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A vote for more support for environmentally benign home solar energy

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SUMMARY -- Some historical trends are clear, such as the trend from a few large central systems to many small, "distributed" or individual ones, as demonstrated by transitions from public to individual transportation and from big central computers to lap tops.

We believe that a similar trend is gaining traction towards distributed electricity generation. This is fueled not only by NIMBY opposition to new utility-sized plants; but now also by simple economics[1]. Distributed solar PV (photovoltaic) generation also reduces fossil fuel imports, air pollution, utility transmission losses and consumer bills. It simultaneously increases good land use. An added small energy storage yields uninterruptible power. Distributed solar generation also increases energy security and independence - as we have detailed below.

We found the 30-year levelized 3-kW home PV electricity cost in Hawaii to be 0.21 $/kWh before subsidies (or 0.23 $/kWh with cost of a loan), vs. 0.46 / 0.23 $/kWh for a central 30-MW PV- / oil-utility, or ~0.15 vs. 0.36 / 0.23 $/kWh after present PV tax credits.

Despite well-received federal and state subsidies via renewable energy tax credits, key barriers to faster implementation of solar PV residential roof systems remain, such as:

1. The still significant installed PV system price tag (especially if battery storage is added),
2. The concern that lost utility profits will have to be made up by those ratepayers without solar installations, despite the utility benefit of delayed new plant capitalization, selling free excess PV capacity and income from the MMC (Minimum Monthly Charge) and
3. The uncertainty or unwillingness by utilities to adapt by adding storage to their portfolio to compensate for the intermittent wind and solar electricity additions to their grid.

Countries in Europe have been more aggressive than the US and most US states in promoting the adoption of PV systems, as evident for example by their published Feed-in Tariff (FIT) terms[2], and ~2.5x lower PV installation costs in Germany than in the US[13]. Europe has shown that good, long-term, decreasing incentives may lead to fast deployment of PVs. Despite the gloating of those opposed to any energy subsidies, after recent downward adjustment of those incentives[2], few disagree with the notion that PV demand

- Has increased PV sales and also reduced PV manufacturing & installation cost.
- Created competition and with it, increased PV panel efficiency
- Together with wind installations have lowered European market power prices[14]

COMMENTS -- The comments below

A. List how we recommend the DOE, DBEDT & NREL to get more involved,
B. Illustrate the benefits of more distributed solar PVs and
C. Demonstrate how greater support for distributed home PVs with storage would be more environmentally benign (save land area and emissions), and be more economical than support for adding utility-scale PVs, storage and transmission lines.

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A. We recommend that DOE and DBEDT (Hawaii Department of Business, Economic Development and Tourism) be more forcefully involved with:

- Understanding residential PV generation data & results, promotion and financial support
- Validating economic and environmental advantages of home PV systems with battery storage over utility-scale systems
- Using PVs for home Electric Vehicle (EV) and Plug-in Hybrid EV (PHEV) charging
- Supporting EV and PHEV battery development and usage
- Developing policies to encourage deployment of the above, including:
  -- Test & publicize efficiency & cost information on available and matching hardware
  -- Structure support (e.g. tax credits) on a multi-year time scale, even showing how that support will decline as PV costs are projected to decline, and thereby avoiding past "boom and bust cycles"
  -- Reduce the support that mature Big Oil still receives at the tune of some 4 B$/year, to instead support renewable residential PV systems
  -- Smart grid implementations and demonstrations

B. The benefits from the above more forceful support of home PV+battery vs. utility PV system adoption would be evident in:

- **Reduced renewable energy cost & land-for-energy use**
- **Reduced air pollution** from fossil fuel combustion
- Reduced need for biomass-to-fuel processing, & its potential for increased food costs
- Greater security for energy in homes & vehicles, and for food and water
- Increased US local economic activity due to reduction of fossil fuel imports[3]

C. To detail how greater support for distributed home PVs with storage would be more economical than support for utility-scale PVs, storage and transmission lines, we listed

