Are Electric Vehicles Actually Cost-Effective?

A recent analysis of the effect of federal tax credits on the purchase of electric vehicles indicates that even the largest tax credit now available is only marginally effective. More realistic assumptions, however, yield a very different and more positive result.

by Robert McCullough

On Tuesday, September 20, 2012, the Congressional Budget Office released a detailed analysis of plug in hybrid and all electric vehicles entitled "Effects of Federal Tax Credits for the Purchase of Electric Vehicles."[1] The basic conclusion of the report was that the current economics of the majority of plug in hybrids and electric vehicles were not cost-effective even considering the current tax credit of as much as $7,500 per vehicle. According to the CBO, even after the tax credit, most plug in hybrids and all electric vehicles fail the cost effectiveness test at even much higher levels. These results seem counterintuitive.

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[1] Congressional Budget Office, *Effects of Federal Tax Credits for the Purchase of Electric Vehicles* (Sept. 20, 2012), hereinafter cited as "CBO Report," available at http://www.cbo.gov/sites/default/files/cbofiles/attachments/09-20-12-ElectricVehicles_0.pdf

I. The CBO report's questionable assumptions

The report states in part:

> "At current vehicle and energy prices, the lifetime costs to consumers of an electric vehicle are generally higher than those of a conventional vehicle or traditional hybrid vehicle of similar size and performance, even with the tax credits, which can be as much as $7,500 per vehicle. That conclusion takes into account both the higher purchase price of an electric vehicle and the lower fuel costs over the vehicle's life. For example, an average plug-in hybrid vehicle with a battery capacity of 16 kilowatt-hours would be eligible for the maximum tax credit. However, that vehicle would require a tax credit of more than $12,000 to have roughly the same lifetime costs as a comparable conventional or traditional hybrid vehicle."[2]

If correct, this would be daunting news for the electric industry. The industry's already poor system load factor, down to 45 percent in 2009 – and the rapid growth of renewables – primarily wind – has stressed off-peak operations in many parts of the U.S.[3] Since wind generation is often off-peak, it is difficult to reduce traditional generation elsewhere on the system sufficiently to avoid over-generation. Given that we have few cost-effective storage alternatives for electricity, a rapid growth of electric vehicles – which have the advantage of using off-peak energy copiously for charging, as well as potentially providing services to the grid – would offset the worsening problem of off-peak generation.

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A close reading of the CBO report, however, indicates that several assumptions tend to drive its result. The report makes no attempt to minimize the importance of these assumptions, but it fails to present a case that would seem closer to current market realities. Replacing the report's assumptions with values closer to current market values changes the results dramatically. In fact, using more realistic assumptions, plug-in hybrids and electric vehicles are shown to be cost-effective across most battery sizes using CBO battery cost estimates. For example, plug-in hybrids and electric vehicles are cost-effective across all battery sizes using market prices from Tesla.

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[2] CBO Report summary at http://www.cbo.gov/publication/43576.

[3] On-peak generation from wind is also a problem. Since wind generation is most typically during off-peak hours, it is often a small contributor to on-peak supply. Thus EVs and PHEVs, which can charge most cost-effectively off-peak at a discounted rate, could contribute to flattening load factor and using the system more efficiently.

CBO's pivotal and determinative assumptions were these:

1. The real discount rate: The report uses 10% and conducts sensitivities at 5% and 20%. Financing for a new car currently stands at 1% real.
2. The report assumes that the cost of electricity is 12 cents/kWh.[4] The implicit assumption is that the vehicles will not be fueled during off-peak periods. This seems an odd assumption, given the significant on-peak/off-peak price differentials in the industry. It also assumes a refueling scenario in which drivers are willing to wait for long periods during day-time refueling.
3. The price of gasoline was assumed to be $3.60/gallon. Prices have been significantly higher than that recently in most parts of the U.S. and could soon go higher still, as large developing economies in Brazil, China, and India produce a growing class of drivers and greater global demand for refined petroleum fuel.
4. The report assumed limited lifetime travel miles for electric vehicles due to recharging requirements. This questionable assumption tends to diminish EV's money-saving potential – and value – to avoid costlier and more polluting gasoline. Logically, buyers of all-electric vehicles would select the most efficient vehicle for their needs. Urban dwellers would accept a lower range while a rancher in Montana would choose another type of vehicle. The assumed daily average use of an electric vehicle in the CBO's study – 21 miles -- seems considerably lower than data in the 2009 National Household Survey.[5],[6]
5. The assumed battery prices are high – considerably higher than current offers from Tesla.[7] The CBO study assumes that batteries will cost $570/kWh.[8] Tesla's batteries are currently offered at $500/kWh.

