WilderShares, LLC
www.wildershares.com

Solar Power for a better Solution.

Many energy options in WilderHill Indexes are technologies that we not only address in a technical sense, but also utilize everyday. We believe practical knowledge-gained can assist in discussing clean energy ahead. For example we are intimately familiar with how solar power, electric cars, and energy efficiency can be sensible today. This is more than theoretical; at our 1-acre San Diego site we utilize several different systems to:

1) generate electricity and
2) harness solar power to run electric vehicles, and
3) provide building hot water.

To visualize how sunshine can power fast electric cars, let's start with the solar. To generate our power we harvest considerable electricity from the sun using PV (PhotoVoltaic = electricity making) panels. They total about 6.65 kilowatts (kW) and are 'grid-tied' meaning this building is connected to the grid; in daylight we generally make much more power than we consume and automatically 'sell' extra power to grid.

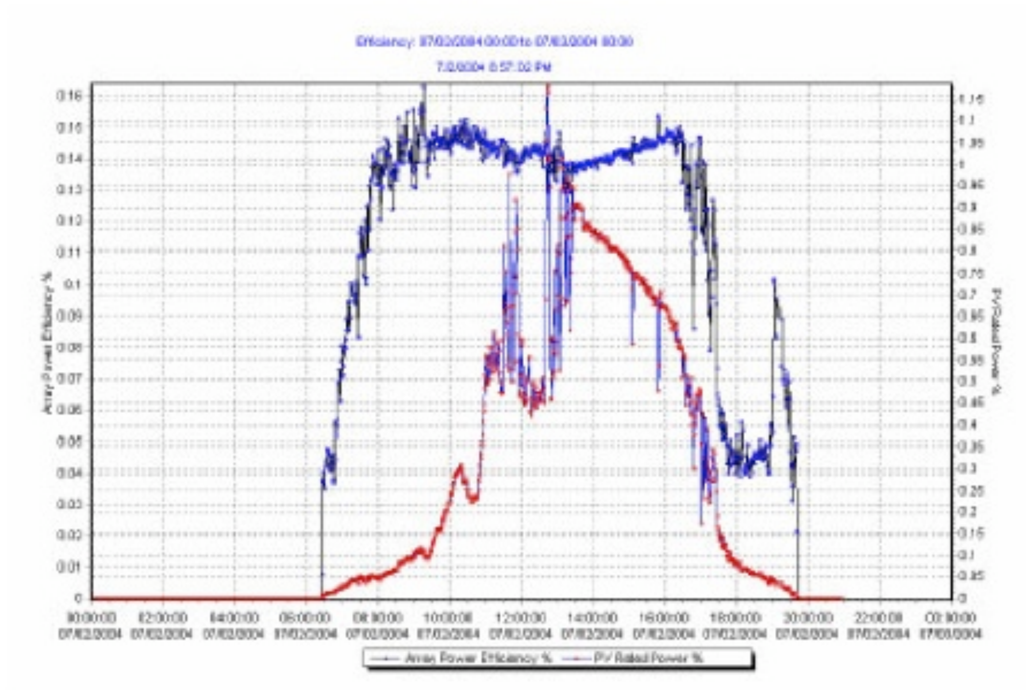
At night it's reversed; we 'buy' power from the grid — our meter runs the opposite way. Being grid-tied simply means we avoid cost of batteries and allows rebates from the State of California. Also, as will be shown, using the grid increases solar power's value. Our PV has performed well in its cost/benefits, its return on investment, and in practice.

Phase 1: The start of solar here was 2003 installation of a 3.85 kilowatt (kW) solar rooftop array, calculated to achieve payback in very roughly, approximately 10 years (see solar PV system costs). That fairly 'short time' to payback was due to two crucial components: 1) *California's solar subsidies, and 2) *Time of Use metering (TOU) by our utility.

Certainly, the upfront costs were significant. And yet we estimate that after making solar power for 10 years, we'll recoup a full return on investment. Afterwards it goes on making power for our building+the 'fuel' for our cars in years to come, at no charge: it's free!

We first installed 21 new 185-watt panels (see spec sheet) with then-high 14.2% module efficiency rating to get the most from rooftop space. We chose ***mono***crystalline PV made in USA, at the time among the most efficient consumer PV (instead of ***multi***crystal PV). Monocrystalline we'll shorten to 'mono' and it was paired to a 3,500 watt inverter along with a 1st, then 2nd web-based real-time monitoring system in one of the first such applications in California though no single aspect of this system was a big leap.

