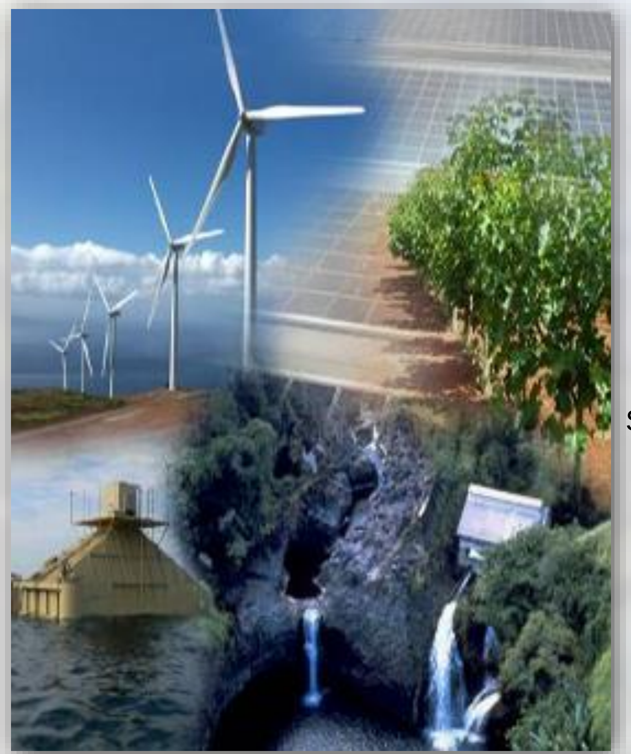
Clean Energy Transition in the Hawaiian Islands



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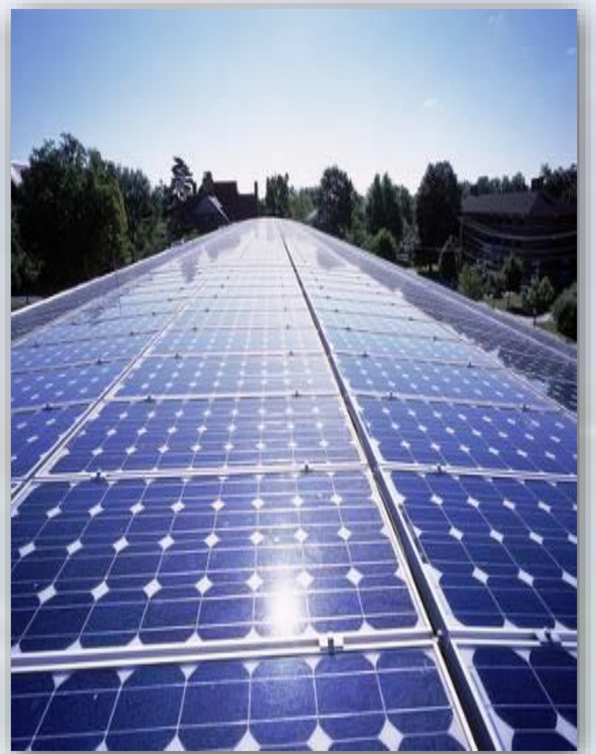


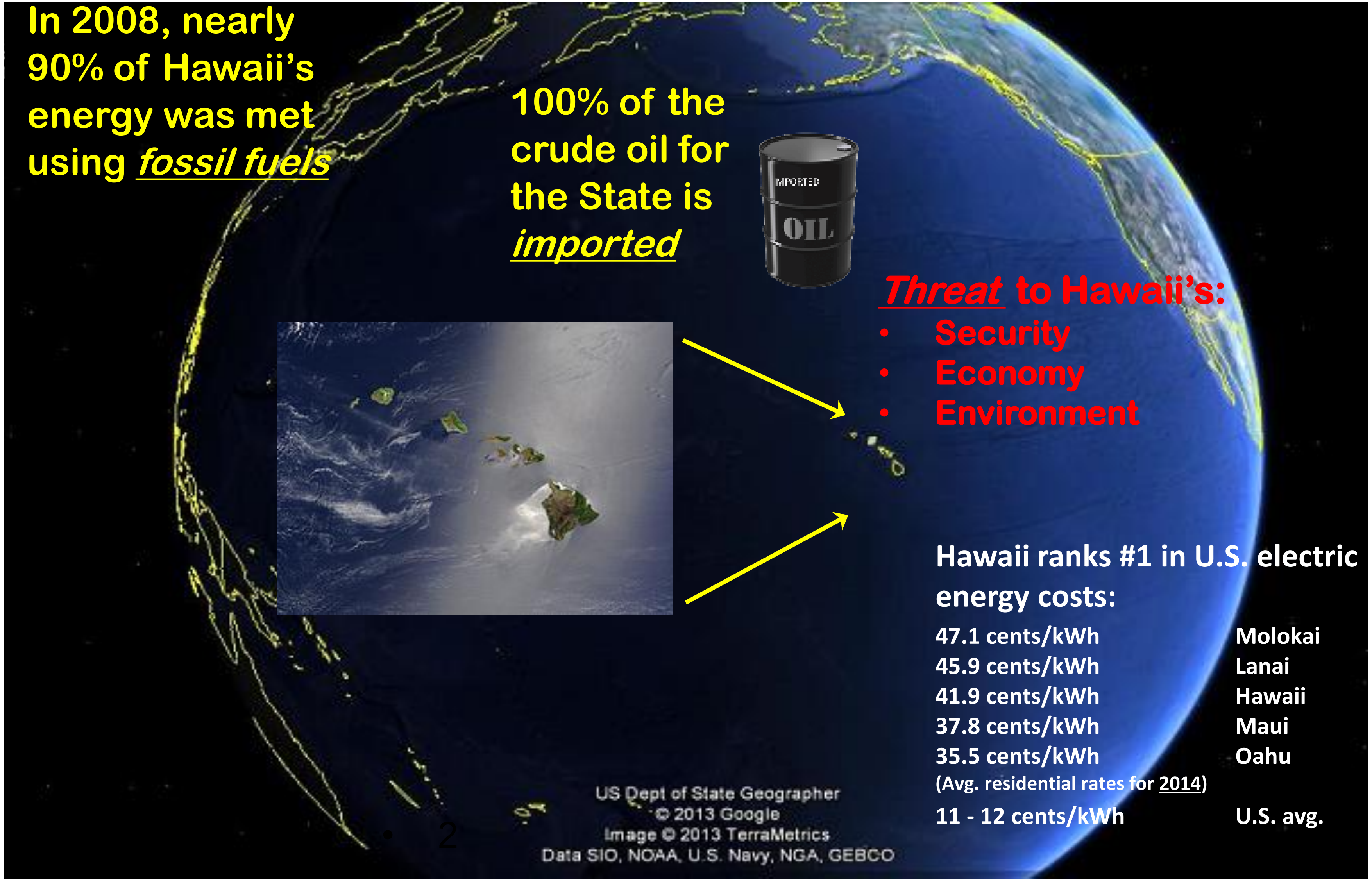
30TH ANNUAL PPA CONFERENCE

Board of Directors Workshop

September 26, 2023

Crowne Plaza Resort, Saipan

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*

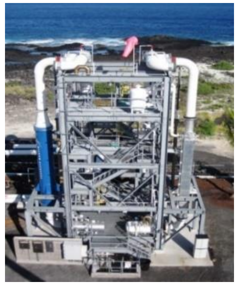
***Threat* to Hawaii's:**

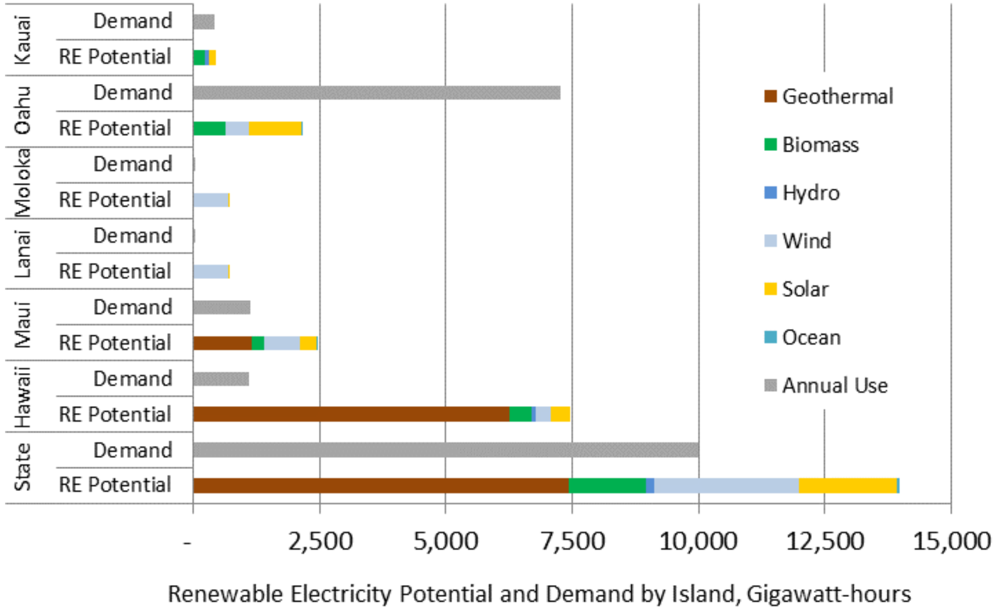
- **Security**
- **Economy**
- **Environment**

