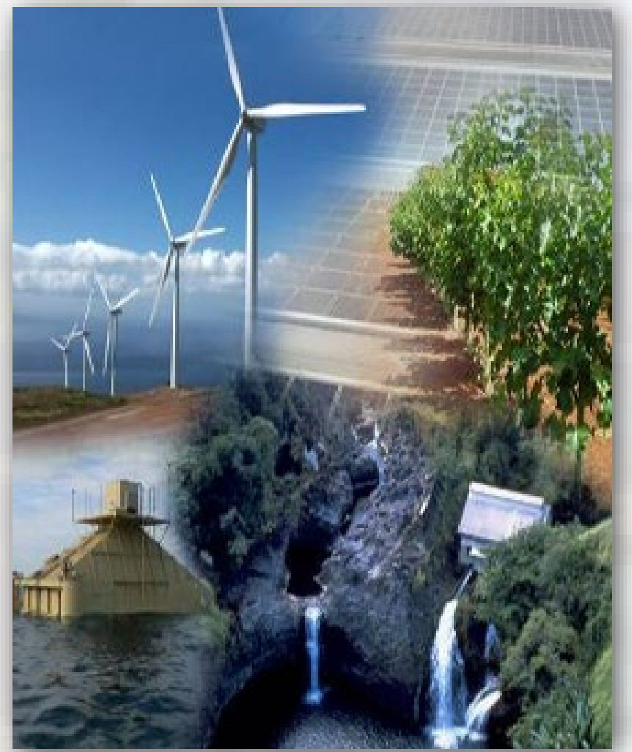
# Lessons Learned Along Hawaii's Energy Transition Journey



GridSTART
Hawai'i Natural Energy Institute | University of Hawai'i
*Grid System Technologies Advanced Research Team*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University of Hawai'i Mānoa

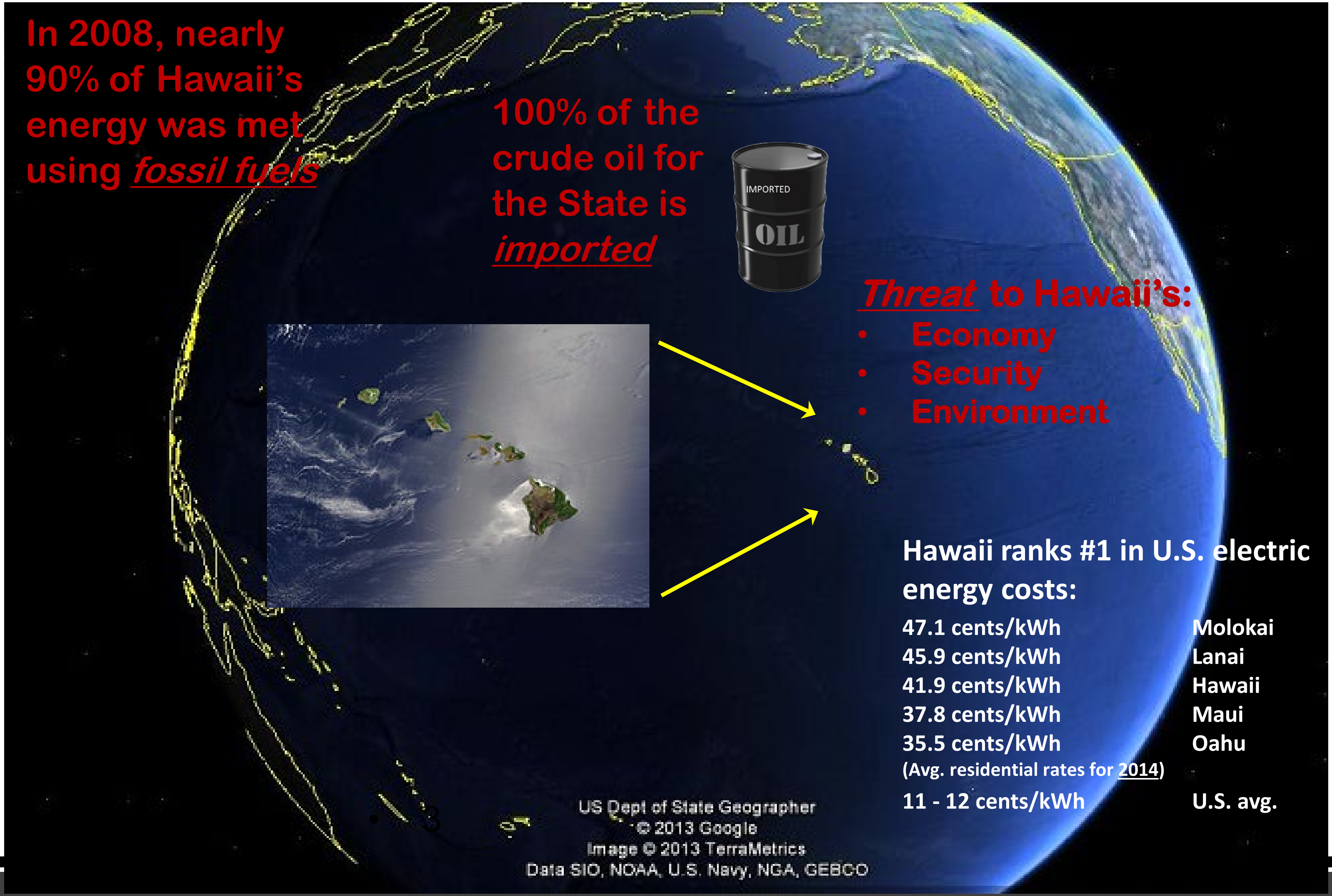
## APEC 58TH EGNRET AND 34TH EGEDA JOINT MEETING

HONOLULU, HAWAII, UNITED STATES

April 4 - 5, 2023

# Hawaii’s Energy Transition

# Hawaii's Isolation Poses a Serious ***Challenge***




In 2008, nearly 90% of Hawaii's energy was met using *fossil fuels*

100% of the crude oil for the State is *imported*

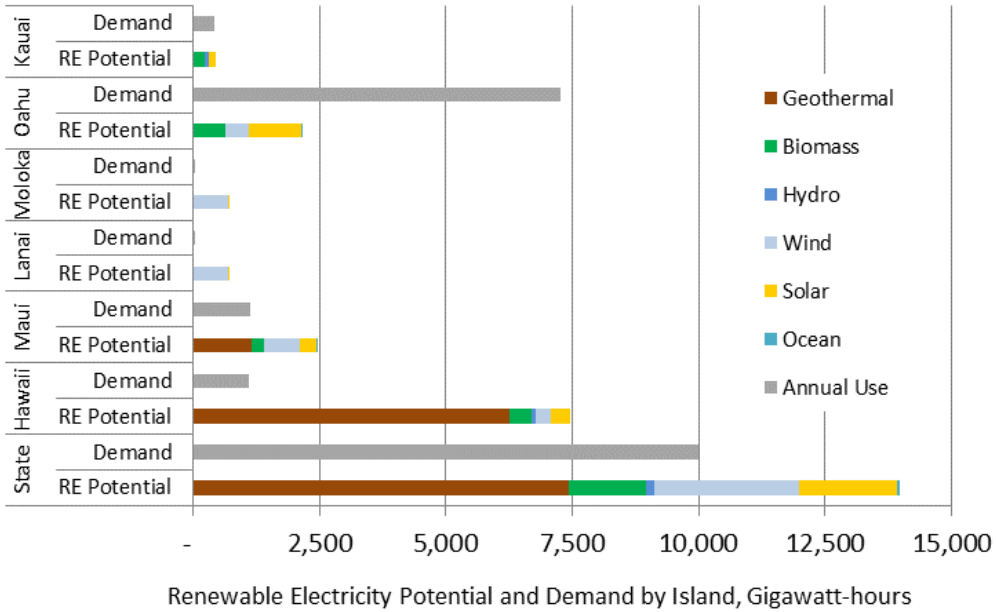
*Threat* to Hawaii's:

- Economy
- Security
- Environment

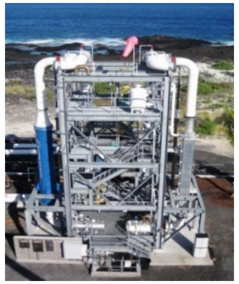
**Hawaii ranks #1 in U.S. electric energy costs:**

| | |
|---|---|
| 47.1 cents/kWh | Molokai |
| 45.9 cents/kWh | Lanai |
| 41.9 cents/kWh | Hawaii |
| 37.8 cents/kWh | Maui |
| 35.5 cents/kWh | Oahu |
| (Avg. residential rates for 2014) | |
| 11 - 12 cents/kWh | U.S. avg. |

