Hawaii's Clean Energy Transformation

Future Opportunities and Challenges

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May 22, 2017

Hawaii Clean Energy Transformation – Summary

- Hawaii leads the nation in penetration of rooftop solar PV systems and is migrating from “dumb” solar to “smart” DERs to realize grid benefits

- Hawaii has expanded its renewable energy penetration from 7% to 27% in last decade, and in doing so, reduced generation oil consumption by 25%, but may now be reaching an inflection point

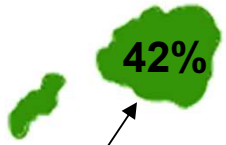
- Hawaii’s clean energy transformation is a capital substitution strategy -- ability to deploy capital effectively, efficiently and competitively is critical to ensuring future affordable electricity rates

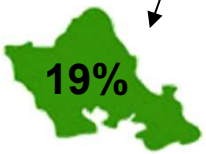
Hawaii Electric Systems -- 4 Electric Utilities; 6 Separate Grids*

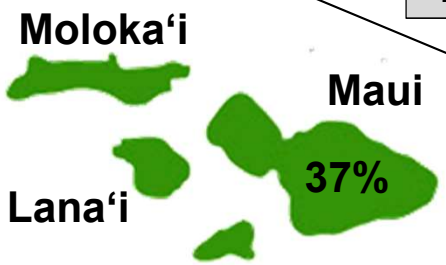
Hawaiian Electric
Customers: 304,300
Sales: 6,660 GWh
System Peak: 1,192 MWs
445 MW PV / 99 MW Wind /
69 MW WTE / 120 MW Biofuel

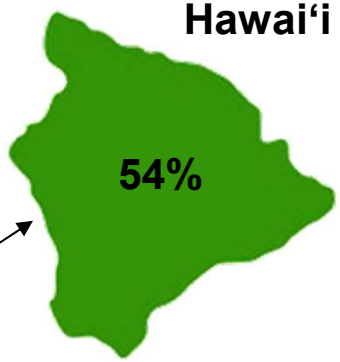
* Island Grids Not Interconnected

Maui Electric
Customers: 70,900
Sales: 1,118 GWh
System Peak: 212 MWs
100 MW PV / 72 MW Wind /
1 MW Hydro





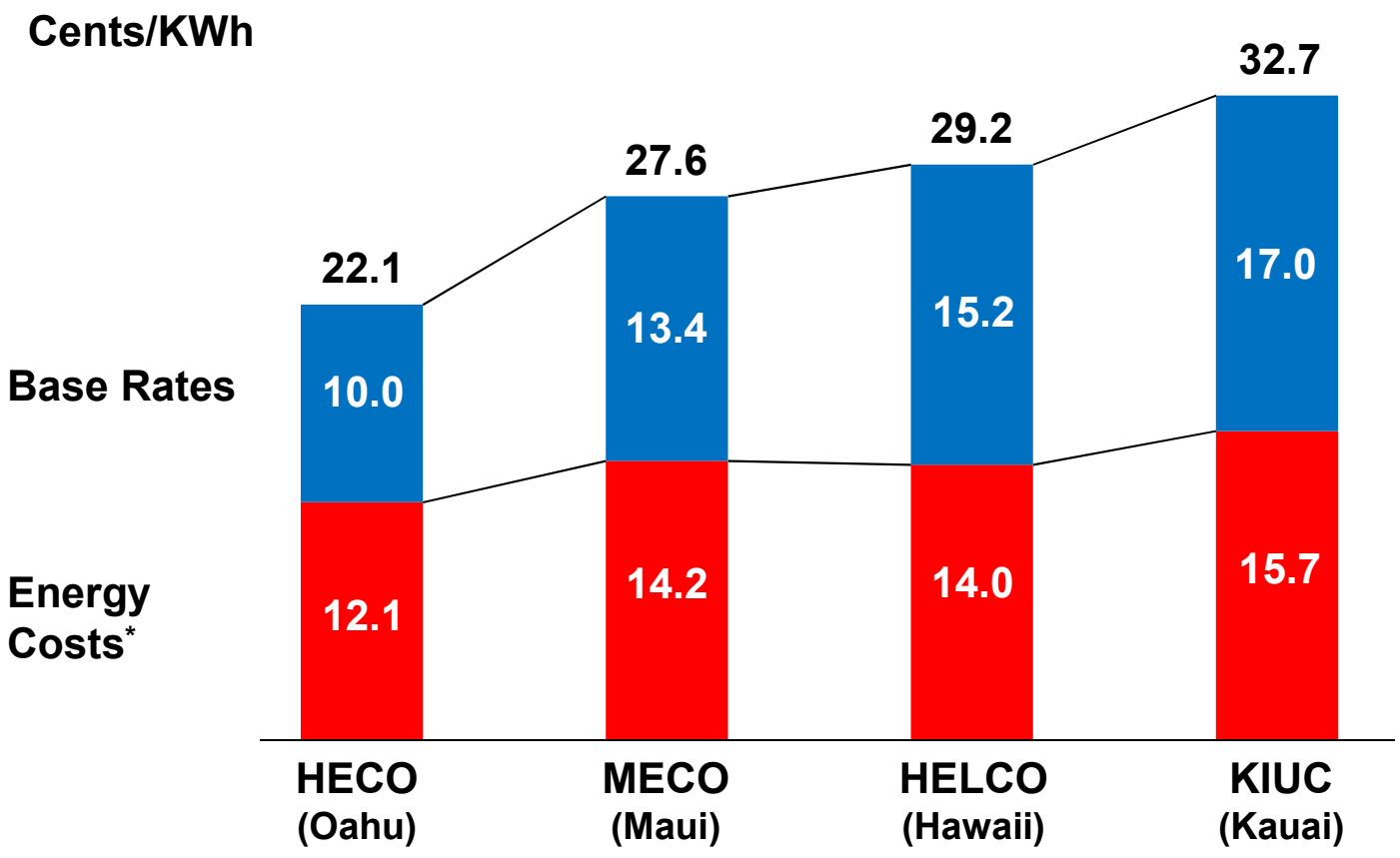




Kauai Island Cooperative
Customers: 37,100
Sales: 439 GWh
System Peak: 78 MWs
53 MW PV / 9 MW Hydro /
7 MW Biomass

