High Penetration
of
Distributed Solar PV Generation

Lessons Learned from Hawaii

September 30, 2014

Discussion Overview

- Solar PV penetrations trends in Hawaii
- Lessons learned from Hawaii's high penetration of solar PV
- Need for new distributed solar PV business model and DER 2.0

Hawaii Electric Systems -- 4 Electric Utilities; 6 Separate Grids

Kauai Island Utility Cooperative

34 MW PV (12 MW in development)
System Peak: 72 MW
Customers: 32,700

Maui Electric

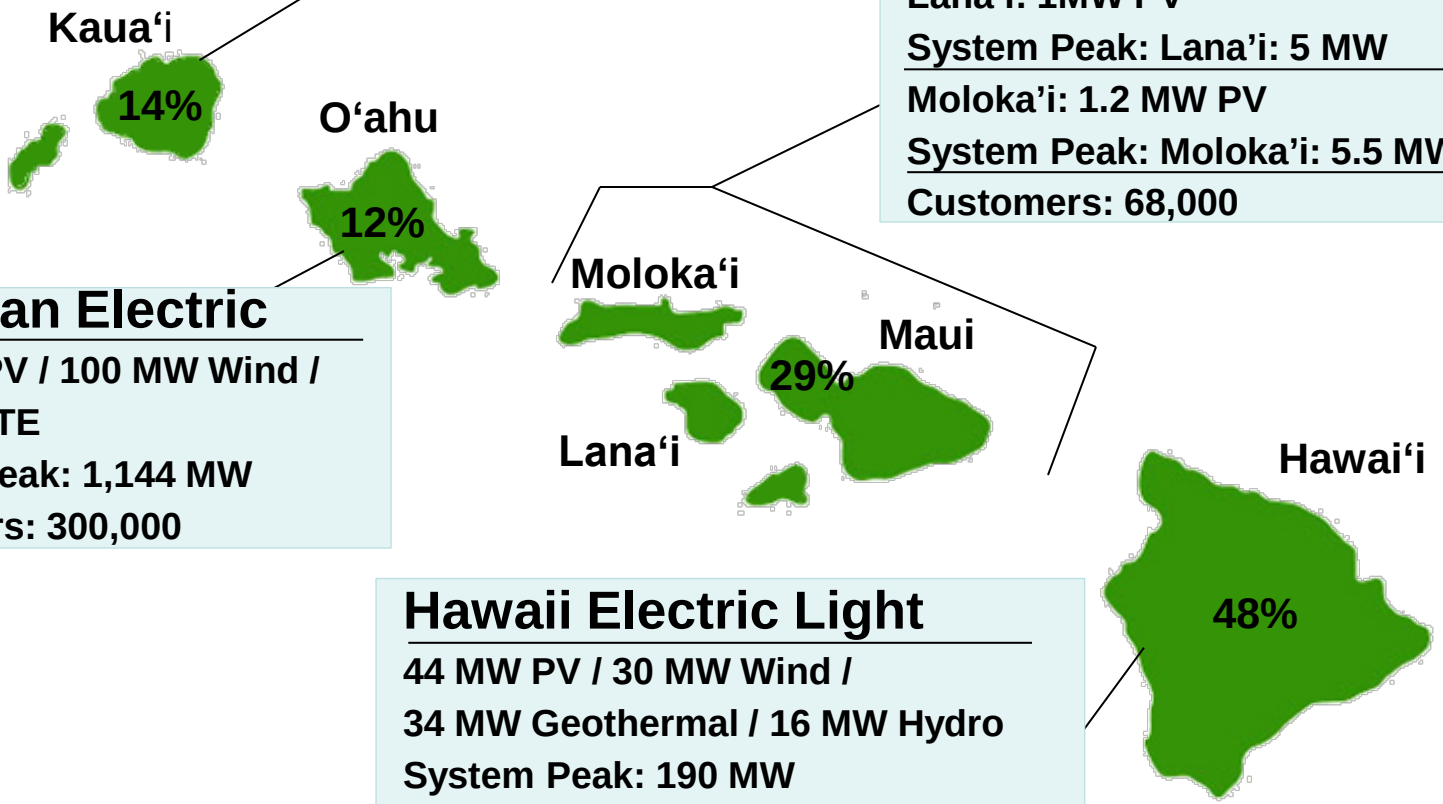
Maui: 45MW PV / 72MW Wind
System Peak: Maui 190 MW
Lana'i: 1MW PV
System Peak: Lana'i: 5 MW
Moloka'i: 1.2 MW PV
System Peak: Moloka'i: 5.5 MW
Customers: 68,000