As illustrated by data below in detailed graphs, the panels have delivered efficiencies roughly 5% to 10% over manufacturer rating. Inverter efficiencies are also measurably high. Over long sun hours in Summer/Fall, we generally make on average around 14 kilowatt/hours (kWh) per day from Phase 1 PV. In Winter with fewer daylight hours, or cloudy days anytime with less irradiance (Watts/Meter^2), we will make much less:



Phase 1: Monocrystalline rooftop performance graph series, 2003.

Installation: Phase 1 mono going on rooftop, 2003.

<u>Phase 2</u>: Pleased with 2003 Phase 1 results, we next installed a competing PV design by adding 24 **multi**crystalline ('multi') PV panels rated 120 watts each. We chose a different, passive inverter design as well. This Phase 2 alone was rated at 2.8 kW, so total ongoing PV capacity for both of these systems put together here is about 6.65 kW overall.

Rooftop space gone, eager to try a new set up, the Phase 2 multicrystalline panels were ground-mounted in 2 rows seen below at greater inclination angle than roof PV. Ample space also allowed us to optimize the ground panels for all year round, giving advantage over roof panels (though ground panels are hindered now by a bit of shading).

That roughly 6 kW combined solar PV was then right-sized for our own electricity needs, clearly enough power for our building plus our moderate daily pumping of water.

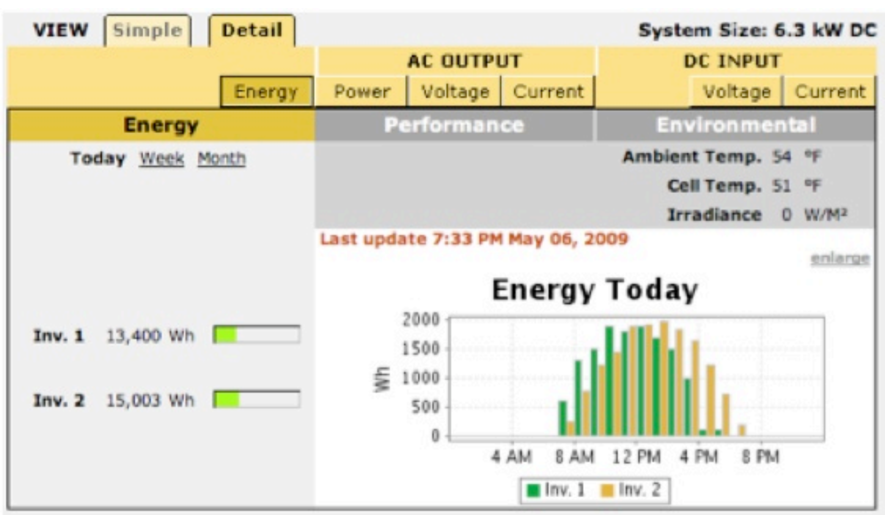
PV for Phases 1 & 2 came from diverse big-cap conglomerates, so unlike solar PV 'purer plays' their stock price hasn't been moved by the changing prospects for PV. (Phase 2 panels were 1999 surplus and donated by a university researcher). Unfortunately yet unavoidably, few pure-plays then existed to capture prospects for varying PV types. Since that time, many new pure-plays are now present across solar; increasingly they capture discrete prospects for instance in monocrystalline or multi solar, thin film, STEG, etc.

One lesson learned is we're surprisingly pleased with multicrystalline panels of Phase 2. Back in 2002 we'd had slight bias towards monocrystalline given higher efficiencies. But in a few short years, multi narrowed that gap. Now it achieves efficiencies greater than even the mono PV from just a few years ago.

Multicrystalline 2.8 kW, ground-mounted.

Relative performance is seen in the Chart below over a typical day in May. Compare ground-mounted multi-crystal PV Inverter 1 (green) – vs. the roof PV at Inverter 2 (orange) — their output isn't far different. In mornings the ground-mounted leads; the rooftop mono peaks a bit later. While rooftop mono makes 15 kWh — multi panels come close at 13 kWh (shading by a small growing tree is lately halting its output around 4 pm).

The roof panels are regrettably encumbered by unnecessary disadvantages. They're mounted at flat angle due to local height rules favoring sun late Summer and have a non-ideal orientation due to limited roof space. Those & other confounding variables conspire to fog comparisons, but a point is we're very pleased with both systems that total 6 kW:



Inv 1 (ground mount, green) vs Inv. 2 (roof, brown): 1-day.