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

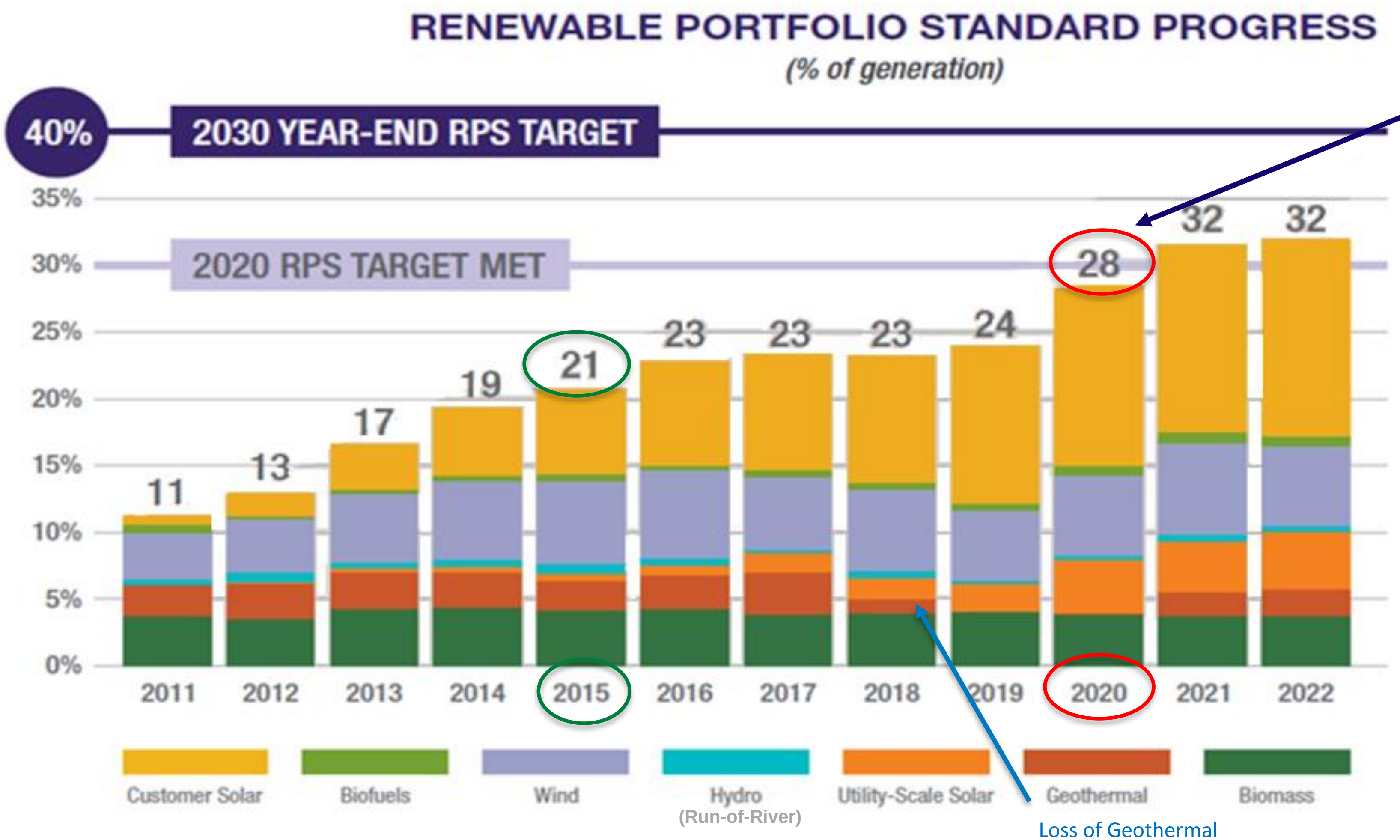




Source: National Renewable Energy Laboratory, Hawaii Clean Energy Initiative Scenario Analysis, 2012; and DBEDT

Progress Toward A Clean Energy Future

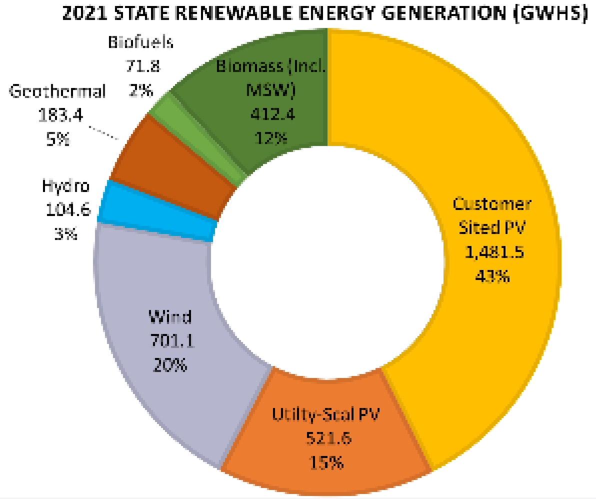
Hawaiian Electric Companies

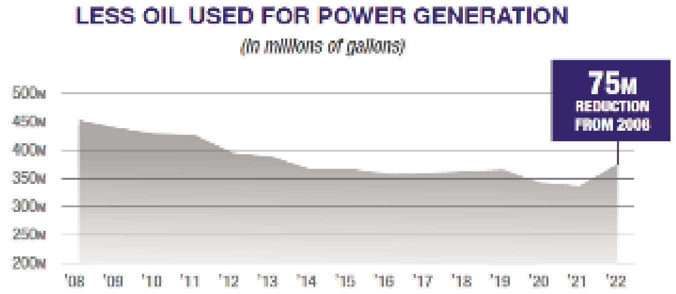


Source: Hawaiian Electric Sustainability Report 2022-2023

Hawaii RPS Goals

2015 - 15%
2020 - 30%
2030 - 40%
2040 - 70%
2045 - 100%





Hawaii Electric Systems –

4 Electric Utilities; 6 Separate Grids; % Renewable Energy

Kauaʻi Island Utility Cooperative (April 2023)
System Peak: 80 MW
125 MW PV* / 7 MW Biomass / 16 MW Hydro* / 260 MWh BESS
Installed PV: 156% of Sys. Peak

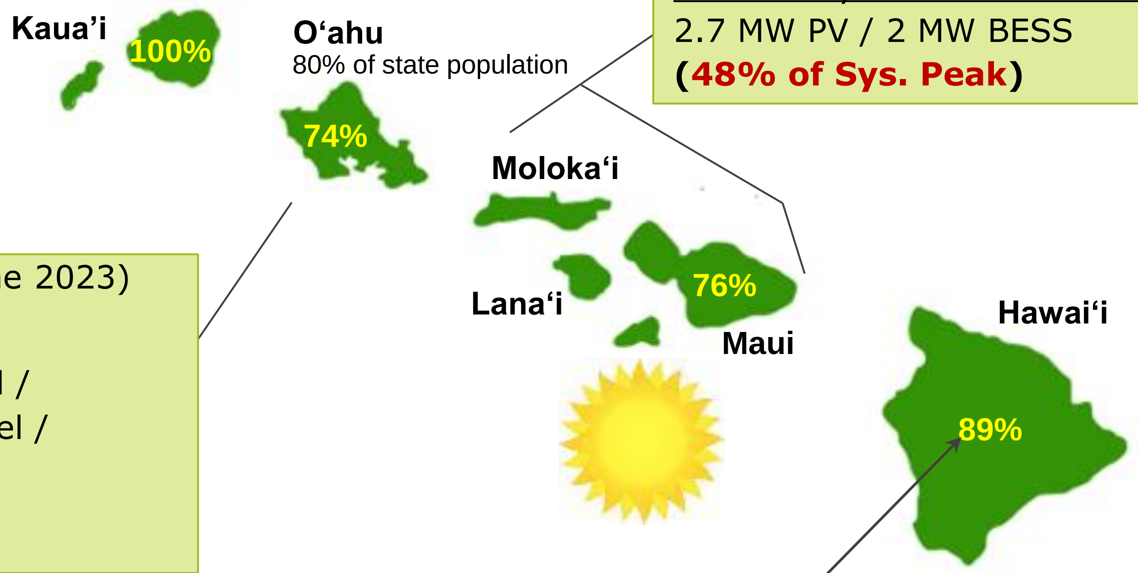
*West Kauai Energy Project
(Approved)
Hydro 4 MW
PV 35 MWac/56 MWdc
+ 35 MW/70 MWh BESS
20 MW Pumped Hydro

