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
Jay Moore & Corpuz Poncho, Poncho’s Solar, 2669 Kilihau St, Honolulu, HI 96819
Takahiro Tanaka & Harumi McClure, Tabuchi Electric, 5225 Hellyer Ave, suite 150, San Jose, CA 95138
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

Max Solar Energy Mode

Rainy Day Mode

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
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!

Refrigerator/Freezer

Battery Fully Discharged/Drained by 7PM!
Introduction: 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!

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!

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

San Diego Gas & Electric

Current TOU solar production:
46% peak
54% semi-peak

Proposed TOU solar production:
23% peak
77% off-peak

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!

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

Effective Dec 1, 2017
Hawaiian Electric TOU Rates

Sample Interim Time-of-Use Rates*

26.2¢/kWh – Feb 2017

Price (¢ per kWh)

45
40
35
30
25
20
15
10
5

Off-Peak

26.0¢

Mid-Day

17.3¢

On-Peak

39.6¢

MIDNIGHT

NOON

EVENING

Hours

*Illustration reflects effective February 2017 interim Time-of-Use rates, which include applicable surcharges. Neighbor Island rates may vary. To understand how charging an electric vehicle at home may affect a customer’s total energy costs, visit www.hawaiianelectric.com/wattplanforEV.

J.O.B. Technologies (Strategic Marketing, Sales & Technology)
The “Duck Curve”:
- Minimum net loads move to the afternoon
- Three-hour net load ramps increase

CAISO Updated Duck Curve and Solar-PV Curtailment reported at Solar Power International Sept 11, 2017
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
I Tried It for Hawaii Post-NEM: Sounds Good But Wrong, Results in ROI of 16 Years!

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.
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 of maturity. The diagram shows the product price (US$ 2015 per kWh) on the y-axis and the cumulative installed nominal capacity (GWh) on the x-axis. Different technologies are represented by various symbols and colors, indicating their status as Emerging, Maturing, or Mature. The sources for the data are cited at the bottom of the slide.

Poor economics \textbf{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!

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= Home Storage Battery

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

Installed June 1, 2016 by Poncho’s Solar:
27 Hyundai-260W Panels with Tabuchi Electric 5.5kW Inverter and Panasonic 10kWh Li-ion Battery Storage

Nov 3rd added 2nd Solar Hot Water panel → 157°F
Jan 18th added 40 gallon water storage tank → 120 gallon total
Jan 25th BOD-HOT thermal storage → reduce Grid-Buy by 3.0kWh/day
Feb 16th new Tabuchi software → reduce Grid-Buy by 5kWh/day

Aug 14th 2nd battery and new Tabuchi inverter control system and software → 100% Renewable → Off-Grid operation 6 days a week
Why Residential Rooftop Solar PV?
Hawaii High Cost of Electricity 24-37¢/kWh

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)
Sep 2017=$17.00 TOU service fee!
Retail electricity prices are much higher than wholesale prices

1 Euro=$1.20

15.6¢/kWh

33.8¢/kWh

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%

EU-PVSEC Sept 2018
HECO $/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
Actual PV Results

<table>
<thead>
<tr>
<th>Month</th>
<th>Solar Radiation (kWh/m²/day)</th>
<th>AC Energy (kWh)</th>
<th>Energy Value ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>4.52</td>
<td>584</td>
<td>3317</td>
</tr>
<tr>
<td></td>
<td></td>
<td>383kWh (65.5%)</td>
<td></td>
</tr>
<tr>
<td>February</td>
<td>5.20</td>
<td>609</td>
<td>374kWh (61.4%)</td>
</tr>
<tr>
<td>March</td>
<td>5.74</td>
<td>738</td>
<td>489kWh (66.2%)</td>
</tr>
<tr>
<td>April</td>
<td>5.89</td>
<td>735</td>
<td>512kWh (69.7%)</td>
</tr>
<tr>
<td>May</td>
<td>6.32</td>
<td>811</td>
<td>499kWh (61.5%)</td>
</tr>
<tr>
<td>June</td>
<td>6.36</td>
<td>786</td>
<td>560kWh (71.2%)</td>
</tr>
<tr>
<td>July</td>
<td>6.41</td>
<td>818</td>
<td>599kWh (73.0%)</td>
</tr>
<tr>
<td>August</td>
<td>6.46</td>
<td>820</td>
<td>599kWh (73.0%)</td>
</tr>
<tr>
<td>September</td>
<td>6.32</td>
<td>777</td>
<td>452kWh (58.2%)</td>
</tr>
<tr>
<td>October</td>
<td>5.41</td>
<td>697</td>
<td>360kWh (51.6%)</td>
</tr>
<tr>
<td>November</td>
<td>4.71</td>
<td>589</td>
<td>368kWh (62.5%)</td>
</tr>
<tr>
<td>December</td>
<td>4.40</td>
<td>568</td>
<td>309kWh (54.4%)</td>
</tr>
<tr>
<td>Annual</td>
<td>5.65</td>
<td>8,532</td>
<td>2,816</td>
</tr>
</tbody>
</table>

~35% PV Loss/Dumping

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

- January: $4,212 (~95%) ROI=7yrs
- February: $2,256 (~50%) ROI=16yrs
- March: $2,880 (~70%) ROI=9.8yrs

www.pvwatts.nrel.gov Simulation Results for Oahu
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 DUMPING! Lowest cost ($/W install) is more important than highest cell/module efficiency!
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

- 2017 expectation: ≈ 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
Tracker Gives Best Solar-PV Yield ~15% But Costly!
Bifacial Modules
~20% Higher Gain!

