Grid Integration of Renewable Energy

Robert S. Kaneshiro, P.E.
Operations Assistant Superintendent
Hawaii Electric Light Company (HELCO)

October 2012

Contents

- HELCO System Overview
- Challenges of integrating solar at the distribution level
- System-wide operations issues that arise in small systems with large levels of renewables.

HELCO System Overview

- Autonomous system (no interconnections)
  - Minimum load ~90MW
  - Day peak ~160MW
  - Evening Peak ~180MW
- Automatic Generation Control (AGC) performs frequency control and economic dispatch.
- Renewable energy available from wind, hydro, geothermal and solar.

HELCO System Overview (cont'd)

- Generation Capacity:
  - Conventional (Fossil Fuel) unit dispatchable by AGC
    - Must-Run (24-hour) Units
      - 3-Steam Units (49MW)
      - 2-Combined Cycle Combustion Turbine Units (55MW)
      - 1-Geothermal (27MW off-peak, 30MW on-peak)
    - Intermediate Units
      - 2-2nd Combine Cycle Combustion Turbine Units (55MW)
      - 1-Simple Cycle Gas Turbine (20MW)

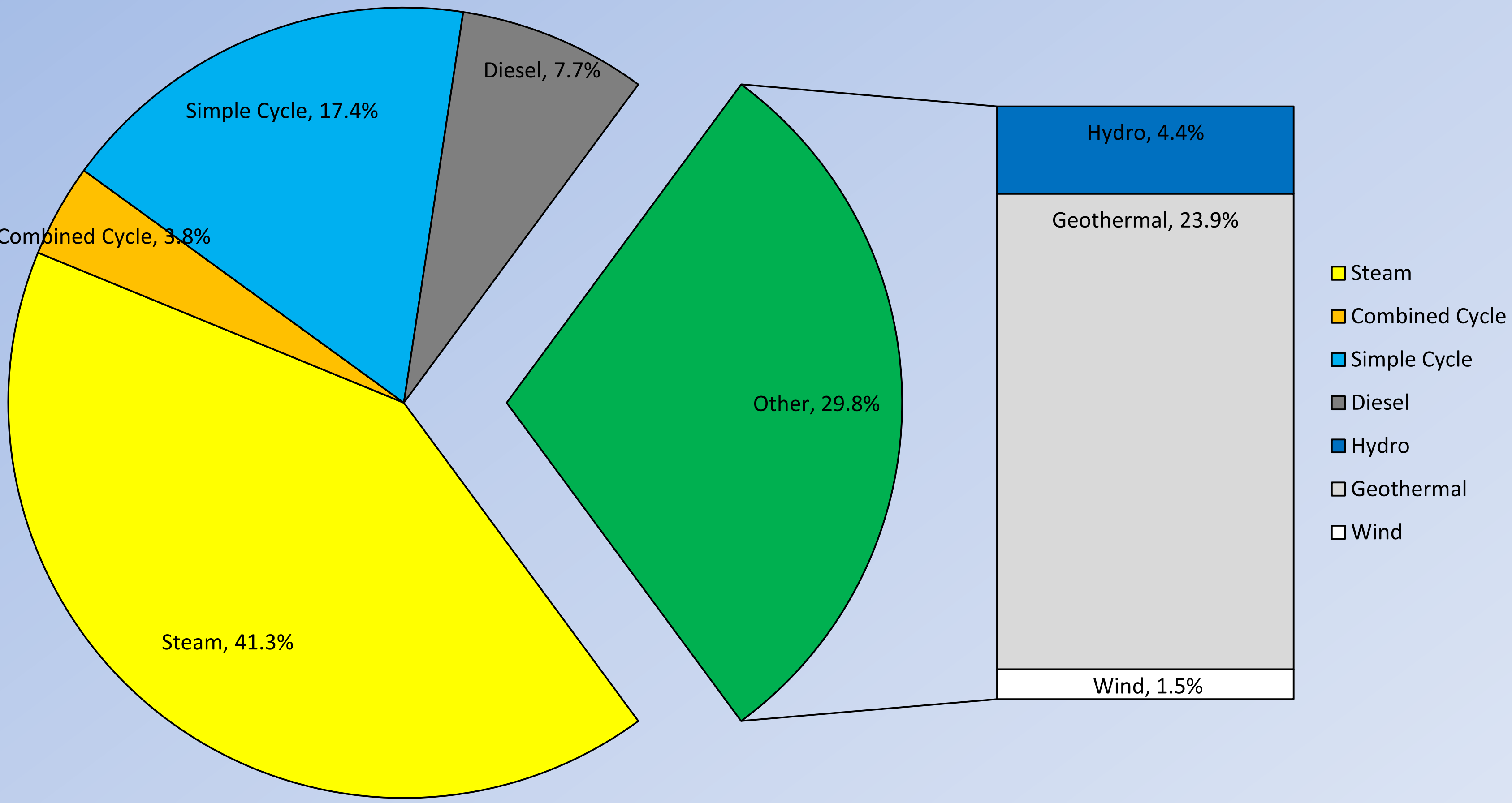
HELCO System Overview (cont'd)

- Generation Capacity (cont'd):
  - Peaking/Emergency Units
    - 2-Simple Cycle Gas Turbines (25MW)
    - 14-Small Diesel Generators (28MW)
  - Reserve Units (Requires >12hrs notice)
    - 2-Small Steam Units (15MW)

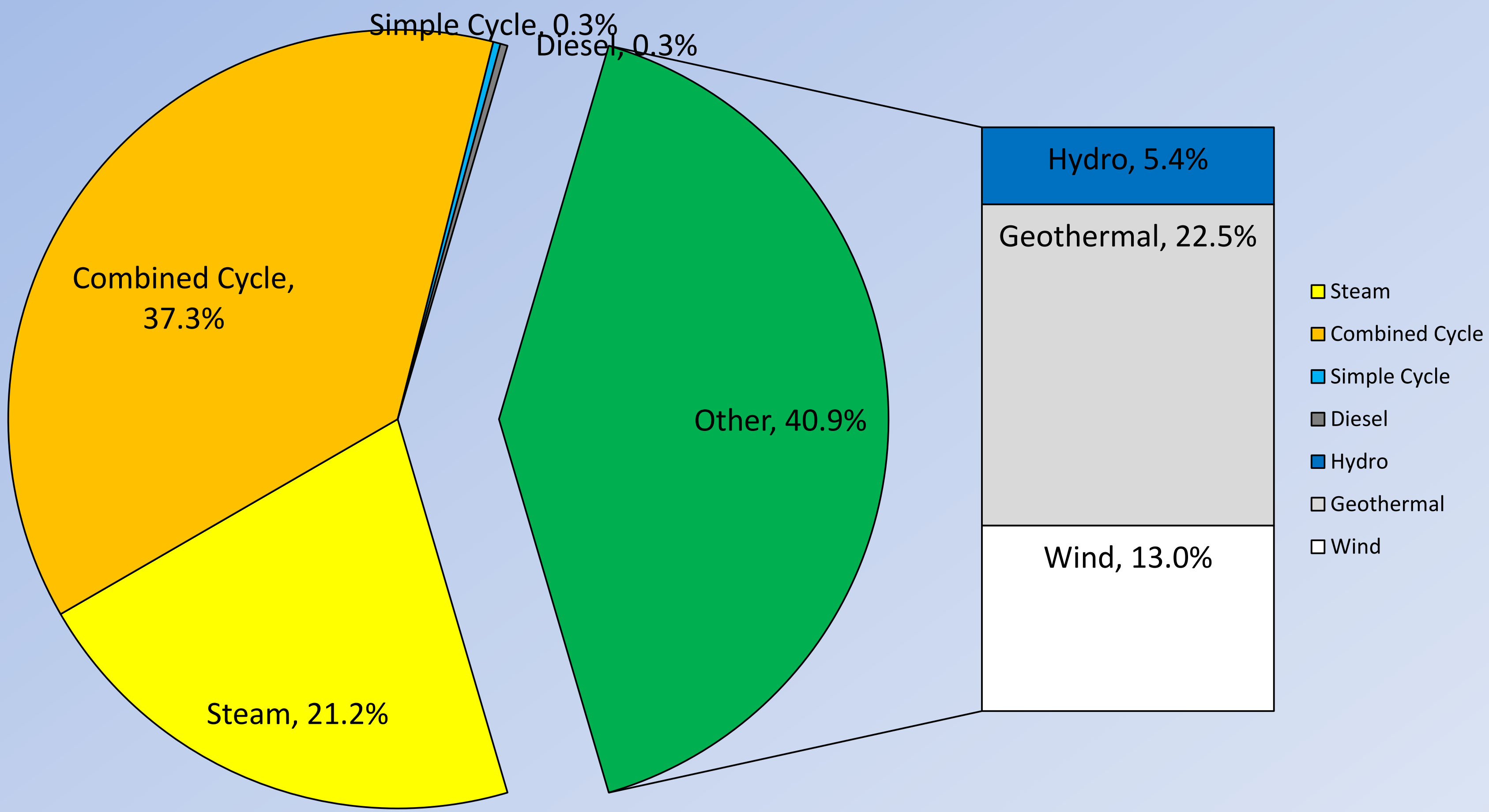
HELCO System Overview (cont’d)

- Generation Capacity (cont’d):
  - Renewable
    - Must-Run unit dispatchable by AGC
      - Geothermal (38MW)
    - Must-Take (As-Available)
      - Wind (30MW)
      - Run-of-River Hydroelectric (15MW)
    - Distributed Generation
      - Feed-In Tariff
      - Net Energy Metering
      - No Sale
      - Schedule Q

