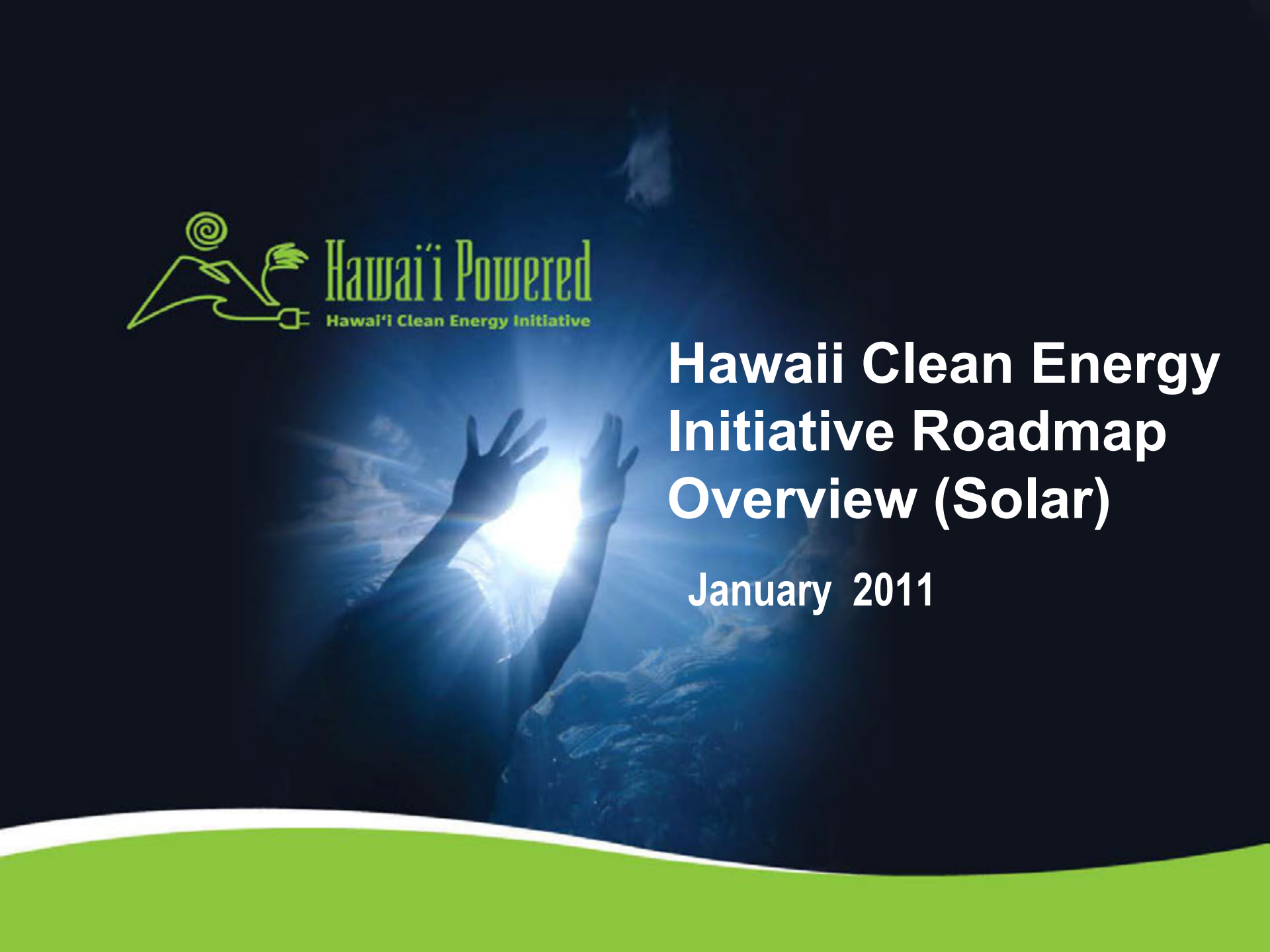


Hawaii Clean Energy Initiative Roadmap Overview (Solar)

January 2011

Outline

- Hawaii Clean Energy Initiative (HCEI) Goals
- HCEI Roadmap Overview
- HCEI Accomplishments by sector
- Roadmap Summaries by sector
  - Electricity
  - End-Use Efficiency
  - Transportation
  - Fuels
- Solar energy sector role
- Direction of analysis for solar

HCEI Goals

HCEI provides a framework to help Hawaii realize these goals:

