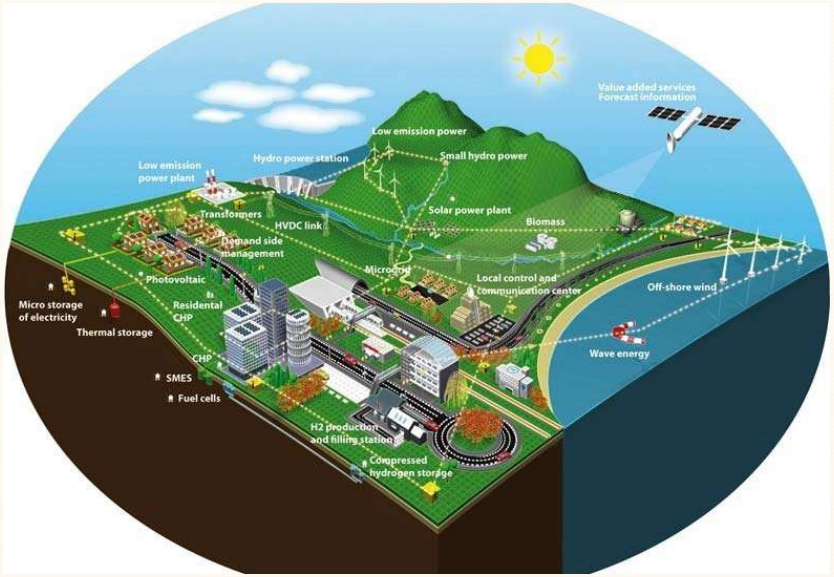
Integration of Renewable & Distributed Energy Resources



Staci Sadoyama

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Honolulu, Hawaii 96822

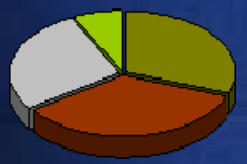
7th International Conference on Integration of Renewable and Distributed Energy Resources

Niagara Falls, Ontario
October 24-28, 2016

Hawaii's isolation poses serious risks ….

Nearly 90% of Hawaii's energy is met using *fossil fuels*

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



GASOLINE/ MARINE FUEL	34%
ELECTRICITY	28%
JET FUEL	27%
OTHER	11%

Risks to our

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

US Dept of State Geographer
© 2013 Google
Image © 2013 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

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High Electricity Price and Volatility Linked to Overdependence and Cost of Oil

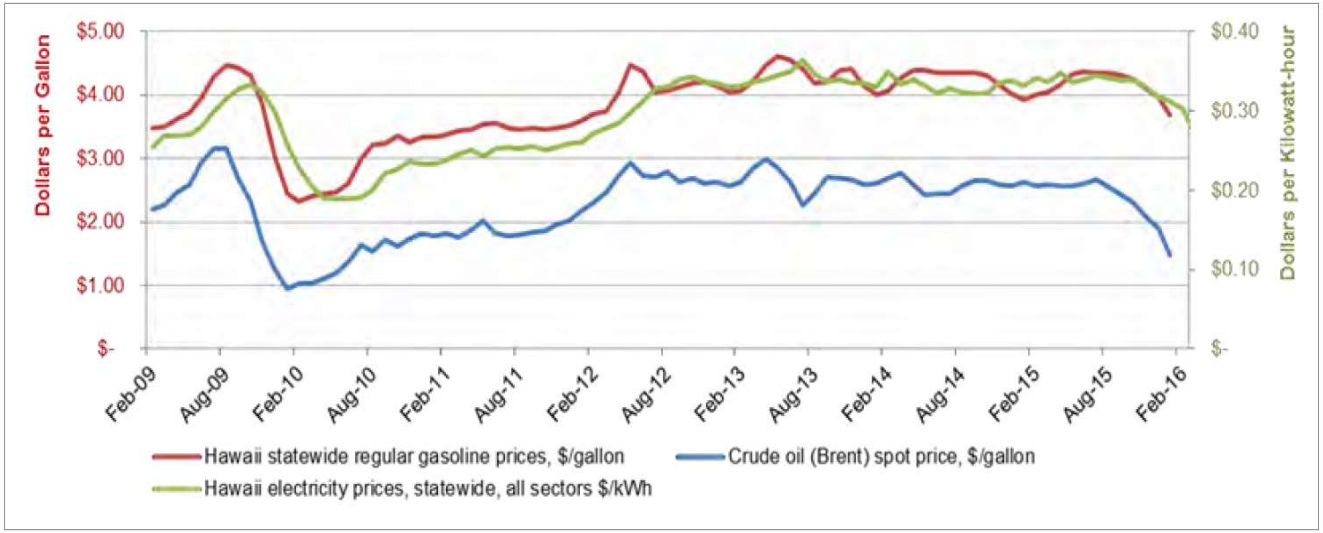
High Cost of Service

Hawaii ranks #1 in US electric energy costs:

45.85 cents/kWh Lanai
47.06 cents/kWh Molokai
41.89 cents/kWh Hawaii
37.83 cents/kWh Maui
35.48 cents/kWh Oahu
(Avg. Residential rates in **2014**)

11 - 12 cents/kWh U.S. avg.

Source: Hawaiian Electric Company and Hawaii DBEDT



Renewable Energy Aimed to "Break the Link" and Lower Cost

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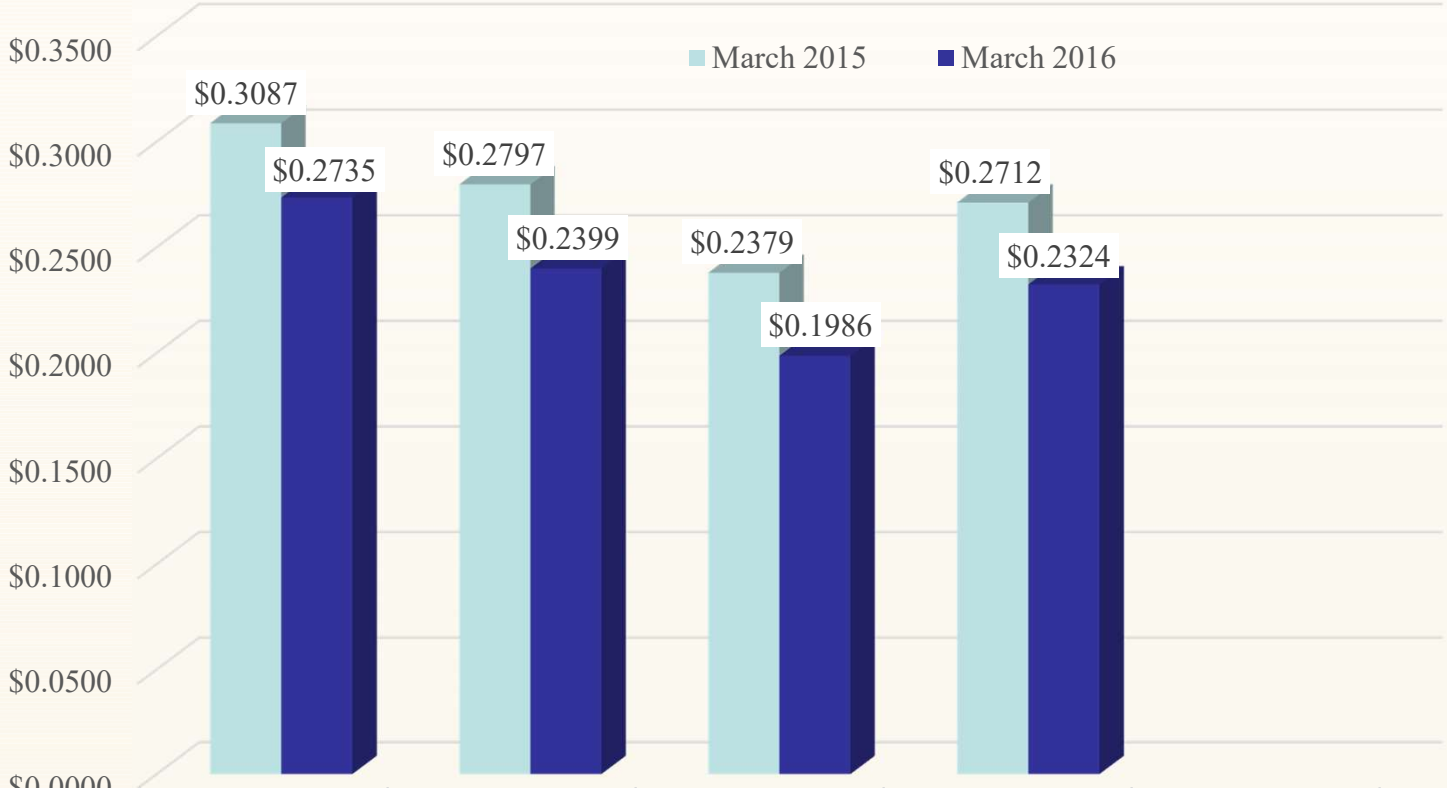
Hawaii Retail Electric Rates
2015 – 2016 ¢/kWh



	Residential	Commercial	Industrial	All Sectors
March 2015	$0.3087	$0.2797	$0.2379	$0.2712
March 2016	$0.2735	$0.2399	$0.1986	$0.2324

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Hawaii's Progressive Leadership in Clean Energy Policy

2008

Hawaii Clean Energy Initiative (HCEI)

Editorials

TUESDAY | OCTOBER 21, 2008

Ambitious energy agreement charts right course

A promising new agreement between the state and Hawaiian Electric Co. is expected to make some significant progress in reducing Hawai'i's dependence on fossil fuels.