# ***Opportunity*** for Sustainability in Hawaii is Abundant



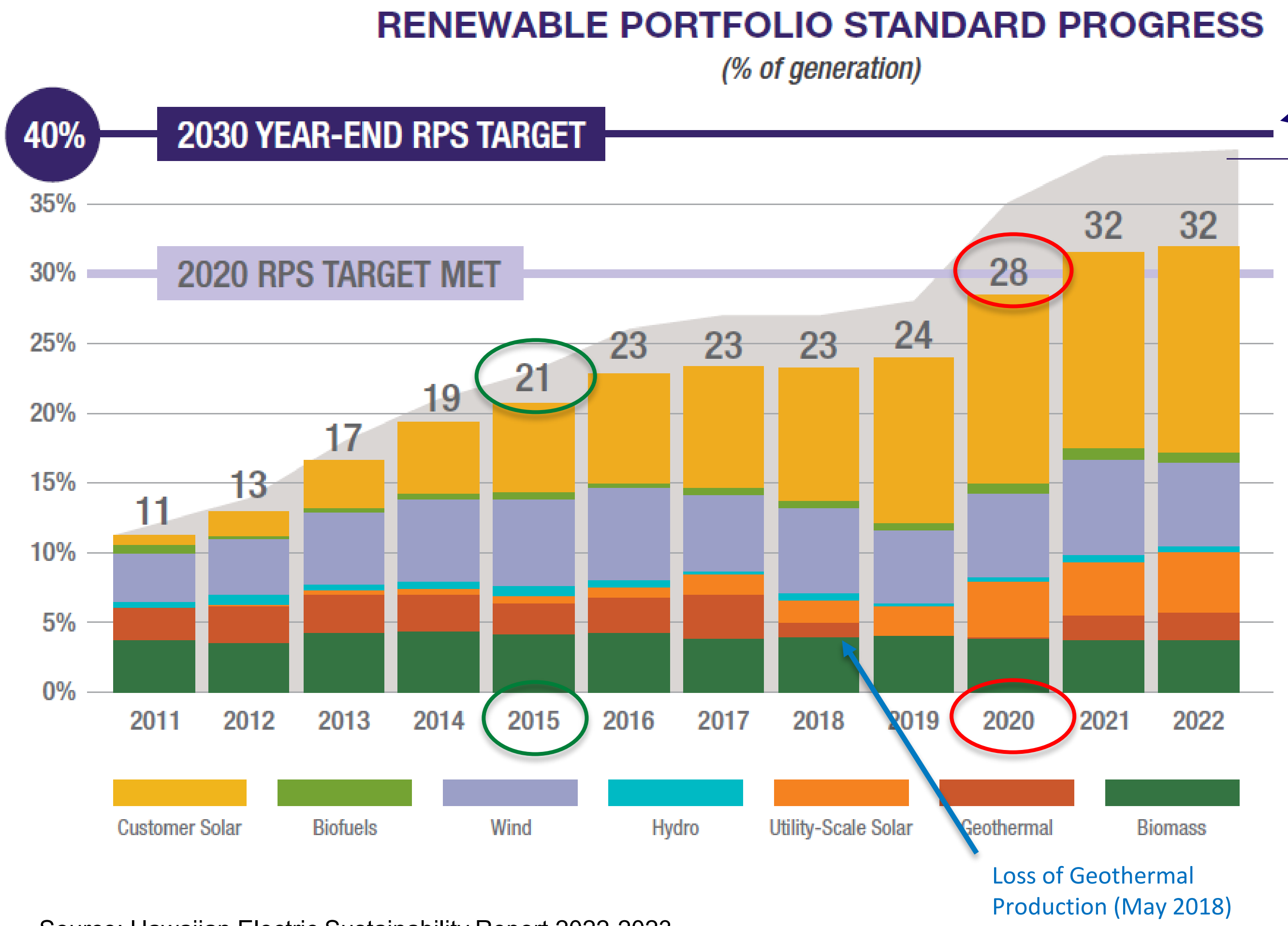

Source: National Renewable Energy Laboratory, Hawaii Clean Energy Initiative Scenario Analysis, 2012; and DBEDT



# Progress Toward A Clean Energy Future

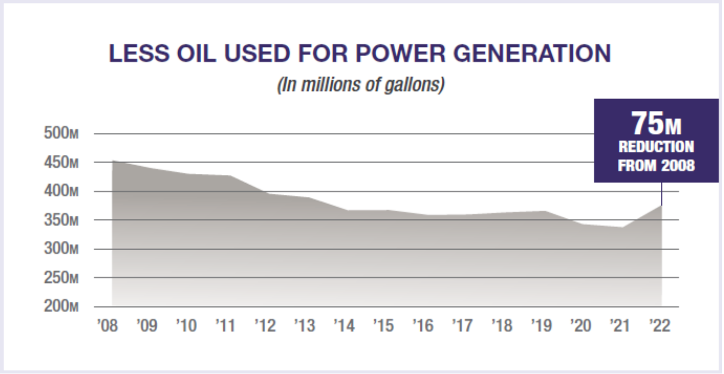
## Hawaiian Electric Companies

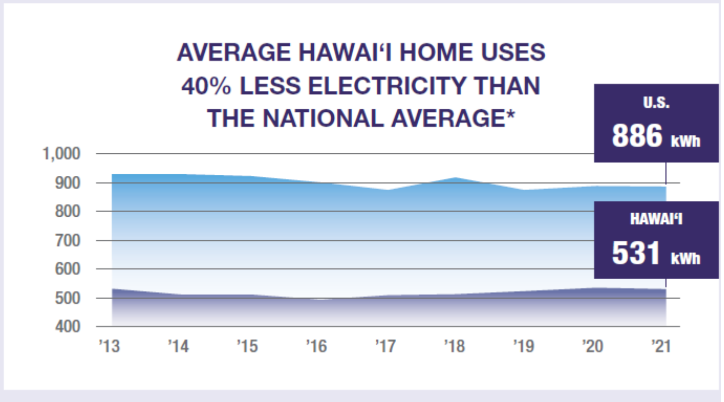
**Hawaii RPS Goals**
2015 - 15%
2020 - 30%
2030 - 40%
2040 - 70%
2045 - 100%




*Shaded area shows RPS as % of sales*

**NOTE:** The definition of Renewable Portfolio Standard (RPS) was changed by state law in 2022. It is now defined as the percentage of electricity generated by renewable resources. It was previously defined as the percentage of electricity sold that came from renewable resources. The revised definition is a more accurate way to measure progress toward the goal of achieving 100% renewable energy by 2045.




*Monthly per household in kilowatt-hours in 2021

SOURCE: U.S. Energy Information Administration

Source: Hawaiian Electric Sustainability Report 2022-2023

# Hawaii Electric Systems –

## 4 Electric Utilities; 6 Separate Grids; % Renewable Energy

**Kauaʻi Island Utility Cooperative** (2021 Yr.-end)
System Peak: 78 MW
119 MW PV* / 7 MW Biomass / 16 MW Hydro*
**Installed PV: 153% of Sys. Peak**

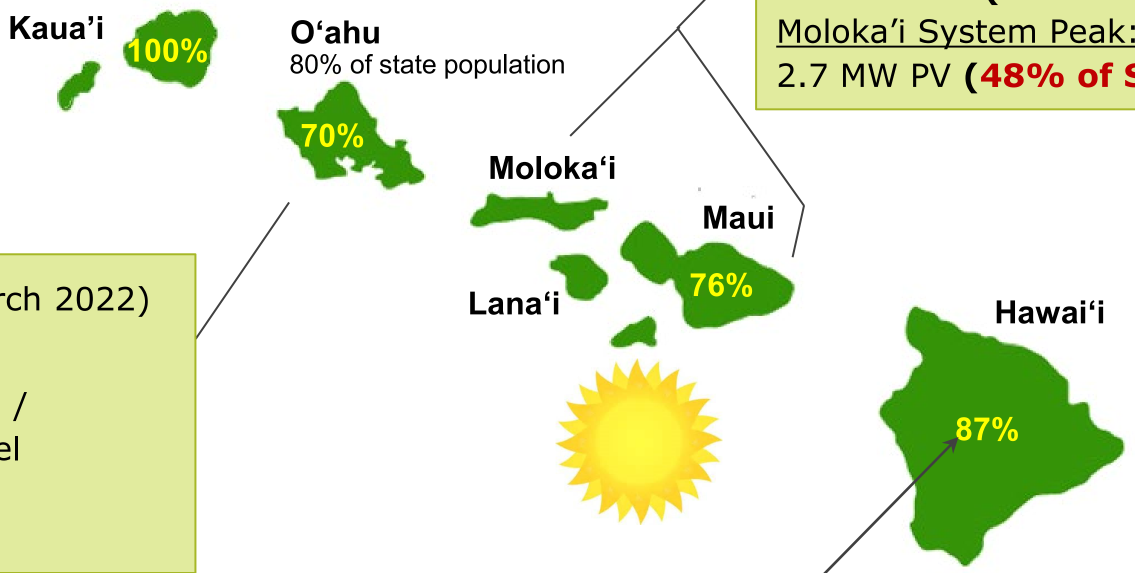
*West Kauai Energy Project (Approved)
Hydro 4 MW
PV 35 MWac/56 MWdc
+ 35 MW/70 MWh BESS
20 MW Pumped Hydro

**Maui Electric** (March 2022)
Maui System Peak: 206 MW
135 MW PV* / 72 MW Wind
**Installed PV & Wind:**
**100% of Sys. Peak**
Lana'i System Peak: 5.1 MW
2.9 MW PV* (**57% of Sys. Peak**)
Moloka'i System Peak: 5.6 MW
2.7 MW PV (**48% of Sys. Peak**)

**Maui (Approved)**
* **175 MW PV + 700 MWh BESS**

- 60 MW PV + 240 MWh BESS
- 20 MW PV + 80 MWh BESS
- 40 MW PV + 160 MWh BESS
- 15 MW PV + 60 MWh BESS
- 40 MW PV + 160 MWh BESS

Lanai (Pending Approval)
*18 MW PV + 74 MWh BESS




**Hawaiian Electric** (March 2022)
System Peak: 1,216 MW
768 MW PV* / 123 MW Wind /
69 MW WTE / 168 MW Biofuel
**Installed PV & Wind:**
**73% of Sys. Peak**

* **311.5 MW PV + 1,373 MWh BESS (Approved)**
42 MW PV + 168 MWh BESS (Pending Approval)

Renewable Energy Peak Daily Production in 2021
(e.g. occurred on 7/1/2021)

**Hawaii Electric Light** (March 2022)
System Peak: 191 MW
118 MW PV* / 34 MW Wind /
38 MW Geothermal* / 17 MW Hydro
**Installed PV & Wind:**
**80% of Sys. Peak**

* **2 x 30 MW PV + 120 MWh BESS (Approved)**
Proposing an 8 MW expansion, to 46 MW Geothermal Plant in operation at reduced capacity (25 MW) due to volcanic eruption.

# Existing and Planned Generating Facilities on Oahu

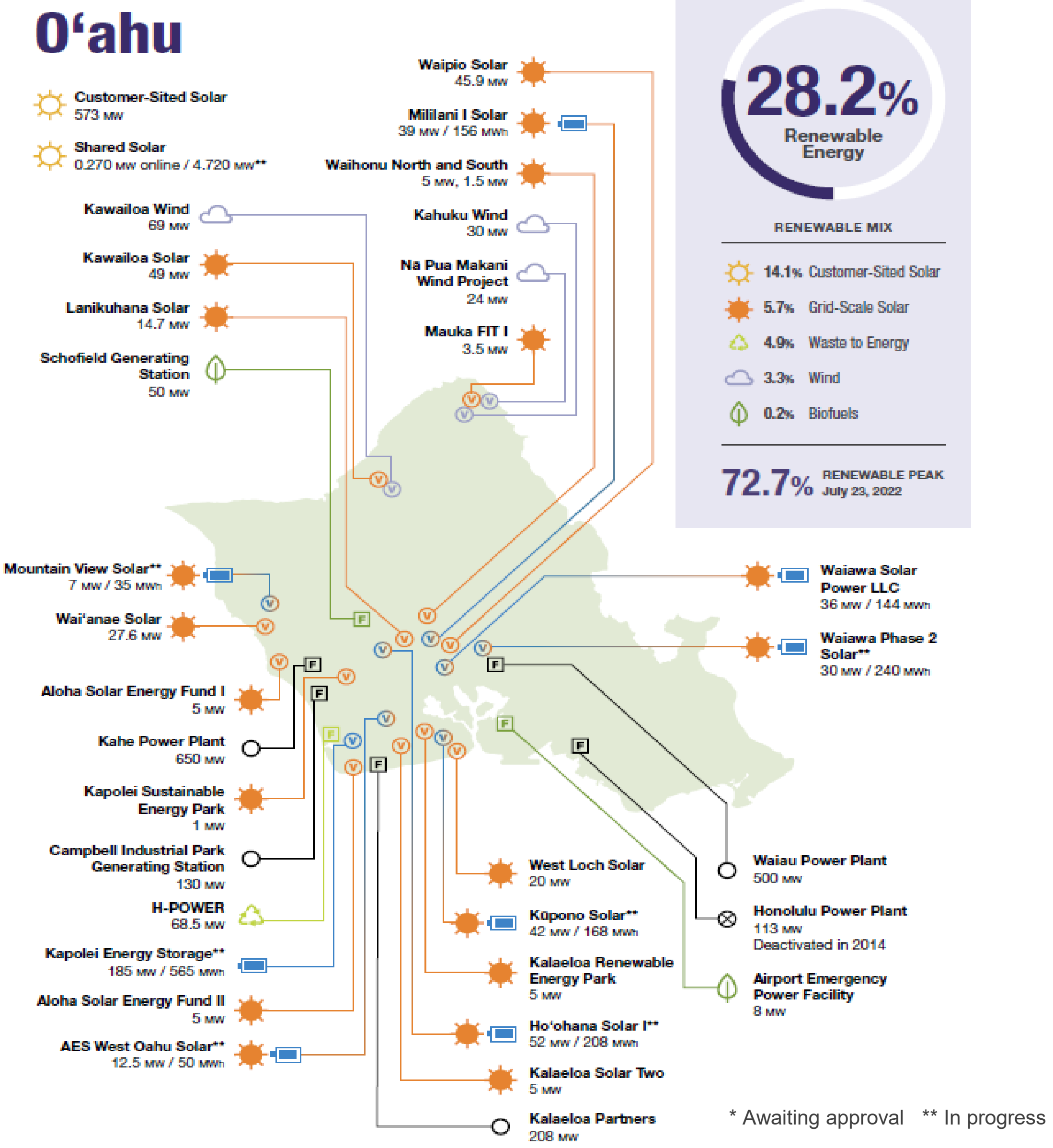
-- Hawaiian Electric Company's service territory

