Cost estimates of PV-, geo- LNG- and oil-based electricity in Hawaii County for 2014-2024

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ABSTRACT: This is an analysis of whether distributed, solar, on-grid PV (with suitable storage or battery backup, PVBB) can be a prime (but not necessarily lone) renewable energy solution, and become the energy back-bone for Hawaii and maybe other regions. Grid-tied PV is environmentally and socially accepted. If for discussion purposes, PVBBs were to approach a penetration near 100%, can we live with its economics, output variabilities, reliability and sustainability?

On the economics, we show that presently in Hawaii, private PVBBs compete well with hypothetical utility-scale PVBBs (<20 vs. 43 ¢/kWh, i.e. a bit higher than oil-based electricity of 42 ¢/kWh) and by 2024 may match "private" geothermal electricity costs (~14 ¢/kWh), which in turn will continue to beat the retail cost of utility-scale geothermal (~46 ¢/kWh). If oil-based electricity were to continue its rise at 4.5%/year, it would reach 42x1.045^10 = 65 ¢/kWh in 2024. But despite the rush away from oil-based energy to PVBBs, grid and utility jobs may be retained by smartly transitioning our utilities from the "central" paradigm to investing in and partnering with distributed PVBB providers. Introducing LNG is unlikely to stop that "rush," based on an effective cost 12 $/millionBtu or 61 $/barrel equivalent and the resulting retail price of 35 ¢/kWh in 2014 and 54 ¢/kWh in 2024. Mean-while, PVBB-utility solar will have come down to 41 ¢/kWh and private PVBB to 12 ¢/kWh.

Regarding variability of PV, others have shown that PVBBs can eliminate output variations due to passing clouds, and follow variable load demands. Solutions to the day-to-day +/-55% peak-to-peak PVBB output variabilities around their average (see Fig.4: The 2-kW PV generated an average output of 9 kWh/day) may be achieved by combining PV oversizing with demand-side management. A 40% oversized PV (with regular sized battery) would raise electricity cost by only 5 ¢/kWh.

The reliability of private PVBB equipment and controls does not need to approach the reliability standards of utility scale equipment to prevent service interruptions or blackouts. The sheer number of distributed generators more than make up for that, so that the probability of even a small number of unplanned, simultaneous blackouts of 100-1000 customers is statistically many orders of magnitude less likely than the unplanned outage of one utility serving over 10,000 customers.

INTRODUCTION: Much is being written these days about the growth of PV. This includes delays with interconnecting new PV systems; reduced utility sales; whether the existing NEM-PV accounts pay their fair share for their use of the grid to "store" day-time surplus PV energy; and for causing rate increases to non-PV users by reducing the capacity factor of utility generation and transmission equipment. Let us go beyond hand waving about PVBB technology qualifications and get down to some numerical estimates of the economics, since we can easily agree that PVs excel in all other criteria. We can start by listing some basic assumptions, published costs, and cost trends:

1. Ignore gov. subsidies or cost of capital: they tend to at least partly compensate each other.
2. Trends: Inflation for labor and conventional hardware, including geothermal: 2%/year;
3. Rise of fuel-oil cost (2.5x in 10 years – NY MEX, or): 9.6%/year (~7.6%/year in constant dollars)
4. Rise in HELCO's retail rates historical trend: 4.5%/year;
5. Cost of oil-based electricity: 22 ¢/kWh, resulting in
6. Retail price of oil electricity of: 42 ¢/kWh in April 2014. This means that 20 ¢/kWh are needed for overhead, admin., customer service, profit, T&D, etc – and is largely independent of the type of energy source
7. Retail price of utility PV electricity of: 16 ¢/kWh-cost + 20¢/kWh-overhead, etc = 36 ¢/kWh, without battery storage, but add 4 ¢/kWh for MMC (Minimum Monthly Charge).
8. Cost of installed utility storage: 1 to 2 ¢/kWh (flywheel by BeaconPower). But AES Li-battery, at 1000 $/kW & 250 $/kWh[1], or more costly "long-duration" batteries by A123 with power electro-nics may cost ~1500 $/kWh. Requiring ~2 kWh storage (as per Fig.1) for each kWp PV, may therefore add 2*1500/(1*8760*30years*0.17)/100 = 6.7 ¢/kWh to the PV electricity cost. The main point is that they are "shovel ready" and can provide up several hours of full power.
9. Cost of home battery storage: Storing at least 50% of daily PV output (see Fig.1), or 8 kWh for an average "500-kWh/month" home with a 4-kWp PV, would cost 8*$1500 (for long-duration Li

batteries, power electronics, installation, etc), i.e. 3 $ per PV-watt(peak). The 5 $/Wp PV then becomes 5+3 $/Wp PVBB for Hawaii with a capacity factor of 0.17 and add ~7 ¢/kWh to the PV electricity cost. In regions with half the capacity factor but otherwise same energy needs, it would be 10+1.5 $/Wp to make and store 8 kWh each day. Both lead-acid and lithium batteries can be and should be recycled after the end of their service life.

