NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Does an Island Approach to Higher Penetration Renewables Make Sense for the Mainland?

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ASES Solar 2018 Conference
August 7, 2018

NREL/PR-5000-72213

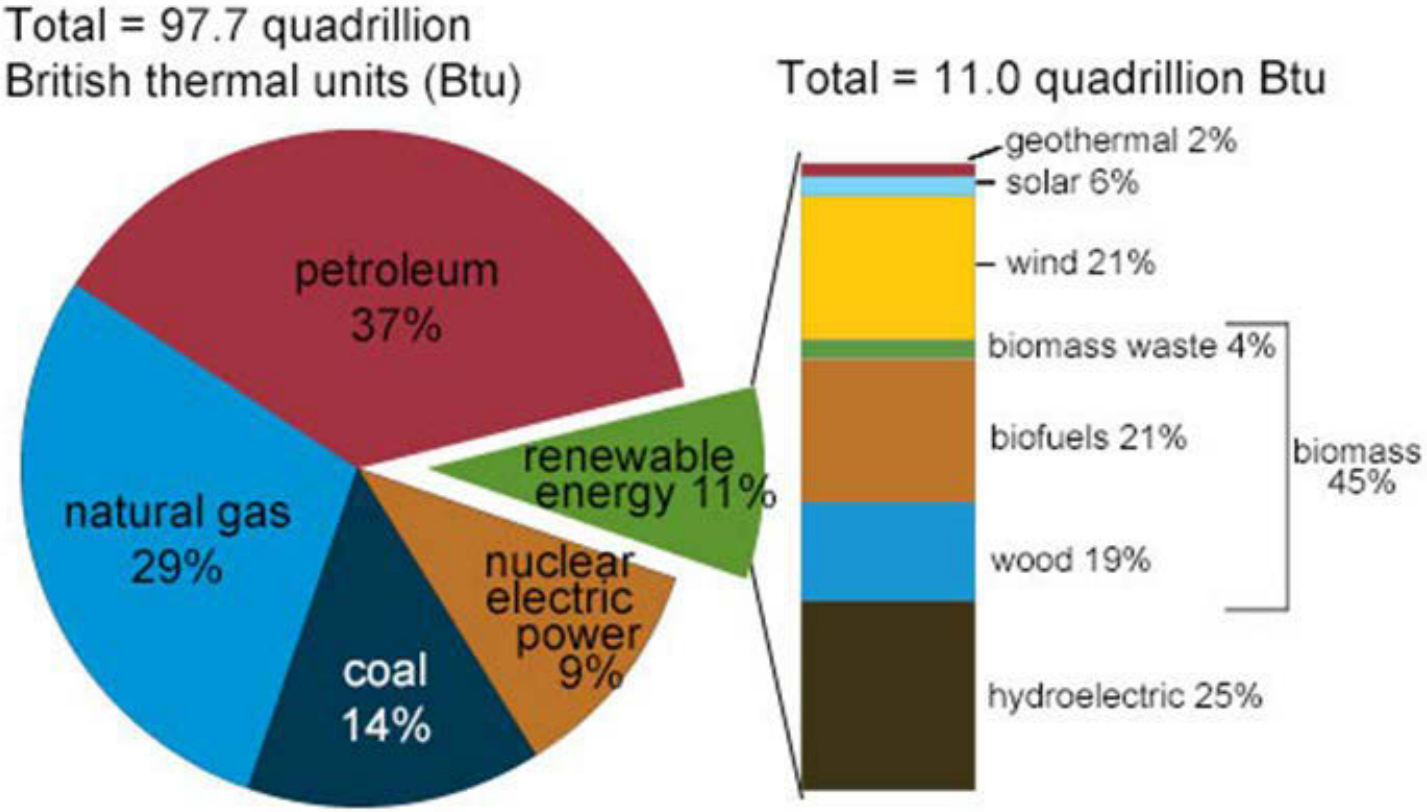
Island Approach to Higher Penetration Renewables

Outline

- Where Are We Now?
- Higher Renewable Energy (RE) Penetration Challenges
- Stakeholders—Island vs. Mainland
- Advantages of "Island Approach"
- What "Island Lessons Learned" Can Be Applied to Mainland Applications?

Challenges of Higher RE Penetration

U.S. energy consumption by energy source, 2017



Note: Sum of components may not equal 100% because of independent rounding.
Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 1.3 and 10.1, April 2018, preliminary data

The energy sectors

- Electric Power (38%)
- Transportation (29%)
- Industrial—Process/ HVAC/Other (22%)
- Commercial/ Residential (11%).

Challenges of Higher RE Penetration

The energy sectors

- Electric Power (38%)
- Transportation (29%)
- Industrial—Process/HVAC/Other (22%)
- Commercial/Residential (11%).

