The Ravina Project

PV And E-Cars 05

E-car Energy Compensation using PV Generation

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PV and E-Cars

Introduction

We went to the auto show just recently here in Toronto to take a look at the all electric cars or e-cars as we will call them in this paper. We were pleasantly surprised by what we saw. We looked at four all electric vehicles: Mitsubishi MIEV, Ford Focus, Mercedes-Benz Smart Car and the Nissan Leaf. We use the term e-car rather than the more generic EV because we are focused on electrically powered Town Cars. The term EV encompasses everything from golf carts to electrically powered sports cars to delivery vans and the like.

Given all the generation data we have recorded, we thought it would be interesting to use the data we have gathered on the e-cars and combine it with our generation data to attempt to answer a few questions.

The Questions

1. Is it possible to generate all the energy we use in an e-car such that the operation of the e-car is totally net carbon free?

2. Given our household usage of electrical power, what additional net load would an e-car place upon the Grid?

3. Is it possible to calculate the carbon offset the solar panels produce if they provide the vehicle with 100% clean energy used in its operation?

4. Based upon our household data is it possible to scale our findings up so that we can make an approximate estimation of the additional net load placed upon a local utility by the use of e-cars?

5. What are the costs of e-car operation with and without a solar array?

Our Assumptions

For the purposes of this paper we will make the following assumptions:

- Every Watt we generate from our 1,500 Watt solar array displaces Grid power we would have used. Since there is no other electrical power source for our household we believe this assumption is valid.
- We can treat the Grid as an energy bank in the sense that we can make energy deposits to it or withdraw energy from it.
- Displaced Grid Watt-hours become our deposits to the Grid energy bank.
- If we run an energy deficit for a period of time, we have used more Grid energy than what we have generated during that same period of time.
- Our generated energy is 100% carbon free.

- We can ‘apply’ our generated energy to any device such that we can generate an energy balance sheet between that device and the generator. For instance, we can monitor the energy used by the toaster over a period of time. We can derive an energy balance sheet between the toaster and the generator.
- The e-car’s battery can be completely discharged in order to get maximum amount of km from the battery.
- There is no degradation in the e-car’s battery such that the number of km driven per kWh of battery charge does not decrease over time.
- All references to the term ‘battery’ in this paper references batteries that are rechargeable like the battery within an e-car. One time use or disposable “batteries” will not be referenced.

E-cars

The first thing we have to do in the paper is to establish what e-car we are talking about. We find conveniently, that the specifications of the four e-cars we have data on, fall into rather neat ranges. The capacity of the on-board batteries ranges from a low of 16 kWh to a high of 23 kWh. The distance one can drive using a full charge ranges from a low of 112 km to a high of 160 km. Note that cold weather reduces the amount of energy available in an e-car’s battery. Hot surroundings, like slow traffic in mid summer with almost melting asphalt underneath, limit the rate at which the batteries can be discharged.

This data provides us with a range per charge from high to low and a range of battery capacities from high to low. This gives us our error ranges such that with any of these e-cars their true performance will fall into these ranges.

Just as the efficiency metric ‘miles per gallon’ driven is used for carbon energy based cars, the e-car can be evaluated by the metric ‘kilometers per kilowatt-hour’ used or km/kWh. This metric describes the e-car’s efficiency at getting from point A to point B.

E-car Make	Battery size	low range	high range	low km/kWh	hi km/kWh
	kWh	km	km		
MIEV	16	120	136	7.5	8.5
Leaf	23	140	160	6.1	7.0
Focus	23	140	160	6.1	7.0
Smart Electric	16.5	112	128	6.8	7.8
			Range	**6.1 - 7.5**	**7.0 - 8.5**

Both ranges are about 1.5 km/kWh in breadth. The ranges overlap by 0.5 km/kWh. Later on in the paper we will provide some graphics which use 6.1 km/kWh and 8.5 km/kWh in a range that would encompass all four e-cars mentioned in the paper.

Generation Data

We are located at: 43.68 N and 79.34 W.

The Ravina Project consists of several related projects. One of these projects attempts through data collection, to describe the household's thermodynamics as completely as possible. The data are agnostic as to what devices use the energy. An e-car, from the point of view of the data, is just another energy consumer like our toaster.

The Ravina Project is in its fifth year. We have more than 48 months of continuous daily data, that is we have four Januaries through four Decembers. We can look at and make a dataset of our daily data by the month, by the season or by the year or any other way we wish to segment our data. One could characterize our data as being of a rather high fidelity.

Demographics

North America and Australia have an interesting demographic inversion (bulge) called the Baby Boom generation. Over the next 15 years or so many of these people will chose to retire. They will down size into smaller premises and they may even chose to down size their vehicle.

It is our opinion here at The Ravina Project that many people will chose to purchase an e-car for their retirement years. For many it will be the ideal 'town car'. An above zero centigrade daily range of 120 km makes for a flexible daily schedule. Low maintenance costs, high gasoline prices and an overnight charge-up will make an e-car the ideal choice. Trips and long distance driving can be tackled by a rental car.

Who knows, companies like Zipcar ™ may offer discounts to e-car users who only use a carbon powered car on a very occasional basis.

Battery

We see a lot of e-car batteries being attached to the Grid in the next 15 years.

What is a battery?

A battery is, at its most fundamental level, like a chameleon, that is, it changes its function depending upon its environment. When a battery is located in an environment which needs more generation capacity, it becomes a generator. If the environment has too much generation capacity, the battery can provide a load to try to neutralize the excess.