2000 Energy Source

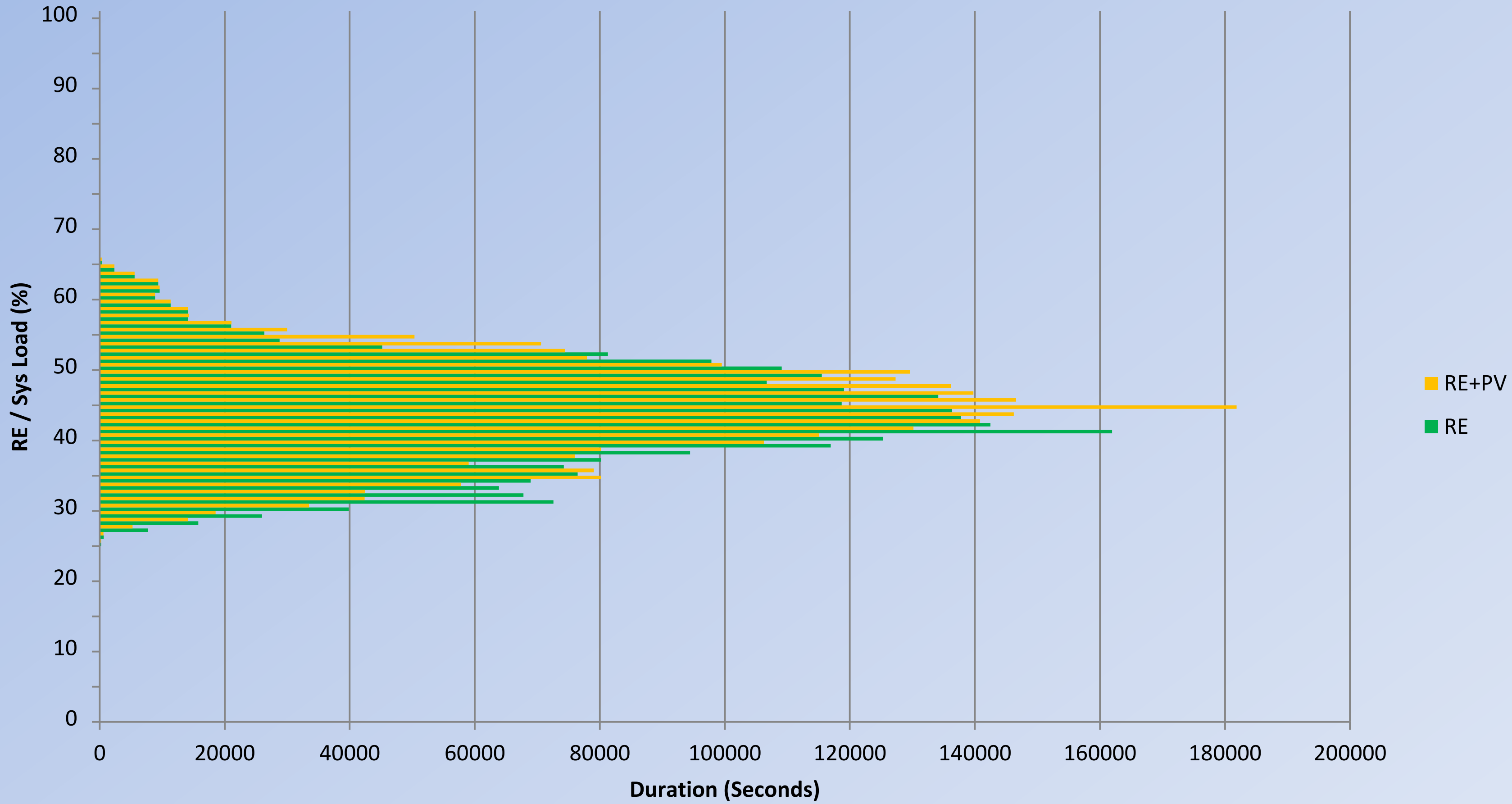


2012 YTD Energy Source

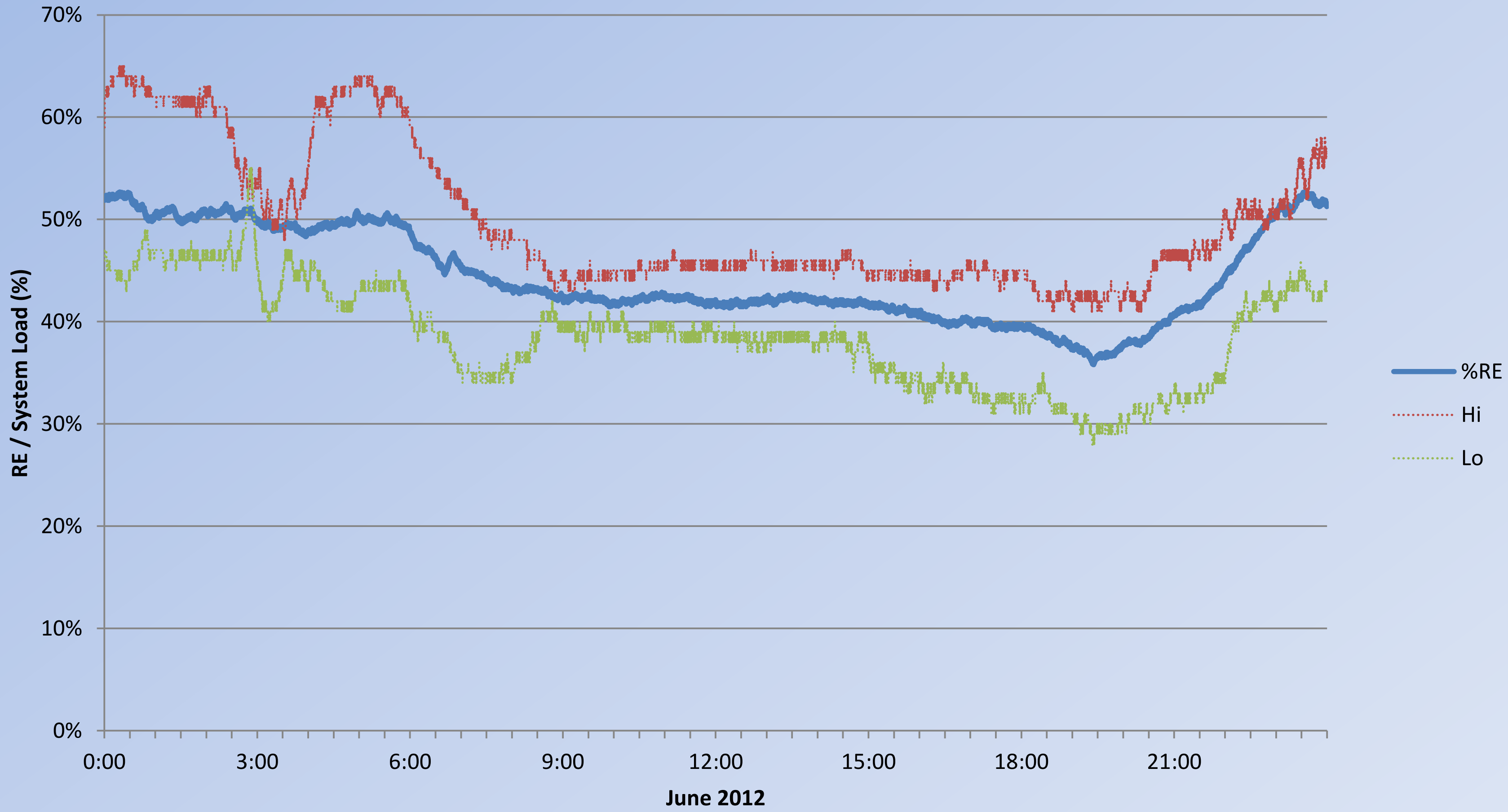


Renewable Energy Percentage Duration

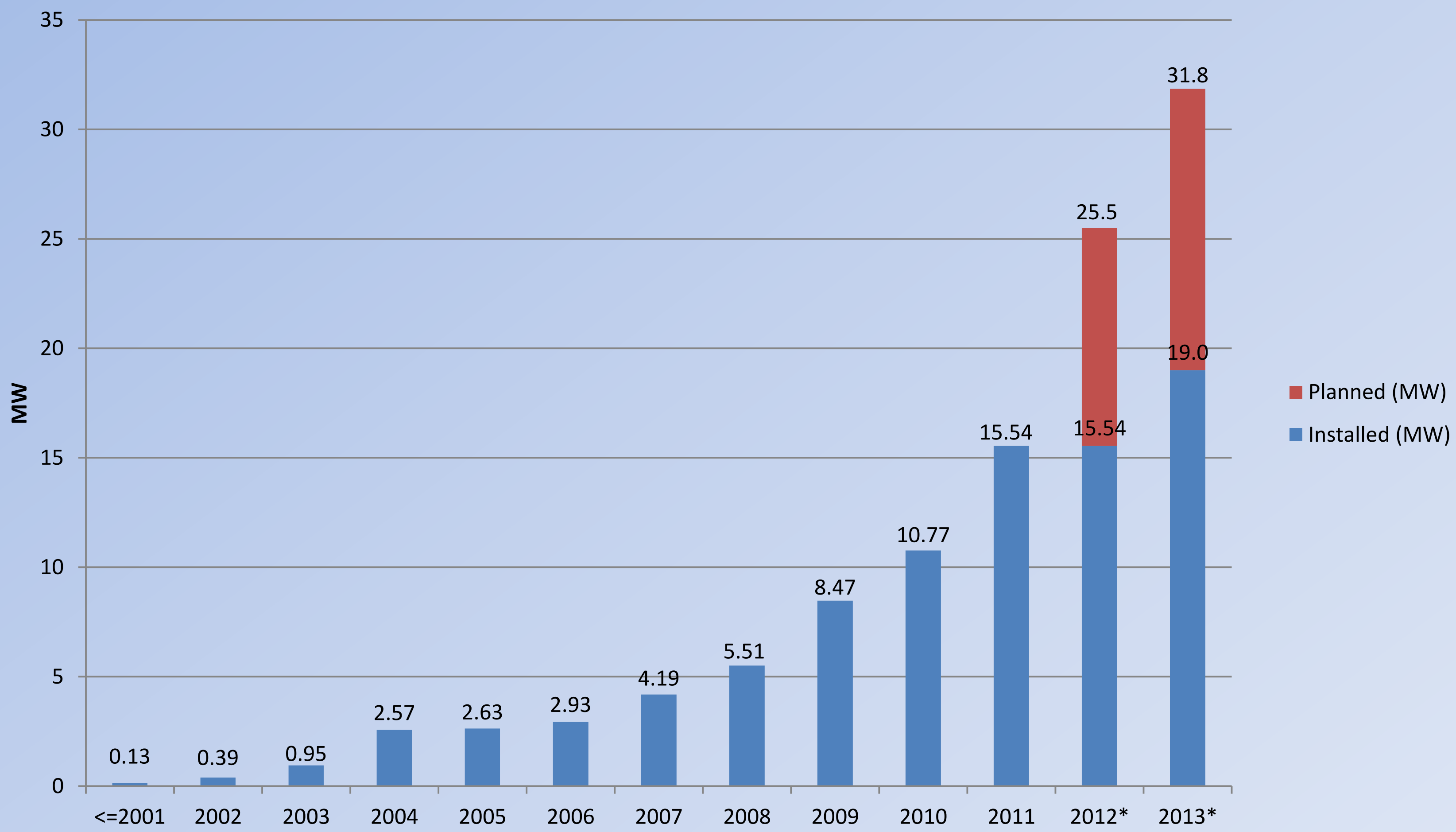
June 2012



Average Daily %RE Profile



Growth of DG (Primarily PV)



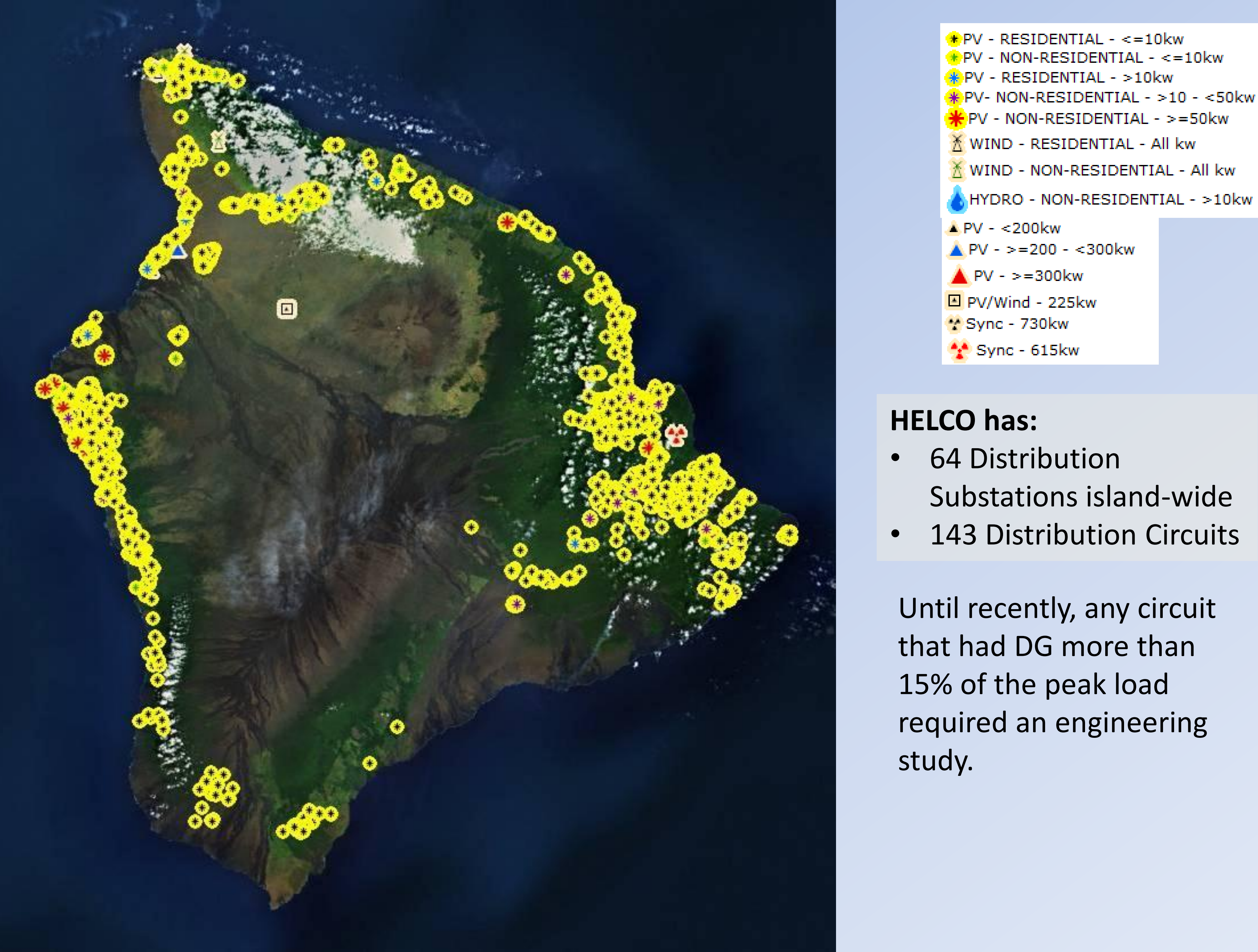
As of August 2012

Distributed Generation

	PV	Hydro	Wind
FIT	250kW	-	-
NEM	13,579kW	49kW	121kW
No Sale (SIA)	3,096kW	-	40kW
Schedule Q	100kW	168kW	-
TOTAL	**17,025kW**	**217kW**	**161kW**