- Transform to a 70% clean energy economy by 2030
- Reap economic and environmental benefits of such transformation, including:
  - Increasing Hawaii's energy and economic security
  - Fostering and demonstrating Hawaii's innovation
  - Building the work force for the future
  - Serving as a clean energy model for the U.S. and the world

HCEI Long-Term Commitment

HCEI became a statute with the passage of Act 73 in April, 2010

The Hawaii Legislature solidified Hawaii's commitment to reaching HCEI's clean energy goals and formalized the objectives, partnerships, resources, and reporting required by the legislature

HCEI represents a vital collaboration of committed stakeholders

- Federal, state, and county governments
- Non-profit organizations
- Academic institutions
- Military installations
- Private sector: utilities, refiners, project developers, builders, farmers, landowners, and the automotive industry

HCEI 70 % Clean Energy Goal

Electricity Sector

40% RPS by 2030

Strategies:

- Align regulatory and policy framework with clean energy goals
- Increase process certainty in developing new RE
- Deploy RE and grid infrastructure
- Explore next gen technologies and new applications

Interim Targets …

Accomplishments…

Important Actions …

Efficiency Sector

30% EEPS by 2030

Strategies:

- Align regulatory and policy framework
- Retrofit residential and commercial buildings
- Strengthen new constructions policies / building codes
- Identify non-building related energy efficiency measures

Interim Targets …

Accomplishments …

Important Actions …

Transportation Sector

Displace 70% Petroleum by 2030

Strategies:

- Accelerate EV and H2 vehicle and infrastructure deployment
- Increase renewable fuel use in the transportation sector
- Improve vehicle fleet efficiency
- Reduce vehicle miles traveled

Interim Targets …

Accomplishments …

Important Actions …

Fuels Sector

Meet In-State Demand for Renewable Fuels

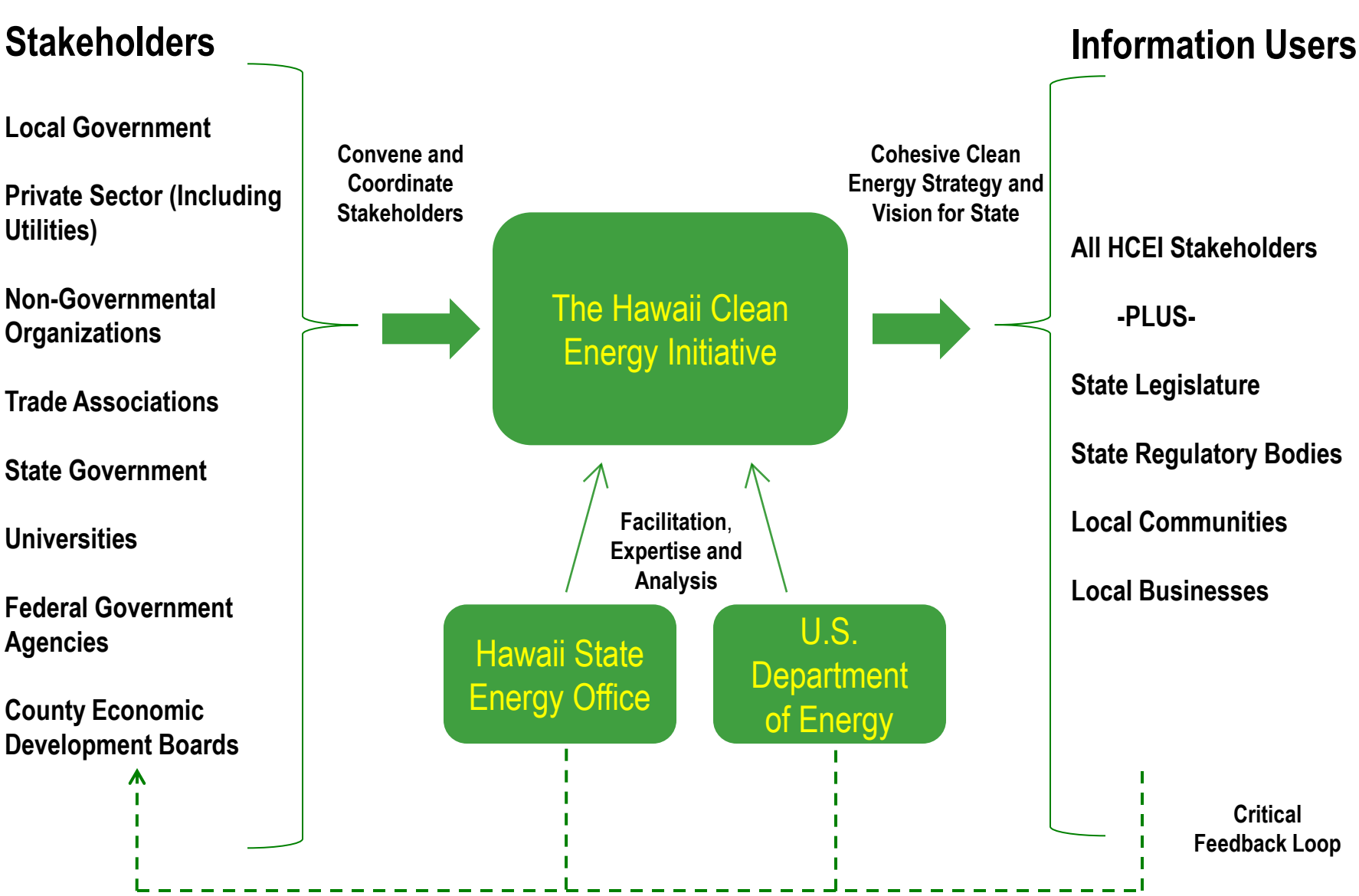
Strategies:

- Support development of local agricultural industry
- Invest in key infrastructure at scale
- Evaluate and develop renewable fuel processing infrastructure
- Match potential fuel supply with in-State demand

Interim Targets …

Accomplishments …

Important Actions …


Stakeholders
Local Government
Private Sector (Including Utilities)
Non-Governmental Organizations
Trade Associations
State Government
Universities
Federal Government Agencies
County Economic Development Boards
Convene and Coordinate Stakeholders
The Hawaii Clean Energy Initiative
Facilitation, Expertise and Analysis
Hawaii State Energy Office
U.S. Department of Energy
Cohesive Clean Energy Strategy and Vision for State
Information Users
All HCEI Stakeholders
-PLUS-
State Legislature
State Regulatory Bodies
Local Communities
Local Businesses
Critical Feedback Loop

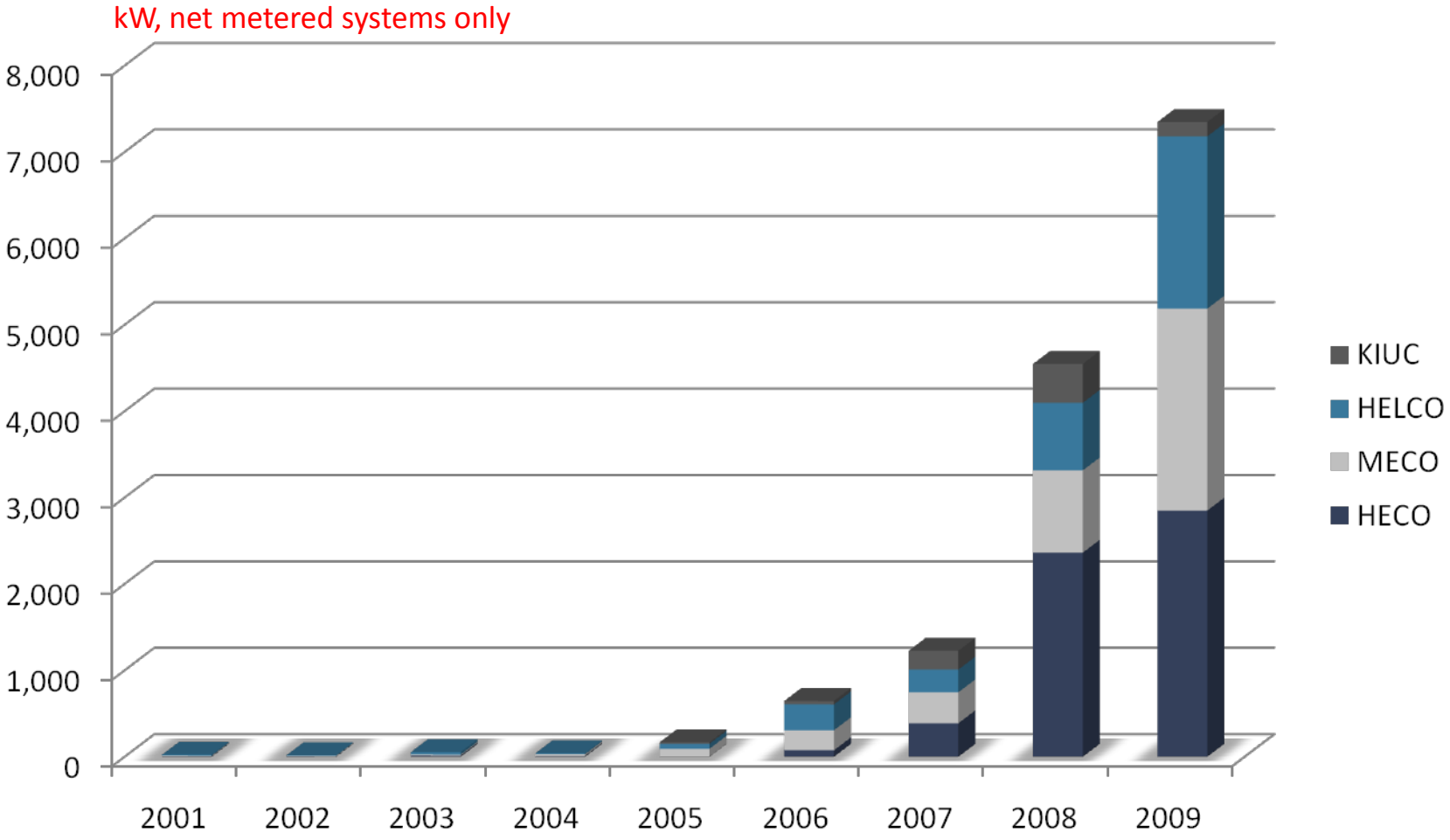
Electricity Sector Accomplishments

- Established **40%** State Renewable Portfolio Standard
- Completed HECO Energy Agreement with the state:
  - Energy commitments
  - Measures to increase energy efficiency
  - Improvements to grid operation and infrastructure
- Set aggressive **renewable energy goals** with Kauai Island Utility Cooperative
- Completed construction of **30MW** Kahuku Wind Farm on Oahu
- Constructed and commissions biofueled Campbell combustion turbine
- Established Hawaii as the nation's **leader** in growth rate of distributed generation PV installation
- Completed wind and solar power **grid-integration** and **grid-impact** studies for all islands

Can't We Get There With Just Oahu Solar?

- 400 MW Wind project = **1.4B kWh a year**
- 100% Penetration of rooftop solar on Oahu = **1.36B kWh a year**