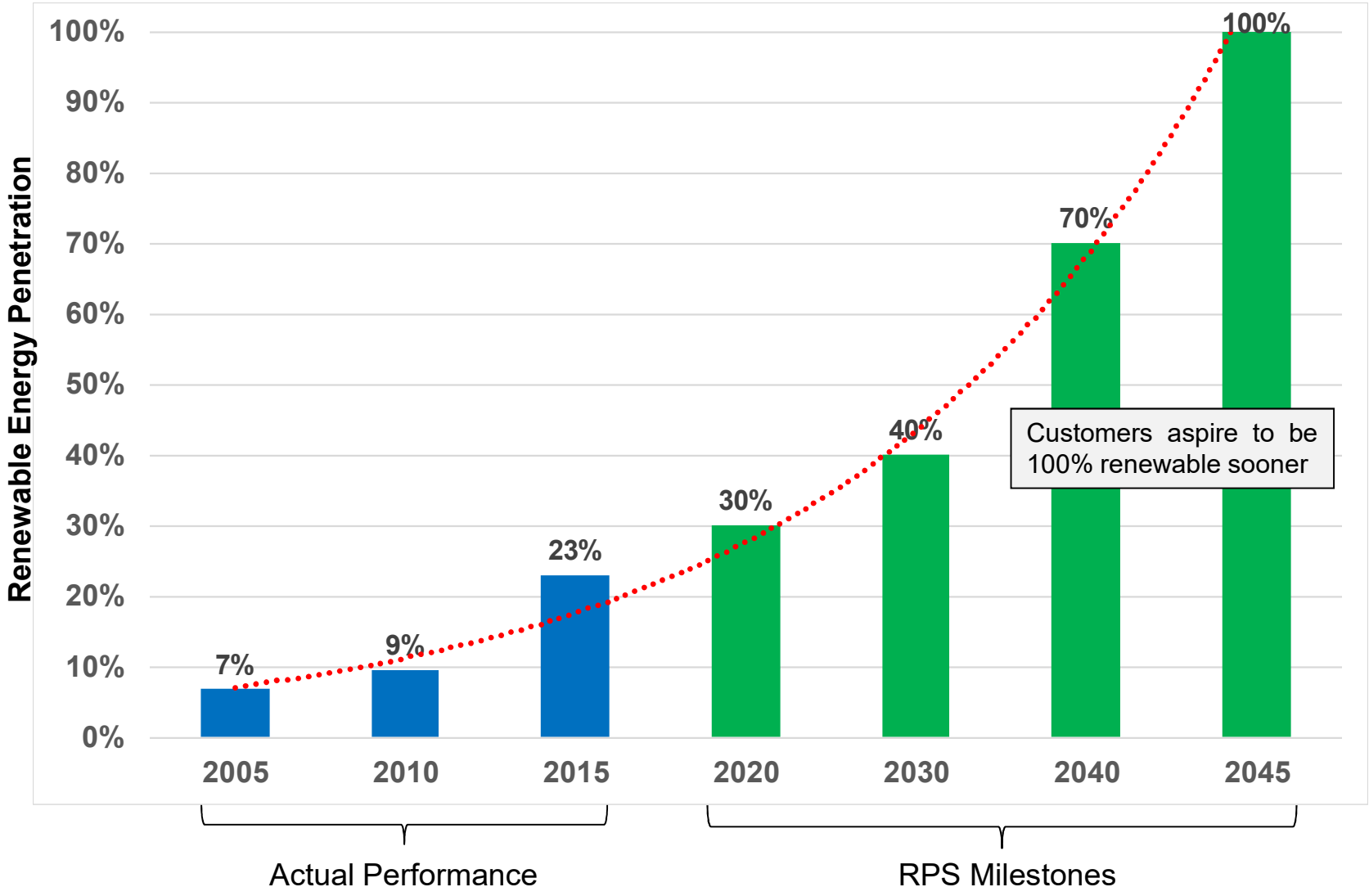
Hawaii Electric Light
Customers: 85,000
Sales: 1,067 GWh
System Peak: 189 MWs
82 MW PV / 31 MW Wind /
16 MW Hydro / 34 MW Geothermal

Average Electric Rate Level by Utility/County – 2016

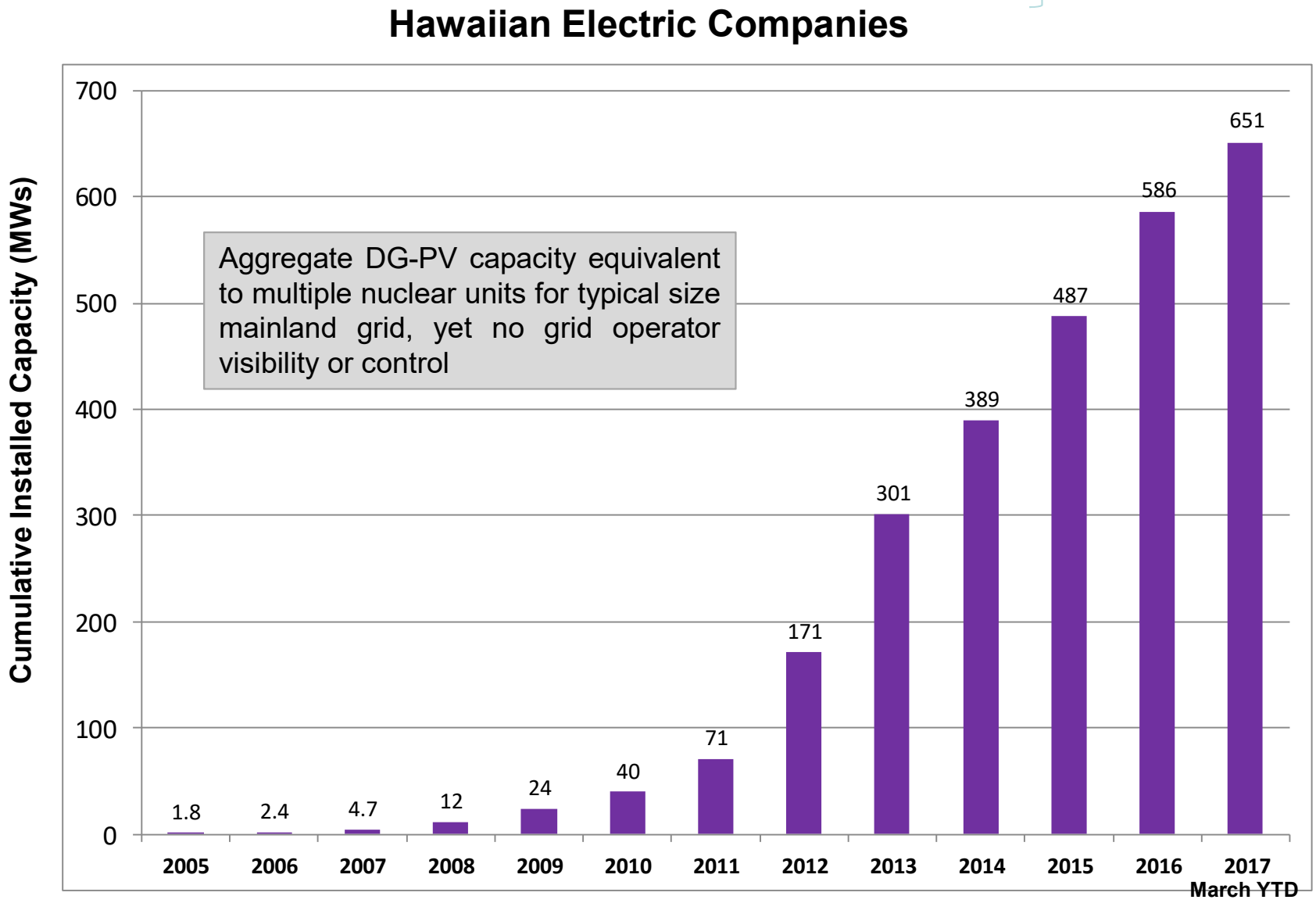


* Includes applicable capacity payments to IPPs and revenue taxes associated with fuel and purchased power expense.

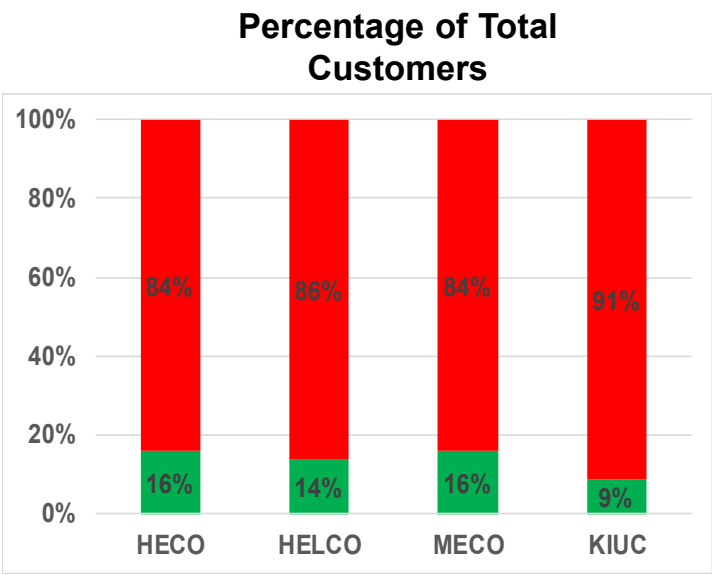
Hawaii's Renewable Portfolio Standards



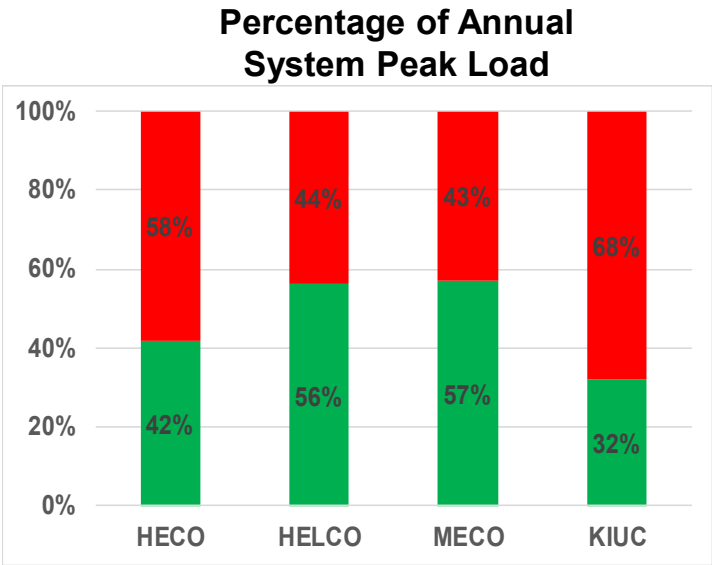
Distributed Solar PV -- Installed Capacity Growth