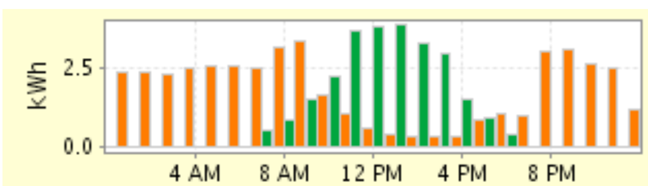
Importantly since the 2003 inception of this solar PV system, it has provided us about 24 kWh (kilowatt/hours) per day of electricity. That's roughly enough to meet needs of many a small business, or home. Do remember 24 kWh per day, it's an amount we here think of as "One Sun" and will be relevant with addition of our first electric car below.

It's also an average. We make for instance well over 25+ kWh on longer, typically sunny, and non-foggy days of late Summer & Fall. Conversely on shorter Winter days, or on any cloudy or foggy days, solar production will be very substantially less.

Consider next our billing period on TOU (Time of Use) metering is a 1-year annual basis — not monthly. So with grid essentially a battery, and a 1-year billing cycle, we can use greater power in late Summer/Fall to offset Winter shortfalls. As PV from day covers night use over 24 hours, surplus Summer & Fall carries the Winter year in and year out.

Practical Knowledge Gained from Adding an Electric Vehicle

Next, add in our exciting recent addition of a 2008 electric car. It's already very much loved here: clearly exceptional, great to drive, quick & lovely. Importantly too it uses our solar PV. Simply plug in and this car dovetails elegantly with our solar as in essence a sort of virtual 'solar EV'. We've also gained practical experience mating PV+EV. Consider first our energy-made (**green**) vs. our energy-used (**orange**) for a typical day in May:



Size & shape of solar energy *made* (**green**) is predictably as before— roughly a parabola that matches (no surprise!) the sunshine and these are the hours usefully utilities charge most. PV production hasn't changed at all, since an EV was added to the equation.

But now a height & shape of our energy *demand*, in **orange,** with EV is far different. We now consume a good deal more, although now it's mostly at night. The reason is simply that significant EV charging starts late and goes overnight until the battery is at full. After some driving the next day, recharging repeats the next evening.

That's seen in high 2+ kWh orange bars above left/right in May, charging at 120 volts. Adding one EV suddenly enlarged & shifted our energy-use, something to be mindful of when you're solar powered. (Plus in June 2009 we changed to charging at 240 volts — so the bars now get really high!) For our live data, http://wildershares.com/solar.php

On the other hand we're not paying for gas now — plus this particular EV has supercar performance and so not surprisingly a very big battery. This battery holds 54 kWh giving the car great speed and its good range, but therefore needs much (solar) 'juice'.

It's important to understand here that due to cooling and other losses charging, filling from empty actually takes about 68 kWh, or some 26% more than a 54 kWh it holds new. This latter **68 kWh** is a seminal amount here since it quantifies how much truly is needed; we'll use it to determine how far you can go from the power of the sun.

Crucially we do all our EV charging overnight because with Time Of Use (TOU) metering here the cost is, in 2009, ‘only’ 18 cents/kWh during the Off-peak hours at night.

By contrast On-peak rate is far higher, (now) 30 cents/kWh from 11 am-6 pm (weekdays) when our PV nicely makes and sells back surplus power from the sun, giving us a credit.

To charge overnight isn’t a sacrifice at all; we’d do that anyway. Moreover this car captures so many natural benefits of EVs. For instance it isn’t slow like a gasoline car, or “gasser”. Thus it isn’t ‘slow’ like, say, an average Porsche or BMW. Only the very fastest gassers are in its league or quicker, such as a fastest Turbo/GT Porsche, or Ferrari.

Better acceleration than most any gasser and far more fun to drive, with 100% torque and it doesn’t require maintenance of a gasser. All this, and you’re not dependent on vexing oil at all plus you can make your own clean fuel from sunlight to boot!

A ‘solar electric car’, in foreground.

For this, the first-ever production EV sold our fuel is PV – we just plug in. Plus we’ll add ‘more fuel’ of differing PV ahead, possibly with small windpower too. Contrast that with a gasser. There an only fuel is unlikely to make yourself-gasoline; yes, it’s energy-dense but finite, dirty, comes only from elsewhere and a gasser can’t go 10 feet without it.