A battery is a really useful device which has many different implementations. Some use compressed air, water, chemicals, and fuel among other media to maintain their functionality. I like the idea of burning / creating fuel energy in a closed system … creating fuel when the battery is acting as a load and burning that same fuel when the battery is acting as a generator.

Think of a water splitter and fuel cell working with a pool of high purity water between them. The water both becomes the waste created when fuel is consumed and raw material for the creation of more fuel.

E-cars use chemical batteries. Energy is stored in chemical charges and released when chemical bonds are formed.

The Grid

With the influx of a huge demographic into the ‘retirement’ lifestyle over the next 15 years, and the possibility of many e-car purchases, the demands placed upon the Grid could be substantial. What we hope to do with this paper is to graft an e-car onto our household statistics to demonstrate the affects of owning an e-car might have upon our local Grid.

The Questions

Is it possible to generate all the energy we use in an e-car such that the operation of the e-car is totally net carbon free?

Let’s tackle this question by using a budgetary approach. Because we want carbon free operation, our driving range budget for the e-car is determined by how much energy we harvest using our solar panels. Most, but not all, North American Grids have some carbon component to Grid power generation. So, in order to be sure we operate the e-car net carbon free we will have to generate all the energy the e-car uses.

As discussed above we have an energy/range profile set up for the e-cars. They fall into the two overlapping ranges when assessed for the number of km they can travel per kWh of storage: 6.1 – 7.5 and 7.0 – 8.5. We will use these ranges to make our calculations.

Firstly, let’s examine our daily generation data on a yearly basis and calculate what kinds of ranges we are limited to.

Consider the following chart:

Yearly km Budget for E-cars					
Year	**Generation**	**Low Range**	**Low Range**	**High Range**	**High Range**
	total in kWh	**Minimum**	**Maximum**	**Minimum**	**Maximum**
2007	1603.4	9780.7	12025.5	11223.8	13628.9
2008	1630.0	9943.0	12225.0	11410.0	13855.0
2009	1693.8	10332.2	12703.5	11856.6	14397.3
2010	1675.4	10219.9	12565.5	11727.8	14240.9
km per week		193.6	238.1	222.2	269.8
Number of charges/week		1.4	2.0	1.6	2.0

Let's unpack the numbers. The generation totals are real generation numbers for the years based upon the total of our daily generation readings from our 1,500 Watt, 12 square meter solar array of 12.5% PV panels. From the chart above we have taken the minimum and maximum of the low and high ranges for the e-cars listed above.

We can see that at a minimum the lowest number of km we can drive is 9,780.7 in 2007 if we generate all the energy used in the car and the e-car is performing at the lowest efficiency, that is, the lowest km per kWh all year long. Of course this is not the case except for a situation where the e-car was located in a cold climate all year long. Normally the summer months would provide enough heat that the batteries would have a cooling problem and not a heating problem. That low number corresponds to an average of 193.6 km a week. No effort has been made to account for changed driving habits according to the season.

Speaking of seasons what do these numbers look like if we could break out the driving budget according to the months of the year?

Consider the following chart:

Monthly Generation Totals In kWh

	2007	2008	2009	2010
January	69.9	66.4	89.4	71.9
February	107.7	91.7	114.6	77.2
March	134.7	154.8	167.2	157.8
April	123.4	196.4	175.9	198.7
May	215.4	187.0	215.9	204.4
June	218.9	173.3	187.3	182.3
July	193.2	197.9	173.6	212.5
August	182.4	170.5	176.7	183.9
September	161.9	134.6	162.3	123.2
October	87.8	124.9	73.4	109.7
November	70.5	75.0	92.5	96.6
December	37.6	57.5	65.0	57.2
Total:	**1603.4**	**1630.0**	**1693.8**	**1675.4**

This chart is pretty straightforward. We have 4 years of data broken out by months.

Let's turn these numbers into range numbers so we can see how much driving we can do if we want a zero balance for our net energy budget with the Grid on a monthly basis instead of an annual basis.

Consider the following chart:

Monthly km budget using low range minimum of 6.1 km/kWh

	2007	2008	2009	2010
January	426.4	405.0	545.3	438.59
February	657.0	559.4	699.1	470.92
March	821.7	944.3	1019.9	962.58
April	752.7	1198.0	1073.0	1212.07
May	1313.9	1140.7	1317.0	1246.84
June	1335.3	1057.1	1142.5	1112.03
July	1178.5	1207.2	1059.0	1296.25
August	1112.6	1040.1	1077.9	1121.79
September	987.6	821.1	990.0	751.52
October	535.6	761.9	447.7	669.17
November	430.1	457.5	564.3	589.26
December	229.4	350.8	396.5	348.92

As you can see based upon the e-car's worst battery efficiency we are limited to about 230 km for the whole month during December of 2007. During many months we are limited to a monthly ration of over 1000 km. There are 20 of the 48 months (41.6%) where we are limited to 1000 km or more driving kilometers. This is the bottom end of the range into which most of the e-cars will fall. What is the top end?

Consider the following chart:

Monthly km budget using high range maximum of 8.5 km/kWh

	2007	2008	2009	2010
January	594.2	564.4	759.9	611.2
February	915.5	779.5	974.1	656.2
March	1145.0	1315.8	1421.2	1341.3
April	1048.9	1669.4	1495.2	1689.0
May	1830.9	1589.5	1835.2	1737.4
June	1860.7	1473.1	1592.1	1549.6
July	1642.2	1682.2	1475.6	1806.3
August	1550.4	1449.3	1502.0	1563.2
September	1376.2	1144.1	1379.6	1047.2
October	746.3	1061.7	623.9	932.5
November	599.3	637.5	786.3	821.1
December	319.6	488.8	552.5	486.2

This looks quite different.

