Achieving 100% Renewable Energy (Off-Grid) for Residential Hawaii with Solar Energy + Multi-Storage

1st Published in Renewable Energy World Aug. 2, 2017

Then Presented at Solar Power International Sept. 11, 2017 Mandalay Bay Las Vegas, NV

Now Oct 20, 2017 AVS Sponsored West Coast Junction Users Group Meeting

Then Nov 15th at the Photovoltaic Science &Engineering Conference,

John Borland, J.O.B. Technologies, 98-1204 Kuawa St, Aiea, HI 96701

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Puerto Rico Hurricane Lose Of Centralized Grid Power Lines For Months To Remote Areas Shows The Critical Need For Residential Standalone Solar Energy + Multi-Storage For Off-Grid Operation This Will Save Lives. Tesla's Grid-Scale Solar + Battery Farm Requires Homes To Be Grid-Tied And Battery Completely Drained By 9PM After 4 Hours!

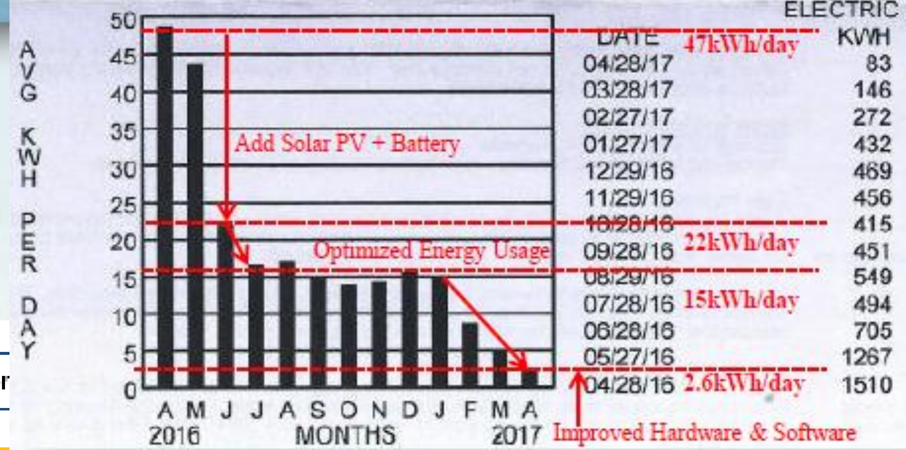
*With **single battery** storage I achieved **12+ days** a month **Off-Grid** since April 2017.

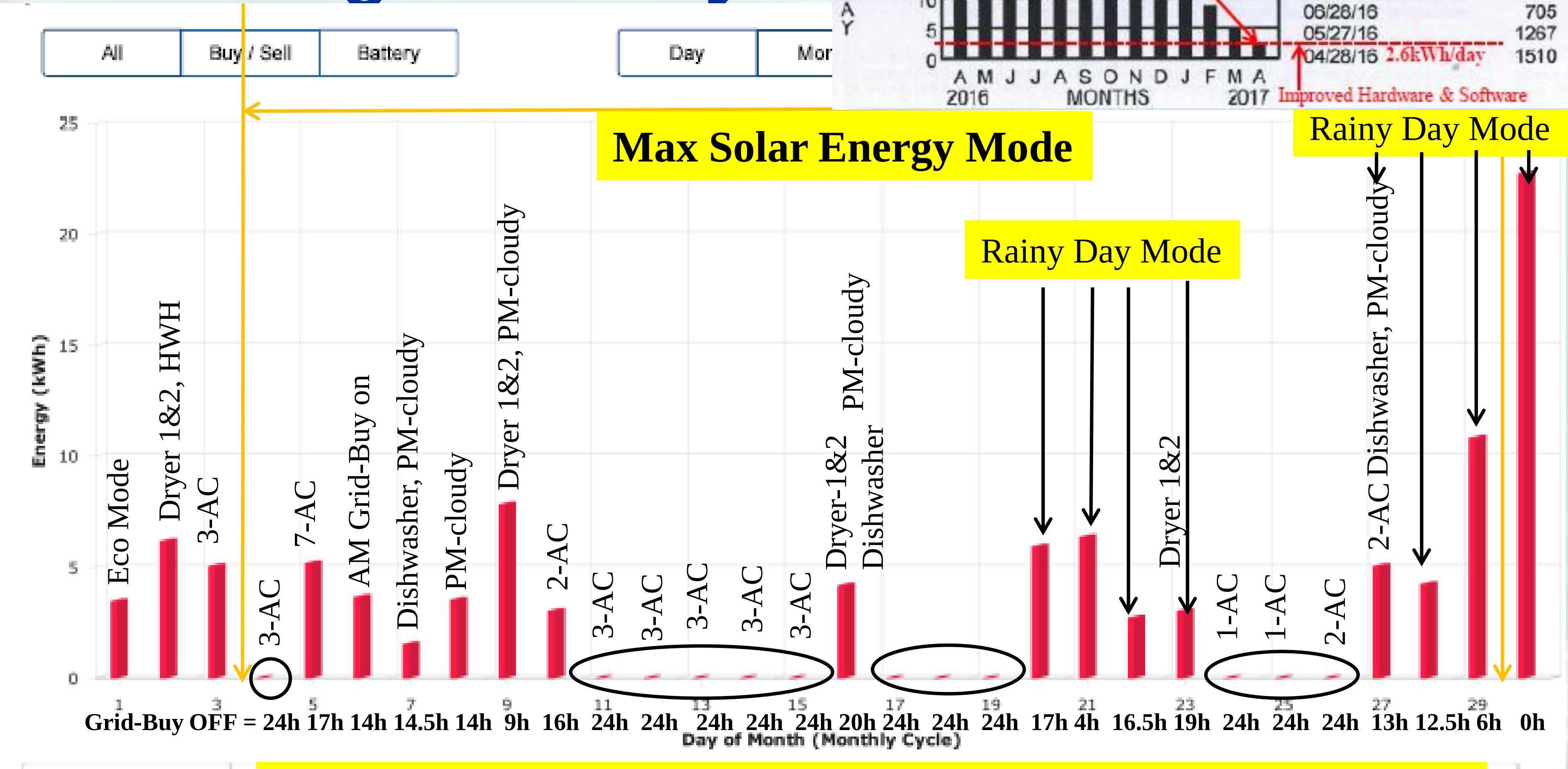
*With **dual battery** storage I achieved **24+ days** a month **Off-Grid** since Sept 2017.

Tabuchi Electric America Donates Solar-Plus-Storage Solutions to Help Puerto Rico and the Caribbean Islands Accelerate Power Restoration

October 16, 2017 01:28 PM Eastern Daylight Time

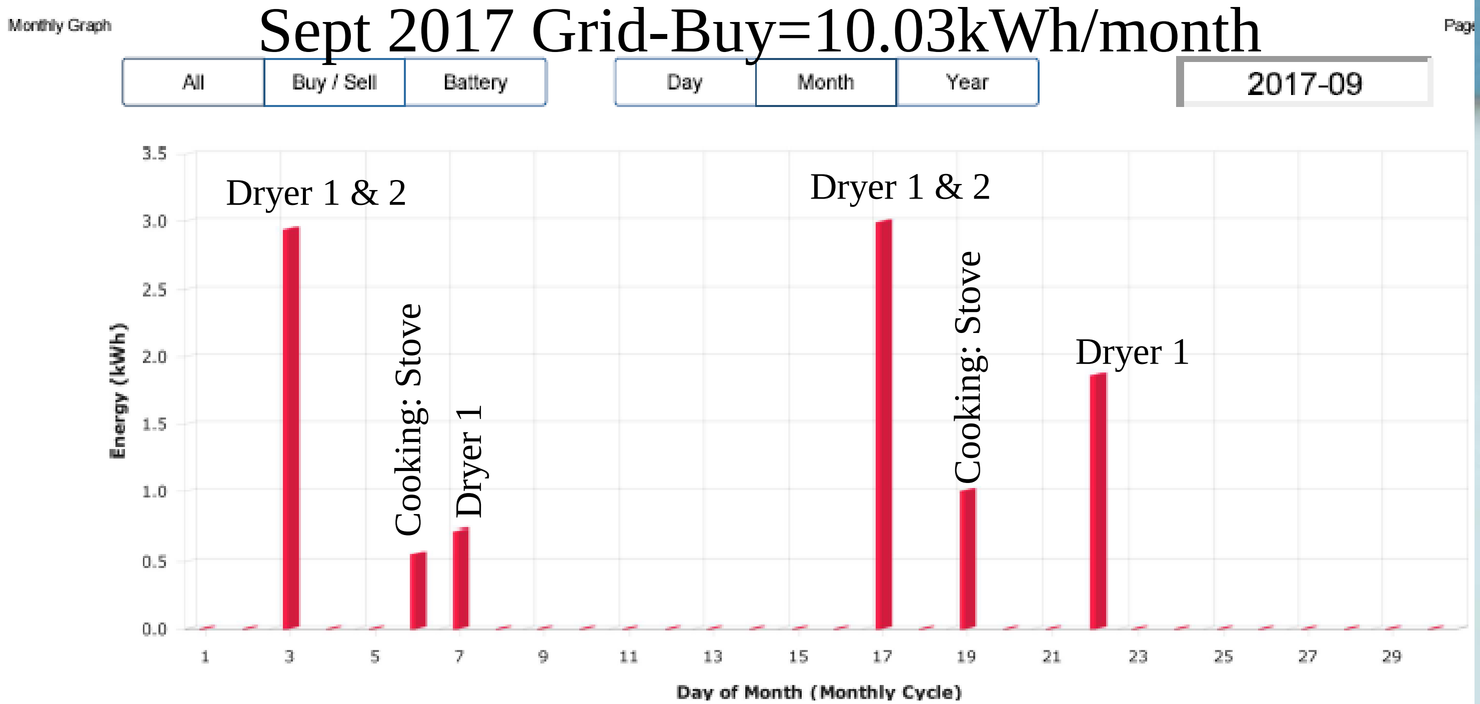
April 2017 Off-Grid 12 Out Of 30 Days With Single Battery

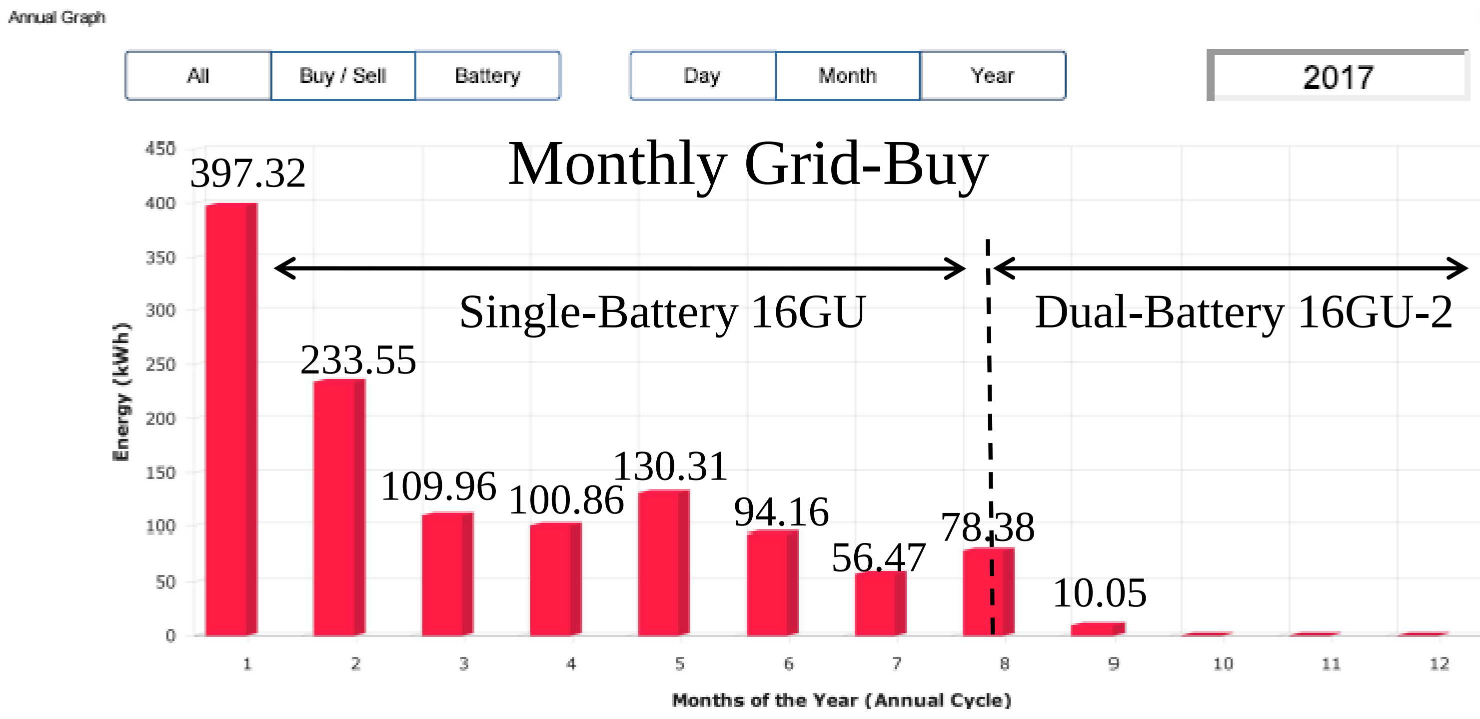




11 days were rainy or cloudy or would have been 23 days Off-Grid!

Sept 2017 Off-Grid 24 Out Of 30 Days With Dual-Battery

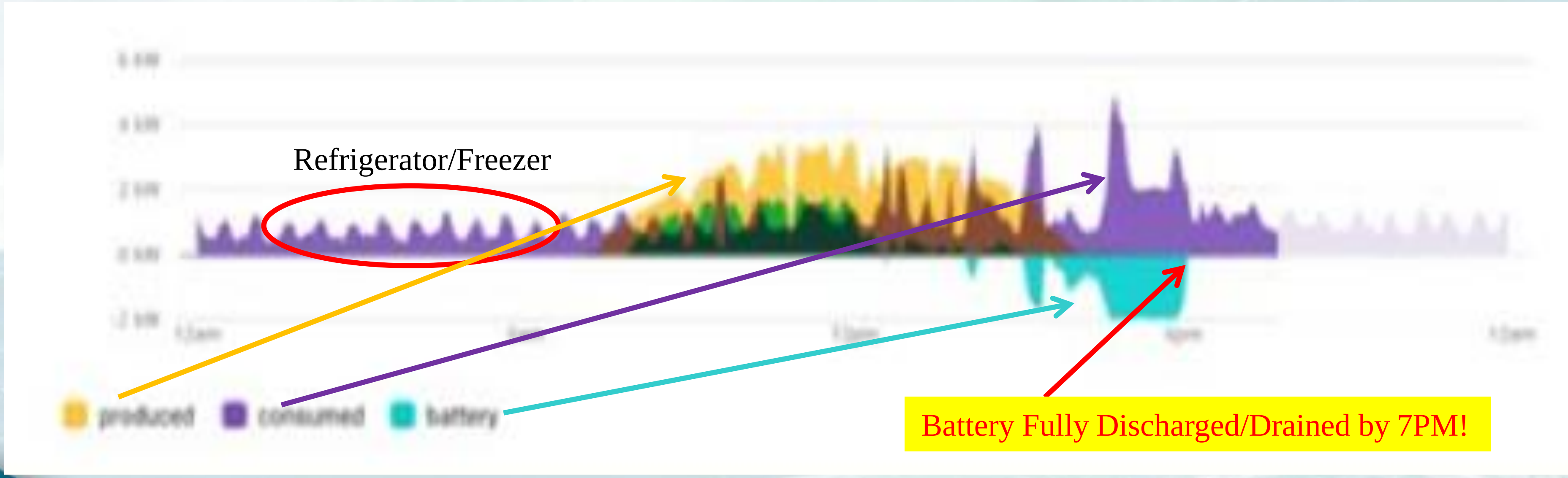




J.O.B. Technologies (S
Marketing, Sales &
Technology)

Off-Grid Operation Must Conserve Battery Discharge To Last Overnight, Not Fully Discharged After 4 Hours!

Solar Power International-2017
Tesla PowerWall-2 in Residential
Australia ROI=21.9 years!

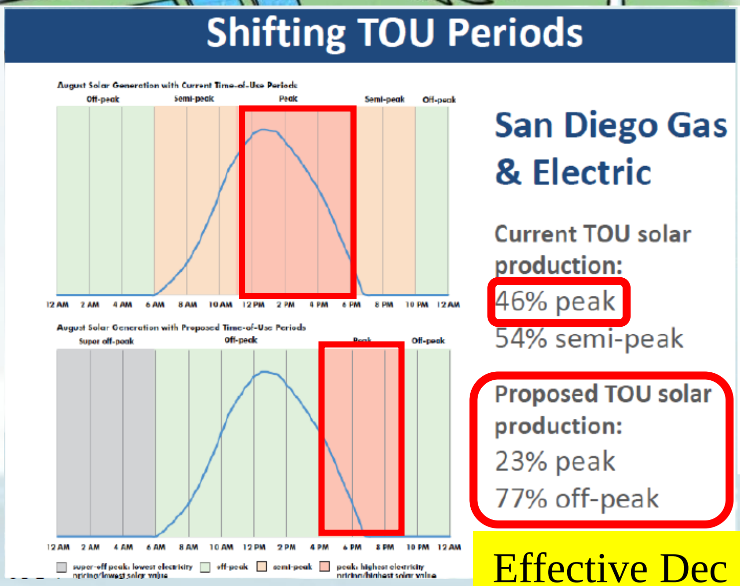


Battery Fully Discharged/Drained by 7PM!

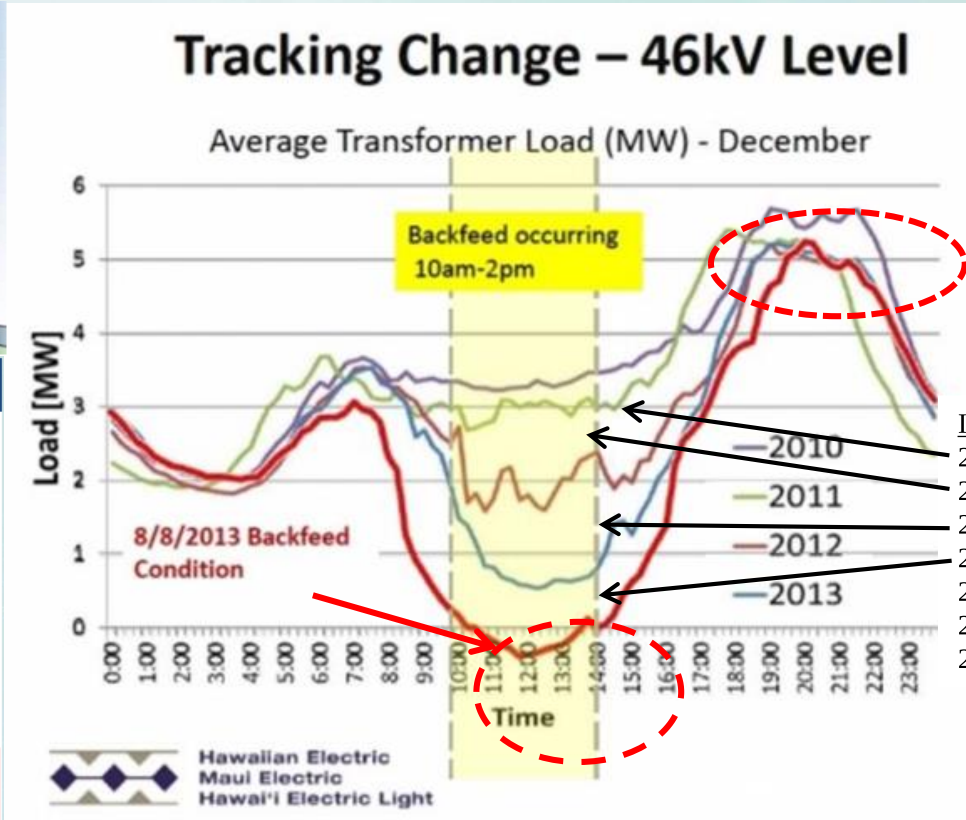
Outline

- Introductions: Residential Grid-Buy Electricity Cost Reduction!
  - NEM Excess Rooftop Solar-PV Generation export/back-feed to the Grid leads to Duck Curve Problem for Utilities
  - CA shifting TOU rates to coincide with evening peak energy usage (4PM to 9PM) and require smart inverter so they can control/curtail rooftop solar-PV generation
  - Oahu (Hawaiian Electric: HECO) end NEM export and voluntary TOU
    - In the No-NEM customer self-supply world, the economics of solar-PV is quite different than with NEM. For NEM the amount of $ savings and ROI is determined by excess daytime solar-PV generation and selling/export back to the utility grid to off-set the night time grid-buy energy to achieve Zero Net Metering. This resulted in oversizing of residential rooftop PV systems leading to the severe utility Duck Curve problem
    - Post-NEM world, maximum $ savings and ROI is realized by achieving zero grid-buy which results in 100% Renewable Energy and therefore Off-Grid operation!
- Methods:
- Results:
- Conclusion:

Duck Curve Problem: Excess Back-feed of Rooftop Solar-PV Generation to the Grid!



Effective Dec 1, 2017



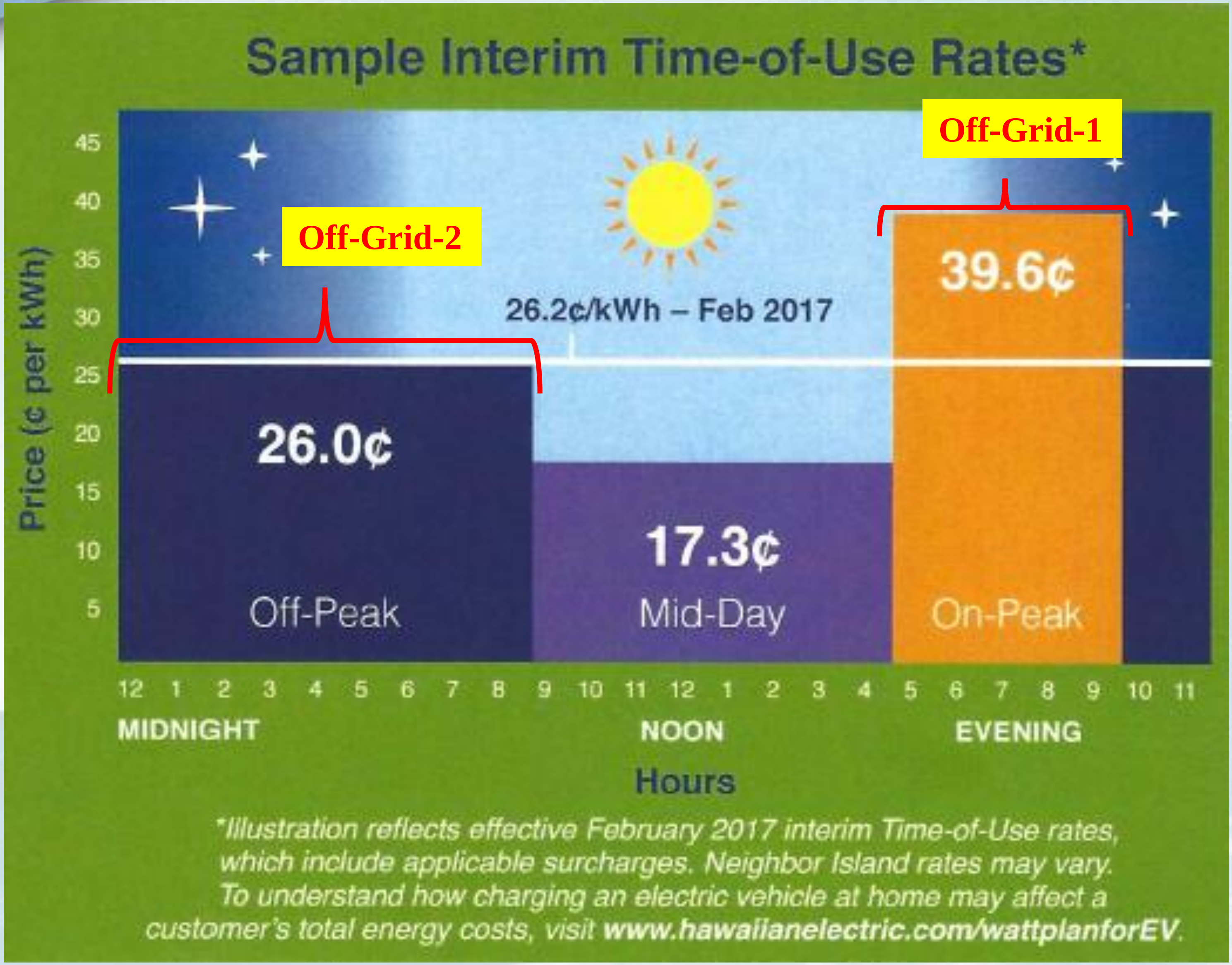
Oahu permits/year
2012 ~16.7K
2013 ~13.1K
2014 ~6.1K
2015 ~6.5K
2016 ~5.2K
2017 ~1.5K(Aug)
Total ~49.2K

Installed PV
2010=+16MW
2011=+39MW
2012=+92MW
2013=+130MW
2014=+88MW
2015=+98MW
2016=+99MW

CA requiring Smart Inverters so the Utility companies can turn-off residential solar PV generation Sept 2017!