It calls for streamlining the regulatory process to achieve some worthy goals, including sending wind energy from Maui, Lāna'i and Moloka'i to O'ahu via state-of-the-art undersea cables, and developing a "smart grid" so customers can get lower rates during off-peak hours.

That's the good news. But

Join the conversation. Post your comments about our editorials at .com

the 50-page agreement also lacks some key details. Perhaps the most important one, given these tough economic times, is how much will it all cost, and how much of that cost will the consumer be asked to bear?

Admittedly, it's a difficult question to answer, given the scope and complexity of the plan. Still, looking out for ratepayers' and taxpayers' interests will be crucial. Part of that responsibility rests with one of the agreement's signatories, consumer advocate Catherine Awakuni, and the Public Utilities Commission.

Awakuni and the PUC have the obligation to ensure that the average ratepayer isn't unfairly burdened by the cost of developing the new, renewable-energy infrastructure.

There will be significant up-front investment costs. The undersea cable alone could run in the hundreds of millions of dollars, and the state should maximize opportunities for federal funding through the Department of Energy or similar sources.

And even with federal funding — U.S. Sen. Daniel K. Inouye attended the signing ceremony for the new agreement — ratepayers will likely be asked to pick up some of these costs as an investment in the state's renewable energy future.

Certainly, this future is the direction in which the state needs to be moving. Achieving the state's goal of 70 percent clean energy by 2030 is a laudable plan that sets us on the right path. Indeed, Hawai'i is uniquely positioned to be a leader in the area of wind, wave and solar energy efforts.

And in the long term, renewables offer an unlimited supply of environmentally friendly energy and reduces our over-reliance on fossil fuels — a more sensible and sustainable future.

It's an ambitious plan. If the agreement's goals are met, the result will be a fundamentally changed energy model. A more unified, more efficient grid will support different energy sources, primarily wind; HECO will move from a sales-based company to an energy services provider; and the consumer will have more control over energy costs with new ways to conserve using technology.

The Lingle administration hopes the agreement will be a win-win for everyone — the state, HECO and consumers. Refining these details will help ensure that success.

Hawai'i Powered
Hawai'i Clean Energy Initiative

The State of Hawaii, US DOE, and local utility launched HCEI in January 2008 to transform Hawaii to a 70% clean energy economy by 2030:

- ***Increasing Hawaii's economic and energy security***
- ***Fostering and demonstrating Hawaii's innovation***
- ***Developing Hawaii's workforce of the future***
- ***Becoming a clean energy model for the U.S. and the world***

2009 *Strong Hawaii Policies*

Highest RPS Target in the United States

40% by 2030
(2015 - 15%; 2020 - 25%)

Other key policies:

- **Tax incentives**
- **Retail Rate Net metering**
- **Feed in tariffs**

2011 *Policy Evolution Reflecting Market Realities …*

Amended the definition of "renewable electrical energy" to include starting in 2015, customer-sited, grid-connected renewable energy generation

2015+ *Continued Policy Evolution …*

- **New RPS targets: 30% by 2020; 100% by 2045**
- **Net metering change – wholesale rate sale**

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Exceeding Hawaii RPS Goals

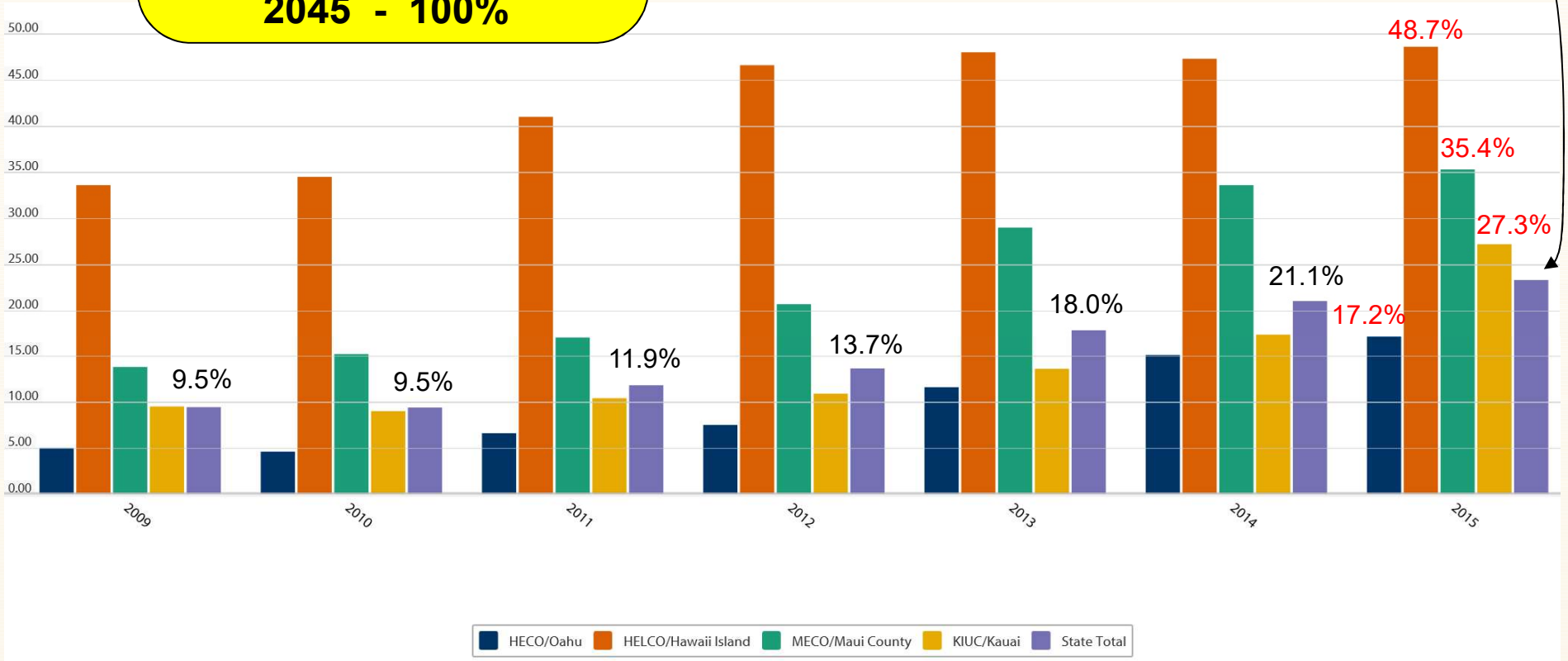
Hawaii RPS Goals

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

State-wide 2015 RPS Goal = 15%

RPS year-end 2015 @ 23.42%

(9.5% RPS at year-end 2009)



Source: State of Hawaii, "Hawaii Energy Facts & Figures," Hawaii State Energy Office, Honolulu, May 2016