Of the 48 months we have 29 months (60.4%) where we can drive over 1000 km.

There you have it, a minimum and maximum number of km we can drive our e-car and cover our energy use totally from our solar panels. Note that this calculation is across 4 models of e-cars. We have seen the specifications for the Volvo E-30. They seem to be well within these limits. The low range minimum supports our driving range requirements.

Our answer to the question is: Yes, we can ensure that our e-car is operating totally net carbon free.

What happens to our driving km budget when we upgrade our solar array from the older 12.5% panels to modern 20% panels?

Consider the following chart:

Yearly km Budget for E-cars with modern 20% solar panels

Year	Generation total in kWh	Low Range Minimum	Low Range Maximum	High Range Minimum	High Range Maximum
2007	2672.3	16301.2	20042.5	18706.3	22714.8
2008	2716.7	16571.7	20375.0	19016.7	23091.7
2009	2823.0	17220.3	21172.5	19761.0	23995.5
2010	2792.3	17033.2	20942.5	19546.3	23734.8

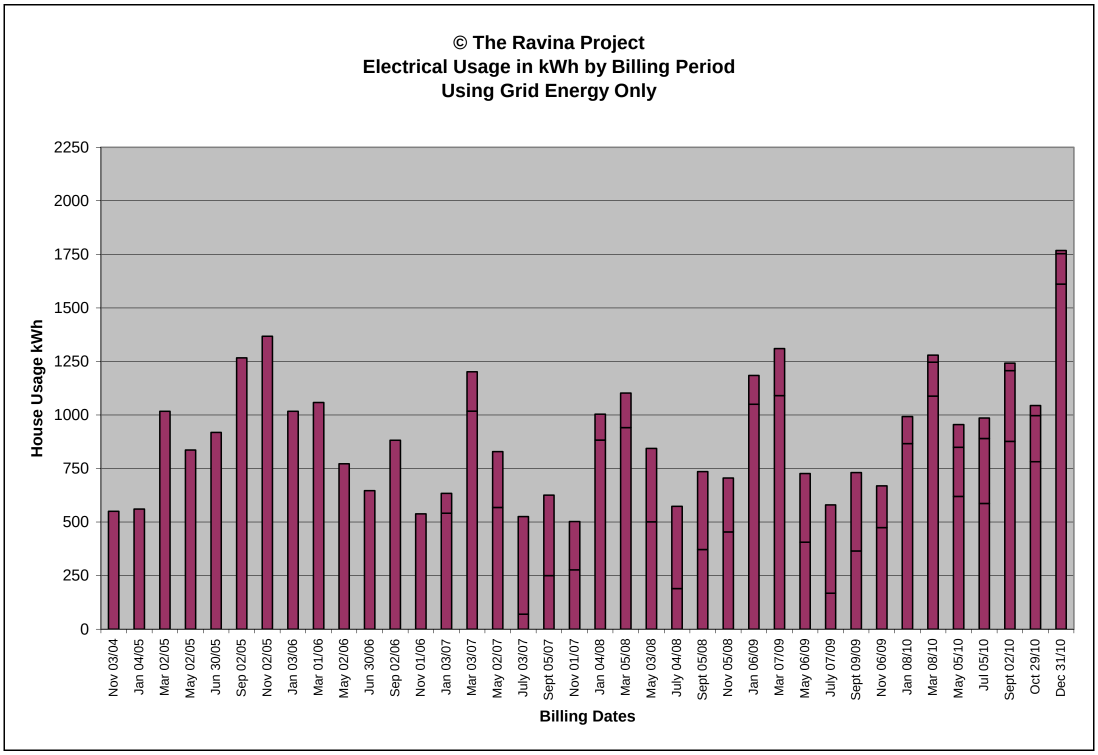
km per week	322.7	396.8	370.3	449.7
Number of charges/week	2.3	2.8	2.6	3.2

We see for the first time the e-car range capabilities to support a 50 km round trip to work each day plus lots left over for weekend and evening errands a busy family might require.

The e-car has, combined with the above energy harvesting ability, left the realm of a retired couple running errands and entered the mainstream work place.

Given our household usage of electrical power, what additional net load would an e-car place upon the Grid?

All electrically powered devices in our household would, without our solar array, get their power solely from the Grid. For the purposes of this paper our actual energy usage chart has been modified to show our Grid energy usage if we assume we have no solar panels, that is, we get all our power from the Grid. The length of each bar below corresponds to our total usage of Grid electrical energy for that billing period going back to September 2004.