Maui Electric (June 2023)
Maui System Peak: 206 MW
145 MW PV* / 72 MW Wind/ 24 MWh BESS
Installed PV & Wind:
105% 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 / 2 MW BESS
(**48% of Sys. Peak**)

Maui
* **75 MW PV + 300 MWh BESS (Approved)**
40 MW PV + 160 MWh BESS
(Pending Approval)

Molokai (Pending Approval)
*2.45 MW PV + 11 MWh BESS

Lanai (Pending Approval)
*17.5 MW PV + 89 MWh BESS



Hawaiian Electric (June 2023)
System Peak: 1,216 MW
905 MW PV* / 123 MW Wind /
69 MW WTE / 168 MW Biofuel /
300 MWh BESS*
Installed PV & Wind:
85% of Sys. Peak

* **143.5 MW PV + 1,266 MWh BESS (Approved)**
12 MW / 12 MWh BESS (Pending Approval)

Renewable Energy Peak
Daily Production in 2022
(e.g. occurred on May 22, 2022)

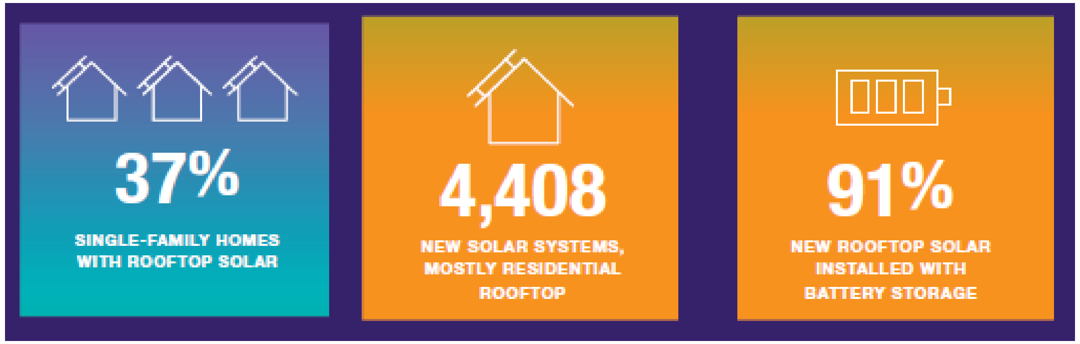
Hawaii Electric Light (June 2023)
System Peak: 191 MW
159 MW PV* / 34 MW Wind / 120 MWh BESS
38 MW Geothermal* / 17 MW Hydro
Installed PV & Wind:
101% of Sys. Peak

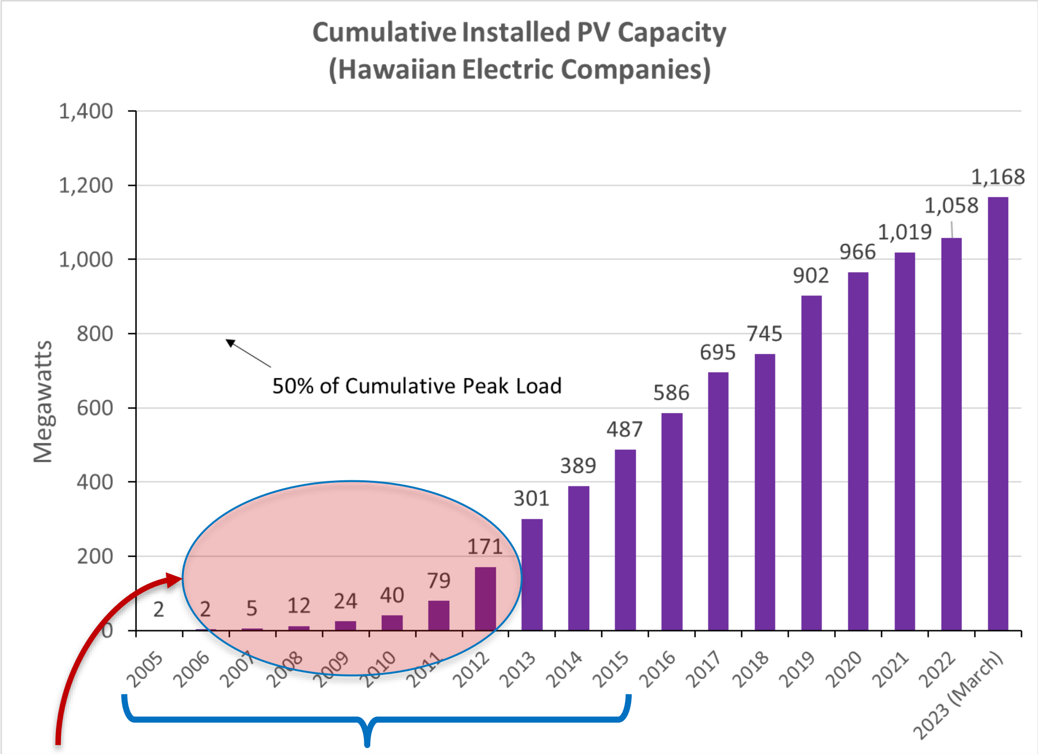
* **30 MW PV + 120 MWh BESS (Approved)**
Geothermal Plant is in operation at reduced
capacity (30 MW) due to volcanic eruption.
An 8 MW expansion, to 46 MW, is approved

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: Customer	Yes: Economic Yes: Customer (Economic)
Communications	N/A	Yes	N/A	N/A
Hypothetical Bill Comparison:**	$93.28	$118.38	$169.09	$93.79

2022 Status





Year-over-year market doubling of rooftop-solar

Retail rate NEM

Grid Codes & Pre-qualified Inverters

The Foundation

Hawaiian Electric
Maui Electric
Hawai'i 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)

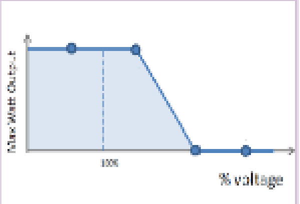
https://www.hawaiianelectric.com/Documents/clean_energy_hawaii/list_of_advanced_legacy_equipment.pdf

Proven Advanced Inverter Functions Enable Higher PV Circuit Penetration

IEEE 1547-2018 standard

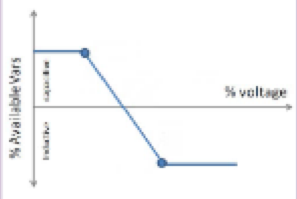
- Provides performance requirements for generation connected at the distribution level, including inverter-based generation.
- Addresses issues related to <u>*high*</u> penetration levels of inverter-based generation, whereas previous IEEE 1547-2003 version assumed low level of distributed generation.

Volt-Watt



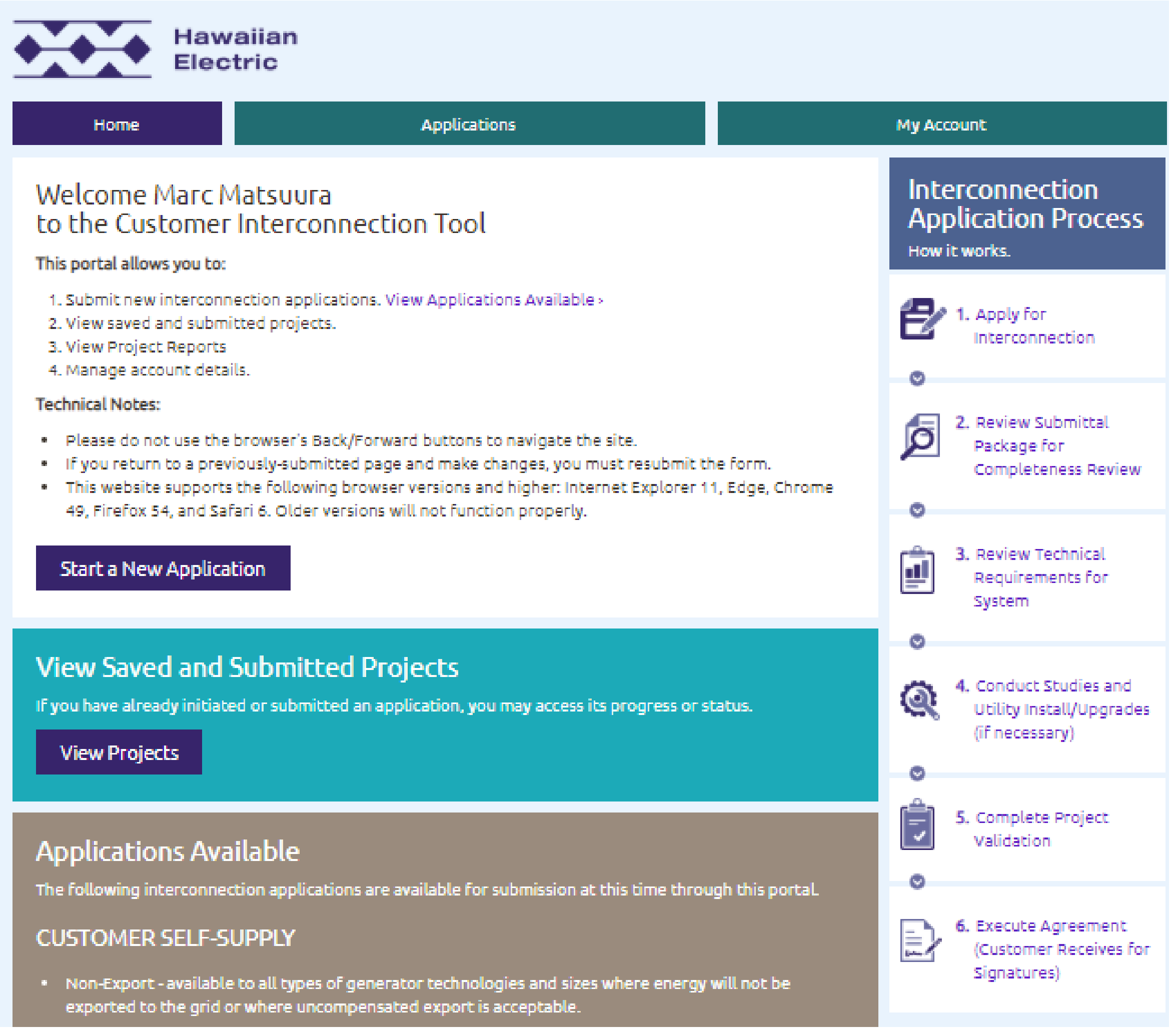
Mitigates secondary high voltage by reducing real power as a function of voltage.