A. The Discount Rate

The most important assumption in many economic studies is the discount rate. This standard economic tool allows us to compare costs and benefits that occur in different years. For example, lotteries often offer a "lump sum" option in which winners you can receive 50% of the lottery winnings paid immediately, instead of getting a specified amount paid year by year. To compare these two options, you would discount the stream of future winnings by a discount rate. The payment at the end of year one would be the payment divided by one plus the discount rate. The payment at the end of year two would be divided

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[4] U.S. average residential rates vary widely. As a general rule, only California, Texas **[??]**, New York, and New England have average rates as high as 12 cents/kWh. In most states with time of use tariffs, off-peak rates are considerably lower than average rates.

[5] CBO Report at 32.

[6] http://www.solarjourneyusa.com/EVdistanceAnalysis7.php

[7] http://www.teslamotors.com/models/options

[8] CBO Report at 29. The CBO assumes $950/kWh for hybrids and $570/kWh for all electric vehicles.

by one plus the discount rate to make it equivalent to year one and then divided by one plus the discount rate again to make it equivalent to an immediate payment. This calculation can be extended far into the future. Winnings received 20 years in the future would be deeply discounted, divided by the one-plus-discount rate factor twenty times.

The selection of discount rate is generally based on the cost of capital. For most of us, this is the interest rate charged by the local bank for a loan. The real cost of capital is the cost of capital reduced by expected inflation. A standard source for expected inflation is the value used in the U.S. Federal Budget – approximately 2% over the next seven years.[9]

At the moment, the real cost of capital to a car-buying consumer is very low – approximately 1.0% for a six year financing.[10] Thus the ten percent real discount rate assumption in the CBO study is approximately ten times the current market based discount rate. In defense of this high value, the CBO cites several studies estimating high consumer discount rates from the last decade.[11] There are many reasons to question the assumption and the studies cited. Suffice it to say that they depend on data before the current recession when interest rates and consumer opportunity costs were very different. It is also worth considering whether consumer perceptions of the viability of new energy-efficient vehicles are affected by recent positive experience with hybrids.

Example No. 1: The Plug-in Hybrid Electric Vehicle

The CBO's basic arithmetic of electric vehicles is very straightforward. The CBO compares the annual cost of an electric vehicle's battery with the differential in fuel costs between gasoline at $3.60/gallon and 25 miles per gallon fuel efficiency – 14.4 cents per mile – with the cost of electricity at 4 cents per mile.[12]

The consumer's decision is to weigh the additional costs of the battery and electric generator against the annual savings of using electricity instead of gasoline. If the consumer can borrow at 1.0% real, for instance, the annual cost of his 4 kWh battery and generator is $950/kWh x 4 kWh + $4,000 for the generator - $2,500 for the tax credit. This comes to $5,300. Financed at 10% real the real annual payment is $746.13.

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[9] 2013 U.S. Federal Budget at 244. The inflation rate is forecasted as 1.9% in 2013, increasing to 2.1% by 2016.

[10] Advantis Credit Union, Portland, Oregon, Sept. 28, 2012, quoted 3% for a new car loan. With an inflation rate of 1.8 percent, the real rate is 1.2 percent.

[11] See, e.g., David L. Greene, John German, and Mark A. Delucchi, *Fuel Economy: The Case for Market Failure*, in Daniel Sperling and James S. Cannon, eds., REDUCING CLIMATE IMPACTS IN THE TRANSPORTATION SECTOR (Springer, 2009).

[12] This assumes purchasing electricity at the average U.S. retail rate and 3 miles range per kWh of battery. Since most recharging is likely to be off-peak and at an off-peak rate, the actual cost for electricity is likely to be much lower that 4 cents per mile, perhaps one-third or one-quarter of the CBO-assumed 4 cent value.

The consumer's savings come from two areas. First, his first 12 miles per day will be fueled using electricity with a 10.4 cents per mile advantage. After the first twelve miles, the consumer gets the benefits of a hybrid's better economy on acceleration and its ability to store energy while braking. Even with CBO's assumptions, a plug-in hybrid will save the consumer $206.77 a year.[13]

If the consumer's discount rate is tied to the cost of borrowing, however, the situation changes dramatically. At a 1% real discount rate, the annual cost of the battery decreases to $436.80 and savings increase to $516.10 a year.[14]