- 7 square miles of utility solar = **1.4B kWh a year**
- 6.4B kWh generated from petroleum on Oahu in 2007
  - **(2008 Hawaii Data Book)**
- 100% roof top solar penetration possible, but will require further regulatory changes
- **Bottom line – we need both rooftop PV and Interisland Wind to achieve our clean energy goals**

Hawaiian PV Market is Growing



Note: Net metered installs are only a portion of the total. In 2009 total installs were 14 MW indicating about only half of installs were NEM.
Source: HECO Companies Net Energy Metering Annual Status Report 2009 for HECO/MECO/HELCO, personal communication with KIUC staff for KIUC. KIUC had 93.1 kW installed prior to 2005.

Grid-Tied Solar Installs

Capacity Installed in 2009 (MW)		Cumulative Capacity in 2009 (MW)	
California	220	California	1,102
New Jersey	57	New Jersey	128
Florida	36	Nevada	100
Arizona	23	Colorado	59
Colorado	23	Arizona	50
Hawaii	14	Florida	39
New York	12	New York	34
Massachusetts	10	Hawaii	27
Connecticut	9	Connecticut	20
North Carolina	8	Massachusetts	18
Others	29	Others	78
Total	441	Total	1,653

Note: Includes all grid-tied PV & CSP.
Source: SEIA. US Solar Industry Year in Review 2009. Page 5.

Grid-Tied Solar Installs Per Capita, 2009

State	2009 MW	2009 Population (mil)	watts per capita
Hawaii	14	1.3	10.8
New Jersey	57	8.7	6.6
California	220	37.0	5.9
Colorado	23	5.3	4.3
Arizona	23	6.6	3.5
Connecticut	9	3.5	2.6
Florida	36	18.5	1.9
Massachusetts	10	6.6	1.5
North Carolina	8	9.4	0.9
New York	12	19.5	0.6
Others	29	190.6	0.2
Total	441	307.0	1.4

Note: Includes all grid-tied PV & CSP.
Source: SEIA. US Solar Industry Year in Review 2009, Page 5. US Census Bureau Population Estimates, July 1, 2009.