**Retirement of AES Coal Plant**

*Retirement of the 180-megawatt AES Hawaii coal plant on O'ahu ended the use of coal for power generation in the state. Closure of the plant — one of the largest emitters of greenhouse gases — aligns with Hawaiian Electric's overall plans to decarbonize its energy systems. Photo courtesy of AES.*

## Firm capacity coal being replaced by Solar + BESS

- At the end of July 2022, Clearway Energy's Mililani Solar I, a 39 MW PV / 156 MWh BESS project, came online.
- In January 2023, Clearway's Waiawa Solar Power, a 36 MW PV / 144 MWh BESS reached commercial operation.
- Coming online in 2023, AES West Oahu Solar, a 12.5 MW PV / 50 MWh BESS.
- Coming online in 2023, Kapolei Energy Storage, a 185 MW / 565 MWh lithium-ion BESS project by Plus Power LLC. The project will enhance grid reliability and enable more renewable energy on Oahu.




Source: Hawaiian Electric Sustainability Report 2022-2023

# "Hawaiian Electric Announces 'Mind-Blowing' Solar-Plus- Storage Contracts"

Source: Jan. 4, 2019, Greentech Media

"It's hard to overstate the scale of this announcement," said Dan Finn-Foley, a senior energy storage analyst at Wood Mackenzie Power & Renewables.

Hawaiian Electric
Maui Electric
Hawai'i Electric Light

NEWS RELEASE

FOR IMMEDIATE RELEASE

**New solar-plus-storage projects set low-price benchmark for renewable energy in Hawai'i**

*Seven contracts submitted to regulators for review*

**HONOLULU, Jan. 3, 2019** – Hawaiian Electric Companies have submitted contracts for seven grid-scale, solar-plus-storage projects on three islands to the Public Utilities Commission for review. The projects are part of the largest and lowest cost portfolio of new renewable energy resources to be assembled in Hawai'i.

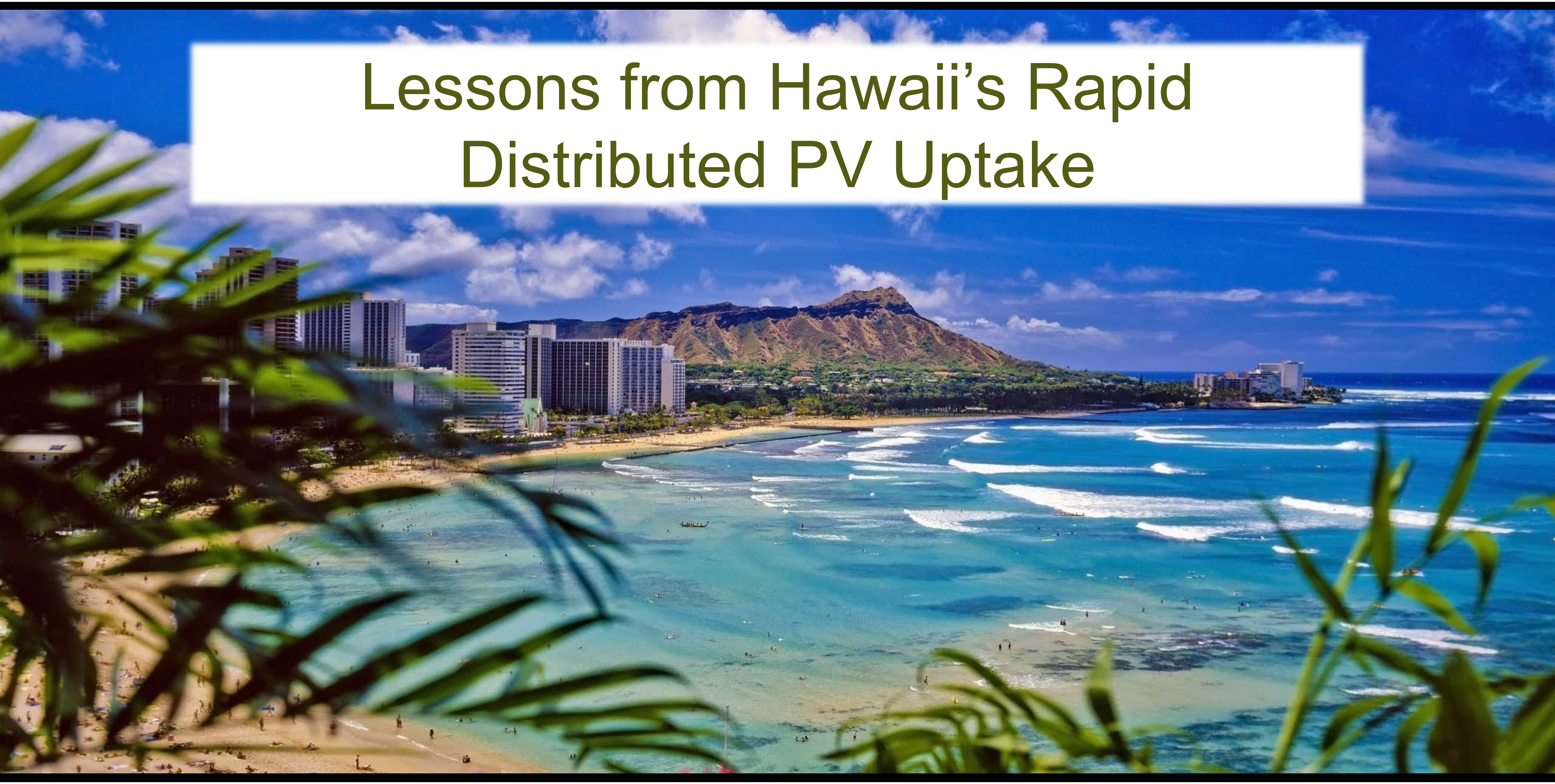
The projects – three on O'ahu, two on Maui and two on Hawai'i Island – will add approximately 262 megawatts (MW) of solar energy with 1,048 megawatt-hours (MWh) of storage. The energy storage can provide four hours of electricity that can further reduce fossil fuel use during peak demand in the evening or at other times when the sun isn't shining.

**HECO to install 1 GWh of new BESS**
**Entire BESS market in US (in 2019) was 1.4 GWh**

| Project name | Island | Developer | Size | Storage | Cost per KWh |
|---|---|---|---|---|---|
| Waikoloa Solar | Hawai'i | AES | 30 MW | 120 MWh | $0.08 |
| Hale Kuawehi | Hawai'i | Innergex | 30 MW | 120 MWh | $0.09 |
| Kuihelani Solar | Maui | AES | 60 MW | 240 MWh | $0.08 |
| Paeahu Solar | Maui | Innergex | 15 MW | 60 MWh | $0.12 |
| Hoohana | O'ahu | 174 Power Global | 52 MW | 208 MWh | $0.10 |
| Mililani I Solar | O'ahu | Clearway | 39 MW | 156 MWh | $0.09 |
| Waiawa Solar | O'ahu | Clearway | 36 MW | 144 MWh | $0.10 |

Source: Jan. 4, 2019, Greentech Media

# Lessons from Hawaii's Rapid Distributed PV Uptake



# How Much DG PV can we Connect on a Feeder?

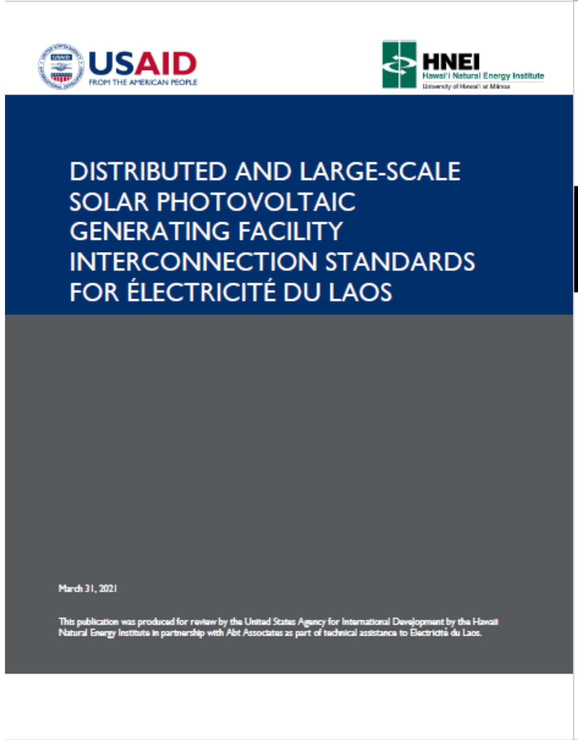
**A Lot!**

- Many lessons already learned – leverage it
- Grid Codes are **key**
- PV inverters have matured
- Reverse Power Flow is the new normal

# IEEE Interconnection Standards

- Technology of rotating generation (fossil fuel, hydro, biomass, geothermal) has not changed much for many years.
- However, there have been many lessons learned and technology improvements in inverter-based resources (e.g., solar PV, wind, BESS).
- Updating interconnection standards (i.e., Grid Codes) for distributed solar was a **first priority** as feeder penetration levels quickly outpaced the requirements in IEEE 1547-2003 as rooftop solar became economical.
  - The IEEE 1547-2018 update incorporated many of the lessons learned from Hawaii and California operating experience.
- Penetration levels of inverter-based resources were also growing quickly on bulk power systems. Existing performance requirements at the transmission level were proving to be inadequate as well.
  - A new standard, IEEE 2800-2022, was recently released to standardize interconnection requirements for inverter-based resources on transmission systems.