As of August 2012

Challenges of Integrating Solar at the distribution level



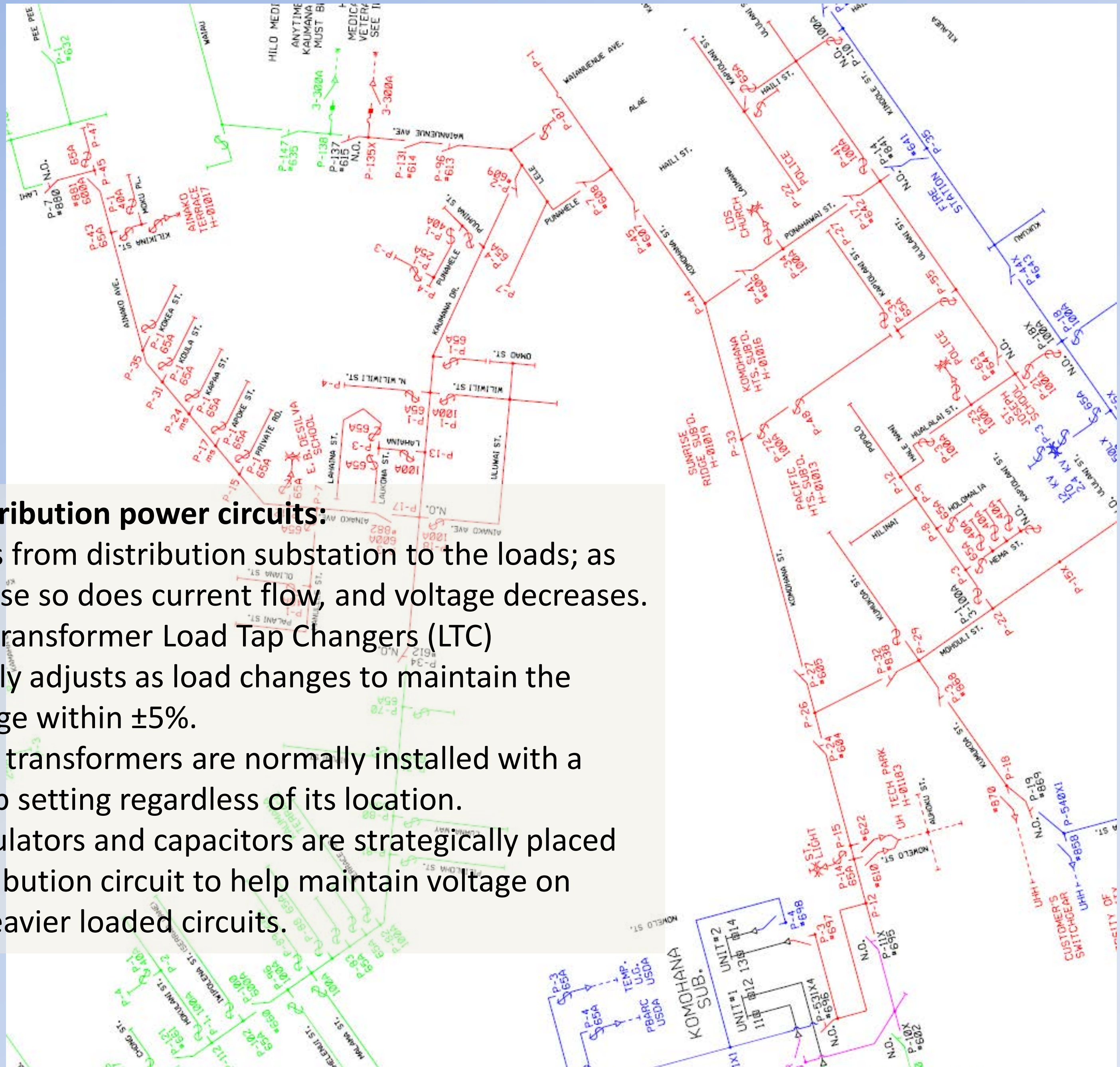
HELCO has:

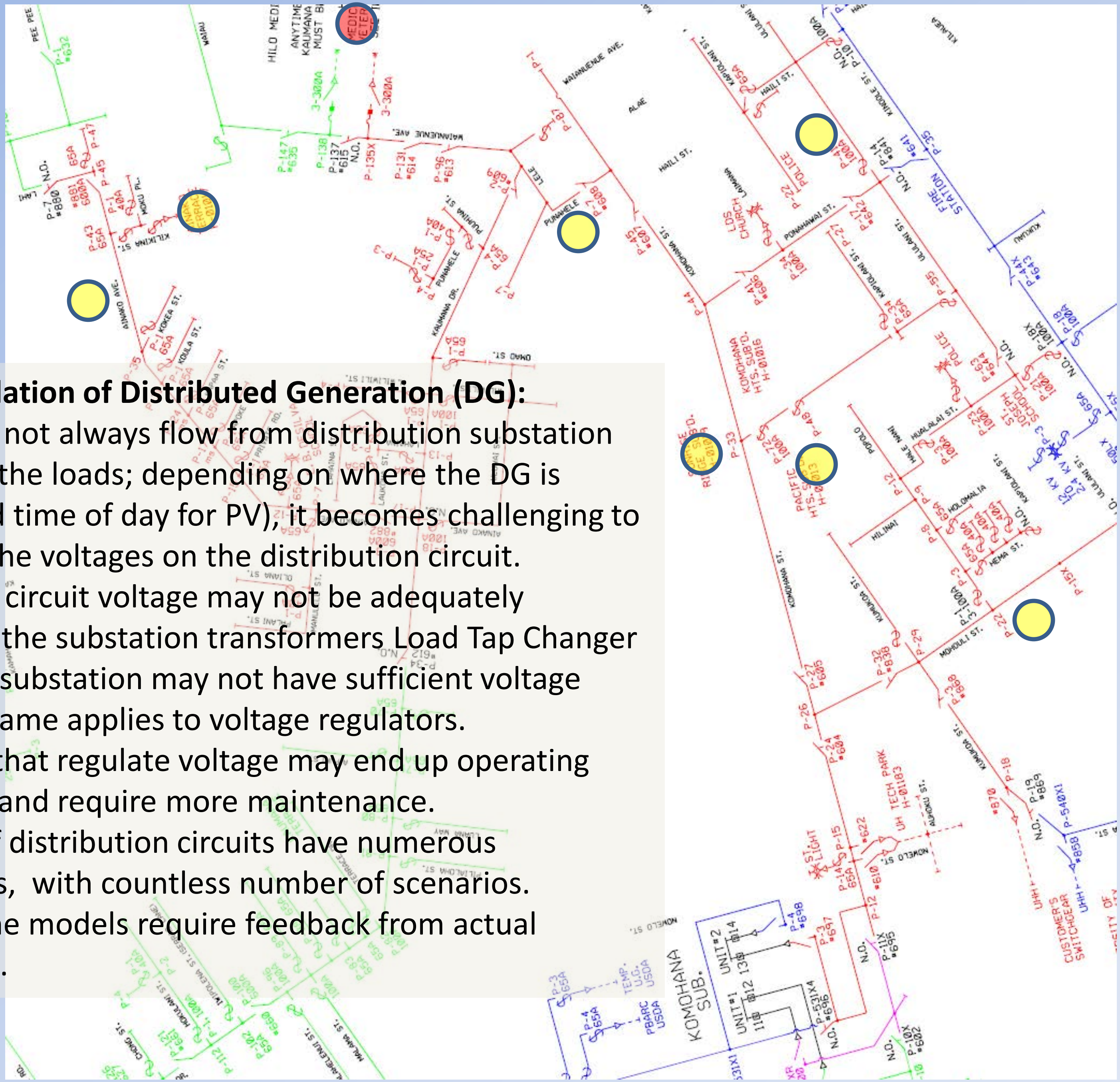
- 64 Distribution Substations island-wide
- 143 Distribution Circuits

Until recently, any circuit that had DG more than 15% of the peak load required an engineering study.

Traditional distribution power circuits:

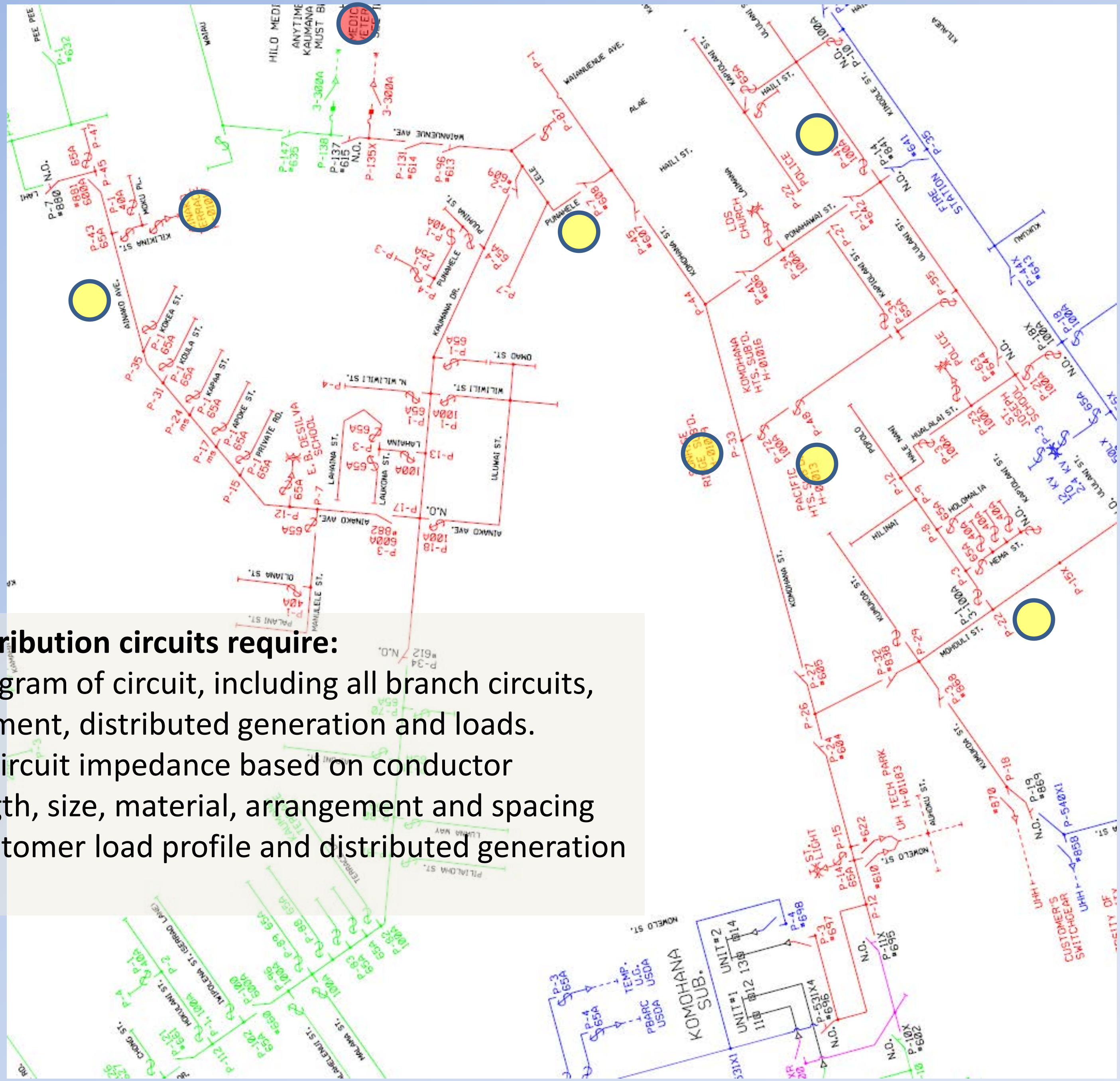
- Power flows from distribution substation to the loads; as loads increase so does current flow, and voltage decreases.
- Substation transformer Load Tap Changers (LTC) automatically adjusts as load changes to maintain the circuit voltage within ±5%.
- Distribution transformers are normally installed with a common tap setting regardless of its location.
- Voltage regulators and capacitors are strategically placed on the distribution circuit to help maintain voltage on longer or heavier loaded circuits.