Hawaii – Current Distributed Solar PV Penetration



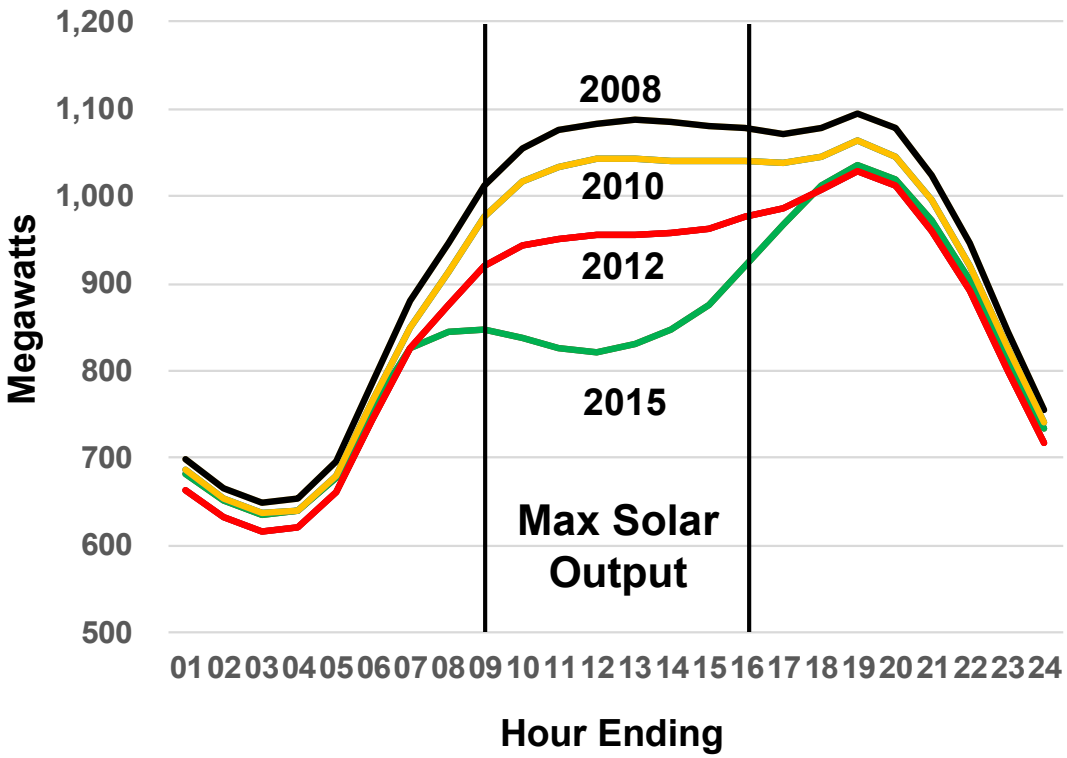
- Approximately 71,000 customer installations or approvals for installation
- 30% - 40% of all owner-occupied, single-family homes have solar PV systems
- Community renewable program essential to reach all customer segments



- 750 MWs of DG-PV installed or approved for installation –about 45% of peak load
- Individual PV system size limits would enable more customer installations
- Forecloses future opportunities to integrate lower cost, utility-scale renewable resources

PV Doesn't Provide "Monetizable" Grid Benefits in Hawaii

Hawaiian Electric Company (Oahu)
Annual Average Daily Load Curve



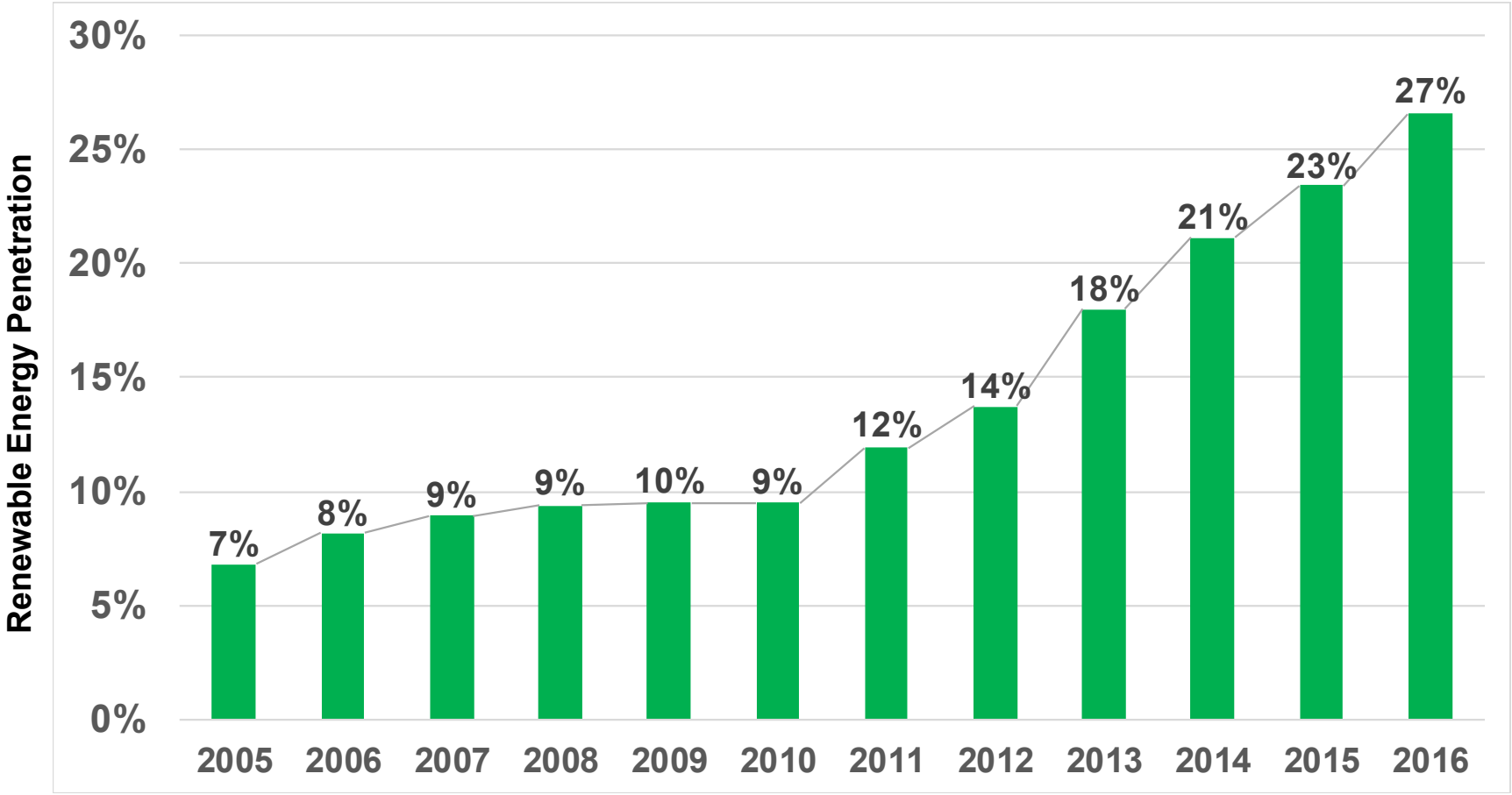
Unlocking Value of DERs for Distribution is Critical

- In Hawaii, DG-PV maximum output not coincident with generation or distribution system peak periods
- DG-PV systems essentially export expensive wholesale energy
- Portfolio of DERs – PV, storage, DR and targeted EE required to provide location-specific capacity deferral benefits