High penetration of residential rooftop solar-PV with NEMs results in severe Duck Curve causing utility facility stress due to late afternoon rapid ramp-up of generators. HECO shows Hawaii noon-time net load demand can drop to below Zero!

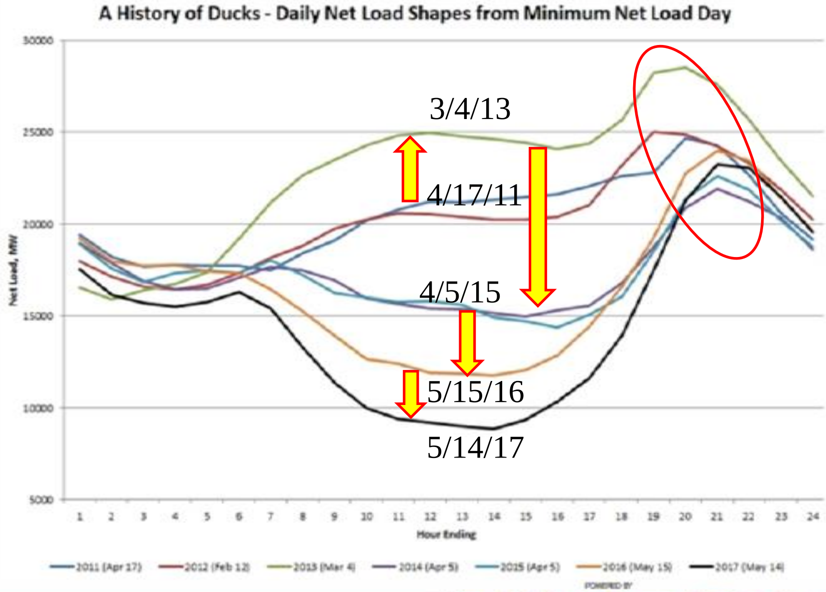
Hawaiian Electric TOU Rates



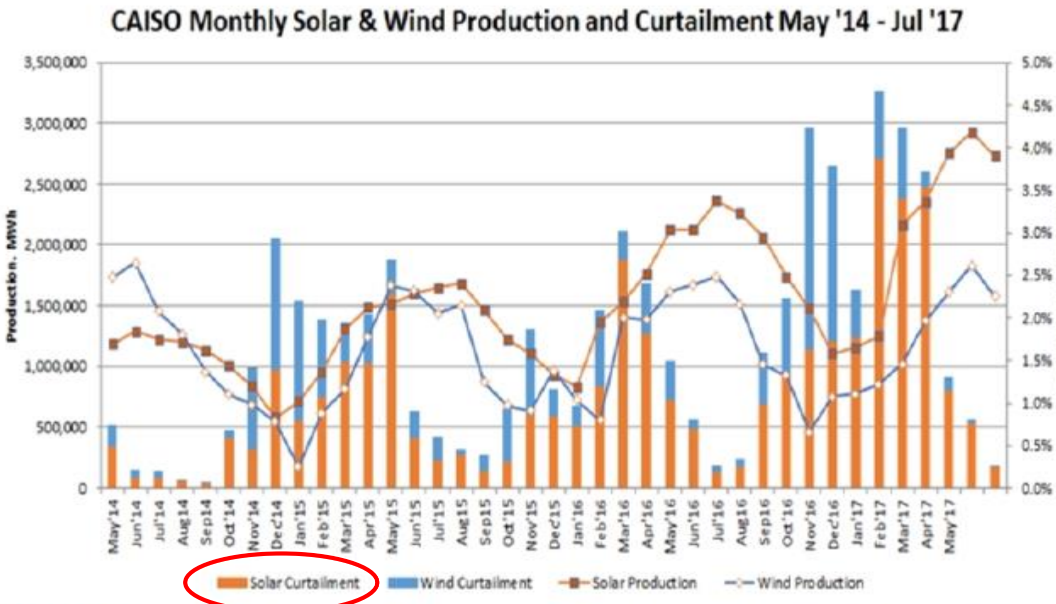
CAISO Updated Duck Curve and Solar-PV Curtailment reported at Solar Power International Sept 11, 2017

The "Duck Curve":

- Minimum net loads move to the afternoon
- Three-hour net load ramps increase

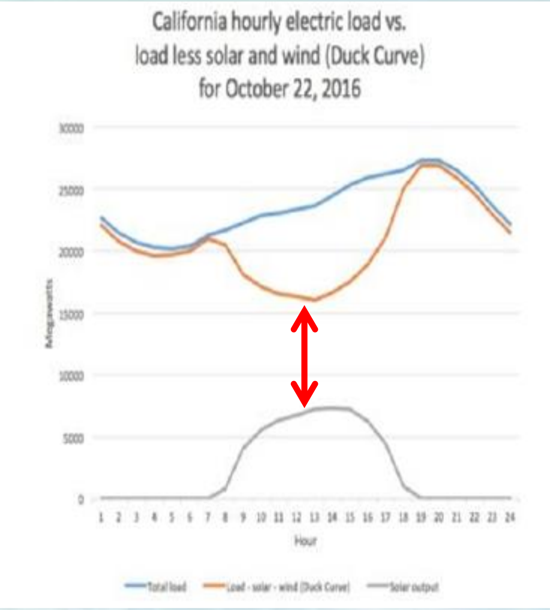


Production and Curtailment

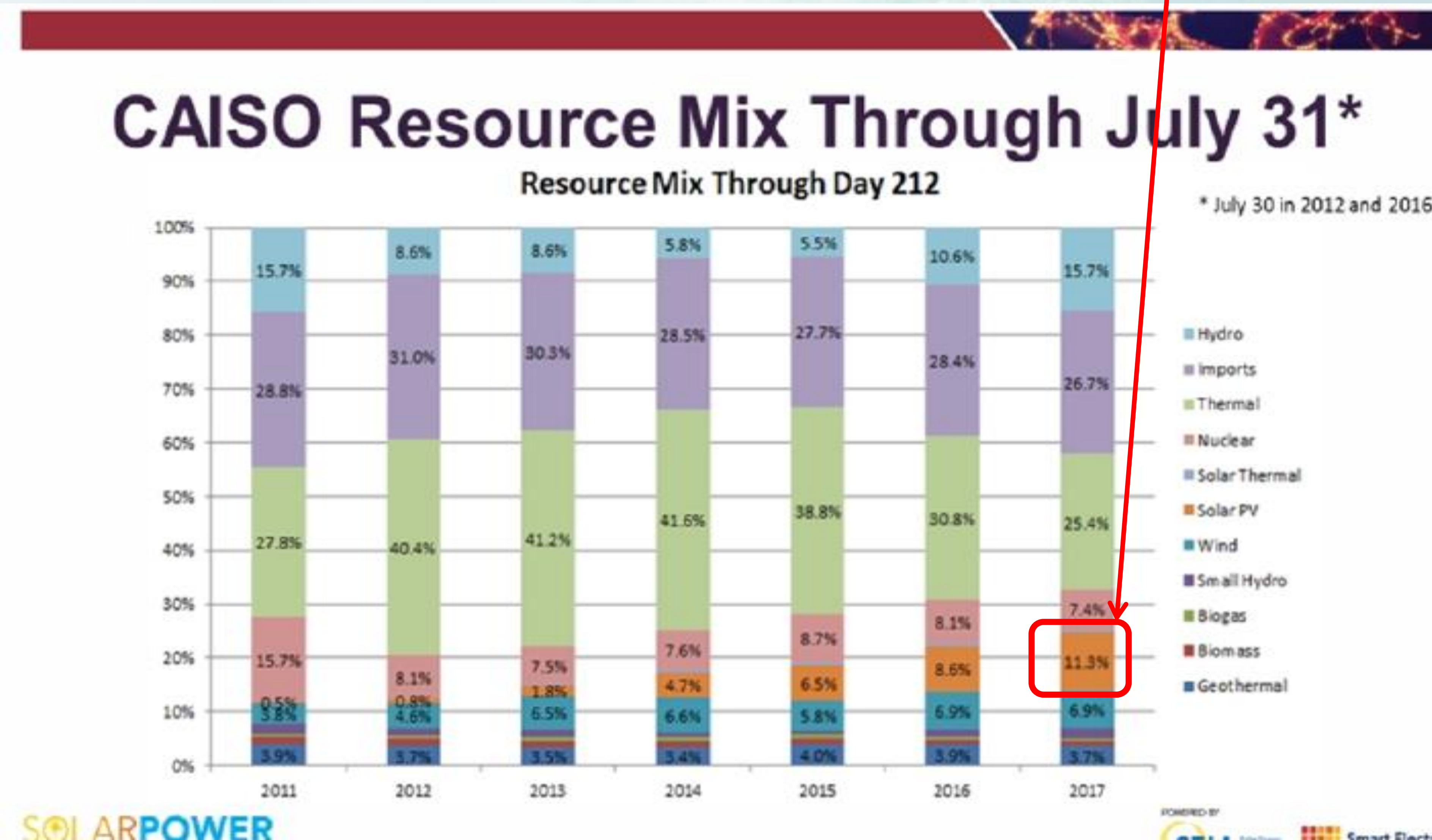


SOLARPOWER INTERNATIONAL

POWERED BY SEIA Smart Electric Power Alliance



CAISO Reports Solar-PV Up To 11.3% Total Energy Generation

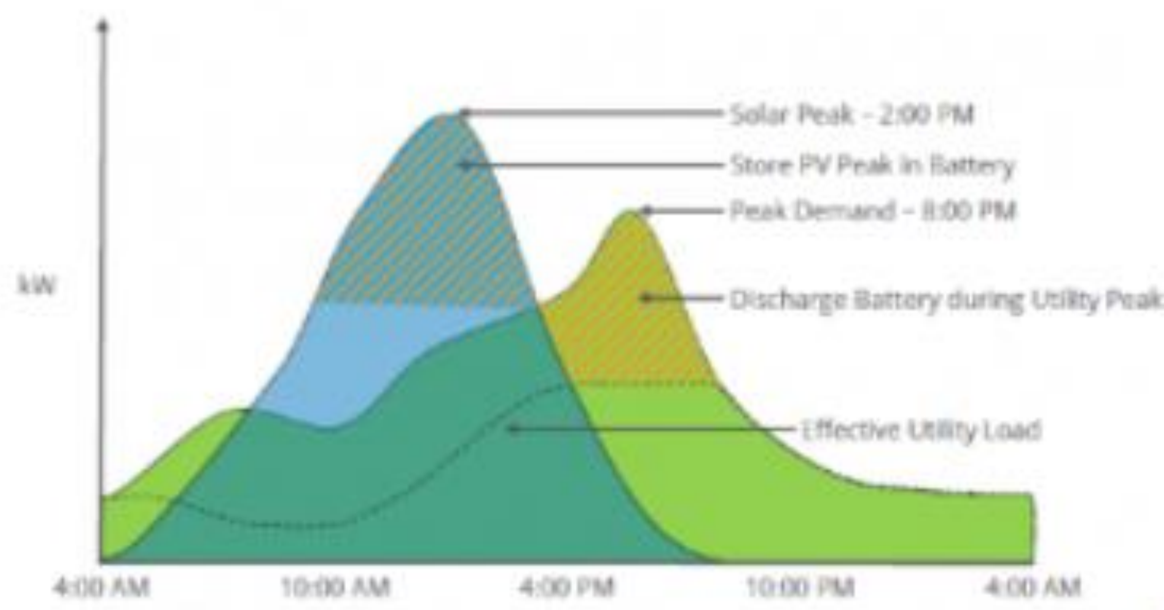


- My suggestion is End Solar-PV Farms, only add Battery Storage Farms like Kauai-IUC to prevent further Daytime Solar-PV Duck Curve Degradation!
  - Kauai-IUC reported solar-PV farm energy purchase costs at 11.9¢/kWh over 20yrs and Tesla 52MW Battery Storage farm with 13MWh solar-PV (50K-panels) for charging for **4 hour peak evening discharge** at 13MW/hour energy purchase costs at 13.9¢/kWh for 20yrs. KIUC Diesel power =15.5¢/kWh. HECO oil =11-12.5¢/kWh (note that utility scale solar-PV farms LCOE=4¢/kWh)
- How to make residential solar-PV economical for Post-NEMs (No-NEM)?
  - Add Battery electrical storage? Yes but→ROI=12-16 years well beyond the 10 year battery warranty!
    - **NREL** Feb 2017 reports battery storage doubles energy cost with battery COS (cost of system) = $2/W!
    - **Home Power** Jul/Aug 2017 magazine reports Li-ion battery lifetime costs of energy (L-COE) is 31¢/kWh. My case battery Lifetime-COE= 24.3¢/kWh (1 cycle/day) or 20.3¢/kWh (1.2 cycles/day) with ROI=16 years. With full Hawaii & Federal tax credit L-COE= 9.2¢/kWh and ROI=5 years.
  - Answer is Solar Energy (PV+Thermal) with Multiple-Storage (Electrical Battery Storage + Hot Thermal Storage + Cold Thermal Storage) and HEMS (Home Energy Management System) with fast efficient inverter control system and optimized TOU (time-of-use) for key household appliances.
    - Rooftop Solar-PV L-COE= 3.2¢/kWh over 20 years
    - Rooftop Solar Hot Thermal Storage L-COE= 4.1¢/kWh over 10 years
    - Electrical Battery Storage L-COE= 9.2¢/kWh over 10 years
    - Cold Thermal Storage L-COE= 3.2¢/kWh over 20 years

Solar Industry Strategy For Solar+Storage

I Tried It for Hawaii Post-NEM: Sounds Good But Wrong, Results in ROI of 16 Years!

Figure 51: Theoretical load curve reduction with Storage



Source: Sunpower 2014 Analyst Day

ENERGY TIME SHIFTING

Utilize Generated PV Energy When Its Value is Highest

Energy Storage allows bulk energy shifting of solar generation to take advantage of higher PPA rates in peak periods, or to allow utilities to address daily peak demand that falls outside periods of solar generation.

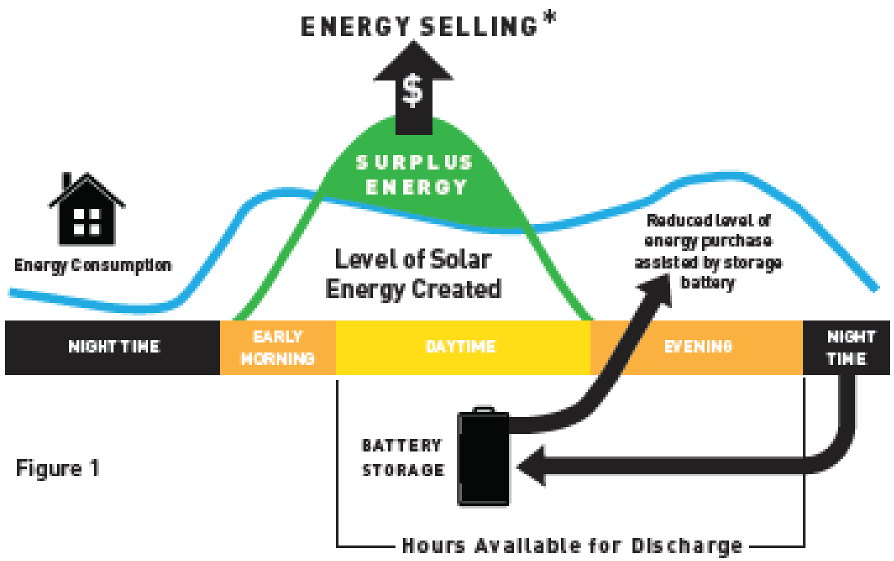


Figure 1

NREL Feb 2017 PV + Storage Report

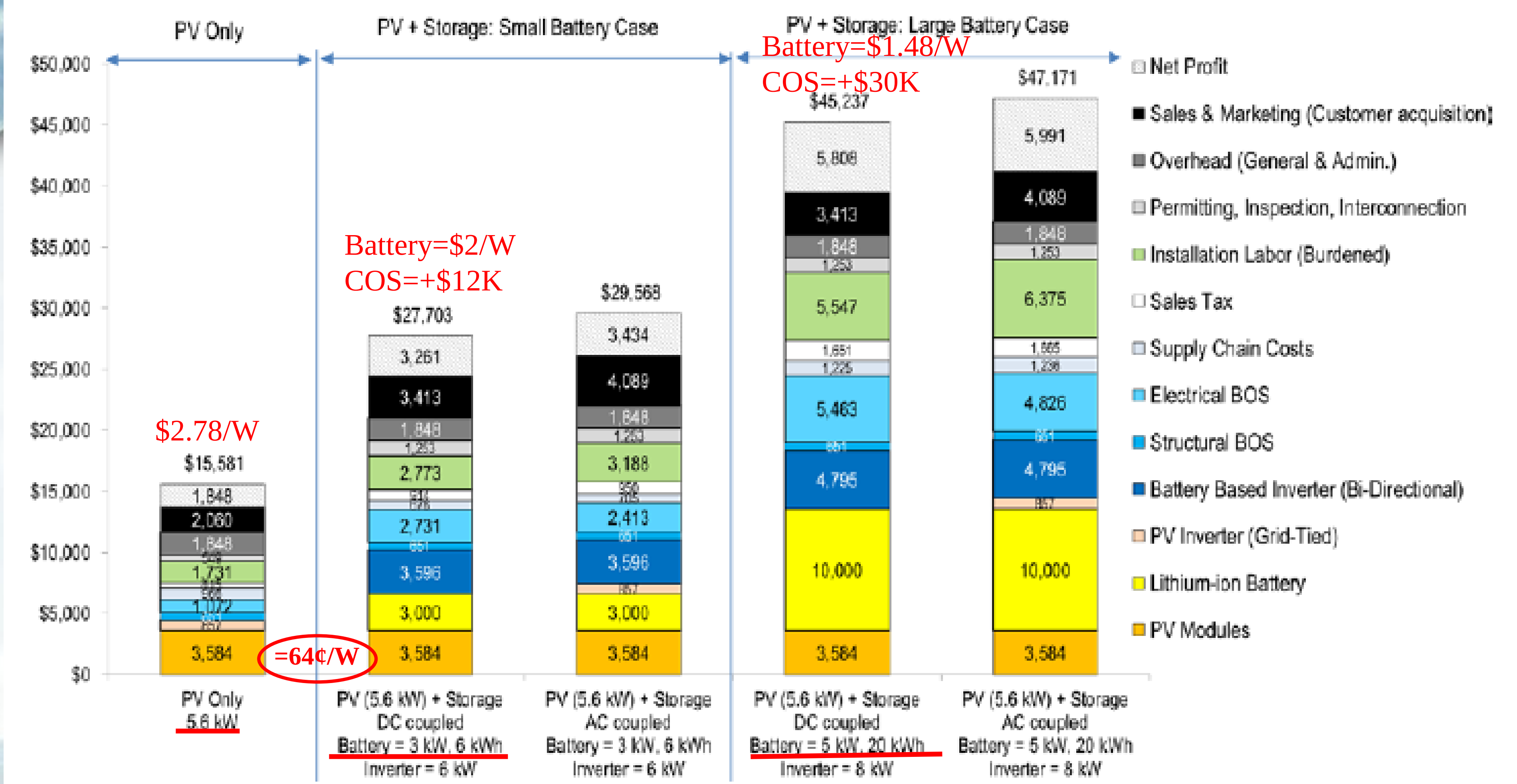
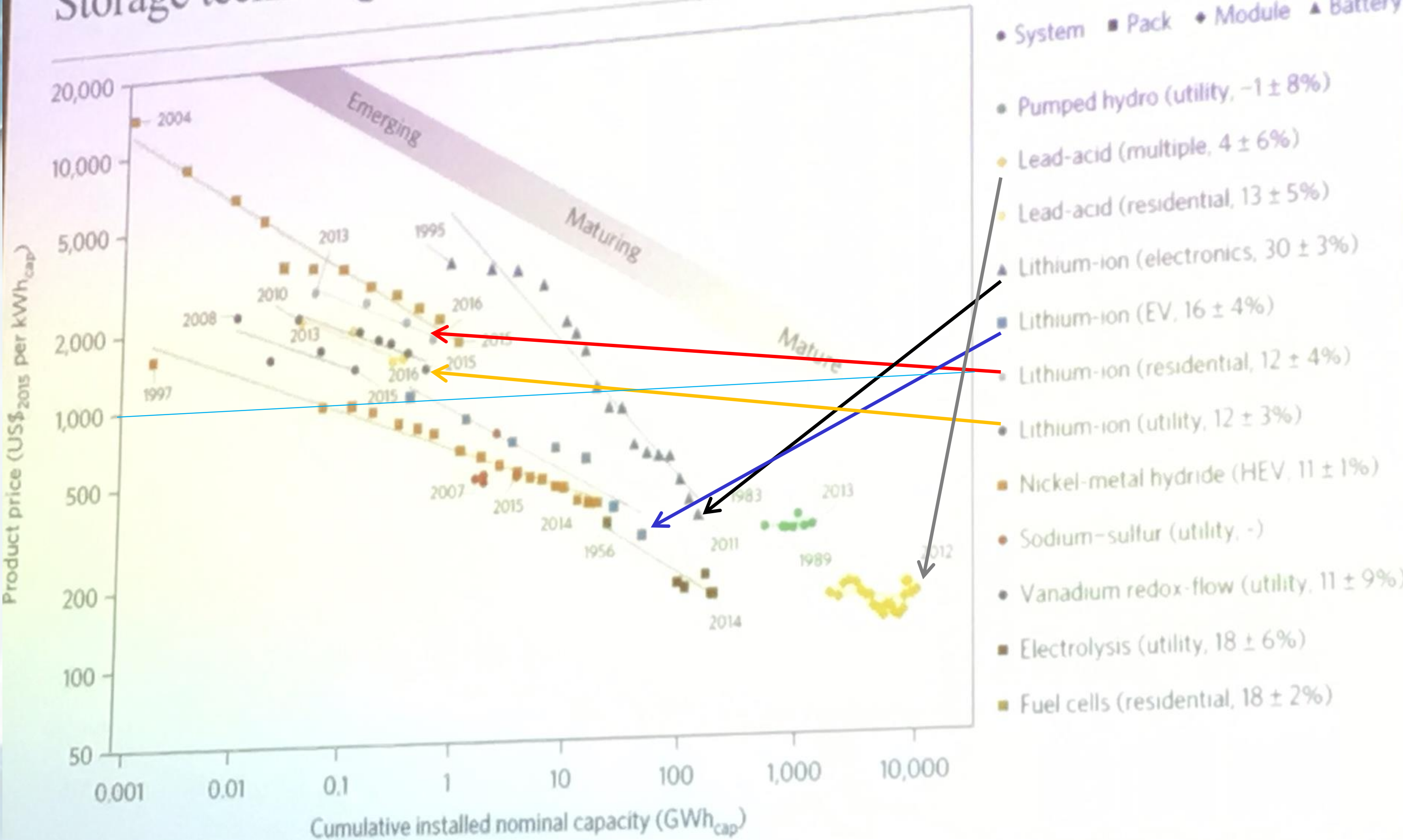


Figure ES-2. Modeled total installed cost and price components for residential PV-plus-storage systems, small-battery case vs. large-battery case (2016 U.S. dollars)

Current utility rate structures and battery costs generally do not support battery deployment based on customer bill savings alone. REopt only deploys batteries in two of the five case studies. However, batteries may be more economical when other value streams are considered (e.g., grid services and grid-outage resiliency) or if declining price trends continue.

Storage technologies are in different stages ...



Source: O. Schmidt, A. Hawkes, A. Gambhir, I. Staffell, The future cost of electrical energy storage based on experience rates, Nature Energy, Vol. 2, Article Nr 17110 (7/2017).