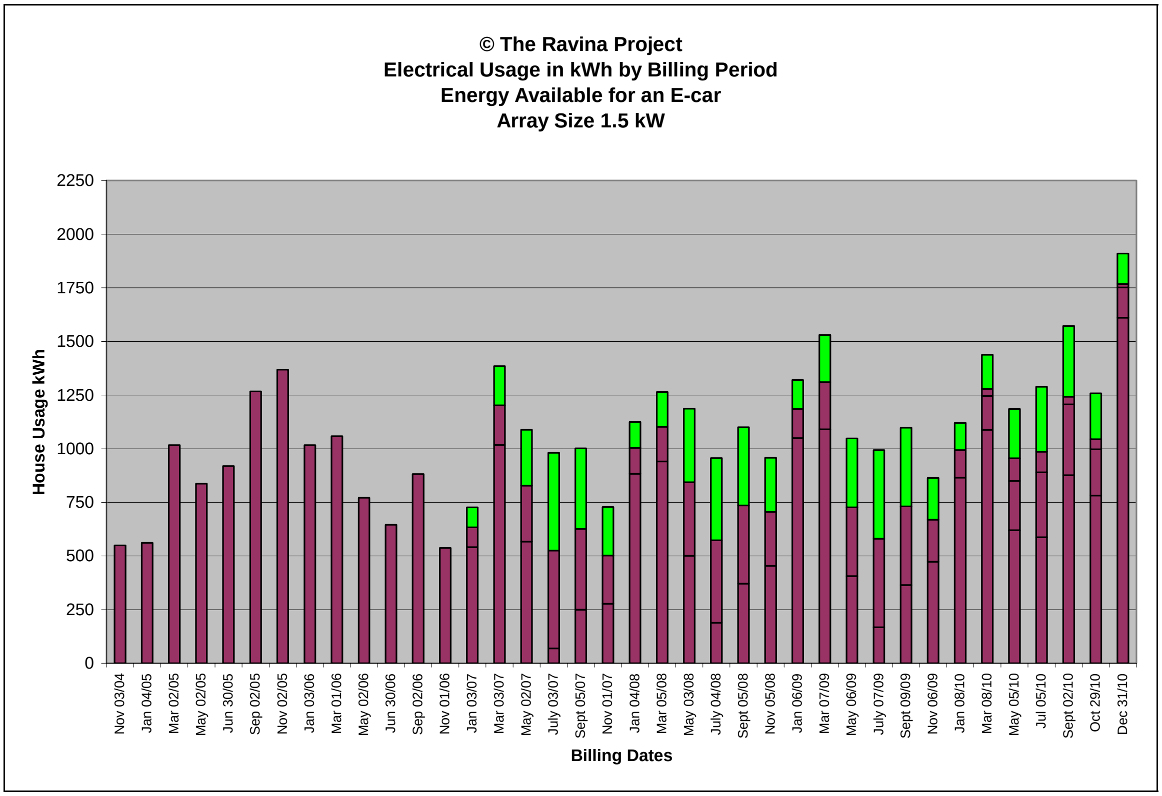


In short, this chart represents our historical load upon the Grid broken out by billing period if we had no solar panels.

We constructed it to provide us with a baseline for the argument below.

Suppose now we add in extra energy identical to the energy we generated per billing period. However, we dedicate this extra energy to the e-car and not the household.

Consider the following Graphic:



All the green parts of the columns correspond to the amount of clean energy we generated and since we want the e-car's operation to be both net Grid energy neutral and carbon free, the green part of each column represent the clean energy available for the e-car. In energy accounting terms the green areas are the energy budget available for the e-car during each billing cycle. However, from another perspective these green areas represent the extra load placed upon the Grid by an e-car if we had no generation capacity.

In fact, the extra load placed upon the Grid by an e-car, if we consumed this energy, but had no generation facility, would be:

Year	**Extra Grid Load kWh**
2007	1603.4
2008	1630.0
2009	1693.8
2010	1675.4

Is it possible to calculate the carbon offset the solar panels produce if they provide the vehicle with 100% clean energy used in its operation?

This calculation can be tricky.

On one hand the utility may generate Grid power using various levels of carbon during a 24 hour period. Base load carbon generation by the utility may be quite different than the amount produced during peak load. Some places in North America have no carbon based Grid power generation no matter what the time of day. Other places generate all their Grid power by coal, the most carbon intensive method for power generation.

Here in Toronto we generate about 25% of our Grid power from carbon sources.

But there is a catch to this calculation. The e-car is replacing a carbon fuelled car of about equal weight and size and both have similar carbon footprints when they are manufactured. The e-car does not use any more carbon in its operation and does not use any net Grid energy. The carbon use equivalent offset of the e-car is the sum of the carbon offset from the Grid power generators and the carbon used by a similar carbon fueled vehicle. Whatever the actual numbers: the algorithm is total offset equals Grid carbon plus gasoline carbon. With the Smart Car there are two different versions on the same chassis. The electric version is heavier, interestingly enough.

Bottom line, yes it is possible to calculate the total carbon offset the panels provide.

Based upon our household data is it possible to scale our findings up so that we can make an approximate estimation of the additional net load placed upon a local utility by the use of e-cars?

As we have seen, using solar panels is a good way of offsetting the load placed upon the local utility by an e-car. According to our assumptions, even a modest 12 square meter array of modern high efficiency solar panels can offset much if not all of the energy required to run an e-car for a year. There would be no additional net load placed upon the Grid.

If we scale up our household's transportation requirement we can support our e-car entirely from our generation capacity. No matter how many times we are duplicated across the local Grid, they would use little in the way of net Grid positive load over time.

From our calculations above, 1000 e-cars would place an extra yearly load of between 1,603 MWh and 1,693 MWh upon the Grid if they were driven within our energy budget described above and there was no clean power generation offsetting the energy they would use.

What are the costs of e-car operation with and without a solar array?

We were limited in our energy budget by the generation capacity of the solar array over time. When we cost out this energy we must cost out the same amount as what we have generated. A net Grid neutral e-car operation would cost nothing.