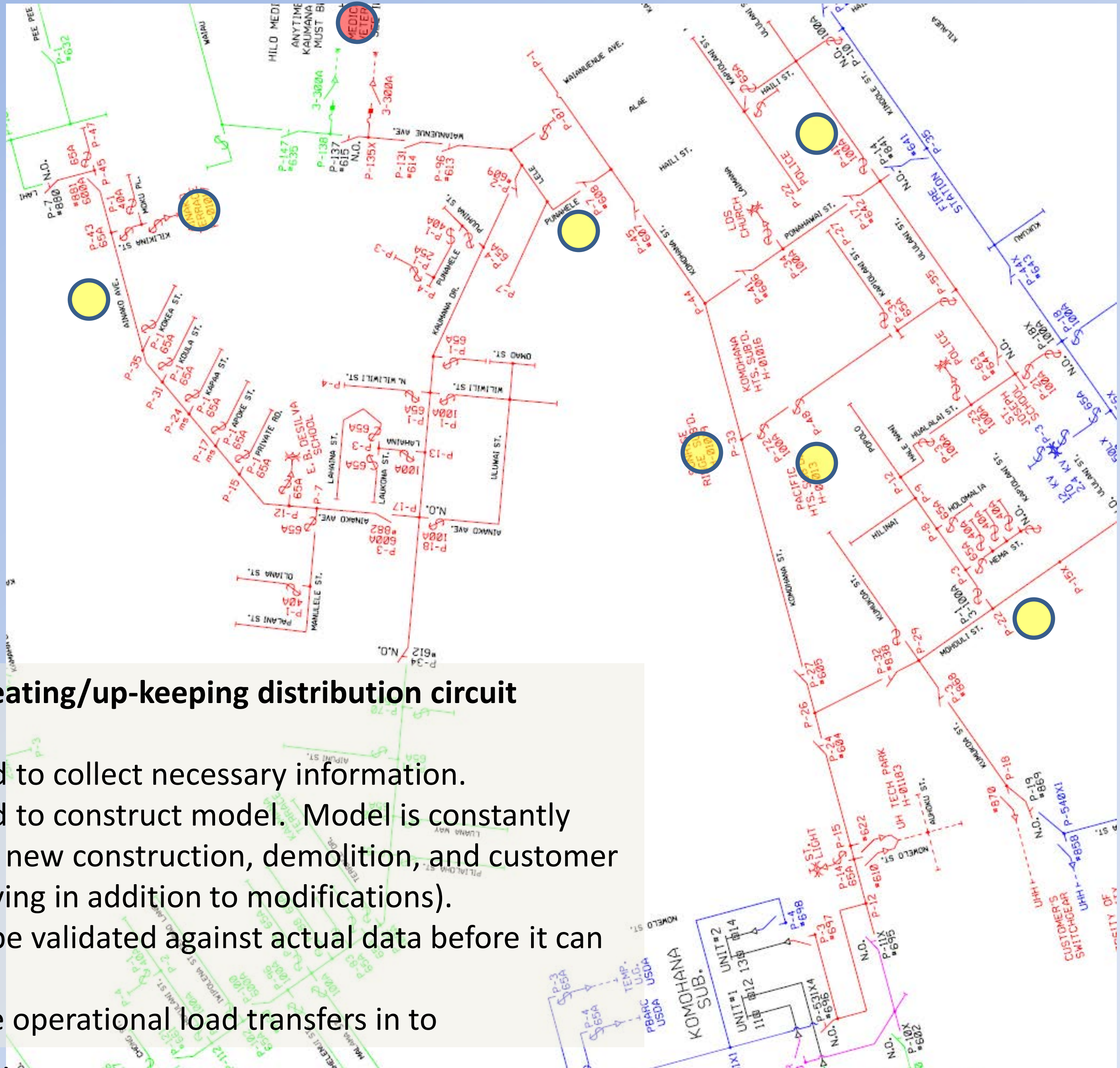
With the installation of Distributed Generation (DG):

- Power does not always flow from distribution substation breakers to the loads; depending on where the DG is located (and time of day for PV), it becomes challenging to determine the voltages on the distribution circuit.
- Distribution circuit voltage may not be adequately adjusted by the substation transformers Load Tap Changer (LTC) as the substation may not have sufficient voltage feedback. Same applies to voltage regulators.
- Equipment that regulate voltage may end up operating more often and require more maintenance.
- Modeling of distribution circuits have numerous assumptions, with countless number of scenarios.
- Testing of the models require feedback from actual installations.



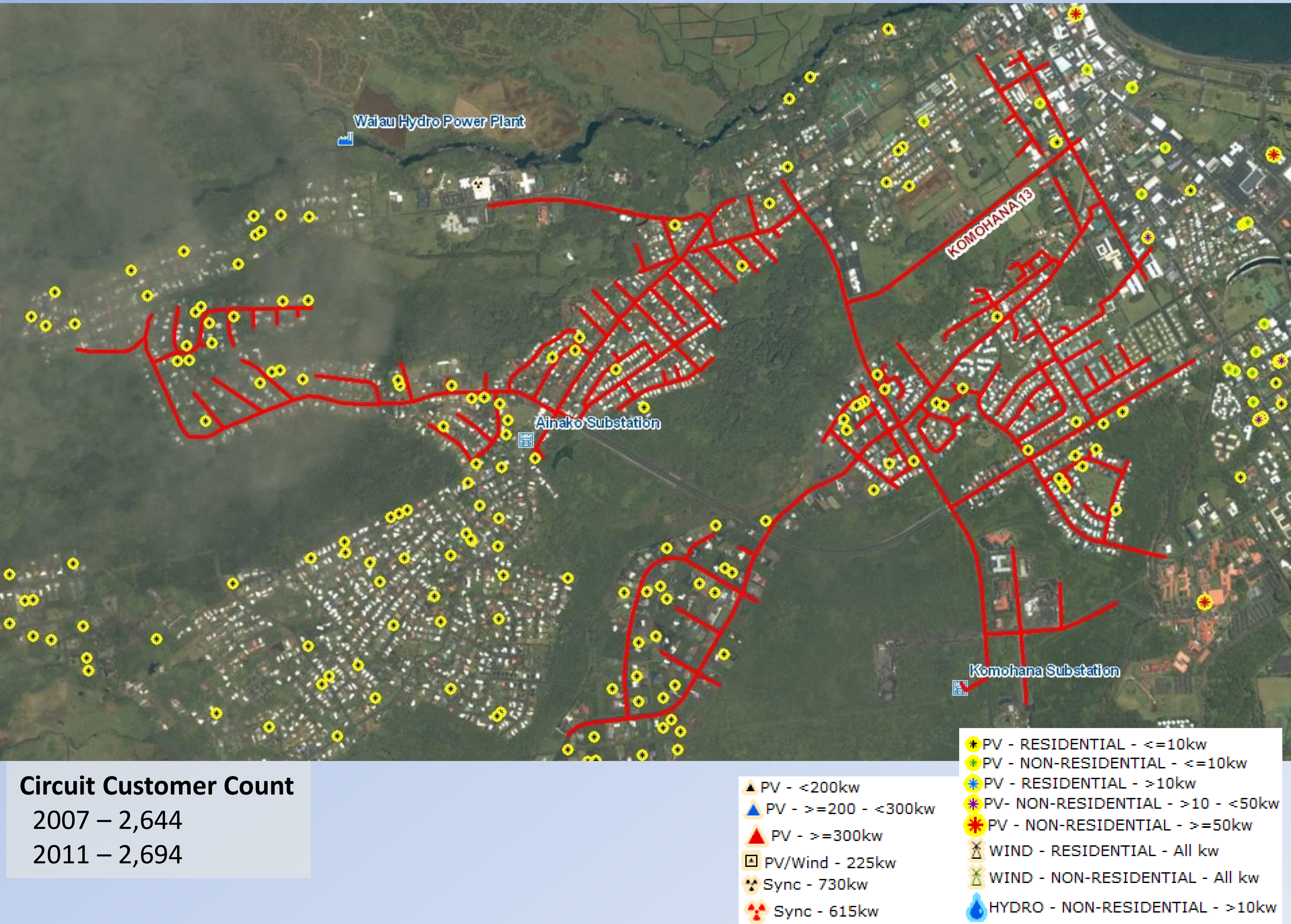
Modeling of distribution circuits require:

- Complete diagram of circuit, including all branch circuits, power equipment, distributed generation and loads.
- Distribution circuit impedance based on conductor quantity, length, size, material, arrangement and spacing
- Model of customer load profile and distributed generation resource.



Challenges of creating/up-keeping distribution circuit models:

- Time required to collect necessary information.
- Time required to construct model. Model is constantly evolving with new construction, demolition, and customer changes (moving in addition to modifications).
- Model must be validated against actual data before it can be accepted.
- Does not take operational load transfers in to consideration.