Fortum

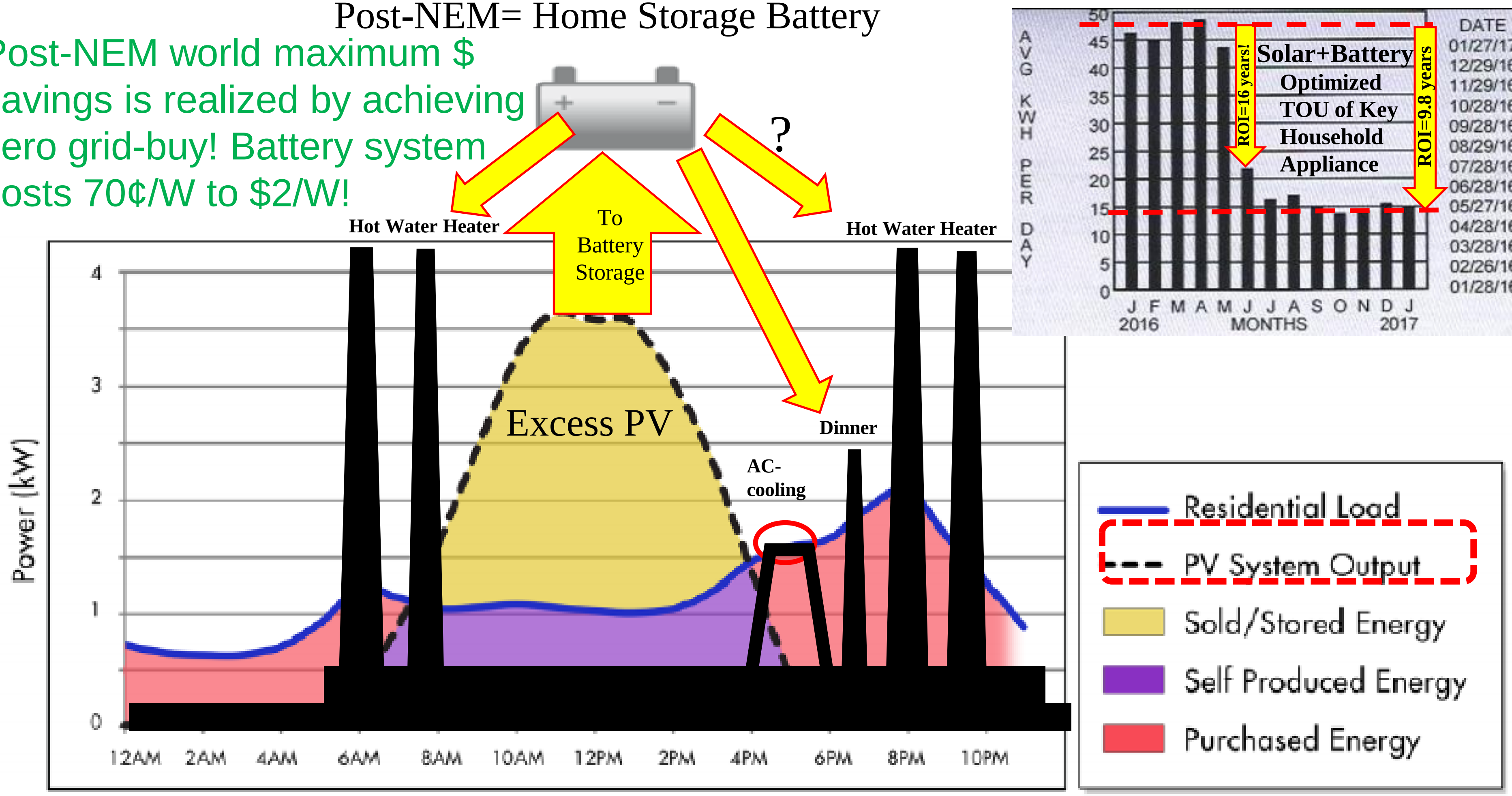
EU-PVSEC Sept 2017

Poor economics **ROI=12-16 years!** Household appliances create energy spikes and not peaks completely discharging battery after just a few hours each night. Also night time energy usage usually >2-3x day time usage requiring large battery storage capacity so expensive!

WHY STORAGE: MISMATCH OF LOAD AND PV SUPPLY

Post-NEM= Home Storage Battery

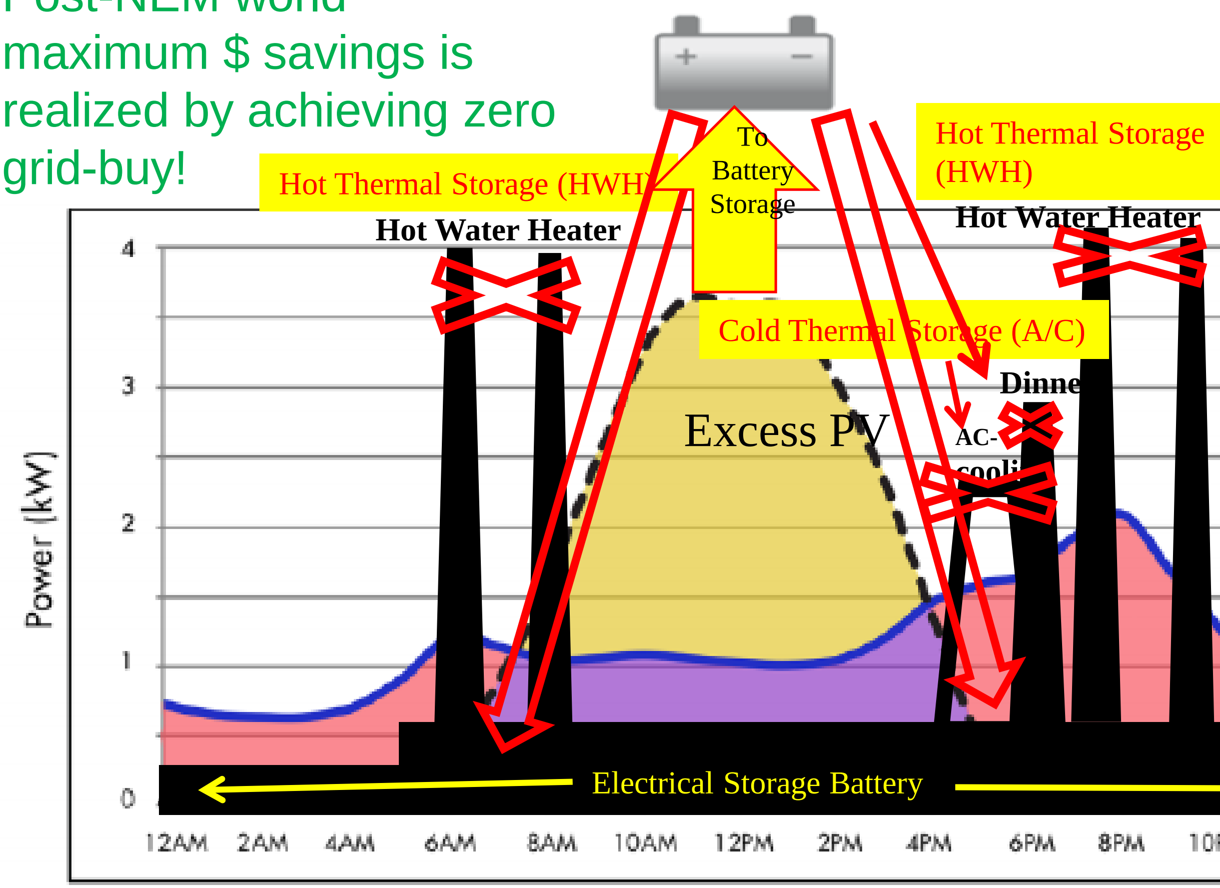
Post-NEM world maximum $ savings is realized by achieving zero grid-buy! Battery system costs 70¢/W to $2/W!

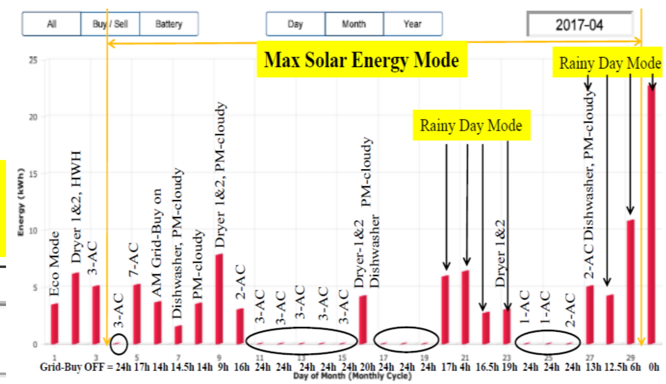


Best Economic Solution: Find alternative Renewable Energy Storage (Hot & Cold Thermal Storage) to eliminate the AM & PM energy peaks/spike and use battery storage discharge to achieve Zero Grid-Buy →100% Renewables (Off-Grid)!

WHY STORAGE: MISMATCH OF LOAD AND PV SUPPLY

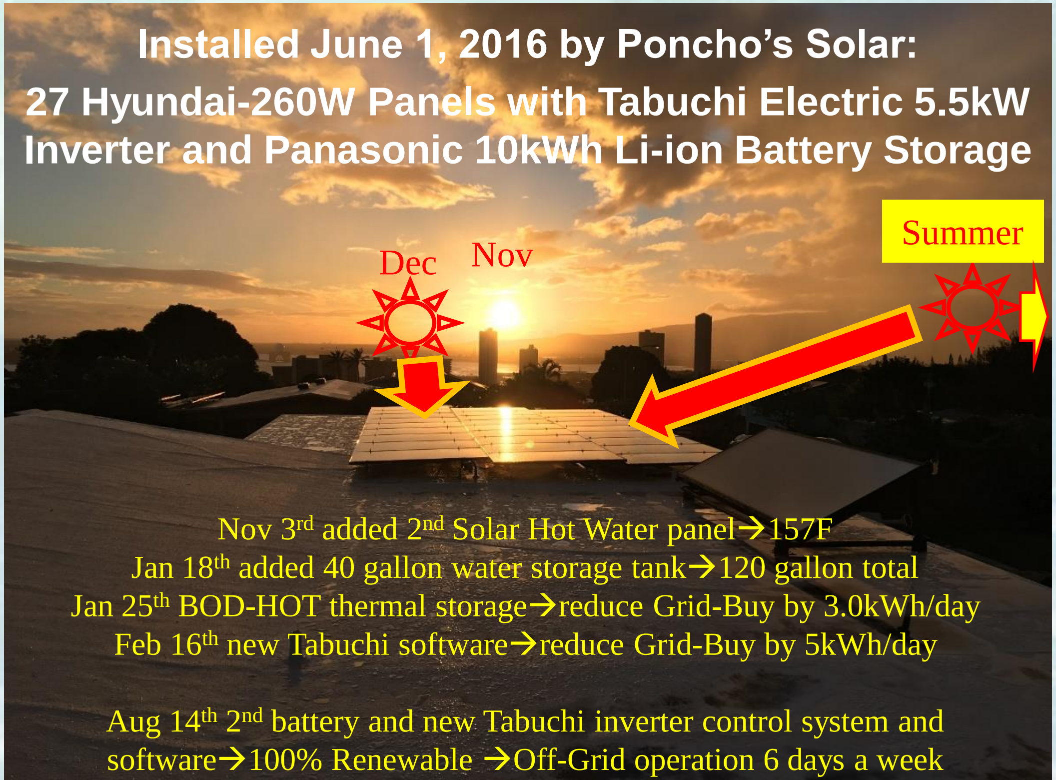
Post-NEM world maximum $ savings is realized by achieving zero grid-buy!





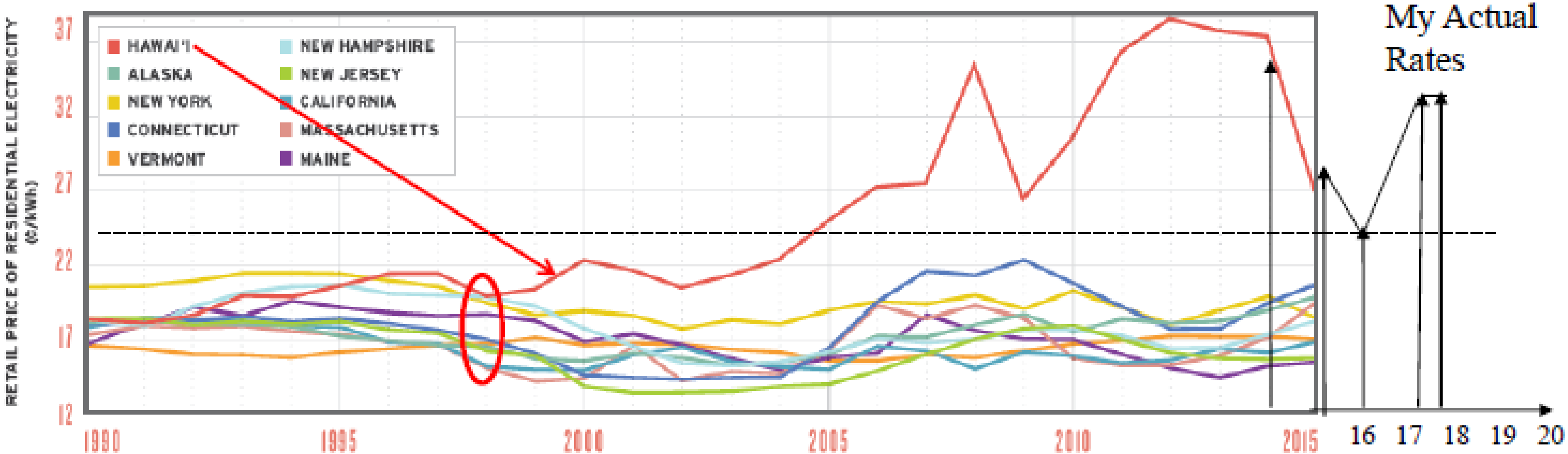
Outline

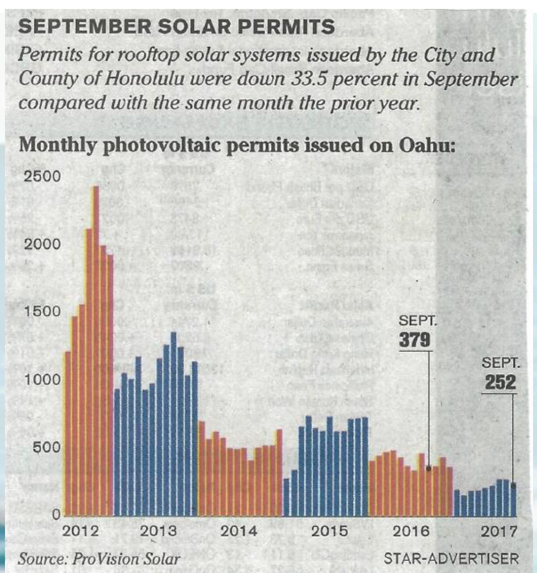
- Introduction: Residential Grid-Buy Electricity Cost Reduction!
- Methods: Poncho's Solar installed solar-PV + solar Hot thermal storage integrated with Tabuchi Electric Inverter + Battery Electrical Storage
- Results:
- Conclusion



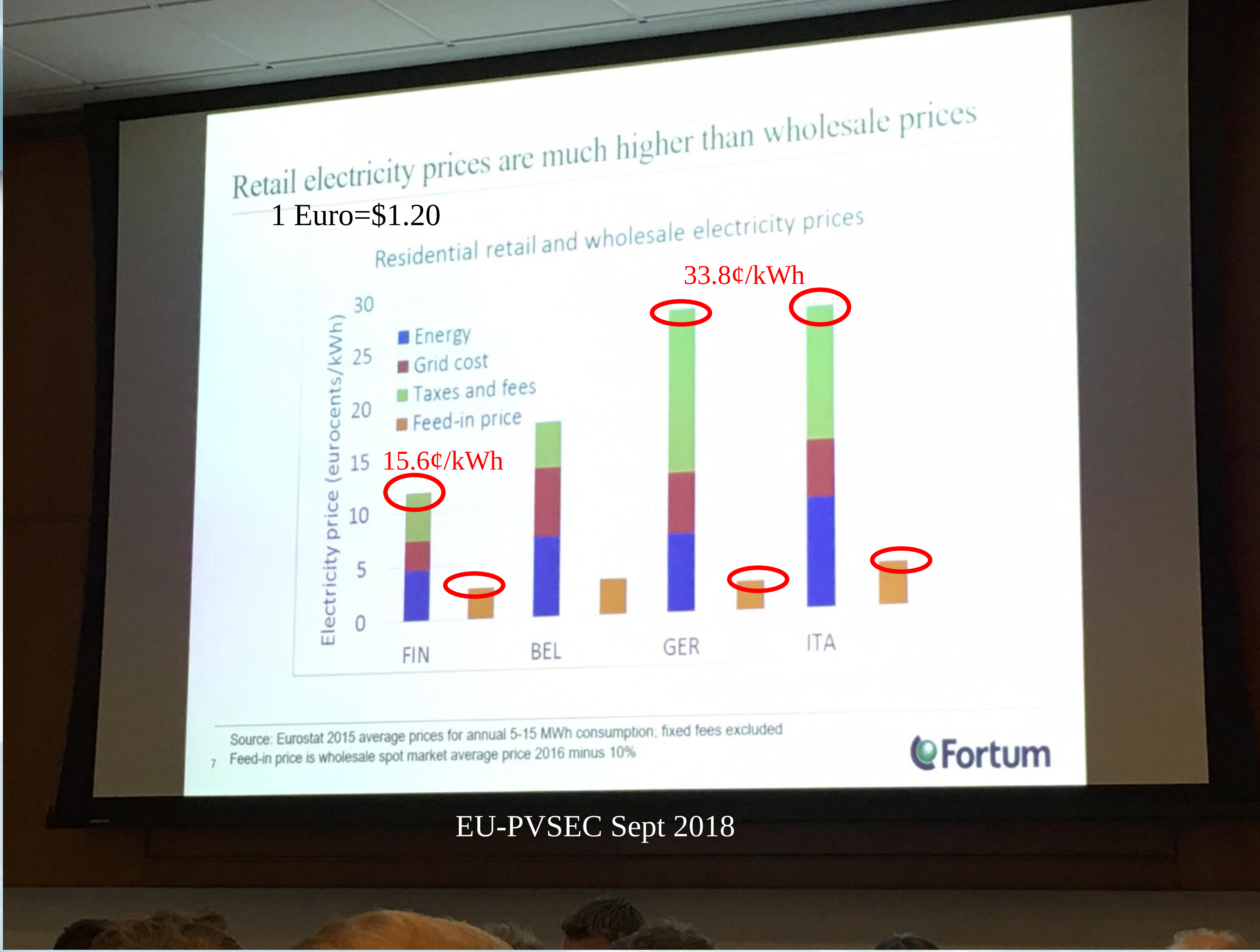
Why Residential Rooftop Solar PV?
Hawaii High Cost of Electricity 24-37¢/kWh

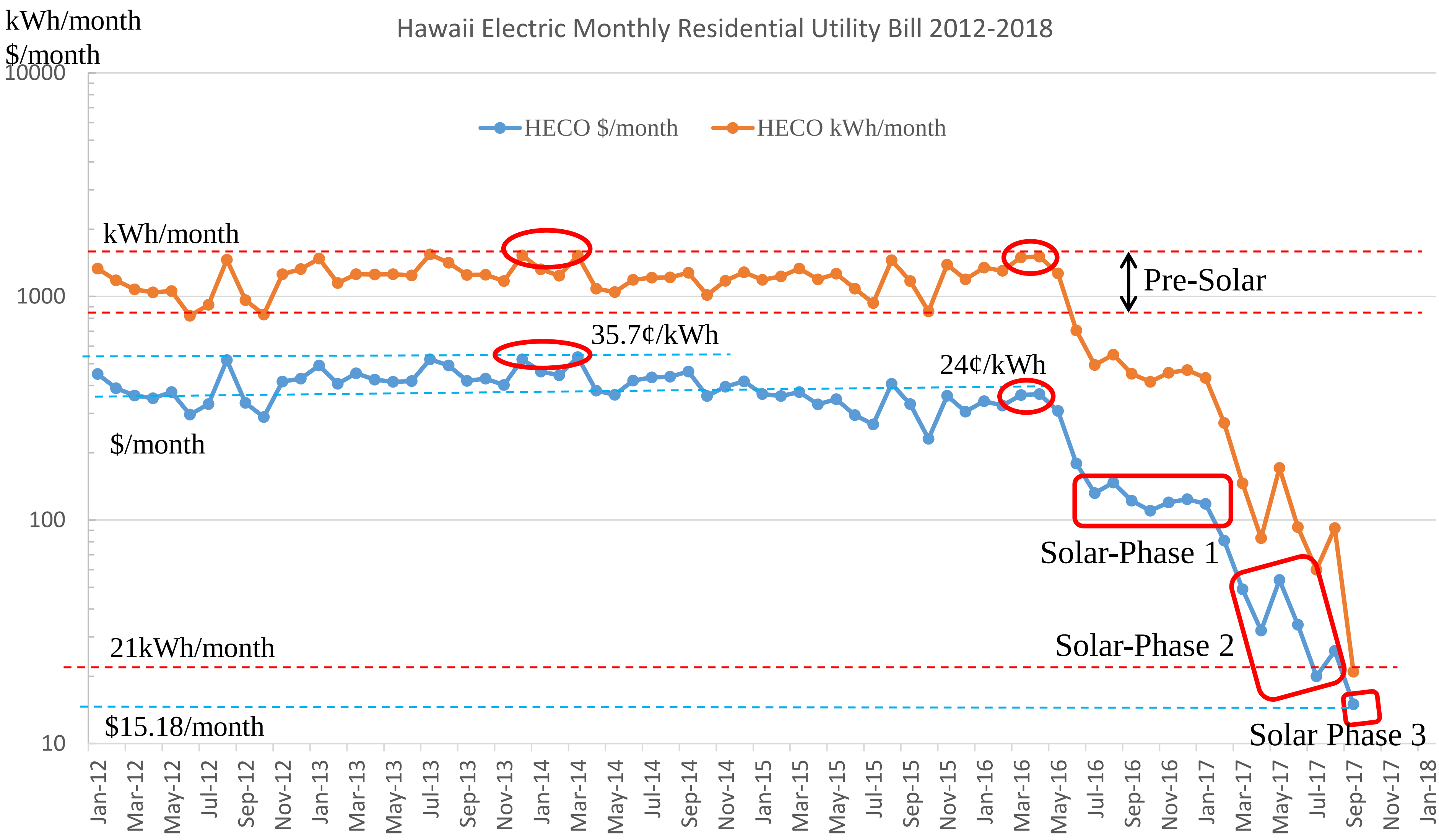
HAWAI'I RESIDENTIAL ELECTRICITY RATES





Feb-2014= 35.7¢/kWH ($535/month)
Apr-2016= 24.4¢/kWH ($366/month)
Dec-2016=26.6¢/kWH (Solar→$124/month)
Feb-2017=29.8¢/kWH ($80/month)
March 2017=33.4¢/kWH ($48/month)
July 2017=TOU rates 12.8/21.6/35.1¢/kWH ($20.59/month)
Sep 2017=$17.00 TOU service fee!