On the other hand, lessons are being learned as well about real PV+EV limits today. For instance in the Chart above that charger turned on in evening: however this big battery could only be part-charged; it still ‘wants’ more time than TOU allows per night, since when drawing a maximum of 15 amps from the common 120V outlet, it’s just too slow. (There is an Optional wall mounted quick charger, but we do not have that here).

Picture this as moving water from a pond into a jug: a size of the tube matters. Pushing it through a narrow straw (120V outlet @15a) slows things; a wider tube is quicker.

We thus recently changed at where this EV is habitually parked, to a more robust 240V (@30 amps on a NEMA 14-50, 4 wire) connector. This dramatically shortens charge time; a depleted battery now fills in ‘just’ 8 hours max—rather than 24+. Because we never start with battery at zero, beginning at 10 pm means we always finish before 6 am.

Next, a measuring unit to help explain energy/time is ‘kilowatt/hour’, kWh. Elegantly it applies equally to energy made by our PV — or energy used in a building or car; 500 watts in 2 hours, 1,000 watts in 1 hour, or 2,000 watts in 30 minutes, each = 1 kWh.

Consider with our TOU rates, a kWh surplus power made On-peak is worth 1.6X per kWh used Off-peak, due to billing ratio of 30:18. Were *all* 24 kWh made On-peak 11 am-6 pm, leveraged 30:18, it's akin to receiving 41 kWh Off-peak. *But not quite all* is On-peak (graphs; weekdays) so we'll call it like being able to supply say, 30 kWh/day Off-peak.

What next is the Range for this car wanting 68 kWh (about 2 days of good sun)? To give an exact range is slippery, regardless of solar PV or not. Yes this fast car is impressively EPA rated at 244-mile range, *or* can go 0-60 in 3.9 seconds. Yet it can't go both far *and* fast.

To explain sit inside, turn the key, and you'll see 3 driving modes; we choose from two. Main default mode is 'Standard' and we most always use it. A second 'Range' mode allows for a bit more battery charging, but it slightly shortens battery life; we sometimes use it if we're going unusually far — but it slows the EV considerably so it's like driving a gasser. (A third Sports mode is for track-type performance and we don't use it).

Being so grin-inducing fast in Standard, there's no need for us to use anything else except occasional Range mode if we're going say, 200 miles or more on a single charge.

After turning the key in Standard, you see 'Ideal' range: it may start at say 195 miles — not the EPA rated 244 and so you 'lost range' being able to go fast in Standard. You're seeing only 80% of theoretical range partly for battery management. Charging to 90% in Standard prolongs life, with another 10% left in reserve also not shown onscreen.

Yet, likely range is even less. Temporarily you can switch from 'Ideal' to 'Estimated' range based on how you've driven recently. Estimated will give a still lower number.

In our experience typically driving to where state of charge shows about ½ 'tank' (or ½ charge) left, we've gone approximately 70-75 miles. Extrapolating and being conservative we normally expect some 140-miles of total range; that's without dipping into 10% Reserve and by driving only in the fast Standard that's so enjoyable.

Sample screen at battery ½ depleted.

So at ½ charge there may be around 71 Estimated miles left, or say 95 miles ideally. Driving mindfully ahead you could easily get greater than 71 miles or nearer 95 miles on remaining juice if you prefer to slow a bit, while Range mode could give more.

<u>Forget oily old MPG: We're getting 72 Miles Per day of Sunshine, or 72 MPS!</u>

OK, now to a key question: what's real-world range in this fast EV powered by sunshine? We suggest rephrasing the question: H*ow far does our 6 kW solar PV make this car go?* Recall we make 24 kWh in an average day; we call this 24 kWh in a day, 1 "Sun." Broken down over 24 hours, roughly *1 kWh is made per hour*; we call each kWh one "sol" — same as each kWh *used* by a building or car. Two hours is 2 kWh, or 2 sol, etc.

As will be shown we get about 3 miles range per kWh, or 3 miles/sol in this fast car.

A full 24 kWh/Day, means this car can be driven 72 Miles from each day of sunshine. Thus it has a range of 72 Miles Per day of Sun, or 72 MPS. Translating how far you go on stored sun power alone, and seeing that it's 72 Miles Per Sun (MPS), or 3 miles per sol (3 m/sol) may feel more intuitive and simply more elegant than oily old MPG. With its large battery, this car stores enough energy onboard to go 200+ miles from a few days' worth of sun.