Key Barriers/Market Flaws

- Grid access (NEM program/system limits; proposed new 14H/FIT limits; interconnection rules; lack of true reliability standards; etc.)
- Government and Utility incentive structure for solar
- Cost of storage demands careful grid analysis and management
- Grid quality/smart grid status
- Financing for middle/lower-middle class owners for residential PV

Hawaii Renewable Integration and Transmission Study

- This task supports the HCEI Energy Agreement in which Hawaiian utilities and cooperatives will integrate large amounts of renewable energy onto their electric grids
- This task includes evaluation of power system impacts from variable renewables on the electrical grid and transmission expansion analysis (e.g., cable)
- System planning work to date focuses on:
  - Up to 400 MW wind from Lanai and/or Molokai via undersea cable
  - 100 MW of wind in Oahu
  - 100 MW of PV in Oahu
  - Expansion of solar work on Kauai, Lanai, and other locations
  - Compliments work in Maui by others
- Our Resource Planning work assesses the resources across the state

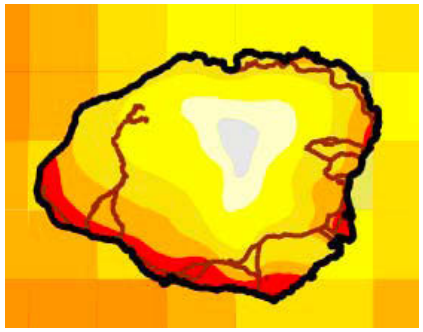
HRITS Strategy

- Utilities and coops face challenge with high penetrations of variable generation
  - Utilities need good data and grid impact analysis to evaluate variable generation scenarios
- Our strategy is to work very closely with HECO and other utilities to understand their needs and then to provide analysis and data that helps with implementing HCEI goals
- Our grid integration work is closely integrated into the utilities' work
- We also link into DBEDT and the renewable energy industry, providing a small bridge between institutions where possible
- Technical review committee's provide technical guidance and review

Overview of Solar Work in Hawaii

Dense network of solar measurement stations

Solar measurement stations across islands



High fidelity solar dataset

Oahu/Maui Solar Integration Study Technical Review Committee

Kauai Solar Integration Study (Sandia)

Lanai project and PV Transient Study

Kauai Solar Integration Study

- Estimate spinning reserve requirements and integration cost for PV deployment scenarios
  - Three deployment scenarios: 5 MW, 10 MW and 15 MW
    - Combination of 1 MW and 3 MW plants
  - 2011 is study year
- Approach
  - Synthesize high resolution PV profiles for scenarios
  - Develop KIUC model AGC/Regulation model
  - Use AGC/Regulation model and high resolution PV profiles to characterized increased regulation requirements
  - Use annual solar data set to estimate costs of increased regulation requirements