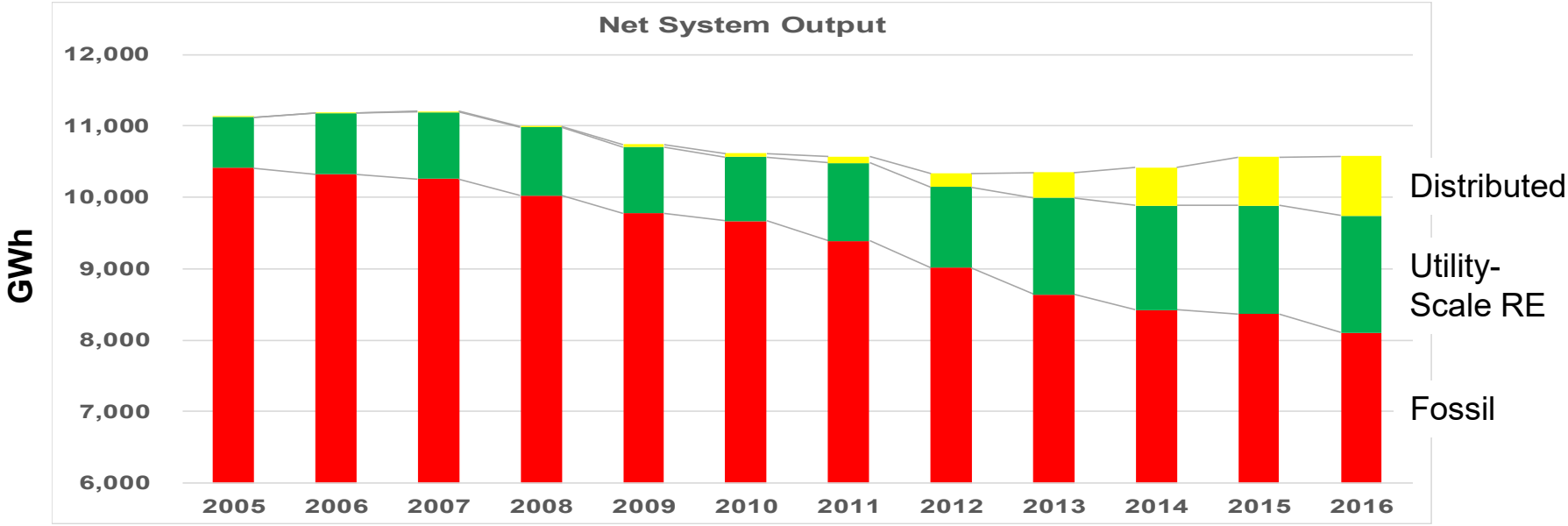
Hawaii's Distributed Solar PV – Integration Challenges

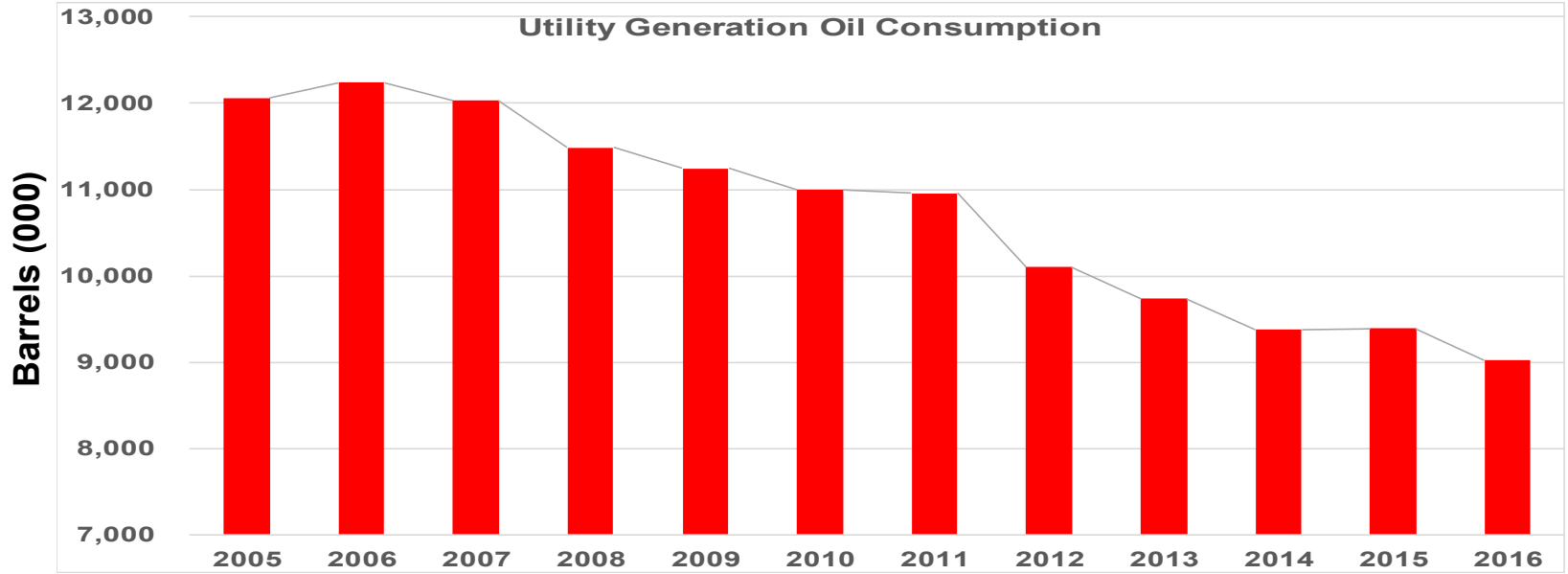
- **Distribution circuit interconnections not technically difficult as envisioned**
  - Majority of distribution circuits have PV penetration levels in excess of 100% gross day-time minimum load; many of them at, or exceed, their hosting capacity
  - Bulk power system reliability constraints, not individual distribution circuit penetration levels, binding constraint on island electrical grids
- **Operational challenges exist that need to be addressed**
  - Limited grid operator visibility of, and no control over, most DG-PV systems
  - Advanced inverters required but grid protocols to leverage new technology needed
  - Provision of essential grid services needs to be defined; cybersecurity risks are significant
  - Grandfathered legacy DG-PV systems need to be upgraded, at a minimum, to ride through frequency and voltage excursions – unclear who – utility, customer or DER provider – has the responsibility to upgrade and obligation to pay
- **Integrated distribution resource planning (IDRP) essential**
  - Identify grid locations where DER portfolios could provide capacity deferral benefits
  - Establish grid modernization strategies and distribution platform requirements to enable DERs to provide grid services