Table 1. $/kWh-performance of home-PV versus utility-PV (and -fossil) systems, in $, $/kW(peak) and $/kWh

	Home PV	Home PV+B	Home PV+B	Utility PV	Fossil Fuel
CAPEX per 1 kW(peak) PV	On-Grid	Off-Grid	On-Grid	On-Grid	Utility
--	$/kW(peak)	$/kW(peak)	$/kW(peak)	$/kW(peak)	$/kW(peak)
PVs, including installation & inverter	6,000	5,000	5,000	3,000	1,500
Batteries, enough for 5-hour storage	0	1,000	1,000	2,500	0
Charge controller & information technoogy	0	340	340	0	0
Back-up generator, 2 kW/kW-PV	0	200	0	200	0
Installation of system other than PV & inverter	0	1,540	1,340	2,700	1,500
Transmission & distribution, at 1 M$/mile	0	0	0	3,333	3,333
Environmental impact anal., permits & reports	0	0	0	33	100
Real utilization of generated kWh by home or grid, %	70	70	70	70	43
OPEX for 30 yrs. per 1 kW PV; Capacity Factor, %	16	16	16	16	90
Minimum Monthly Charge	2,400	0	2,400	0	0
Land lease at 6000 $/y/acre	0	0	0	360	18
Op.& maintenan., taxes, salaries, insurance	0	0	0	3,520	3,800
Transmission loss (~10% for utilities)	0	0	0	1,383	4,872
Fuel for generator energy, back-up	0	720	0	360	33,660
Total life cycle cost in $/kW(peak)	**8,400**	**8,800**	**10,080**	**17,390**	**48,784**
A. Levelized electr.cost w/o subsidies in $/kWh	0.200	0.209	0.240	0.455	0.227
B. Levelized electr.cost after subsidies in $/kWh	0.129	0.124	0.157	0.363	0.227
C. Real level.electr.cost after subsidies in $/kWh	0.185	0.177	0.225	0.498	0.272
			FSyn\TL-11-MP-H2-Techs, 6 Oct.'12		

and added up the main CAPEX and OPEX items for such systems in Table 1, after normalizing all items for three 3-kW(peak) home-PV (consuming 242 kWh/month), a 30-MW(peak) utility-PV and -oil installations (last 2 columns) to 1 kW(peak). For purposes of this comparison, as shown in Table 1, bottom row A, home PV systems, whether with or without battery, generator and/or grid back-up, can generate a lower, levelized, unsubsidized, life-cycle cost of **0.20 to 0.24 $/kWh**, than utility-sized PV systems, despite their size (lower PV installation costs), but because of tougher voltage and frequency stability requirements; and transmission & distribution costs and losses. With higher CAPEX and OPEX costs, PV-utilities end up with a higher price of electricity of **0.45 $/kWh** (10% profit included); the oil-utility with 0.23 $/kWh was within the same range as the home-PV cost.

The Row B $/kWh costs include applicable subsidies, and shifted to a new set of values of 0.13 to 0.16 versus 0.36 / 0.23 $/kWh for the PV- and oil-utilities.

The underlying assumptions and choice of listed costs are detailed in the Appendix. But note that just like utilities have average utilization percentages of less than 50% of the installed US generation ability, so might home PV systems be oversized by up to 2x, to have enough generation “reserve” and to minimize the use of back-up energy from the grid or on-site generators. This extra reserve means that while the home-generated $/kWh still remain lower than the PV-utility $/kWh, the absolute $/kWh values for both home and utility-generated electricity are higher in Row C (based on a utilization of 70% for PVs and 43% for oil), resulting in the values of 0.19 to 0.23 versus 0.50 / 0.27 $/kWh.

We did not factor in the PTC (Production Tax Credit) for renewable energy by utilities. As Table 1 shows, the present credit of 2.2 cents/kWh[7] would not alter our conclusions.