# Update of Proposed Interconnection Requirements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FROM THE AMERICAN PEOPLE

HNEI
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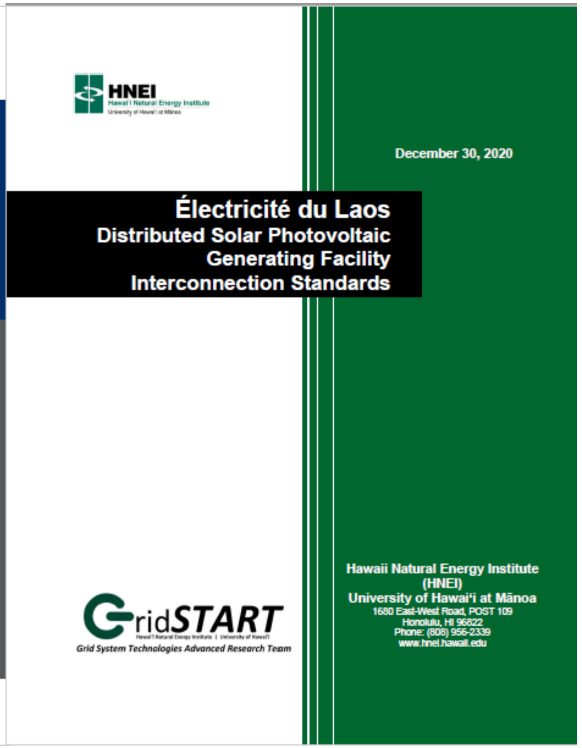
DISTRIBUTED AND LARGE-SCALE SOLAR PHOTOVOLTAIC GENERATING FACILITY INTERCONNECTION STANDARDS FOR ÉLECTRICITÉ DU LAOS

March 31, 2021

This publication was produced for review by the United States Agency for International Development by the Hawaii Natural Energy Institute in partnership with Abt Associates as part of technical assistance to Électricité du Laos.


HNEI
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December 30, 2020

Électricité du Laos
Distributed Solar Photovoltaic Generating Facility Interconnection Standards

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The interconnection requirements delivered in 2021 will be updated to incorporate the IEEE 2800-2022 requirements for interconnections to the transmission system and to streamline the reference to the IEEE 1547-2018 requirements for interconnections to the distribution system.

# Pre-qualified Inverter List

Hawaiian Electric
Maui Electric
Hawaiʻi Electric Light

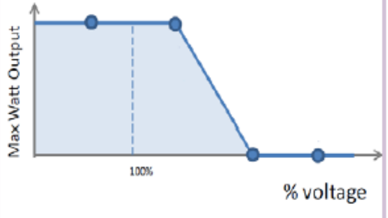
## QUALIFIED GRID SUPPORT UTILITY INTERACTIVE INVERTERS AND CONTROLLERS MEETING MANDATORY FUNCTIONS SPECIFIED IN RULE 14H

(EQUIPMENT THAT MEETS CUSTOMER GRID SUPPLY AND STANDARD INTERCONNECTION AGREEMENT (SIA))

| Technology Type: | Manufacturer: | HI SRD Certification | Model: |
|---|---|---|---|
| Inverter | Apparent Energy | No Information Submitted | SG424 (120V/208V/240V) |
| Inverter | Canadian Solar | No Information Submitted | CSI-36KTL-CT (DSP FW Ver 0.30) |
| Inverter | Chilicon Power LLC | No Information Submitted | CP-250-60/72-208/240-MC4-MTC (FW 232 or greater) |
| Inverter | Chilicon Power LLC | No Information Submitted | CP-250-60-208/240-MC4 (FW 232 or greater) |

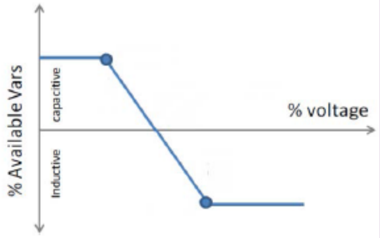
https://www.hawaiianelectric.com/Documents/clean_energy_hawaii/list_of_advanced_legacy_equipment.pdf

### Volt-Watt



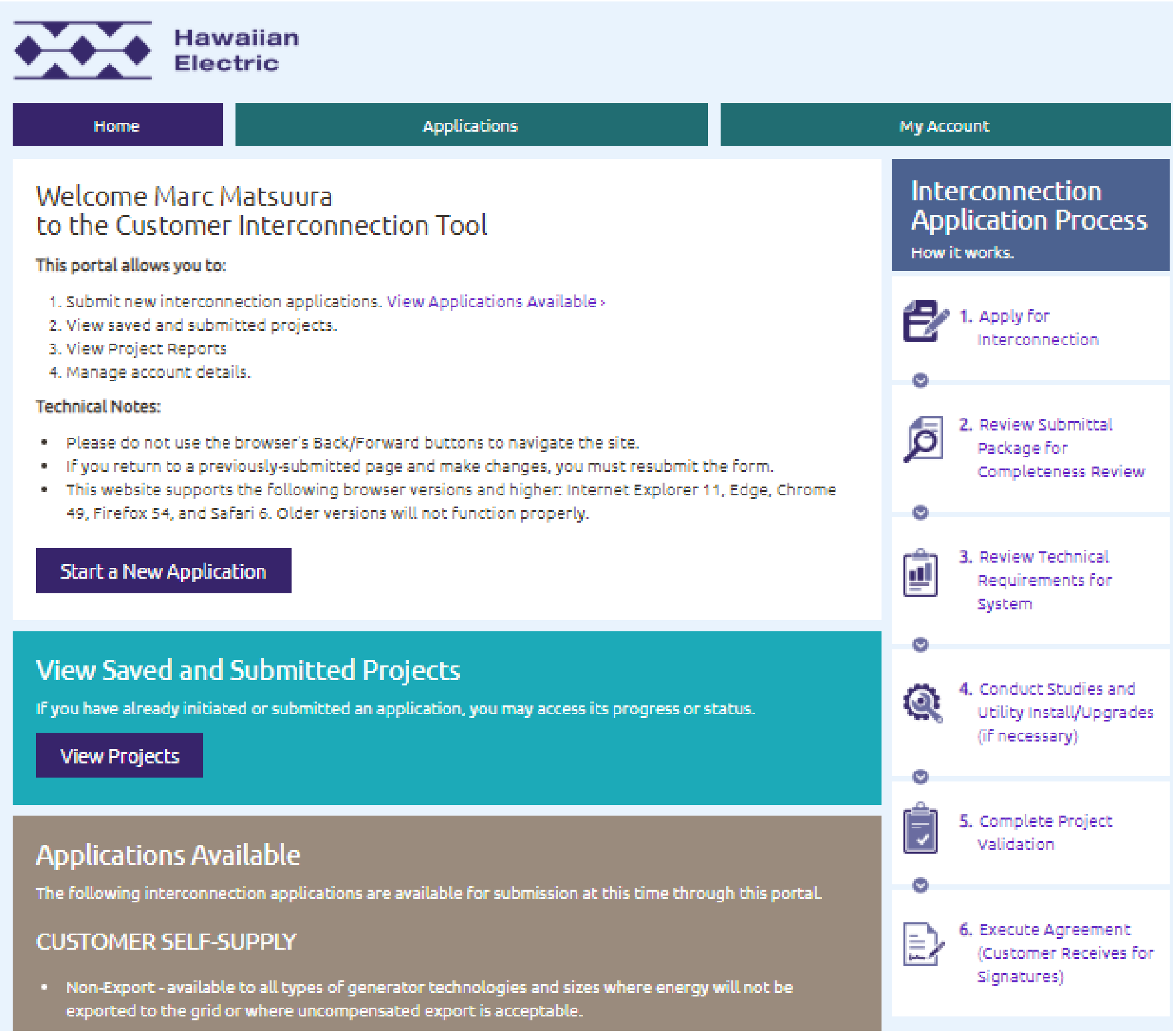

Mitigates secondary high voltage by reducing real power as a function of voltage.

### Volt-Var




Circuit voltage optimization; regulates voltage as a function of vars.

# Online Interconnection Application

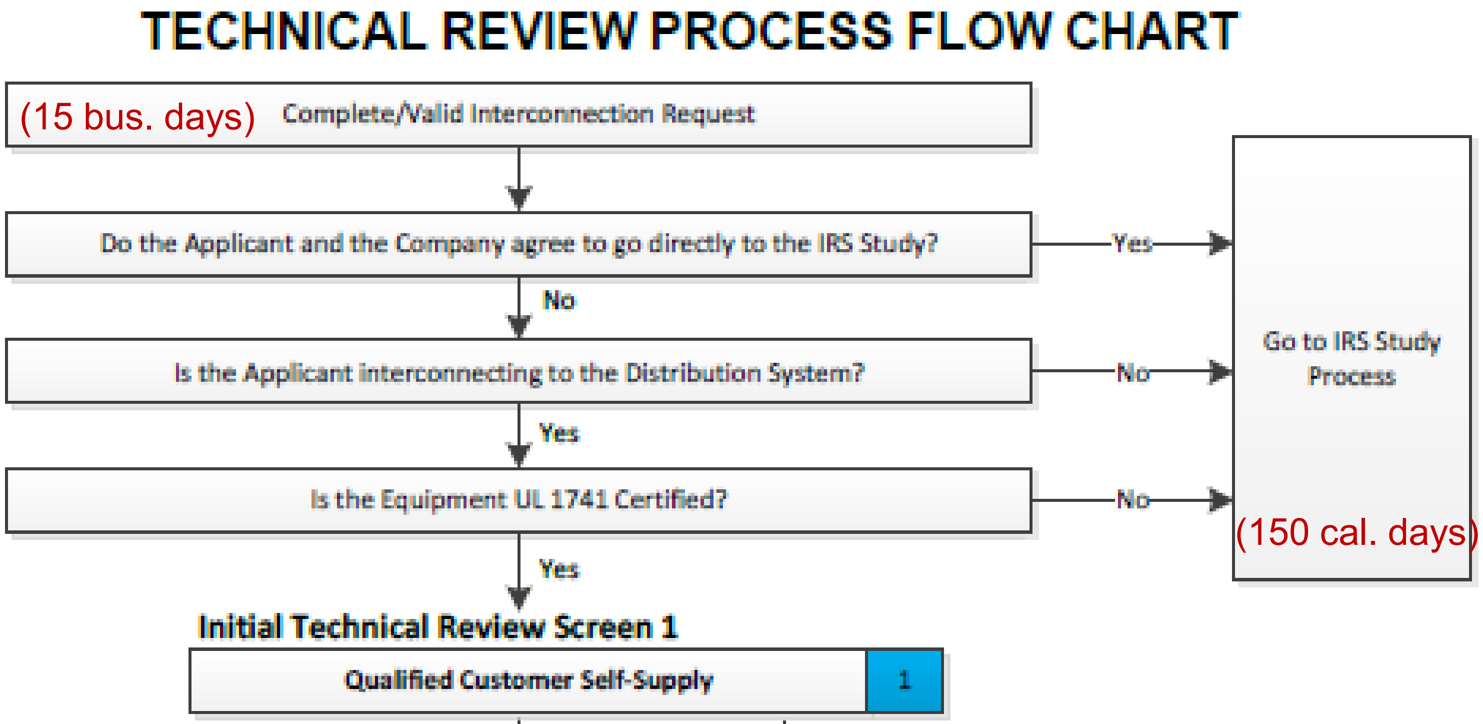



Hawaiian Electric has an online interconnection application portal to take the customer or their contractor through the application process.