Volt-Var



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

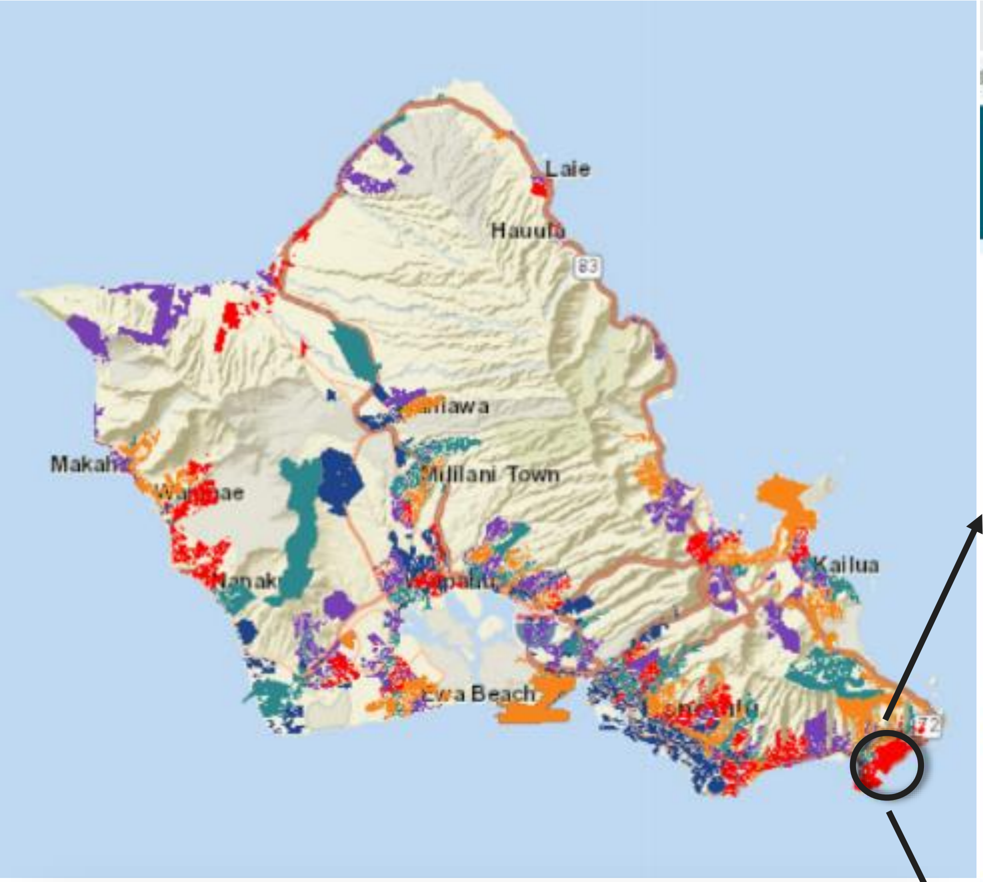
Online Interconnection Application

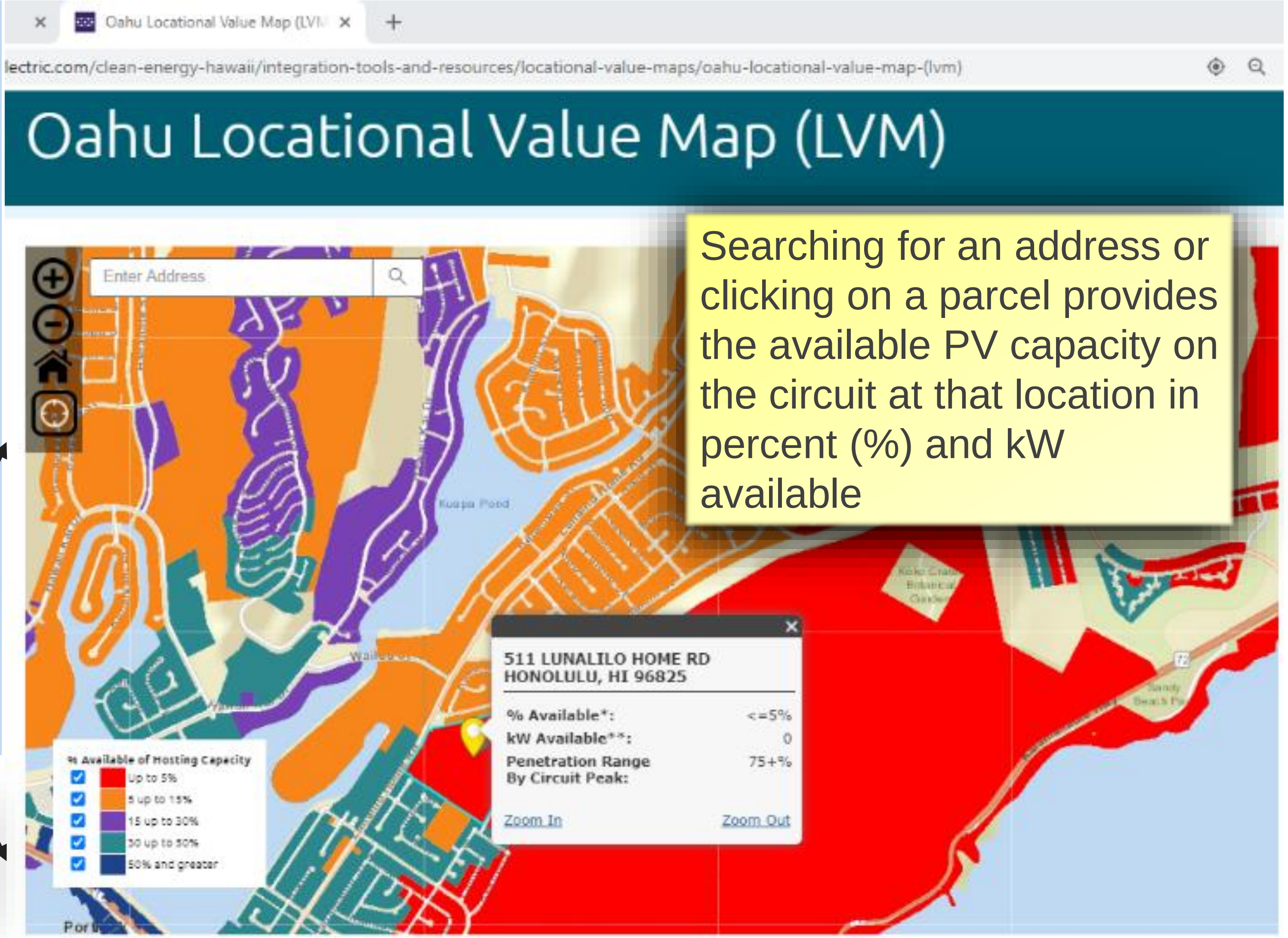


Hawaiian Electric has an online interconnection application portal to take the customer or their contractor through the application process.

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

Posted Hosting Capacity – Searchable Website





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.