Retail electricity prices are much higher than wholesale prices
1 Euro=$1.20
Residential retail and wholesale electricity prices
33.8¢/kWh
15.6¢/kWh
Energy
Grid cost
Taxes and fees
Feed-in price
Electricity price (eurocents/kWh)
0
5
10
15
20
25
30
FIN
BEL
GER
ITA
Source: Eurostat 2015 average prices for annual 5-15 MWh consumption; fixed fees excluded
Feed-in price is wholesale spot market average price 2016 minus 10%
7
Fortum
EU-PVSEC Sept 2018



kWh/month
$/month
Hawaii Electric Monthly Residential Utility Bill 2012-2018
10000
1000
100
10
HECO $/month
HECO kWh/month
kWh/month
Pre-Solar
35.7¢/kWh
24¢/kWh
$/month
Solar-Phase 1
Solar-Phase 2
21kWh/month
$15.18/month
Solar Phase 3
Jan-12
Mar-12
May-12
Jul-12
Sep-12
Nov-12
Jan-13
Mar-13
May-13
Jul-13
Sep-13
Nov-13
Jan-14
Mar-14
May-14
Jul-14
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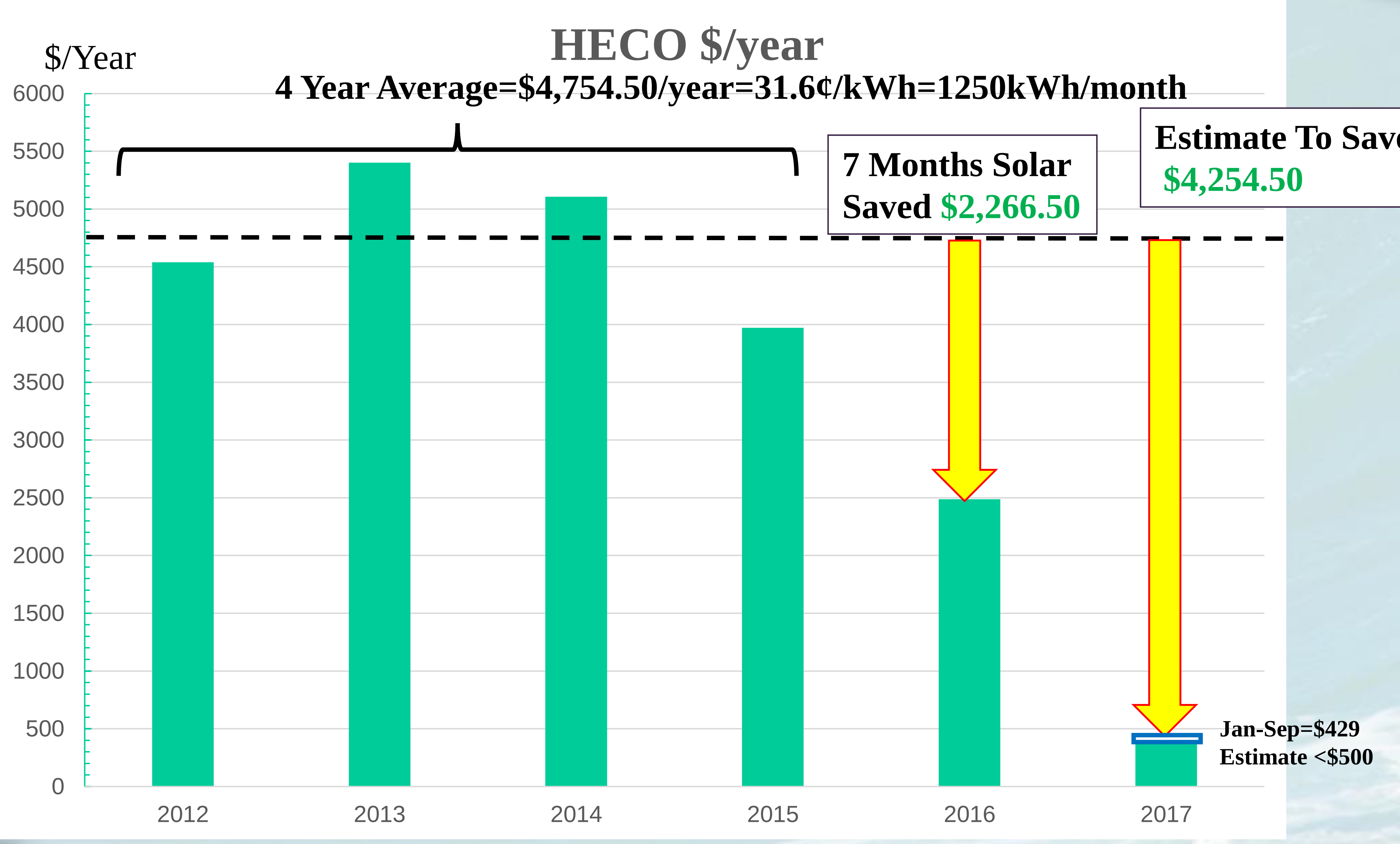
Sep-17
Nov-17
Jan-18


HECO $/year
$/Year
4 Year Average=$4,754.50/year=31.6¢/kWh=1250kWh/month
7 Months Solar
Saved $2,266.50
Estimate To Save
$4,254.50
Jan-Sep=$429
Estimate <$500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
2012
2013
2014
2015
2016
2017

www.pvwatts.nrel.gov Simulation Results for Oahu

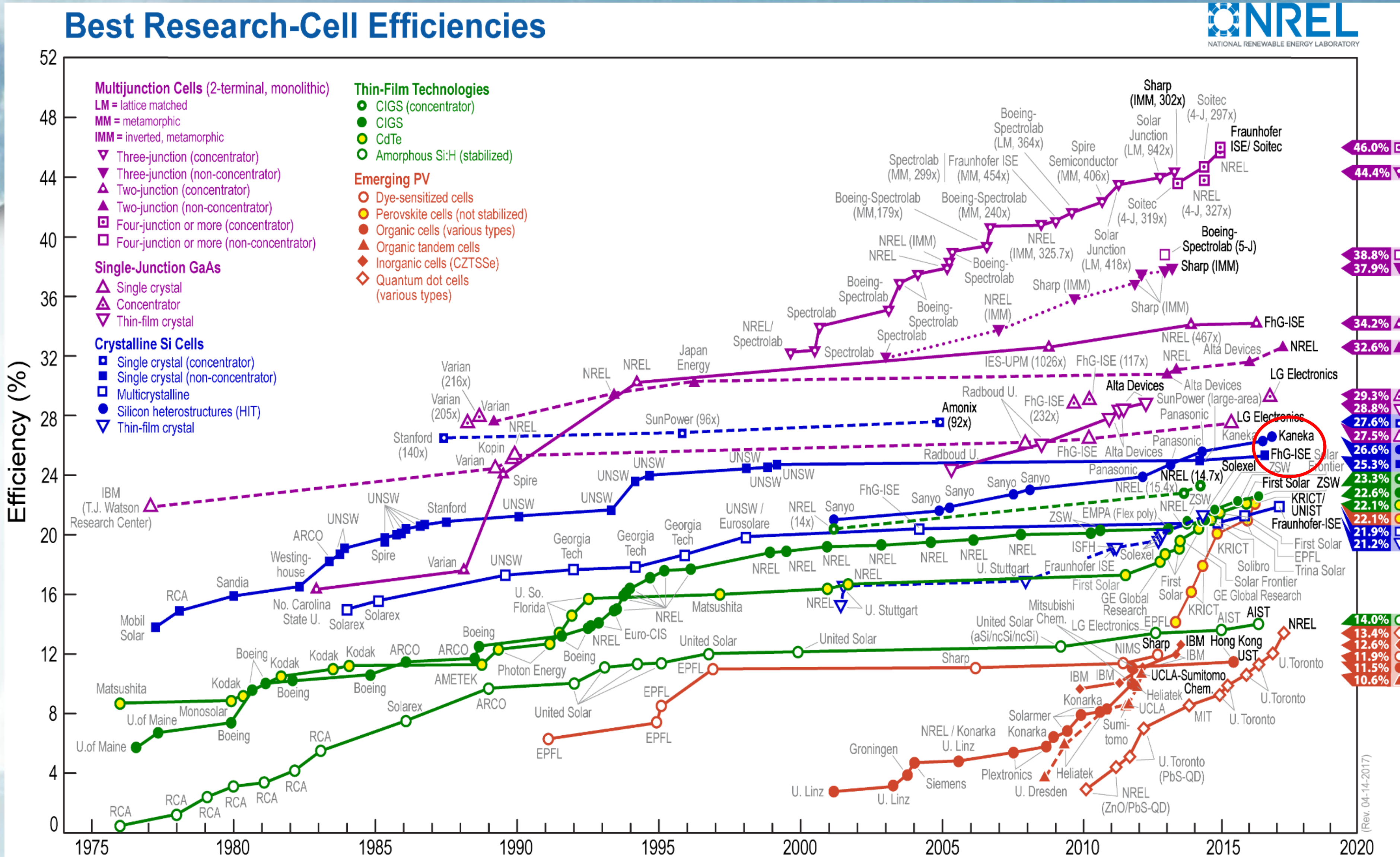
Month	Solar Radiation (kWh / m² / day)		AC Energy (kWh)	~35% PV Loss/Dumping Actual PV Results	Energy Value ($)
January	4.52	=23.9kWH/Day	584	→383kWH (65.5%) =12.4kWH/Day	193
February	5.20	=27.7kWh/day	609	→374kWh (61.4%) =13.34kWh/day	201
March	5.74	=30.3kWh/day	738	→489kWh (66.2%) =15.8kWh/day	244
April	5.89	=31.2kWh/day	735	→512kWh (69.7%) =17.1kWh/day	242
May	6.32	=33.3kWh/day	811	→499kWh (61.5%) =16.1kWh/day	268
June	6.36	=33.4kWH/Day	786	→560kWH (71.2%) =18.6kWH/Day →382	260
July	6.41	=33.6kWH/Day	818	→461kWH (56.4%) =14.8kWH/Day →492	270
August	6.46	=33.7kWH/Day	820	→599kWH (73.0%) =19.3kWH/Day →619	271
September	6.32	=33.0kWH/Day	777	→452kWH (58.2%) =15.1kWH/Day →499	256
October	5.41	=28.6kWH/Day	697	→360kWH (51.6%) =11.6kWH/Day	230
November	4.71	=25.0kWH/Day	589	→368kWH (62.5%) =12.3kWH/Day	194
December	4.40	=23.3kWH/Day	568	→309kWH (54.4%) =10.0kWH/Day	187
Annual	5.65		8,532		$ 2,816

Post-NEM world maximum $ savings is realized by achieving zero grid-buy!

$4,212 (~95%)
ROI=7yrs→
TaxCr=2.7yrs

$2,256 (~50%)
ROI=16yrs

$2,880 (~70%)
ROI=9.8yrs



New Message at IEEE-PVSC Solar Conference June 6-10, 2016 was "**LCOE Reduction of PV Electricity: Does PV Cell Technology (efficiency) still matter or Climate Optimized Energy Yield**" As a Solar PV End-User my views has now also changed due to the ~35% PV energy DUMPNG! Lowest cost (\$/W install) is more important than highest cell/module efficiency!

ITRPV-2017

Module Price learning Curve

Shipments /avg. price at years end:

2016: 75 GWp / 0.37 US$/Wp
08/2017: 0.35 US$/Wp

o/a shipment: ≈ 308 GWp
o/a installation: ≈ 300 GWp

2017expectation: ≈ 380 GWp

300 GWp landmark was passed!

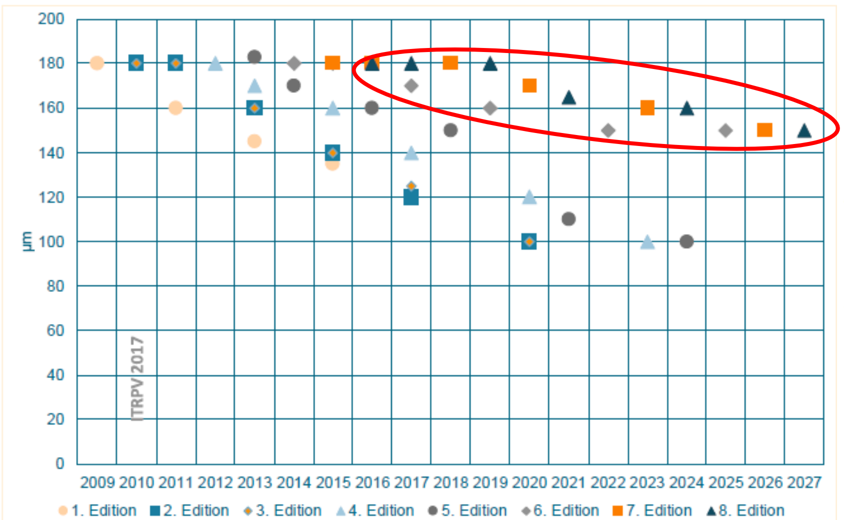
LR 22.5 % (1976 .... E 2016)

dramatic price drop due to market situation
→ Comparable to 2011/2012, but faster

ITRPV-2017

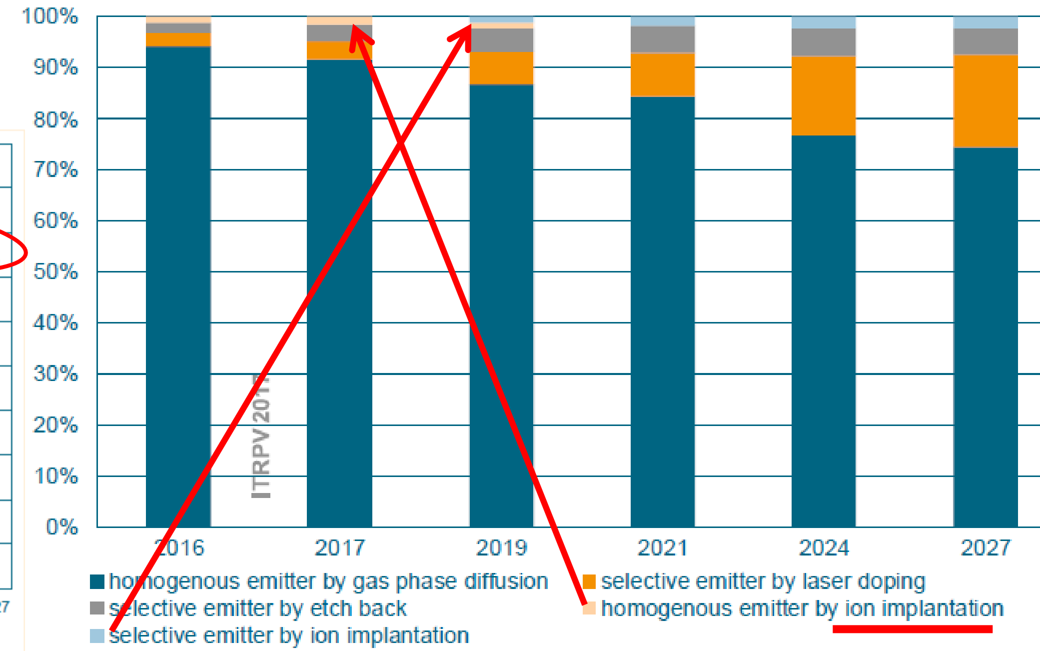
Review ITRPV predictions

Wafer thickness (multi)

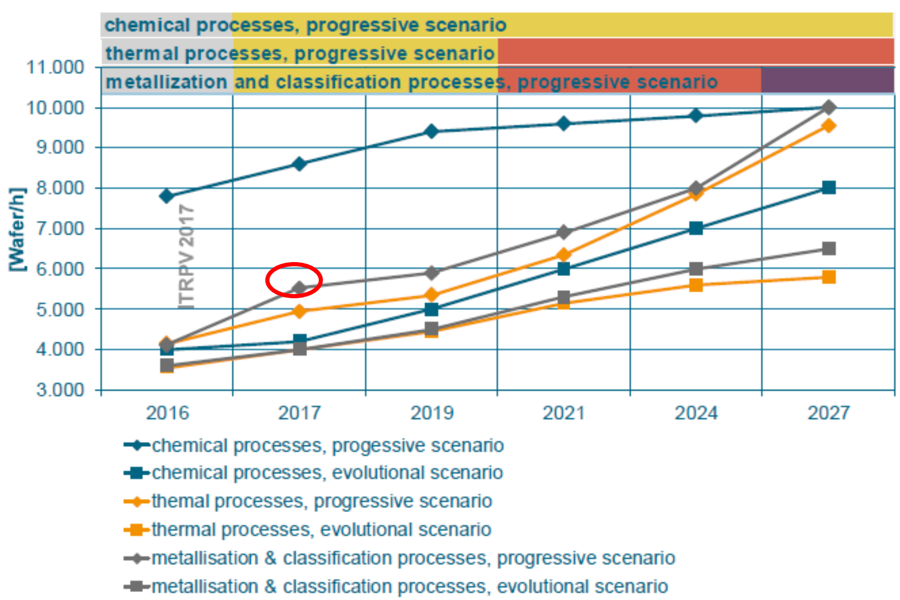


Different phosphorous emitter technologies for p-type cells

World market share [%]

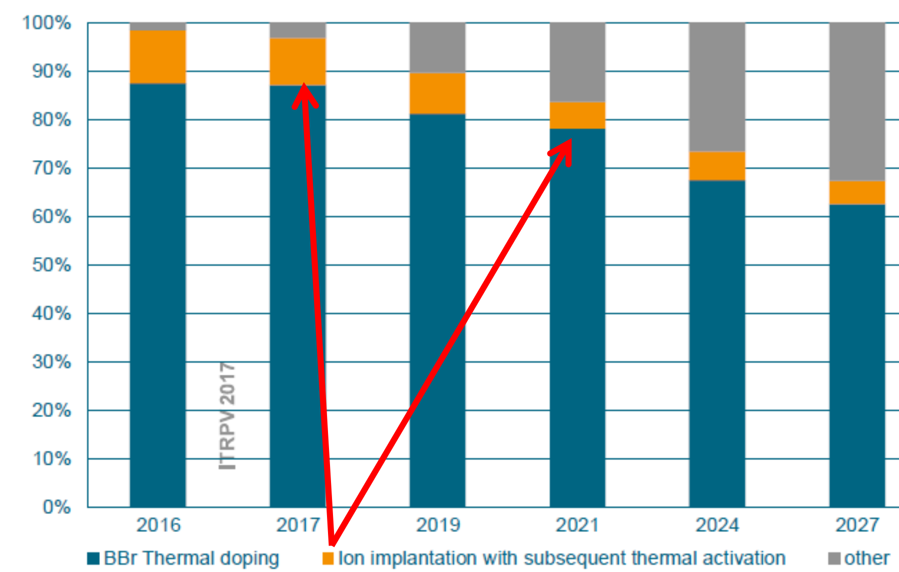


Cell production tool throughput

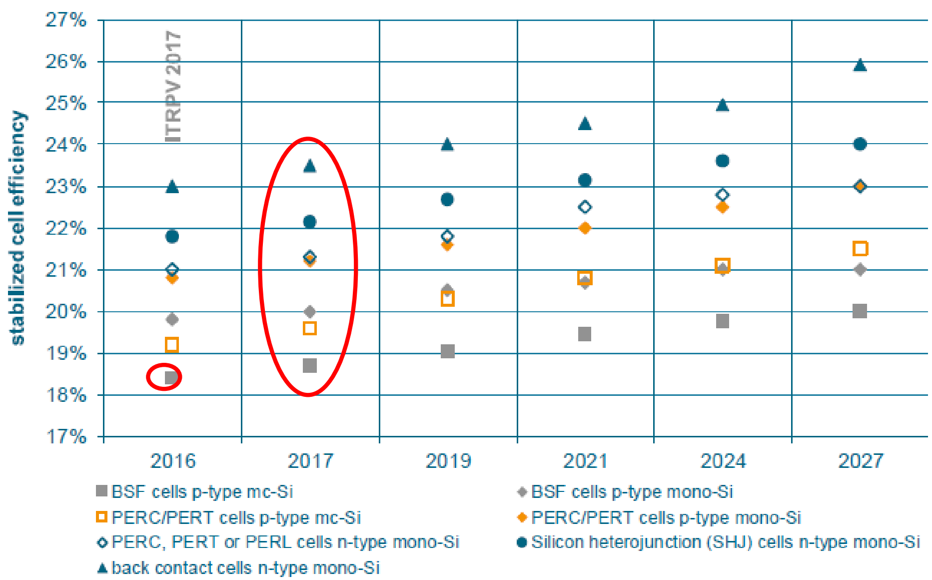


Different technologies for boron doping (n-type cells)

World market share [%]

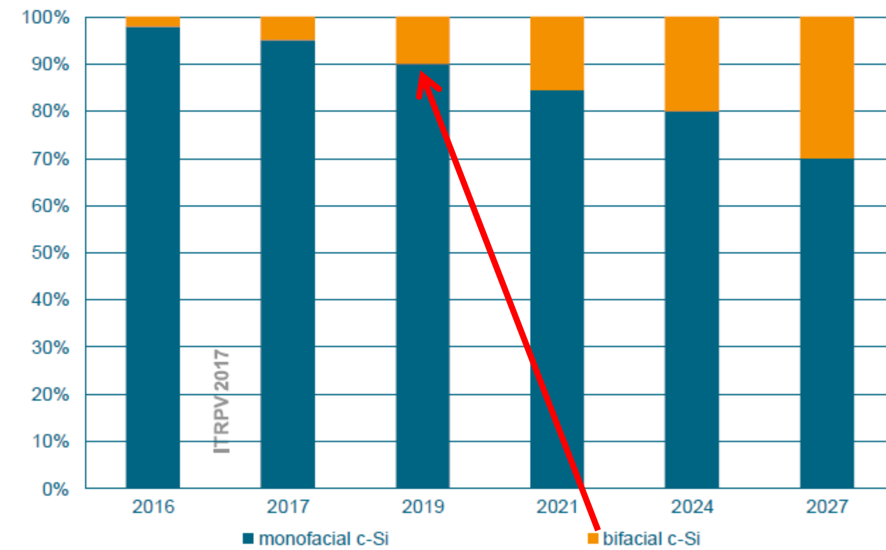


Average stabilized efficiency values for Si solar cells (156x156mm²)



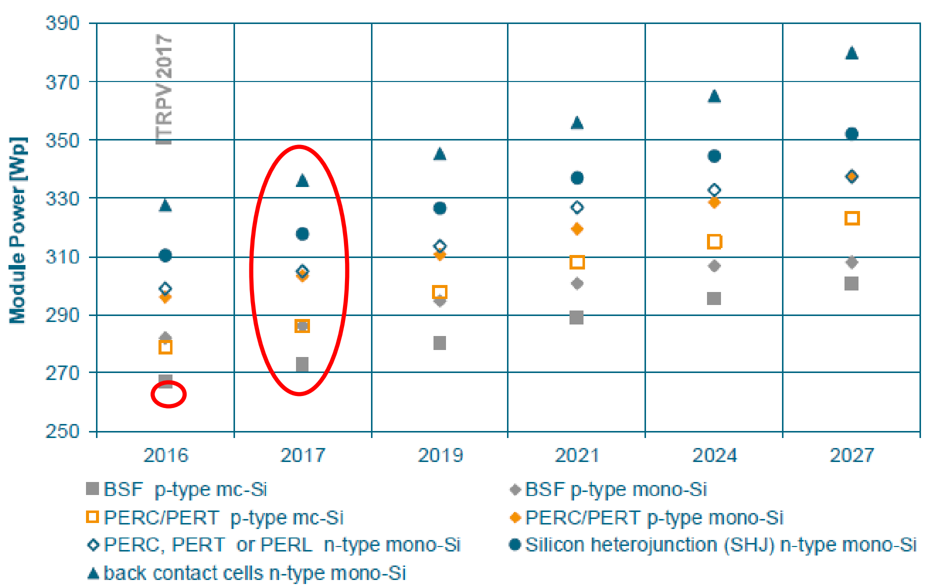
Bifacial cell technology

World market share [%]



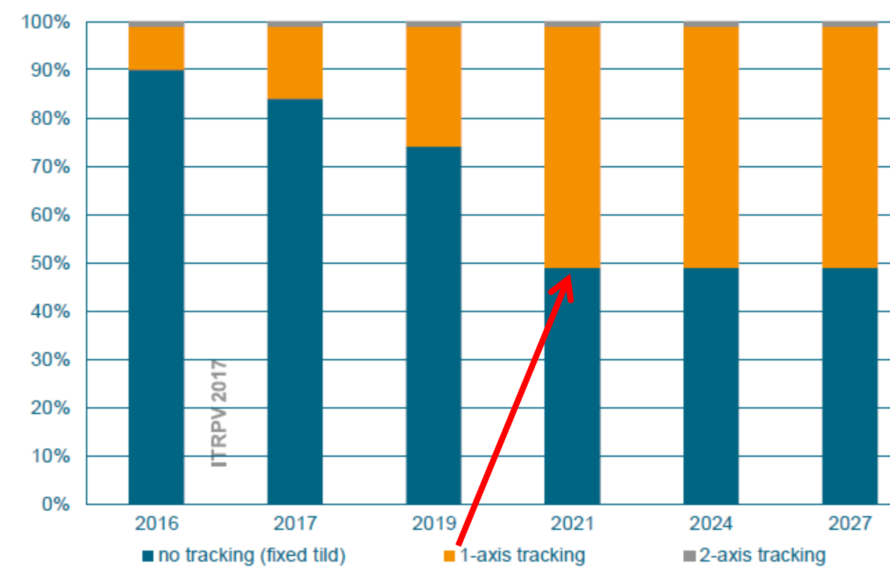
ITRPV-2017

Module Power for 60-cell (156x156mm²) module



Tracking systems for c-Si PV

World market share [%]



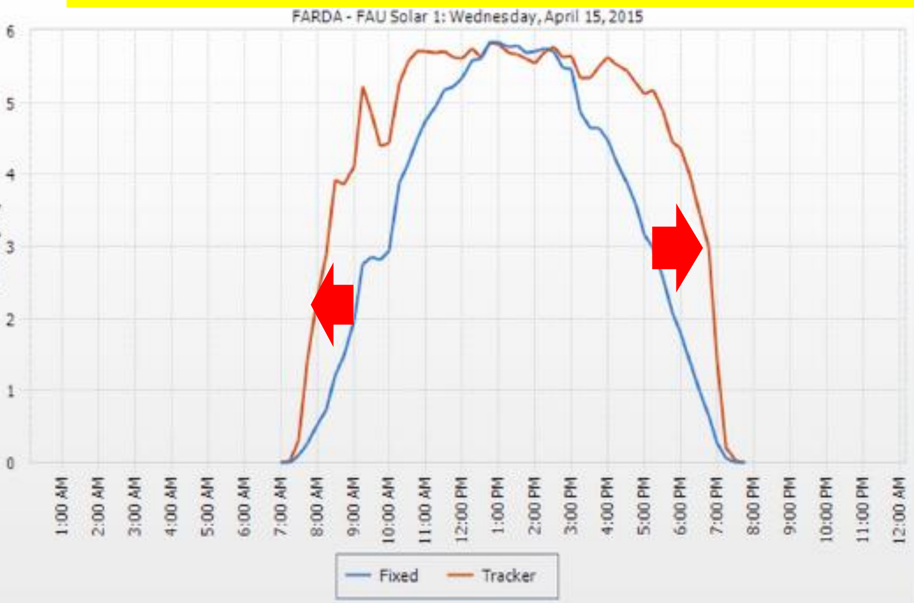
Annual Performance Comparison Between Tracking and Fixed Photovoltaic Arrays

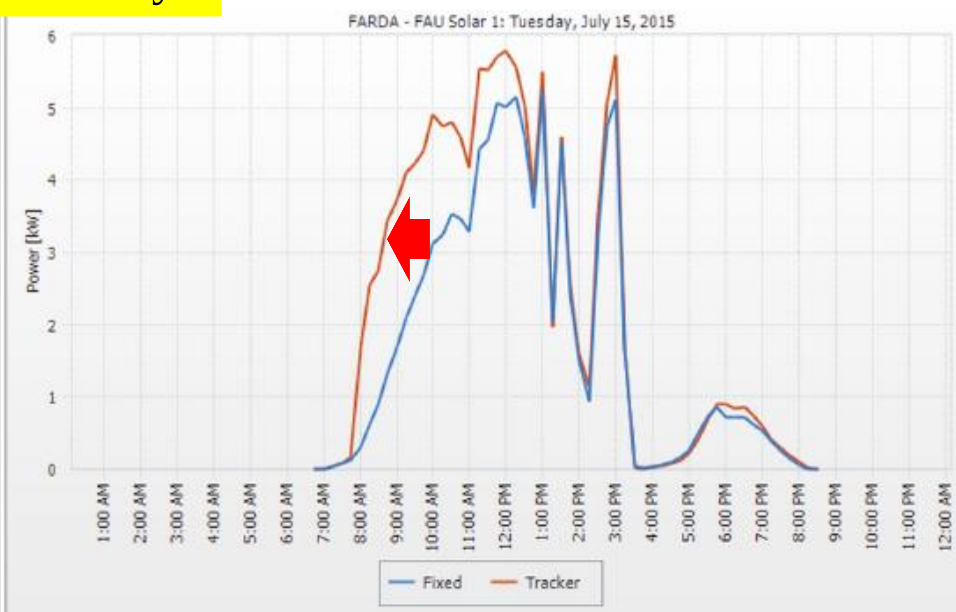
Hadis Moradi, Amir Abtahi and Roger Messenger

Florida Atlantic University, Boca Raton, FL

IEEE-PVSC June 2016

Tracker Gives Best Solar-PV Yield ~15% But Costly!