Coal (34%)
Natural Gas (26%)
Nuclear (23%)
Renewable Energy (17%)

Wind	6.2%
Solar	1.8%
Hydro	7.4%

DOE's Wind Vision cites a penetration goal of 20% wind by 2030. 6.2% equates to 89 gigawatts (GW) by end of 2017. To get to 20% the U.S. will need 287 GW by 2030.

DOE's SunShot program does not cite deployment or penetration goals by 2030. They cite energy cost goals: $0.05/kilowatt-hours (kWh) for residential PV; $0.04/kWh for commercial PV and $0.03/kWh for industrial PV. It is anticipated that at those levelized cost of energy (LCOE) levels, photovoltaic (PV) penetration rates across each market will be high.

Source: https://www.eia.gov/totalenergy/data/monthly/pdf/flow/css_2017_energy.pdf

Challenges of Higher RE Penetration

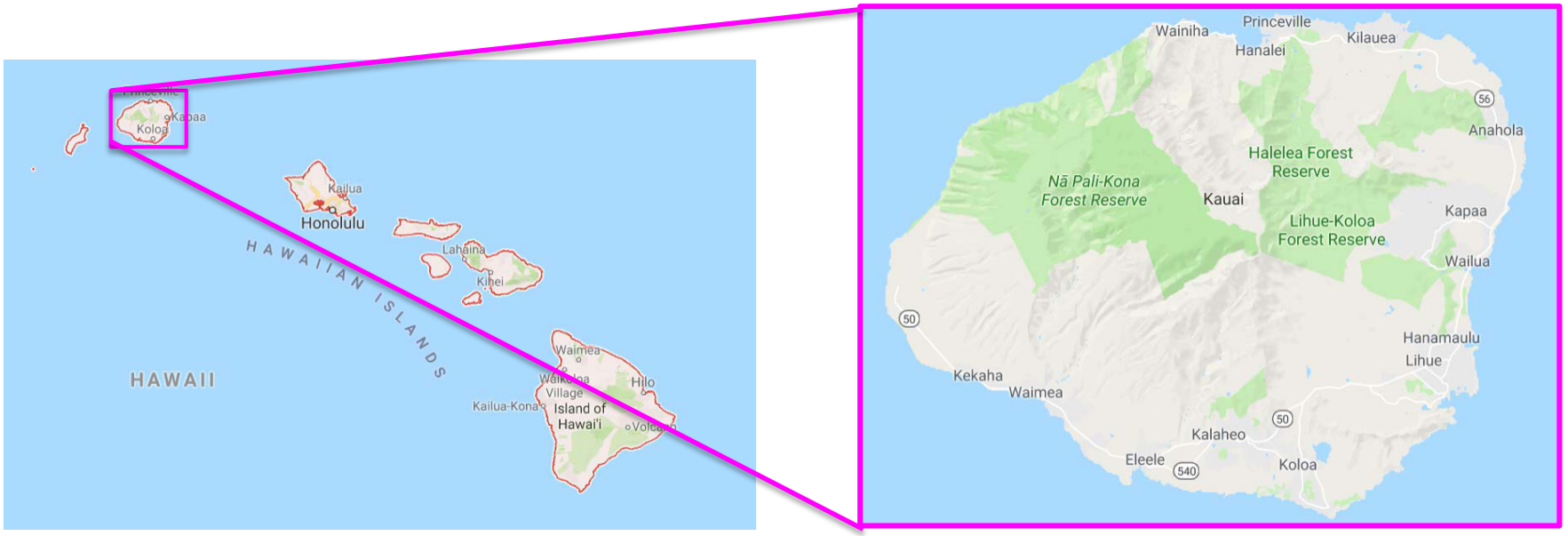
Stakeholders

- Any utilities expecting reduced revenues or fewer customers
- Any generator seeing declining percentage or declining capacity from existing generation
- Any transmission owners that will see drop in use of their transmission lines and revenue
- Landowners impacted by new installations of wind, solar, pumped storage hydro, geothermal, or biomass
- Environmental orgs seeing new development impacting endangered or threatened species.

What Is Different Today?

- Most of us were not alive when many of today's nuclear, coal, and hydro plants were permitted and installed
- Same with many of the transmission lines (though 2005–2020 has new capacity in regions; very little capacity additions added late 1980's–2005 due to deregulation uncertainty)
- In the 1930's (except for impact of Great Depression—economic stagnation/shrinkage) Public Works Administration drove installation of large hydro
- 1940's, 50's, and 60's—the economic pie was always getting larger; generation needs always growing; regulated utilities planned for growth and got more generation, transmission.

Kaua'i Island Utility Cooperative (Co-op) Profile



Kaua'i Island Utility Co-op (KIUC) has 140 employees.