Hawaii's Renewable Energy Portfolio Performance

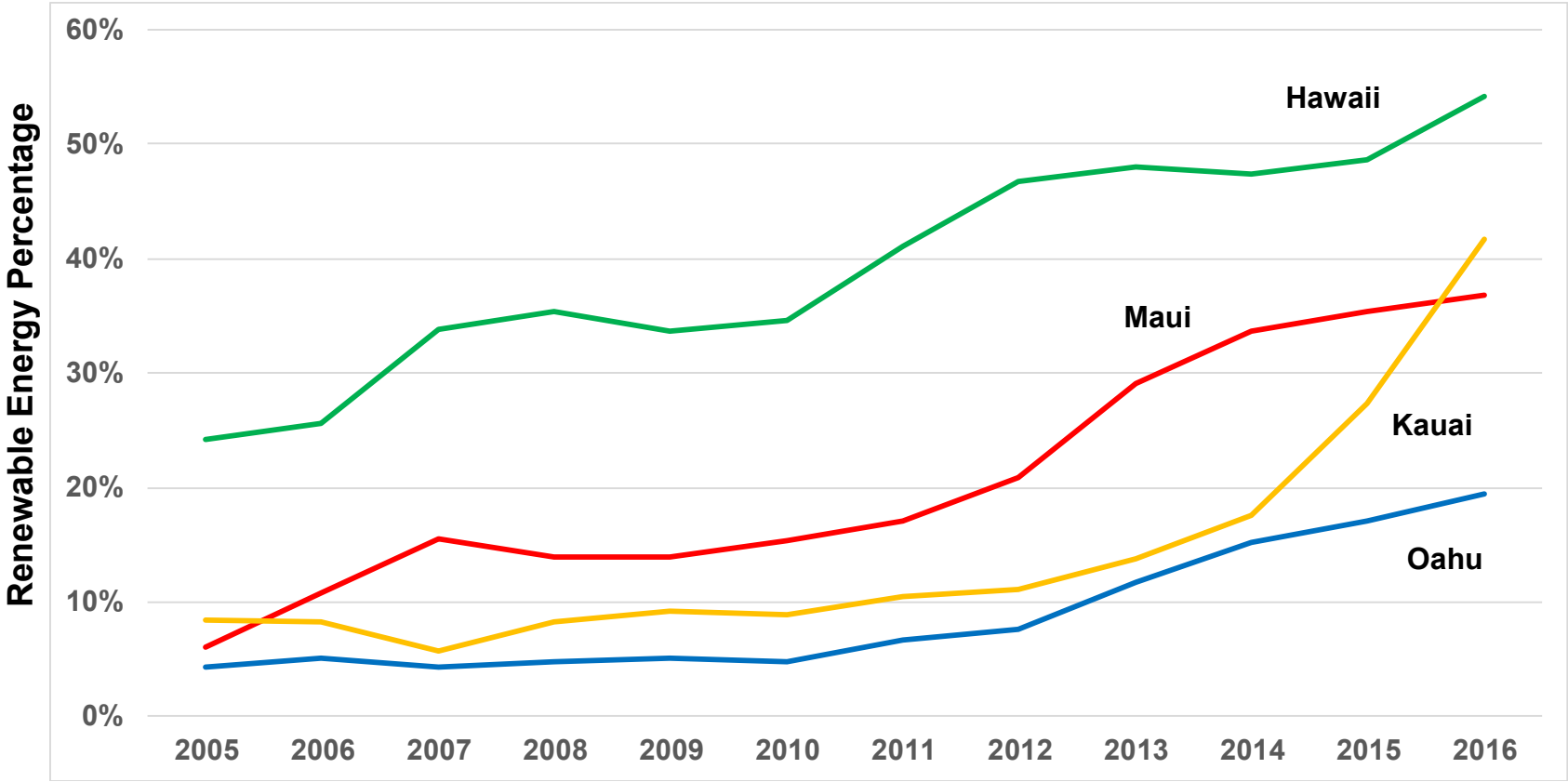


Reduction in Utility Generation Oil Utilization

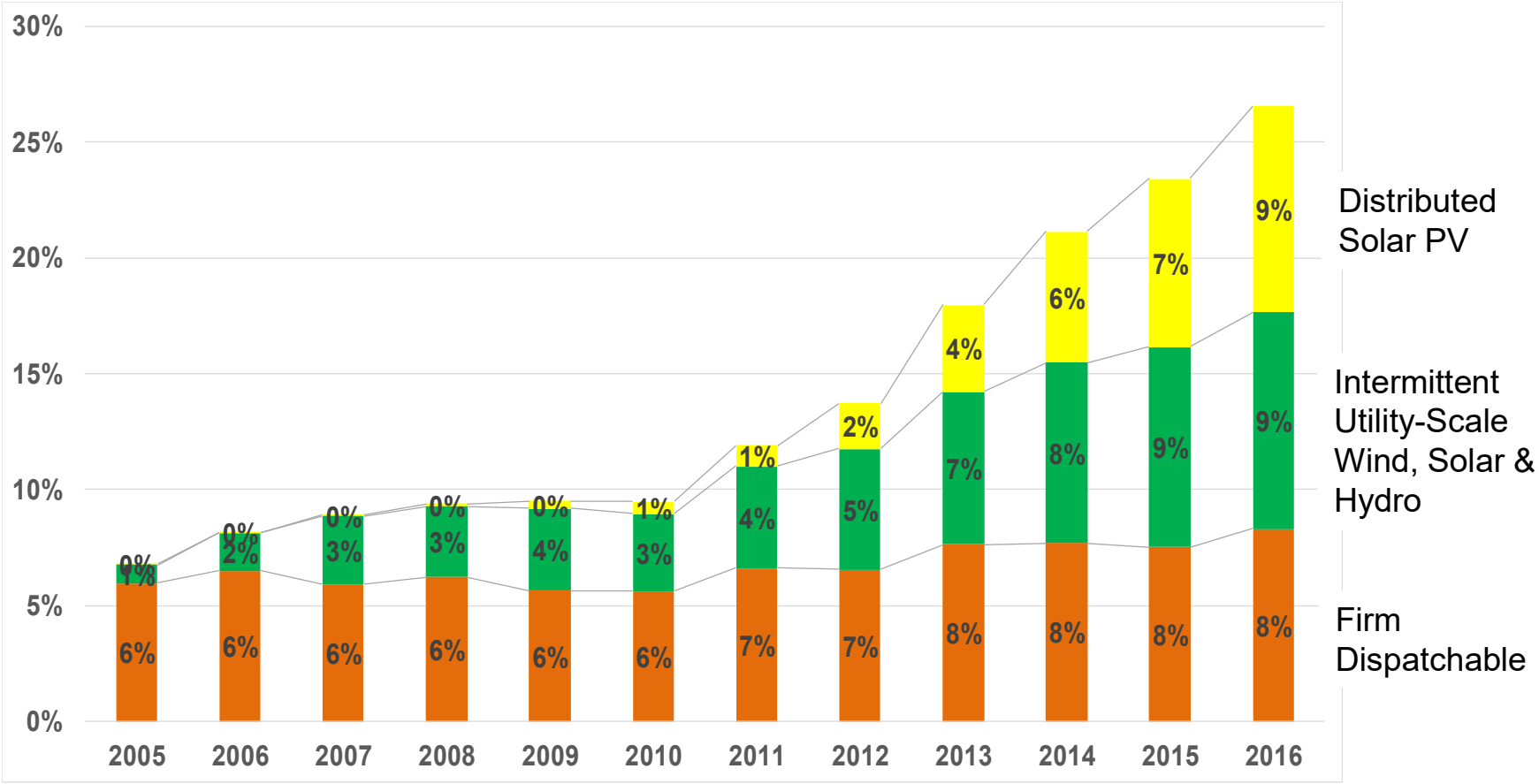




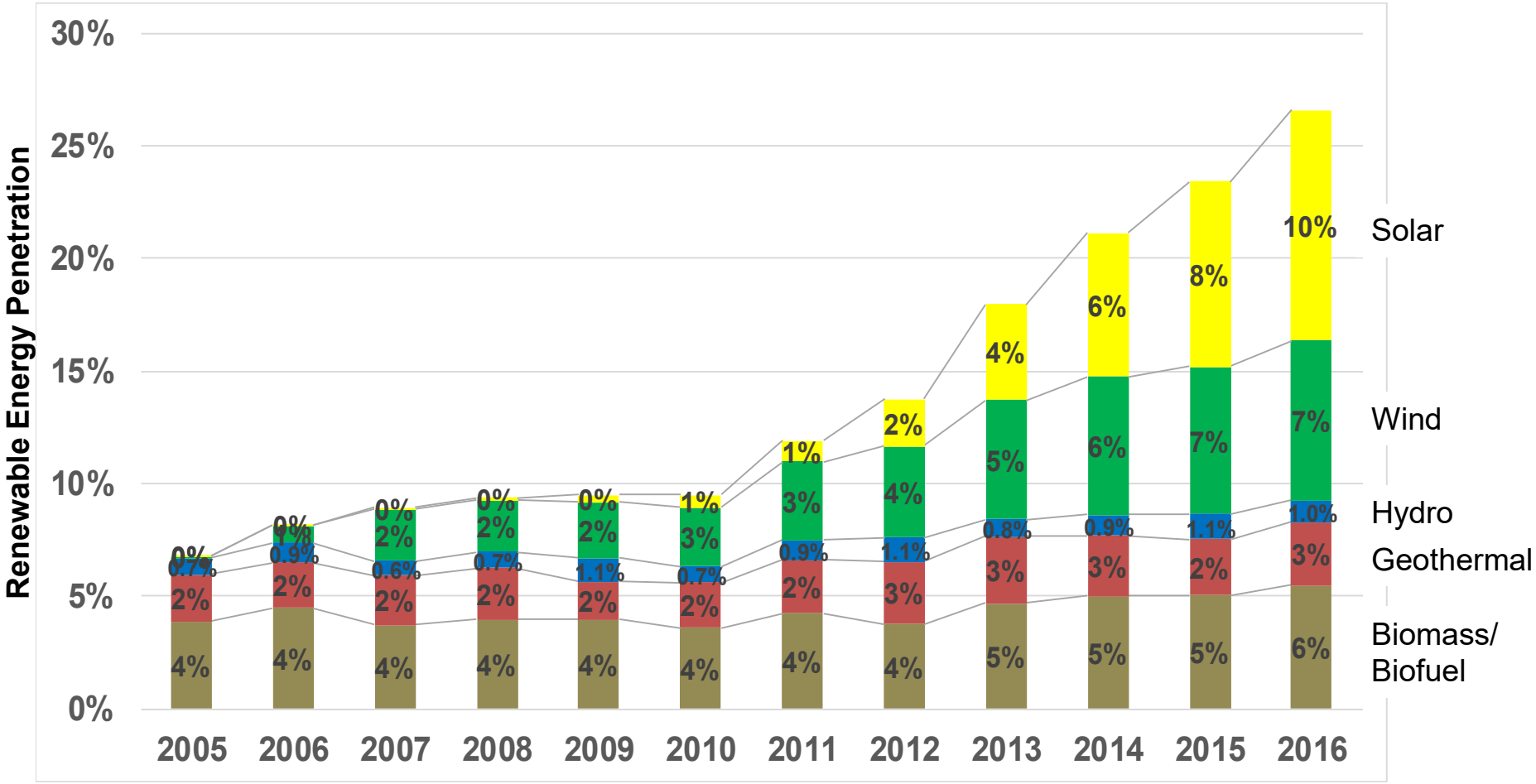
Renewable Energy Penetration Trends by Island