Consider the following chart:

Totals for Electricity			
Days			1,587
kWh billed			18,545
Total Billed		$	2,711.37
cost per kWh	$		0.15
kWh/day			11.69
Billed per day	**$**		**1.71**

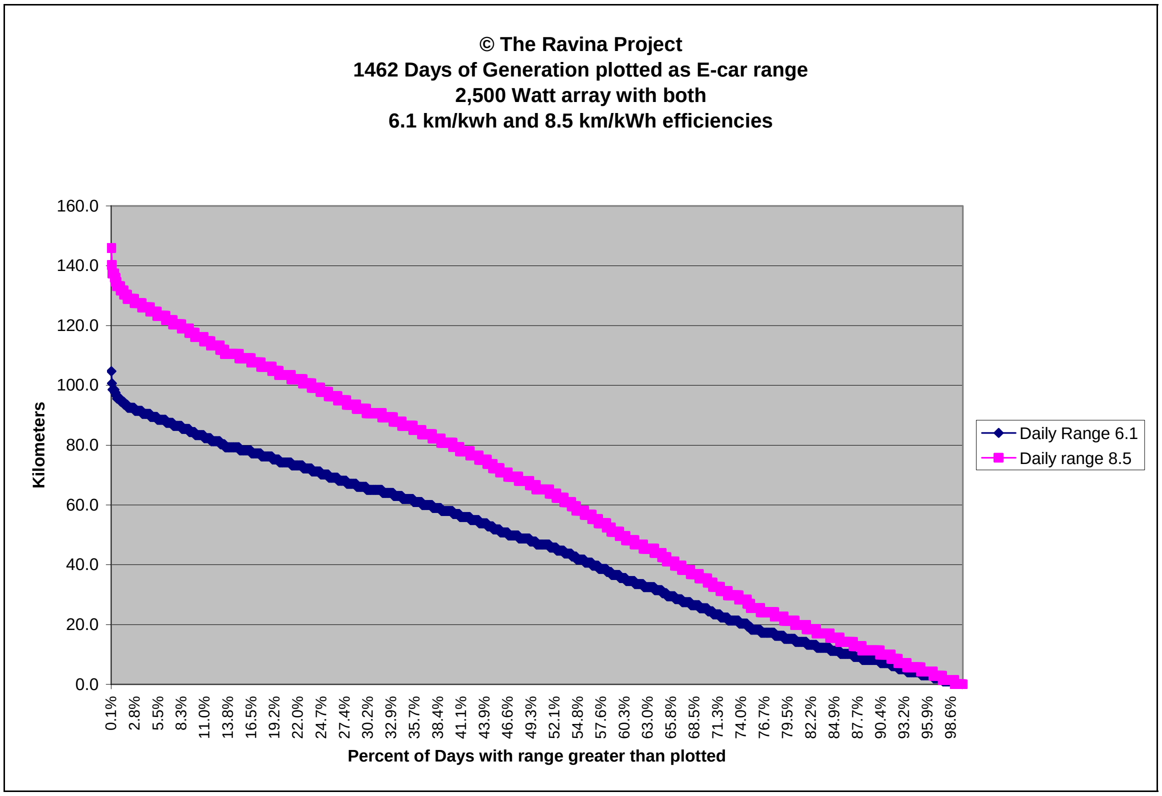
Our 'no solar panel' operational energy costs will be $ 0.15 times the total amount of kWh we have generated over the last 4 years.

Our e-car energy cost without solar panels but on the same energy budget, comes out to: 6,602.6 kWh times $ 0.15 per kWh equals $990.39 over 4 years.

Some Other discussion using our data

Let's play with the data and see what kinds of insights we can find.

Consider the Graphic below.



We assume we have upgraded our array to 2,500 Watts, generated 4 years of data and calculated the range we could drive the next day based upon the amount we generate on any given day. On day 1 we generate 'x' amount of energy. On day 2 we translate this energy into our driving range budget for that day. The results are placed upon the graphic above for the two efficiency ranges, 6.1 and 8.5 km/kWh.

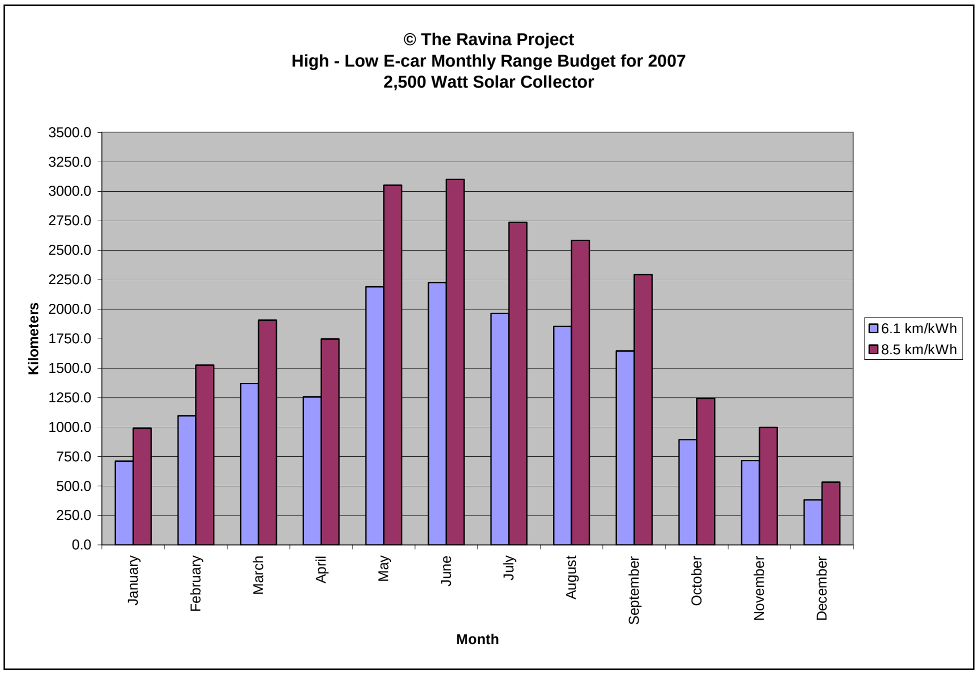
Notice our assumptions have changed somewhat. There is no Grid available, just panels and the e-car. It's a closed system.