Rural electric co-op exists solely to provide electricity to its members and:

- Provide safe, reliable, fairly and competitively priced power
- Encourage conservation and efficient use of resources
- Increase sustainable power supply and environmental stewardship.

2008: Renewable Energy Goal 50% by 2023

2010: 92% of energy from imported oil

Source: http://kiuc.coopwebbuilder2.com/sites/kiuc/files/PDF/annualreport/AnnualReport2017.pdf

Kaua'i Island Utility Co-op Profile

2016 Utility Bundled Retail Sales - Total

(Data from forms EIA-861- schedules 4A & 4D and EIA-861S)

Entity	Customers (Count)	Sales (Megawatthours)	Revenues (Thousands Dollars)	Average Price (cents/kWh)
Hawaii Electric Light Co Inc	84,609	1,067,398	309,521.3	29.00
Hawaiian Electric Co Inc	304,261	6,660,195	1,466,224.8	22.01
Kauai Island Utility Cooperative	32,967	439,088	143,007.0	32.57
Maui Electric Co Ltd	70,724	1,117,742	306,766.9	27.45
OneRoof Energy, Inc.	290	2,971	353.3	11.89
SolarCity Corporation	3,810	55,514	7,063.7	12.72
Spruce Finance	160	1,826	375.5	20.56
SunEdison LLC	16	5,063	1,116.4	22.05
SunPower Capital Services, LLC	180	2,129	506.7	23.80
SunPower Capital, LLC	659	8,540	1,608.1	18.83
Sunnova	316	3,159	646.2	20.46
Sunrun Inc.	3,883	34,993	7,209.0	20.60
Vivint Solar, Inc.	4,341	38,529	8,399.9	21.80

33,000 customers 439,000 megawatt-hours (MWh) $0.33/kWh

Source: https://www.eia.gov/state/print.php?sid=GQ

Kaua'i Island Utility Co-op Profile

	Type	MW	% of Sales
ACTIVE IN USE			
KIUC, Kōloa	Solar	12.0	4.6
KIUC, Anahola	Solar	12.0	4.6
Green Energy Team	Biomass	6.7	10.4
McBryde, Port Allen	Solar	6.0	2.4
McBryde, Wainiha	Hydro	4.0	3.3
KIUC, Waiahi	Hydro	1.5	1.5
McBryde, Kalāheo	Hydro	2.0	1.0
Gay & Robinson, Olokele	Hydro	1.3	0.8
KAA, Waimea/Kekaha	Hydro	1.5	0.4
Pioneer, Waimea	Solar	0.3	0.1
Kapa'a Solar	Solar	1.0	0.4
Tesla Solar Storage	Solar	13.0	3.3
MP2, 'Ōma'o	Solar	0.3	0.1
Customer Solar	Solar	29.9	11.5
UNDER CONSTRUCTION/PERMITTING			
Gay & Robinson, Olokele	Hydro	6.0	4.2
AES Lāwa'i Solar Storage	Solar	20.0	11.0
AES PMRF	Solar	14.0	7.0
UNDER CONSIDERATION			
Westside Pumped Hydro Storage	Hydro	25.0	14.0