10. Retail price of utility PVBB electricity of: 16[2]+7 ¢/kWh-cost + 20 ¢/kWh-overhead, etc = 43 ¢/kWh
11. Retail price of utility geoth. electricity of: 18[3] ¢/kWh-cost + 20¢/kWh-overhead, etc = 38 ¢/kWh, but would be 11.4 + 20 = 31 ¢/kWh for new geothermal[3]
12. Private grid-tied PVBB electricity cost: 18 ¢/kWh (see Fig. 1) + 4 ¢/kWh for MMC (Minimum Monthly Charge for grid-tied PV owners) = 22 ¢/kWh
13. Private off-grid PVBB (PV 40% oversized; no generator): 18*(5*1.4+3)/8 = 22.5 ¢/kWh (no MMC)
14. Drop in PV costs (NREL Solar Tech; and maybe also in battery & power electronics: 4.6x in 20 years, or): 8%/year
15. If LNG is imported, and port, storage and regasification facilities are built, its effective cost may be 11-17 $/MBtu[9]; (here: M=Mega or million). For this discussion I chose a conservative 12 $/MBtu or 12/(1e6/115000/44)= 61 $/barrel oil equivalent, or at least 70% of the 2.2 $/gal oil price, which is now leading to 22 ¢/kWh (cost) and 42 ¢/kWh (retail price). When converted to electricity we might get 22*0.7+20 ~ 35 ¢/kWh (retail). After 10 more years it would have escalated to 35*1.045^10= 54 ¢/kWh. Meanwhile, utility solar PVBB may have come down to (16+7)/1.04^10+20*1.02^10=40 ¢/kWh and private on-grid PVBB to 18/1.04^10 = 12 ¢/kWh.
16. Hydrogen (H2) is not being considered here as a viable energy storage alternative to batteries. This is because H2-storage cannot compete with batteries, which have a ~2x higher “round-trip” (i.e. charge and discharge) efficiency, lower capital cost (if on the H2 side, the electrolyzer plant, fuel cell, compressors, storage tank and safety requirement costs are included) and over 3x longer service life. In addition, the extreme flammability of H2 (7x higher flame speed, 15x lower ignition energy and 4x higher diffusivity and 250°C (450°F) higher flame temperature than LNG), would make it very costly to provide for the proper safety of citizens close to any equipment using H2, especially close to facilities such as those producing H2, refueling FuelCellVehicles, and/or storing H2.
17. Consider installation, O&M and capital cost trends separately

DISCUSSION: Based on the above, including the present values of the MMC where appropriate (the added 4 ¢/kWh represent the equivalent of the 20.50 $/month MMC for average “500-kWh/month” PV or PVBB users), the table below (plotted in Fig.3) shows ¢/kWh estimates for 2014 and 2024:

	2014	2024
Private cost of PV-electricity (4%/year drop) in ¢/kWh:	11+4	7.4+4
Private cost of on-grid PVBB-el. (4%/year drop) in ¢/kWh:	18+4	12+4
Private cost of off-grid PVBB-el. (4%/year drop) in ¢/kWh:	23	15
Hypoth. utility cost of PVBB (4%/year drop) in ¢/kWh:	43	40
(Private/PGV cost of geo-electricity (2%/year rise*) in ¢/kWh:	11+4	14+4)
Utility cost of geo-electricity (2%/year rise*) in ¢/kWh:	38	46
Utility cost of oil-electricity (4.5%/year rise) in ¢/kWh:	42	65
Utility cost of LNG-electricity, starting at 12 $/millionBtu:	35	54

* Geothermal electricity rate is assumed to rise along average inflation rate for labor and fully developed drilling and rotary generation equipment[3].

We can accept, as Germany and Japan have via subsidies, that responsible “PV-citizenship” requires the addition of storage able to store 50-60% of an AVERAGE PV’s daily output, as illustrated in Fig.2, in which the day’s load profile of a peak-load day of Hawaii County[8] is compared to the output of a PV profile of equal energy output. Figure 2 can be scaled down to any individual business or home or sub-grid. Preferably, the associated storage would be on-site, to minimize transmission losses, but may be financed by a home, business or a utility. The above table tells us that:

1. With the overall projected drop in PV [and PVBB] prices of 4%/year (=combination of 8%/y PV drop and no drop nor rise in the labor cost of the installation), the 2014 ~$20,000 [$32,000] PV capital costs for an average "500-kWh/month" home would only drop by 20,000*0.04 = $800 in each future year ($1280/year), while the utility bill continues at > $2520/year. Ergo: Waiting is more costly every year than installing PV (or better: PVBB) and enjoying a low 30-year-levelized cost of 0.18*500*12+20.50*12 = $1326 per year.
2. If utility overhead, etc. costs stay at 20 ¢/kWh, as they are now for oil-based electricity retail price, utility PPAs at 16 ¢/kWh would still result in retail prices of 16+20 ¢/kWh, just as for oil with 22+20 = 42 ¢/kWh. Ergo: Hawaiian utilities cannot presently compete with private PV or PVBB electricity costs, despite their economy of scale. This may be caused by extra costs of land (~1.6 ¢/kWh, rather than free roof-tops), grid (1.2 ¢/kWh), admin. & cust.serv. (~3 ¢/kWh), etc.
3. Utility business philosophy may be part of a (misguided?) rationale to delay investing in PV and PVBB, since their cost is dropping ~8%/year, and delay investing in storage until reaching a cumulative PV power penetration corresponding to Hawaii's capacity factor of 17-18%.
4. Private (but not utility) geothermal electricity rising cost may reach parity with the dropping PVBB el. cost of 14 ¢/kWh in 10 years, by 2024. Utility geo-el. may then retail at 46 ¢/kWh, i.e. higher than even utility PVBB el. cost. Ergo: Lets provide some transparency and some healthy debate: Short-lived, high-maintenance rotary equipment, not-load-following geothermal generation, environmentally-hazardous geothermal vs. long-life, low-maintenance, quiet, unobtrusive, environmentally friendly, load-following-via-battery-backup PVBB.
5. The 2014 HELCO rate of 42 ¢/kWh will be 65 ¢/kWh by 2024, if the present trend continues.

Regarding the issue of fairness of NEM-PV accounts relative to non-PV neighbors: It is a complex issue. Accounting for the "value of solar" (VOS) PV to a utility, and to society if pollution reduction is included, the California PUC study had this to say: "…the NEM (PV) accounts appear to be paying slightly more than their full cost of service," despite the fact that utilities in California reimburse NEM-PV accounts at the end of each year for some surplus kWh at wholesale price. Minnesota and Austin, TX, adopted the VOS methodology to compensate grid energy provided by distributed PV, as with FIT contracts. For more details of the VOC methodology, whose value and cost components also determine the "fair" but (hopefully in the future) differentiated MMC to non-PV, PV and PVBB ratepayers, see Fig. 5 and http://alohafuels.pbworks.com/f/PB-14-VOS-Hawaii.pdf.

Our state legislators passed the GEMS bill and postponed the "Community Solar" bill, for which we now need to muster the "Political Will" (as per Jeff Mikulina's presentation at the 2014 HERISS) to implement them, so that no citizen need be excluded from using PVBB energy, because of his/her home preference (house or apartment) or roof suitability.

According the chart on HELCO's reported revenue[4], the combination of T&D expenses (2.9% or 1.2 ¢/kWh) and Customer Accounts & Sales (2.3% or 1.0 ¢/kWh) only add up to 2.2/100*500 kWh/mo. = 11 $/month for an average "500-kWh/month" ratepayer, so that the present 20.5 $/mo. MMC for PV users and especially for PVBB users should be more than fair. Fairer yet would be for the MMC to have at least 3 tiers, decreasing from PV-, to non-PV-, and to PVBB-users.

As with energy efficiency improvements in homes and businesses, solar generation benefits all ratepayers, PV and non-PV alike, by providing not only clean renewable energy, but much of its energy when it is most needed and is most highly valued – either during mid-day peak periods, as in California,[5] or during Hawaii's peak from 5 to 9 pm via peak-shifting.

For a 100% PVBB scenario, I think the trickiest parts are:

(1) How to manage the sequence of VERY cloudy days (via 20-40% PV oversize), statistics (unlikely that all parts of the island micro-climate will be under heavy cloud cover at the same time) and energy demand management (reduce baking, pumping, washing and drying on those days); and

(2) What to do with the surplus PV energy during sunny days: All of the above like baking, etc., in addition to air conditioning, water-making via desalination or dehumidification[10], and helping other homes under heavy cloud cover that day.

CONCLUSIONS: Aiming to achieve ~100% distributed, renewable energy via PVBB seems technically, environmentally (even before allowing for the saved social cost of CO2 emissions[7]) and economically within reach, if we can craft a consensus (pono) approach to the transition from central, oil-based generation.

Long-life batteries for energy storage at utility-scale and distributed-user scale, with the associated power electronics (efficient, battery management, inverters, chargers and disconnects) are “shovel ready” and being offered by many firms[1]. Both the lower-cost lead-acid batteries requiring more maintenance & eventual replacement and the lithium batteries can be recycled after use.

Because Hawaiian utilities, despite their economy-of-scale advantage with PV farms (with storage), cannot compete with distributed PVBB electricity (due to extra costs of land, transmission lines, utility-grade power electronics, PVBB maintenance, etc), lowest 30-year LCoE is via such distributed, private PVBBs. 2014 Mainland utility PPA PV bids are for 4 ¢/kWh, vs. 16 ¢/kWh here.

PVBBs may be financed by the owners, solar installers or utilities, if the latter choose to stay in the generation business. As we approach 100% distributed renewables, the utility oil-based generation equipment can be phased out, overhead costs can drop, so that non-PV hold-outs need not be burdened with cost of maintaining outdated equipment.