The application portal gathers all the information required to complete the technical screening process.

# Application and Technical Screen Process Flow

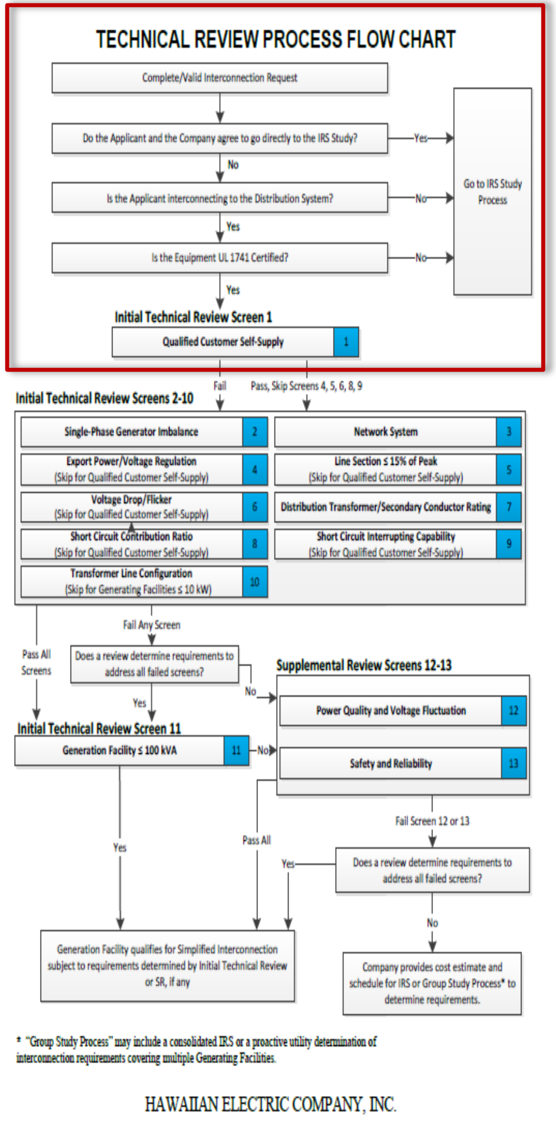
Once all the application information has been submitted, the information is used to complete the technical review process below.




(Customer Self-Supply does **not** allow export to the grid)

Fail

Pass, Skip Screens 4, 5, 6, 8, 9 on the next page

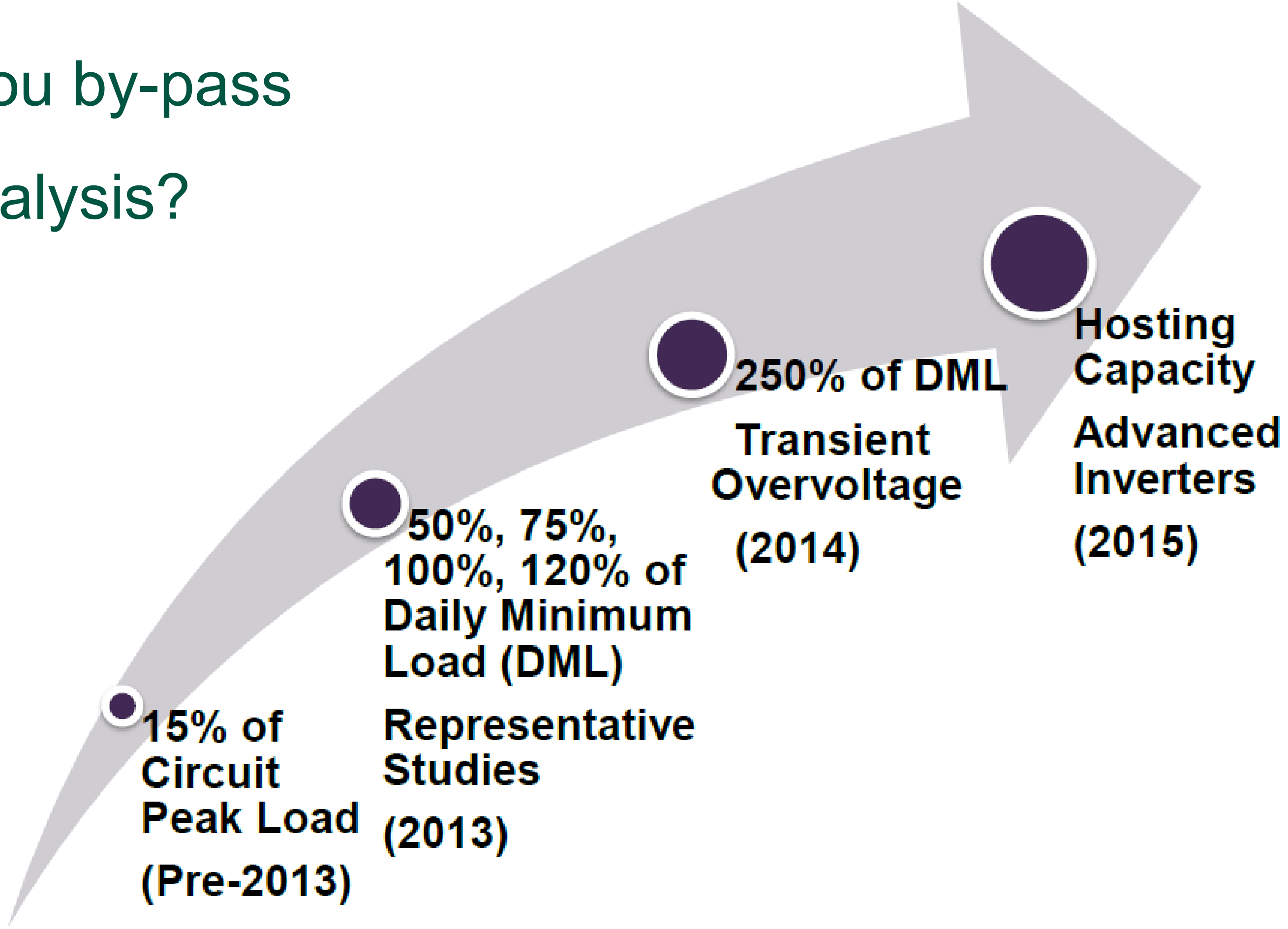


# Evolution of Hosting Capacity "Limits"

## Up to what feeder hosting limit can you by-pass most of the detailed case-by-case analysis?

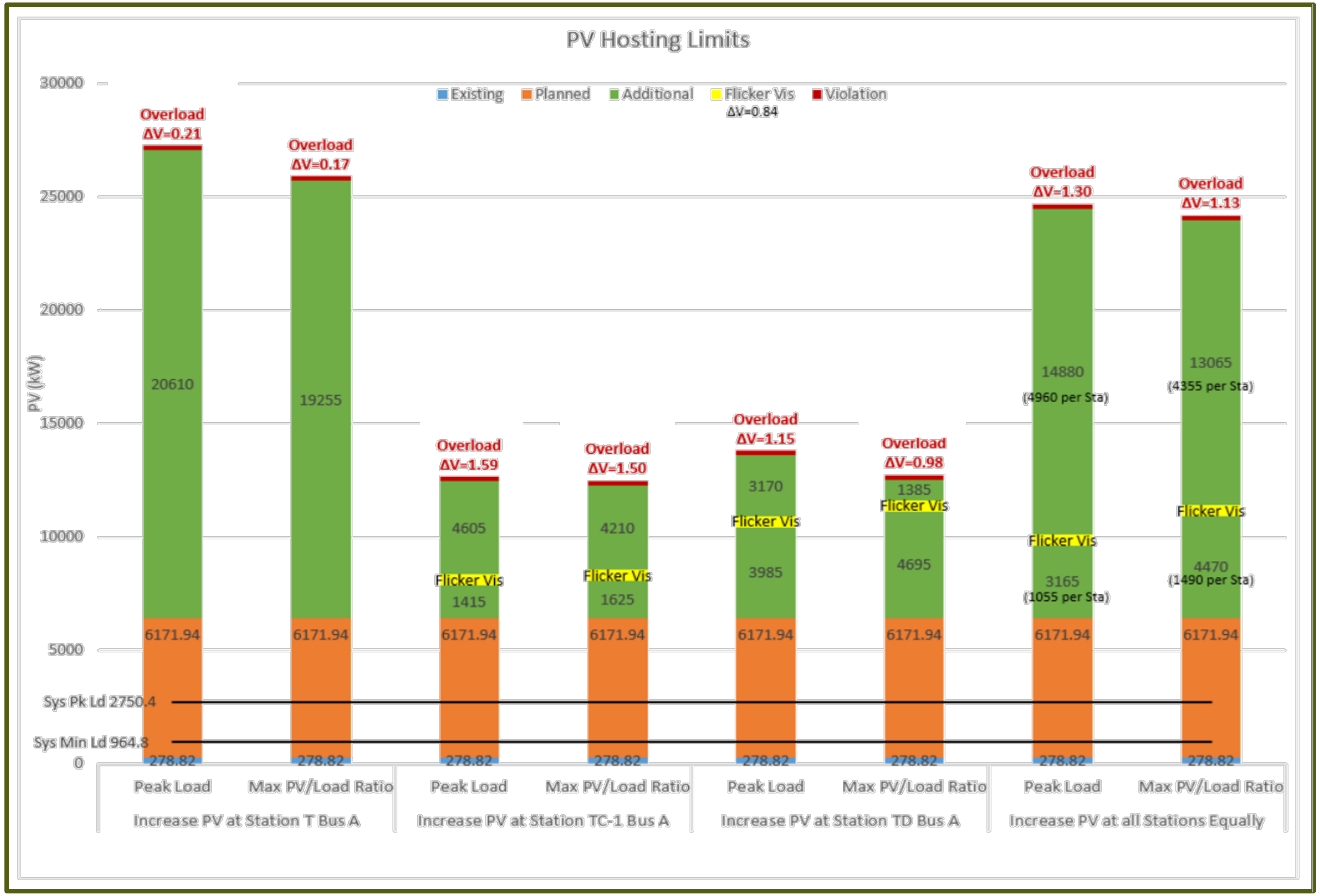
Pre-2013, in the early days of rooftop PV ….