Hawaiian Electric

254 MW PV / 100 MW Wind /
69 MW WTE
System Peak: 1,144 MW
Customers: 300,000

Hawaii Electric Light

44 MW PV / 30 MW Wind /
34 MW Geothermal / 16 MW Hydro
System Peak: 190 MW
Customers: 81,000

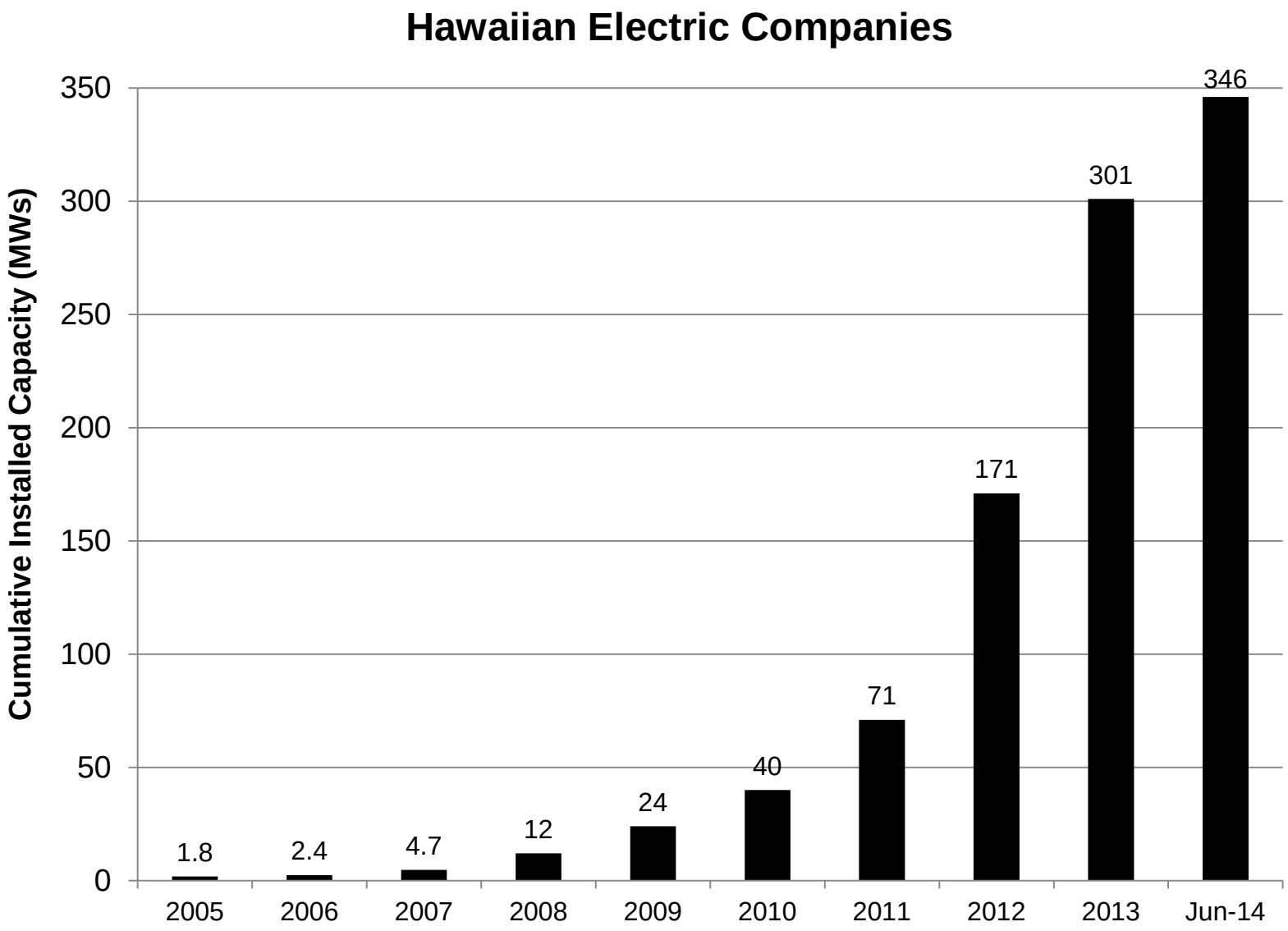