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

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

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

- **Market share 2017 [%]**: p-standard 80, p-PERC 13, n-PERT/HJT 5, nIBC 2
- **Efficiency 2017 [%]**: p-standard 20+, p-PERC 21+, n-PERT/HJT 21+, nIBC 22+
- **Bifaciality [%]**: p-standard 0, p-PERC 70+, n-PERT/HJT 90+, nIBC 80+
- **Market share 2022 [%]**: p-standard 40, p-PERC 30, n-PERT/HJT 20, nIBC 24+
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!

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!

10.2kWh/day

Energy Used: 21.05 kWh

Hot Water  Dryer 1&2  Hot Water
Strategy 4: Grid-Interactive Water Heating

- Acts as a low-cost “battery”
- Stores a full day’s supply

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

45 Million Electric Water Heaters

Census Housing Survey Table 2.5 (2010)
Figure 1: Solar Module Average Costs, Prices and Price/Cost Delta, 2006-2016
February 8, 2017
By Paula Mints
Founder/Chief Market Research Analyst

Bust was 2012
today PV companies have no profits!
Profits are with the PV installation companies as install costs have increased since 2011.
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

System Pricing from Select States
2.5 kW–10 kW

Hawaii + Battery Storage
Cost of System (COS) = (+$0.71 → $2.80/W)

Hawaii Solar-PV
Cost of System (COS) = ($3.20 → $4.60/W)

COS (cost of system)
L-COE (Lifetime-cost of energy)
Solar-PV (7kWh)
COS=$22,400=$3.20/W → Tax Cr=$1.28/W
L-COE=8¢/kWh/20yrs → TaxCr=3.2¢/kWh

Battery (10kWh)
COS=$7,100=71¢/W → TaxCr=28.4¢/W
L-COE=23¢/kWh/10yrs → TaxCr=9.2¢/kWh

Solar Thermal (16kWh)
COS=$6,000=37.5¢/W → TaxCr=15¢/W
L-COE=10.3¢/kWh/10yrs → TaxCr=4.1¢/W

24%
0.61x(-39%)
0.22x(-88%)
8.25%
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!
• **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 with 10 Year Battery Life

- $29.5K-50%
- $29.5K-70%
- $29.5K-94.5%
- $13.5K-50%
- $13.5K-70%
- $13.5K-94.5%

Full Tax Credits = $13.5K
Full Price = $29.5K

Replace battery year 11
+$7,100
+$37,530

Replace battery year 21
+$7,100
+$99,800

ROI Analysis For System Costs = $29,500
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**: 2\textsuperscript{nd}/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: 1\textsuperscript{st} primary source is solar thermal, 2\textsuperscript{nd} alternative source is solar-PV, 3\textsuperscript{rd} alternative source is battery optimized discharge (BOD) and 4\textsuperscript{th} 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

Where does it all go?
Here’s how a typical O‘ahu home uses energy
J.O.B. Technologies (Strategic Marketing, Sales & Technology)

Tabuchi Wall Remote Monitor

Laplace Solar-link Web 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

1 hour resolution real-time
Few second resolution real-time
Sunday (laundry & AC)

**Comp=83.5kW/day**

Solar=39.5kW/day (47%)

Grid-Buy=42.3W/day

---

**Use Solar-PV For A/C!**

**Key Consumption Appliances**
- 7-Air Conditioning Units
- Washer & Dryer-1&2
- Hot Water Heater

**Peak PV-Gen=6.6kW/hr**

**Grid-Buy**
- =3.2kW/h

**Battery Discharge**
- =2.0kW/h
- Pool Pump
- Refrig-on/off

**Lunch**

**Dinner**

**Laplace Solar-link Web Monitor**
- 1 minute resolution off-line
Home Energy Usage

6/1/2016 installed 7kWh Solar PV
+80 gallons Solar Hot Water Thermal Storage
+10kWh Electrical Battery Storage