This short analysis left many questions open, such as: When will we expand the use of PV energy from EVs, to also available E-boats and E-planes; will utilities overcome PV interconnection issues via battery deployment and embrace distributed PV generation; what to do with surplus energy from oversized PV during sunny days (; how do we move not only PV-communities but whole counties towards 100% renewables?

A recent PUC Decision may be paving the way: PUC’s Decision and Order No. 32055, 29 April 2014, p.58, states: “…Prompt development of available DR (Demand Response) and **energy storage resources** for the benefit of MECO’s customers…in reducing curtailment and adding more renewable energy in the near-term future – should be undertaken immediately.”

What proactive ratepayers could do is to draft a resolution or bill that would call for more general administrative (not subsidy) support for PVBBs, get feedback, update it, and then try to get as many legislators as possible to like it and vote for it. For example:

a. Require and/or incentivize all new homes to have PVs or PVBBs.
b. Allow utilities to partner with solar installers, to finance, “own and operate” PV systems, as San Diego Gas & electric’s Ted Reguly suggested (http://www.utilitydive.com 25 Feb 2014)
c. Develop a list of PVBB configurations that are “pre-approved” by the PUC, utilities and County Building Departments, extending HECO’s present TOV (TransientOverVoltage) inverter list.
d. Encourage PV (but not necessarily battery) oversizing, so that collectively, the PVBBs generate enough power during very cloudy days, and utilities can verify satisfactory voltage and frequency control with high penetration of such distributed generation (DG).
e. Develop a “fair” Minimum Monthly Charge, which is transparently tiered to represent utility costs to interconnect PV, non-PV and PVBB users. Such costs to include: Grid capital and maintenance costs, interconnection costs to different type of users, and (as appropriate) avoided or saved costs of base-load and peaking generators, grid-scale storage, T&D losses, sophisticated grid upgrades, and deployment of smart meters.
f. Require the utilities to interconnect PV and PVBB homes, while proactively increasing the needed battery backup, and reducing fossil-fuel-based generator backup. Regarding battery backup, the HECO RFP released 5 May 2014, for 60-200 MW (for 0.5 hours) is great news.
g. Require greater transparency of utility overhead and administrative costs, so that the PUC can compare such costs with those of other mainland utilities (Benchmarking).

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REFERENCES:

[1] http://www.greentechmedia.com/articles/read/aes-energy-storage-targets-30-billion-peak-power-

substitution-market. Others offering utility-scale batteries, bedsides AES, BeaconPower and A123 include SaftBatteries, Altairnano, OjaiEnergy, Corvus, Sony, Aquion, Greensmith and AxionPowerInt'l.

[2] As per recent HECO RFP (Request for Proposal) for utility PV farms by HECO; Mainland bids are for 4 ¢/kWh

[3] DBEDT Hawaii State Energy Office, HI Energy Facts & Figures, June 2013, http://energy.hawaii.gov/wp-content/uploads/2011/10/FF_June2013_R2.pdf, page 8. Cost of geo-electr. based on 6 $/W for CapEx and 10% CapEx/y for O&M and a 15-year life of a geo-well: C = 6 $/W(1+0.1*15)/(0.001*8760*15)=11.4 ¢/kWh. The cost assumed for utility geothermal electr. of 18 ¢/kWh is based on the mean of the present contract

[4] HELCO: "Utility Revenue, 2012, by Expense Category," PUC Annual Report 2012-13, p. 56, Fig. 19. http://puc.hawaii.gov/wp-content/uploads/2013/04/PUC-Annual-Report-Fiscal-Year-2012-13.pdf

[5] Donald Osborne in commentary to http://theenergycollective.com/hermantrabish/326831/solar-s-faceoff-feed-tariff-versus-net-energy-metering

[6] U.Bonne, "Can Hawaii County Really Be Energy Self-Sufficient?" 18 Oct. 2009, http://friendsofnelha.org/can-hawaii-county-really-be-energy-self-sufficient/

[7] EPA, "The social cost of CO2," http://www.epa.gov/climatechange/EPAactivities/economics/scc.html, 2013 update: 39 $/metric ton of CO2; 3% discount rate; amounts to 3.2 ¢/kWh for oil-based electricity. The social cost of CO2 from "cleaner" LNG emissions would still be 2.5 ¢/kWh

[8] Jeremiah Johnson, Dan Leistra, Jules Opton-Himmel, Mason Smith, Marian Chertow, Arnulf Grübler, and Derek Murrow (Yale University), "Hawaii County Baseline Energy Analysis," 10 May 2006, rev. 19 Feb. 2007, p. 22, http://www.kohalacenter.org/pdf/hawaii_county_baseline_energ.pdf

[9] Robbie Alm, executive VP for public affairs at Hawaiian Electric Co., quoted: "... by the time you made a contract, got LNG here and added in the shipping and building the regasification facilities, I think the numbers will be much more like the numbers discussed at the recent Hawaii Clean Energy conference: $11/MMBtu to $17/MMBtu. And most of the people in that room leaned toward $17/MMBtu." http://www.hawaiibusiness.com/Hawaii-Business/September-2012/Is-Liquefied-Natural-Gas-a-viable-option/