- 15% of circuit *Peak Load*
  - Historical utility "Rule-of-Thumb" for synchronous generation


Hawaiian Electric
Maui Electric
Hawai'i Electric Light

# Circuit Level PV Hosting Capacity




- ***<u>Proper Grid Codes</u>*** are essential to reliably achieve high distributed PV penetration
- ***<u>Advanced inverter</u>*** capability use is critical
- ***<u>Circuit level analysis</u>*** is important to achieve high penetration of distributed PV
- Distributed PV circuit penetration several times served load may be achieved

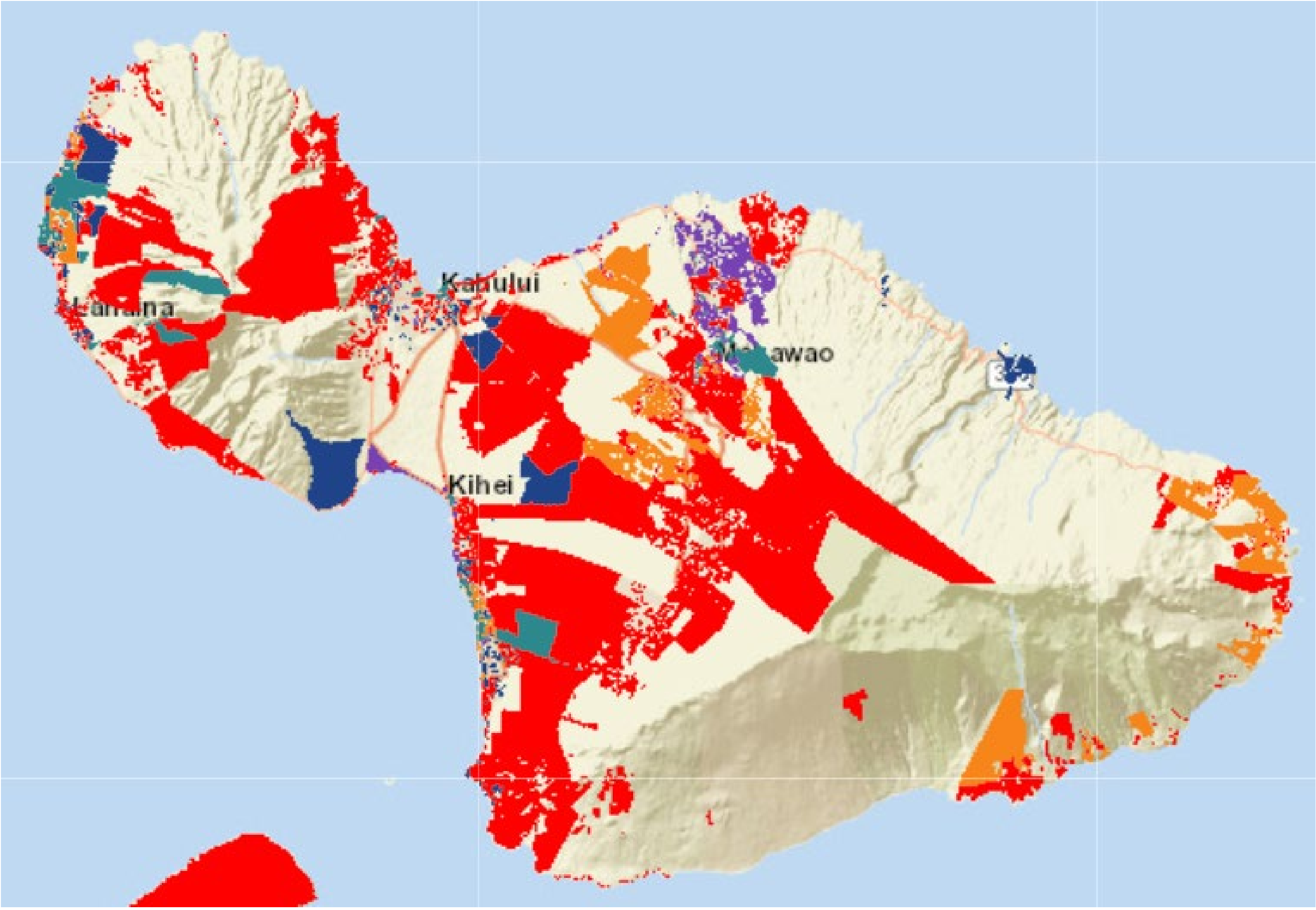
# Maui Distributed PV Circuit Penetrations

**<u>Maui Electric</u>** (March 2022)

<u>Maui System Peak: 206 MW</u>
135 MW PV / 72 MW Wind
**Installed PV & Wind:**
**100% of Sys. Peak**

DG PV capacity = 61% peak load
26% Energy
Wind capacity = 35% peak load
21% Energy

Reverse power flow exists on the *<u>majority</u>* of circuits today




**DG PV penetration on some circuits exceed 300% DML**

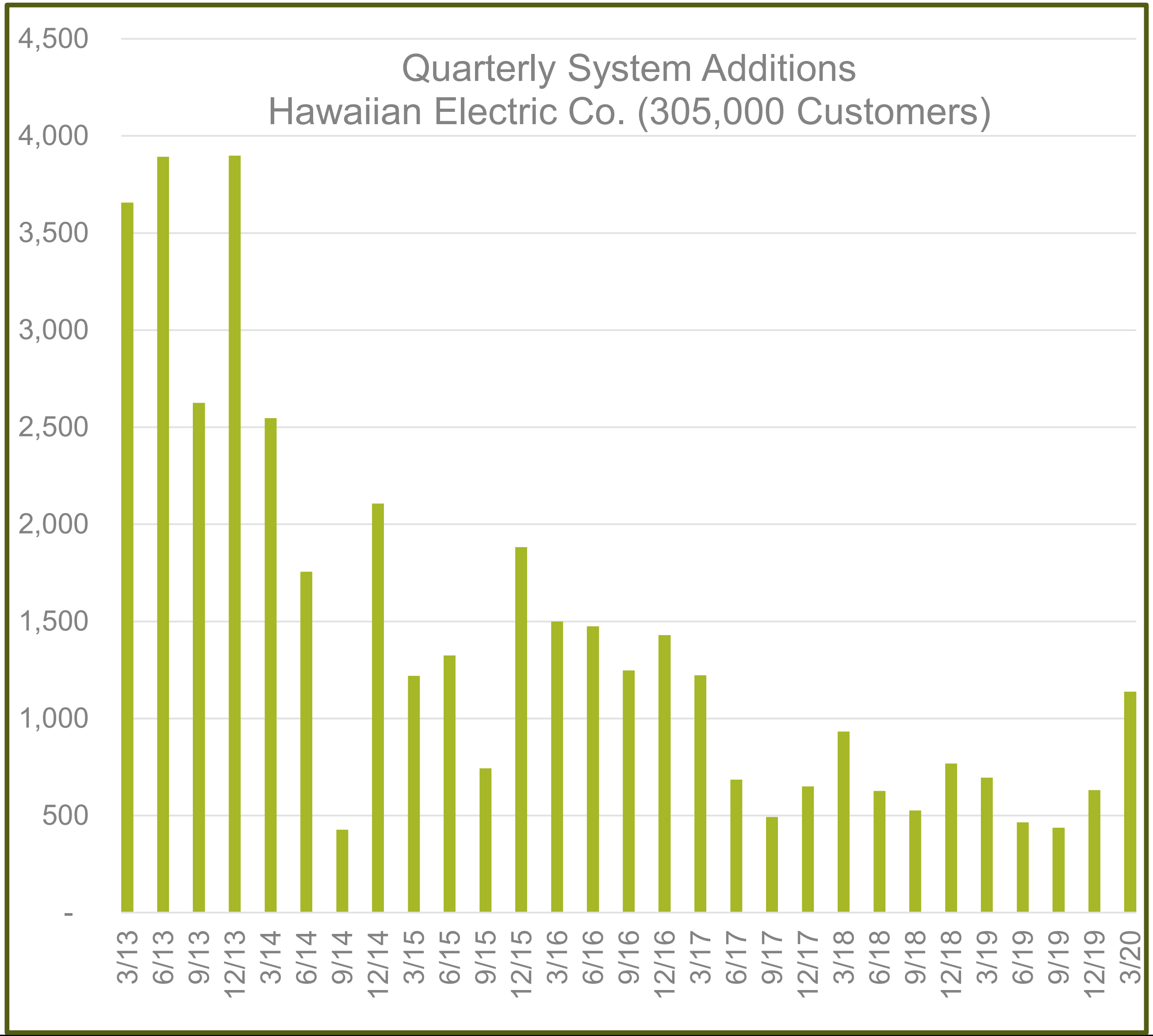
# DPV Staffing Needs

<u>Hawaiian Electric Company:</u>

Application tracking and processing: 8 Positions

Technical screening and analysis: 4 to 5 full-time equivalent (FTE)

- Distribution Planning staff today has doubled to 14 planners since 2012
- Foundational work to update models and conduct hosting capacity studies added another 2 to 3 FTE for approximately two years
- Time required for screening review and analysis was reduced once the back log was cleared, models were validated and hosting capacity analysis was completed.