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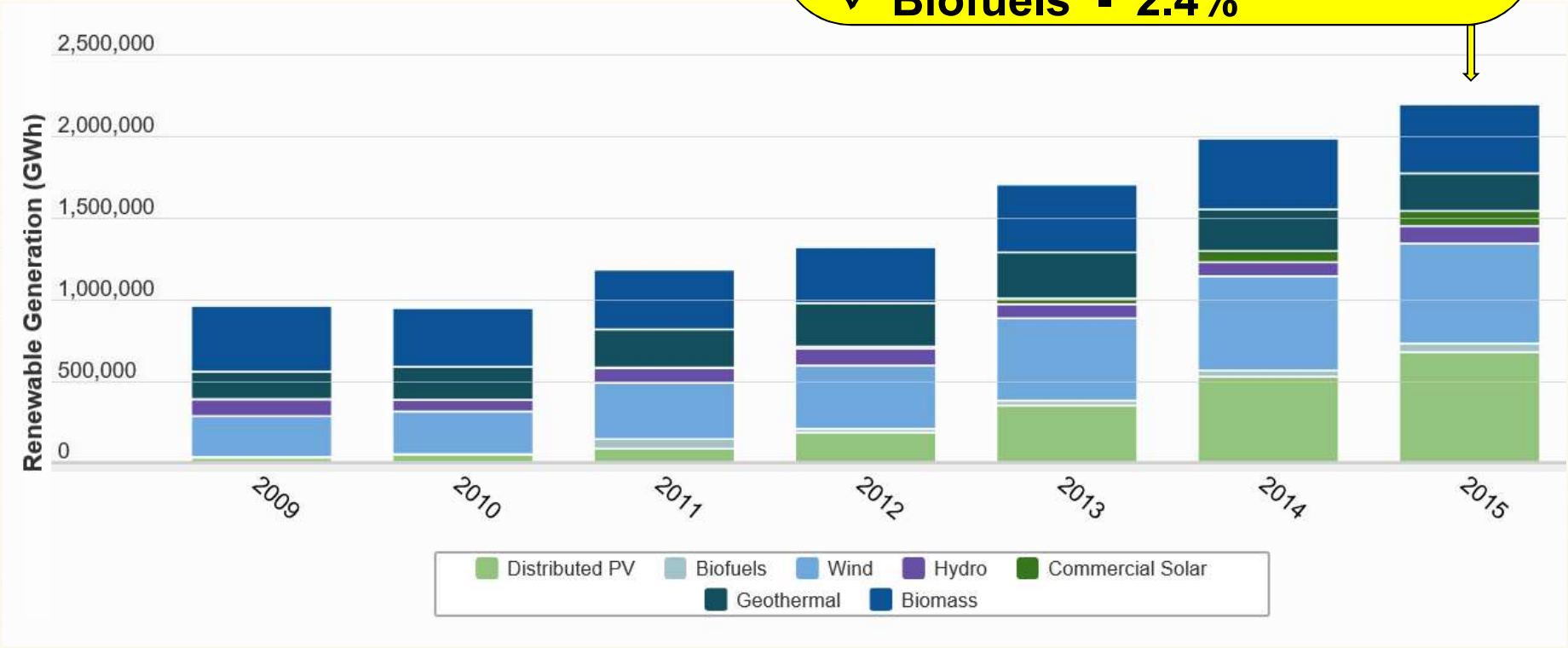
Renewable Energy Production by Resource

At year-end 2015 RE Production by:

- ✓ **Distributed PV - 31%**
- ✓ **Wind - 27.9%**
- ✓ **Biomass - 19.2%**
- ✓ **Geothermal - 10.5%**
- ✓ **Hydro - 4.8%**
- ✓ **Commercial Solar - 4.2%**
- ✓ **Biofuels - 2.4%**



Source: State of Hawaii, "Hawaii Energy Facts & Figures," Hawaii State Energy Office, Honolulu, May 2016

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Hawai'i Natural Energy Institute (HNEI)

Advancing Renewable Energy and Grid Technologies

Renewable Power Generation
- Ocean Energy
- Photovoltaics

Power Systems Optimization and Systems Integration of Renewables
- Grid modeling and analysis
- Smart grid and micro-grid R&D
- Application of grid storage

GridSTART
Grid System Technologies Advanced Research Team

Electrochemical Power Systems
- Batteries
- Fuels Cell

Energy Efficiency
- Building Technology
- Sea Water Air Conditioning

Alternative Fuels:
- Biomass, Biofuels, Hydrogen, Methane Hydrates

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

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Maui Island

Leading the way in Wind and Solar Power

Wind - 72 MW
PV - 114 MW
186 MW

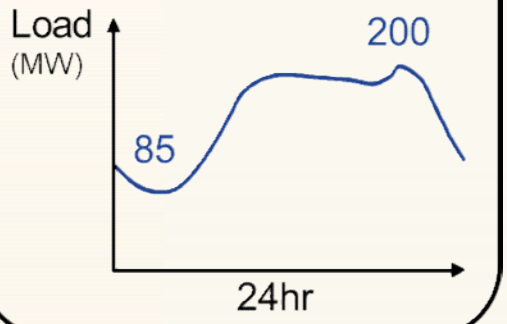
74 MW Existing Distributed PV
~40 MW PV Pre-approved/Review
114 MW Total

Kaheawa I
(30 MW)

Kaheawa II
(21 MW)

63,000 Customers

Daily Load Shape



Auwahi
(21 MW)

69kV/23kV/12kV T&D System

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Maui Advanced Solar Initiative

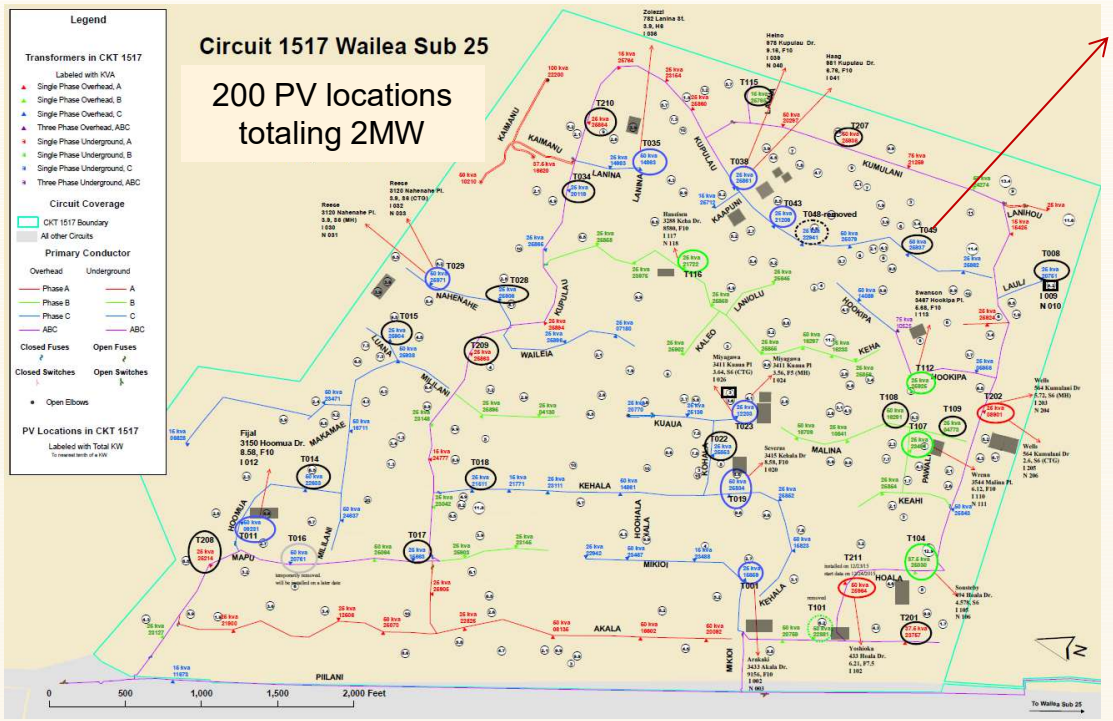
US DOE & ONR funded, HNEI led project to develop and demonstrate advanced PV inverter functionality in a smart grid environment