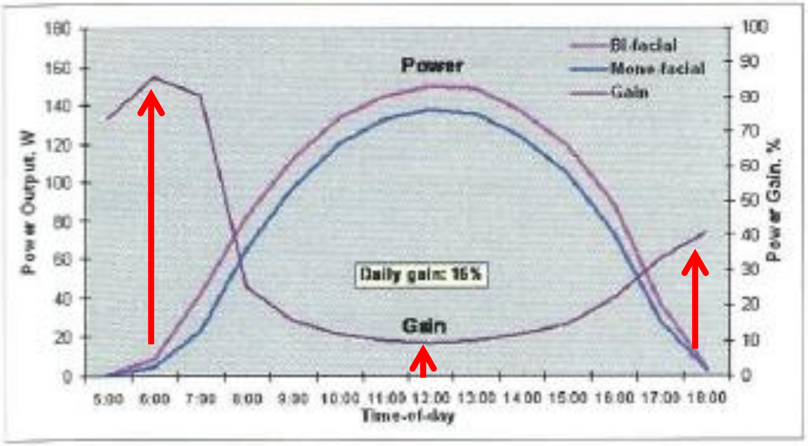
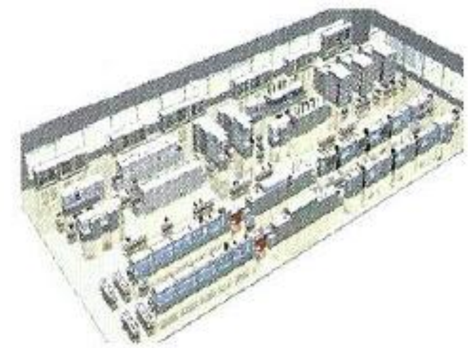


Figure 8. Daytime energy generation by regular and bifacial in-field installed modules

In production

1) PVGS: PERT (EarthON)
2) Panasonic: HJ
3) NSP: PERT and now bifPERC
4) Yingli: PERT (Panda)
5) Mission Solar: PERT - STOPPED
6) MegaCell: PERT (BiSoN) - STOPPED
7) Solarworld: PERC+ (Bisun) - STOPPED
8) LG: PERT (NeON)
9) Sunpreme: HJ
10) HT-SAAE: PERT
11) Jolywood: PERT
12) QXPV: PERT
13) ShanxiLu'an: bifacial mcPERCT
14) Sunrise: bifacial PERC
15) Aleo: bifacial PERC
16) LONGi: bifacial PERC
17) Adani: PERT (BiSoN)
18) TRINA: bifacial PERC
19) and many others



In pilot

a) Motech: PERT
b) TRINA: PERT
c) Tesla/Panasonic: HJ
d) REC: PERT
e) SolAroud: pPERT
f) First Solar/Tetra Sun: "HJ" - STOPPED
g) and many others

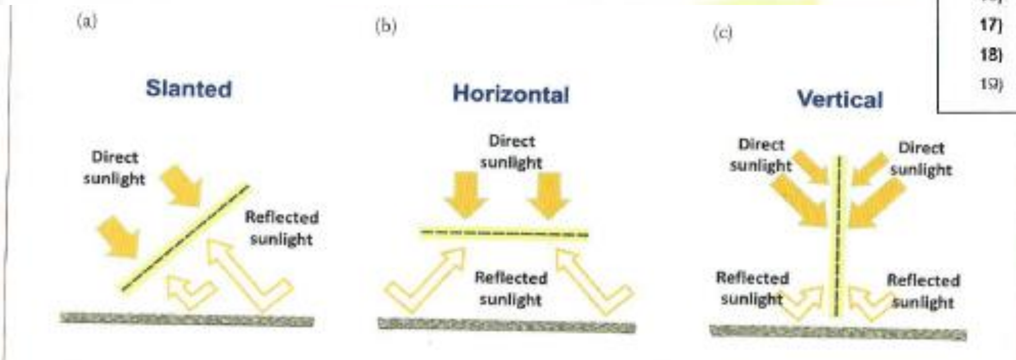


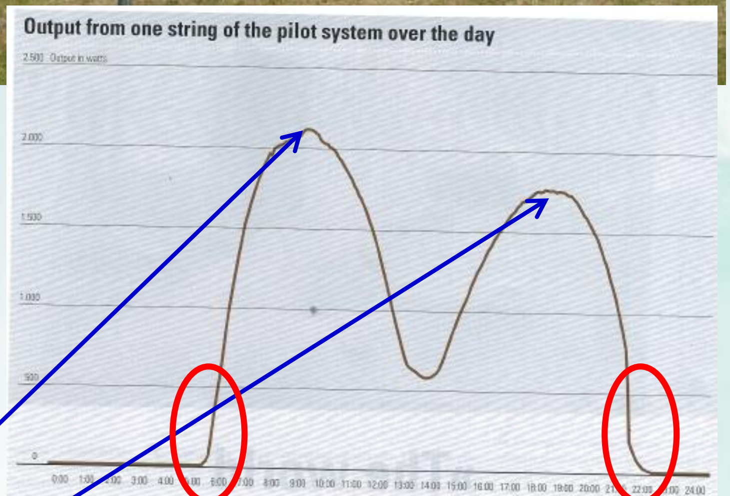
Figure 2. Possible installation geometries for bifacial modules: (a) slanted, (b) horizontal, (c) vertical.

Bifacial Modules

~20% Higher Gain!

	Standard Al-BSF	pPERC	nPERT/HJT	nIBC
	p-standard	p-PERC	n-standard-bifacial	n-rear contact-bifacial
Market share 2017 [%]	80	13	5	2
Efficiency 2017 [%]	20+	21+	21+	22+
Bifaciality [%]	0	70+	90+	80+
Market share 2022 [%]	40	30	20	10
Efficiency 2022 [%]	21+	22+	23+	24+

Table 1. Technology share, efficiency and bifaciality numbers of screen-printed low-cost industrial cell concepts



Photon International May 2017 Next2Sun Bifacial Two-Hill Island Solar PV Farm in Germany with 90 degree Vertical East/West Facing Panels to Increase AM PV-Gen and Extend PM PV-Gen

Said This Type of Grid-Optimized Solar PV-Generation Should Be Rewarded by Paying More $ For 6-9AM and 5-8PM PV-Gen export feed-back to the Grid with Low 11AM-3PM PV-Gen so No Duck Curve!

I Agree and should make this Future Policy Especially With Battery As I Have Been Saying Since June 2016!

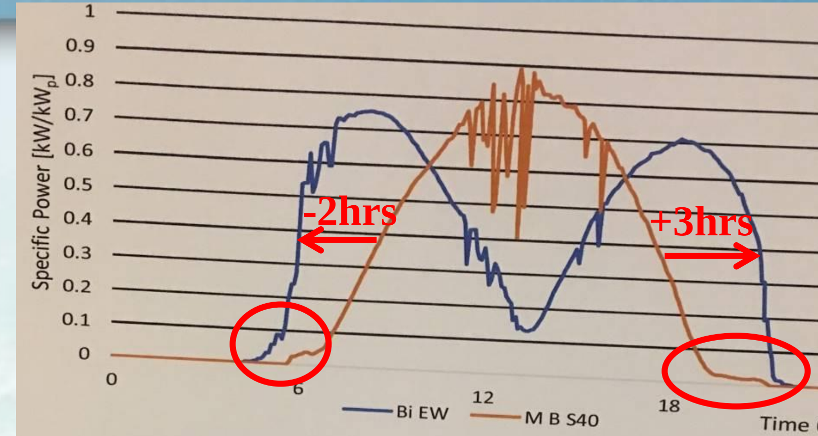


Figure 6. Site 2. Clear day, 5 June 2016.

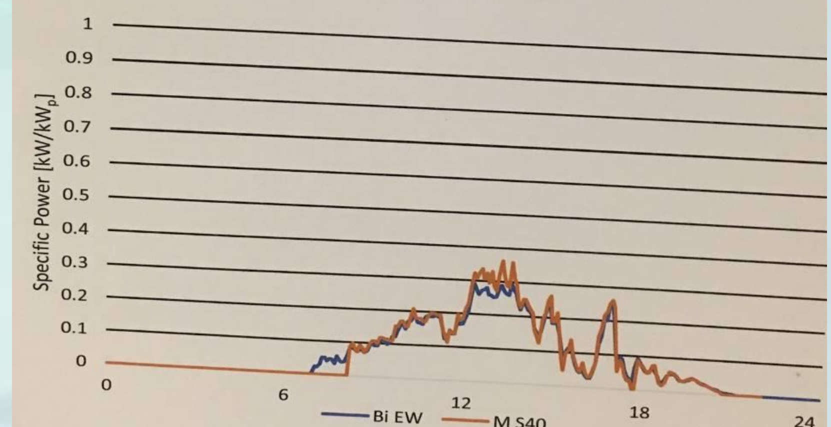
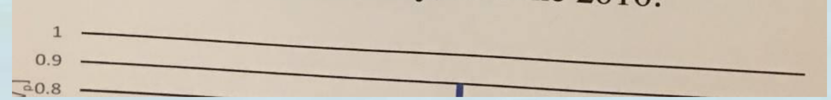


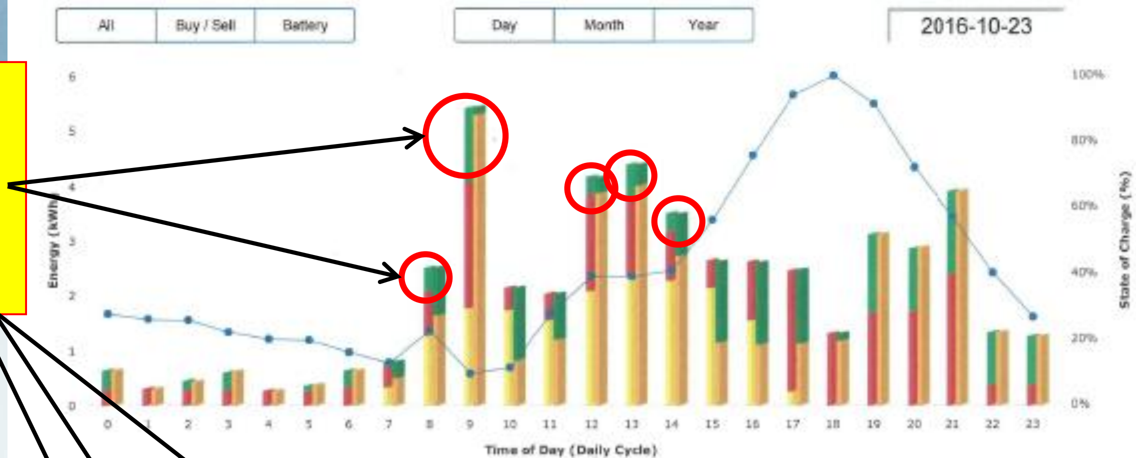
Figure 8. Site 2. Cloudy day, 18 June 2016.

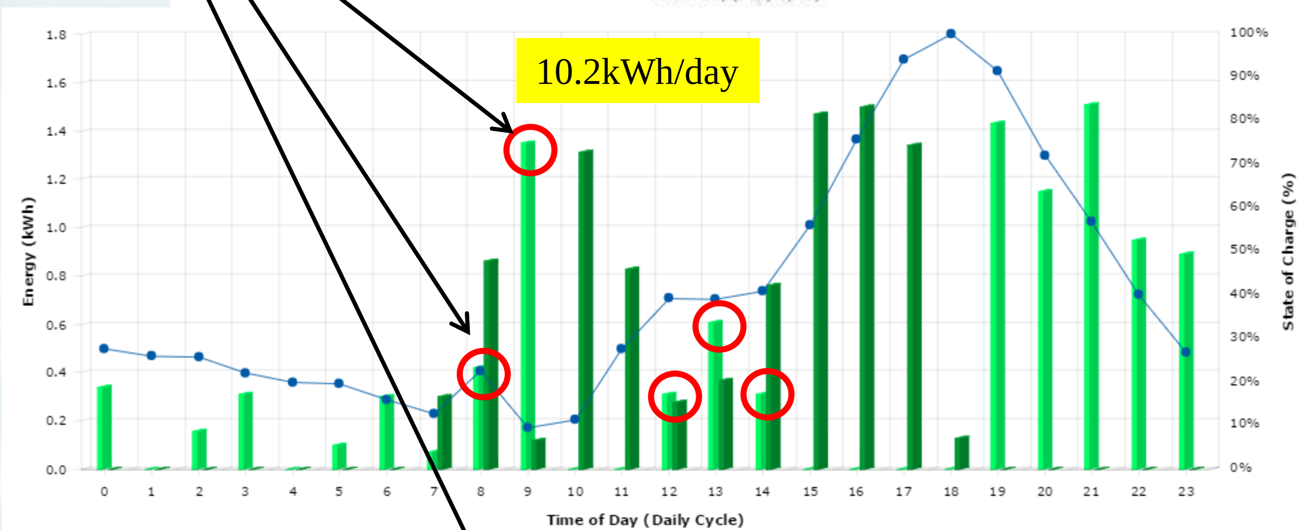


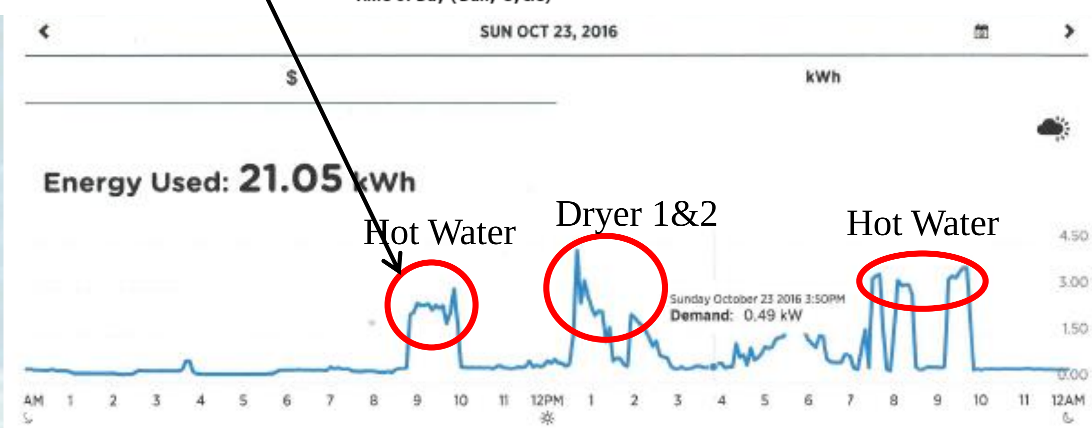
For Sweden being so far North, vertical standing Bifacial facing East/West yields ~12% higher PV-gen than mono facing South!

EU-PVSEC Sept 2018

Need AM/Morning Battery Discharge For Hot Water!



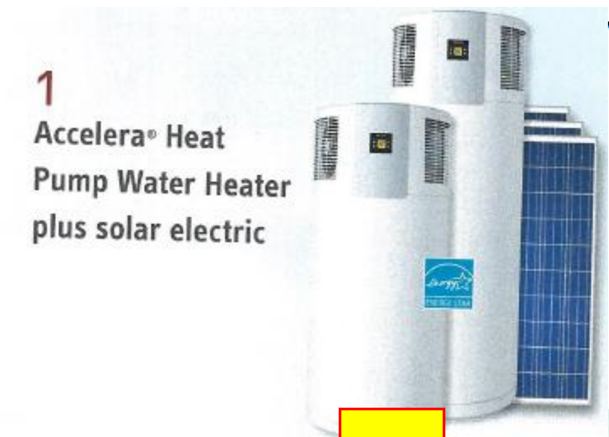




Strategy 4:
Grid-Interactive Water Heating

- Acts as a low-cost "battery"
- Stores a full day's supply

ices to th



My case Hybrid Solar Thermal/PV/Battery Hot Water Heater

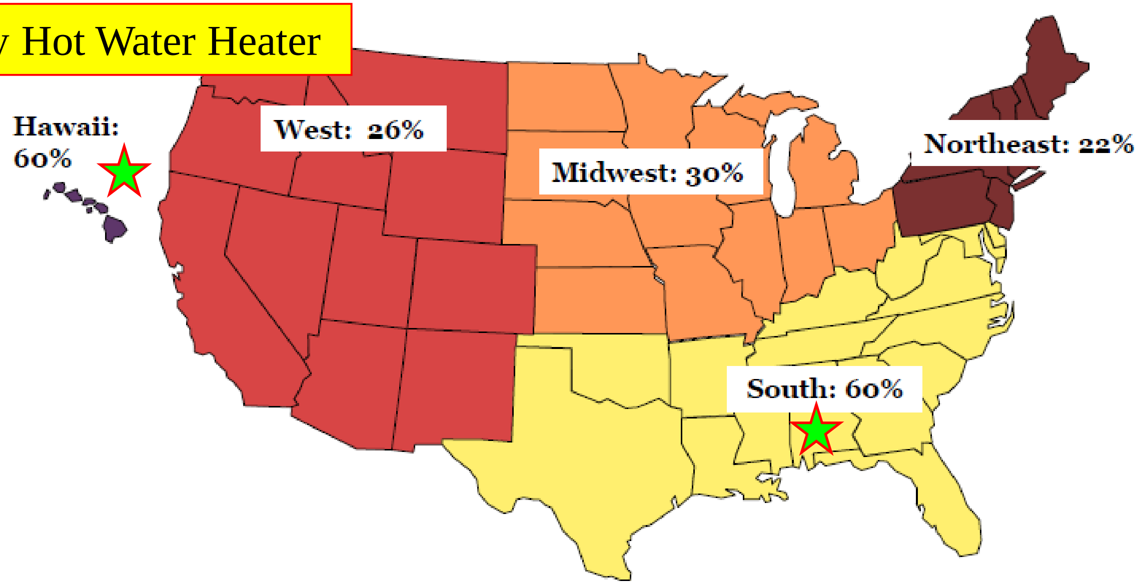
Strategy 4:
Control Electric Water Heating

Install grid control of electric water heating;
Supercharge to 140F – 170F during low-cost hours.

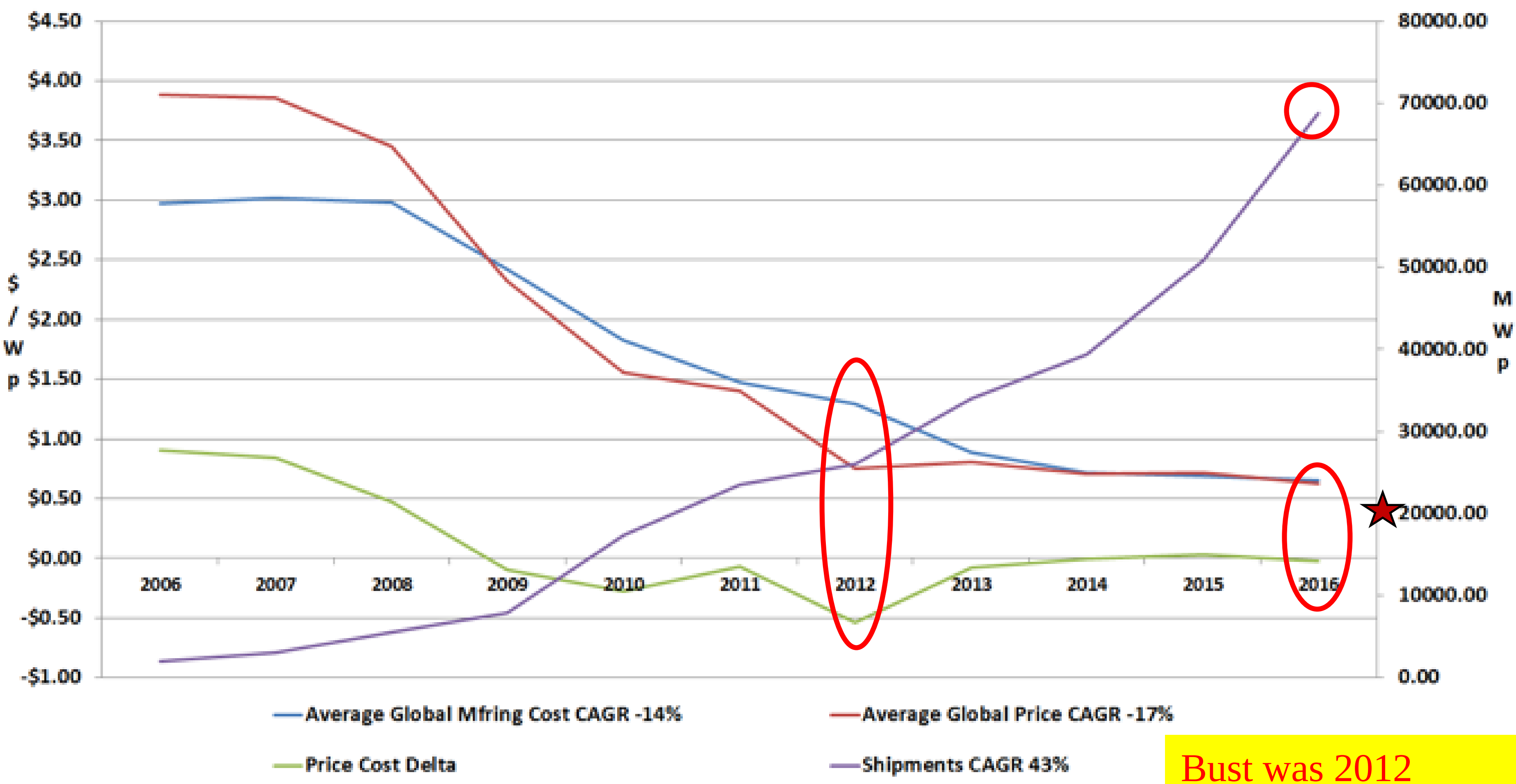
45 million electric water heaters in the U.S.

Each can provide balancing for ~2 kW of wind or solar.