Hawaii – Becoming World Leader in Solar PV Adoption

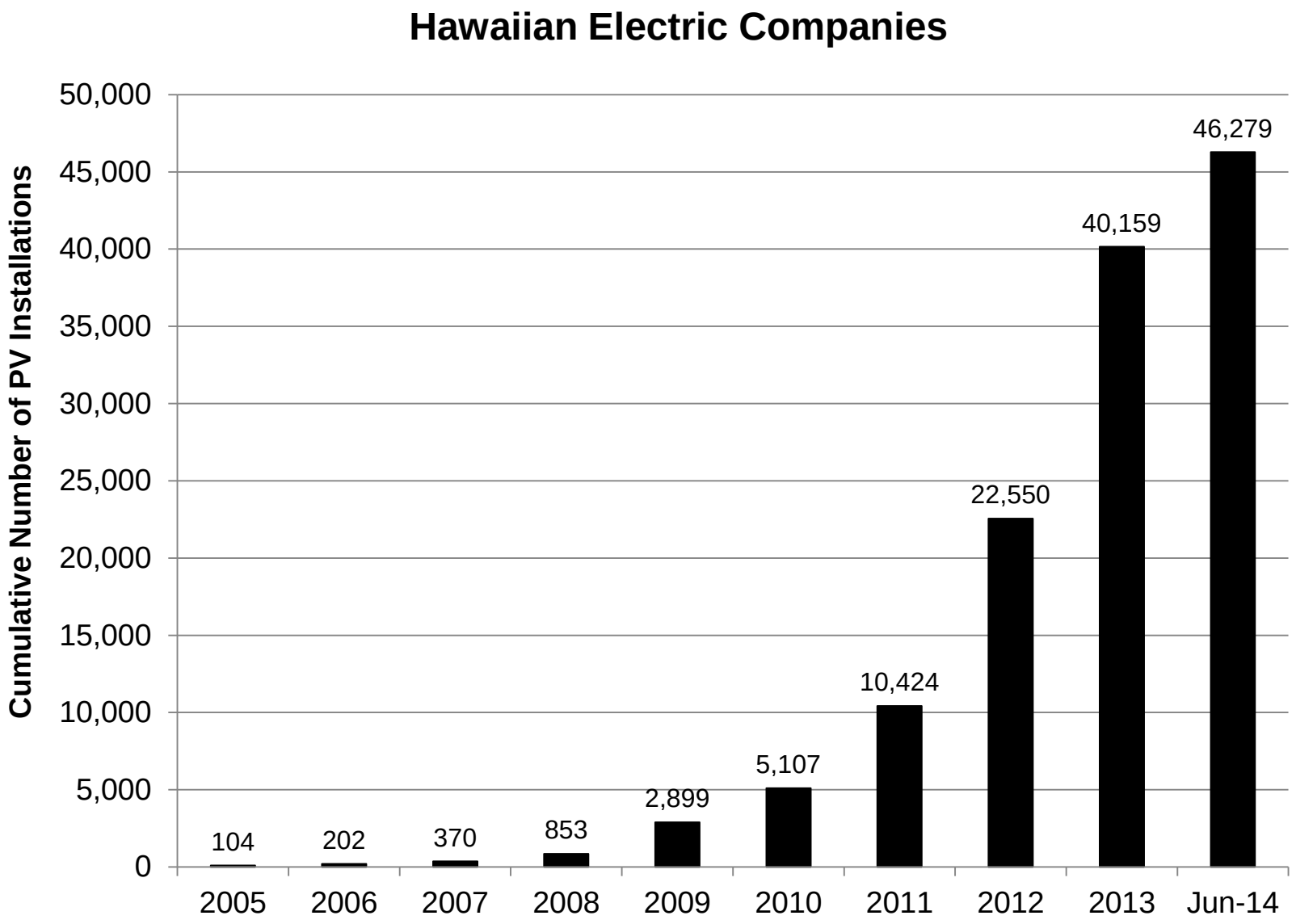
Hawaii leads the nation in the penetration of residential rooftop solar PV systems and as a result, is at the forefront of the integration challenges associated with high solar PV penetration levels.

