from customer-owned rooftop photovoltaics (PV) (19%).
The island of Maui has one of the highest levels of customer-owned PV of any grid in the world, as a percentage of total generation.

A new 60-MW solar PV plant with 240 megawatt-hours of battery storage came online on the island of Maui this year,
and will supply 15% of Maui's energy needs (AES Kuihelani Solar-Plus-Storage in central Maui).

Source: 2023 Sustainability Maps, Hawaiian Electric (2024), https://www.hawaiianelectric.com/clean-energy-hawaii/sustainability-report-and-maps

Impact of Lahaina Fire on Customer-Sited Solar Photovoltaics (PV) and Storage

Question: How many rooftop solar PV systems were impacted by the Lahaina fire, and what was the potential impact on capacity?

Analysis and Findings

- We compared addresses in the burn zone from the Maui Recovers website (areas listed “Local Access Only” or “Closed” as of July 17) with the count of solar PV and storage systems in Lahaina from before the fire from *Tracking the Sun* (2024).
- We found there were **2,022 solar PV systems installed** in Lahaina through the end of 2023.
- We estimate there were between **570 and 600 solar PV systems** installed on structures in the burn zone (~28% of affected structures).
- Assuming an average system size of 6.5 kilowatt (kW) solar PV (*Tracking the Sun*, 2024), we estimate that **3,705–3,900 kW** of customer-sited solar PV capacity may have been impacted by the fire.

Next Steps

We’re interested to hear from people whose solar PV and battery storage systems were impacted by the fire and to try to help get answers to your questions. National Renewable Energy Laboratory contact: robin.burton@nrel.gov.