45 Million Electric Water Heaters



Census Housing Survey Table 2.5 (2010)

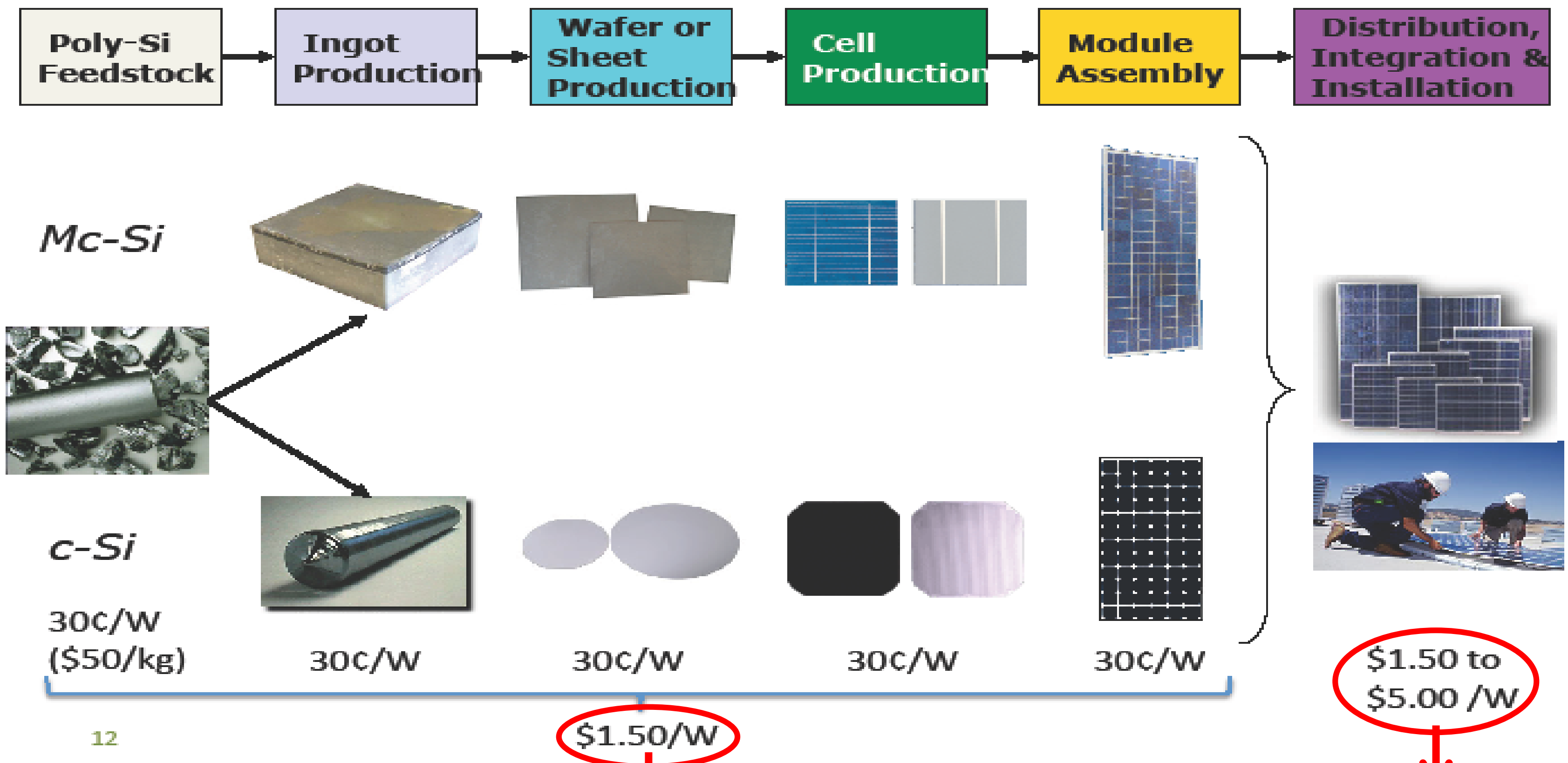


Bust was 2012 today PV companies have no profits!

Figure 1: Solar Module Average Costs, Prices and Price/Cost Delta, 2006-2016

February 8, 2017
By Paula Mints
Founder/Chief Market Research Analyst

Solar PV Module Value Chain

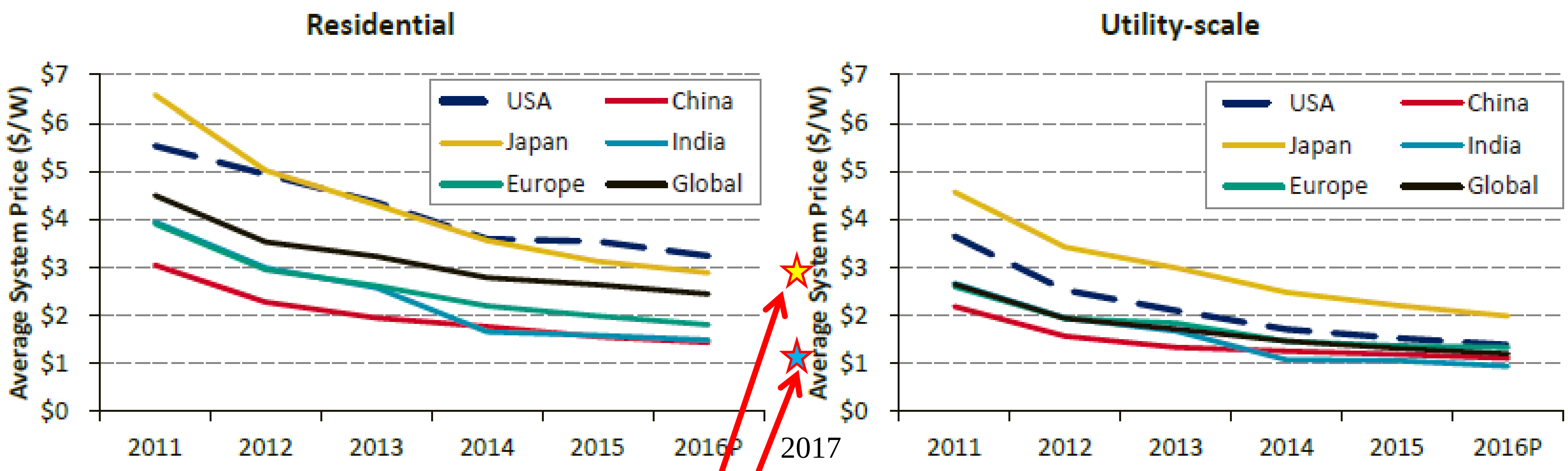


$0.33/W (2017)

$3.06-$5.60/W (2016)

Profits are with the PV installation companies as install costs have increased since 2011

Residential and Utility-Scale System Prices by Region



- The price of residential systems in the United States remains much higher than in much of the world, including developed regions.
  - A report from Lawrence Berkeley National Laboratory cited non-hardware costs as the primary difference in distributed PV system pricing, owing to differences in market size, incentive levels and incentive design, solar industry business models, demographics and customer awareness, building architecture, systems sizing and design, interconnection standards, labor wages, and permitting and interconnection processes.
- While U.S. utility-scale projects are higher than global averages, the gap is much smaller than in the residential sector.

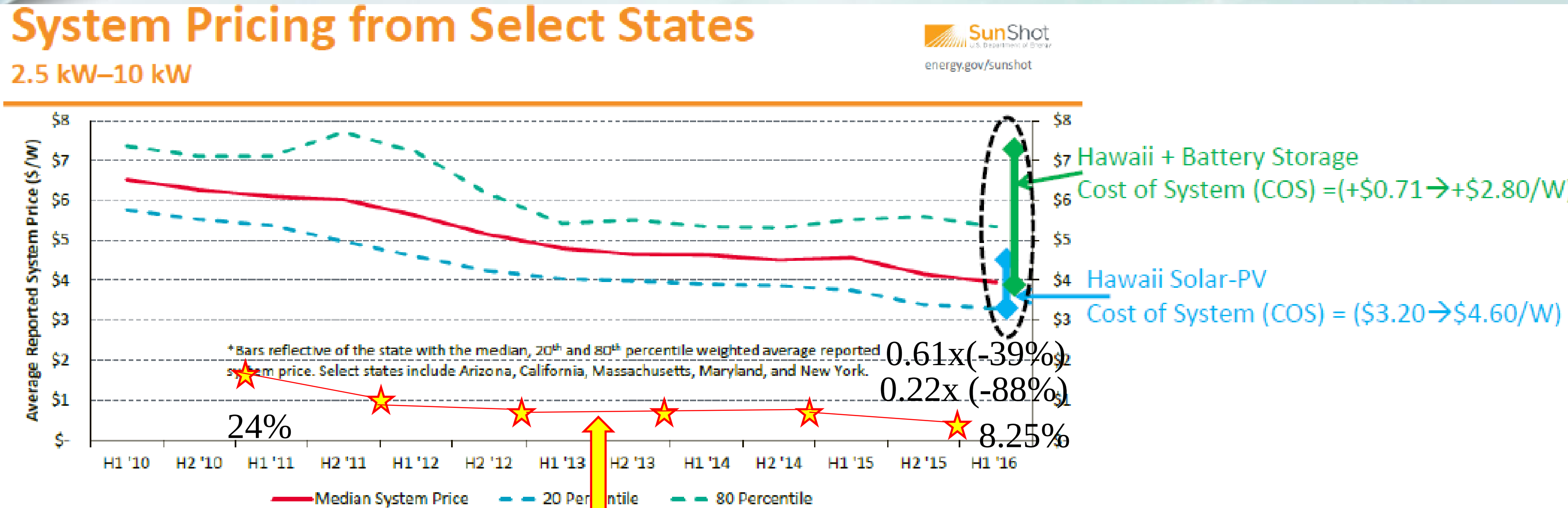
Sources: IHS Technology, "PV Demand Market Tracker – Q3 2016." September 2, 2016; Barbose and Darghouth, "Tracking the Sun IX," 2016

SunShot U.S. Department of Energy

energy.gov/sunshot

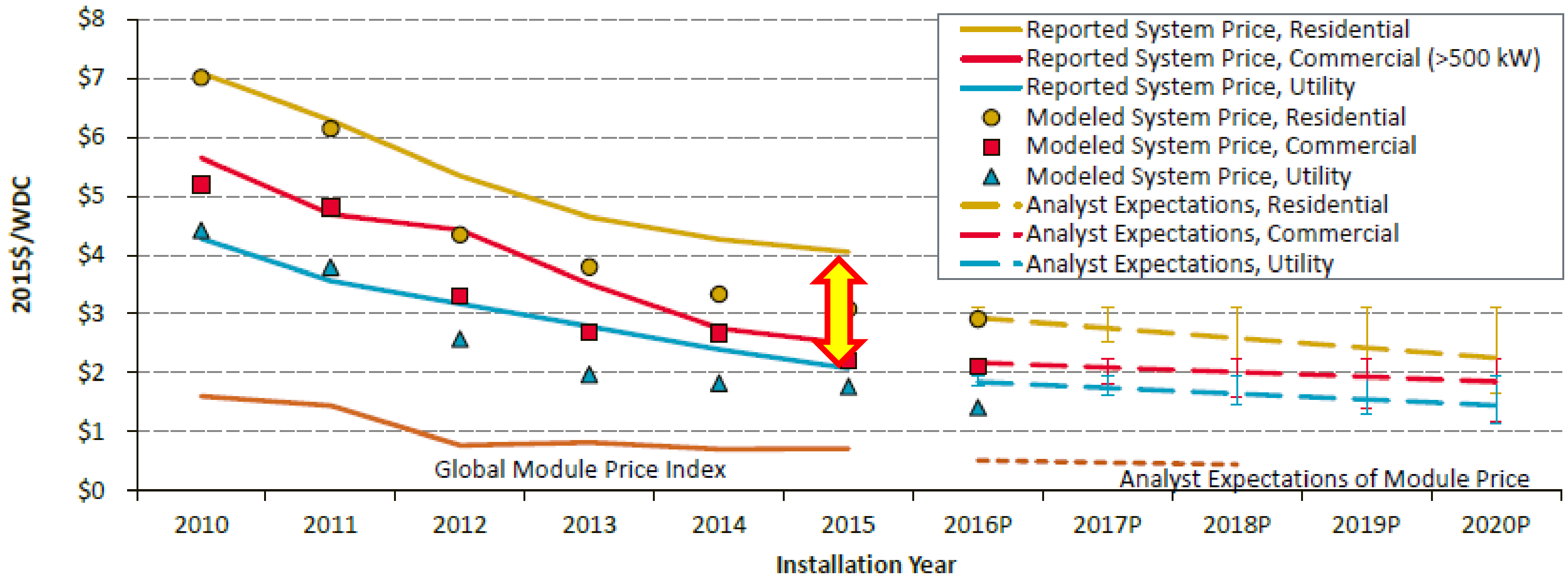
At EU-PVSEC conference Sept 25-29, 2017 rooftop PV total cost for system installed in Europe was **~$1.00/W** and US was **~$2.80/W**

Solar PV + Battery Package Costs ROI Analysis



COS (cost of system)
L-COE (Lifetime-cost of energy)
<u>Solar-PV (7kWh)</u>
COS=$22,400=$3.20/W→Tax Cr=$1.28/W
L-COE=8¢/kWh/20yrs→TaxCr=3.2¢/kWh
<u>Battery (10kWh)</u>
COS=$7,100=71¢/W→TaxCr=28.4¢/W
L-COE=23¢/kWh/10yrs→TaxCr=9.2¢/kWh
<u>Solar Thermal (16kWh)</u>
COS=$6,000=37.5¢/W→TaxCr=15¢/W
L-COE=10.3¢/kWh/10yrs→TaxCr=4.1¢/W

Reported, Bottom-Up, and Analyst-Projected Average U.S. PV System Prices over Time



- All methodologies show a downward trend in PV system pricing.
- Reported pricing and modeled benchmarks historically had similar results; however, they have recently diverged in estimated pricing.
- Analysts expect system prices to continue to fall with low-end projections approaching SunShot targets by 2020.

Note: Reported prices represent the median national U.S. averages. Note. Error bars represent the high and low analyst expectations.

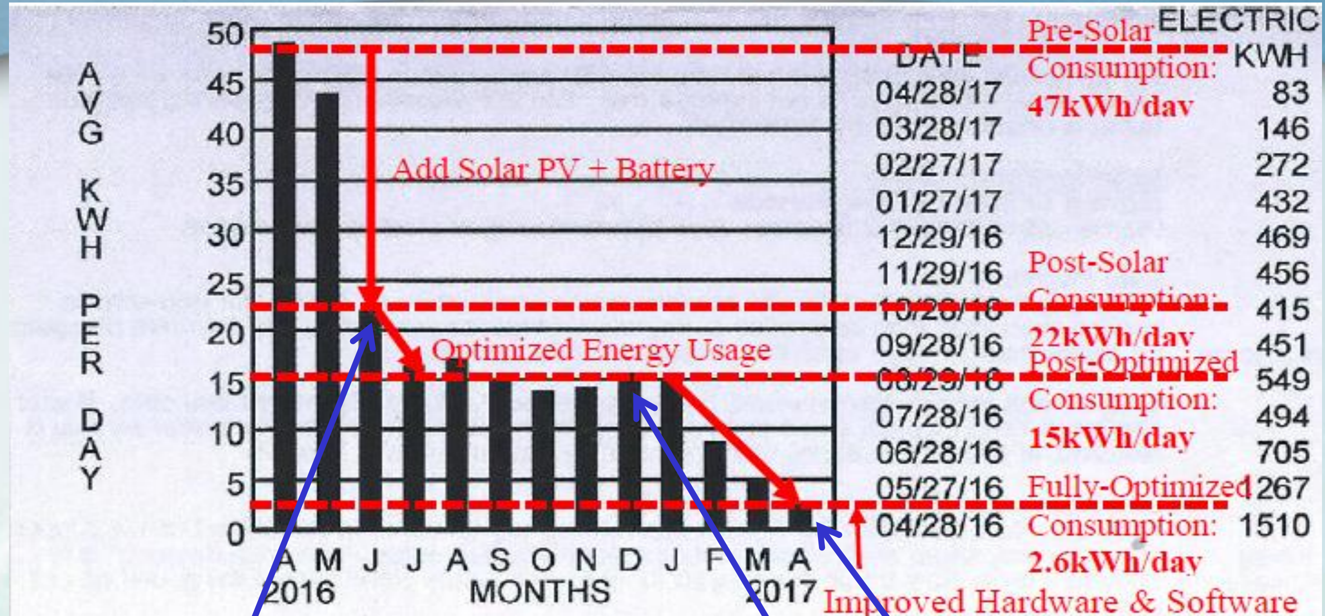
Sources: Reported residential and commercial system prices (Barbose and Dargouth 2016); reported utility system prices (Bolinger and Seel 2016); modeled system prices (Fu et al. 2016); analyst expectations (Cole et al. 2016); The Global Module Price Index is the average module selling price for the first buyer (P. Mints SPV Market Research); analyst expectation of module price) see Slide 44.

SunShot U.S. Department of Energy

energy.gov/sunshot

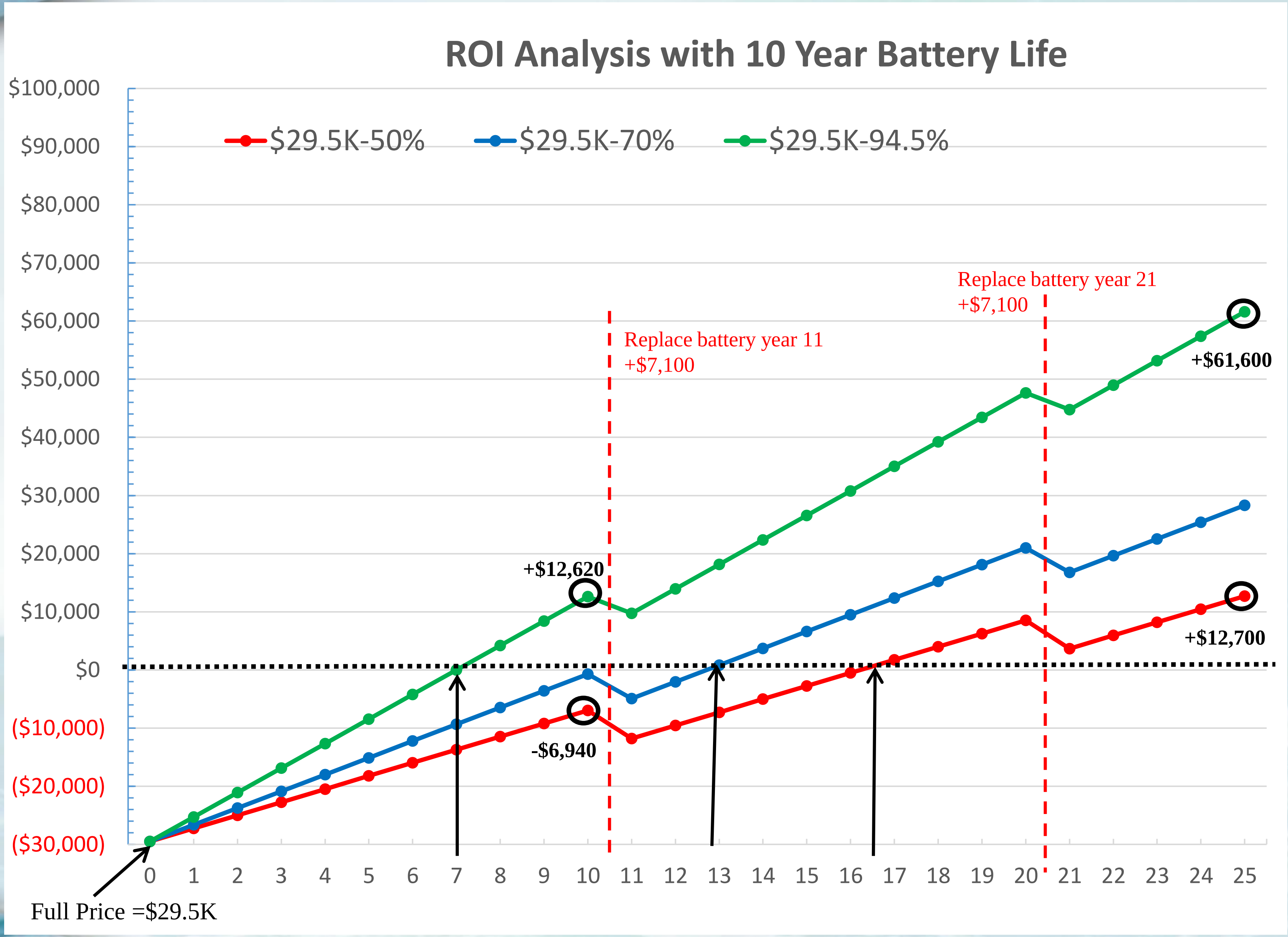
Utility Scale Solar PV System Costs is ~50% Lower Than Residential Costs L-COE for Solar-PV Farm L-COE is 4¢/kWh/20 years and sell to Utility at 11.9¢/kWh compared to residential Hawaii at 9¢/kWh! This is why Utility does not want residential rooftop solar-PV only solar Farms!

Outline

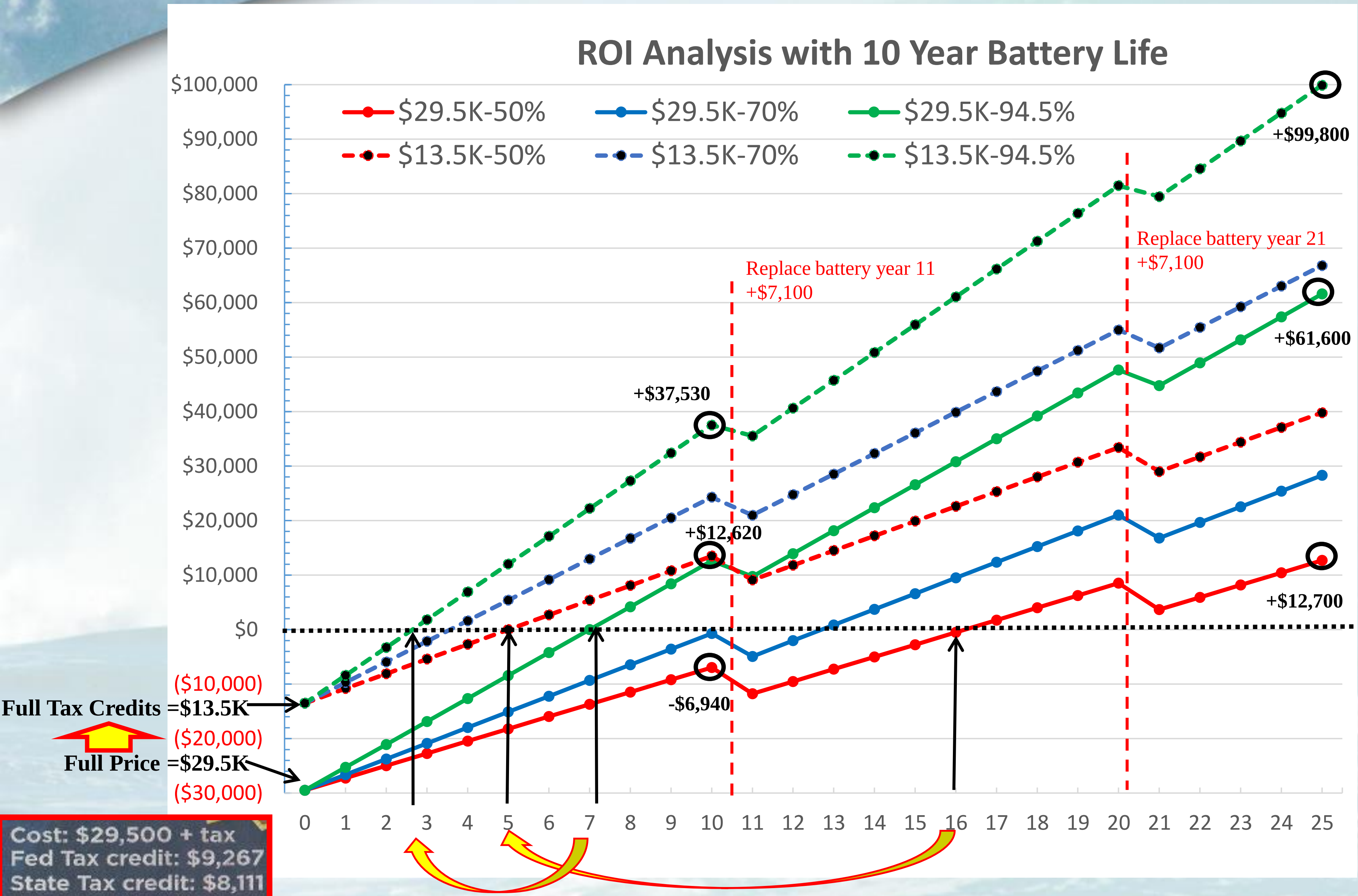


- Introduction:
- Methods:
- Results:
  - Solar + Battery 1st month 50% reduction ROI=16 years
  - Integration & Optimization July 2016 to Jan 2017 for 70% reduction ROI=9 years
  - Hardware & Software improvements Feb 2017 to Apr 2017 for 95% reduction ROI=7 years or 3 years with Full Hawaii & Federal Tax Credit (~60%)
- Conclusion