Total Renewable Energy in Service 2017

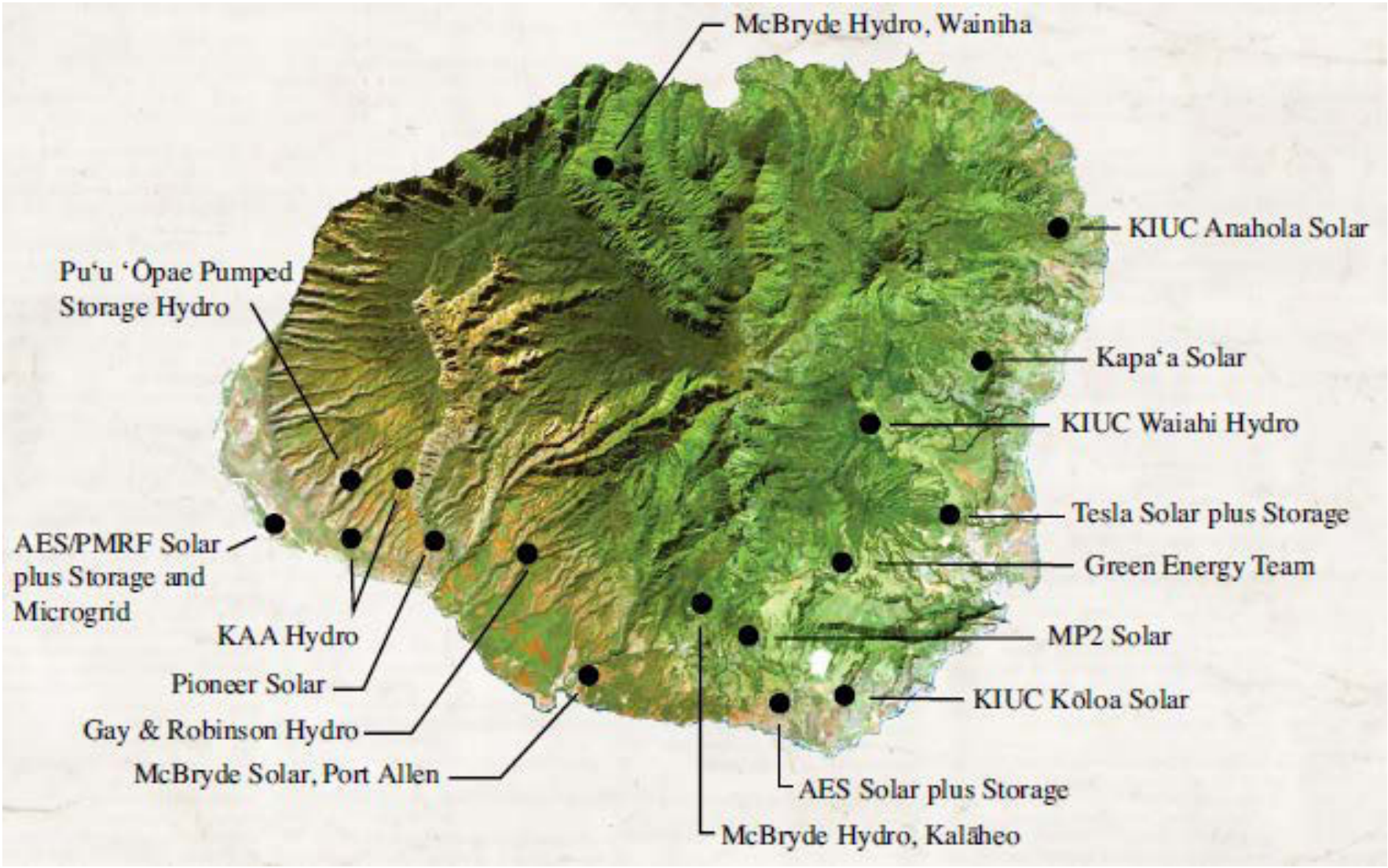
91.5 Megawatts(MW)/44%

Potential Renewable Energy in Service 2025

156.5 NW/80%

Source: http://kiuc.coopwebbuilder2.com/sites/kiuc/files/PDF/annualreport/AnnualReport2017.pdf

Kaua'i Island Utility Co-op Profile



Source: http://kiuc.coopwebbuilder2.com/sites/kiuc/files/PDF/annualreport/AnnualReport2017.pdf

Kaua'i Island Utility Co-op Current Projects

2017:

- Solar plus storage: 20 MW of storage for 5 hours—> 100 MWhs of solar for meeting peak evening demand
- Power purchase agreement (PPA) for 14 MW of solar PV with 70 MWhs of battery energy storage systems (BESS) at Pacific Missile Range Facility—Barking Sands.

PPA price for each was ~$0.11/kWh for 25 years

2017: 44% RE—hydropower, biomass, and solar PV

2017: New RE penetration goal—70% RE by 2030

For KIUC, they are actually experiencing a downward pressure on rates due to cost of renewable PPA's.

Source: http://kiuc.coopwebbuilder2.com/sites/kiuc/files/PDF/annualreport/AnnualReport2017.pdf

KIUC Success Factors in Higher RE Penetration

In 2005, KIUC commissioned a study to identify viable renewable technologies:

- Wind, biomass, hydroelectric, landfill gas, and waste-to-energy rose to the top.