The above graph is read along the bottom. Look at the percentages in conjunction with looking at the daily km to be driven. For example, we want to complete a 40 km round trip to work and back every day using our e-car. We look at the graph, find the 40 km line and follow it across until it meets the first graphed line. In this case it will meet the line that graphs the efficiency of 6.1 kilometers per kilowatt-hour. Once that intersection is found a glance to the bottom will read off the percentage possibility that a round trip of length 40 km is possible. It looks like it's around 55 percent of the time the e-car at this efficiency will have been charged enough the previous day to take us on a 40 km trip.

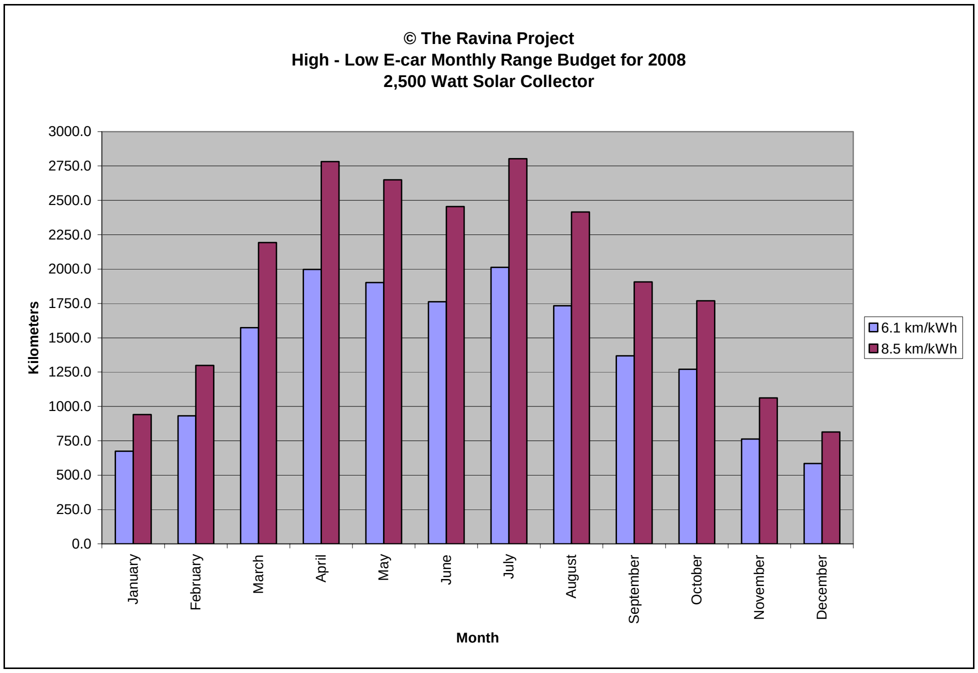
Note that this first reading is based upon the lowest efficiency in our range. If we follow over 40 km until we reach the other curve, we notice that the percentage of days which can support the same trip has increased to about 65.

The following are a series of graphics that break out the range budget by month and e-car efficiency. This is actual data for the year extrapolated via a constant ratio of 5/3. We turn energy collected by a 1,500 array into the amount collected with a 2,500 Watt array. The e-car range we have available each month from generation is set out for the years below.