To compensate for the uncertainty in the price and life of batteries, one could triple the battery cost for the middle columns from $1000 to $3000, to allow replacement every ten years. This would increase the home PV + battery total cost and the levelized $/kWh cost to 64% of the PV utility-based rate, but would not alter the conclusion that economics favor home PV systems. A similar trend was already independently reported and highlighted in 2011 by comparing home PV with utility-scale concentrating solar panels[1].

The calculations of $/kWh rates for a 2 $/gal oil-fired utility served as a further sanity check of our economic model, with its own capacity factor of 90% and utilization of 43% and found its rate to be 0.27 $/kWh (Row C), i.e. only a bit higher that the favored “Home PV+Battery On-Grid” system. However, that oil-utility rate would drop to 0.16 $/kWh if fired with 4 $/millionBtu (=0.44 $/GGE) natural gas, to the rate level close to that of the first two home PV systems in Row C.

CONCLUSIONS -- The simple cost calculations and estimates presented in Table 1 show that the need for building and maintaining transmission lines (and the assumed 10% transmission loss) tilt the economics to significantly favor off- or on-grid home or distributed PV systems over large utility-scale PV "farms" or even oil-fired utilities, without or with subsidies.

The resulting PV-home-30-year-levelized rates ($/kWh) were estimated to be **~ 36% to 45 % of those of a PV-utility rate of 0.50 $/kWh,** after including subsidies, new transmission lines, realistic capacity factors (16%) and utilization percentages (70%).

PV home rates are even lower than $/kWh rates of 2 $/gal oil-fired utility generation of 0.27 $/kWh. This rate becomes comparable to home PV rates if the battery cost is 3x higher than the assumed $1000 for the reference 1 kW(peak) PV with 5 kWh of storage.

Furthermore, the home PV + battery systems provide home and PHEV or EV transportation energy that is not subject to utility power outages nor to fuel / electricity cost escalations.

Regarding EV and PHEV charging, we conclude that the home PV system electricity costs, see bottom line of Table 1, are equivalent to retail gasoline prices of 5.96, 5.70, 7.25 $/gal (and 16.10 for PV-utility). But thanks to the about 4-fold higher "fuel-to-wheel" efficiency of EVs, these prices would be equivalent to enabling EVs and PHEVs to achieve over 3x lower $/mile fuel costs than conventional gasoline-powered vehicles.

Judging from prices of electricity and gasoline in many other US states and countries[8,9] being above 0.20 $/kWh and above 4 $/US gal, the prime conclusion of our comments about furthering distributed over central electricity generation holds true well beyond Hawaii or US borders. Distributed solar generation has profound economic, environmental benefits. It also dramatically increases energy, water and food security, while leaving agricultural lands for food production instead of PV-farms or bio-fuels. We would indeed have enough appropriate roof space for 100% of Hawaii County's electricity needs, including energy for 100% conversion to EVs[11].

To summarize, we recommend that DOE, DBEDT and NREL dramatically increase its support for the development of distributed PV systems by focusing on those businesses who demonstrate best practice integrations, sizing and lowest installed cost*** of PV systems, which combine PV, storage and EV charging means. Likewise, they should watch for legislation that might hinder effective or rapid growth of distributed PV generation, as reported from Australia[12]. *** The installed cost of PV systems is 2.5x less in Germany than in the US, despite similar PV panel costs[12,13].

Our recommendations also include thoughts about the role of utilities. They could profit from distributed solar PV in a number of ways, e.g. by using their access to low-cost capital to become low-cost installers of home PV systems. Despite utility costs for centrally generated power being higher than for distributed PV and despite kWh billing reductions due to new home PV systems, we see revenue opportunities for utilities such as:

- Reduce $/kWh rates as indicated below, to stimulate demand for more electricity business. New on-grid PV homes increase revenue via the MMC and via excess kWh sales. The "loss" of kWh sales due to conversion of one old home to PV generation can be balanced by the excess PV energy from it and about half of a new PV home installation, from both of which the utility receives MMC (Monthly Minimum Charge) revenue and for which the utility can sell the free excess PV energy.
- Income from the MMC (Monthly Minimum Charge) – $20/month now in Hawaii County, which would allow an overall utility rate reduction by 3 and 11 cents/kWh for oil- and PV-utilities, respectively, for each new PV-home with a NEM contract added to the utility customers,
- Free home-PV excess PV energy, which maintains some kWh sales without fuel purchases. The sale of these excess kWh are equivalent to rate drops of 2 and 12 cents/kWh, for oil- and PV-utilities, respectively, for the assumed home PV utilization of 70% or 1.43x PV system oversize. Note that for a utility to maintain kWh sales as PV penetration increases, it is enough that the utility acquire 1.3 new PV-home customers for each old home "loss" to on-grid PV, because each "loss" is worth the excess energy from 1/(1.43-1) = 2.3 PV homes, including the one "lost".
- Revenue balance -- Even for an oil-utility, the above benefits, MMC, free PV energy and fuel savings compensate 8 + 43 + 25 = 76% of the kWh sales loss when one old home is converted to on-grid PV. By adding just a fraction (24/51 = 47%) of a new PV

home to the grid, the utility will have recovered 100% of the "lost" revenue, saved 100+30+30*0.47 = 144% of the fossil fuel (it only takes 0.86% of its output to serve as back-up for these PV systems), and still distributes 30+30*0.47 = 44% of the original kWh-energy, with its transmission losses, to mostly non-PV rate payers..

- The reduction of transmission losses per total community generated kWh from central & distributed sources is especially well achievable if PV homes are equipped with battery back-up, which further reduces and dampens transmission peaks and its losses, besides the uninterrupted power valued by electricity consumers.
- Decreased costs and $/kWh rates of utility-installed PV systems, because of standardization benefits, and reduced regulatory and land costs.

The above analysis did not consider the utility dynamics of meeting the load demand minute-by-minute & 24/7, especially when increasing the contribution of distributed PV generation. However, many regions, including Germany, found that the wind and PV day-time energy additions helped to flatten the daily load demand curve[14], reduce the operating time of costly peaking units and thus lowered the overall European $/kWh rate.

APPENDIX – For Table 1, we assumed a conservative PV capacity factor of 16%. The ability of a PV system to deliver kWh to the home was assumed to be 1.34x greater than the average needed amount, i.e. the PV system utilization was assumed to be 70% for home and utility PV systems (free fuel !) and US-average of 43% for the fossil fuel utility. We ignored the cost of capital (which would further favor home PV systems because of its lower CAPEX), ignored inflation and fuel escalation rates, and assumed installation & miscellaneous costs to equal 100% of the equipment cost. Exception: The home (but not the utility) PV panel cost includes installation, inverter and installer profit.

<u>Capital and operating expenses (CAPEX & OPEX) for each kW(peak) of generation capacity</u>

• Home PV installation of PV	5000-6000 $/kW(p) (incl. inverter & profit)	
• Home PV battery	200 $/kWh[4]	
• Home battery charge control	340 $/kW(peak)	
• Home engine generator CAPEX	100 $/kW(peak)[5]	
• Home genset fuel use (0.5 gal/kW(peak)/month) or 3.5 kWh/kW(peak)/month, equivalent to 3% of PV-utility or 0.54% of fossil-utility output	2 $/kW(peak)/month	
• Home (w/o battery) back-up by grid power	1.4 $/kW(peak)/month	
• Home & utility installation costs = 100% of equipment cost other than the PVs		
• Real home PV utilization	70 %	
• Profit	0 %	
	<u>PV-Utility</u>	<u>Fossil Fuel Utility</u>
• Profit, included in Rows A, B and C	10 %	10
• Real utility utilization	70 %	43
• Utility capacity factor	16 %	90
• Utility generator installation (PV or fossil fuel)	3,000 $/kW(p)	3,000
• Utility battery 1 MW / 2 MWh at 1 M$ or	500 $/kWh	0
• Utility battery charge control cost, incl. in battery	0 $/kW(p)	0
• Utility EIS, analyses, permits, reports ~1 & 3 M$	33 $/kW(p)	100
• Utility transmission & distribution lines 1 M$/mile,		