[10] Raghied Mohammed Atta (Dept.EE., College of Eng., Taibah University, Saudi Arabia), "Solar Water Condensation Using Thermoelectric Coolers," Int'l. J. Water Resources & Environments 1(2): 142 (2011), ISSN 2079-7079, http://www.psipw.org/attachments/article/273/IJWRAE_1(2)142-145.pdf.
An off-the-shelf, most efficient dehumidifier is the Santa Fe, Model "Ultra-Aire XT105H" 530 W, 120 V, 4.9 A, 4.2 L/kWh or 8.8 pints/kWh, 105 pints/day at 80F/60% RH. Air filter: MERV 11, MERV 14; Warranty 1-5 years; http://www.thermastor.com/Ultra-Aire-XT105H/ Will make water costing $13.53 per 1000 gal, based on 20 ¢/kWh PVBB electricity; $2150. See also (less efficient but) Peltier-effect-based dehum. by Eva-Dry

HI\- and AlohaFuels.pbworcs.com/f/PB-14-ElectricityCostTrends

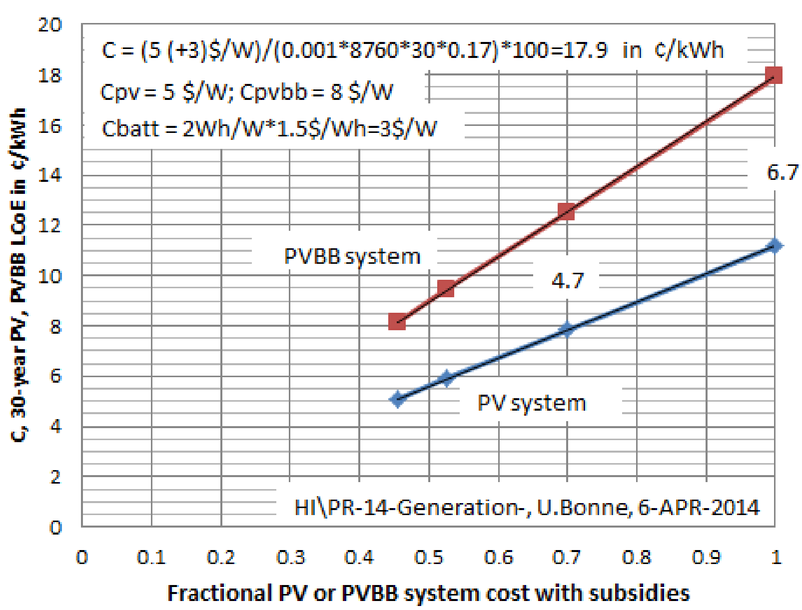


Fig. 1. 30-year levelized cost of electricity (LCoE) for PV and PVBB systems, as a function of their fractional cost due to present and future subsidies. Residential installed PV system cost is assumed to be at 5 $/Wp; and its battery cost at 3 $/Wp.

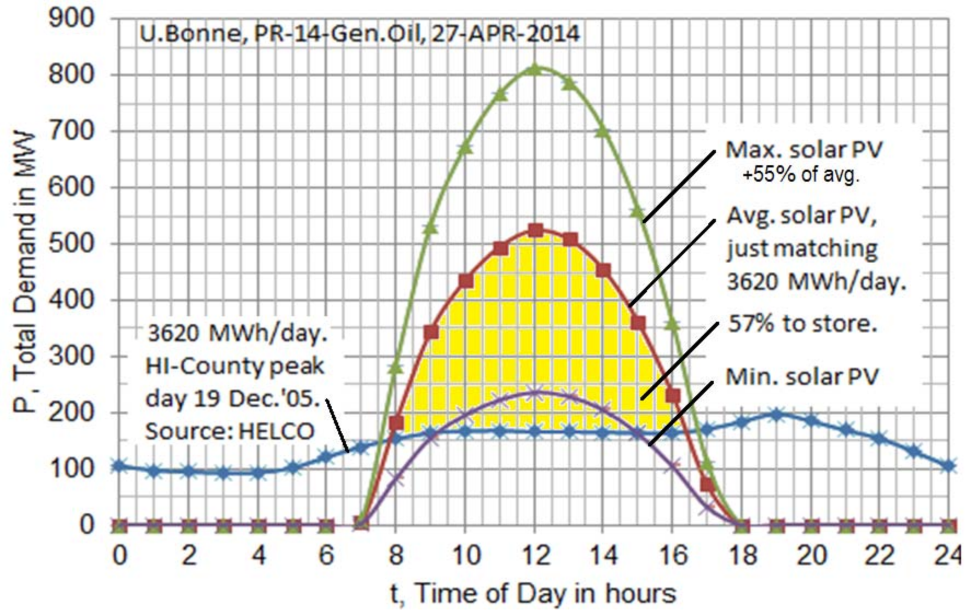


Fig. 2. Average solar PV matched to peak HELCO-day, 19 Dec. 2005. The average daily PV output curve is 1.55x lower than the maximum and 1.55x higher than the minimum PV output, as recorded in Kailua-Kona between 2009 and 2013, see Fig.4.