~800 customers

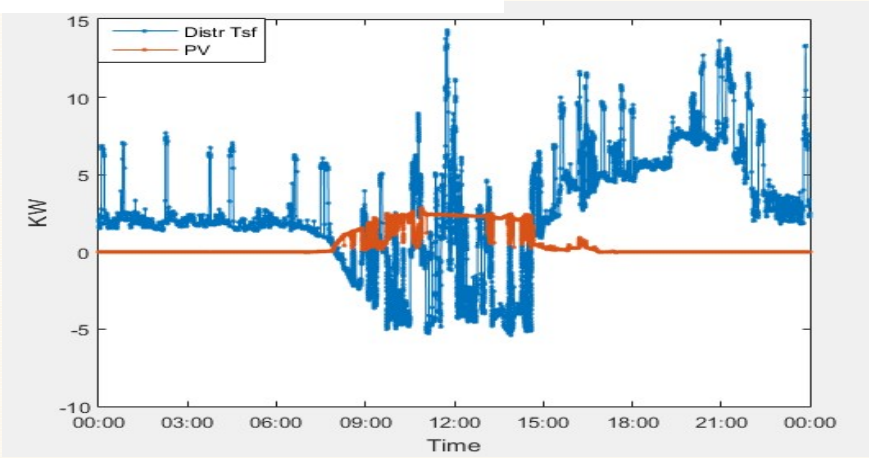
~200 PV systems = 2MW

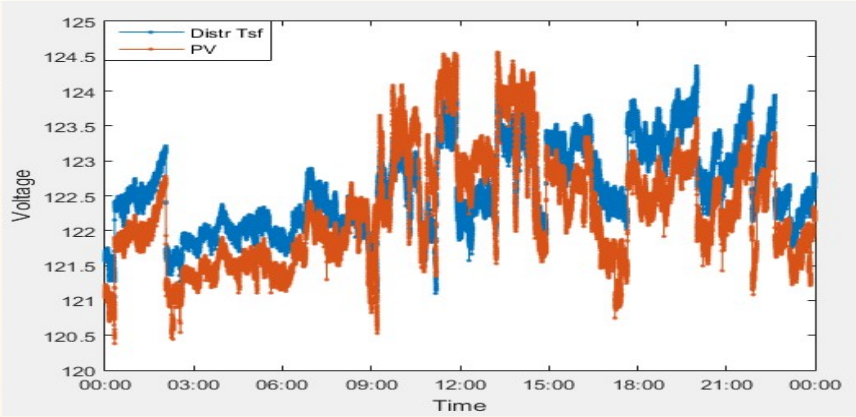
MDL = 976kW

% Penetration = $\frac{2MW}{976kW}$ =205%



Field Performance & Data Mining





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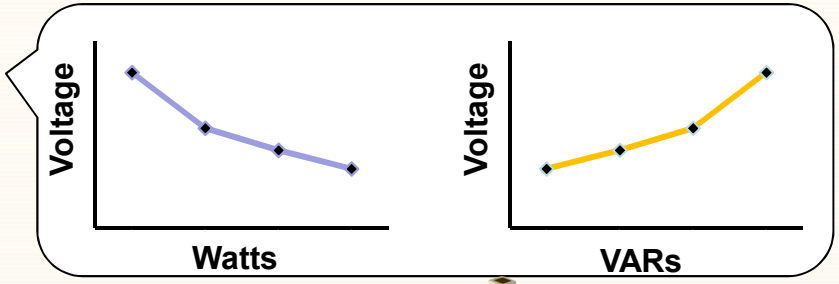
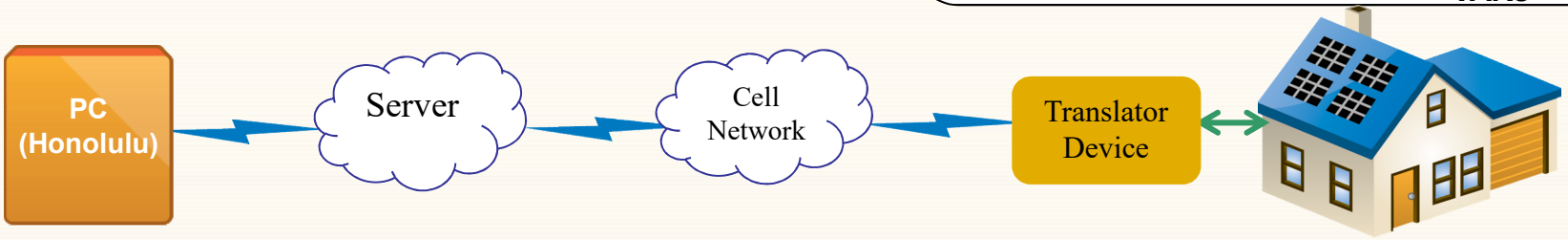
Software sends control curves to adjust inverter

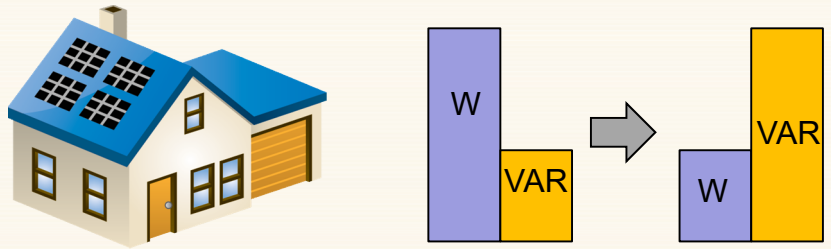
1 Sends Volt-VAR or Volt-Watt curve to Smart Inverter to adjust inverter VAR or Watt injections into the grid