Yet numbers used can dramatically impact calculations. For instance in Range mode you could get 240 miles from 68 kWh. That means going 240 miles on a charge from say 2 very strong days of Summer sun (TOU at 34 kWh/day Off peak x2). Or for one day, you can get 100+ Miles/Sun if mainly going at say 30-50 mph and so as 'slowly as a quick gasser'.

Going the other way, you might get only say, 15 Miles Per day of Sunshine (15 MPS) or less! Some days it's very cloudy with peak-measured irradiance under 100 W/M^2 or under 5 kWh all day. Phase 1 PV at only 2.5 kWh on one June day yields <5 kWh total. Cloudy or Winter days being much less productive, figures can go very low this other direction.

Consider too the energy made for this car, is in addition to meeting building demand. On many days PV isn't even able to meet building demand, so there's perhaps zero PV EV fuel some days. For purposes here we assume away the building demand in calculating MPS.

Yet we will watch cloudy &Winter days over a year, to see how PV meets actual demand with EV ahead. Probably more PV kW (maybe wind too) will go in as Phases 3/4 ahead.

Solar is more changeable than 24 kWh/day (or 30+/day Off-peak due to *when* sol are made), however for simplicity sake we've kept 1 Sun constant. Yet a 2nd major variable is *energy expended* in driving. That's keenly influenced by *how*, & *where* we drive an EV.

We'd estimate our average use is 330 Wh/mile after charging losses and reckon as follows. On local streets and mainly going 30-50 mph this EV expends relatively little energy. We often see 250 Wh/mile or less, so 1 sol (kWh) from battery before charging losses gives 4 miles. But add in more 60 mph speeds, and we'll then spend say 270 Wh/mile (Ex. 1).

Add in fast freeway miles and consumption rises to say 300 Wh/mile (Ex. 2). We don't drive freeways much, but with either that and/or some good strong & fun acceleration, costs at battery swiftly go above 0.300 sol/mi; efficiency drops quickly at higher speeds.

Example 1, 0.270 kWh/mile typically spent in 30-50 mph stop & go traffic.

Example 2, add in some highway miles and We can spend say, 0.301 kWh/mile or more.

Much fast acceleration or 80+mph driving pushes it to 350+, so speed is a big variable. In sum our own driving mix is mostly local & probably near/under 280 wh/mile overall; subtract a bit for our Range/distance at times and we likely see a bit under 270 wh/mile average. With 270 and adding a 26% charging loss takes us to 0.330 kWh/mi, so we get roughly 3 miles range per kWh, or 3 miles/sol. The EV manufacturer's data are here.

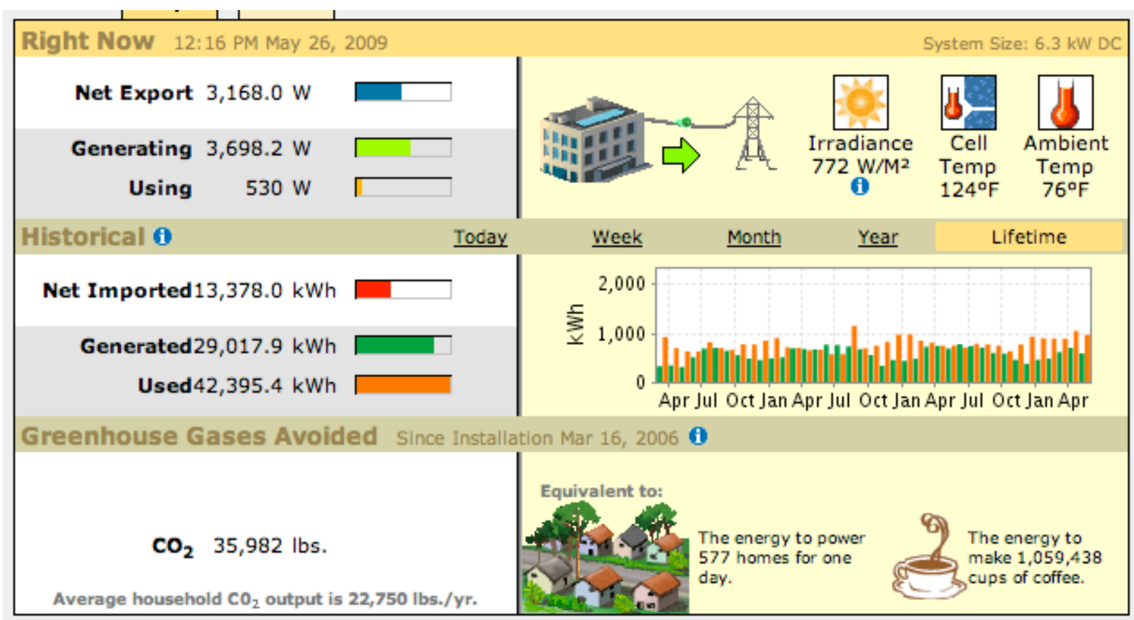
Generating 'our own sol' makes us better aware of building demand. Similarly, an eye to demand behind the wheel yields noticeably more range in an EV, than a gasser. This isn't bad *per se*, especially since this EV is simply so better than a gasser. Or we could just forget that EV speed penalty, but sometimes to drive this EV for its range is fun too.