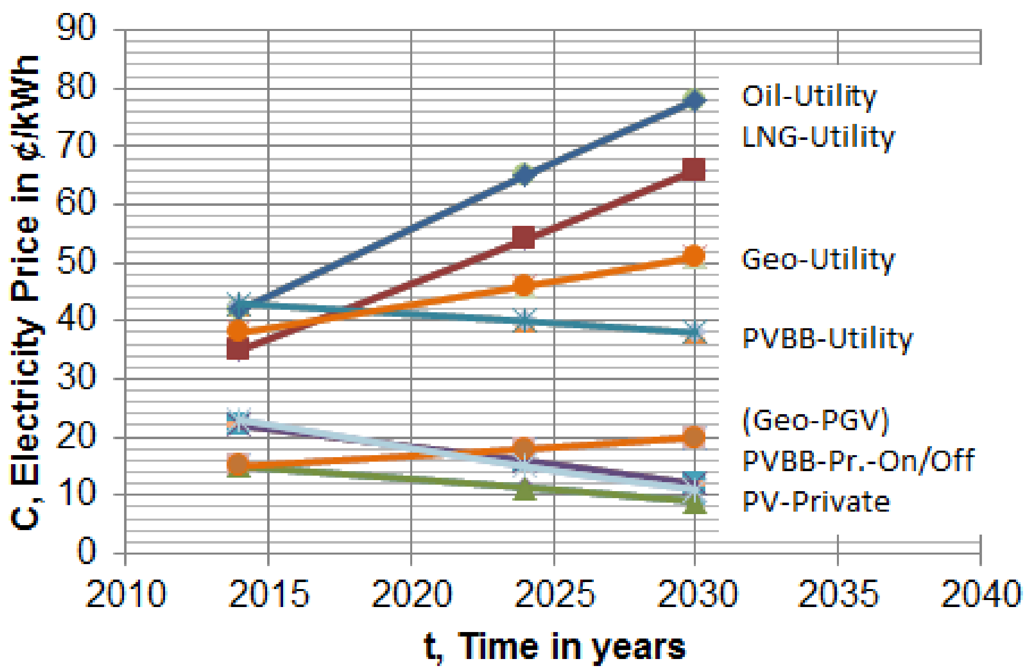


Fig. 3. Estimated trends of Hawaii County electricity prices, w/o considering tax credits nor cost of money. The plotted trends are based on historical trends of crude oil, solar-PV installations and inflation. The latter may influence labor and established conventional generation hardware costs, while the PV and battery hardware costs are still trending down.

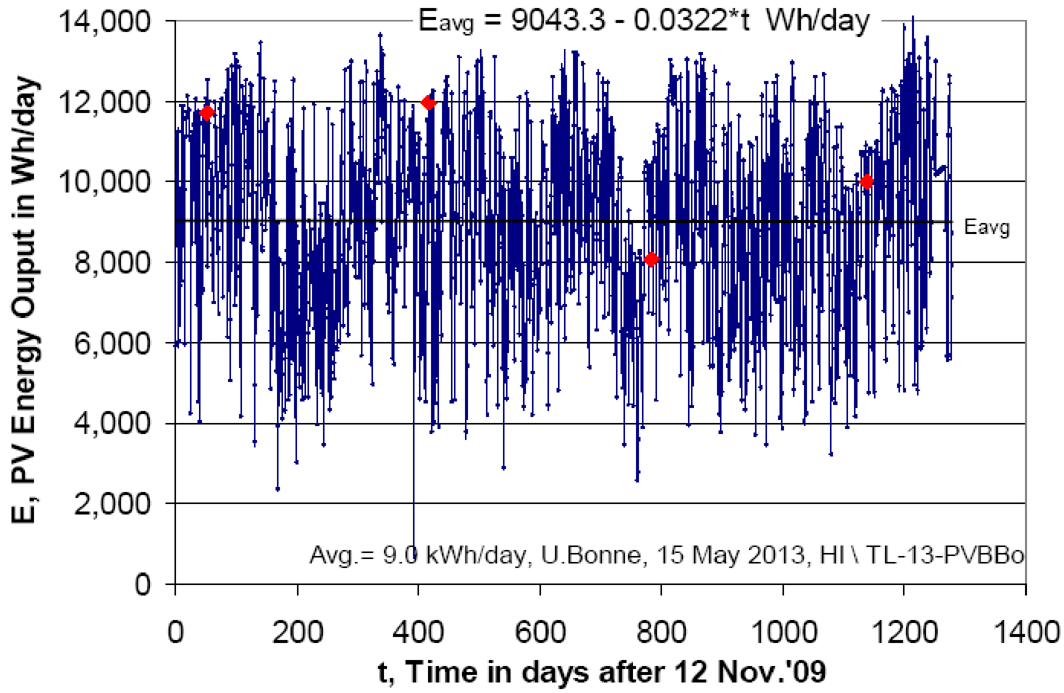


Fig. 4. Total daily output of a 2-kW PV for more than 3 years. The red dots mark Jan. 1st of each year. As shown, there is no measurable seasonal PV output variation, but an overall peak-to-peak variability of ~ +/- 55%.

