Batteries and PV

'cause, "I wanted it" ever since the first winter in this house 19 years ago and PG&E was out every month.

Why Battery? Was the question that was asked of me all during the research and engineering of this system. The lead in above was the only justification I needed. Over the years I had explored several different options, generators - noisy, smelly, needs fuel and maintenance. Other battery systems, too small, too expensive for what you got etc., solar to expensive.

Then the cost's came down, rebates, the California energy crises, and the phase of the moon made the whole thing doable, practical remains to be seen. Home Power Magazine was a gold mine of information. http://www.homepower.com

For an in town grid tied system the same kinds of questions kept coming up.

- Why battery?
- Grid tied only is cheaper and has a faster pay back
- Battery systems are less efficient
- Battery systems are hard to size.
- Battery systems require a lot of maintenance.

So I will try to answer those comments and questions below.

--------- other generic reason's for PV --------

- Life support for critically ill.
- Life support for an aquarium, or other critters that need a controlled environment.
- Life support for Internet server site.
- Life support for a home business.
- Meltdown prevention for refrigerator and freezer.
- You got a lot of money tied up in a home theater system and you want to protect your investment from PG&E.
- Energy independence. Thumb your nose at PG&E. This is not a case of your PV system will be cheaper than utility supplied power, it will not be. But a choice of "where" you spend your money. "put your money where your mouth is"

Pay back - is how **you** define it. For this paper I will use a different standard some thing everyone is familiar with --- a Lexus. My truck is 12 years old; my car is 29 years old, I choose to spend my cash on a solar power system.

- Even without the CEC (California Energy Commission) rebate a 2.5 kwh PV (40-Seimens SP-75 PhotoVoltaic panels), 5 kwh inverter (1-Advanced Energy System MM5000), and 24 kwh of battery (8-Concorde Battery PVX-12255) still costs less than a Lexus. For those interested in ZEV (Zero Emissions Vehicle) see http://www.corbinmotors.com for their Sparrow II Electric Vehicle, and Toyota is offering a Rav4 EV Electric Vehicle. http://rav4ev.toyota.com/consumer/rav4ev_0_home/rav_home.htm
- Will you still have the Lexus in 20 years? The PV system will still be pumping out power near the same rate as when you installed it.
- Yes, you can move the solar system to the next house. But it would be better to install another.
- Will your Lexus be making money for you sitting in a sunny parking lot while you are at work?
- Is your Lexus non-polluting?
- How much more will you pay into your Lexus in:

  - Fuel
  - Oil
  - Batteries
  - Maintenance
  - Pollution
  - Rubber
  - Insurance

AND PV is the right thing to do. Every day the sun shines your PV system makes a difference preventing some pollution from being produced.

Grid Tie -- Battery vs. Non-Battery

- The most efficient battery that both systems actually use is the utility grid it is 100% efficient. It returns 100% of the electricity you put in up to the amount you have used and then keeps 100% of the excess. The good news the plus and minuses are averaged over 12 months.
- First grid tie only - no battery - will be least expensive and lowest maintenance.
- Non-battery grid tie system will only operate when utility power is present.
- When PG&E is down and the sun is shining you are dead! These systems are designed to go offline when grid power fails.
- With a battery system day or night when PG&E goes away you still have power, from your battery bank. During the day, all or part of the load will be supplied from the PV array. You do have the extra cost of the battery bank and sub-panel for the 'critical loads'.

Grid tie only systems are more efficient than battery systems.

- Yes and No
- The PV panels will have the same efficiency

- The inverter will have the same efficiency
- The battery charger and batteries will absorb some power.
- Remember we are talking about a grid tied system. The battery bank is sized to carry a reduced load for a short period of time. From a few hours to a couple days. The battery bank is not sized to carry the full house load through the roughest weather. The battery bank will spend most of its time in float mode. Even my battery bank, large for a grid tied system is only about 20% - 25% of the size I would need to go PG&E free. With the size battery bank I have it is possible to test living on only battery and find out what it would take to go backwoods / PG&E free.
- I have noticed the battery bank gets it's top off charge first thing in the morning before there is really enough power to export. Then the rest of the day the power meter spins backwards!!! Even cloudy days produce some power.
- For residential use I only recommend solar power systems that use an integrated power management system. Example of a fully integrated system is Advanced Energy MM series. http://www.advancedenergy.com. Other integrated systems are appearing. Advanced Energy MM series battery backup PV system is qualified for CEC rebate.
- Individual charge controllers and inverters that are floated across a battery can only be less efficient example: Xantrex/Trace http://www.traceengineering.com

Sizing your PhotoVoltaic (PV) array.