At the same time, Hawaii is on track by 2017 to become a world leader in the utilization of solar PV resources – both distributed and utility-scale – with installed solar PV capacity penetration levels exceeding 75% of typical daytime gross system loads likely on several island electric grids.

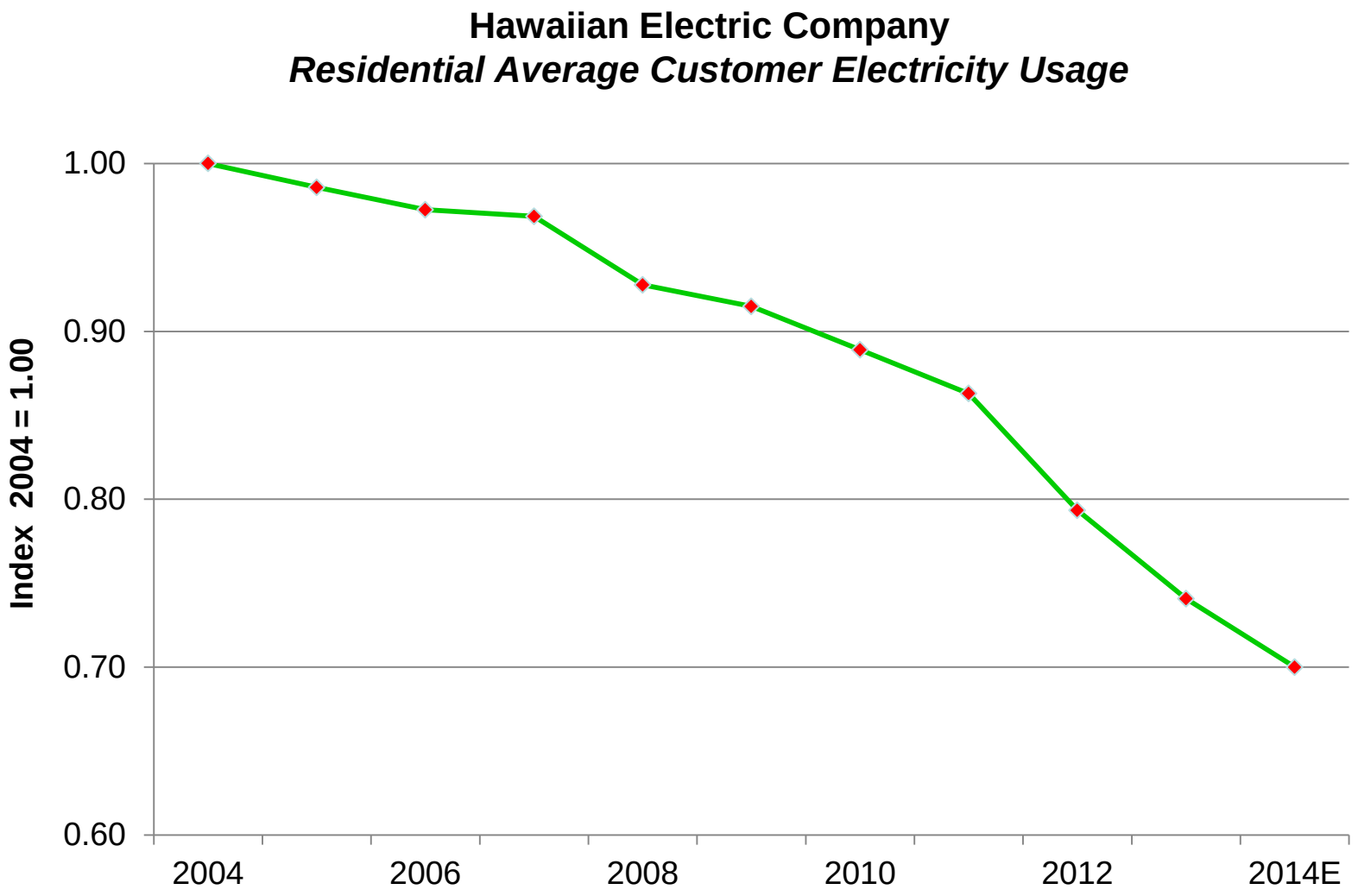
Hawaii's Distributed Solar PV Capacity Growth