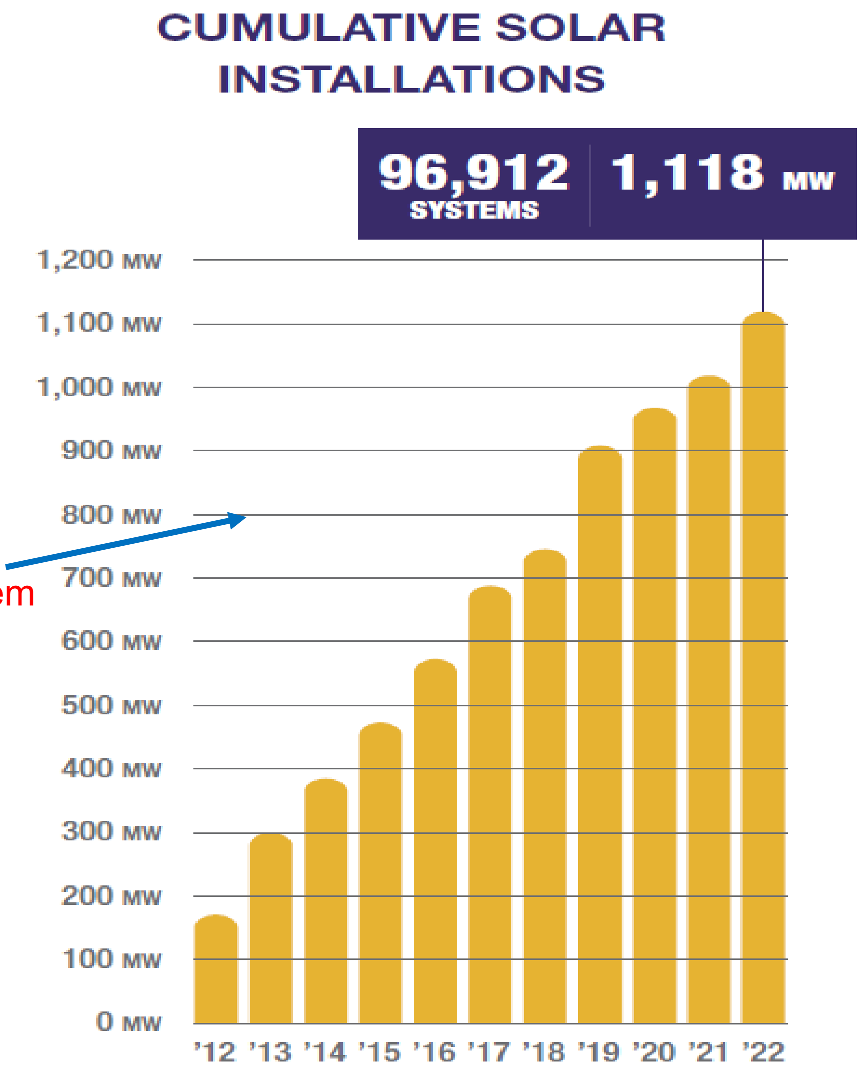


# Get ahead of the curve!

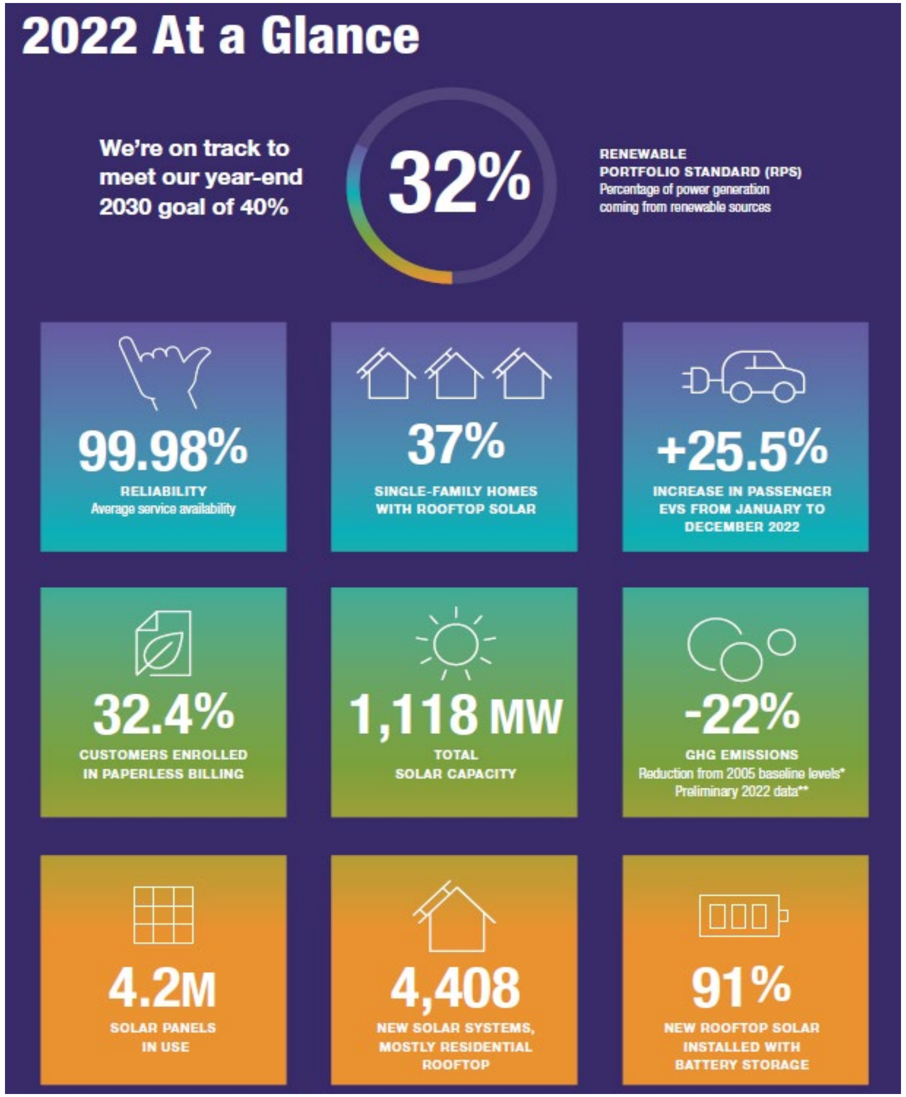
- Rooftop solar is a customer choice; customers want options
- Grid Codes are key - *adopt the latest version of IEEE-1547*; build in inverter performance requirements today to enable high PV penetration tomorrow
- Adopt a *pre-approved* compliant inverter list
- Defining circuit penetration limits below which DPV can be added without much detailed analysis helps to *streamline* the interconnection process
- These limits can then *evolve (increase)* as penetration limits are approached and modeling and data resources are developed
- Move toward *proactive* methods such as circuit Hosting Capacity analysis rather than rule-of-thumb screens
- Implement post-installation *field inspection* to ensure proper inverter settings
- DPV program implementation requires *additional* administrative and technical staff/budget/capacity building to implement

# Installed PV Capacity - HECO Companies

(2005 to 2022)




½ Cumulative System Peak Demand




Source: Hawaiian Electric Sustainability Report 2022-2023

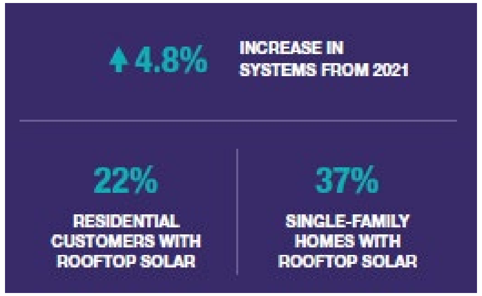
# Distributed PV Programs in Hawaii Today

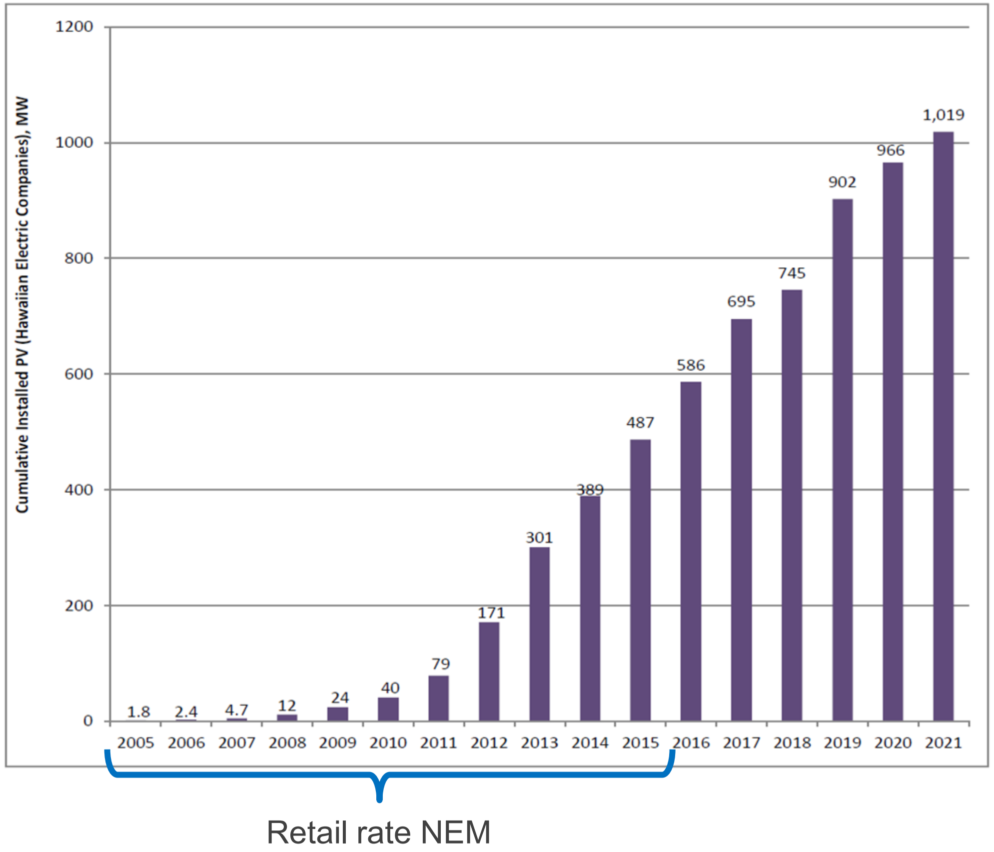
- **Retail Rate Net Energy Metering (NEM)** was closed to new applicants in 2015.
- **Customer Grid-Supply (CGS)** participants receive a PUC-approved credit (less than full retail rate) for electricity sent to the grid and are billed at the retail rate for electricity they use from the grid. Program is fully subscribed today; the program only remained open until the installed capacity was reached.
- **Customer Grid-Supply Plus (CGS Plus)** systems must include grid support technology to manage grid reliability and allow the utility to remotely monitor system performance, technical compliance and, if necessary, control the system for grid stability.
- **Customer Self-Supply (CSS)** is intended only for private rooftop solar installations that are designed to not export any electricity to the grid. Utility verifies non-export controls enabled for the system.
- **Smart Export (SE)** customers with a renewable system and battery energy storage system have the option to export energy to the grid from 4 p.m. – 9 a.m. Systems must include grid support technology to manage grid reliability and system performance.
- **Standard Interconnection Agreement (SIA)** is designed for larger customers who wish to offset their electricity bill with on-site generation. Customers are not compensated for any export of energy.