- For a PV system to generate power the sun needs to be shining and since this is highly variable it has been found a year round average of 5 hours makes a good compromise, this is often referred to as a solar day.
- Next check the summary block at the bottom of your PG&E bill. To the far right of the summary block is an entry for your daily average for the current month. Find all bills for the last twelve months and average all 'daily average' for the whole year.
- My 'whole year daily average' worked out to be 18 kwh per day.
- Next take your 'whole year daily average' 18 kwh / 5 hours = 3.6 kwh. This is the amount of raw PV output you would need to satisfy 100% of your (my) electrical needs.
- Next survey your house what kind of things can you do to lower your load.
  - Start by using your utility meter recording kwh readings both in the morning before leaving for work and in the evening just as you return. This will provide a profile of your energy use and is a valuable tool to find where the energy hogs are.
  - Like replace incandescent light bulbs with compact fluorescent.
  - New Energy Star rated refrigerator. Ice and water dispensers in the door are energy hogs.
  - Unplug the 'fridge in the garage that only has a six pack in it.
  - Replace that torcher lamp.
- Doing this dropped my load down to 15 kwh / 5 = 3000 watts much better.
- Look for a place to mount the PV panels. A sunny roof, new trellis to shade a backyard, clear space on the ground.
- Look for shade from trees etc., what can be trimmed.
- Not every house has good exposure to the sky for solar power.
- Determine how many square feet you have available.
- Depending upon panels selected your power output will be 1 kwh per 100 - 120 square feet.
- I have 256 square feet over a trellis enough for 2 kwh and another 64 square feet for another .5 kwh for a total of 2.5 kwh, without poking any holes in my roof. I have another 256 square feet for expansion but requires making holes in my roof, for a total of 4.5 kwh possible.
- This provides mounting for 40 Siemens SP-75 solar modules. Built into 10 - 48 volt panels CEC rated at 270 watts.

Metering: E-net or Time Of Use (TOU) metering.

- E-net metering is very simple.
  - PG&E comes out with a standard wattage meter that has been calibrate to be accurate within +/- 2% running in either direction.
  - When the sun is up the meter runs backwards, to the left, the correct direction. You are a, Energy Net generator. Any surplus is rolled over into the next month up to your anniversary date.
  - When the sun is down the meter runs forward to the right, the wrong direction. Your are a, Energy Net user.
  - The difference is what you are billed for. If at the end of the year you are a net generator it is gifted to PG&E. CEC net metering & you http://www.energy.ca.gov/greengrid/net_metering.html
- TOU Metering.
  - PG&E puts in a fancy new bi-directional meter that can also tell time of day. Your billing day is split between peak hours 1200 noon to 600pm and off peak hours 600pm to 1200 noon, weekends and holidays. Two seasons summer and winter.
  - Two different billing rates very high peak and low off peak. The idea is to use very little power during peak hours and all high consumption during off peak hours. Best example would be everyone goes to work or to school all day, and there is no one home between 1200 noon and 600pm.
    - If there is normally some one at home, wife, home office, etc. then the continued usage of power will be at a very high rate, and negate any benefits.
    - Also if the house is vacant a lot, no one home on weekends, nights etc. then the accumulated credits may not be used and get turned back to PG&E wasting the investment.

- An example: the Toyota Rav4 EV battery charger uses 240v @ 30 amps x 6.5 hours = 46.8 kwh for a full charge. PG&E have a special TOU metering rate for Electric Vehicles and the Rav4 EV has a timer on the charger you set to begin charging after 600pm.
- TOU metering with solar power. During the peak daytime hours while your meter is spinning backwards your account is being credited at the higher rate. During off peak hours you are buying at the lower rate. TOU is quoted to give a solar array a boost of 2.5 to 3 times it's nominal rating. Not in actual power output but in 'Dollars' off your bill.