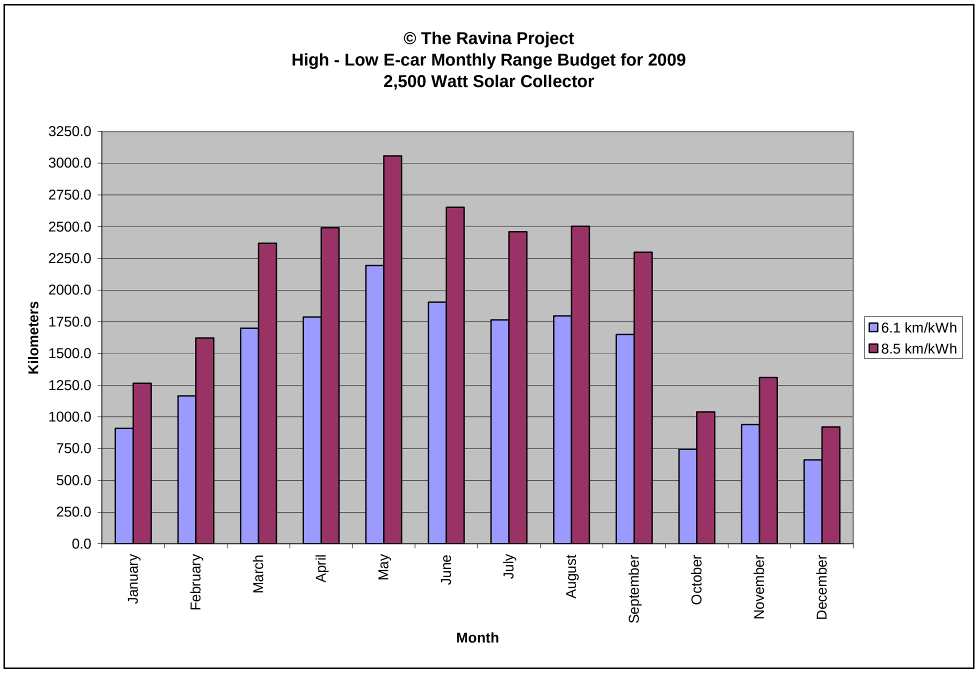
2007



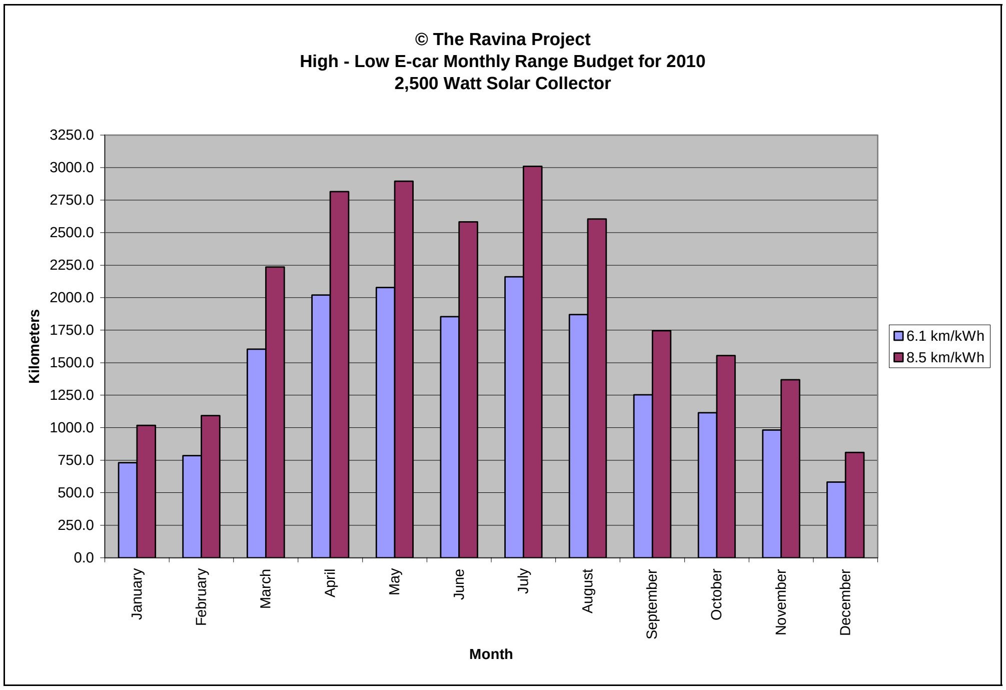
2008


© The Ravina Project
High - Low E-car Monthly Range Budget for 2008
2,500 Watt Solar Collector
Kilometers
3000.0
2750.0
2500.0
2250.0
2000.0
1750.0
1500.0
1250.0
1000.0
750.0
500.0
250.0
0.0
January
February
March
April
May
June
July
August
September
October
November
December
Month
6.1 km/kWh
8.5 km/kWh

2009


© The Ravina Project
High - Low E-car Monthly Range Budget for 2009
2,500 Watt Solar Collector
Kilometers
3250.0
3000.0
2750.0
2500.0
2250.0
2000.0
1750.0
1500.0
1250.0
1000.0
750.0
500.0
250.0
0.0
January
February
March
April
May
June
July
August
September
October
November
December
Month
6.1 km/kWh
8.5 km/kWh

2010



There are some interesting problems when envisioning how such an isolated system might work. Since both energy consumption and generation in this system proceed through time, there are temporally induced dynamics that become apparent. That is, time introduces rates which can be applied to both generation and load. And further, time introduces the constriction of simultaneity. The time constriction is demonstrated by the fact that when the generator is generating power the car must be parked and loading that power. For best efficiency, the e-car usage is restricted to those times when the generator is not generating power or the e-car's battery is full and can't be further charged. Night driving anyone?

These two cases demonstrate that much precious harvested energy will be wasted. Firstly, many times the e-car is being used when there is power being generated and secondly, when the e-car's battery is full. In both these cases time is not our friend but works against us.

What we need in this system is a device that will reduce or completely eliminate the constrictions placed upon us by time. We need a device that stands between the generator and the e-car, and absorbs generated energy even if the e-car's battery is full or if the e-car is being driven. We need that device to have the ability to dump its energy into the e-car on demand when the e-car returns to its charge stand.

With such a device inserted into our closed system the e-car and PV generator can work together very efficiently with little energy wasted.

Such a device would do well at a Condominium charging stand where the Condo's roof top panels charge a small fleet of shared e-cars that are used by Condo owners for trips around town.

The following charts show the actual numbers used in the graphics above.