ROI Analysis For System Costs =$29,500



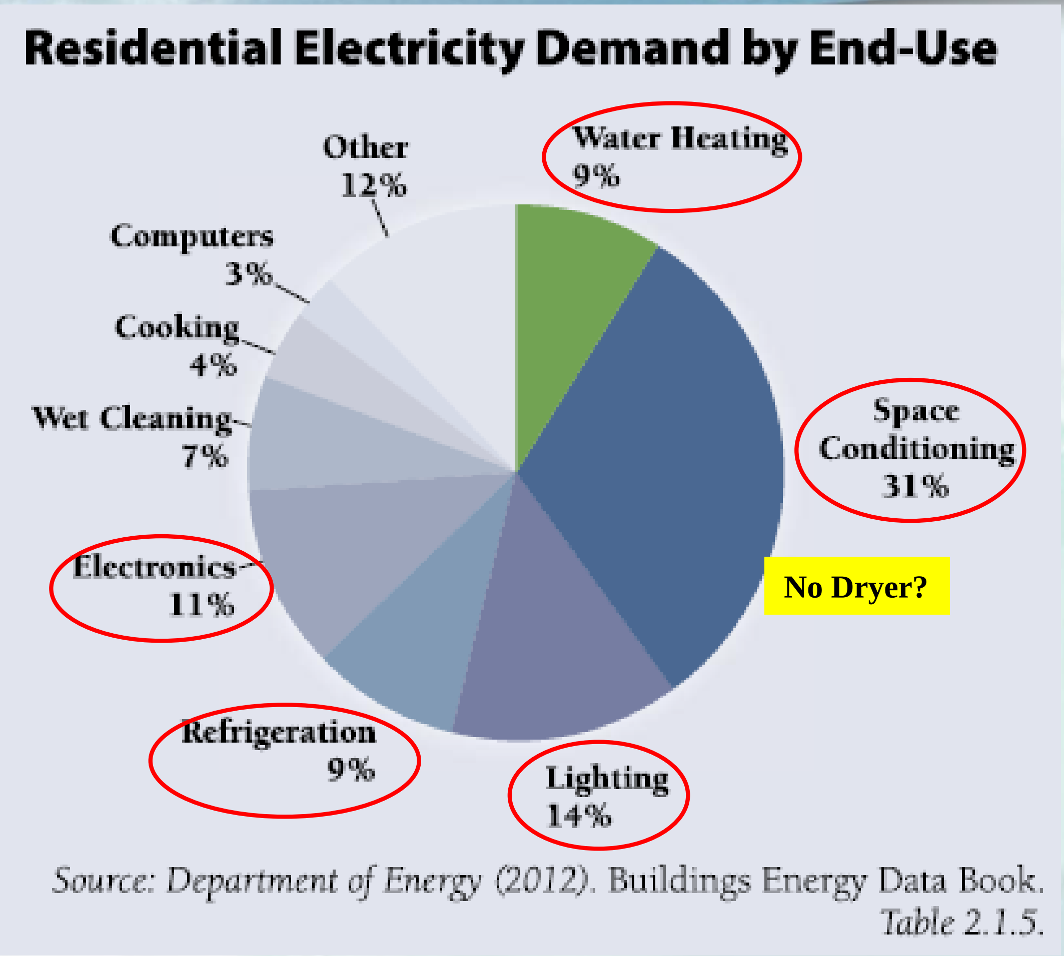
ROI Analysis For System Costs =$29,500



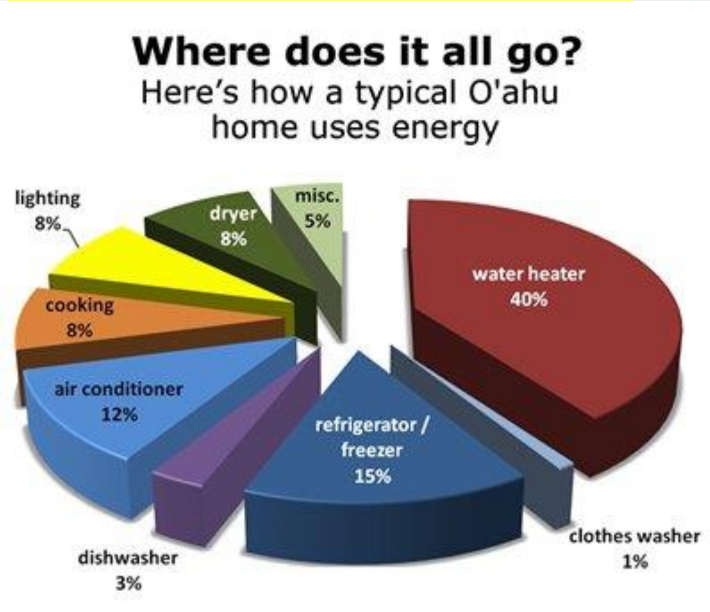
Cost: $29,500 + tax
Fed Tax credit: $9,267
State Tax credit: $8,111
Net Cost: $13,511*

Methods To Achieve Results

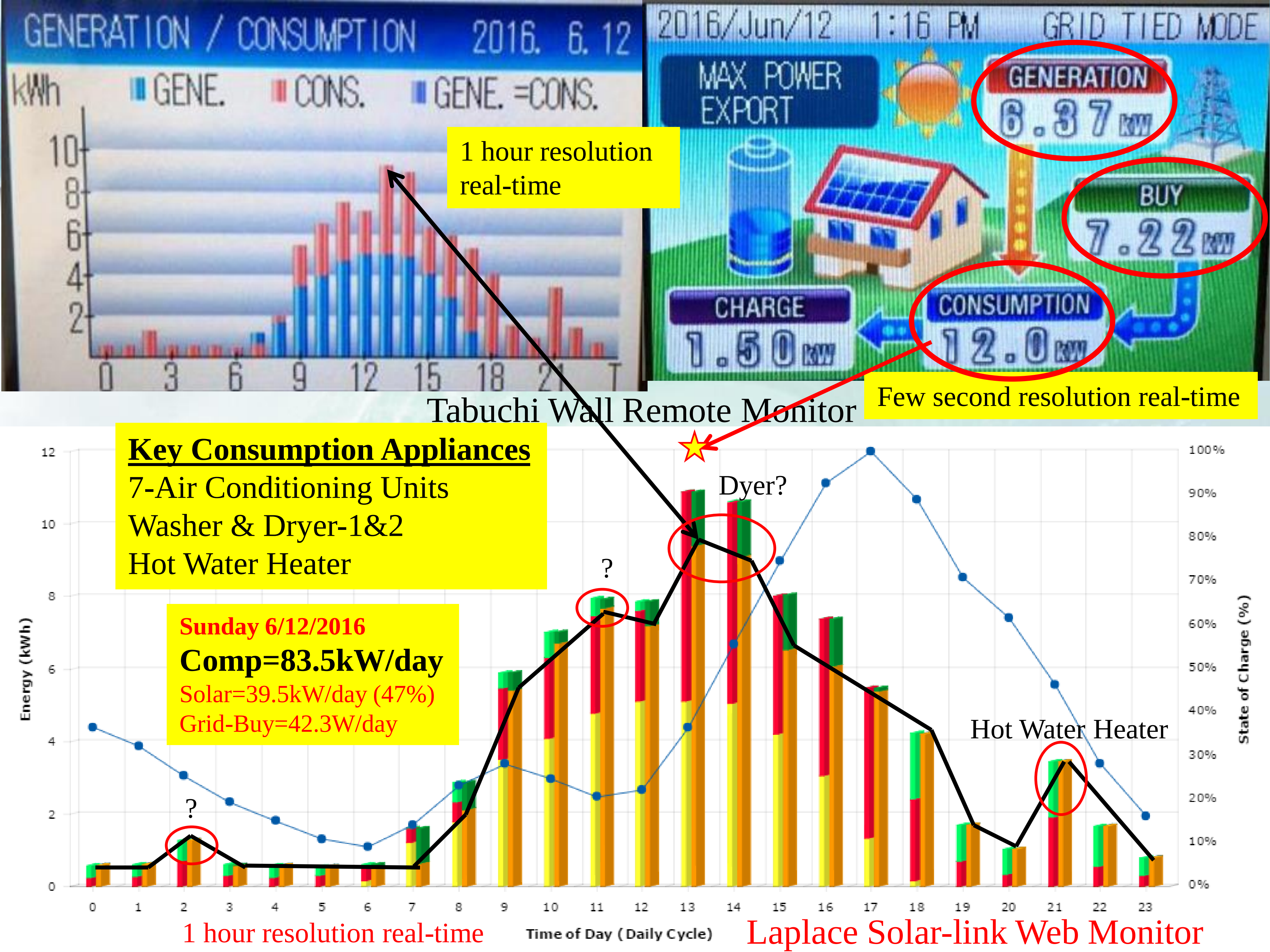
- Pareto analysis and identify **root cause** of top six key appliance energy usage. Required 3 different energy usage monitors (Tabuchi wall remote, Bidgely and Laplace website) with <5 minutes to 3 second data collection resolution for accurate verification of energy usage.
- Find renewable energy alternative to eliminate Grid-Buy (Battery discharge <6.6kWh/day at 9.2¢/kWh, super-charged solar Hot water thermal storage to >165F=16kWh/day at 4.1¢/kWh and chilled room/house Cold thermal storage 4-11kWh/day at 3.2¢/kWh)
- Improve Tabuchi inverter efficiency/communication for Battery Charging and Discharging: 2nd/multi AM battery charge & discharge
  - Electrical Storage battery discharge 6kWh/day single battery or 12kWh/day dual battery.
- Hot Thermal Storage: Super charge to >165F and modify hot water tank for 3 different renewable energy sources: 1st primary source is solar thermal, 2nd alternative source is solar-PV, 3rd alternative source is battery optimized discharge (BOD) and 4th source is Grid-Buy electricity
- Cold Thermal Storage: Run solar PV-A/C during the day from 8:30AM to 5:30PM to lower room temperature from 79F to <69F avoiding afternoon peak of 89F and to maintain the cold room temperature for several hours after sunset.



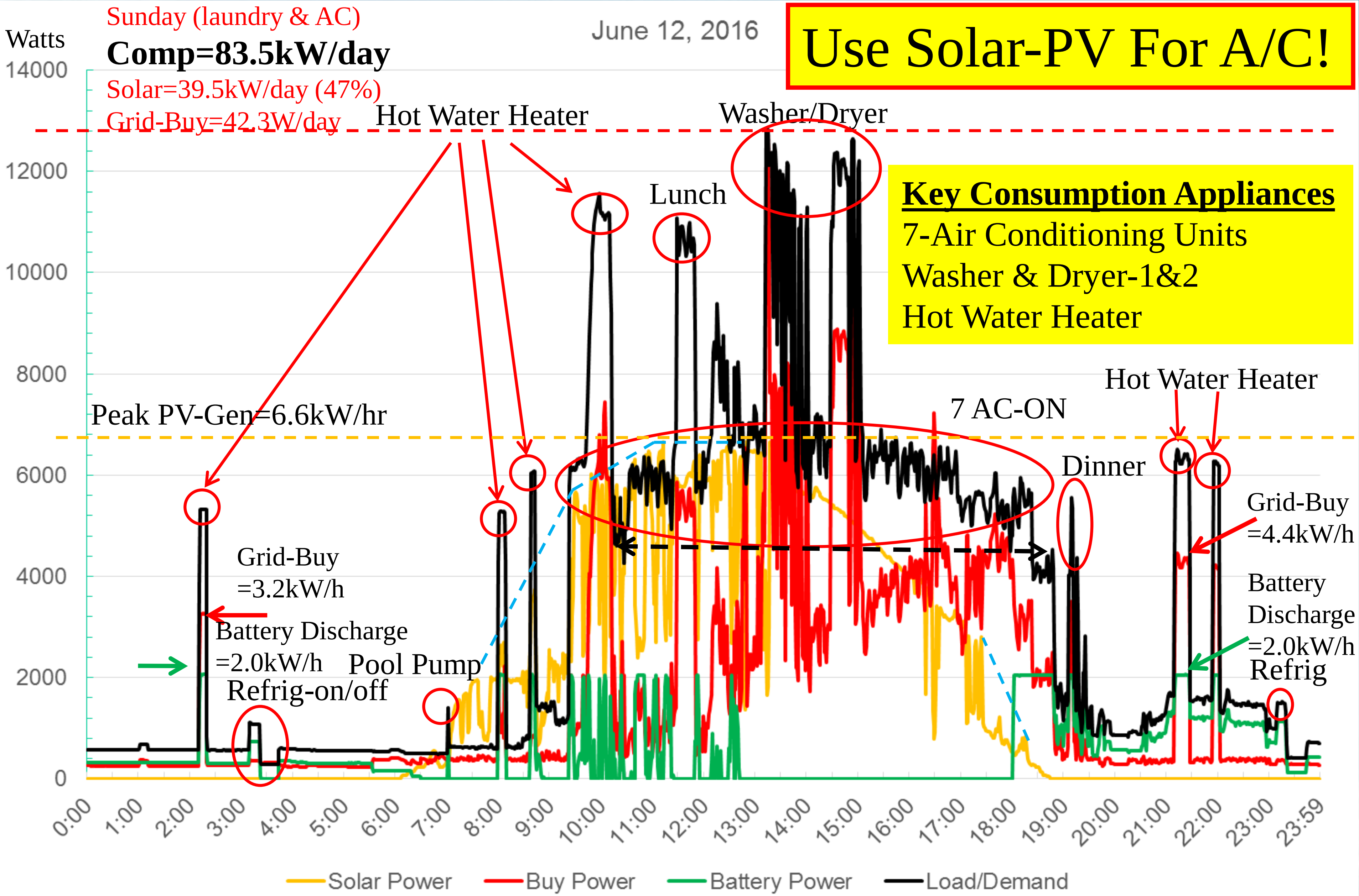
HECO Report (Ave ~500kWh/month)
#1: Electric Hot Water Heater (40%)
#2: Refrigerator/Freezer (15%)
#3: Air Conditioner-A/C(12%)
#4: Clothes Dryer (8%)
#4: Cooking (8%)
#4: Lighting (8%)
#7: Dishwasher (3%)
#8: Clothes Washer (1%)



Case Study (Ave ~1250kWh/month)→solar energy + Multi-Storage=100% Renewable Energy and Off-Grid operation
#1: A/C=18-45kWh/day→summer time use PV-A/C cold thermal storage (Apr-Sep)
#2: Electric Hot Water =16kWh/day→1st solar hot thermal storage→2nd solar-PV→3rd Battery Discharge→4th Grid-Buy
#3: Clothes Dryer=12.0kWh/day→ noon time PV and battery discharge (Grid-Buy <3kWh/day)
#4: Refrigerator/Freezer=7.2kWh/day→ timer so off 7.5 hours over night
#5: Plasma TV entertainment center=6.4kWh/day→ switched to LED-TV
#6: Pool pump=2.8kWh/day→daytime PV
#7: Cooking, Lights and Others=<3kWh/day→use PV or battery discharge

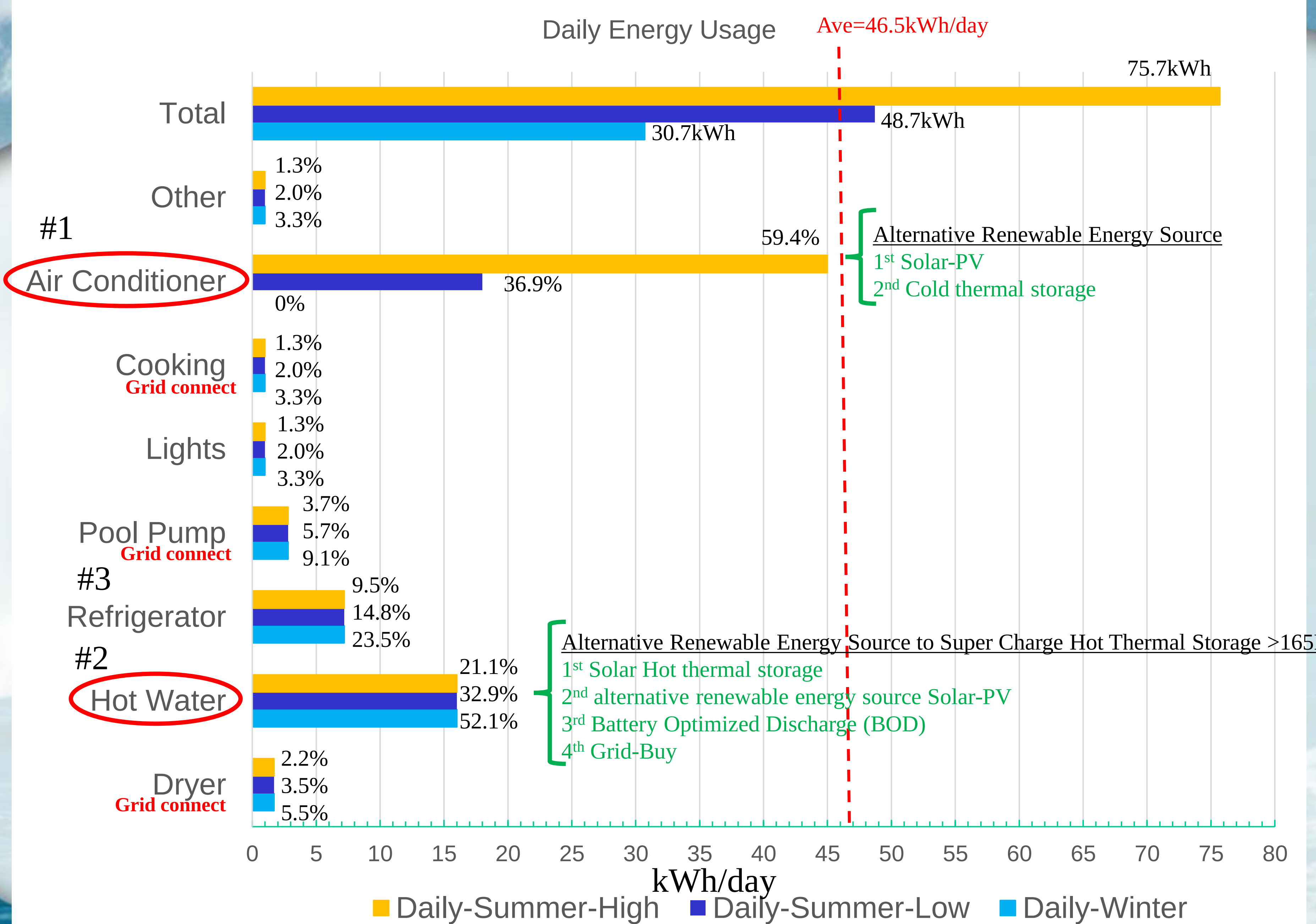

GENERATION / CONSUMPTION 2016. 6. 12
kWh
GENE.
CONS.
GENE. =CONS.
1 hour resolution real-time
2016/Jun/12 1:16 PM GRID TIED MODE
MAX POWER EXPORT
GENERATION
6.37 kW
BUY
7.22 kW
CHARGE
1.50 kW
CONSUMPTION
12.0 kW
Few second resolution real-time
Tabuchi Wall Remote Monitor
Key Consumption Appliances
7-Air Conditioning Units
Washer & Dryer-1&2
Hot Water Heater
Sunday 6/12/2016
Comp=83.5kW/day
Solar=39.5kW/day (47%)
Grid-Buy=42.3W/day
Dyer?
?
?
Hot Water Heater
Energy (kWh)
State of Charge (%)
Time of Day (Daily Cycle)
1 hour resolution real-time
Laplace Solar-link Web Monitor

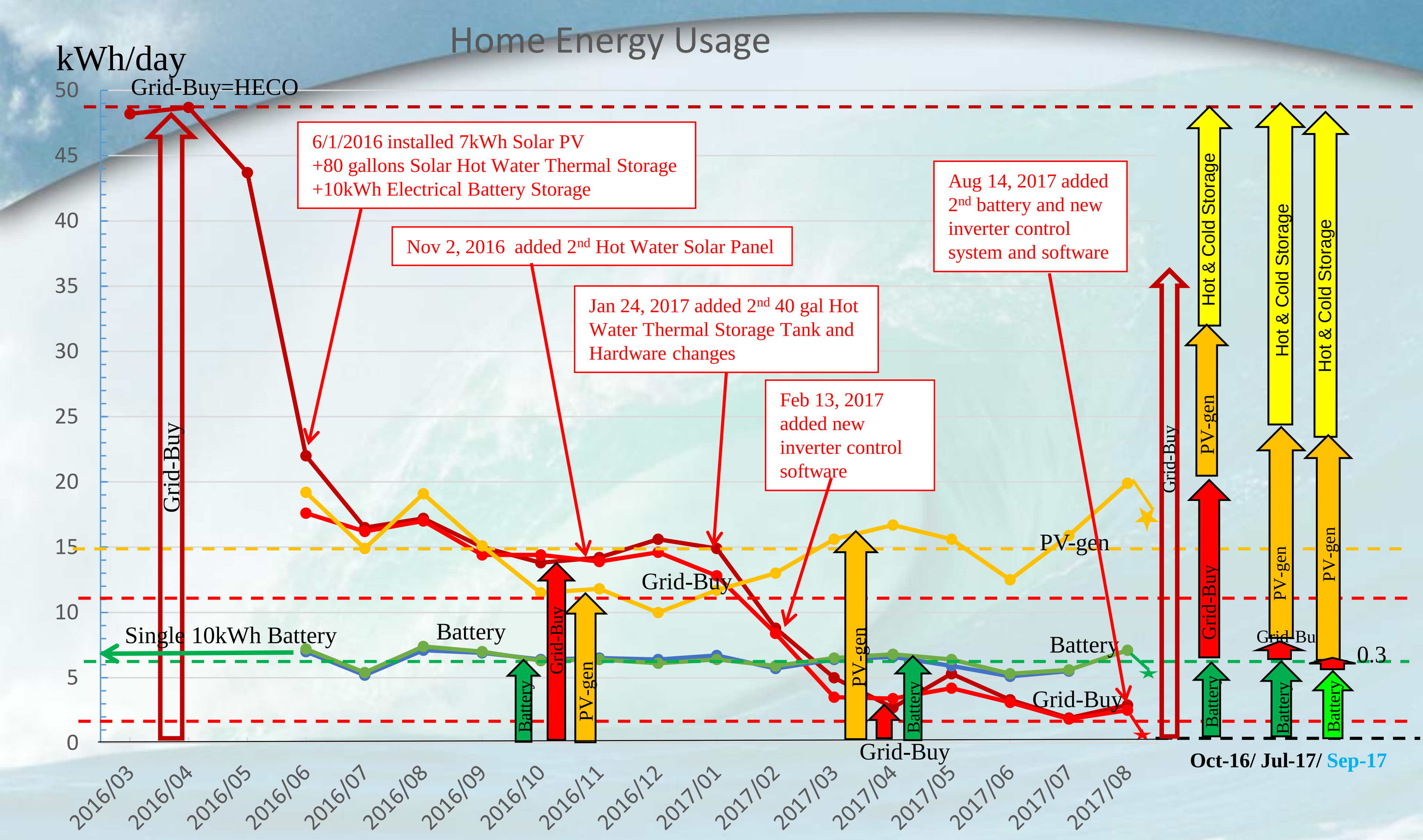
Use Solar-PV For A/C!