Transportation Option Using a ZEV and TOU

- Is a ZEV possible for you? Start by using the trip meter in your car. Zero it out before leaving home and check it upon return. Make a mental note of the number of stops you made. Today I drove 19 miles, 7 stops, and refueled for $19. Yesterday was similar except no gas stop. Round trip to work is less than 25 miles.
- SUV example: I drove a Rav4 EV. It was much better than I expected. I was really impressed on the ride, handling, acceleration, and top speed all were very good for running around the peninsula up and down 101. What its range and recharge needs are etc. no opinion.
- Using the Toyota Rav4 EV. If I bought the Rav4 EV My daily load will need to be adjusted.
  - 46.8 kwh + 15 kwh (my normal daily load) = 61.8 kwh this would be my new daily load.
- To get the new required PV array size
  - Divide 61.8 kwh (new daily load) / 5 (solar day) = 12.36 kwh per hour.
  - Then 12.36 / 3 (TOU meter factor) = 4.12 kwh the new size required to produce 100% of the electricity need by my house and a all electric SUV.
  - I have 2.5 kwh so I might want to add another 2 kwh, for a total of 4.5 kwh solar.
- PTM example: Corbin Motors calls their Sparrow II a Personal Transport Module. It's the exact opposite of the Rav4 EV. The Sparrow II is a small single person few frills, three wheels, it's a trike!!. Since it only exists as a prototype I've not driven it. I've seen the shell and other than it look's good, the only info I have comes from their web site.
- Spec page indicates a full charge on 120volts takes 6 hours same as the Rav4 EV but only needs 7.5 kwh, - I rounded up.
- Using the same formula from above:
  - 7.5 kwh + 15 kwh (my daily load) = 22.5 kwh.
  - 22.5 kwh / 5 (solar day) = 4.5 kwh per hour.
  - Then 4.5 kwh / 3 (TOU factor) = 1.5 kwh solar array.
  - Since I already have a 2.5 kwh solar array I do not need to add anything just convert from E-Net metering to TOU metering.
- Billing at the end of your yearly anniversary date is the same; any excess is gifted to PG&E. (run the hot tub more.)

Now imagine that, having all of your basic transportation needs, all electric power for your house with battery backup, powered from the Sun. And you get to thumb your nose at PG&E and OPEC. Got your attention yet? Can't do that with a Lexus.

This is all very cool you are generating your own electricity using the utility to 'store' the excess. PG&E are buying it at a high rate and sell it to you at a low rate.

Batteries load calculations are complicated and batteries require a lot of maintenance.

- Well how much maintenance do you do on the battery in your Lexus?
- Your choice of battery will make a 'big' difference for PV Solar. Use only batteries designed for solar power service (period!!). These are deep cycle batteries optimized for solar power. I only recommend GEL or AGM batteries for their low maintenance in residential use. There are high quality flooded batteries, with long life. http://www.rollsbattery.com.
- My research has shown that Concorde Battery http://www.concordebattery.com makes one of the best AGM (Absorbed Glass Mat) sealed batteries. They are in a class of lead acid batteries called VRLA (Valve Regulated Lead Acid) battery. Expensive, but for in town use expect 10-15 year life, backwoods 8-10 year life.
- The oldest and cheapest batteries are what are known as flooded cells - do not bother. Get'em pass city inspection is only the first challenge. If you insist on using flooded cells, you will be unhappy and I will say - "I told you so". Having said that, if you are a chemist and can afford the cost and time, Rolls flooded cells can last twenty years or more.
- Sizing your battery bank is at least as important as the selection of vendor and battery type. On your Lexus some one else did this for you.
- Basic ohm's law:
  - Watts = volts x amps,
  - Amps = watts / volts.

  Battery basics:
  - All batteries used are the same size and type NO mix and match.
    - Batteries in parallel, add the amps, volts stay the same.
    - Batteries in series, add the volts, amps stay the same.
- Example: I used my refrigerator and freezer as my starting point.

- I bought a new fridge rated at 457 kwh per year, I have a small freezer which should consume half the power of the fridge, 457 kwh x 150% = 658.5 kwh per year.
- So then, 658.5 kwh / 365 days = 1.878 kwh per day, call it 2 kwh.
- Plus I want to operate a TV, stereo, microwave, ceiling fans, lights, furnace, garage door opener, that will be another 4 kwh for a total of approximately 6 kwh (Hardship is doing without the hot tub!!)
- Now remember this is the total for a full 24 hour period, 6 kwh / 24 that gives a total per hour running rate of 250 watts!! That is not much, that's just 4 - 60 watt light bulbs.
- I wanted two days supply that's, 6 kwh x 2 = 12 kwh.

Now to convert that to battery size, the black magic part of batteries is that they are rated at total energy capacity if you tried to use the total capacity you will destroy the battery. There is a term: DOD (Depth of Discharge) that is used to rate lead acid batteries, nominal DOD is 50% for solar use. To qualify for the CEC battery rebate the battery must be able to withstand repeated DOD of 80%, it is not wise to use this discharge level, as it does not provide a reserve. Use a 50% - 60% DOD this then gives you 20% - 30% reserve.

