Photovoltaic Distributed Generation
Hawaii Case Study

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Solutions to Facilitate Successful RE Integration on the Distribution System

Asia Clean Energy Forum

June 5, 2018
Manila, Philippines
New Regulatory Compact

- Government policy set to drive clean energy action
  - Renewable & Energy Efficiency Portfolio Standards
  - Net Energy Metering & Feed-in Tariffs
- Financially sound utility needed to implement the policy
  - Why?
    - RE projects must be “bankable” (utility is contract counter-party)
- But, these policies reduce energy sales for the utility ... so what’s in it for the utility?
- New regulatory compact aligns utility’s business interest
  - Utility rates “decoupled” from energy sales (utility ensured to recover it’s costs even if sales declining)
  - Investment in grid renewal encouraged (utility earns on CapEx)
Installed PV Capacity - HECO Companies
(2005 to 3/2018)

½ Peak Load

37% of total RE
Hawaiʻi Electric Systems –
4 Electric Utilities; 6 Separate Grids; % Renewable Energy

Kauaʻi Island Utility Cooperative
System Peak: 78 MW
65.6 MW PV / 7 MW Biomass / 9 MW Hydro
Installed PV: 84% of System Peak
41.7% RE in 2016

Maui Electric
Maui System Peak: 202 MW
100 MW PV / 72 MW Wind
Installed PV & Wind:
85% of Sys. Peak
34.2% RE in 2017
Lanaʻi System Peak: 5.1 MW
2.53 MW PV (50% of Sys. Peak)
Molokaʻi System Peak: 5.6 MW
2.3 MW PV (41% of Sys. Peak)

Hawaiian Electric
System Peak: 1,206 MW
512 MW PV / 99 MW Wind / 69 MW WTE
Installed PV & Wind:
50% of System Peak
20.8% RE in 2017

Hawaii Electric Light
System Peak: 192 MW
92 MW PV / 30 MW Wind / 38 MW Geothermal / 16 MW Hydro
Installed PV & Wind:
64% of System Peak
56.6% RE in 2017

% Renewable Energy

Kauaʻi 41%
Oʻahu 19%
Molokaʻi
Lanaʻi 37%
Maui
Hawaiʻi 54%

80% of state population

85% of Sys. Peak

50% of System Peak

54% of System Peak

41% of System Peak

19% of state population
Distributed PV Circuit Penetrations

Average Penetration: ~110% Gross Min Daytime Load*

*GMDL = Net min load + 75% of installed PV capacity
Why is DG PV So Popular in Hawaii

**Federal Incentives**
30% of the cost of Solar systems with no cap. *Extended to 2019 (Ramps down through 2020 to 26%, then in 2021 to 22%)*

**State Incentives**
35% of the actual cost or $5,000 per system, whichever is less. No expiration date

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**Average Price of Residential Electricity (EIA)**

<table>
<thead>
<tr>
<th>State</th>
<th>Mar-18</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 North Dakota</td>
<td>9.65</td>
</tr>
<tr>
<td>2 Washington</td>
<td>9.65</td>
</tr>
<tr>
<td>3 Louisiana</td>
<td>9.79</td>
</tr>
<tr>
<td>4 Idaho</td>
<td>9.99</td>
</tr>
<tr>
<td>5 Nebraska</td>
<td>10.25</td>
</tr>
<tr>
<td>46 New Hampshire</td>
<td>19.93</td>
</tr>
<tr>
<td>47 Rhode Island</td>
<td>20.22</td>
</tr>
<tr>
<td>48 Connecticut</td>
<td>21.04</td>
</tr>
<tr>
<td>49 Alaska</td>
<td>21.47</td>
</tr>
<tr>
<td>50 Massachusetts</td>
<td>22.49</td>
</tr>
<tr>
<td>51 Hawaii</td>
<td>32.05</td>
</tr>
<tr>
<td><strong>U.S. Average</strong></td>
<td>12.99</td>
</tr>
</tbody>
</table>
Why is DG PV So Popular in Hawaii

The average Hawaii resident spends about 0.37 per kilowatt-hour (kWh) and uses about 515 kilowatts (kW) per month. With an average month’s electric bill totaling $190.36 it definitely makes sense to see if you can save money on power.

Key Solar Facts – Averaged for Hawaii
Average savings per year: $3,539.18 ($294.93 per month)

Estimated time for the system to pay for itself: 6 years, 0 months

Is solar worth it in Hawaii? Based on the price of electricity in Hawaii (an average of 0.37 per kW) and high amounts of sun (8% more than average) compared to other states, solar power is 238% more cost effective than the rest of the nation.

Our final opinion: solar panels are an obvious financial choice in Hawaii.

Source: Decisiondata.org
**DG PV Programs**

**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 for grid stability.

**Smart Export** 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.

**Customer Self-Supply (CSS)** is intended only for private rooftop solar installations that are designed to not export any electricity to the grid. Customers are not compensated for any export of energy.