2 Smart Inverter receives curve, senses system voltage

3 Smart Inverter adjusts VAR or Watt output based on curves to respond to system voltage fluctuations

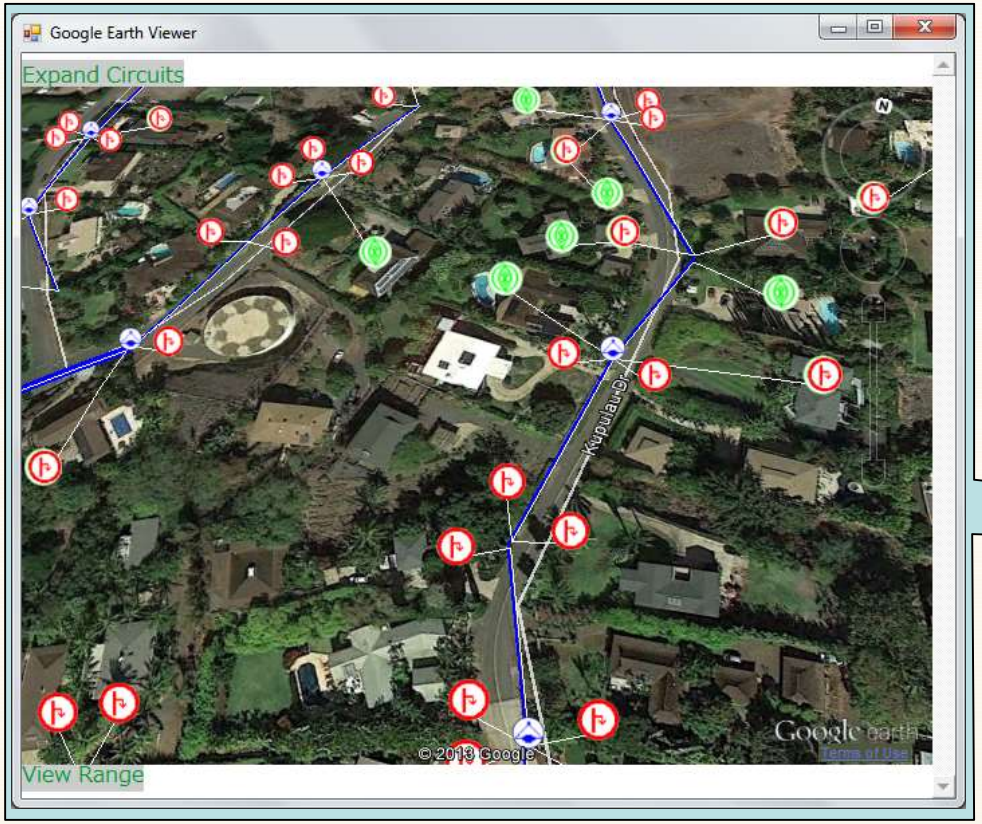


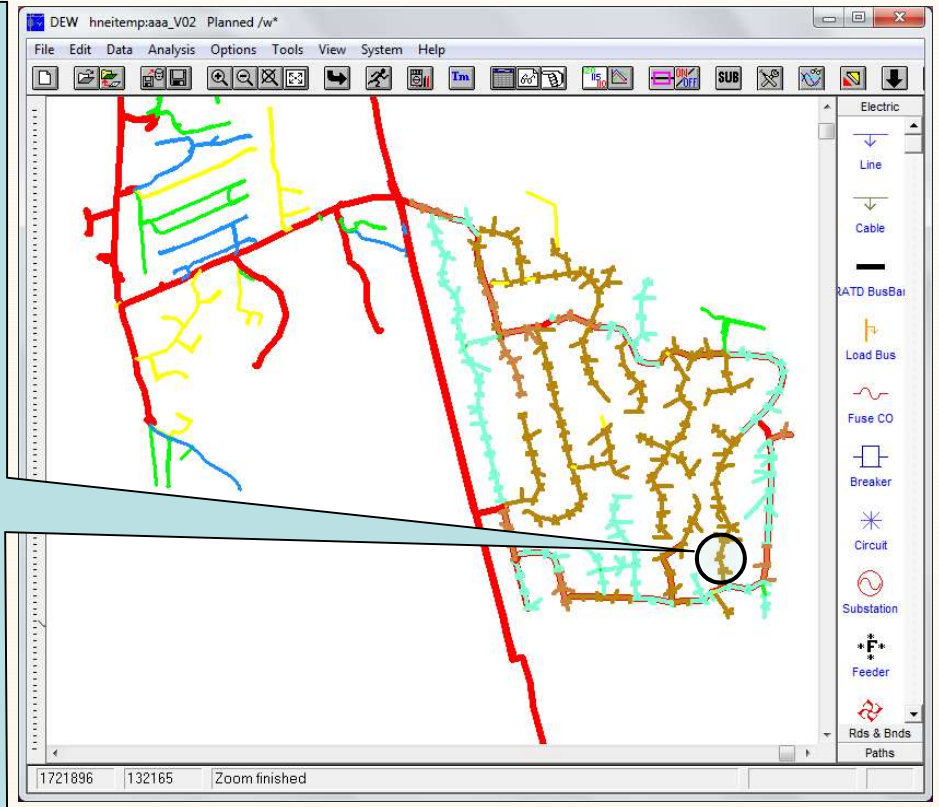
2-way data flow

Wireless communications

Technology Validation and Optimization

- Field survey and circuit modeling
  - Investigate / collect circuit information
  - Analyze and model circuit data and smart inverter functionality
  - Use model to develop and optimize smart inverter control algorithms and iterate with field operation and measured performance





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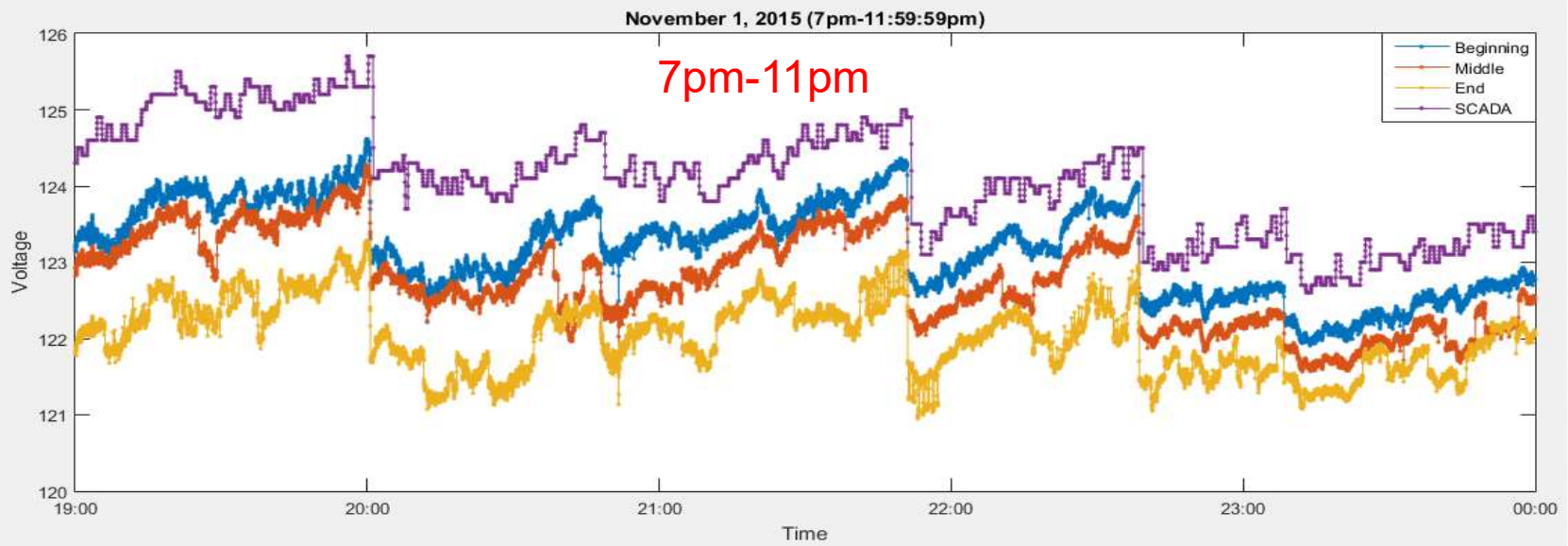
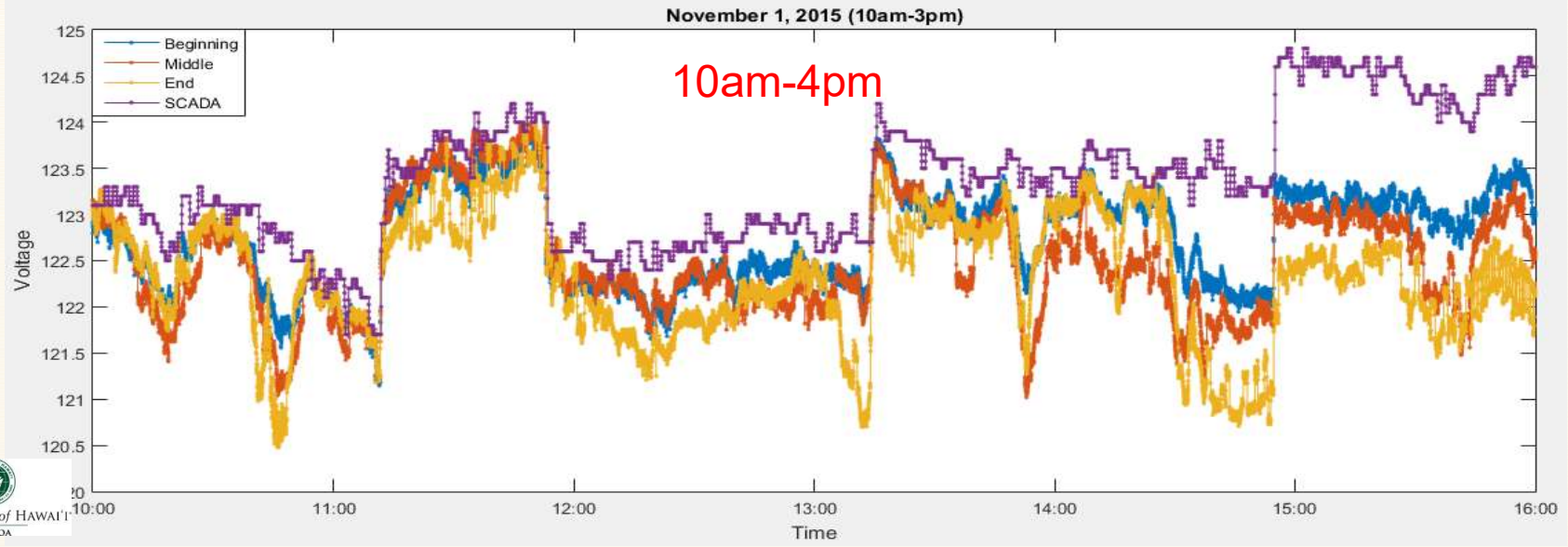
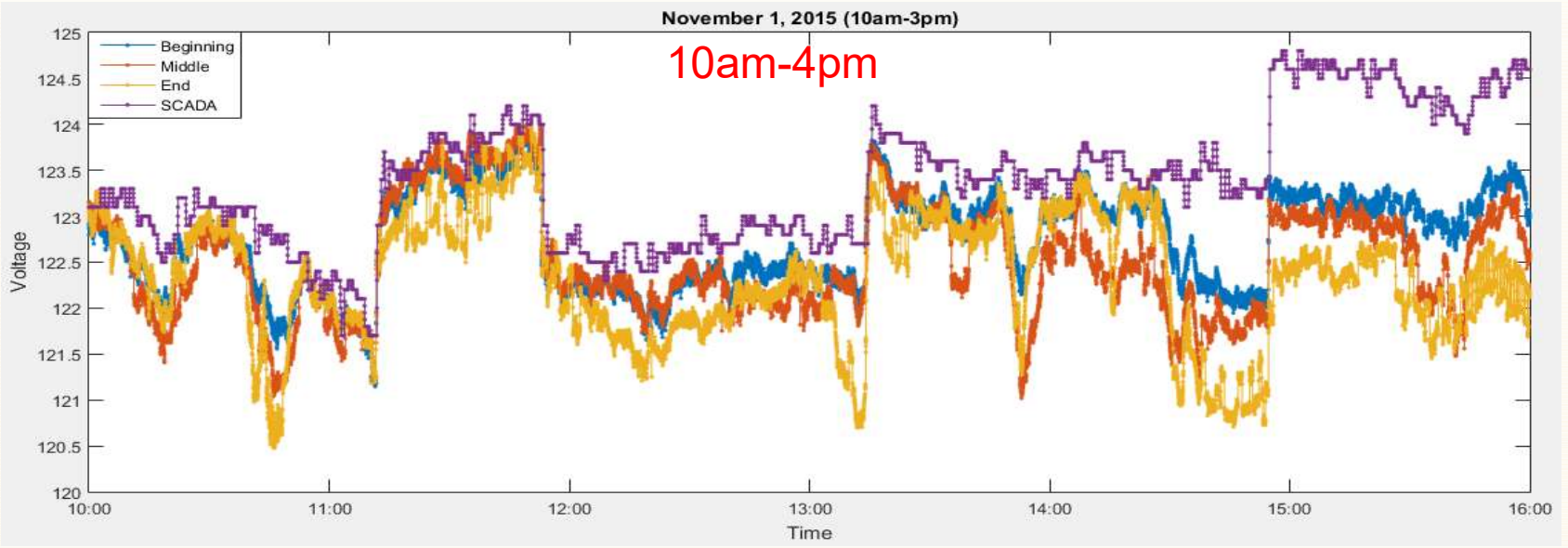
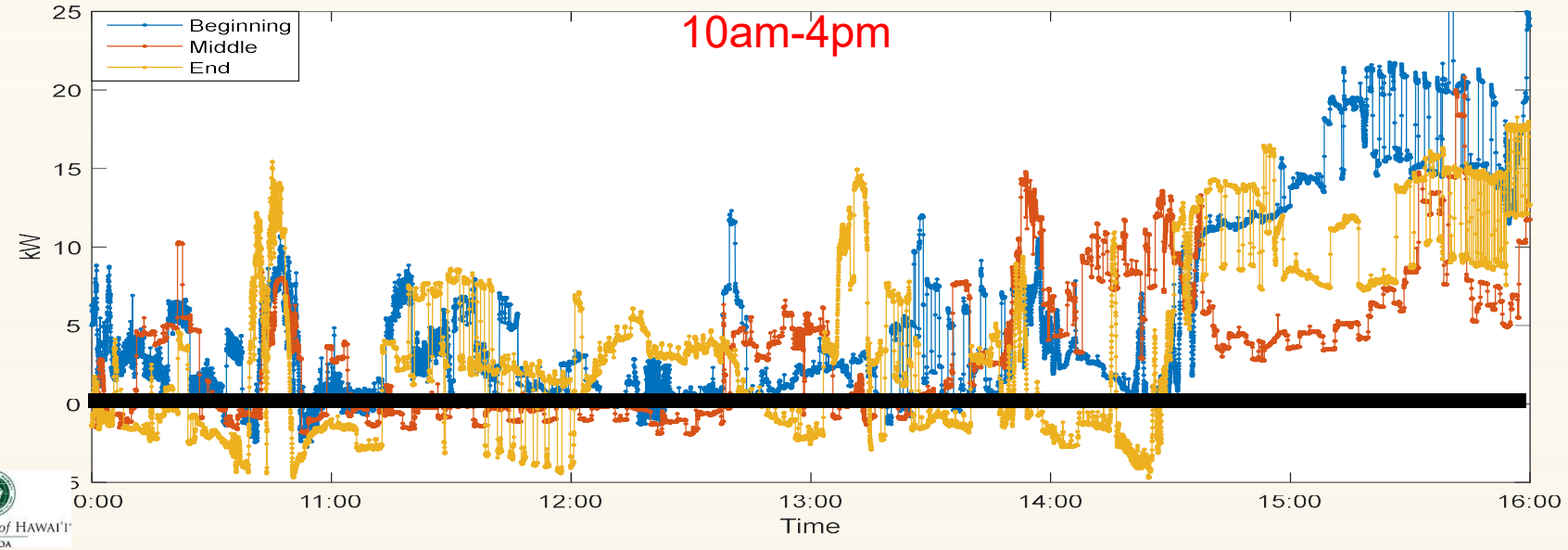
Voltage Along the Feeder