- Therefore my battery bank capacity would be 12 kwh (my target load) / 50%(DOD) = 24 kwh total.
- The nominal MM5000 system voltage is 48v DC, 24 kwh / 48v = 500 amps.
- Concorde battery spec sheets have several discharge rates listed, use the 24-hour rate.
- Since there are no 48v batteries listed I went with the 12v size, four 12v in series makes 48v.
- The largest 12v I found had a capacity of 255 amps (when I purchased, now listed as 258 amps).
- Four batteries in series will give 48v at 255 amps, two 48v strings in parallel give 48v at 510 amps.
- That's it!!

Total capacity is:
- 48volts x 510amps = 24,480 watts.

Total usable kwh:
- At 24.48 kwh x 50% = 12.24 kwh.
- At 24.48 kwh x 80% = 19.58 kwh.
- My battery bank is 8 - Concorde PVX-12255 these are 8D size, like a truck battery.
- Battery rack is from Two Seas Metal Works: http://www.2seas.com BR-88D-BP.

Maintenance

- Shortly after installation of your system you are going to do a live load test. Live off of your battery bank to see how long it lasts both on sunny days and cloudy. Keep records of time and battery DOD. My first live load test I ran 36 hours and reached a DOD of approx. 45% this was in Jan of 2002 before PG&E sign off. I have to run another test since I am now totally blessed by the City of Mountain View and PG&E. I seemed to have reached my goal.
- Once a month there after flip your mains breaker or PG&E cutoff switch to off. To be sure fail over works properly. Run for 30-60 minutes minutes on battery, checking everything. Watch out for your mains breaker as its poles may not always switch properly and it messes with the inverters brain.
- Check battery connections for corrosion and tightness every six months. Of course as part of your installation you sprayed the terminals with a corrosion inhibitor!!
- Once a year do a live load test. Keep records, as this is how you will know how well your battery bank is aging.
- During the live load test measure the battery voltage across each 12 battery. You are looking for about a .3v difference between the batteries, the low one will require a standalone trickle charge. Having said that, the only time I would expect to see a problem would be years in the future, if ever. This is a problem usually experienced by battery banks that are discharged to 80% of capacity on a regular basis. Another reason to use a 50% DOD.

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For battery maintenance that's it, if you picked the right batteries
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How much did it cost?

DESCRIPTION	COST
1-AES MM5000, 40 Siemens SP-75 PV modules & mounting hardware	$29,160
24 kwh Battery bank, enclosure, 250-amp circuit breaker, and cables.	$4,166
Building permits	$241
PV installation	$2,510
Electrical installation	$3,900
Sub-total	$39,977
CEC rebate	($11,178)
CA Income tax credit of 15%	($4,320)
Total	**$24,479**

SUV Transportation Option:	
Toyota Rav4 EV Batteries & charger included.	$42,510
CA EV rebate	($9,000)
Additional 2 kwh of PV	$10,000
Misc.	$2,000
Sub-Total	$45,510
Total from Summary	$24,479
Electricity & Transportation Independence, about the price of a cheap Porsche 911 - **Total**	**$69,989**
PTM Transportation Option:	
Corbin Sparrow II	$16,900
Misc.	$1000
Sub-Total	$17,900
Total from Summary	$24,479
Electricity & Transportation Independence, about the price of a cheap Lexus - **Total**	**$42,379**

So the overall cost runs about $10,000 per kilowatt, or about $10 per watt. The life expectancy is 20 plus years or approximately $1,224 per year, or about $102 per month. Remember all during this time the PV system will be generating power and reducing your monthly electricity bill. With E-Net metering best guess of being paid up in 15 years, with TOU much shorter perhaps less than 10 years.

If I add 2 kwh to my system for 4.5 kwh then the cost drops to $7.66 per watt. The reason is my inverter is sized for 5 kwh, all of the high fixed costs have already been paid. I'm just adding panels.

Running an Electric Vehicle should cost a lot less, fuel is free, and maintenance is very low. Fixed costs of depreciation, tires, license fees, and insurance are the same. You get to use the diamond lanes even if you’re the only one.

Limited range 126 miles, limited speed 78 mph, limited chargers - though they are free and next to the disabled parking where available. The 100,000 mile service is a killer, you get to change the battery.

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