Oahu High-Penetration into Distribution Grid

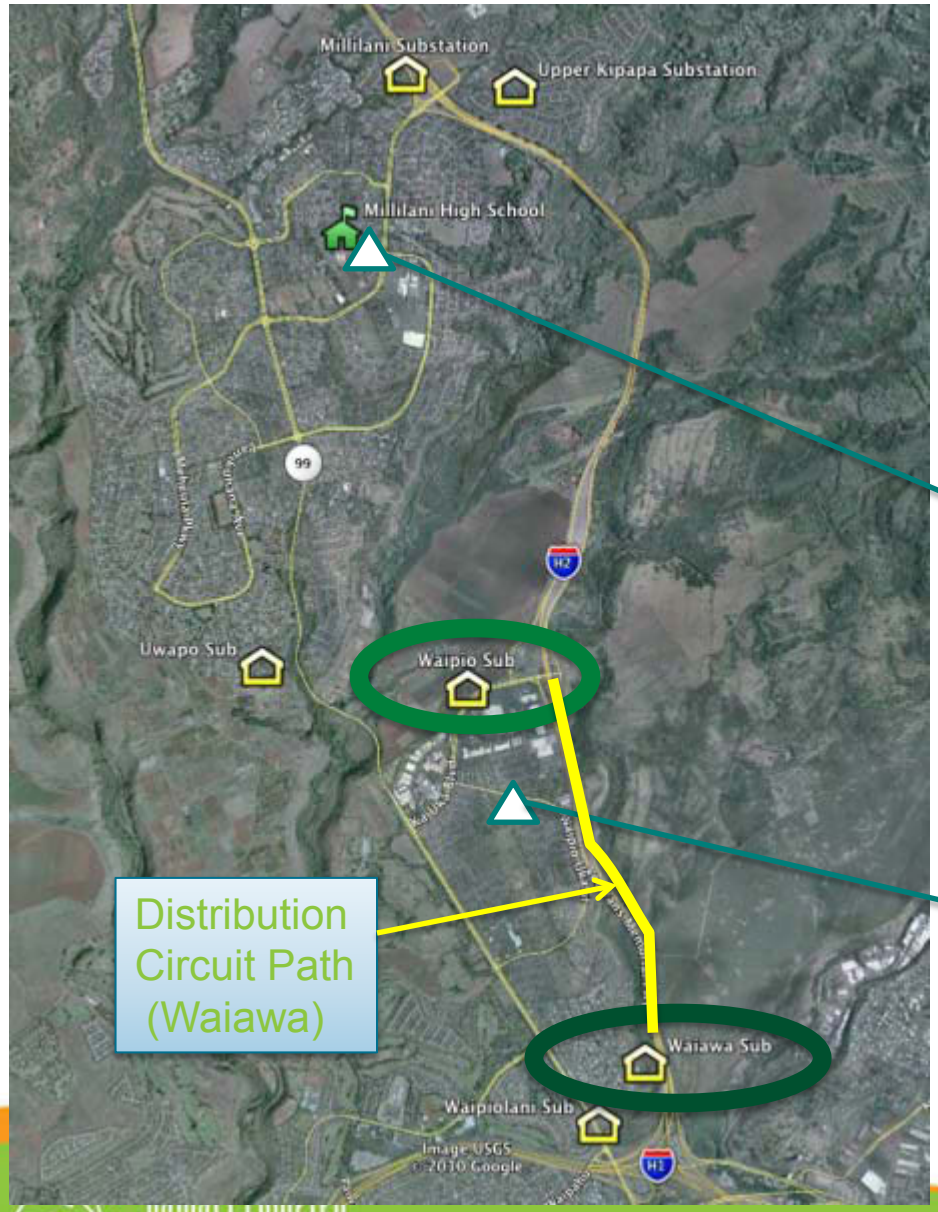
Collaborative Research Effort Between

- HECO
- BEW Engineering
- NREL

Project Phases:

- Phase 1 – (April, 2010 – December, 2010)
  - Monitoring and Analysis
    - Modeling
    - Steady-state analysis
  - Circuit model validation
- Phase 2 – (January, 2011 – December, 2011)
  - Dynamic analysis
  - Grid Integration Analysis of high penetrations of PV

Solar Monitoring Acquisition System (SMAS)



Installed at 2 locations

SMAS Location 1 - Waiawa

SMAS Location 2 - Waipio

Milliani High School
(Sept. 2010 will be taking 1 sec time synchronized data at plane-of-array)

Kanoelani Elem School
(Possible future site location)

Completed Phase 1 – 2010

- Install and collect 3 – 6 months of high-fidelity load monitoring data

- Model, validate, and conduct technical analysis on the Waiawa distribution circuit

- Generate a system studies report determining the results of the steady-state analysis of the high penetration PV connected to Oahu's electric grid

Lanai Renewable Integration Study

- Battery sizing analysis by SunPower, Sandia Labs and NREL in early 2010
  - **1 second power and irradiance data from similar-sized PV farm**
  - **10 months field-recorded data**
  - **Three independent approaches using common input data set**