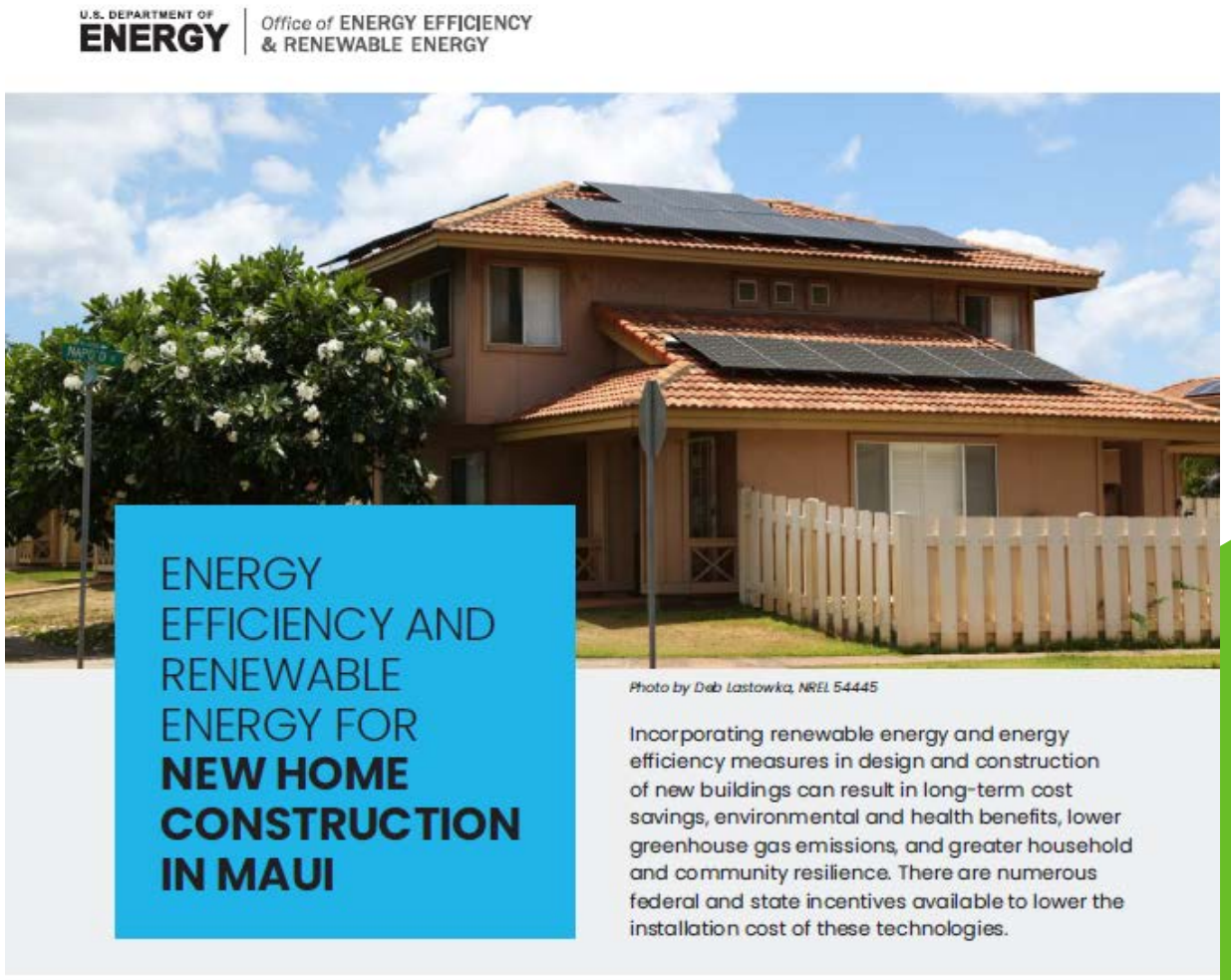
Acknowledgments

Thank you to our colleagues Eric O’Shaughnessy and Galen Barbose with Lawrence Berkeley National Laboratory for conducting this analysis.

Sources: Lawrence Berkeley National Laboratory (2024), *Tracking the Sun*, https://emp.lbl.gov/tracking-the-sun; Maui County (n.d.), Maui Recovers, ”Re-entry Zones,” https://www.mauirecovers.org/maps/reentry-zones.
Limitations: 1. There may be a few PV systems not reflected in our *Tracking the Sun* dataset, though the project has good coverage in Hawai‘i 2. Address matching is never perfect, so we probably missed a few.

NREL Fact Sheet on Rebuilding in Maui

- The National Renewable Energy Laboratory (NREL) developed a fact sheet to provide information and resources to property owners rebuilding in Lahaina.
- Available online at: https://www.nrel.gov/docs/fy24osti/89946.pdf
- Available in print at the County of Maui Recovery Permit Centers in Lahaina and Kahului and on the *Maui Recovers* website (at the bottom of the page under “Housing Handouts”) https://www.mauirecovers.org/housing



NREL Decision Support for Hawai‘i and Maui

- NREL has been working with Hawai‘i energy system stakeholders for decades as the state has led the nation in integration of renewable energy resources.
- Sample publications:
  - NREL contributed to Hawai‘i Pathways to Decarbonization, Act 238, Session Laws Of Hawai‘i 2022: Report to the 2024 Hawai‘i State Legislature (Hawaii State Energy Office, 2023)
  - NREL Methods Assist Maui in Approaching 100% Renewable Operations, NREL news story (2021)
  - Learn about NREL's partnership projects with the Hawaiian Electric Co. (HECO), NREL webpage
  - NREL and Hawaiian Electric Navigate Uncharted Waters of Energy Transformation (Part 1) and (Part 2), NREL news story (2018)

Additional Resources

- Hawai‘i Energy, https://hawaiienergy.com/
  - Rate-payer funded program to educate island families and businesses about the benefits of clean energy.
- Hawai‘i Green Infrastructure Authority (HGIA), https://gems.hawaii.gov/
  - Hawai’i’s green bank, attached administratively to the Department of Business, Economic Development and Tourism, manages the Hawaii Green Energy Market Securitization (GEMS) Program and applied to the Greenhouse Gas Reduction Fund Solar for All program to create new or expand existing low-income solar programs for Hawai‘i.
- Hawai‘i State Energy Office, https://energy.hawaii.gov/
  - 2023 Annual Report, https://energy.hawaii.gov/wp-content/uploads/2024/01/HSEO_2023_Annual_Report.pdf
  - Hawai‘i Pathways To Decarbonization Act 238, Session Laws Of Hawai‘i 2022: Report to the 2024 Hawai‘i State Legislature, https://energy.hawaii.gov/wp-content/uploads/2022/10/Act-238_HSEO_Decarbonization_FinalReport_2023.pdf
  - Hawai‘i’s Energy Facts & Figures (2020), https://energy.hawaii.gov/wp-content/uploads/2020/11/HSEO_FactsAndFigures-2020.pdf
- Hawai‘i State Profile, U.S. Energy Information Administration, https://www.eia.gov/state/?sid=HI
- Hawaiian Electric, https://www.hawaiianelectric.com/
  - Clean Energy Hawaii, https://www.hawaiianelectric.com/clean-energy-hawaii/
  - Performance Scorecards and Metrics, https://www.hawaiianelectric.com/about-us/performance-scorecards-and-metrics/ghg-reduction
  - Rebuilding West Maui, https://www.hawaiianelectric.com/rebuilding-west-maui
- Molokai Community Energy Resilience Action Plan (CERAP), https://www.sustainablemolokai.org/renewable-energy/molokai-cerap

Mahalo

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