DPV Staffing Needs Increase

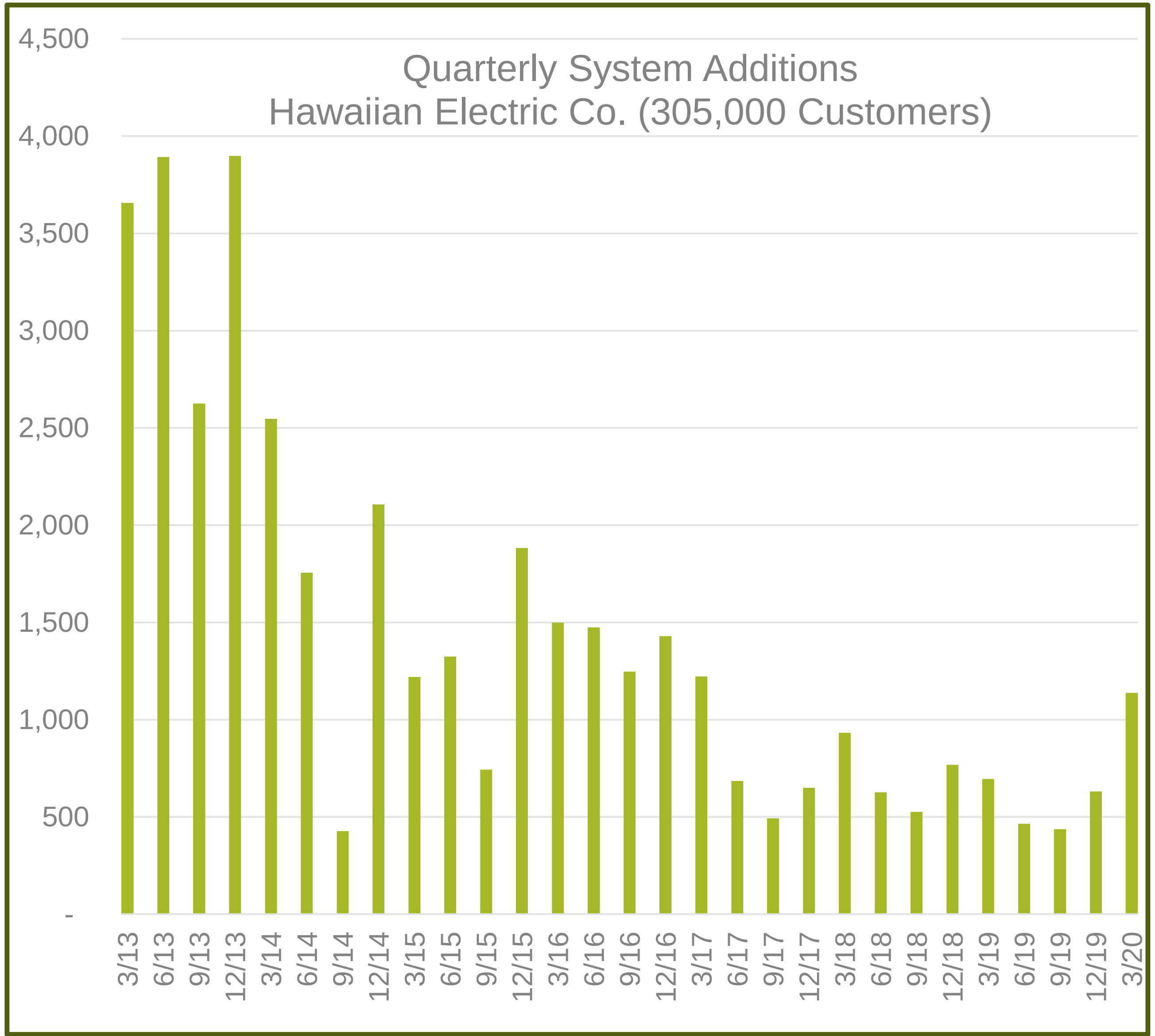
<u>Hawaiian Electric Company:</u>

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

DPV program implementation requires additional administrative and technical staff/budget/capacity building to implement



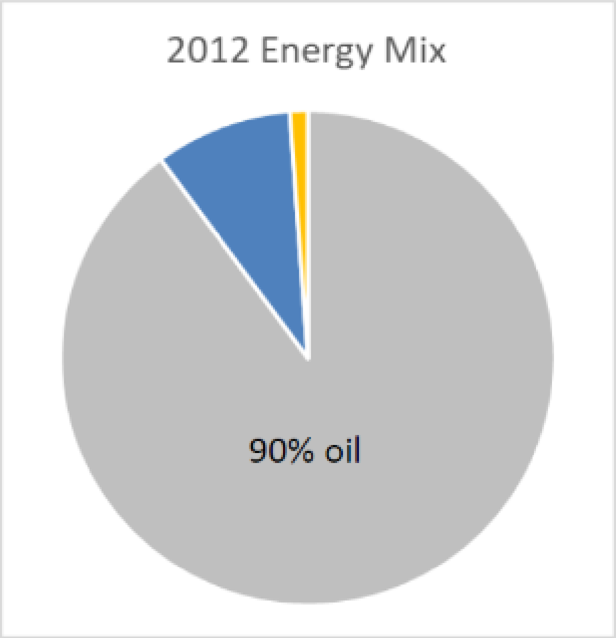

Kauaʻi

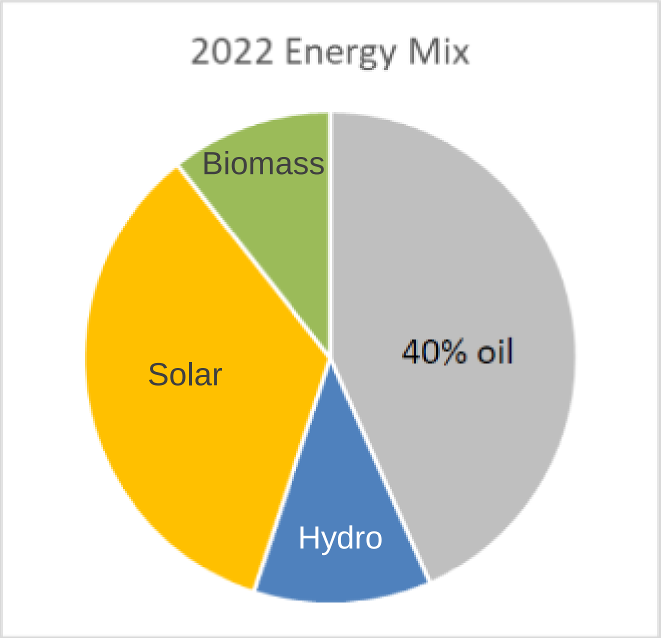
Kauai Island Utility Cooperative (KIUC) – 100% RE Experience

<u>Kaua'i Island Utility Cooperative</u> (April 2023)
<u>System Peak: 80 MW</u>
125 MW PV* / 7 MW Biomass / 16 MW Hydro*
Installed PV: 156% of Sys. Peak

- RE strategy focused on *<u>utility scale solar and batteries</u>* (with 46 MW of customer-owned solar, mostly rooftop)
- 35 – 80 MW daily demand profile
- 107 MW oil-fired capacity (Includes CTs able to operate in synchronous condenser mode)
- 50 MW / 260 MWh battery Storage (11MW / 29 MWh customer owned)

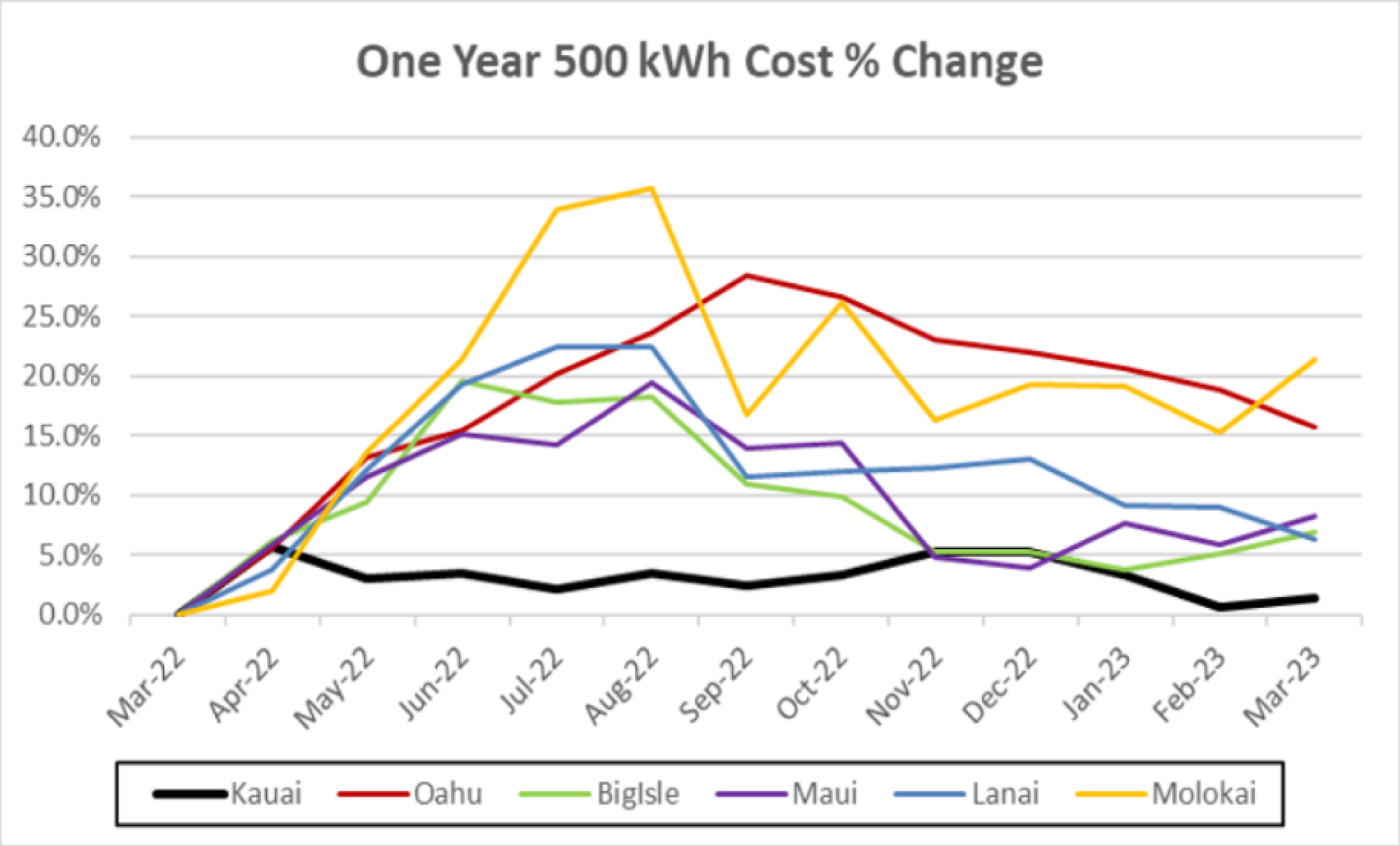
- First ran 100% RE in Feb 2019, for 30 minutes
- Thousands of hours across hundreds of days since then
- Daytime only (record 10 hours)
- Need more long-term storage to extend 100% RE to 24/7/365