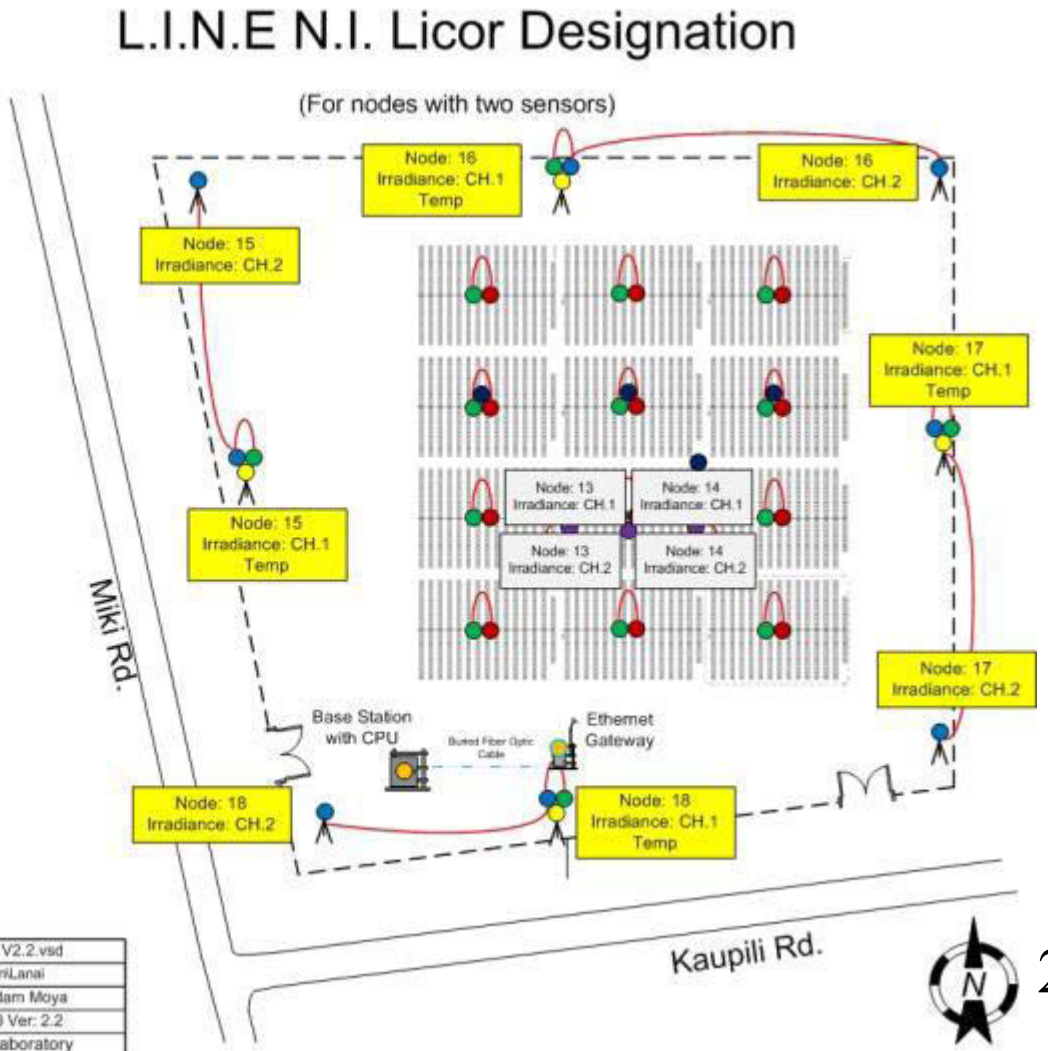
- Battery sizing considerations: Ramp rates, duration and frequency of ramps

- Challenges: Vast amount of data; random ramp rate pattern; uncertainty that all “events” are captured

- Battery size: 450 – 700 kW; 250 – 500 kWh energy required to meet ramp rate support requirements

Irradiance Sensors at La Ola (Sandia)

18	●	I/O, RF
8	●	GH LI200
16	●	POA LI200
1	●	Base Station PC
1	●	Ethernet Gateway
4	○	Ambient TC Probes External
3	●	Module TC Frame of Module
3	●	Router
8	⅄	Tripod
	- - -	Fence



Sandia National Laboratories	Lanai Site Plan V2.2.vsd
	U:\Users\Adam\Lanai
	Prepared By: Adam Moya
	Date: 02/02/2010 Ver: 2.2
Distributed Energy Technology Laboratory	

System Includes:
16 POA Irradiance
8 GH Irradiance
3 Module Temp.
5 Ambient Temp.