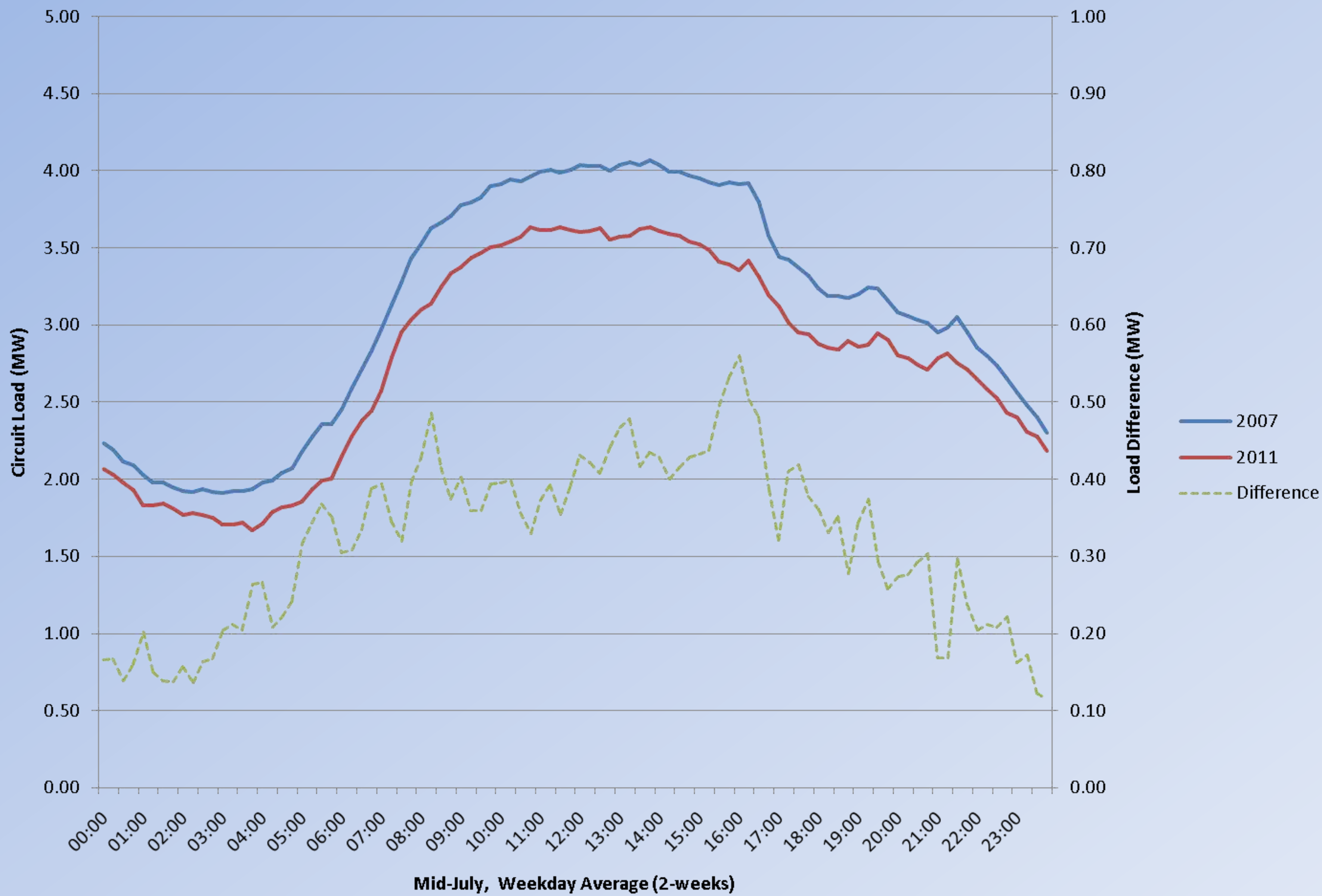


Circuit Customer Count

2007 – 2,644

2011 – 2,694

Distribution Circuit Load



System Issues due to large levels of Renewable Energy

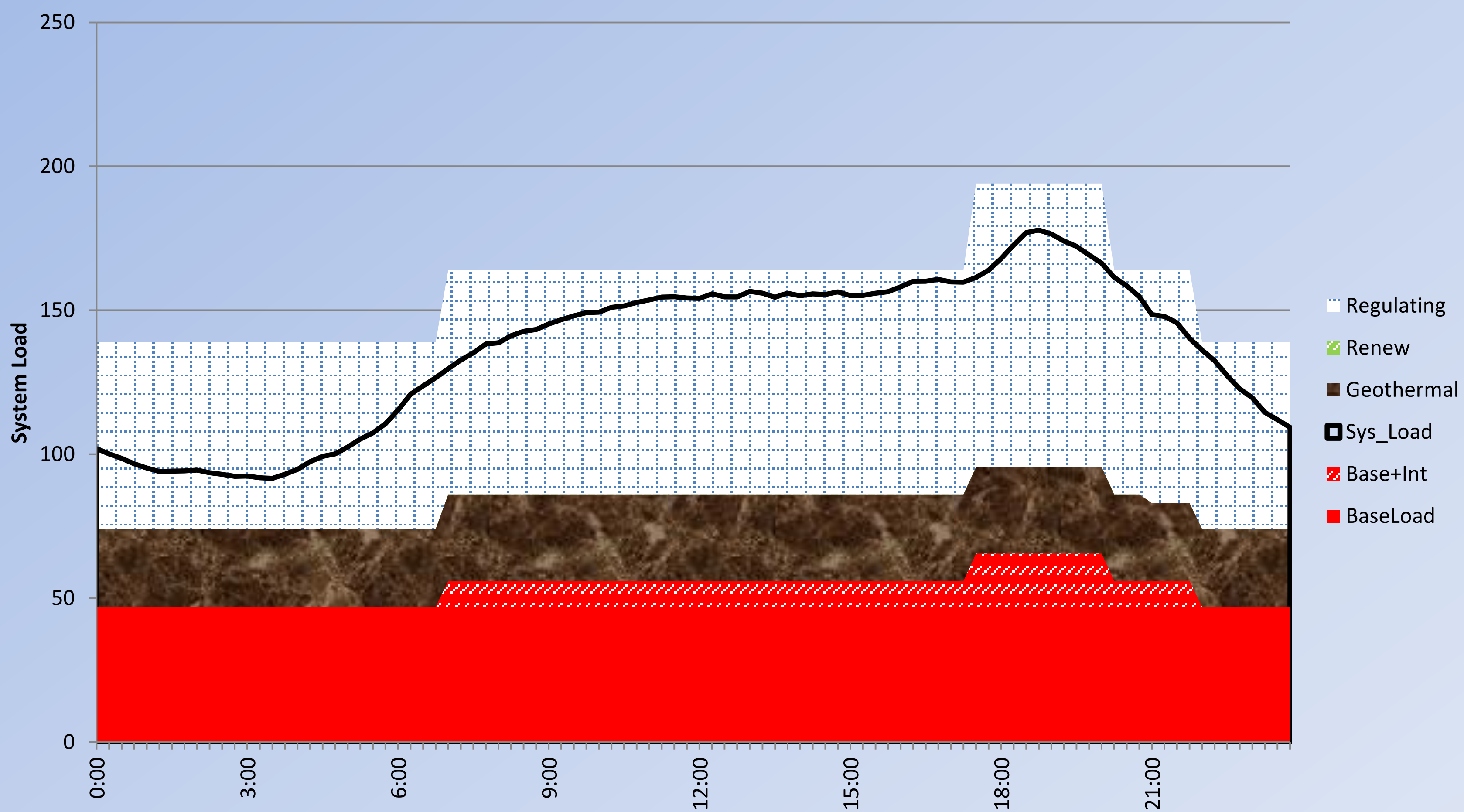
Renewable Energy Impacts To HELCO System

- System Load Reduction
  - Operating traditional units at less efficient levels.
  - Traditional units are forced to deep cycle and/or shut down.
  - Adds challenge to incorporate new renewable energy.
- Challenges in forecasting System Loads
  - It is unknown how much power is generated by the DG at anytime.
  - Errors cause over or under commitment of units.

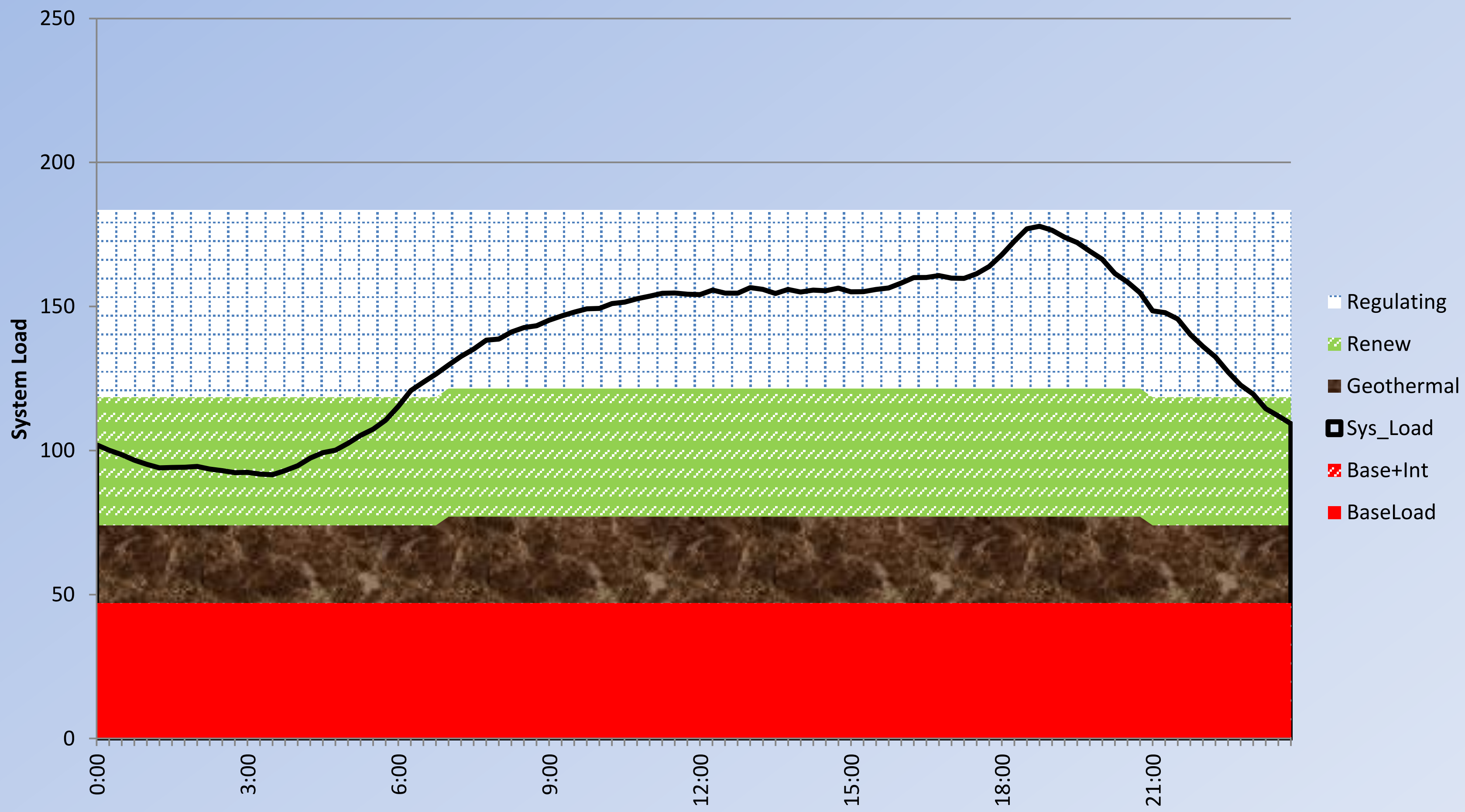
Renewable Energy Impacts To HELCO System (cont'd)

- Adds another variable when restoring power, and could be very problematic when restoring from an island-wide outage.
- As penetration becomes greater, there may be other unintended consequences (risks).

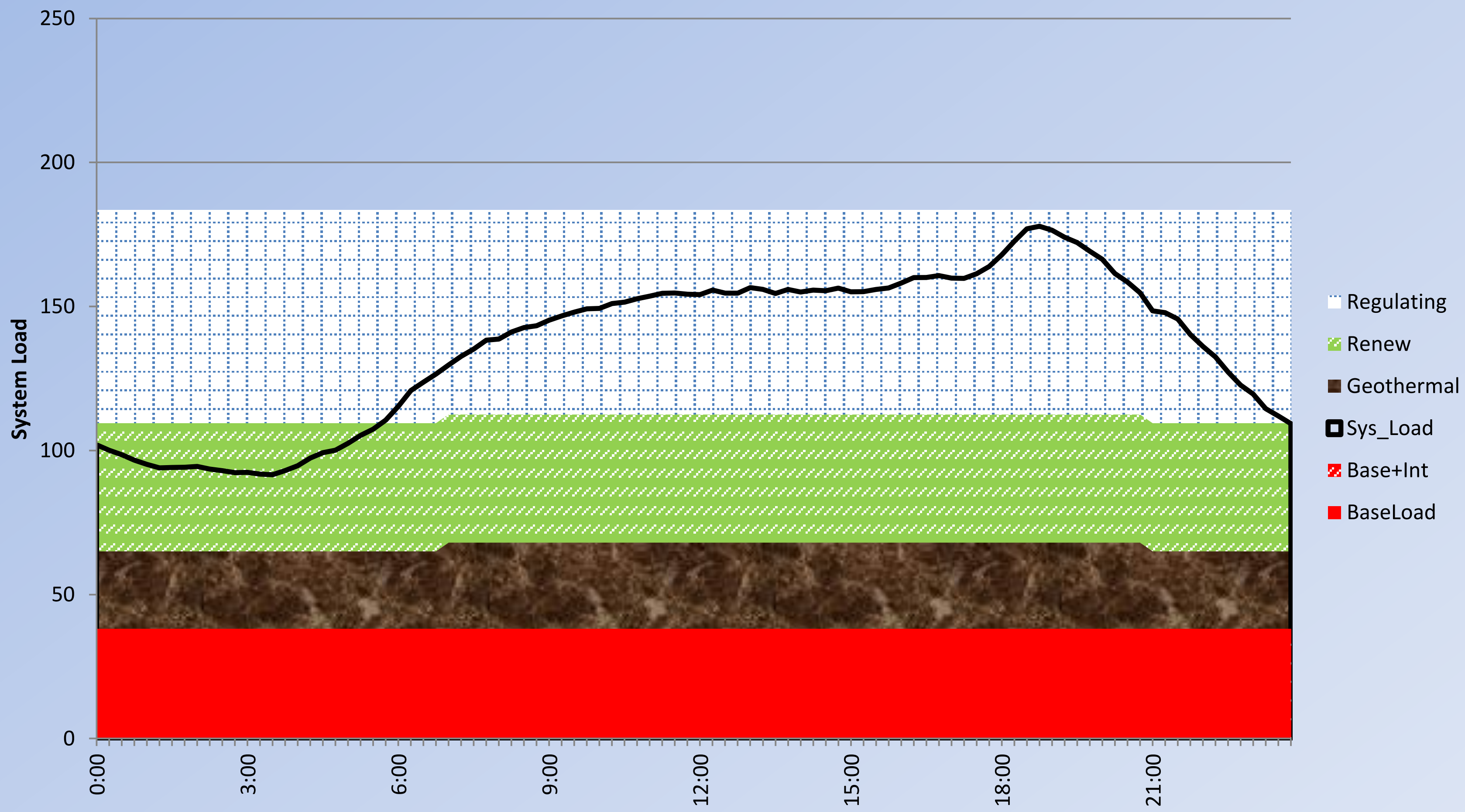
Generation and Load
Low Amount of Must-Take