# Rooftop Solar Integration

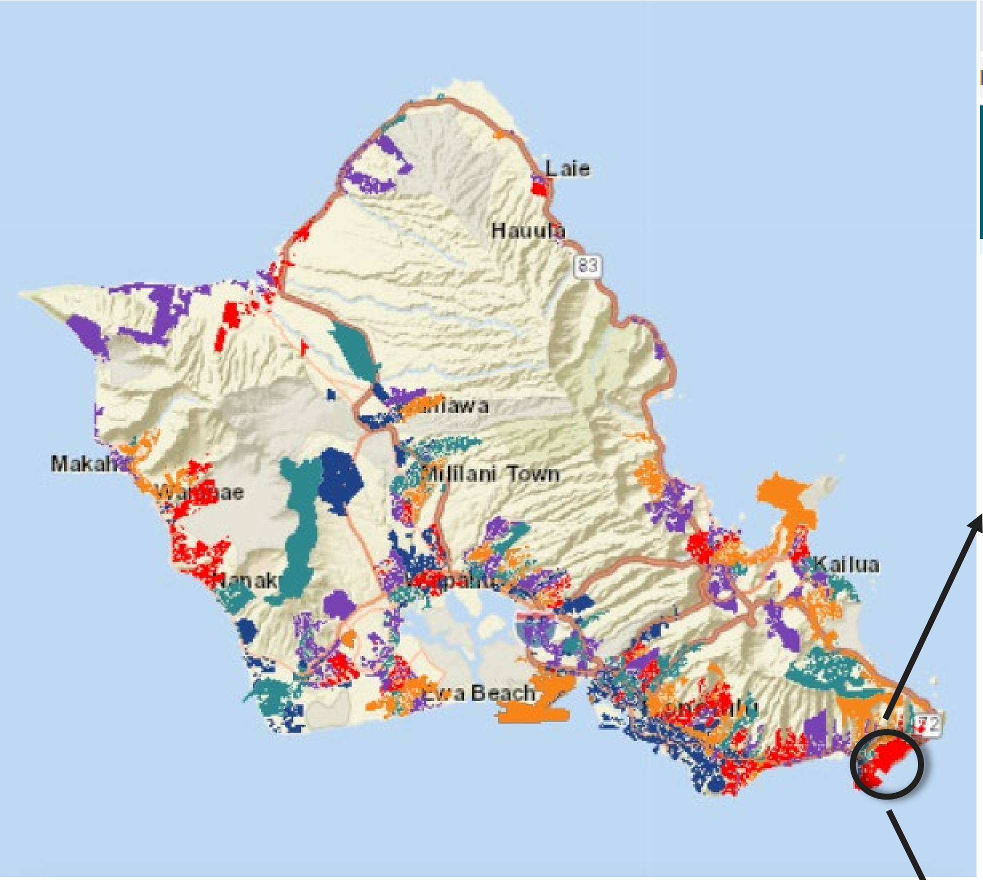
| OAHU | CGS | CGS Plus | CSS | Smart Export |
|---|---|---|---|---|
| **Export Allowed** | Yes | Yes | No | Yes |
| **Export Restrictions** | No | No | N/A | Solar Day |
| **Reconciliation** | Monthly | Annual | N/A | Annual |
| **Minimum Bill** | $25 | $25 | $25 | $25 |
| **Credit rate (c/kWh)*** ** | $0.15 | $0.10 | N/A | $0.15 |
| **Program Cap** | 51.3 MW | 50 MW | N/A | 25 MW |
| **Inverter Requirements** | Advanced with Volt Var and Frequency Watt activated; Fixed Power Factor deactivated.* | Advanced with Volt Var and Frequency Watt activated; Fixed Power Factor deactivated. | Advanced with Volt Var and Frequency Watt activated; Fixed Power Factor deactivated. | Advanced with Volt Var and Frequency Watt activated; Fixed Power Factor deactivated. |
| **Controls** | N/A | Yes: Utility or Aggregator | Customer | Yes: Economic |
| **Communications** | N/A | N/A | Yes | N/A |
| **Hypothetical Bill Comparison:**** | $93.28 | $118.38 | $169.09 | $93.79 |

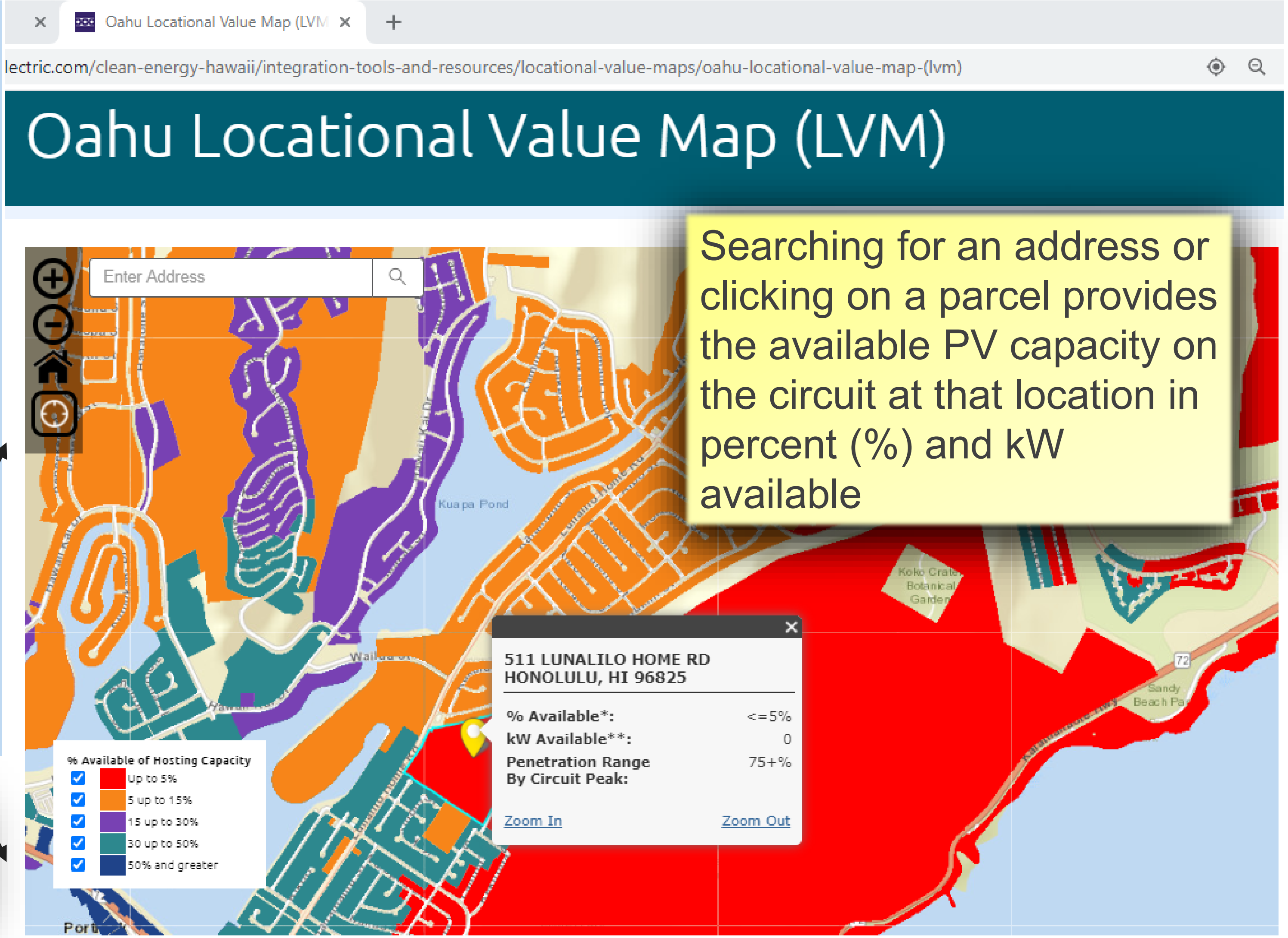
**2022 Customer Energy Resources**



# Managing Customer Expectations




Searching for an address or clicking on a parcel provides the available PV capacity on the circuit at that location in percent (%) and kW available

Provides on-line circuit hosting capacity limits by address on a searchable map.

# Community Based Renewable Energy (CBRE)

The CBRE program is designed to promote broader participation in renewable energy projects by allowing electric utility customers unable to install private rooftop solar to purchase shares in a renewable energy facility to offset their monthly energy consumption via a credit for that renewable energy on their utility bills.

$$\text{Bill credit} = \frac{\text{Credit Rate x Energy Generated}}{\text{Size of Subscription}}$$

*The 28 kW ROIZ CBRE Maui project is online.*

**Procedural History Of CBRE In Hawaii**

- On June 8, 2015, Act 100 requires Hawaii's electric utilities to create a tariff by October 1, 2015 to enable customers to join community renewable programs.
- On April 5, 2018, the PUC, in Order No. 35395, approved and directed KIUC to implement its CBRE tariff.
- On June 29, 2018, the PUC, in Order No. 35560, approved HECO to implement their CBRE program (Phase 1).

https://www.hawaiianelectric.com/products-and-services/customer-renewable-programs/shared-solar

**CBRE Phase 1 Projects**

| Name | Island | Size (kW) | Credit Rate ($/kwh) |
|---|---|---|---|
| ROIZ CBRE | Maui | 28.32 | 0.165 |
| Mililani Tech Solar 1 | Oahu | 270 | 0.15 |
| Palailai Solar 1 | Oahu | 3,000 | 0.15 |
| KHLS | Oahu | 1,720 | 0.15 |
| South Point | Hawaii Island | 750 | 0.15 |
| Kawela Plantation | Molokai | 250 | 0.225 |

**CBRE Phase 2 Projects**

- Unlike Phase 1, which was limited to 8 megawatts, Phase 2 is open to 250 MW of renewable generation across the five islands Hawaiian Electric serves. Phase 2 places special emphasis on *low-to-moderate-income residential customers to participate*.

# Mahalo!

## (Thank you)

For more information, contact:

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# Hawaii Natural Energy Institute (HNEI)

## University of Hawaiʻi at Mānoa

Organized Research Unit in School of Ocean and Earth Science and Technology
Founded in 1974, established in Hawaiʻi statute in 2007 (HRS 304A-1891)

- Conduct RDT&E to accelerate and facilitate the use of resilient alternative energy technologies and reduce Hawaii's dependence on fossil fuels.
- Diverse staff includes engineers, scientists, lawyers; students and postdoctoral fellows; visiting scholars

**Areas of Interest**

- **Grid Integration (Grid*START*)**
- **Policy and Innovation**
- **Alternative Fuels**
- **Electrochemical Power Systems**
- **Renewable Power Generation**
- **Building Efficiency**
- **Transportation**

**Core Functions**

- **State Energy Policy Support**
- **Research & Development**
- **Testing and Evaluation**
- **Analysis**
- **Workforce Development**

GridSTART
Hawaiʻi Natural Energy Institute | University of Hawaiʻi

*Grid System Technologies Advanced Research Team*

**Established to develop and test advanced grid architectures, new technologies and methods for effective integration of renewable energy resources, power system optimization and resilience, and enabling policies**

- Serves to integrate into the operating power grid other HNEI technology areas: energy efficiency, renewable power generation, biomass and biofuels, fuel cells and hydrogen
- Strong and growing partnerships with Hawaiʻi, national and international organizations including Asia-Pacific nations


**Expertise & Focus:**

- *Energy Policy and Regulation*
- *Renewable Energy Grid Integration*
- *Smart Grid Planning & Technologies*
- *Power Systems Planning*
- *RE Resource Procurement*
- *Power Systems Operation*
- *Power Systems Engineering and Standards*
- *Communications Design and Testing*
- *Project Management and Execution*

***Lead for many public-private demonstration projects***