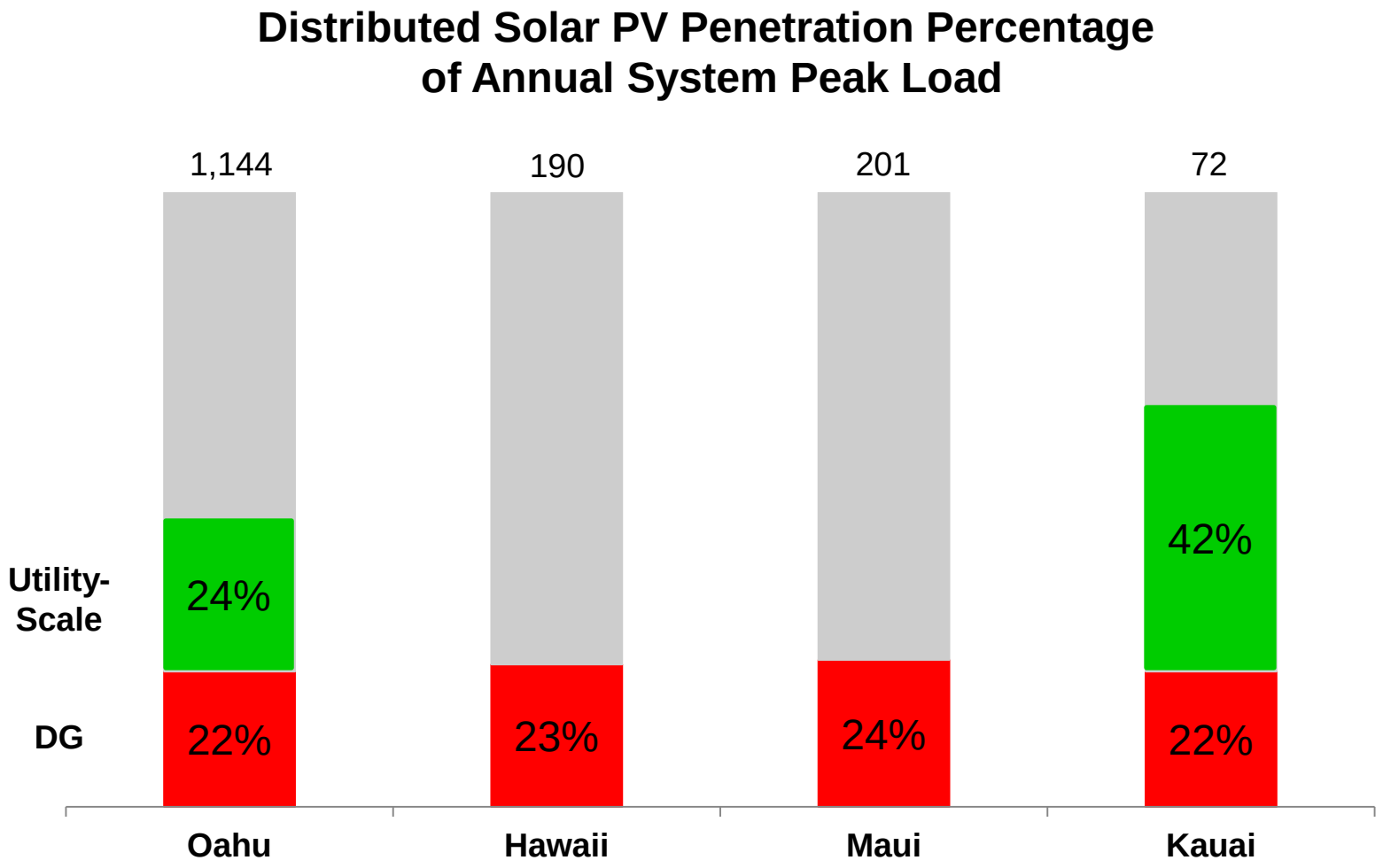
Hawaii's Distributed Solar Customer Adoption