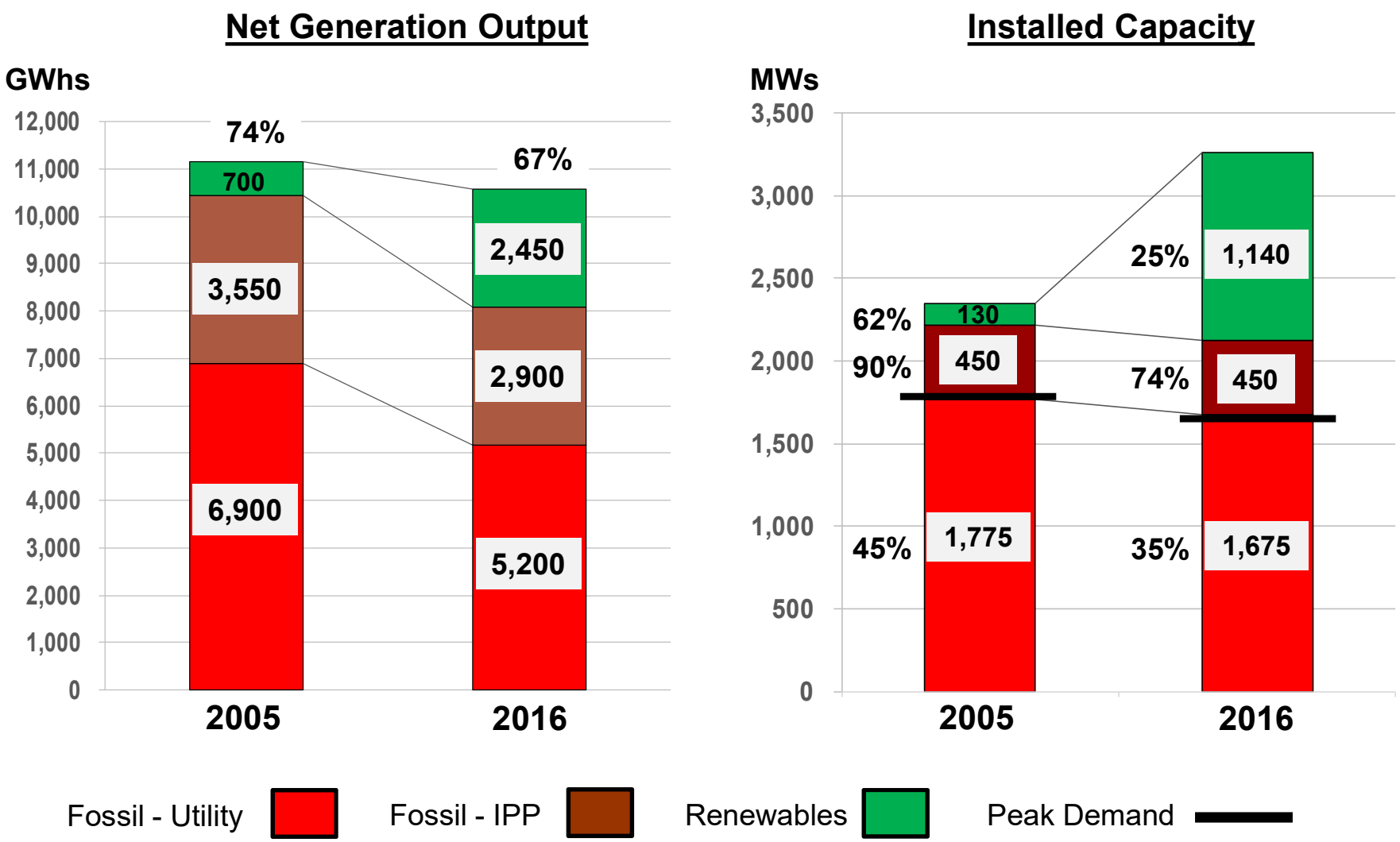
Hawaii's Renewable Energy Portfolio – Major Components



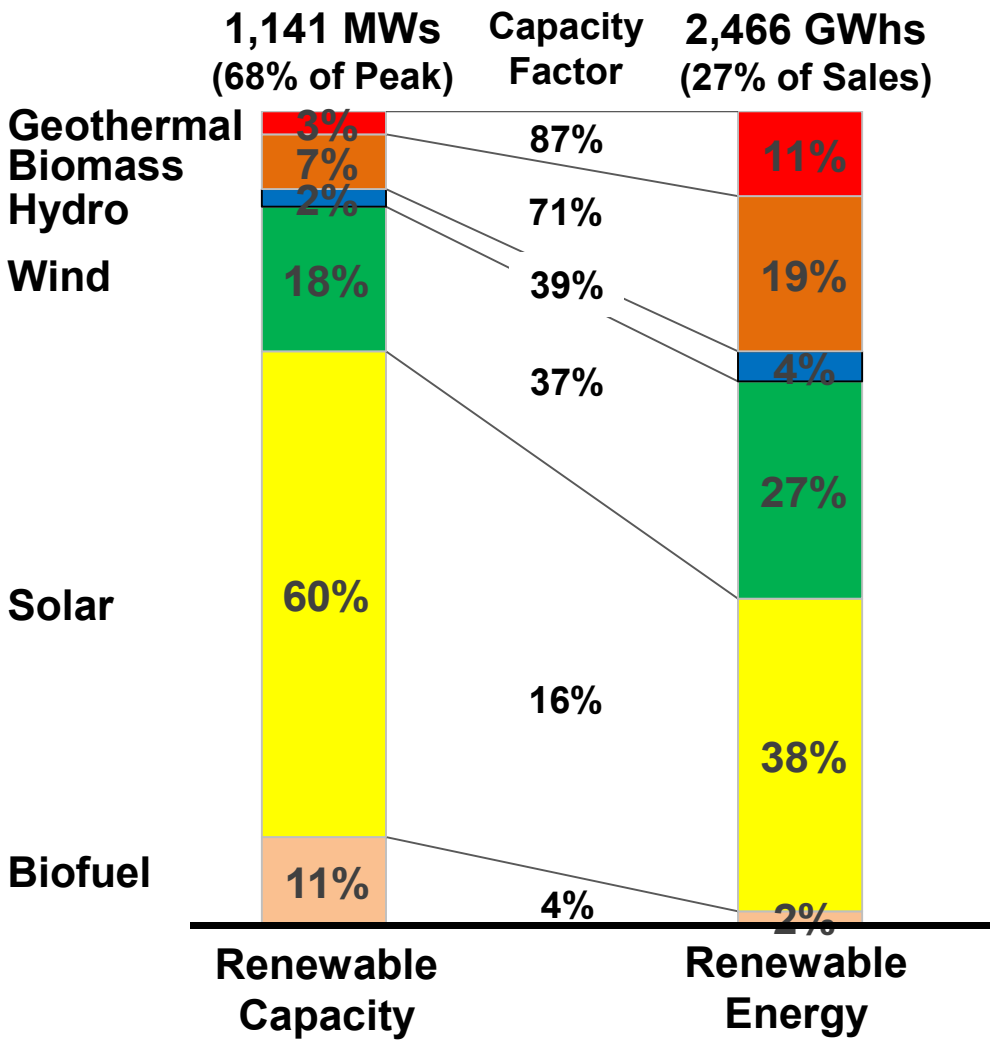
Hawaii's Renewable Energy Portfolio – Technology