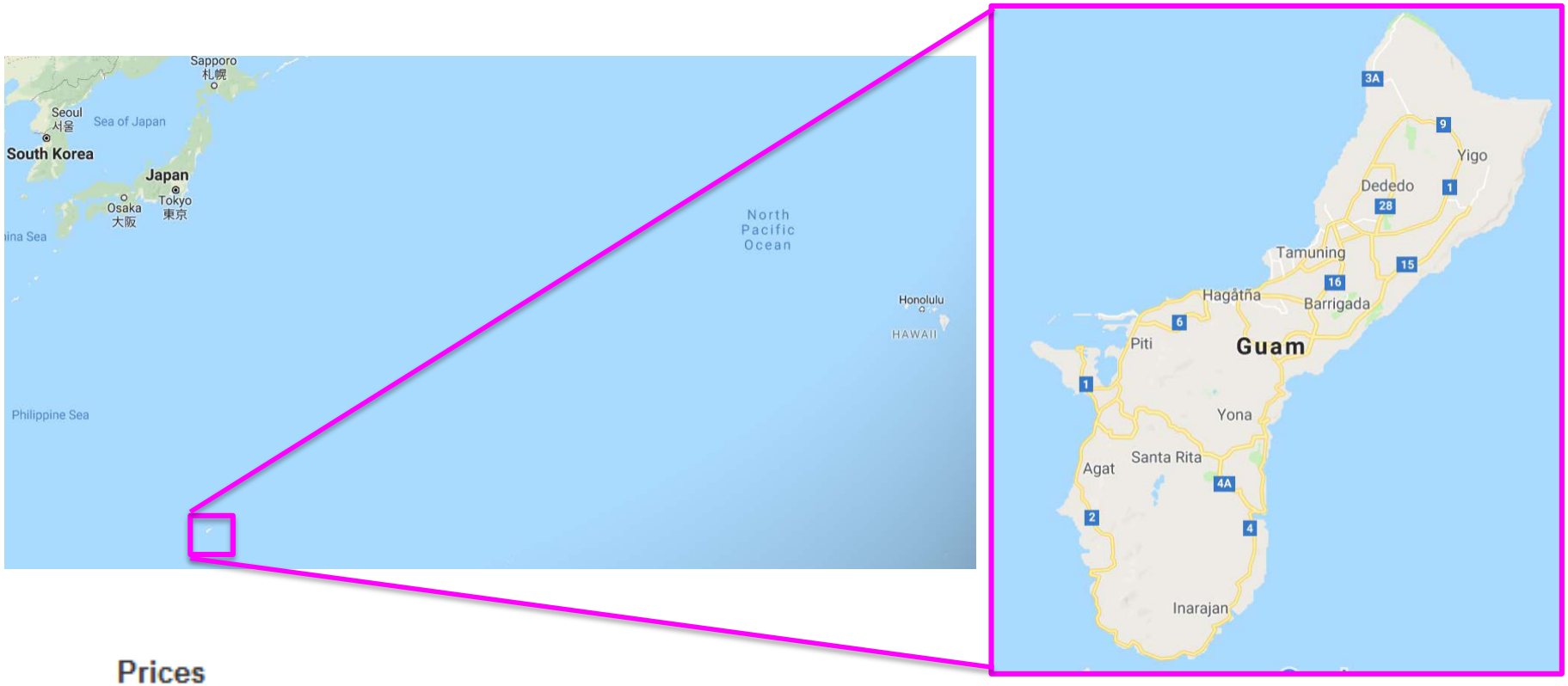
Biomass was the first to be completed (6.7 MW; 10.4% of load).

Landowners on Kauai with thousands of acres of fallow agricultural land who were eager to collaborate on projects in order to put some of their land to productive use.

KIUC indicated that: a) state tax incentives for solar coupled with b) federal tax incentives have been big factors in utility scale projects.

Having good relationships with local, state, and federal elected officials is one key to success.

Guam Power Authority Profile



Prices

Electricity	Guam	United States	Period
Residential	NA	12.89 cents/kWh	Apr-18
Commercial	NA	10.40 cents/kWh	Apr-18
Industrial	NA	6.58 cents/kWh	Apr-18

https://www.eia.gov/state/print.php?sid=GQ

Guam Power Authority Profile

Guam Power Authority (GPA) Background and Beginnings:

- Established May 1968 by the Guam Power Authority Act of 1968
- GPA is a public corporation and an enterprise fund of the Government of Guam
- GPA's governing board is the Consolidated Commission on Utilities (CCU) consisting of five elected commissioners.

Major Plant Assets

- 525 MW Gross Generation Capacity
- 175 Miles of Transmission Lines
- 646 Miles of Distribution Primary Lines
- 28 Substations.

Employees and Customers

- 512 Employees (9/30/14)
- 49,297 Customers (9/30/14).

- **2008 set RPS goal of 25% RE by 2035**
- **GPA will have met Guam's Renewable Portfolio Standard (RPS) of 25% a decade early**
- **New goal is 50% by 2028**
- **Per current plans, will likely achieve by 2025.**

Source: http://www.guampowerauthority.com/gpa_authority/about/gpa_fact_sheet.php and GPA staff.

Guam Power Authority Study Results

GPA completed a Renewable Integration Study. Executive Summary findings include:

- Existing system cannot accept renewables due to several main issues:
  - Non-responsive and non-flexible generation
  - Low short-circuit currents
  - No automatic generation control (AGC)
  - Slow 34.5 (kiloVolt) kV and 115 kV fault clearing
  - Fault-induced delayed voltage recovery.
- With improvements, GPA system can accept renewables up to the economic limit of the renewables, not technically limited
- Required immediate improvements are:
  - 115 kV relay upgrades/communication
  - 34.5 kV relay upgrades.

Electric Power Systems Consulting Engineers

Risks of not implementing these improvements include inverter cessation during disturbances, increased load shedding, and possible system collapse.