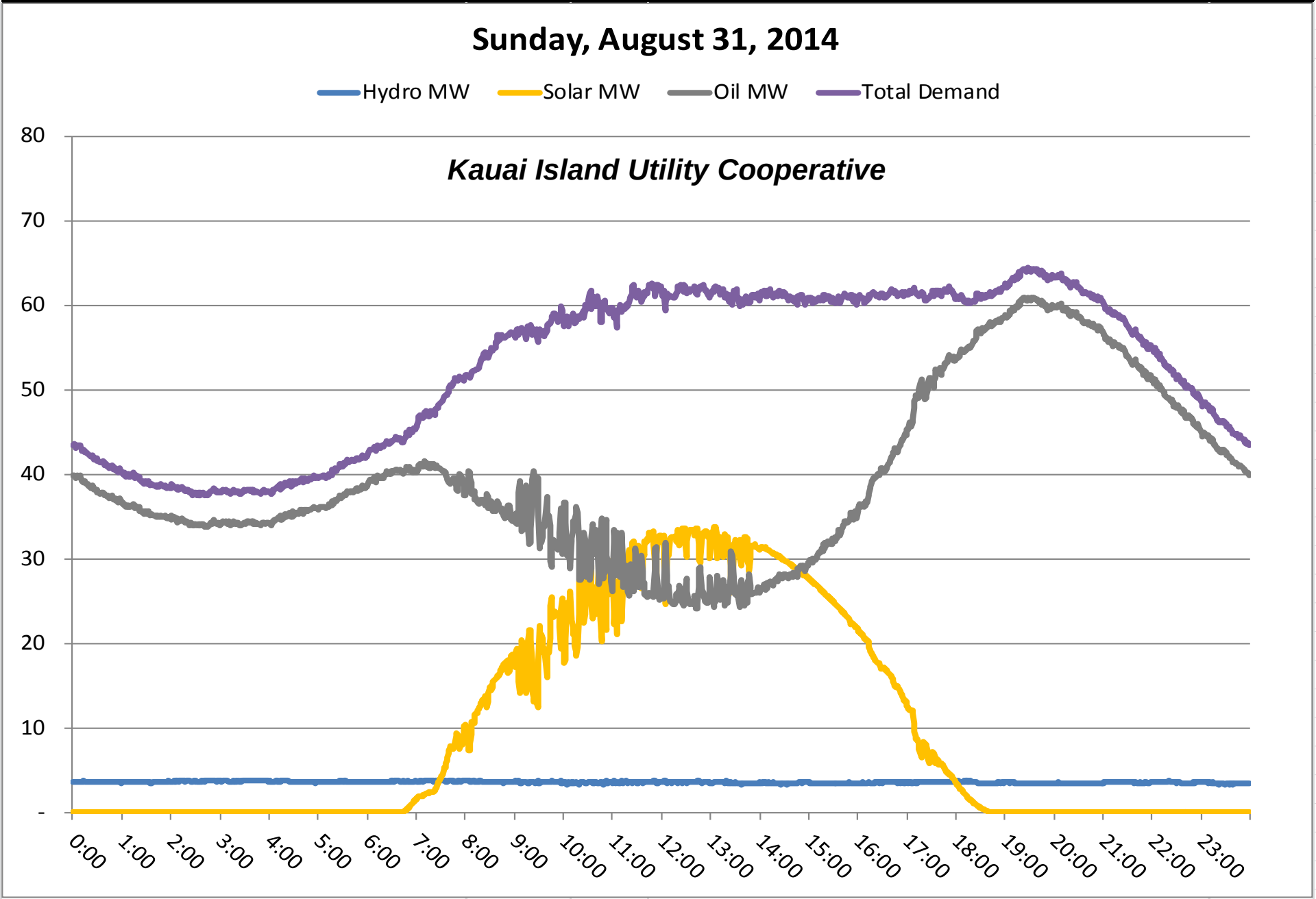
Hawaii – Decline in Average Residential Electricity Usage