Source: KIUC

Rate Stabilization

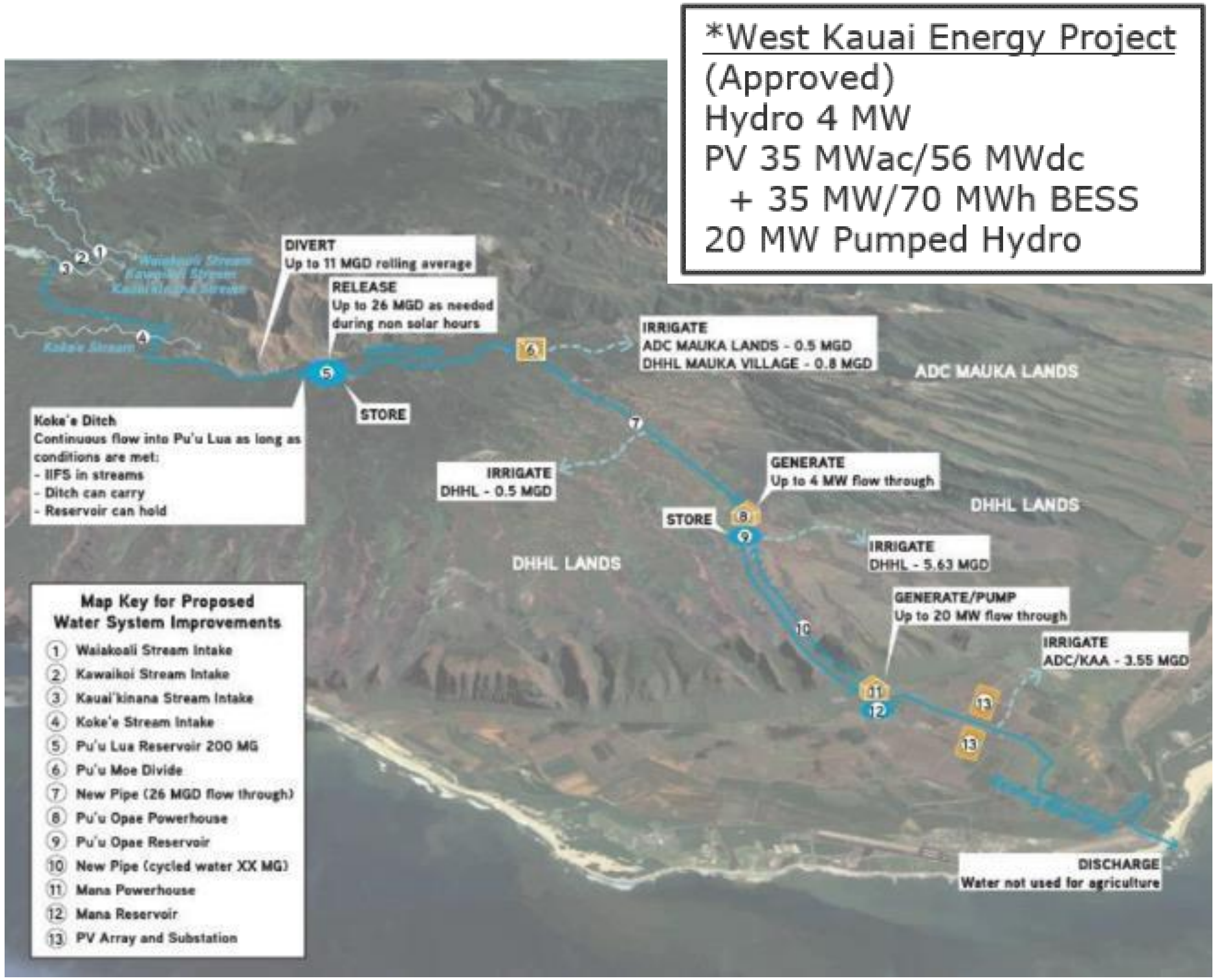


Average Residentail Rates 2022 (cents/kWh)	
Kauai	39
Oahu	43
Big Island	48
Maui	43
Lanai	55
Molokai	53

https://energy.hawaii.gov/energy-data/

Source: KIUC

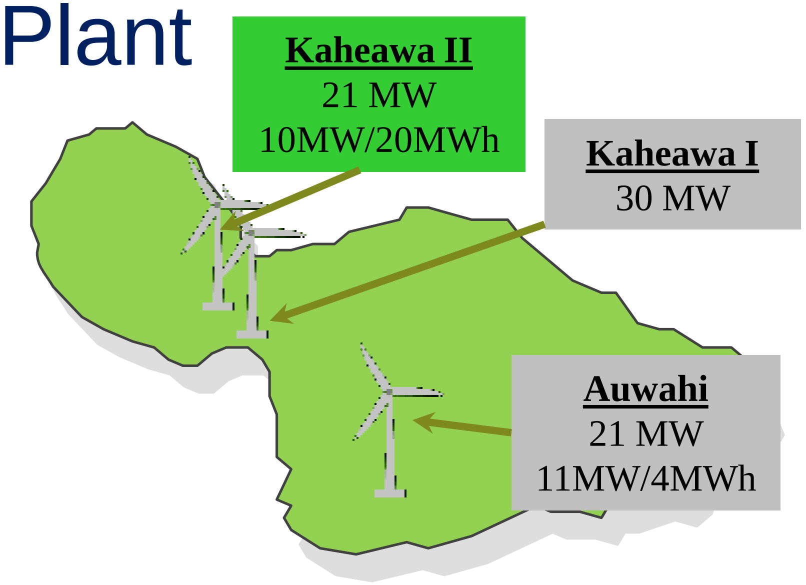
West Kaua‘i Energy Project (WKEP)



- KIUC’s new renewable resource options are limited to solar and hydro
- WKEP meets up to 25% of KIUC’s energy needs
- Will push KIUC close to 90% renewable energy
- *<u>Long duration storage</u>* capabilities significantly extends 100% RE operating time

BESS for Island Power Systems

Maui Wind Integration – Kaheawa II Wind Plant



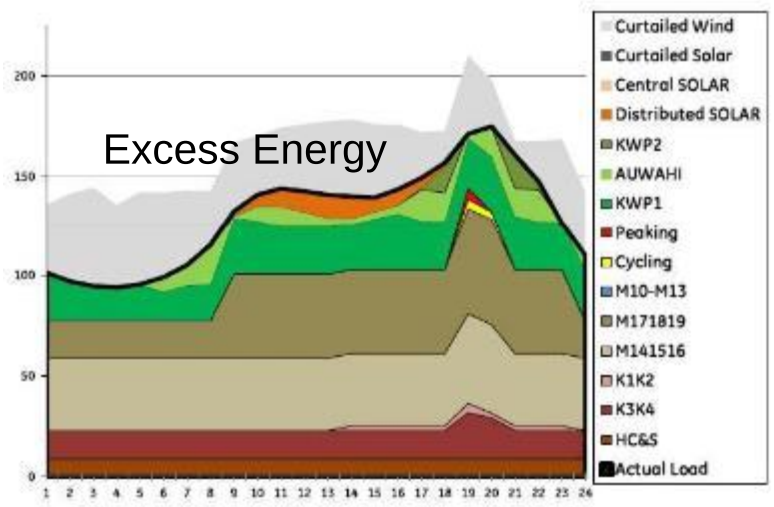
Facility	Percent of available energy delivered (% before / % after)	% increase in delivered energy
Kaheawa I	97% / 99%	2%
Auwahi	72% / 84%	17%
Kaheawa II	27% / 45%	68%