Guam Power Authority Study Results

Executive Summary findings include (continued):

- Required immediate improvements are:
  - Flexible generation plant
  - Malojlij – Agana 115 kV transmission line
  - Energy Storage System (ESS) transient grid support.

The future:

- System with new generation and Phase III & IV renewables was studied out to 2029
- Required improvements for Phase III PV
  - Transient grid support from Phase II ESS
  - Synchronous condensor at flexible generation plant
  - Temes/Yigo/Macheches synchronous condensor upgrades
  - Load-shifting/grid support ESS
- Required improvements for Phase IV & beyond
  - Load-shifting/grid support ESS.

Electric Power Systems Inc. Consulting Engineers

Guam Power Authority Study Results

Specific Recommendations include:

- *Synchronous condensers*
- *BESS*
  - *Contingency batteries*
  - *Energy shifting batteries*
  - *Batteries all contribute to system contingency response*
  - *GPA 40 MW/22MWh BESS*
  - *Flexible, highly efficient new generation*
- *Retirement of Cabras 1&2 (diesel)*
- *Upgraded system protection for all transmission lines*
  - *Five-cycle clearing far and near end*
  - *High-speed fiber communications for relays*
- *With Phase I, II, III renewables, GPA will be 25% RE production*
  - *Phase II is 120 MW with BESS to control ramp ups/downs to one percent*
  - *Phase III will be 40 MW solar plus 40 MW/ 160MWh energy shifting BESS*
- *Automatic generation control to manage batteries, conventional generation.*

Guam Power Authority Energy Future Profile

Description	2016	2017	2018 (Today)	2025
Energy Source (% Electricity)	**(%)**	**(%)**	**(%)**	**(%)**
Fuel Oil	90.8%	90.2%	89.9%	67.2%
Solar	9.2%	9.7%	**10.1%**	**32.8%**
Wind	0.1%	0.1%	0.1%	0.0%
Generation Mix (MW)	**(MW)**	**(MW)**	**(MW)**	**(MW)**
Net Metering (NEM) (MW)	13.7	16.5	18	28
NRG Solar PPA (MW)	25.7	25.7	25.7	25.7
Wind (MW)	0.3	0.3	0.3	0.3
Existing Generation (MW)	390	390	390	258
New Flexible Generation Plant (MW)	-	-	-	180
Phase II - Solar (MW)	-	-	-	120
Phase III (MW)	-	-	-	40
Phase IV (Approx 250 MW cumulative to 2028)	-	-	-	250
Generation Mix Type (MW)	**(MW)**	**(MW)**	**(MW)**	**(MW)**
Fossil Fuel (Oil/Natural Gas) (MW)	390	390	390	438
BESS Supported Solar (MW)	39.4	42.2	43.7	213.7
Wind (MW)	0.3	0.3	0.3	0.3
Total (MW)	429.6	432.4	433.9	651.9
NEM by year (Incremental MW)	5.4	2.8	1.5	10

GPA Success Factors in Higher RE Penetration

GPA completed a Renewable Integration Study that provided detailed information on what was needed to transform existing grid into a high penetration RE grid.

GPA intends producing 50% of its energy from renewables, mainly solar PV, by 2025.

Between solar PV, new more efficient generation, and natural gas, GPA should be able to significantly lower power rates.

Buy-in is less expensive than burning fuel.
Rooftop solar is challenging from a utility perspective.
Utility-scale PV has lower costs and more benefits.

Risks of not implementing these improvements include: inverter cessation during disturbances, increased load shedding, and possible system collapse.

What Advantages Do Islands Have?

- All stakeholders can sit at the table and be part of the discussions—their case can be made, their voice can be heard
- There is one utility, one owner of transmission/distribution, one primary generator, evolving via request for proposals (RFPs) for PPA
- A "Systems Approach" is necessary—and it becomes possible "on an island" because
- All parties have to focus on agreed outcomes—higher penetration RE

What Advantages Do Islands Have? (Continued)

- Existing global status quo will have great impact on a number of islands
- Everyone is impacted in some way with each decision—EVERYONE IS A STAKEHOLDER
    - Island electricity is typically more expensive, so alternatives such as solar, wind, and storage have a smaller impact on ratepayers
    - Where to locate new transmission or distribution
    - Where to site new PV or wind or biomass or nuclear or pumped storage hydro (PSH)

How Can the "Island Approach" Apply to the Mainland?

- Start with representatives of the stakeholder groups (generation, transmission, environmental, landowners, ratepayers (all classes), etc.
- Work to establish societal goals that the energy stakeholders play such a crucial role in attaining—focus on goals, not current position.

How Can the "Island Approach" Apply to the Mainland?