Hawaii's Distributed Solar PV Penetration



Maximum Solar Penetration:	54.8%	Maximum Renewable Penetration:	60.6%
Total Solar Contribution:	18.6%	Total Renewable Penetration:	25.4%



Hawaii's Distribution Circuit DG Penetration Levels

Circuit Penetration Level	No. of Circuits			Percentage of Circuits		
	Hawaiian Electric	Hawai`i Electric Light	Maui Electric	Hawaiian Electric	Hawai'i Electric Light	Maui Electric
> 120% Daytime Minimum Load ("DML")	101	21	8	24.3%	15.4%	5.8%
> 100% up to and including 120% DML	29	9	17	7.0%	6.6%	12.4%
≥ 75% up to and including 100% DML	59	26	21	14.2%	19.1%	15.3%
< 75% DML	227	80	91	54.6%	58.8%	66.4%
TOTAL	416	136	137	100.0%	100.0%	100.0%

Hawaii Distributed Solar PV -- Lessons Learned

- **Exponential growth in customer solar PV installations occurred without fully understanding consequences**
  - High rates, state tax policy, solar leasing and declining solar costs drove growth
  - NEM program size caps removed to accommodate customer demand and solar industry growth; no future check points
  - Outpaced ability of utility to effectively manage customer PV interconnection queue and integration issues – slow to anticipate and recognize consequences
- **Creating "boom-bust" cycle for distributed solar PV in Hawaii**
  - Interconnection approvals have slowed significantly due to utility safety, reliability and operational concerns
  - Technical basis for concerns, and proposed mitigations, not well understood
  - General perception that electric utilities protecting their generation monopoly
  - Cost shift to non-participants only becoming material due to high proportion of avoided energy cost in total cost-of-service (⅔ of electric bill vs ≈ ⅓ on mainland)
- **Substantial utility-scale solar PV development slated for completion by 2016** – harmonize distributed and utility-scale renewable generation deployment

Hawaii Distributed Solar PV – Technical Lessons Learned

- Safety, reliability or operational issues not evident at lower penetration levels due to mostly residential systems and “integration” margin inherent in Hawaii’s electric grids
- Size of customer’s PV grid “footprint” matters -- unscheduled and uncontrolled export of excess solar energy onto grid regardless whether grid can physically or economically utilize energy is major challenge
- Bulk power system reliability challenges, not individual distribution circuit penetration levels, ultimately binding constraint on electrical island grids, and have emerged – finite amount of system technical and economic “capacity” to accommodate
- PV inverters are crucial part of distributed solar PV integration equation with high solar PV penetration; advanced inverters required but path forward uncertain
- Inability to curtail customer solar PV output requires curtailment of utility-scale renewable projects due to excess variable energy; customer PV effectively higher priority grid access
- Potential significant grid integration costs as utility-scale and distributed solar PV penetrations increase; moreover, less renewable energy output to spread mitigation fixed costs due to PV inherent low capacity factor