Nov 2, 2016 added 2nd Hot Water Solar Panel

Aug 14, 2017 added 2nd battery and new inverter control system and software

Jan 24, 2017 added 2nd 40 gal Hot Water Solar Panel and Hardware changes

Feb 13, 2017 added new inverter control software

Before Solar: Grid-Buy=47kWh/day x 30¢/kWh = $14.10/day x 30=$423/month → 30¢/kWh
Phase 1 Solar: Grid-Buy=15kWh/day x 30¢/kWh = $4.50 (115/month) + PV=13kWh/day x 3¢/kWh = $0.39 + battery=6.6kWh/day x 9¢/kWh = $0.59 + Hot=16kWh/day x 4¢/kWh = $0.64 → $6.12/day x 30=$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 x 9¢/kWh = $0.59 + Hot=16kWh/day x 4¢/kWh = $0.64 → $2.16/day x 30 = $64/month → 4.9¢/kWh

Phase 3 Solar (16GU-2): GB=0.4kWh/day x 30¢/kWh/15¢/kWh = $0.12 (3.60/month) + PV=20kWh/day x 3¢/kWh = $0.39 + battery=8kWh/day x 9¢/kWh = $0.72 + Hot=16kWh/day x 4¢/kWh = $0.64 → $1.87/day x 30 = $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
- Grid-Buy: 6.7%, 3%, 3.6%

Total Renewables
- Total Renewables: 93.3%
- Ave Renewables=44.9kWh/day

Cold-Thermal Storage
- Ave Energy Usage=46.5kWh/day
- Cold-Thermal Storage: 8.2%, 13.2%

Hot-Thermal Storage
- Ave Renewables=44.9kWh/day
- Hot-Thermal Storage: 21.1%, 52.1%, 32.9%

Solar-PV
- Ave Grid-Buy=1.6kWh/day
- Solar-PV: 32.6%, 32.9%, 50.2%

Battery Discharge
- Ave Grid-Buy=1.6kWh/day
- Battery Discharge: 8.7%, 13.6%, 21.5%

2nd Battery
Tuesday (Blackout Simulation)
Comp=20.4kW/day
Solar=20.8kW/day (101%)
Grid-Buy=0.0kW/day

Peak PV-Gen=4.0kW/hr

4/4/2017

Standalone Mode
(100% Off-Grid)

BDOSWaT→175F/165F
(Hot Thermal Storage)
Cold Thermal Storage=67F

Off-Grid Single-Battery Discharge Limit

Battery Discharge

Refrig-OFF

3AC-Off 68°F

Dinner

Battery Discharge

3AC-Off 77°F

3 AC-On

3AC-On

(Off-Grid)
Monday
Comp=42.3kW/day
Solar=39.7kW/day (93%)
Grid-Buy=0.6kW/day

PV=6.4kWh
Stove

Off-Grid Dual-Battery Discharge Limit
2-A/C-large
2-A/C-large
BOD-Hot→168F/160F

Microwave & Toaster Oven
3-A/C-small
1-A/C
Refrig

9 hours pool pump on

Load
PV Power   Inverter AC    Grid-Buy    Battery Charging    Battery Discharging
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-hr
- **Discharge duration**: 4 hours @ ST
- **Charge Power / time @ 75°F**: 24 kW-hr / 7.5 hours
- **Peak capacity**: 4.80 kW
- **Modes of Operation**: Air Conditioning, TES & Ice Cooling

---

**Grid-Tie:**

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

**Off-Grid:**

- 4 A/C units = 20K-BTU = $600

---

**Ice Bear 20 Price Comparison vs Li-Ion batteries**

<table>
<thead>
<tr>
<th>Ice Bear 20</th>
<th>Equivalent ST AC</th>
<th>Ice Bear 20 TES</th>
<th>Equivalent Battery*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment Cost: $12,900</td>
<td>Equipment Cost: $6,500</td>
<td>Equipment Cost: $14,900</td>
<td>Equipment Cost: $15,000</td>
</tr>
<tr>
<td>Installation Cost: $2,000</td>
<td>Installation Cost: $2,000</td>
<td>Less ST AC Installed Cost of $8,500</td>
<td>Installation Cost: $1,500</td>
</tr>
<tr>
<td><strong>Total Cost:</strong> $14,900</td>
<td><strong>Total Cost:</strong> $8,500</td>
<td>Net Cost of Ice Bear TES: $6,400</td>
<td>Total Cost: $17,000</td>
</tr>
<tr>
<td>$333/kW-h (19.2 kW-h)</td>
<td>$333/kW-h (19.2 kW-h)</td>
<td>$1,333/kW-h (4.8 kW)</td>
<td>$1,063/kW-h (16 kW-h)</td>
</tr>
</tbody>
</table>

*Li-battery cannot be operated to store solar energy like Ice Bear TES system w/ 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

Off-Grid:

4-A/C units = 20K-BTU = $600

---

We Can Store “Cool” as Ice (in fact, most of us already do)
EV: Electric Vehicles
Power Requirements!
When is EV Too Costly?

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

HECO 1kWh=$0.30
July 29, 2016

107 driving miles
39 kWh used
=$12.00=4 gallons
25MPG

33 driving miles
10 kWh used
=$3.00=1 gallon
=30MPG

Severe Duck Curve
Evening Peak by EV!

RAV4EV CHARGING
AT 9.6 kW
(40A 240V)
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)

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