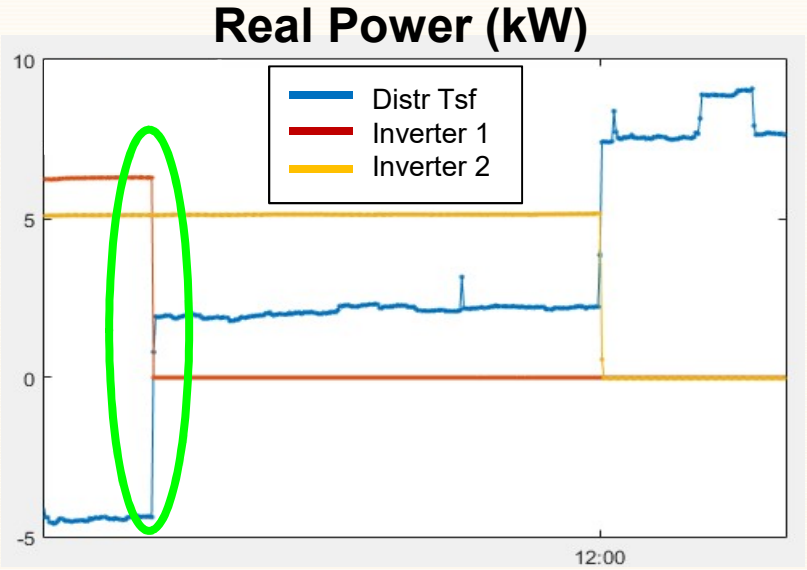
Voltage Along the Feeder (cont.)