**X Customer Grid-Supply (CGS)** participants receive a PUC-approved credit for electricity sent to the grid and are billed at the retail rate for electricity they use from the grid. The program remains open until the installed capacity has been reached.

**X Net Energy Metering (NEM)** is closed to new applicants.

**Standard Interconnection Agreement (SIA)** is designed for larger customers who wish to offset their electricity bill with on-site generation.
# DG PV Programs

<table>
<thead>
<tr>
<th>Program</th>
<th>Grid Export Rate*</th>
<th>Battery Storage Required?</th>
<th>Grid Export Window</th>
<th>Controllable?</th>
<th>Wireless Availability Required?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Customer Grid-Supply Plus</strong></td>
<td>10 cents/kWh</td>
<td>No</td>
<td>Daylight</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Smart Export</strong></td>
<td>15 cents/kWh</td>
<td>Yes</td>
<td>4 p.m. to 9 a.m.</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Customer Self-Supply</strong></td>
<td>N/A</td>
<td>No, but usually installed</td>
<td>N/A</td>
<td>N/A</td>
<td>No</td>
</tr>
<tr>
<td><strong>SIA</strong></td>
<td>N/A</td>
<td>No</td>
<td>N/A</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
Qualified Inverter Lists

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))

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

Evolution of Circuit Penetration Limits (Why is the utility being a roadblock?)

“How much distributed generation can you add before you need to do an expensive Interconnection Requirements Study?”

• 15% of Peak Load
  – Utility “Rule-of-Thumb” for synchronous generation
    • Historically, utilities only measured circuit peaks for planning

• 30% of minimum daytime load (MDL)
  – The actual issue is the generation at minimum load

• 120% of MDL
  – “Typical” distribution circuit modeling showed no issues until the circuit penetration levels reached 120% of the MDL where transient over voltages (TOV) were a concern.
Evolution of Circuit Penetration Limits (Why is the utility being a roadblock?)

- 250% of MDL
  - Modeling studies determined TOV levels were acceptable if new inverters could trip within 1-cycle if its terminal voltage reached 120% pu voltage. TOV trip requirement added to interconnection Requirements

- Individual Hosting Capacity Limit
  - Based only on steady-state power flows (Thermal and Voltage limits) and flicker limits.
  - Actual inverter testing determined that TOV was not an issue if inverters met the TOV requirements
  - “Advanced” Inverter capabilities are now required to expand Hosting Capacity Limits
  - Load Tap Changer settings need to be reviewed with distribution voltage monitoring
  - Emergency configurations need to be assessed
940 Applications Executed in the first quarter of 2018
Rule 14

TECHNICAL REVIEW PROCESS FLOW CHART

Complete/Valid Interconnection Request

Do the Applicant and the Company agree to go directly to the IRS Study?

Yes

Go to IRS Study Process

No

Is the Applicant interconnecting to the Distribution System?

Yes

Is the Equipment UL 1741 Certified?

Yes

Initial Technical Review Screen 1

Qualified Customer Self-Supply

Fail

Pass, Skip Screens 4, 5, 6, 8, 9

Initial Technical Review Screens 2-10

1. Single-Phase Generator Imbalance
2. Export Power/Voltage Regulation
   (Skip for Qualified Customer Self-Supply)
3. Network System
   4. Line Section ≤ 15% of Peak
      (Skip for Qualified Customer Self-Supply)
4. Network System
   5. Distribution Transformer/Secondary Conductor Rating
   6. Short Circuit Contribution Ratio
      (Skip for Qualified Customer Self-Supply)
5. Network System
   7. Short Circuit Interrupting Capability
      (Skip for Qualified Customer Self-Supply)
6. Network System

Fail Any Screen

Pass All Screens

Does a review determine requirements to address all failed screens?

Yes

No

Initial Technical Review Screen 11

Generation Facility ≤ 100 kVA

Supplemental Review Screens 12-13

11. Generation Facility qualifies for Simplified Interconnection
    subject to requirements determined by Initial Technical Review
    or SR, if any

12. Power Quality and Voltage Fluctuation

13. Safety and Reliability

Fall Screen 12 or 13

Does a review determine requirements to address all failed screens?

Yes

No

Company provides cost estimate and schedule for IRS or Group Study Process* to determine requirements.

* “Group Study Process” may include a consolidated IRS or a proactive utility determination of interconnection requirements covering multiple generating facilities.

HAWAIIAN ELECTRIC COMPANY, INC.
And then there’s the system limits...
Is This a Limit?

Cumulative Curtained Wind Energy by the Hour of the Day
Maui Island

- June 2014
- April 2018
Key Messages

• Hawai‘i has made great strides in the integration of distributed PV
• Those strides came through a combination of significant subsidies and solving real technical and process roadblocks
• Policy facilitates change
• Change takes time and needs to be monitored to match technical capabilities and right size subsidies and energy mix.
Mahalo!
(Thank you)

For more information, contact:

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