Monthly km budget using low range minimum of 6.1 km/kWh

	2007	2008	2009	2010
January	710.7	675.1	908.9	731.0
February	1095.0	932.3	1165.1	784.9
March	1369.5	1573.8	1699.9	1604.3
April	1254.6	1996.7	1788.3	2020.1
May	2189.9	1901.2	2195.0	2078.1
June	2225.5	1761.9	1904.2	1853.4
July	1964.2	2012.0	1764.9	2160.4
August	1854.4	1733.4	1796.5	1869.7
September	1646.0	1368.4	1650.1	1252.5
October	892.6	1269.8	746.2	1115.3
November	716.8	762.5	940.4	982.1
December	382.3	584.6	660.8	581.5

Monthly km budget using high range maximum of 8.5 km/kWh

	2007	2008	2009	2010
January	990.3	940.7	1266.5	1018.6
February	1525.8	1299.1	1623.5	1093.7
March	1908.3	2193.0	2368.7	2235.5
April	1748.2	2782.3	2491.9	2814.9
May	3051.5	2649.2	3058.6	2895.7
June	3101.1	2455.1	2653.4	2582.6
July	2737.0	2803.6	2459.3	3010.4
August	2584.0	2415.4	2503.3	2605.3
September	2293.6	1906.8	2299.3	1745.3
October	1243.8	1769.4	1039.8	1554.1
November	998.8	1062.5	1310.4	1368.5
December	532.7	814.6	920.8	810.3

The above argues that our current 12 square meters of solar PV can generate enough energy to cover off the energy use by a retired couple like us.

And further, an upgraded 12 square meters of panels can support a 50 km daily round trip to work (monthly distance of 1,000 km) using little if any net Grid energy on a yearly basis.

When it comes to roof tops, 12 square meters is a very small roof area yet very large when it comes to providing transportation energy.

Conclusions the Recommendations

We see the use of e-cars in a carbon abatement program in the following set of layered approaches:

Roll out e-cars which use Grid power for their charge.

The abatement program in this situation is held hostage by the carbon emitted by the Grid utility. An e-car using 100% Grid power generated by coal is not clean and is not abating anything. The Grid load may be too much for the existing infrastructure. As more cars are connected the extra load may increase faster than Grid upgrades making the Grid less reliable. However, the introduction of e-cars into an area may reduce carbon pollution if the Grid carbon produced per kWh is less than that produced by a similar carbon fuel based car.

Roll out e-cars to existing generators for use in a net Grid usage configuration.

What's different in this case is an attempt has been made to offset the use of Grid power by using a clean power generator. Existing generators get e-cars to integrate with their solar panels or wind turbines or the like. The Grid becomes the energy bank account as discussed above. Only the net Grid power used over and above the generated clean power counts towards an assessment of the e-car's carbon footprint. For many times of the year, the e-car's operation is carbon free and for other times its carbon footprint is very small.

Roll out e-cars with a generation system in a package.

In this case the e-car is sold with a package of technologies that ensure that all power is used to charge the e-car, charge a storage battery or if there is no room for more storage, and pump the excess energy back to the Grid. In this case the first user of the generated energy is the e-car. Under this configuration, the Grid is used only as an overflow (one way) valve when too much energy is produced. Since no energy comes into the system from the Grid then the e-car's operation is truly carbon free. The Grid experiences no extra load. In an emergency the e-car has a charge even if the Grid is down in the area.

The household technology we use, has allowed up to experience the security of not having to rely on the Grid. Our household has, for all intents and purposes, its own uninterruptible Power supply. Depending on the time of year it could take days for us to know that the Grid was down just based upon the availability of electrical power. We see an included option to the package described where the system can be placed in a special mode where its collected and stored energy is made available to the household through an inverter to provide emergency household power when the Gird disappears. It's a 'nice to have' extra.

Battery Technology Development

All through this paper we have mentioned this missing piece, the battery. It is vital to any well designed system that reduces losses, wastage and reduces time constriction to zero. We need a cheap battery technology that can cover the charge of the e-car so that it has enough charge to completely re-charge the e-car. This battery, what ever its technology will be vital to this type of system and all others that must break the chains of time constriction to be efficient.

Condo Developments with e-car spaces built in

We see Condos with generation on roofs and charging stations at the ground floor or in the garage for a fleet of e-cars. Many retirement communities have already a fleet of golf carts that the owners drive. The e-cars would be communally owned, charged and used as Town Cars.

E-car solar panels

All e-cars sold must have built-in generation capability in their roofs. Even 100 watts or so of power adds up on a long trip across town or in stop and go traffic, or even when the vehicle is parked. A sun drenched four hour park producing 100 Watts translates into an extra 3.4 km range using 8.5 km/kWh as an efficiency.

E-car owners to get special treatment

- Companies like Zipcar ™ would develop usage plans for e-car owners that would acknowledge the fact that the Zipcar ™ vehicle would only be used very occasionally.
- Toll roads and automobile congestion tolls in the center parts of large cities would exclude e-cars from the tolls.
- Downtown parking would be free at special parking spaces for e-cars which have built-in charging stands operated with a swipe of a debit card.
- Traditional rental car companies may have special rates for e-car owners.
- E-car owners may get a break on the license fees or other fees / taxes that owners of carbon powered vehicles have to pay.

Project Futures

The Ravina Project lives and dies by numbers. We have created and continue to create high fidelity databases documenting all aspects of our household thermodynamics.

We have a good idea of the energy the e-car would consume but that is somewhat speculative. We love hard numbers rather than extrapolated numbers. It is our goal to get an e-car, drive it, and meter it for at least 3 years. We will publish a series of papers on what we have found. We see this as adding to the existing science / engineering on the matter by being able to do a unique bit of research via data collection.

We look forward to any thoughts or ideas regarding how we might obtain a test e-car for our work.

"If we knew what we were doing, it would not be called research."
- A. Einstein

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