For instance we hardly touch brakes because regenerative braking slows us down while making electrons to boot. So just lift off the 'gas' and this car slows itself, particularly from higher speeds when inertia briefly puts say 30 kW 'back in tank'. This creates a smoother more satisfying ride and it makes you aware how archaic the gassers are, heating brakes to arrest momentum while putting zero fuel back in tank for the effort!

Since you've spent the electrons getting going in a first place, to recapture some by regenerative braking is an item bought & paid for already — you're just being efficient.

Back to PV/EV nexus, we'd estimated PV payback in about 10 years. Now with 5¾ years of solar power under our belt, we're seeing that's about right. Total Phase 1 PV had cost us $15,511 (California's generous subsidies back in 2003 nicely cut our price paid in half).

Since 2003, and based on hard live data from our 2nd monitoring system since March 2006, a back-of-the-envelope review shows we're now about 55% to payback. We expect payback for Phase 1 solar in 2013, having made at least $15,511+ of power by then:



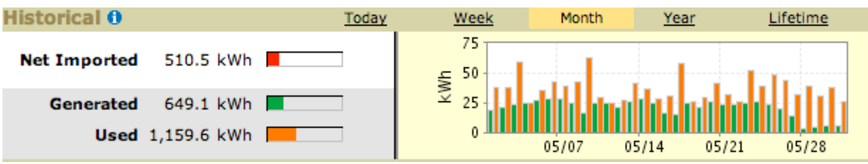
29,000 kWh was ***generated*** *& measured since a 2nd PV monitoring was installed in 2006 (left). For this sample sunny On-peak moment (left, top), Irradiance is a sunny 772 W/M^2; our PV is making 3,698 Watts,* ***demand*** *that moment is 530 Watts, and 3,167 Watts is being exported.*

And our payback might be better still. We'd looked only at a payback for our *electricity* — a complex problem but self-contained one. Now that we also avoid buying *gasoline*, that is a vital 2nd factor accelerating payback. (Gas costs were roughly double electricity alone). We haven't missed going to gas stations at all … it's said the stone-age didn't end because we ran out of stones … elegant solar PV+EV just feels like a solution at hand.

The combination PV+EV works, but there's clearly limits on both sides of the "+".

So this combination of PV+EV works, although we've found limits on both sides of the "+". For instance this car is very thirsty; we're suddenly consuming much more PV than before in powering just a building. Rather than PV meeting fully 100% of a smaller demand pie as before, now the demand pie is bigger. About 30% of greater need is going into the EV, and some 70% is going into the building. There's no free lunch, even with solar.

How well has 6 kW of PV coped? Over a cloudy May, the demand from both building & EV was 1,160 sol (kWh) — yet in that overcast month PV made only 650 sol. That sounds a huge shortfall, but TOU leverage at say, 30:18 almost covers it. But for 4 socked-in foggy days month-end seen below, PV+TOU would have covered bigger combined demand.



650 kWh PV in May becomes like 1,000 sol due to TOU--almost matching 1,160 used.

So clearly not enough watts was made directly head to head. Yet TOU boost means 650 sol made On-peak is like delivering 1,000 sol Off-peak, just short of running building & car together! It's actually more complicated, given some building demand (but not car) is On-peak, weekends etc but this is the basic story. Of 1,160 sol used May, building needed 810 sol or some 70% of total, and car needed 350 sol or 30% (after charging losses).