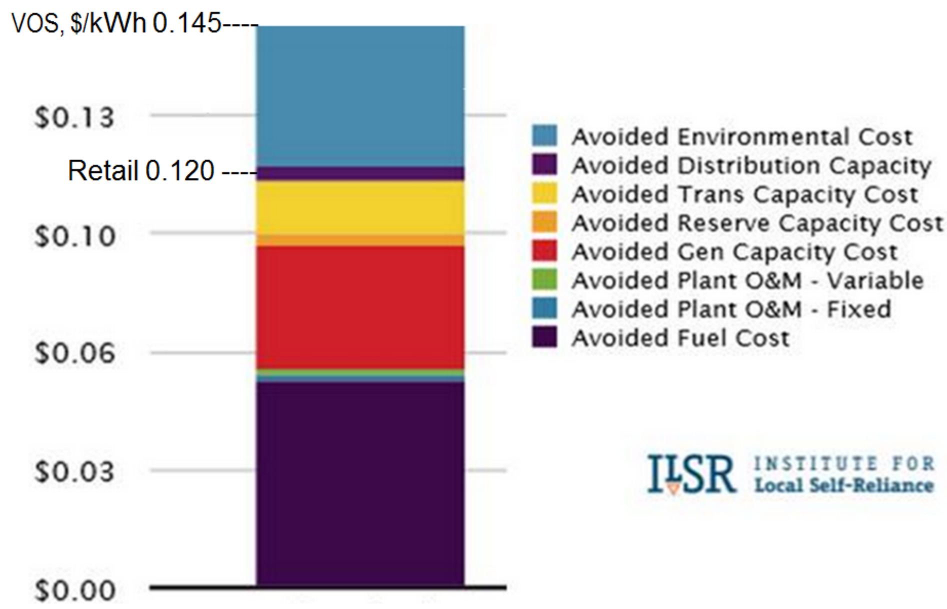


Fig. 5. Value of Solar (VOS) PV derived for Xcel in Minnesota by ILSR, showing that the VOS exceeds the retail cost by ~2.5 ¢/kWh. The avoided environmental cost (based on natural gas-based electricity) is of the same magnitude.

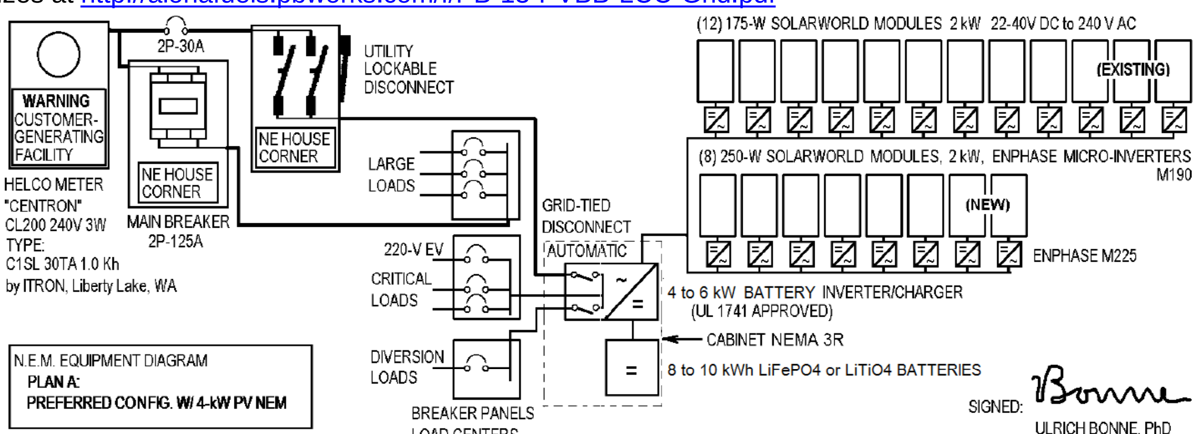
APPENDIX

Personal objectives for installing a grid-tied, AC-coupled PV system with Li-battery backup (PVBB):