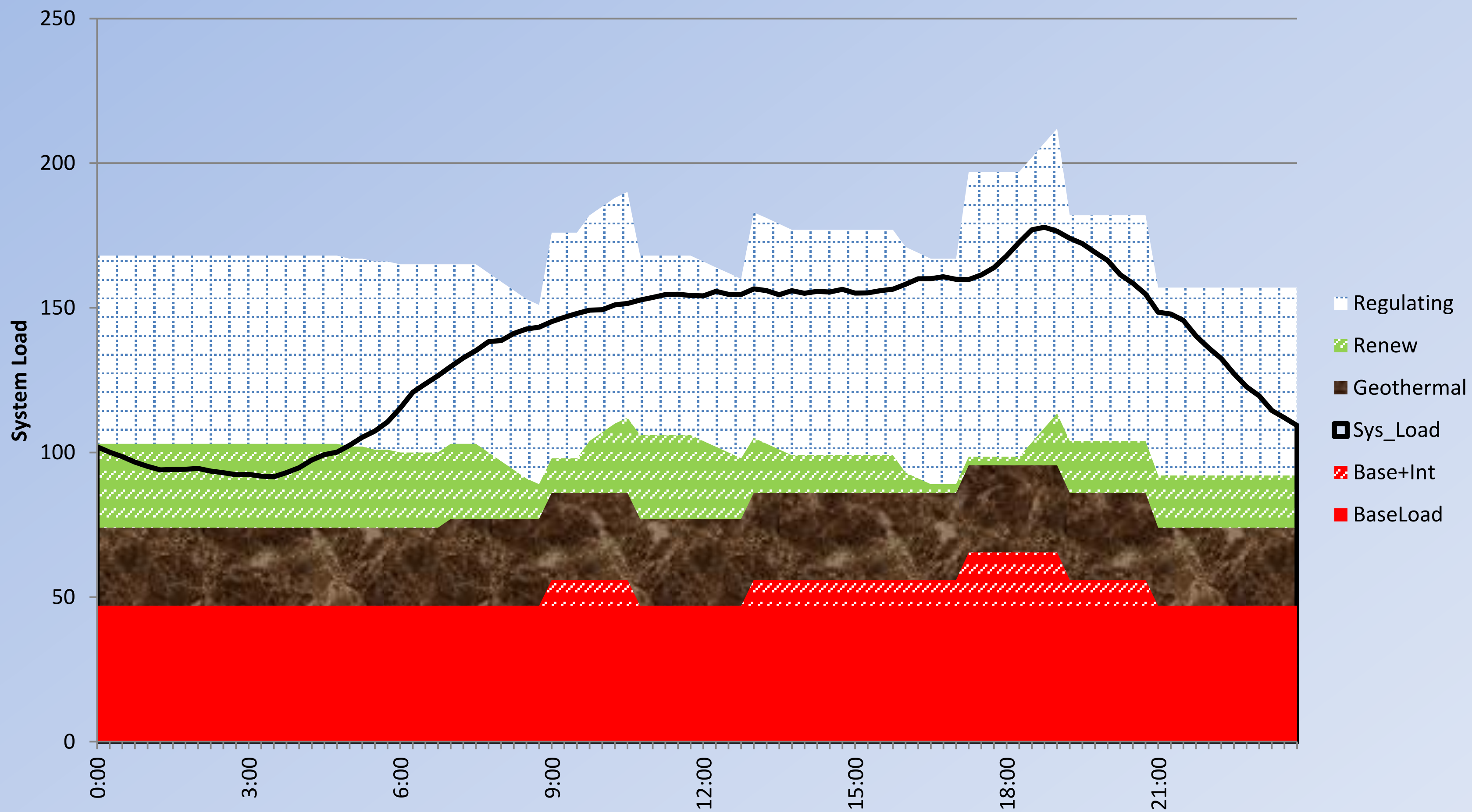
Generation and Load
High Amount of Must-Take



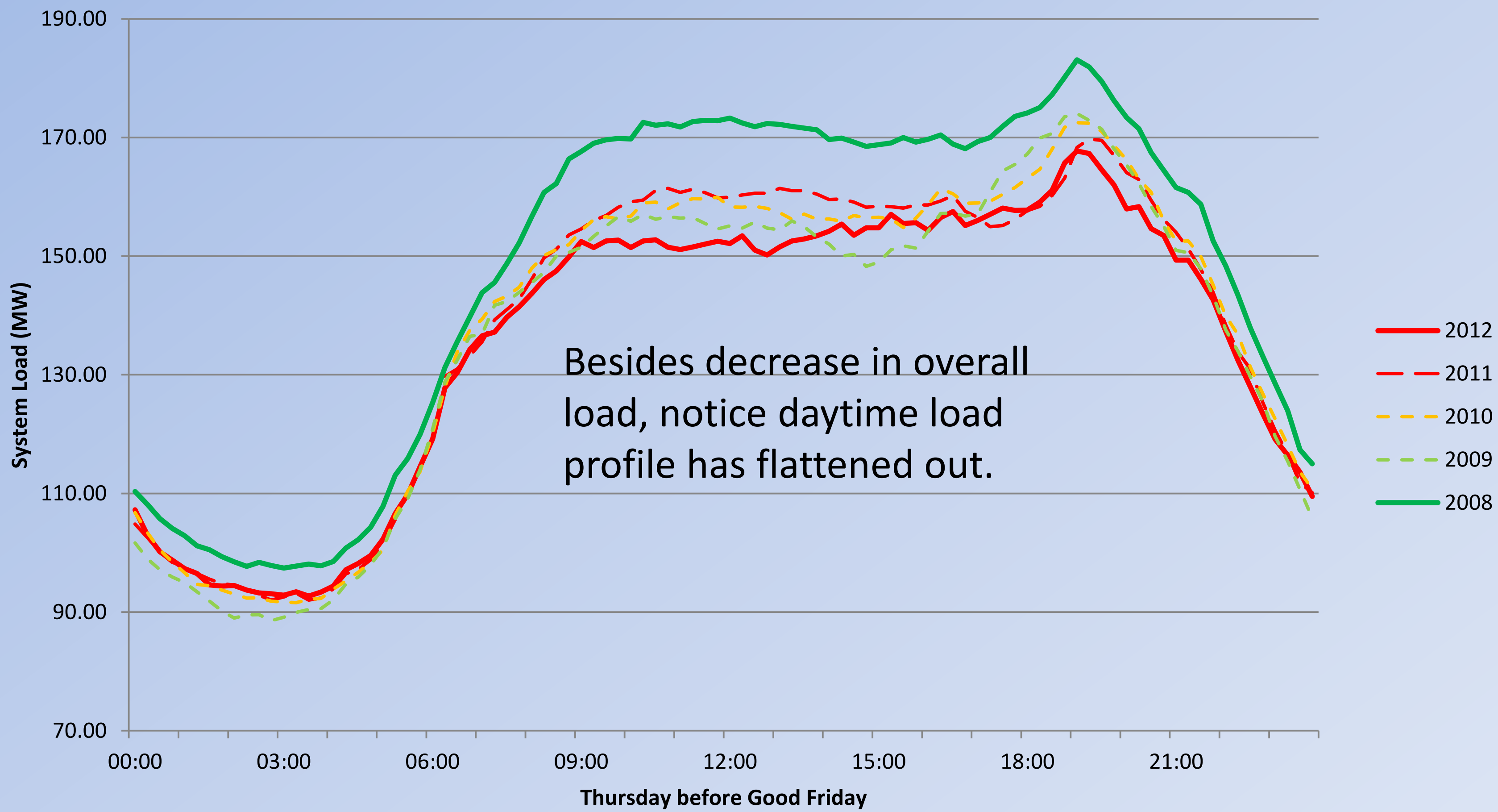
Generation and Load
Lower Minimum Loads on Must Run



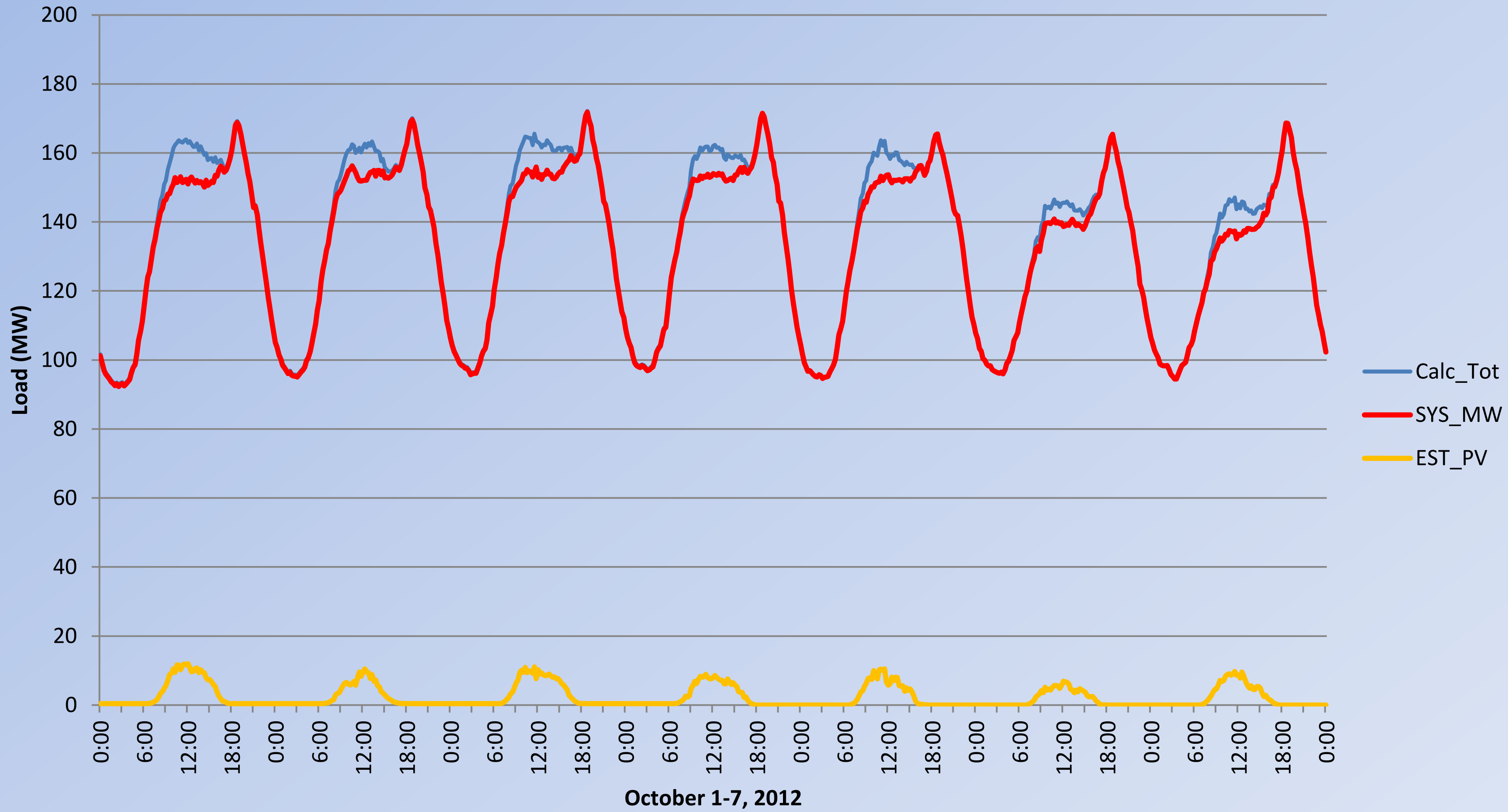
Generation and Load
Variable Winds/Commitment Errors