Array power output data is added to the data stream

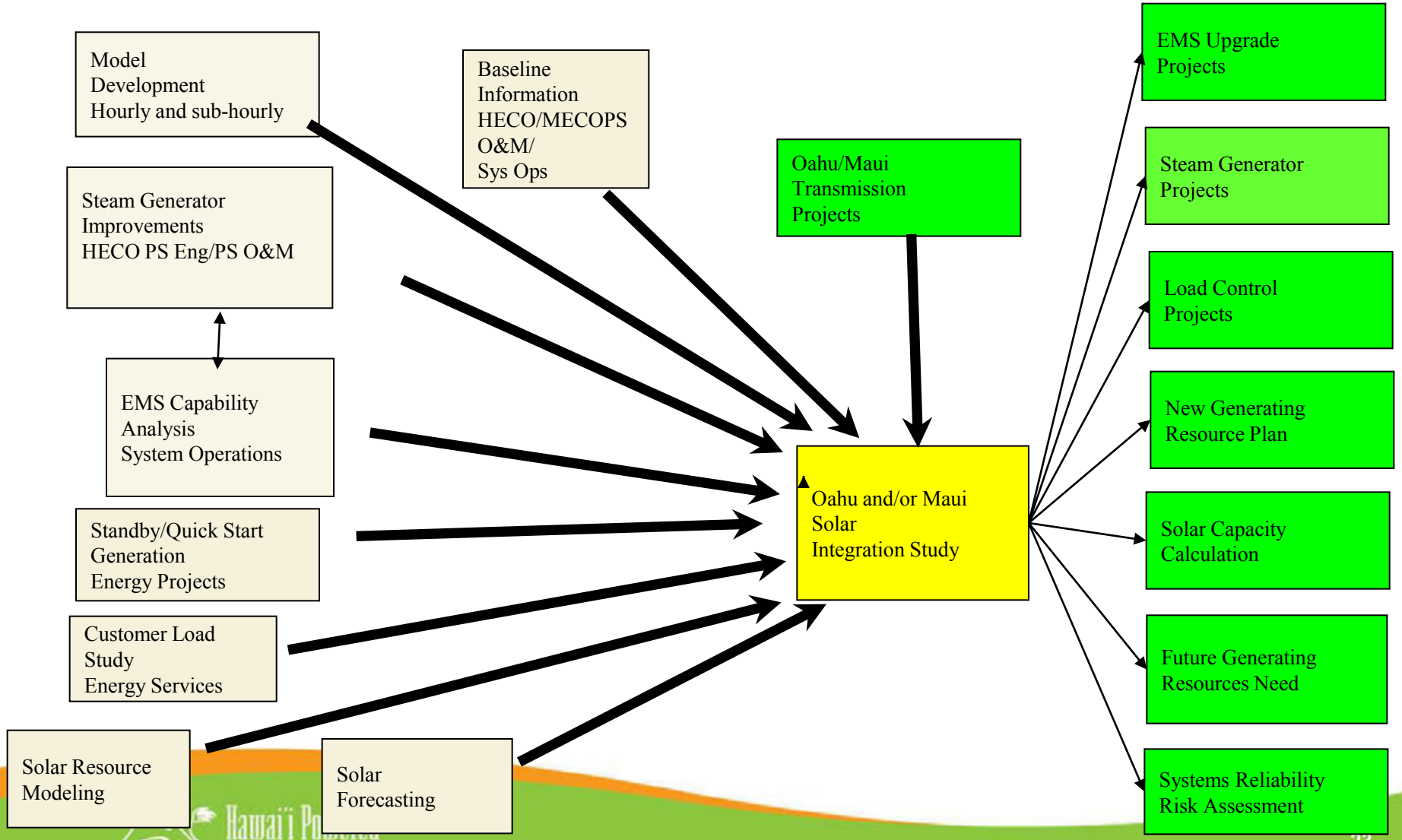
21

Hawai'i Powered
Hawai'i Clean Energy Initiative

Integrating more PV on Lanai

- Up to 800kW of new distributed PV
- How to integrate without storage
- The more geographically spread the systems are, the better to reduce variability due to clouds
- PV system operational windows would need to be widened past IEEE 1547 voltage/frequency limits
- Best to co-locate PV with loads - Examine sites that could be no-export back to grid and Net Energy Meter sites
- Plans are to conduct an Island-wide Interconnection study for more PV

Oahu/Maui Solar Integration Study Tasks



Solar Monitoring and Modeling Approach

- Characterize the solar resource and develop PV datasets for
- Oahu Solar Integration Study
- PV Transient Study
- Kauai Solar Integration Study
- CESP/REZ inputs
- Develop high fidelity models of PV plants up to 50-100 MW
- Set up dense network of solar sensors in Oahu and develop large PV array model
- Characterize variability of solar resource in various regions
- Set up solar sensors across the islands in areas that are likely to have PV development and characterize variability
- Develop high fidelity PV datasets

Research Quality Solar Data Collection

- The organizations collecting data include:
  - HECO, HELCO, MECO, KIUC, HNEI, NREL, Sandia

- Partial List of Project names:
  - Sun Power for Schools
  - Solar Variability Data Modeling Effort
  - High Penetration PV Analysis Project
  - Solar Visualization for Operations Data Project
  - Energy Performance Test Platforms
  - Maui Community College

Research Quality Solar Data Collection

- Continuation of list of Projects
  - Puu Waa Waa Ranch
  - Green Holmes Hall Initiative (GHHI)
  - Maui Economic Development Board (MEDB)
  - Port Allen Warehouse BIPV
  - Ahukini; adjacent to Lihue airport
  - Oahu Solar Dense Grid for PV Variability Assessment
  - Lanai PV Variability and High Penetration of Grid Integration
  - Oahu High Penetration PV Grid Integration
  - Lanai Irradiance Network experiment (LINE)