100 miles for 30-MW(peak) utility output	3,333 $/kW(avg)	3,333
• Utility transmission line losses of 10%	1,383 $/kW(avg)	4,872
• Utility plant land need: acres for 30 MW(peak)	60 acres	3
land lease cost – 6000 $/acre/year	360 $/kW(p)	18
• Utility OPEX, in % of CAPEX/year,	1 %	2
includes monitoring to prevent battery fires[6]	2,698 $/kW(p)	3,800
• Utility generator fuel oil at 2 $/gal	360 $/kW(p)	33,660
(natural gas at 4 $/MBtu is equiv. to 0.44 $/gal)		

One easy-to-install PV system which may appeal to many home owners is shown in Fig.1, and is represented in Table 1 by the 3rd column from the right: Adapted from ref.[10], it features PV panels, batteries, charge controller, inverters and a disconnect switch, as needed for each parallel PV panel, so that the PV system output can be plugged into either one of many existing home (grid) outlets, like an appliance, or into a separate, uninterruptible power cord outlet or circuit, which does not get disconnected during grid outages. The shown battery back-up from the grid via a rectifier is safe, thanks to its isolation transformer. Such a PV system, after UL-type approvals, might not even need utility or building permits as in Germany[12].

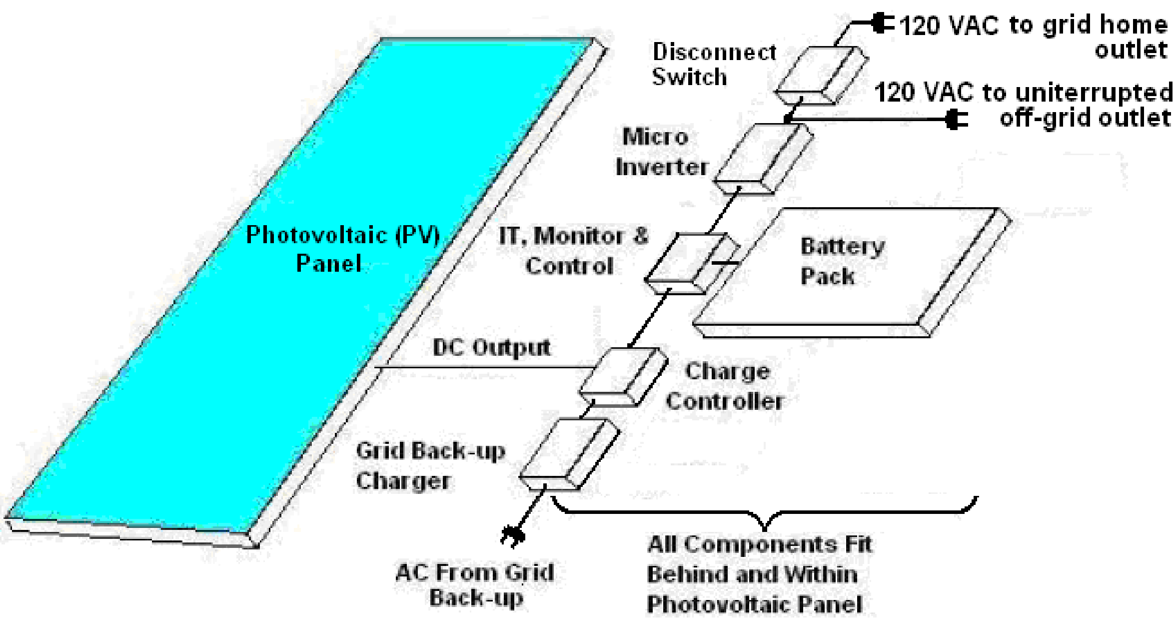

Fig. 1. A mass-producible, plug-and-play solar PV energy appliance, represented as "Home PV+B on-Grid" in Table 1.

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PEIS = Programmatic Environmental Impact Statement (for Hawaii's renewable energy goals)
The deadline for submitting written testimony is Oct 3 or 9, 2012
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