Hawaii Distributed Solar PV – Policy Lessons Learned

- **Future deployment options under high penetration solar PV scenarios not well defined – emerging generic options:**
  - ***Customer self-supply*** ("retail customer choice") – non-energy export option driven by market in response to utility TOU rate and DR options
  - ***Customer grid-supply*** (wholesale energy) – grid energy export option driven by utility energy procurements consistent with least-cost, balanced portfolio of renewable energy resources

- **Current distributed solar PV business model (NEM) not sustainable, nor consistent with either emerging generic customer PV development option**
  - *Customer self-supply* – NEM predicated upon customer "self-supply" financially but relying heavily upon grid physically creating circuit and system challenges (≈ *20% PV capacity factor cannot supply ≈ 75% load factor residential energy usage without significant grid PV footprint)*
  - *Customer grid supply* -- NEM procures "wholesale" energy supply at retail pricing as compared to utility-scale solar PV PPA pricing or where wholesale energy value may be negative due to surplus solar PV energy (*need additional system load, not additional solar PV energy*)

Hawaii Distributed Solar PV – Policy Lessons Learned (continued)

- **Distributed solar PV industry will, out of necessity, have to migrate to a new business model[(1)] ("DER 2.0")**
  - ***Customer self-supply*** – define pricing terms and conditions and regulatory compact for solar PV full or partial "retail customer choice" option that minimizes customer grid footprint (non-export) unless dispatched by grid
  - ***Customer grid-supply*** – define service offerings and pricing constructs for distributed solar PV "virtual power plant" option to supply cost-competitive wholesale energy, ancillary services and DR as required by grid
- **Utility service offerings and pricing options are critical component of DER 2.0**
  - Define technical and operating requirements that enable distributed solar PV to provide maximum grid value under either customer self or grid-supply options
  - Establish transparent grid avoided cost-based price signals that enable DER developers to create product offerings to encourage customer participation
  - Avoids potential adverse economic impacts on non-participant customers
- **Legacy customer and technology issues** – growing challenge until DER 2.0

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(1) See Hawaii Public Utilities Commission Decision and Order No. 32053 in Docket No. 2011-0206, dated April 28, 2014, at 49 - 50. On August 21, 2014, Commission commenced proceeding (Docket No. 2014-0192) to investigate distributed energy resource technical, economic and policy issues.

DER 2.0 – Distributed Solar PV Industry: Selective Perspectives

- TOU rates to incentivize DER customers to align load and generation through non-exporting systems and systems that only export during on-peak system load period

- Develop tariffs for fleets of DER that can be dispatched day-ahead and/or real-time providing ramping, frequency support, voltage support and other ancillary services

- Allow DER customers to participate in demand response programs and tariffs

- Expedited interconnection for DER with advanced inverters, energy management systems, non-export systems and energy storage technology that provide grid support services

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Excerpts from White Paper attached to The Alliance for Solar Choice (TASC) motion to intervene, dated September 10, 2014, in Hawaii Public Utilities Commission Docket No. 2014-0192, proceeding to investigate distributed energy resource technical, economic and policy issues.

Distributed Solar PV Integration – Key Challenges

Electric Utilities – embrace customer DER technologies as potential solutions to renewable integration challenges and grid modernization; not problems that must be accommodated. *Maximizing solar DG grid value minimizes potential grid defection.*

Solar Industry – migrate to new business model that reflects value DER provides to grid (DER 2.0), not predicated upon avoiding grid financially (NEM)

Customers – recognize rapid pace of customer solar PV interconnections not sustainable when grid infrastructure mitigations need to be deployed and advanced inverter functionality not yet available

Public Policy – pursue balanced, least-cost portfolio of renewable energy resources recognizing grid integration costs