Laplace Solar-link Web Monitor

1 minute resolution off-line


Daily Energy Usage
Ave=46.5kWh/day
Total
75.7kWh
48.7kWh
30.7kWh
Other
1.3%
2.0%
3.3%
#1
Air Conditioner
59.4%
36.9%
0%
Alternative Renewable Energy Source
1st Solar-PV
2nd Cold thermal storage
Cooking
Grid connect
1.3%
2.0%
3.3%
Lights
1.3%
2.0%
3.3%
Pool Pump
Grid connect
3.7%
5.7%
9.1%
#3
Refrigerator
9.5%
14.8%
23.5%
#2
Hot Water
21.1%
32.9%
52.1%
Alternative Renewable Energy Source to Super Charge Hot Thermal Storage >165F
1st Solar Hot thermal storage
2nd alternative renewable energy source Solar-PV
3rd Battery Optimized Discharge (BOD)
4th Grid-Buy
Dryer
Grid connect
2.2%
3.5%
5.5%
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
kWh/day
Daily-Summer-High
Daily-Summer-Low
Daily-Winter

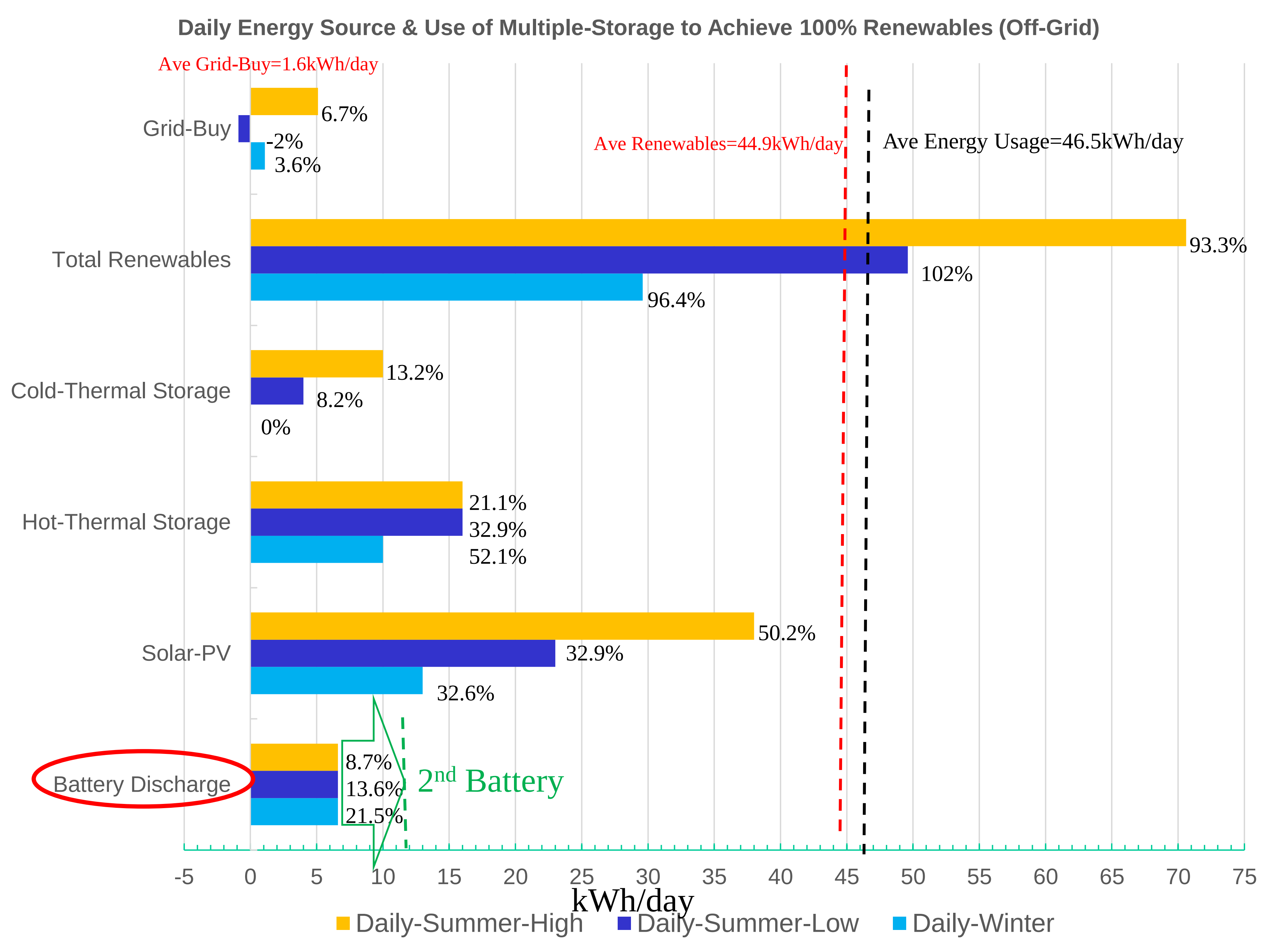


Before Solar: Grid-Buy=47kWh/day x 30¢/kWh = **$14.10/day x 30=$423/month→** **30¢/kWh**

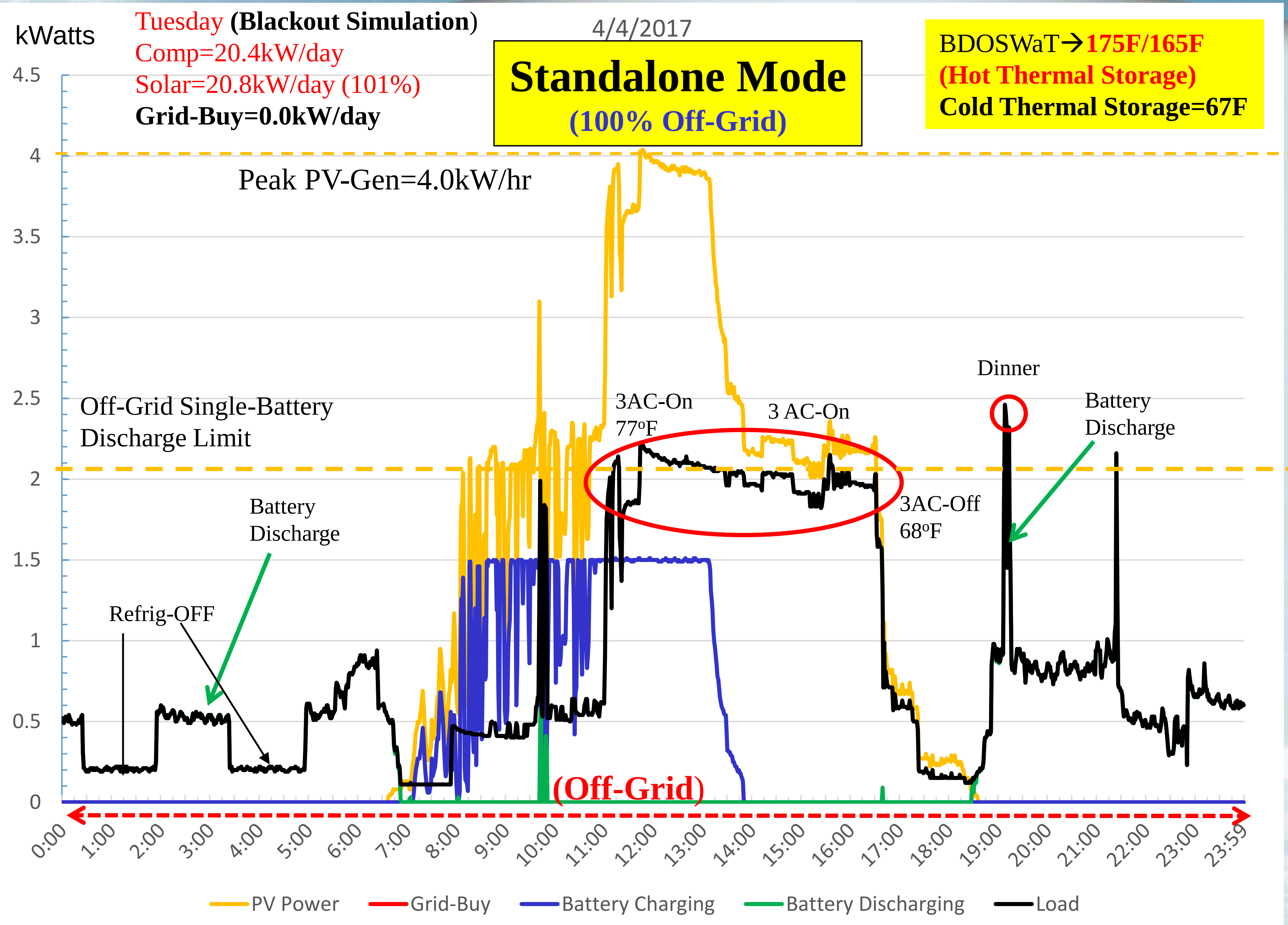
Phase 1 Solar: Grid-Buy=15kWh/dayx 30¢/kWh **=$4.50 ($135/month)**+ PV=13kWh/day x 3¢/kWh =$0.39 + battery=6.6kWh/day x9¢/kWh =$0.59 + Hot=16kWh/day x 4¢/kWh = $0.64 →**$6.12/dayx30=$183/month→** **12¢/kWh**

Phase 2 Solar (16GU-1): GB=1.8kWh/day x 30¢/kWh **=$0.54 ($16.20/month)**+ PV=20kWh/day x 3¢/kWh =$0.39+ battery=6.6kWh/day x9¢/kWh =$0.59 + Hot=16kWh/day x 4¢/kWh = $0.64 →**$2.16/dayx30=$64/month→4.9¢/kWh**

Phase 3 Solar (16GU-2): GB=0.4kWh/day x 30¢/kWh/15¢/kWh **=$0.12 ($3.60/month)/$0.06($1.80/month)** + PV=20kWh/day x 3¢/kWh =$0.39+ battery=8kWh/day x9¢/kWh =$0.72 + Hot=16kWh/day x 4¢/kWh = $0.64 →**$1.87/day/$1.81/day** x30=**$56/month/$54.3/month→** **4.2-3.7¢/kWh**

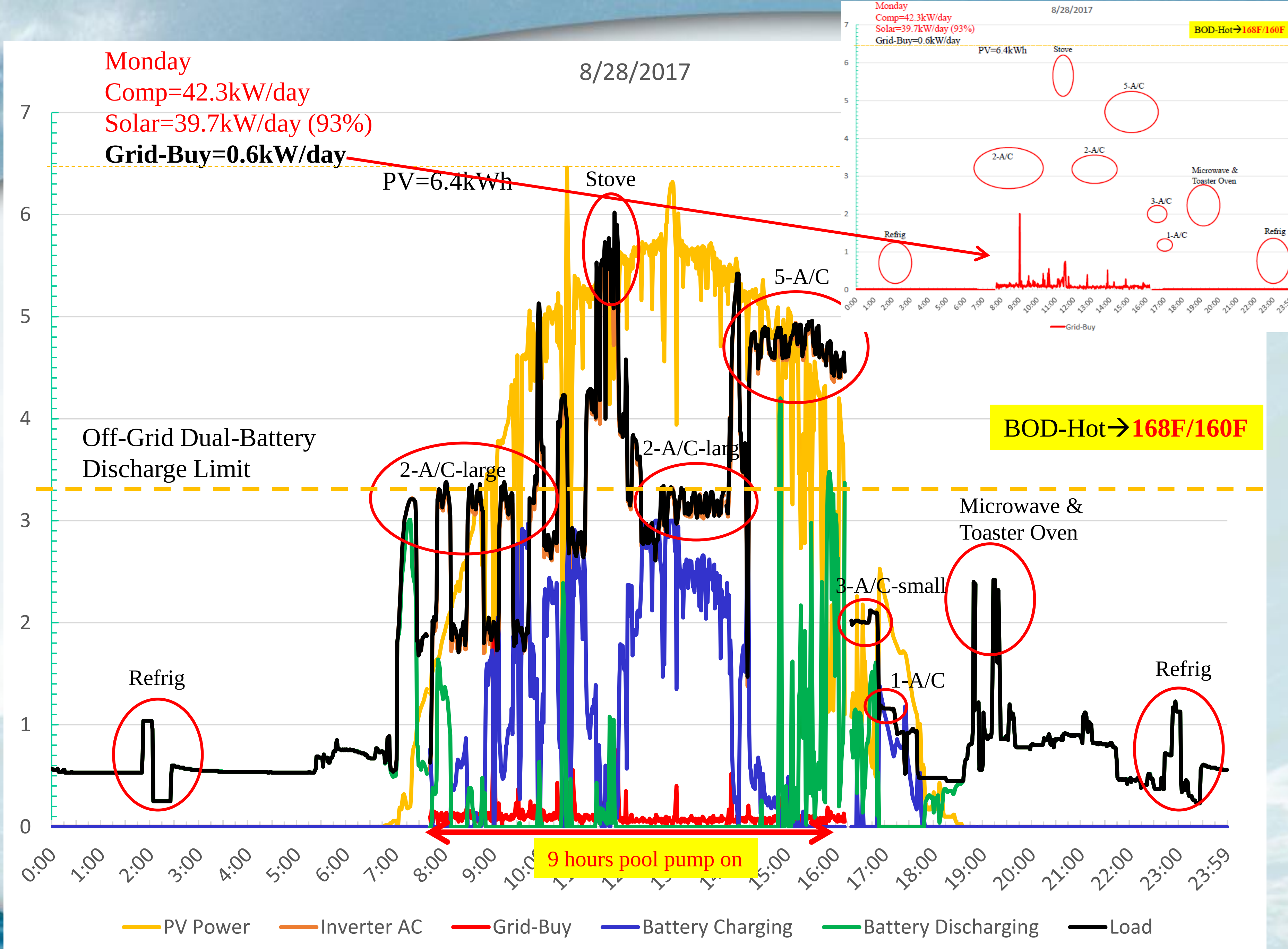


Daily Energy Source & Use of Multiple-Storage to Achieve 100% Renewables (Off-Grid)
Ave Grid-Buy=1.6kWh/day
Ave Renewables=44.9kWh/day
Ave Energy Usage=46.5kWh/day
Grid-Buy
6.7%
-2%
3.6%
Total Renewables
93.3%
102%
96.4%
Cold-Thermal Storage
13.2%
8.2%
0%
Hot-Thermal Storage
21.1%
32.9%
52.1%
Solar-PV
50.2%
32.9%
32.6%
Battery Discharge
8.7%
13.6%
21.5%
2nd Battery
-5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
kWh/day
Daily-Summer-High
Daily-Summer-Low
Daily-Winter



kWatts
Tuesday (Blackout Simulation)
Comp=20.4kW/day
Solar=20.8kW/day (101%)
Grid-Buy=0.0kW/day
4/4/2017
Standalone Mode
(100% Off-Grid)
BDOSWaT→175F/165F
(Hot Thermal Storage)
Cold Thermal Storage=67F
Peak PV-Gen=4.0kW/hr
Off-Grid Single-Battery
Discharge Limit
3AC-On
77°F
3 AC-On
3AC-Off
68°F
Dinner
Battery
Discharge
Battery
Discharge
Refrig-OFF
(Off-Grid)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
23:59
PV Power
Grid-Buy
Battery Charging
Battery Discharging
Load

Technology)


Monday
Comp=42.3kW/day
Solar=39.7kW/day (93%)
Grid-Buy=0.6kW/day
8/28/2017
PV=6.4kWh
Stove
5-A/C
2-A/C-large
2-A/C-larg
Off-Grid Dual-Battery
Discharge Limit
BOD-Hot→168F/160F
Microwave &
Toaster Oven
3-A/C-small
1-A/C
Refrig
Refrig
9 hours pool pump on
0
1
2
3
4
5
6
7
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
23:59
PV Power
Inverter AC
Grid-Buy
Battery Charging
Battery Discharging
Load
Monday
Comp=42.3kW/day
Solar=39.7kW/day (93%)
Grid-Buy=0.6kW/day
8/28/2017
BOD-Hot→168F/160F
PV=6.4kWh
Stove
5-A/C
2-A/C
2-A/C
Microwave &
Toaster Oven
3-A/C
1-A/C
Refrig
Refrig
Grid-Buy

Technology)

Ice Bear 20 for the Home

- Replaces home AC unit
- Hybrid air conditioning and energy storage solution
- **14.56 SEER Air Conditioning**
- **150 EER Ice Cooling**

Thermal Energy Storage
+ Air Conditioning

Storage capacity	20 T-hours / 19.2 kW-
Discharge duration	4 hours @ 5T
Charge Power / time @ 75°F	24 kW-hr / 7.5 hours
Peak capacity	4.80 kW
Modes of Operation	Air Conditioning, TES & Ice Cooling

Ice Bear 20
Price Comparison vs Li-Ion batteries

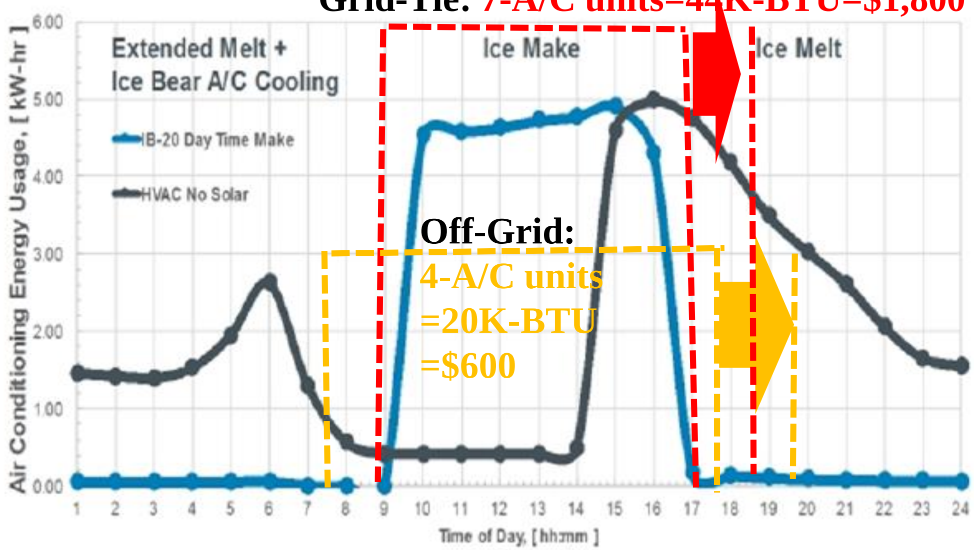
Ice Bear 20	Equivalent 5T AC	Ice Bear 20 TES	Equivalent Battery*
Equipment Cost: $12,900	Equipment Cost: $6,500	Ice Bear 20 Installed Cost: $14,900	Equipment Cost: $15,500
Installation Cost: $2,000	Installation Cost: $2,000	Less 5T AC Installed Cost of $8,500	Installation Cost: $1,500
Total Cost: $14,900	Total Cost: $8,500	Net Cost of Ice Bear TES: $6,400	Total Cost: $17,000
		$1,333/kW (4.8kW)	$2,300/kW (7 kW)
		$333/kW-h (19.2 kW-h)	$1,063/kW-h (16 kW-h)

*Li-ion batteries cannot be operated to store solar over-gen like Ice Bear TES system w/o significant degradation and shortening of life: practical as backup only

Uses Solar Overgen/Flattens Peak

24K-BTU Hybrid PV-A/C=$12K→$5.3K

Grid-Tie: 7-A/C units=44K-BTU=$1,800



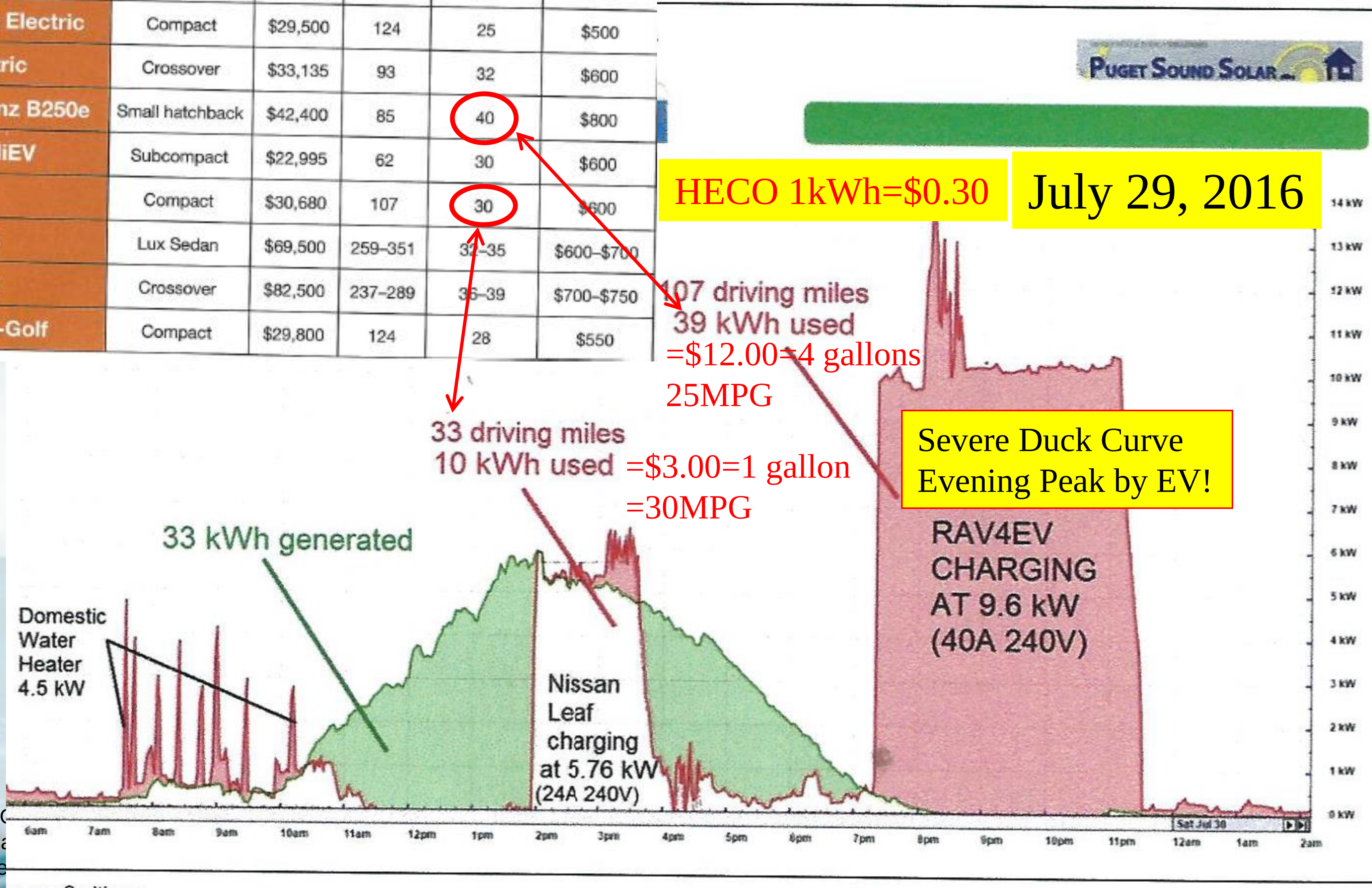
IceEnergy

We Can Store "Cool" as Ice
(in fact, most of us already do)

EV: Electric Vehicles Power Requirements!

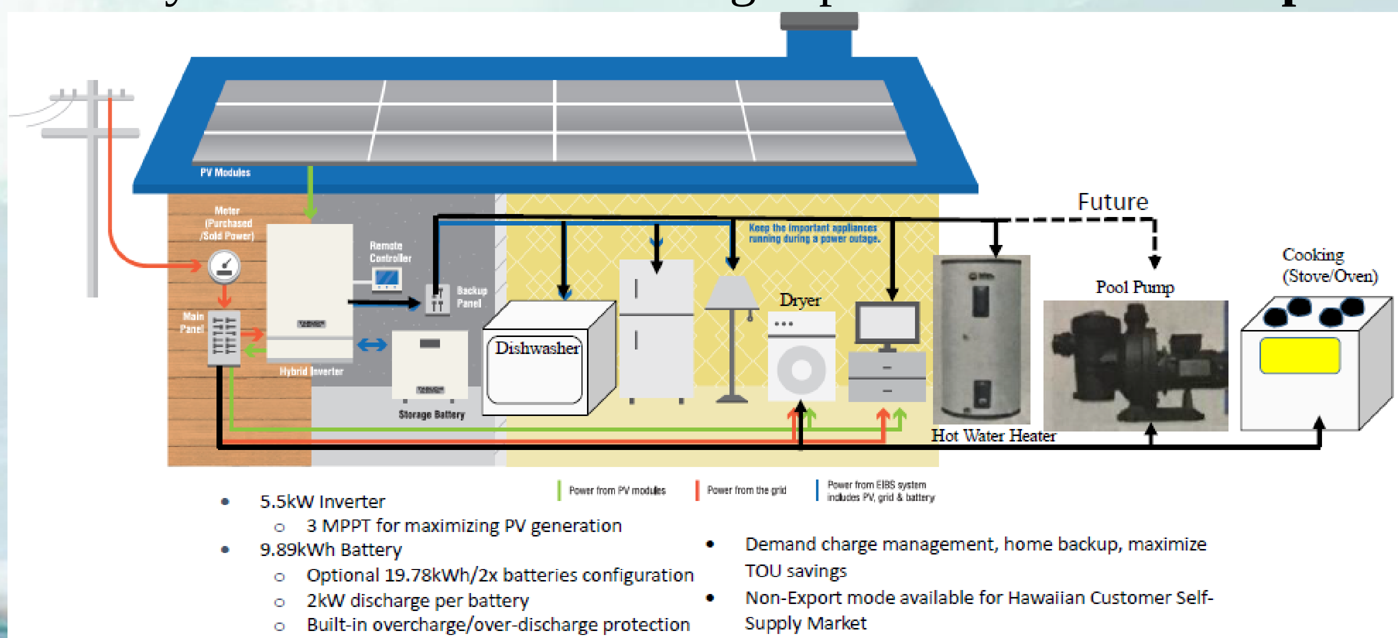
When is EV Too Costly?

Vehicle	Size / Type	Starting Price	Range (Miles)	Energy Used Per 100 mi. (kWh)	Annual Fuel Cost*
BMW i3 BEV	Subcompact	$42,400	114	27-29	$550
Chevrolet Bolt EV	Compact	$37,495	238	28	$550
Fiat 500e	Compact	$32,600	84	30	$600
Ford Focus Electric	Compact	$29,200	115	31	$600
Hyundai Ioniq Electric	Compact	$29,500	124	25	$500
Kia Soul Electric	Crossover	$33,135	93	32	$600
Mercedes-Benz B250e	Small hatchback	$42,400	85	40	$800
Mitsubishi i-MiEV	Subcompact	$22,995	62	30	$600
Nissan Leaf	Compact	$30,680	107	30	$600
Tesla Model S	Lux Sedan	$69,500	259-351	32-35	$600-$700
Tesla Model X	Crossover	$82,500	237-289	36-39	$700-$750
Volkswagen e-Golf	Compact	$29,800	124	28	$550



Summary: 24/30 Days a Month Off-Grid!

-Achieved 100% Renewable Energy for Residential Hawaii **24 days a month** → solar-PV + solar thermal + Hot thermal storage + electrical **dual battery storage** + Cold thermal storage + optimized key household appliance TOU (**single battery=12+days**)
-Eliminated Duck Curve and all AM/PM Grid-Buy energy spikes/peaks.
-HEMS improvements including inverter control system was critical: Inverter software communication between Grid-Buy/solar-PV gen/Battery charge-discharge/House demand efficiently to reduce Grid-Buy by 8kWh/day and maximize PV generation and battery charging for 2nd AM discharge. Inverter improvements →more Household Appliances for Standalone/Off-Grid mode.
-~30% solar-PV energy loss/dumping but still economically reduced **ROI to 2.7 years** by reducing Grid-Buy to Zero with Multi-Storage options for **Off-Grid operation**.



Contents of the Corporate Program Package

- Free desktop solar qualifying and energy consultation
- Complete Package
  - 6.5kW Solar Panel
  - 5.5kW Inverter with 10kWh Battery Storage
  - Laplace Monitoring
  - Installation cost
- ITC Tax Benefit (30%)
- SGIP Submission
- Total estimated at $26k
- We offer optional financing (10 – 20 years)

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My 7kWh Solar-PV + Tabuchi Electric 10kWh Battery & Inverter System Package from Poncho's Solar =$29,500