The EV used 279 kWh in May, or 350 after losses. Note 57 kWh of regen added range.

Seen another way, let's say this building uses 25 sol/day average, much of it Off-peak. Solar PV making 24 sol/day nearly covers it straight — it does so easily with TOU making it more like 30+ sol/day. But add an electric car ... if we drive that 20-30 miles/day and get 3 miles per kWh, we'll call added demand 15 sol/day (that's all Off-peak at least). Now we need say 40 sol/day, with about 70% of that demand from a building, and 30% coming from EV, falling a bit short of how much is being made even with TOU.

We're adding 2 EVs ahead too, so any new PV needed shall be very costly upfront. Yet where in the world does gas go to zero $ — as does the PV for EVs? Plus with TOU it's like gas costing $3/gallon by day wonderfully goes on sale @$1.80 at night. So PV systems even bigger than 6 kW may become the norm once EVs grow in use — lowering costs for solar & wind too. The baselines for 'enough' dispatched kWh PV/wind, might expand with EVs.

Both are immature; modern PV is only a few years old, while modern EVs are quite new. For EVs a limit is batteries. Today's batteries are surprisingly basic, given EVs were vetted a century ago. But after being mocked or ignored, a few seminal EVs have proven wrong the conventional wisdom that they're all slow as golf carts, with just <20-mile range and must look like a science fair project. Myths shattered, a battery race is clearly on.

A century ago, buyers of gassers were made aware their fuel was toxic and flammable, their cars required gears (stick or now automatic) because of inefficient gas engines, and frequent oil changes were mandatory. All of that holds true for the gassers of today, though we the public over time have pretty much assumed those gasser limits away.

Similarly there are limits to EVs too, but just different ones. EV batteries in particular, should be better understood so there are no surprises. Take an EPA rated 244-mile range. Yes if you're willing to drive this superb car slow as a gasser (Range mode), at certain speeds (much more efficient around 30-60 mph) and are OK impacting battery life by 100% fills — then you'll get 244 miles on today's battery. That just needs to be understood.

Plus the passage of time makes all worse, since batteries age. Unbranded commodity batteries of 2009 decline by cycling and calendar-age, so performance degrades without mercy. This applies too to a 54 kWh figure (we've seen figures of 54 and 55 kWh, so use 54 here). But not to paint an overly pessimistic picture, the battery in this 2008 Roadster is up to snuff and notably came with a free, long-term warranty giving us peace of mind.

So we expect this battery to deliver very good to acceptable performance at least for 5 years or 100,000 miles, guessing we might see roughly say, 70% left after years of use. Very importantly too battery technologies improve, so this should get much better.

It feels as if many interesting steps are lately being taken here. For instance one report showed experimental lithium sulphur with possibly higher energy density (Nature Materials, 2460). An EV balances power (kW) for going fast, with energy density (kW/hr) to go far; new chemistries may improve both. Or imagine a new supercapacitor/battery hybridization; Nature subsequently reported interesting "off-stoichiometry" (reactants/products in unbalanced reaction) using LiFePO4, lithium iron phosphate.

Don't let this above obscure a key point: this EV is superbly capable at any speed. Without needing future battery *unobtainium* (something great if it existed today, but doesn't), this Roadster is already catalyzing a global move to EVs. Expect to see numerous new electric and hybrid cars emerge. ***<u>Now it's all about bringing down costs!</u>***

Looking to a bridging ahead, some concepts for new electrics find an analogy in gassers. For instance, we noted this car gets 72 "MPS"; that range per sun is a bit like MPG in gasoline cars. But unlike oily old MPG, MPS is clean, renewable and abundant. This car also has a big 68 kWh battery and so can go 240 miles per charge, the battery is like – but not as limiting, as a gas tank in a gasser. EV batteries are getting better, extending range ahead unlike fixed capacity in a fuel tank that can only be filled with 'rock oil'- gas.

This EV Roadster accelerates quicker than *almost any* gasser, save a few special cars like say quickest Ferraris, or a Turbo Porsche. But consider instead of 0-60 mph, a look at driving enjoyment. Arguably here this EV Roadster beats *every single* gasser. With its 100% available torque, no gears, and unmatched driving feel, it's perhaps second to none.

Forget oily old MPG. Faster, better cars that are sun-guzzlers, that make use of abundant clean sunshine and finally break the bonds of oil to boot, are the better solution.