BESS Function

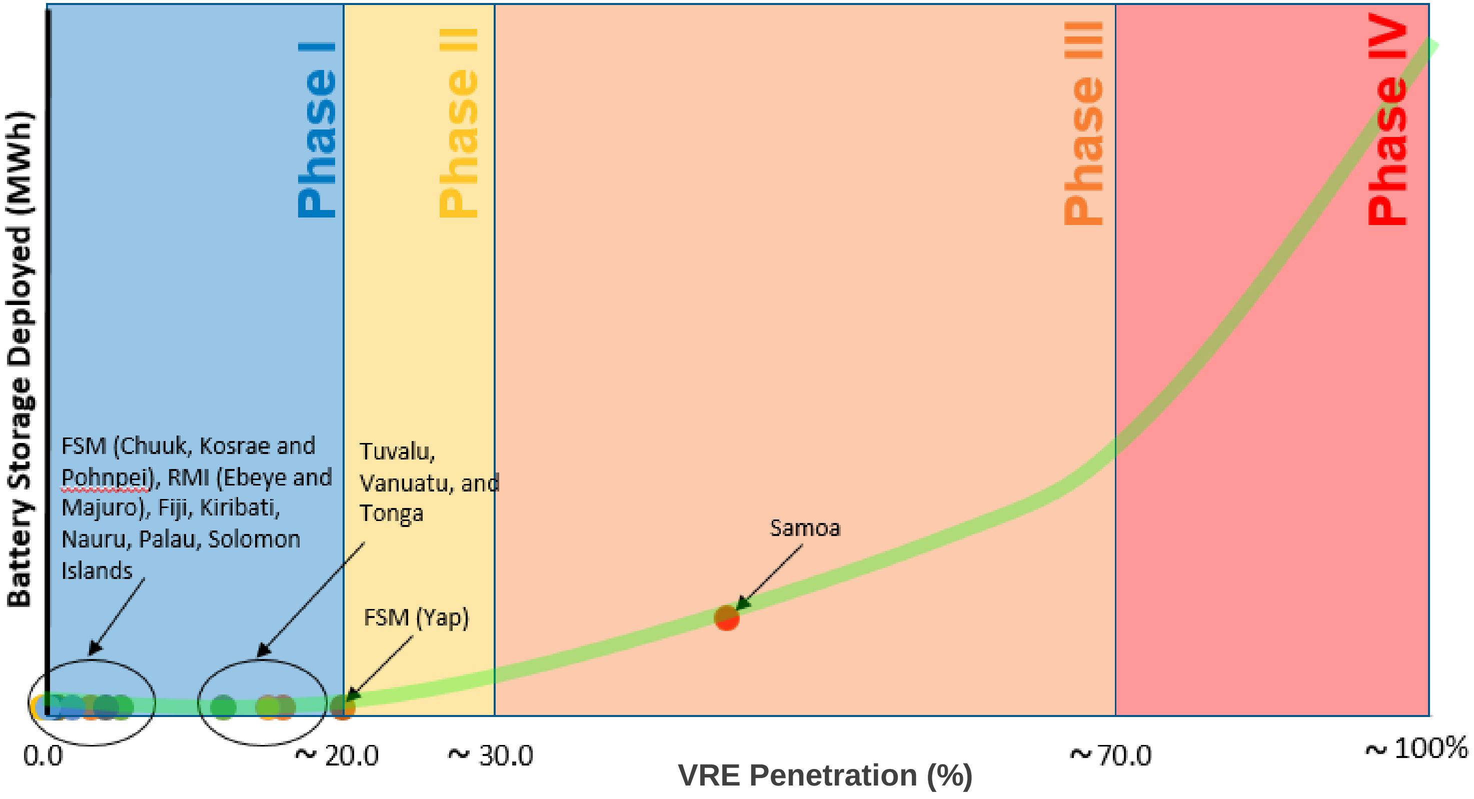
- 10MW / 20MWh
- Manual and AGC Dispatch
- Aggressive Frequency Response
- Ramp Rate Limit within a limited SOC Range

MECO Operations

- Include 10MW of BESS in Up Reserve
- Reduce Down Reserve of M14 & M16 by 1.5MW
- Reduced Operation of K1 and K2
- 50MW Up-Reserve Limit



Example Case – HNEI Report on Curtailment Mitigation in PICs



New VRE Resources

- Case 1: Incremental Solar (100%)
- Case 2: Incremental Solar-Wind (50%-50%)

#	Island	2020 Peak (MW)	2020 RE %	2020 VRE %
	Group 1 (0 - 5 MW)			
1	Kosrae (FSM)	1.3	3.2	3.2
2	Funafuti (Tuvalu)	1.4	15.7	15.7
3	Yap (FSM)	1.9	19.5	19.5
4	Ebeye (RMI)	2.0	0.0	0.0
5	Weno (FSM)	3.0	5.1	5.1
	Group 2 (5 - 7 MW)			
6	Tarawa (Kiribati)	5.6	6.8	6.8
7	Nauru	5.8	7.7	7.7
8	Pohnpei (FSM)	6.2	4.1	4.1
	Group 3 (9 - 16 MW)			
9	Majuro (RMI)	9.4	0.8	0.8
10	Tongatapu (Tonga)	11.5	11.8	11.8
11	Koror (Palau)	11.5	2.0	2.0
12	Efate (Vanuatu)	13.2	14.7	14.7
13	Solomon Islands	15.9	1.7	1.7
	Group 4			
14	Upolu (Samoa)*	30.0	44.4	44.4
	Group 5			
15	Viti Levu (Fiji)	180.2	64.2**	0.4**

* In 2020, Samoa had about 8 MW / 13.7 MWh of storage

** 57% of Fiji's electricity in 2020 was provided by firm hydropower

HNEI Spreadsheet-Based Model for the PICs

3-HOUR BESS

INPUT PARAMETERS

Capacity		
Pmin Diesel	0.45	MW
New Wind	0.0	MW
New Solar	31.6	MW

Storage (MWh)	94.8	MWh
BESS Inverter (MW)	31.6	MW
BESS Duration (hrs)	3.0	hours
Initial BESS SOC	0.0	%
Min BESS SOC	0.0	%
Max BESS Inverter Output	100.0	%

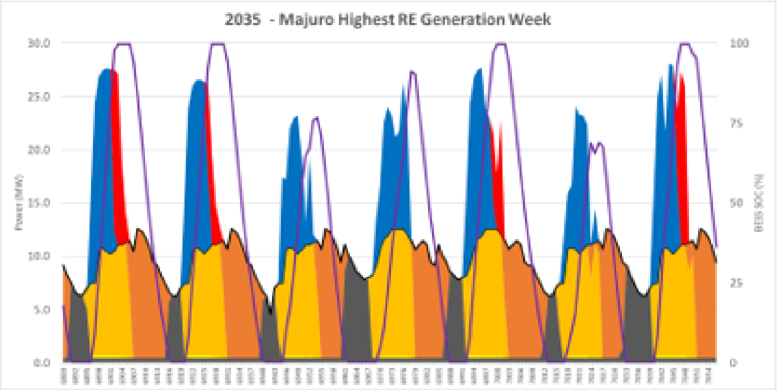
OUTPUT

Energy	MWh	%
Diesel	26,217	29.9%
New Wind	(0)	0.0%
New Solar	60,977	69.5%
2020 RE	496	0.6%
Total Load	87,690	100.0%

RE% 70.1%

	MWh	%
Curtailment	3,032.59	4.7%

% of Available RE



PV Needed: 31.6 MW

BESS: 31.6 MW/ 94.8 MWh

Curtailment: 4.7%

4-HOUR BESS

INPUT PARAMETERS

Capacity		
Pmin Diesel	0.45	MW
New Wind	0.0	MW
New Solar	30.2	MW

Storage (MWh)	120.8	MWh
BESS Inverter (MW)	30.2	MW
BESS Duration (hrs)	4.0	hours
Initial BESS SOC	0.0	%
Min BESS SOC	0.0	%
Max BESS Inverter Output	100.0	%