- Work to identify the larger goals of the community (e.g., improved resilience, reduced CO2, higher penetration of RE technologies, better balancing of all generation technologies)
- Find strategies that everyone can agree moves towards that goal
- Find lower-cost strategies for solar, wind, and storage—will vary by region, resources, and cost
- Find ways to reduce/mitigate impact to the stakeholders most negatively impacted
    - Job training for displaced workers
    - Opportunities to enter the market with new technologies.

Questions ??

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Special thanks to Kauaʻi Island Utility Cooperative

Special thanks to Guam Power Authority and its partners:

A.E. Balajadia Consulting:	
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Irwin B. Loyola, PE	Engineering Supervisor

APPENDIX—Additional Info

Wind Vision: 20% Wind by 2030

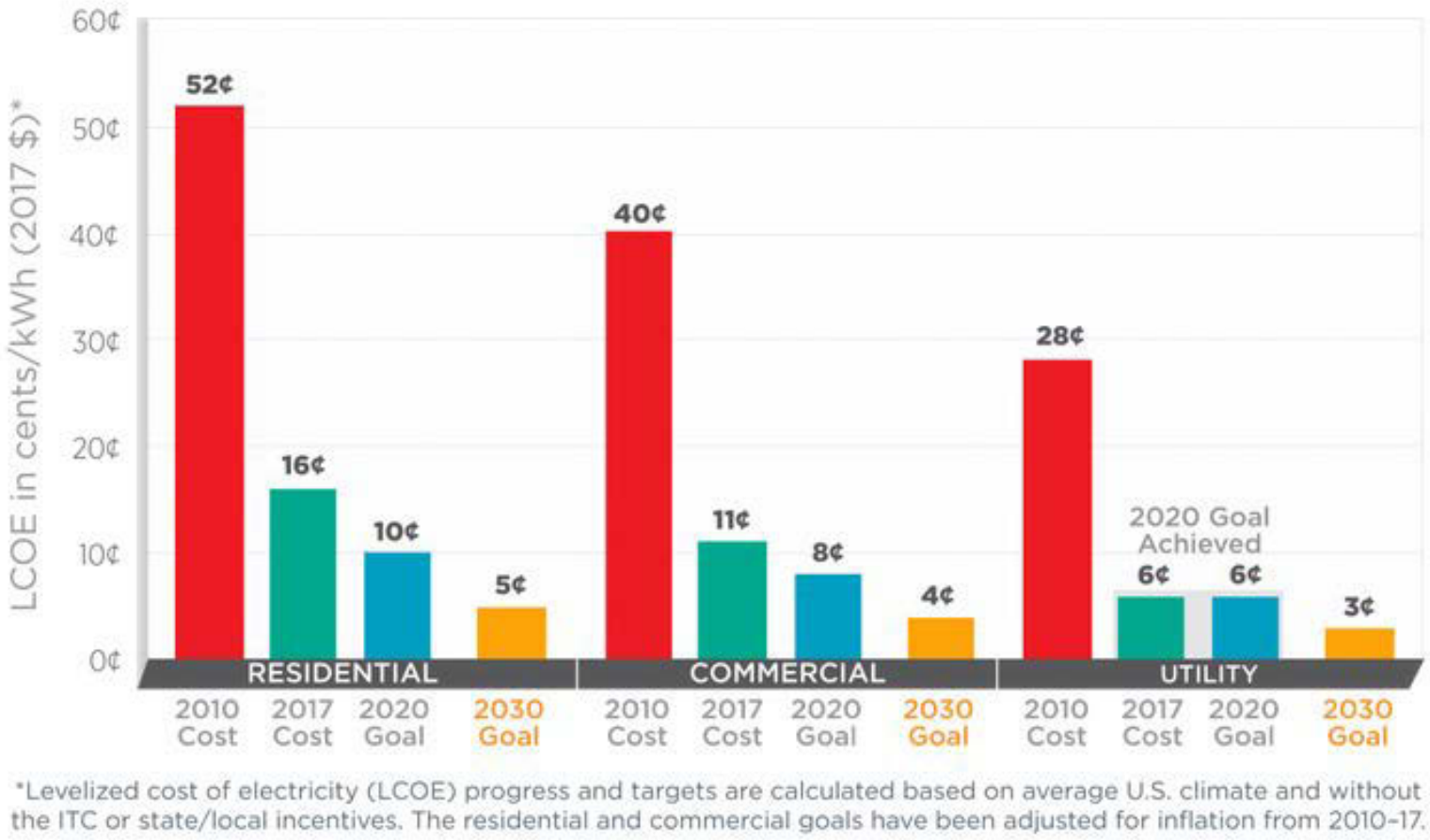
The report's conclusions include:

- Reaching 20% wind energy will require enhanced transmission infrastructure, streamlined siting and permitting regimes, improved reliability and operability of wind systems, and increased U.S. wind manufacturing capacity
- Achieving 20% wind energy will require the number of turbine installations to increase from approximately 2,000 per year in 2006 to almost 7,000 per year in 2017
- Integrating 20% wind energy into the grid can be done reliably for less than 0.5 cents per kWh
- Achieving 20% wind energy is not limited by the availability of raw materials
- Addressing transmission challenges such as siting and cost allocation of new transmission lines to access the nation's best wind resources will be required to achieve 20% wind energy.