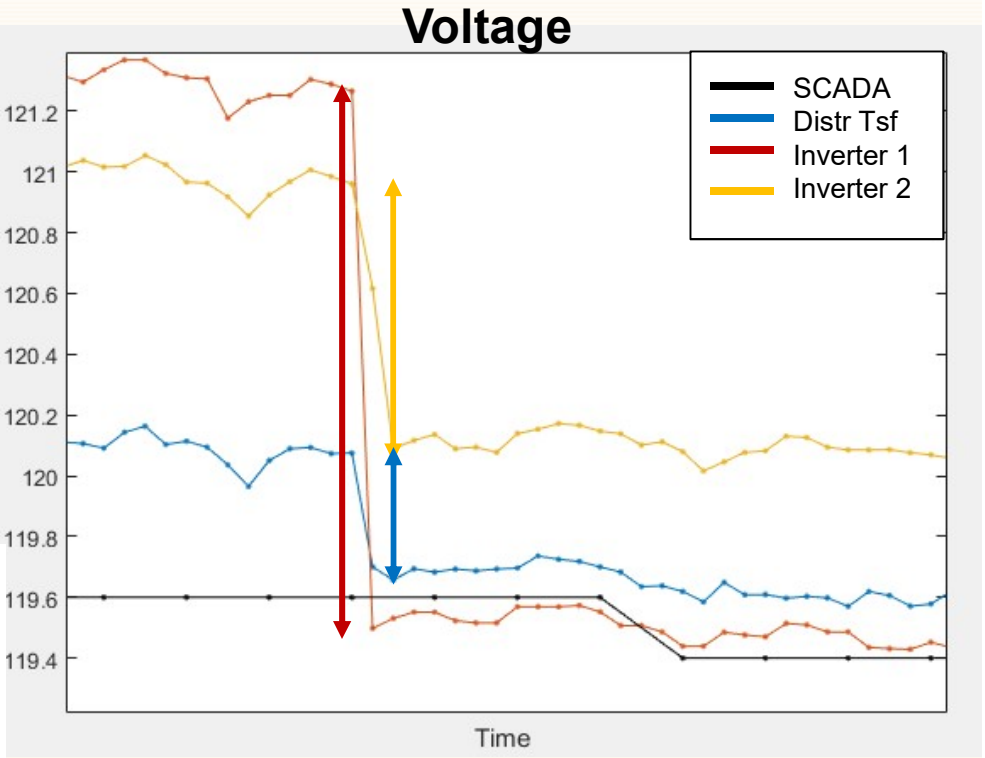


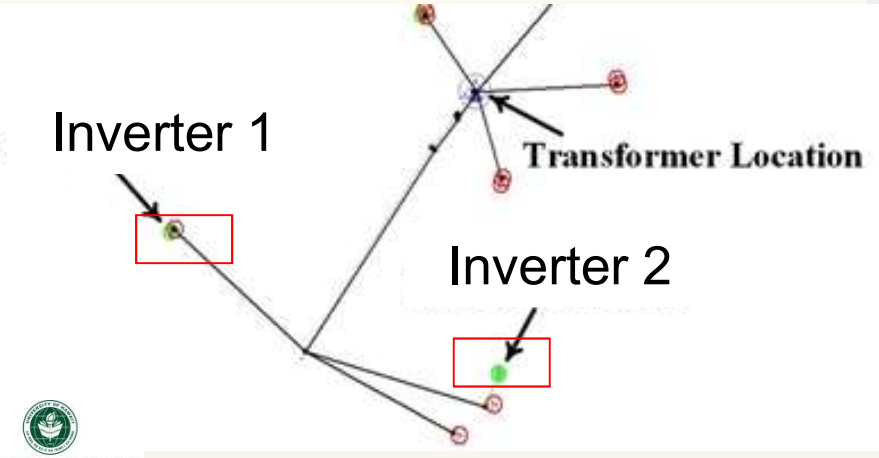


Real Power & Voltage

Magnitude of voltage effects on neighbor is dependent on sec ckt configuration







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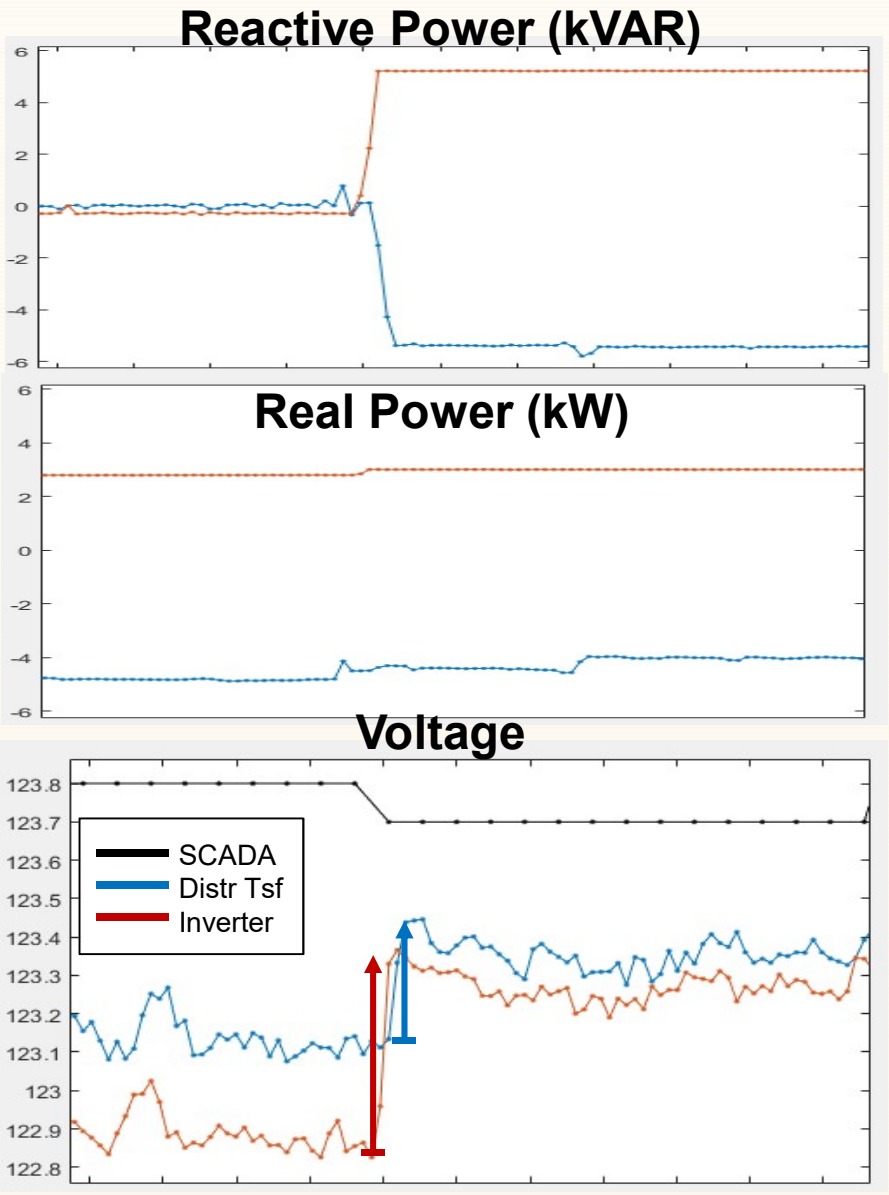
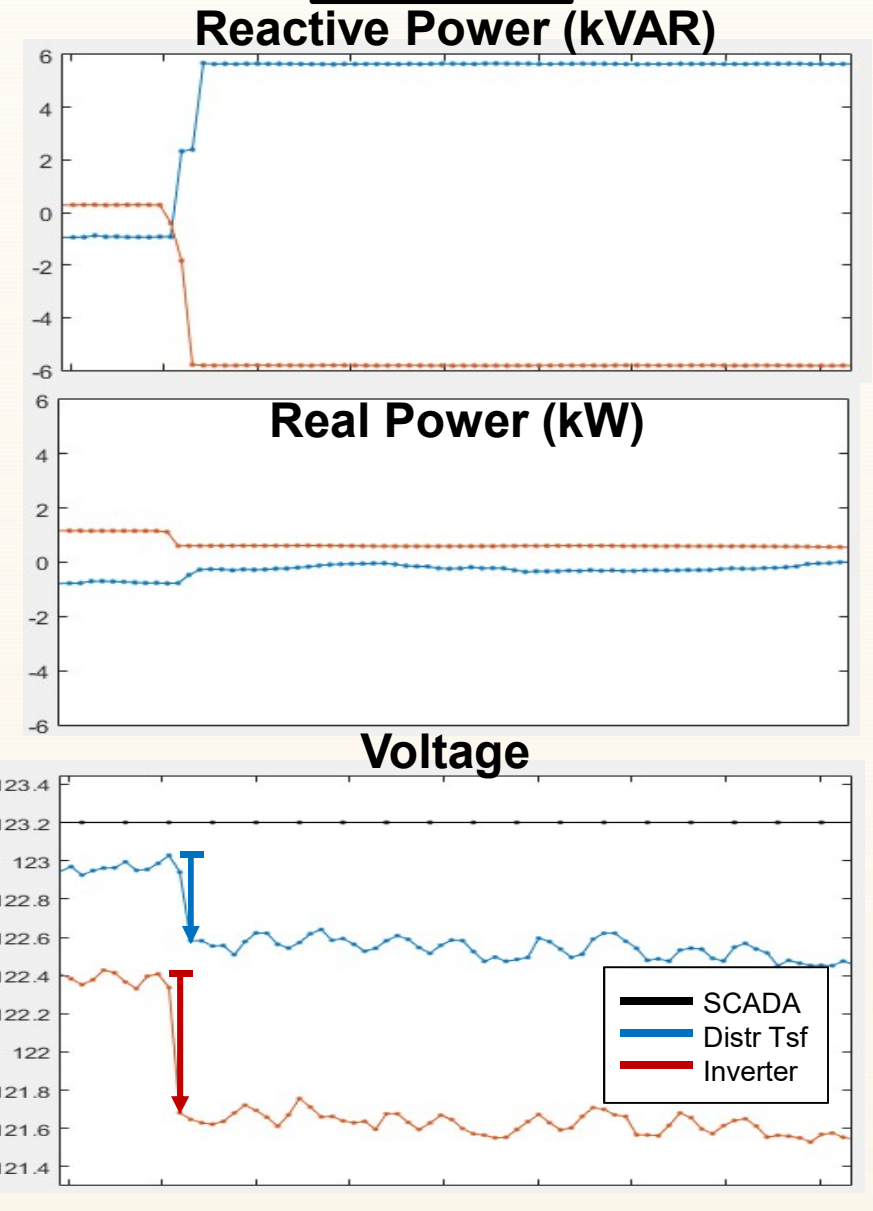
Reactive Power & Voltage