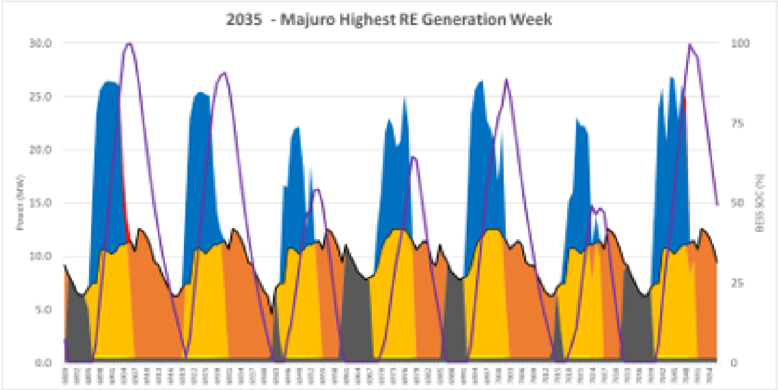
OUTPUT

Energy	MWh	%
Diesel	26,326	30.0%
New Wind	(0)	0.0%
New Solar	60,860	69.4%
2020 RE	496	0.6%
Total Load	87,682	100.0%

RE% 70.0%

	MWh	%
Curtailment	313.87	0.5%

% of Available RE



PV Needed: 30.2 MW

BESS: 30.2 MW/ 120.8 MWh

Curtailment: 0.5%

5-HOUR BESS

INPUT PARAMETERS

Capacity		
Pmin Diesel	0.45	MW
New Wind	0.0	MW
New Solar	30.1	MW

Storage (MWh)	150.5	MWh
BESS Inverter (MW)	30.1	MW
BESS Duration (hrs)	5.0	hours
Initial BESS SOC	0.0	%
Min BESS SOC	0.0	%
Max BESS Inverter Output	100.0	%

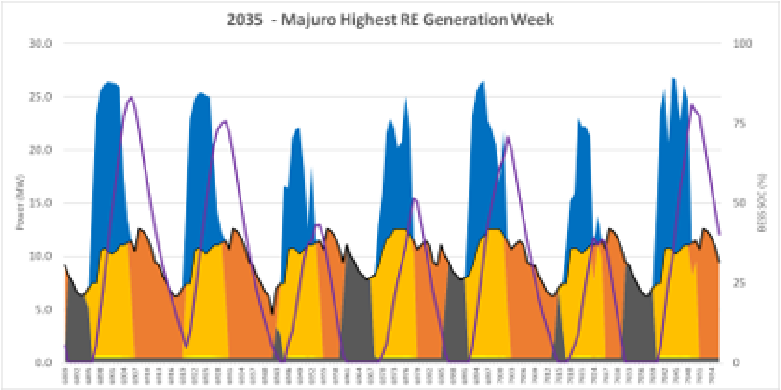
OUTPUT

Energy	MWh	%
Diesel	26,225	29.9%
New Wind	(0)	0.0%
New Solar	60,960	69.5%
2020 RE	496	0.6%
Total Load	87,681	100.0%

RE% 70.1%

	MWh	%
Curtailment	11.59	0.0%

% of Available RE



PV Needed: 30.1 MW

BESS: 30.1 MW/ 150.5 MWh

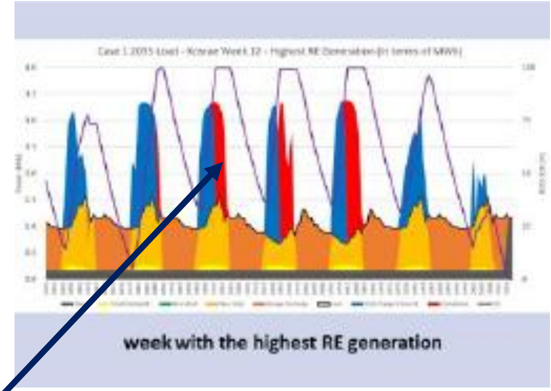
Curtailment: 0.0%

Diesel | Total Existing RE | New Solar | BESS Discharge | Load | BESS Charge | Curtailment | BESS SOC

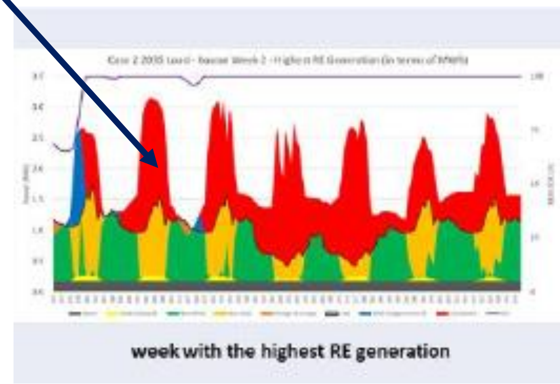
Select takeaways from HNEI's assessment of PIC systems

- Geographic and resource diversity of VRE generation has the effect of smoothing the aggregate VRE power output
- BESS effectively captures and shifts VRE energy production, enabling increased VRE penetration and reducing excess energy curtailment to economically viable levels
- At moderate levels of VRE penetration (e.g., 30 - 50%), a mixture of PV and wind resources combined with BESS results in less VRE excess energy curtailment (and reduced amount of energy shifting BESS needed) versus a PV only case
- However, as VRE penetration reaches higher levels (e.g., > 70%), having a significant portion of wind resources diminishes the ability of energy shifting BESS (e.g., ~3 to 5 hour BESS) to reduce curtailment (shown to the right in red), due to relatively longer duration low and high wind periods (spanning days or weeks) when compared to the diurnal solar cycle
- As VRE penetration is pushed to very high levels (and approaches 100%), the need for <u>long-term storage</u> grows dramatically and economic viability is strained
- Retaining a modest level of thermal generation can offset the need for long-term storage while securing adequate generation capacity and energy availability for isolated island grids

Curtailment on Kosrae at 70% RE purely from PV and a 5-hr BESS



Curtailment on Kosrae at 70% RE with 50/50 PV/wind and a 5-hr BESS



Mahalo!

(Thank you)

For more information, contact:

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GridSTART

Hawai'i Natural Energy Institute | University of Hawai'i

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 & Resilience*
- ➢ *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

Leon R. Roose

Chief Technologist

Mr. Roose is a tenured faculty member of the Hawai‘i Natural Energy Institute (HNEI), University of Hawai‘i at Mānoa, where he formed and has led for over a decade HNEI’s Grid***START*** (Grid System Technologies Advanced Research Team), a team of professionals focused on energy transition enabling policy and regulation, advanced grid architectures, grid modernization technologies, and novel methods to achieve reliable grid integration of RE resources, power system optimization and energy resilience goals.

He served in numerous leadership roles at the Hawaiian Electric Company for 19 years prior including management of renewable energy planning and integration, generation resource planning and competitive procurement, negotiation and administration of all power purchase agreements for the utility, transmission and distribution system planning, smart grid planning and projects, system relaying and protection, and fuel purchase and supply to all utility generating plants. He is a licensed attorney, formerly in private law practice in Hawai‘i and served as Associate General Counsel at Hawaiian Electric. He holds a B.S. in Electrical Engineering and a J.D. from the University of Hawai‘i at Mānoa.

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

Marc M. Matsuura

Sr. Smart Grid Program Manager

Mr. Matsuura joined the Hawai‘i Natural Energy Institute (HNEI), University of Hawai‘i at Mānoa, in 2013 as its Senior Smart Grid Program Manager. He is a founding member of HNEI's Grid***START*** (Grid System Technologies Advanced Research Team), a team of professionals focused on energy transition enabling policy and regulation, advanced grid architectures, grid modernization technologies, and novel methods to achieve the reliable grid integration of RE resources, power system optimization and energy resilience goals.

Prior to joining HNEI, he was with the Hawaiian Electric Company for 21 years. His career at Hawaiian Electric included positions of leadership in the areas of transmission and distribution (T&D) engineering, T&D standards and technical services, system operation, transmission planning, smart grid planning, and system integration. Marc is a licensed professional electrical engineer in Hawaii. He holds a B.S. in Electrical Engineering and an M.B.A. from the University of Hawai‘i at Mānoa.

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Grid System Technologies Advanced Research Team

Damon L. Schmidt

Senior Energy Regulatory/ Policy Analyst

Mr. Schmidt is a Senior Energy Regulatory/Policy Analyst with Grid***START*** (Grid System Technologies Advanced Research Team), a research group within the Hawai‘i Natural Energy Institute (HNEI), University of Hawai‘i at Mānoa. Grid***START***'s focuses on energy transition enabling policy and regulation, advanced grid architectures, grid modernization technologies, and novel methods to achieve the reliable grid integration of RE resources, power system optimization and energy resilience goals.

Mr. Schmidt has over 15 years of energy sector work experience. Prior to joining HNEI, he served as the Director/Manager of Hawaiian Electric Company's Regulatory Non-Rate Proceedings group, and in outside regulatory counsel and financial consulting roles for Hawaiian Electric as both a solo practitioner, and with the law firm of Goodsill Anderson Quinn & Stifel. Mr. Schmidt delivered key regulatory and financial guidance to shape Hawaiian Electric's positions in its many proceedings before utility regulators. He is a licensed attorney in the State of Hawai‘i and holds a B.S. in finance from the University of Hawai‘i, an M.B.A. (international business focus) from Pepperdine University in California, and a J.D. from the University of Hawai‘i William S. Richardson School of Law.