Hawaii's Power Supply Portfolio – 2005 vs 2016



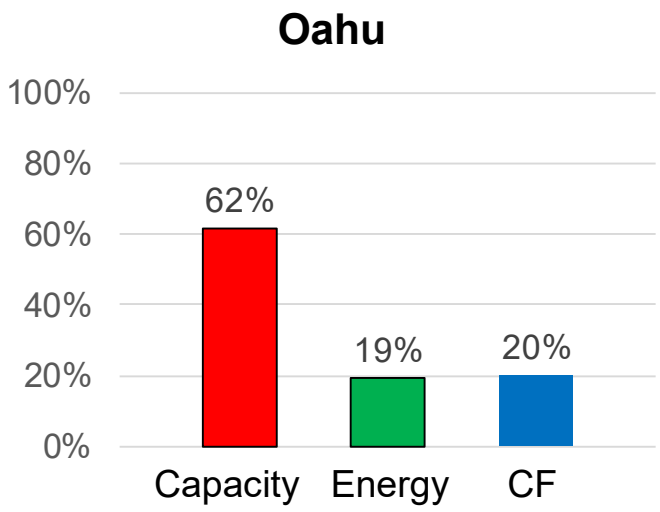
Hawaii's 2016 Renewable Portfolio – Capacity vs Energy Dilemma

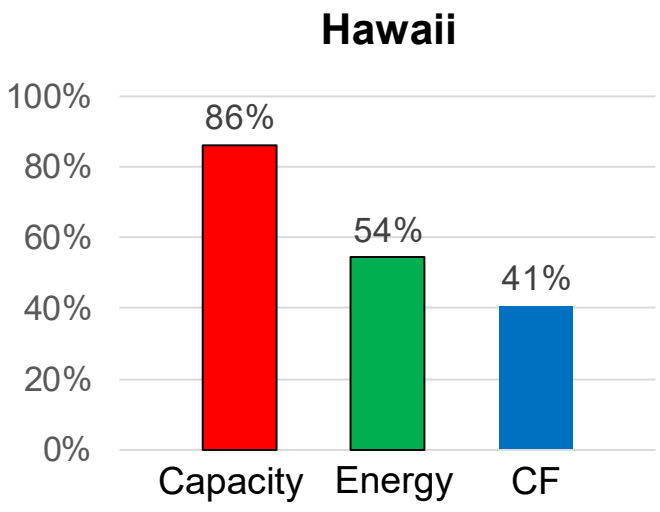


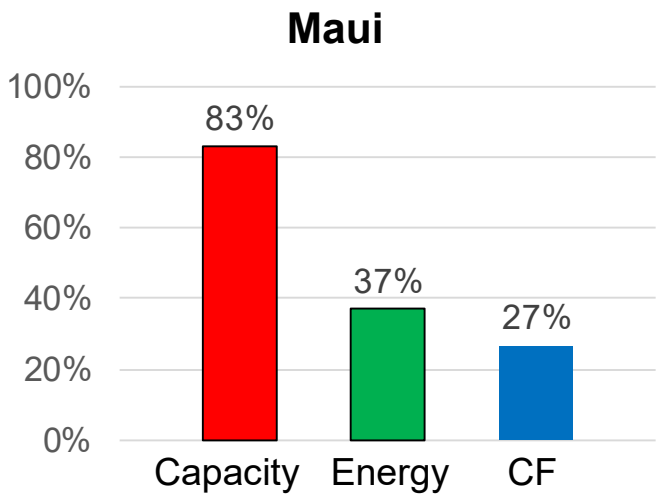
Implications

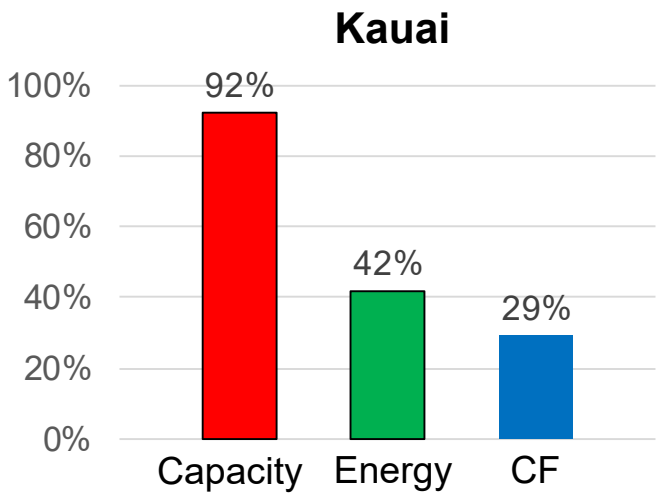
- Capacity factor of Hawaii's renewable portfolio is 25% in 2016; system load factors are 65% - 70%
- Installed renewable resource capacity equivalent to 3 – 4 times system peak demand may be required to achieve 100% RPS
- Substantial bulk energy storage capacity and load shifting required to achieve high renewable penetration levels
- Amount of installed intermittent renewable capacity drives grid integration challenges and mitigation costs

Renewable Capacity vs Energy Penetration by Island-- 2016









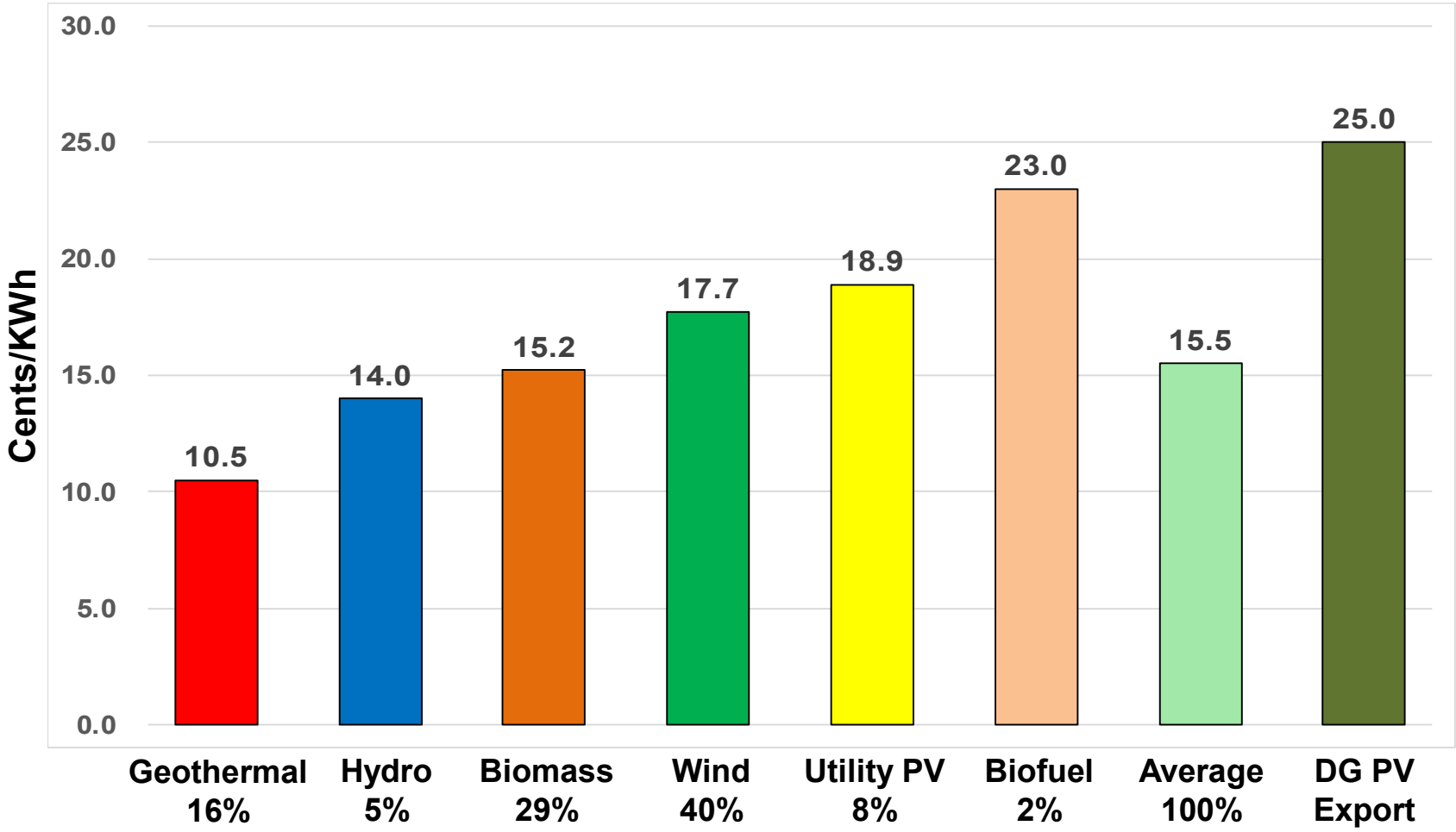
Hawaii Reliability – Under Frequency Load Shed (UFLS) Events