Capacitive

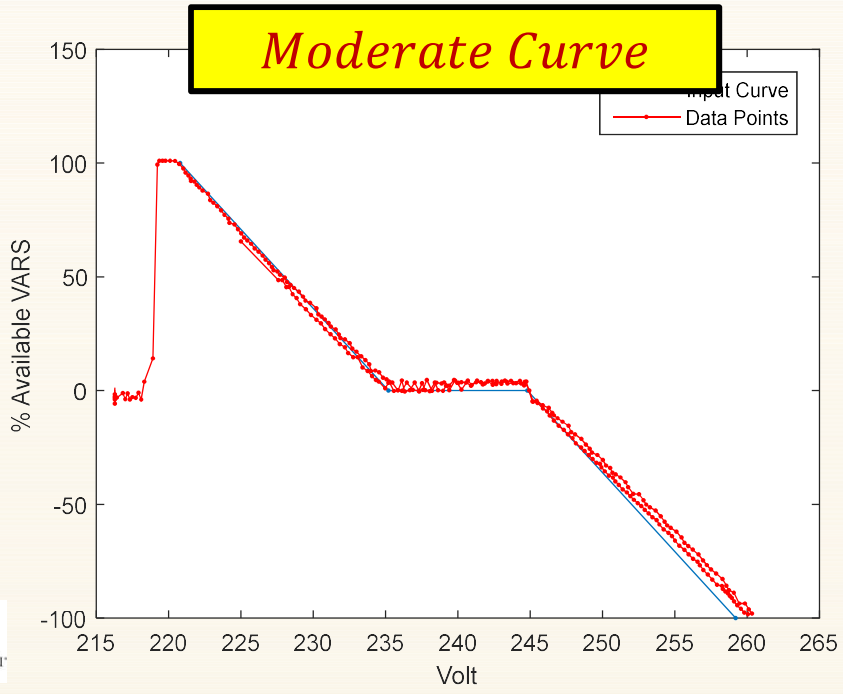


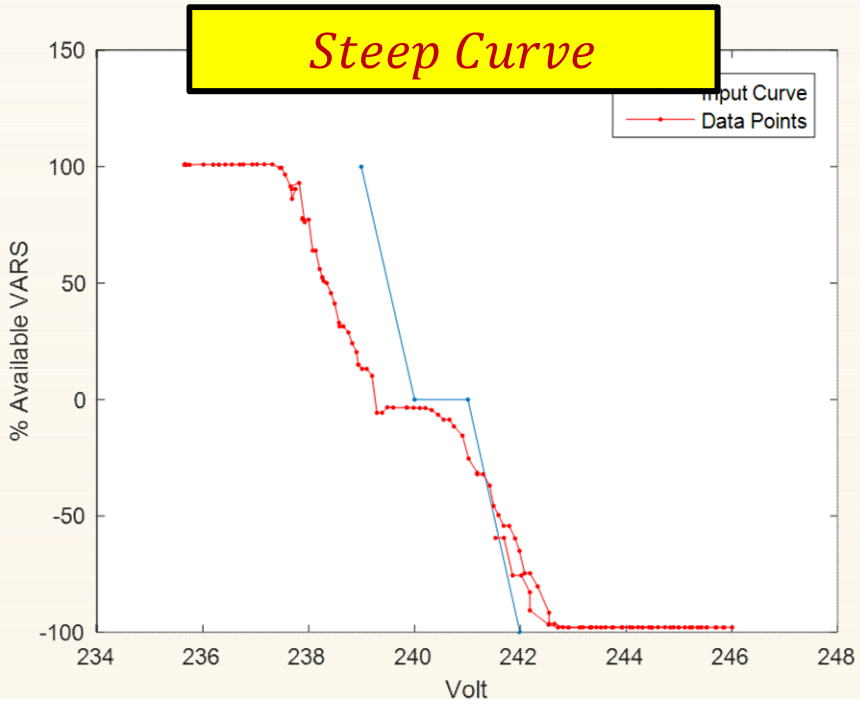
Inductive



Lessons Learned: Inverter Standardization

- Real Power Curtailment
  - % of Inverter Rating
- Volt-Var Curve
  - Number of points
  - Y-axis = % of Available VARs, % of Max Vars, % of Max Watts
    - SMA = 50% of KVA rating
    - Hitachi = 100% of KVA rating (will reduce real power output)
    - Fronius = limited to power factor >= 0.85
  - Steepness of curve





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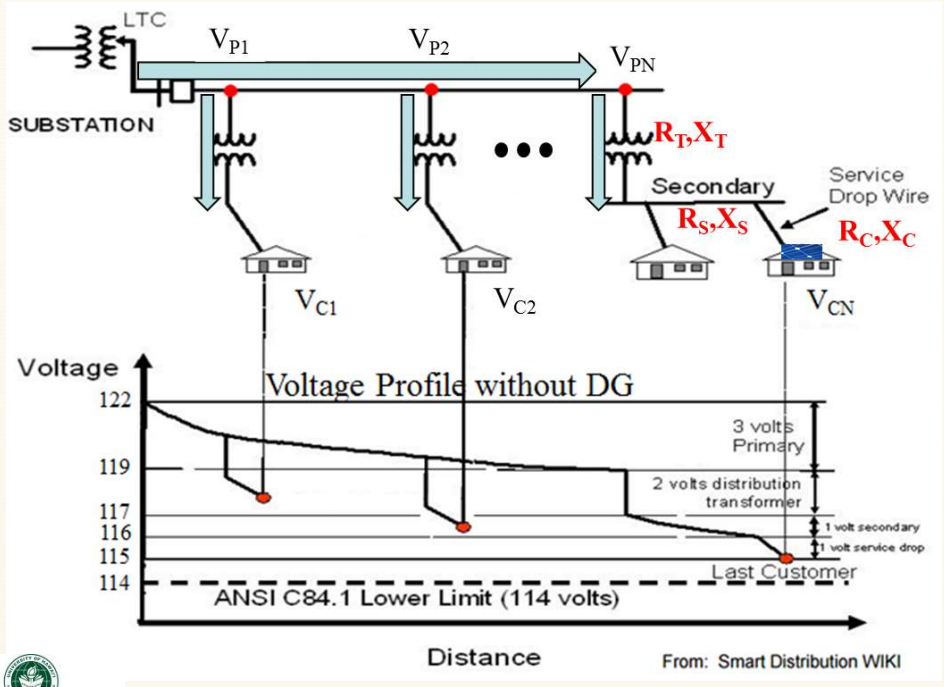
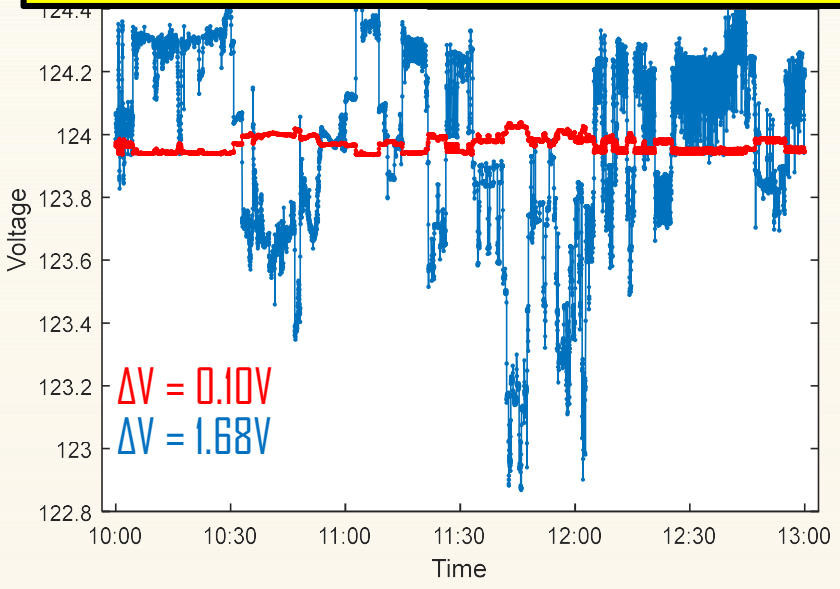
Next Step Applications

- Smart inverters can be used to control voltage
- Voltage effects are dependent on:
  - Loading
  - Topology
- Development of control algorithms to manage voltage



Smart inverter can be controlled to stabilize the voltage



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Mahalo!

(Thank you)

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