1. Reduce present cost of electricity from 42 ¢/kWh (or ~85¢/kWh avg. over 30 yrs) to <20 ¢/kWh***
2. Have available electric energy (PV-generated) even during grid outages
3. Install a safe PVBB system that requires little or no maintenance. Therefore invest in LFP(lithium-iron-phosphate) or LTO(lithium titanate) battery, which are reportedly of longer cycling life, less temperature sensitive and safer than LCO(lithium cobalt oxide) batteries; and despite their higher up-front cost, of lower life-cycle cost than the traditional lead-acid batteries, besides not requiring ventilation to disperse flammable hydrogen emissions.
4. Maximize PV output (w/MPPT, max. power-point tracking) with micro-inverters on each PV panel
5. AC-couple the micro-inverter outputs directly to my home outlets, as per diagram below.
6. Get primary energy backup from on-site batteries (2-2.5 kWh per kW(peak) of PV in Hawaii) via the battery inverter/charger (BIC) and secondary backup from the grid. Upon grid outage, the BIC disconnects from the grid and continues to generate AC by inverting power from the battery DC.
7. Have enough energy for home use and EV charging; send surplus to the diversion load(s)
8. Achieve a 80-90% level of self-consumption (i.e. ~ 3 times higher than without battery backup), whereby the battery only gets charged by the PV system, grid energy is only used if the battery has no charge left, and send surplus energy to the grid only after diversion loads (baking, drying, irrigation pumps and/or water-making via dehumidifiers (~ 13 $/1000 gal) are satisfied.
9. Publish the PVBB configuration as shown below, and its performance in terms of self-consumption and low grid load, so that utilities can interconnect more such PVBBs (rather than PVs) before having to invest in grid-level batteries, other ratepayers can replicate it, and make it easier for utilities to grant PVBB permits.

*** Components & costs for "average 500-kWh/mo. home," which would need a 4-kW PV in Hawaii to generate 16.7 kWh per day, on average. Such a PVBB installation would cost in 2014:

PV w/micro-inverters (5 $/Wpeak) + battery (2 $/Wp) + battery inverter/changer (1 $/Wp), or
Capital cost in $/W(peak): 5 2 1 = 8 $/W(peak) before tax cr. or cost of cap.
Capital cost in $ for a 4-kW PVBB system: 20k + 8k + 4k = 32,000 $ before tax cred. or cost of cap.
Capital cost in $ for a 4-kW PV system: 20k = 20,000 $ before tax cred. or cost of cap.
Electricity cost, C, in ¢/kWh, levelized over 30 years, 90% efficiency, no cost of capital, and a local capacity factor: 0.17: C = (8 $/W)*100/(1*0.17*30*8760*90/100)*1000 < 20 ¢/kWh before tax cr.
The 30-year levelized cost of electricity (LCoE) that escalates at 4.5%/year, starting at 42 ¢/kWh is
C = 42*(1.045^30-1)/(1.045-1)/30 = 85 ¢/kWh
There are several types of PVBB interconnections to the grid: Via a NEM (preferable) or a FIT contract; no contract (i.e. without ability to "store" electricity on the grid); and off-grid. See cost estimates and optimal PV sizes at http://alohafuels.pbworks.com/f/PB-13-PVBB-LCC-Grid.pdf



SIGNED: Bonne

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22 OCTOBER 2013

NOTES:

(1) UTILITY LOCKABLE DISCONNECT SWITCH WEATHER PROOF LABEL 'CUSTOMER-GENERATOR SYSTEM DISCONNECT'; DISCONNECT SWITCH SHALL BE LOCATED WITHIN 10 FEET OF MAIN SERVICE ENTRANCE PANEL AND ACCESSIBLE TO UTILITY PERSONNEL AT ALL TIMES. ACCEPTABLE 2-POLE, 30A, SWITCHES ARE SQUARE D (D221NRB), GE (TG3221R), CUTLER HAMMER (DG221NRB), OR EQUIVALENT.

(2) IF AN ALTERNATE SWITCH LOCATION IS APPROVED BY HELCO, A WEATHERPROOF SIGNAGE OR MAP IS REQUIRED TO BE AFFIXED TO THE MAIN SERVICE ENTRANCE PANEL. ACCEPTABLE SIGNAGE INCLUDES ENGRAVED, LAMINATED PHENOLIC (OR EQUIVALENT) NAMEPLATES WITH 3/8' MINIMUM BLOCK LETTERING, INTENDED FOR PERMANENT APPLICATIONS. REFER TO P. 43 OF THE ESIM.

(3) LABEL 'WARNING CUSTOMER GENERATING FACILITY' SHALL BE AFFIXED BELOW METER BY CONTRACTOR.

PHOTOVOLTAIC SYSTEM FOR					TMK (3)-77029029		
ULRICH & COLLEEN BONNE, 77-206 LAELAE ST., KAILUA-KONA, HI 96740							
CRITICAL LOADS			LARGE LOADS		DIVERSION LOADS		
Appliance	Power in kW	kWh/day		kW		kW	
EV	1.471 x6h=	8.82	Oven	12.80	Dehumidifie	0.60	
Refrigerator	0.613		Grill	1.80			
Lights, TV	0.400		Water htr	4.50	ANNUAL AVG. CONSUMPTION		
Clo.washer	1.250		Drier	3.36		kWh/y	kWh/y
Toaster	0.900			22.46	2&4-kW PV	3293.76	6587.5
Microwave	1.800				GS8048		262.8
Total	4.963		Amps tot =	243.67			