Source: https://www.energy.gov/eere/wind/maps/wind-vision

APPENDIX—Additional Info

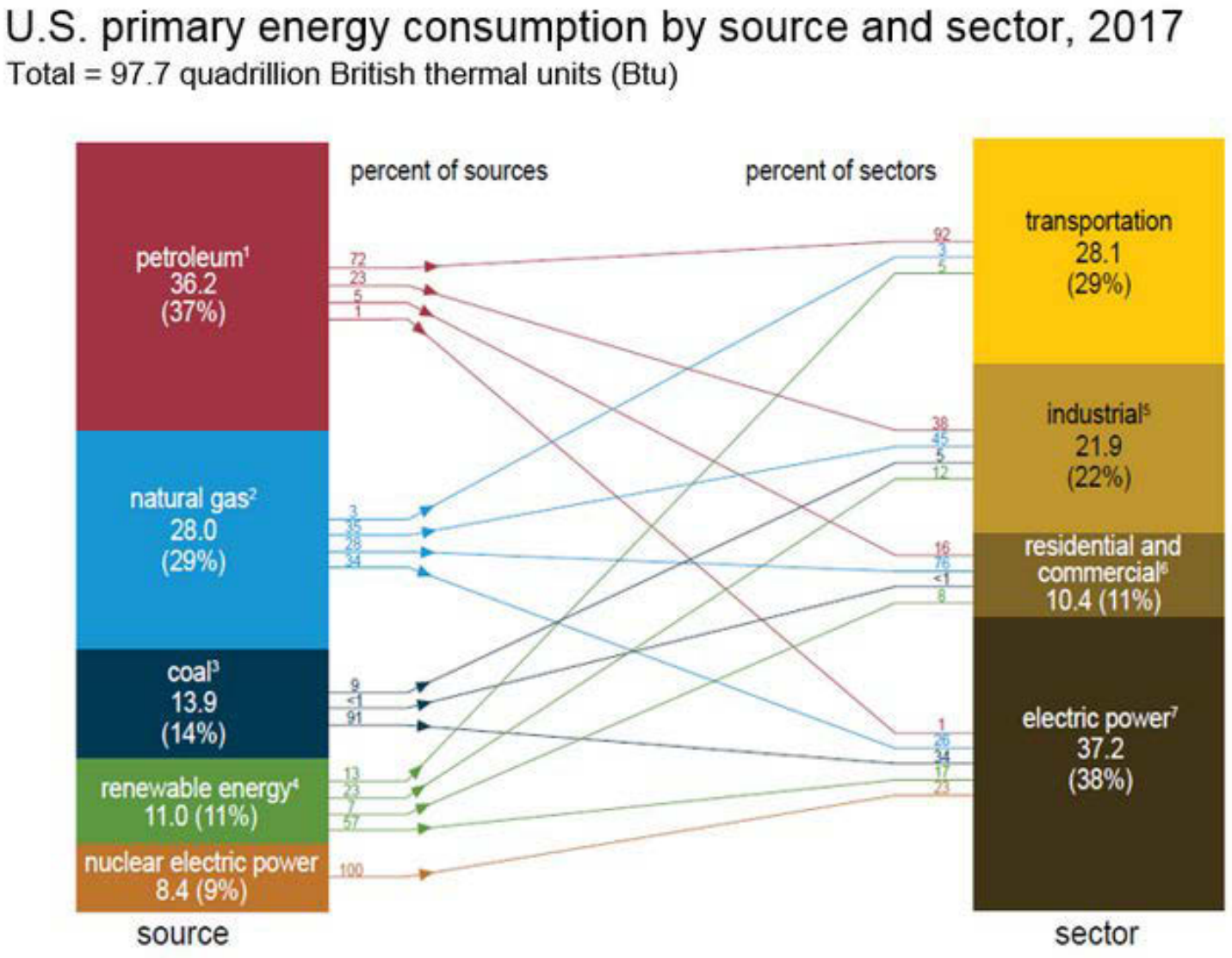
SunShot Initiative: Wide-reaching U.S. Department of Energy (DOE) program partnering with research labs and industry to bring down the cost of solar PV significantly by 2030.



SunShot Progress and Goals

Source: https://www.energy.gov/eere/solar/sunshot-initiative

APPENDIX—Additional Info



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