Island	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Oahu	0	0	0	1	2	1	2	4	3	1
Hawaii	11	18	14	10	12	20	14	15	9	0
Maui	5	2	8	5	7	2	2	3	0	2
Kauai	17	16	14	23	7	2	9	8	3	1

Hawaii must migrate to dynamic UFLS schemes to offset erosion of daytime circuit loads due to distributed solar PV systems.

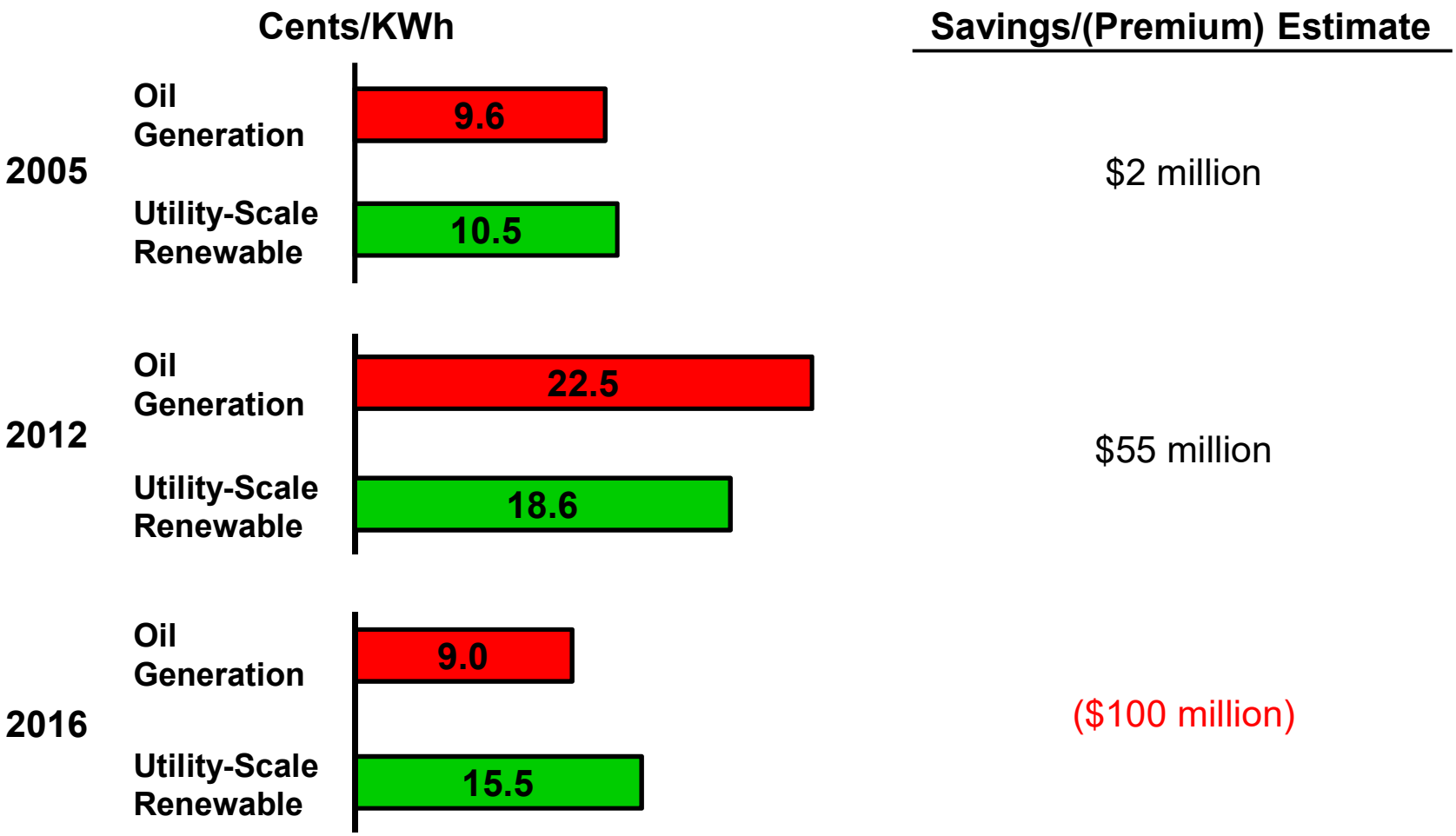
Utility-Scale Renewable Resources – 2016 Composite Prices*

Preliminary



* Excludes applicable capacity payments to IPPs and fixed charges for utility-owned renewable projects.

Hawaii Power Supply Portfolio – Fossil vs Renewable Costs



Hawaii's Renewable Energy Portfolio – Key Issues

- **Renewable portfolio development strategies** – achieving consensus challenging
  - Portfolio composition and optimization -- distributed solar PV vs utility-scale centric
  - Pace of adoption considering technology maturity and future cost trajectories
  - Replacement strategy for existing, inflexible and aging fossil generating units
- **Technical and economic integration issues**
  - Portfolio of flexible supply and demand response resources to respond to availability of intermittent renewable energy
  - Ability to rely upon inverter-based resources (i.e., wind & solar, energy storage, EVs) and demand response to provide ancillary services and fault current
  - Energy storage requirements – functional roles, technologies, capacity, scale and location (grid vs behind meter)
- **Obtaining competitive prices for renewable energy projects in small, isolated markets with high avoided costs**
  - Competitive acquisition and contracting strategies for new renewable resources
  - Strategies to manage curtailment risks – compensation and operational

Capital Deployment By Energy Stakeholders: 2005 - 2016

Rough Estimate

Stakeholder	Resource	Amount	Cost	Investment
		(MWs)	($/KW)	(Billions)
Customers	Distributed Solar PV	610	4,000	$2.45
IPPs	Utility-Scale Renewables	300	4,300	1.30
Utilities	Biofuel	120	1,750	0.20
Sub-Total	**Renewables**	**1,030**	**3,850**	**$3.95**
Utilities	Grid Infrastructure	Increase in Net Plant*		1.60
Total				**$5.55 Billion**

* Represents an 85% increase from 2005; actual plant additions exceeded $3 billion, offset by accumulated depreciation. Overall electric sales declined by 12% during this period.

Clean Energy Transformation – Final Perspectives

- Market forces, and customer preferences, not necessarily resource plans, will drive scope and scale of transformation – get market structures right early

- DERs need to differentiate themselves from their utility-scale counterparts by providing distribution grid benefits, to warrant additional compensation beyond wholesale market prices

- Substantial renewable capacity will be required to achieve high penetrations of renewable energy, if capacity is comprised mostly of lower capacity factor renewable technologies

- Diversified portfolio of renewable technologies is critical to ensure affordable electric rates – balance renewable technology benefits with associated grid integration costs

- New business and regulatory models needed in Hawaii – both for utilities and DER providers

Mahalo