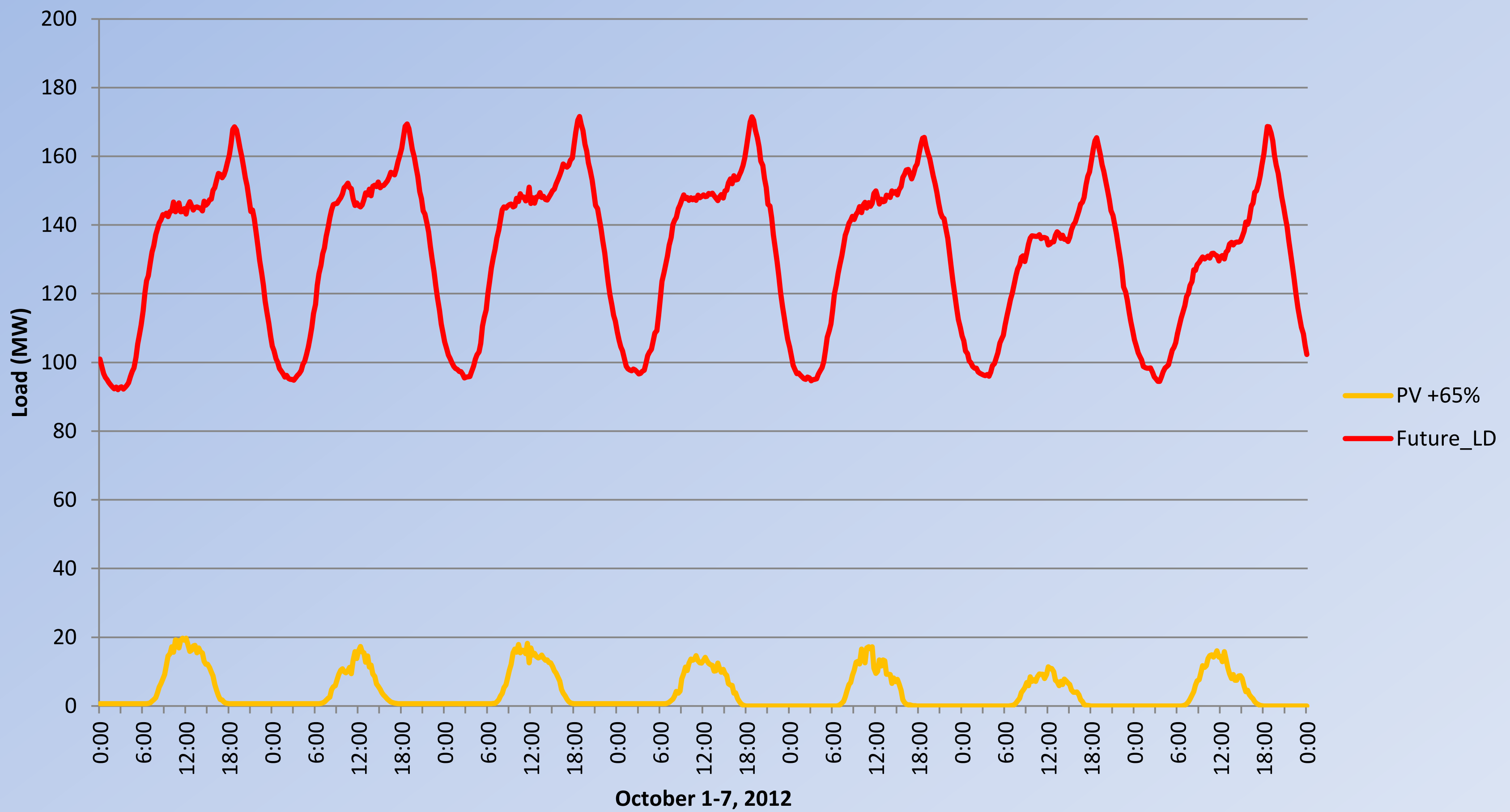
Load Change over past 5 years



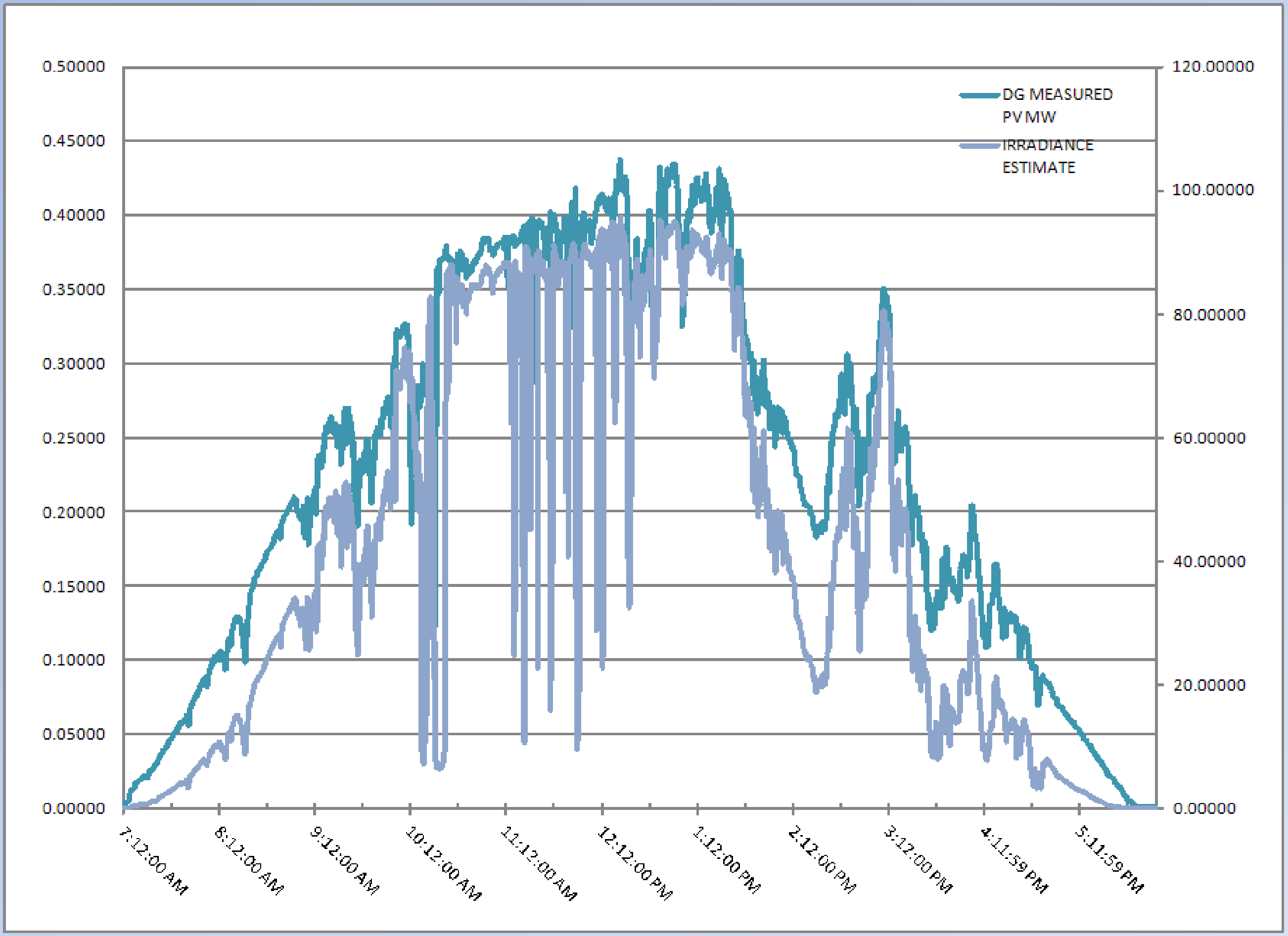
Current Load Profile with estimated PV load added



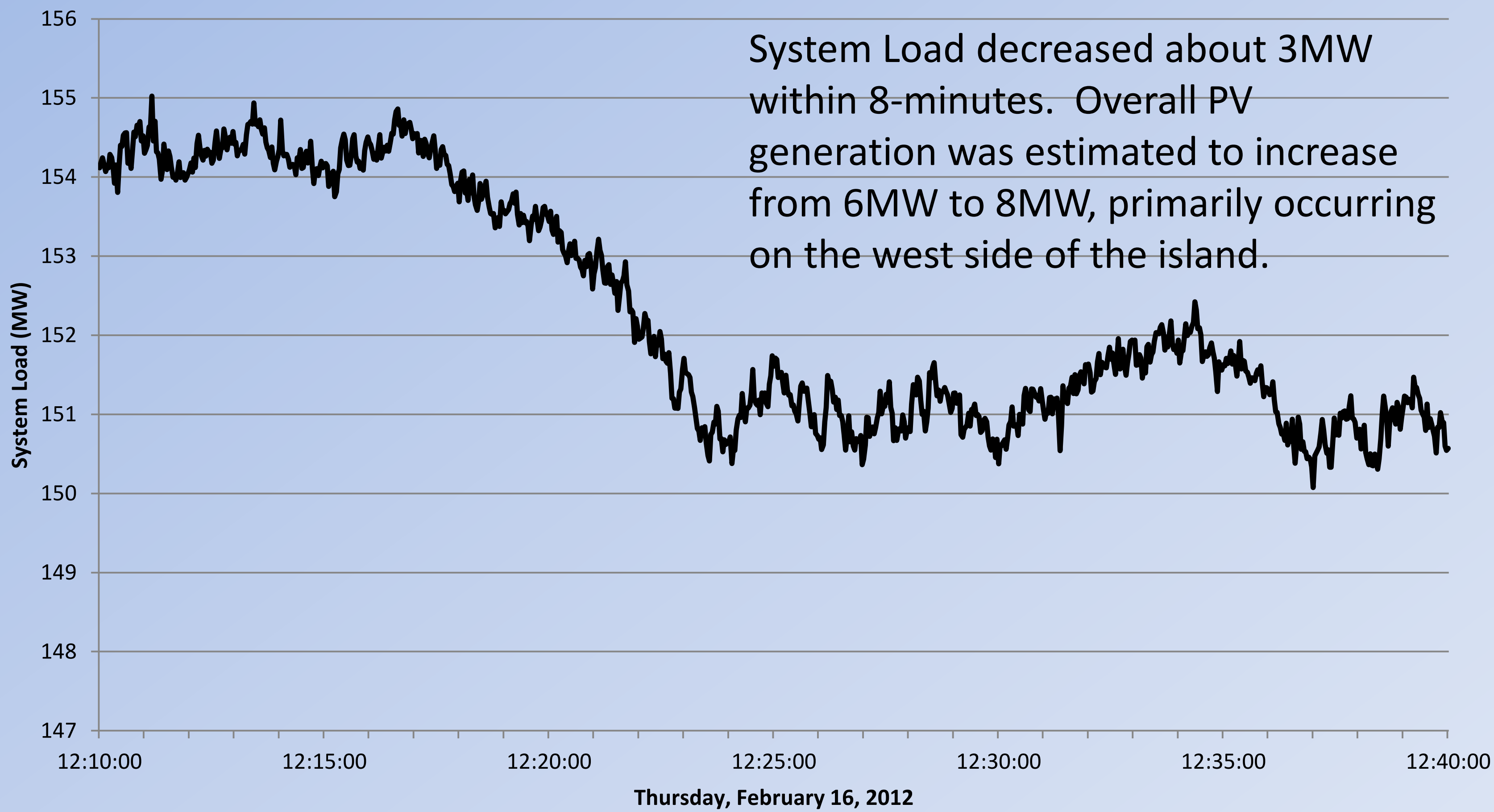
Extrapolated Load profile with 28.2MW (+65%) PV



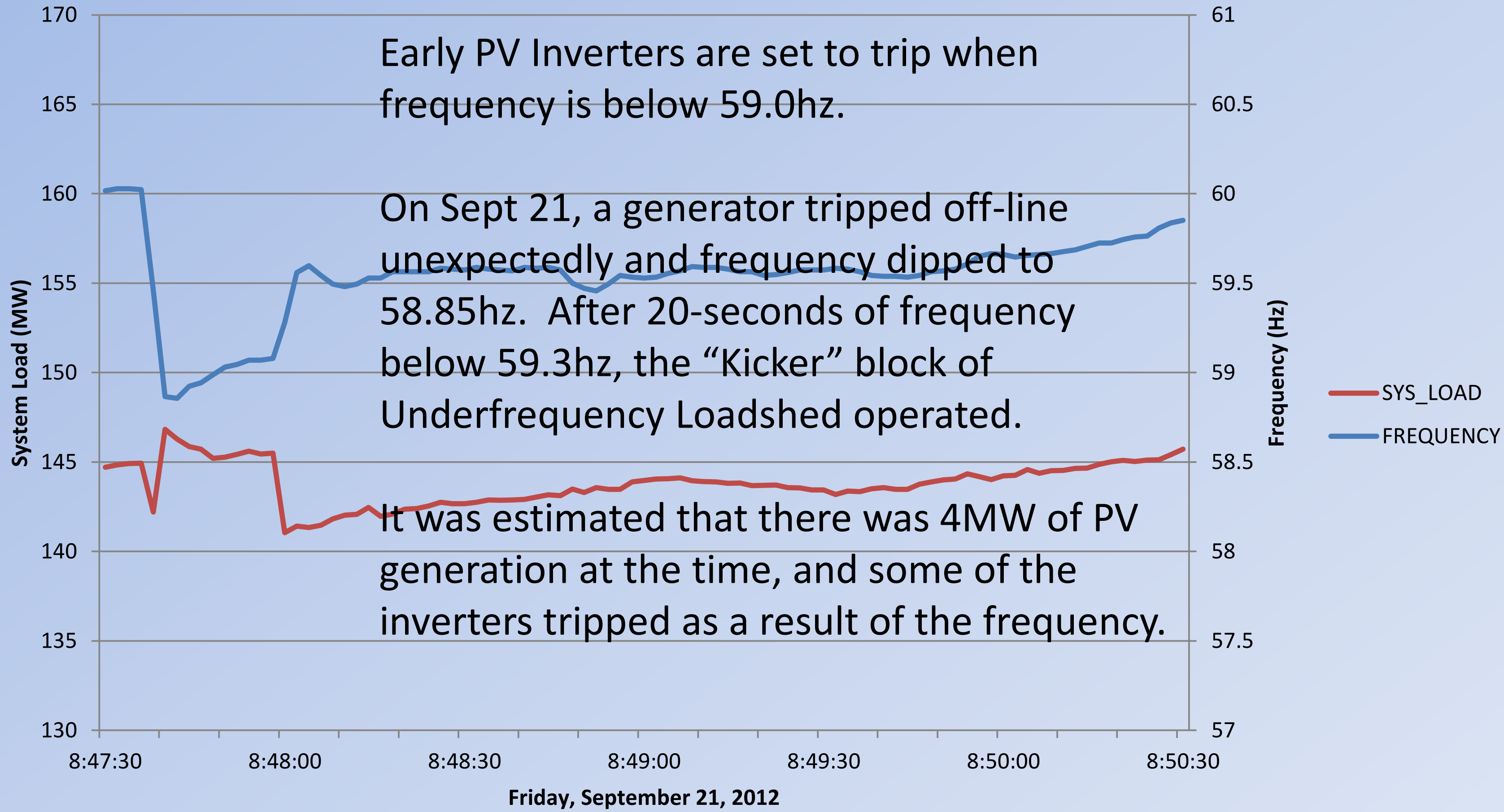
Variability of Solar



Unexpected Fast Change in System Load



Frequency Disturbance

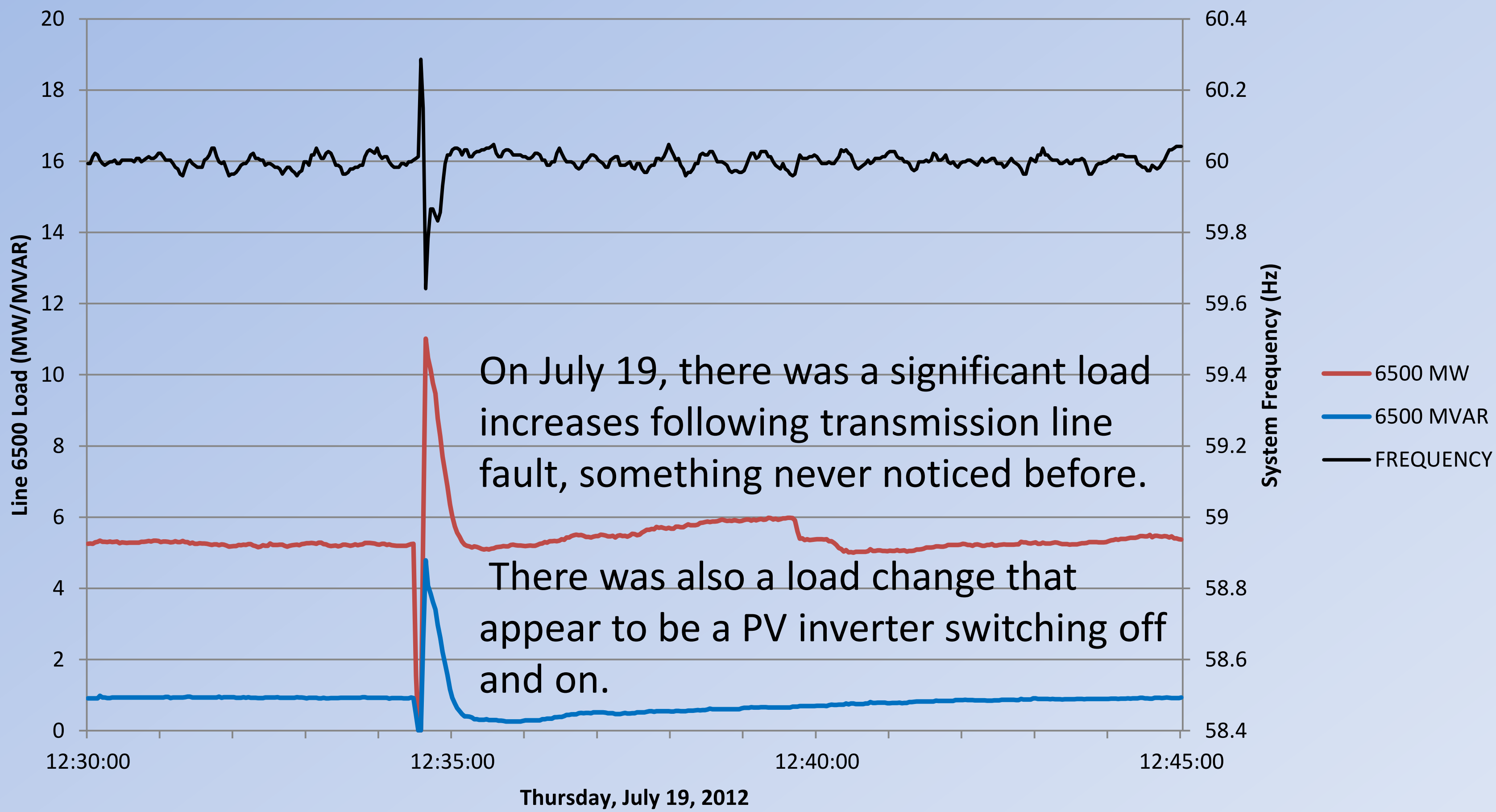


Early PV Inverters are set to trip when frequency is below 59.0hz.

On Sept 21, a generator tripped off-line unexpectedly and frequency dipped to 58.85hz. After 20-seconds of frequency below 59.3hz, the “Kicker” block of Underfrequency Loadshed operated.

It was estimated that there was 4MW of PV generation at the time, and some of the inverters tripped as a result of the frequency.

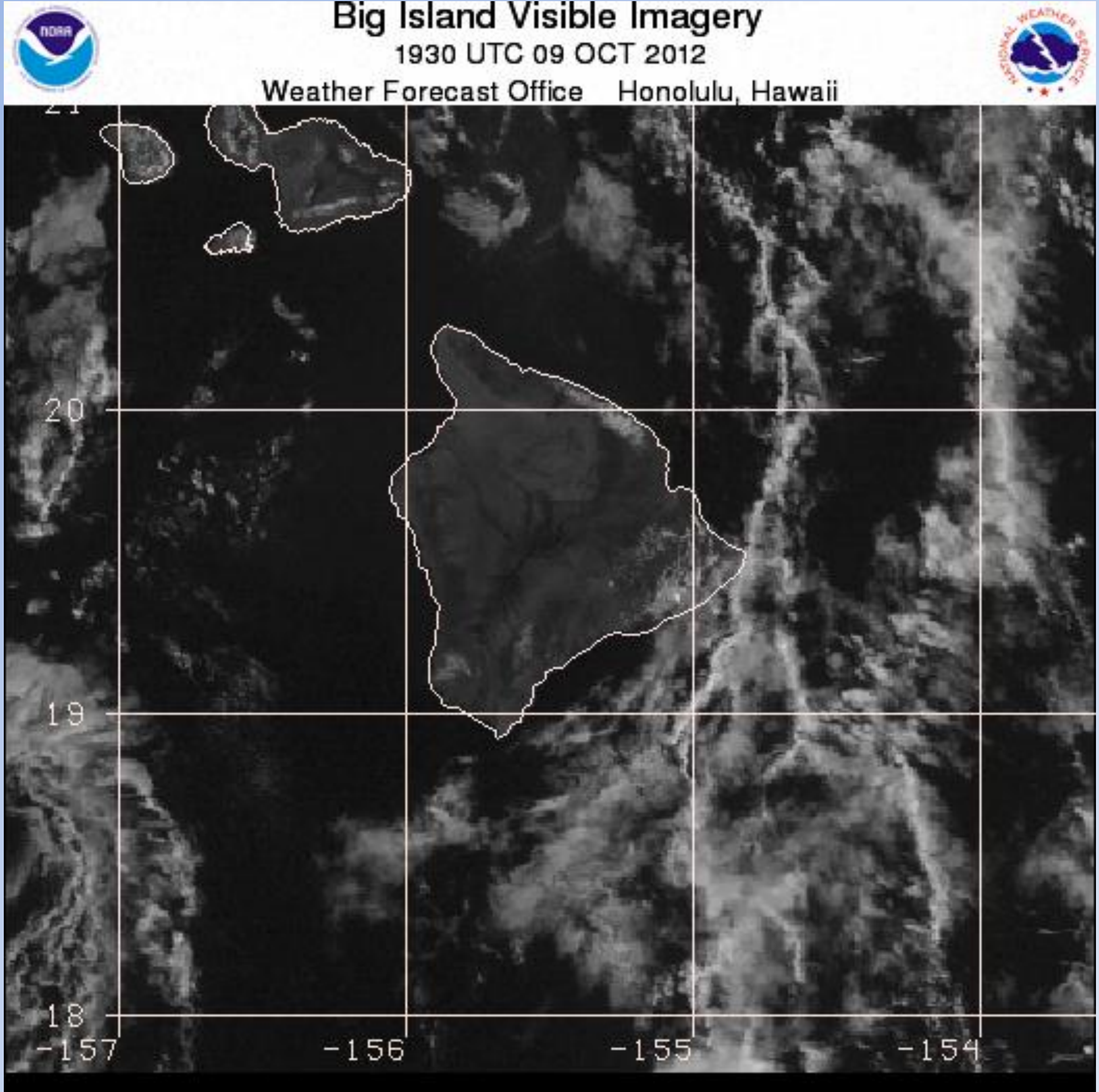
Momentary Interruption of Power



On July 19, there was a significant load increases following transmission line fault, something never noticed before.

There was also a load change that appear to be a PV inverter switching off and on.

Estimated 400kW PV generated
At the time.



Big Island Visible Imagery
1930 UTC 09 OCT 2012
Weather Forecast Office Honolulu, Hawaii
20
19
18
-157
-156
-155
-154

How to Mitigate Impacts

- Be informed of the risks: Perform a System Impact Study that will at a minimum examine:
  - Fault analysis / System stability
  - Equipment protection coordination
  - System frequency response
  - Unit Cycling Analysis
  - Generation reserve requirements
  - Forecasting strategies

Other Considerations

- DG Standards review/updates.
- Costs for making changes to DG equipment if it becomes necessary.
- Excess energy / Curtailment policies and procedures.


Questions?


Have a nice day!