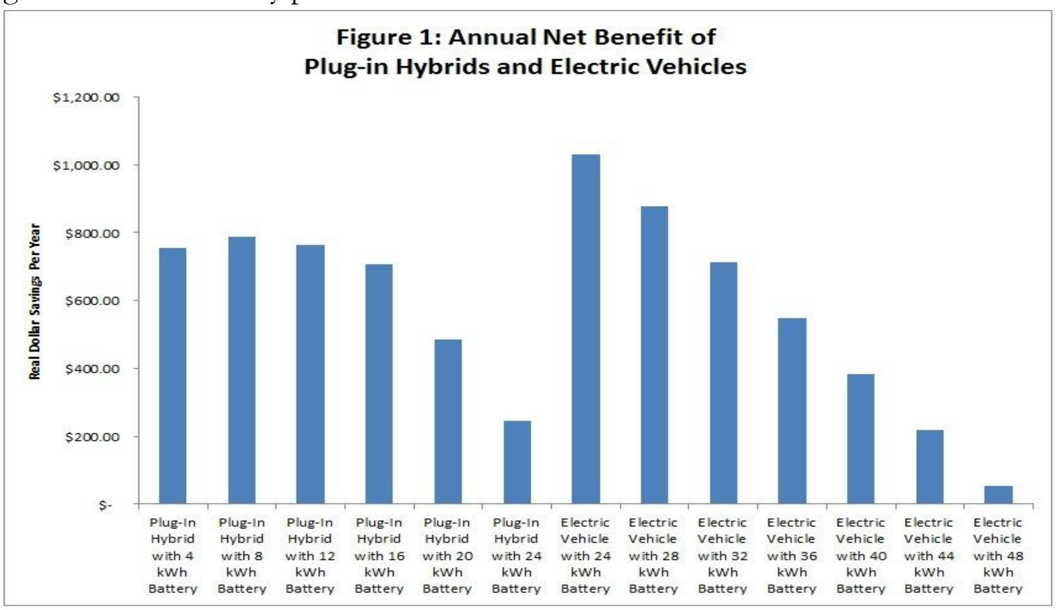
Example No. 2: The All-Electric Vehicle with a 24 kWh Battery

Another alternative is to buy an all-electric vehicle. An electric vehicle with a 24 kWh battery adds $8,580 to the cost of the vehicle after the tax credit. At 10% this would cost $1,207.88 per year. This almost, but not quite, breaks even. At a 1% real financing cost, however, the benefits are quite significant – $481.09 a year, increasing gradually with inflation.

Obviously, the discount rate is the pivotal assumption.

B. Net Benefits of Plug-in Hybrids and Electric Vehicles

Figure 1 shows the annual net benefits of plug-in hybrids and electric vehicles over a wide range of battery sizes. This assumes battery pricing from Tesla, as well as more realistic gasoline and electricity prices. The discount rate is assumed to be 1%.

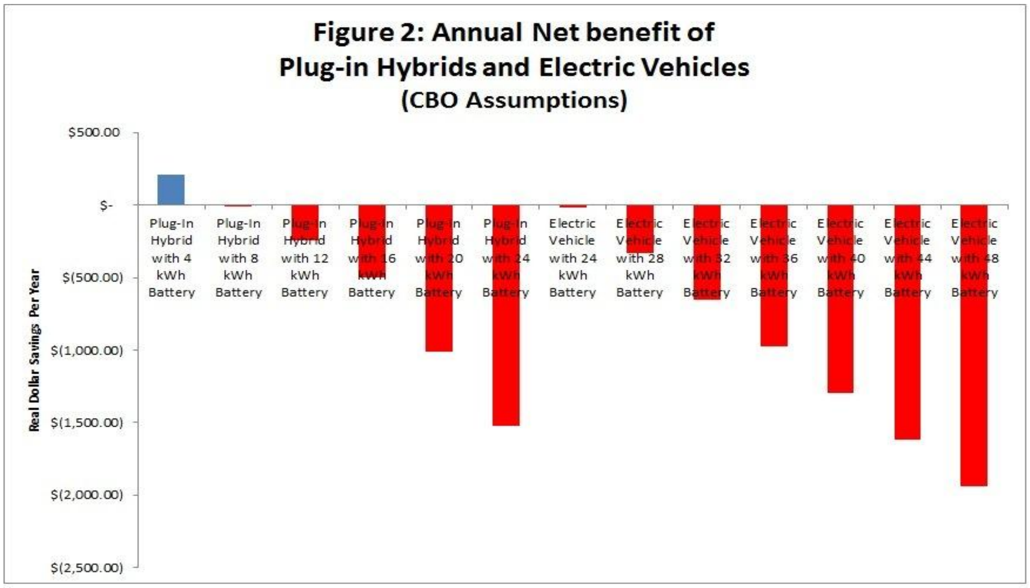


[13] Gasoline cost is for 11,500 miles per year at 25 miles per gallon with a gasoline price of $3.60/gallon. The cost of electricity for the first twelve miles per day is only $156.12. Miles per gallon for the remainder of the annual mileage is 50 miles per gallon.

[14] The difference between a real 1% rate and the CBO's real 10% rate is significant -- $398.34 per year at 1% and $746.13 at 10%,

Larger batteries are not always optimal for the consumer unless the vehicle is going to be driven longer distances on an ongoing basis.

The extreme discount rate in the CBO study, shown in **Figure 2**, effectively presupposes the question of cost effectiveness:



A better description of the economics of plug-in hybrids and electric vehicles is that the size of the battery – and the range of the vehicle on a single charge – may be the deciding factor for most consumers. Shorter range plug-in hybrids and all-electric vehicles are more attractive than gasoline fueled vehicles at shorter ranges, but are not more cost effective a longer ranges.

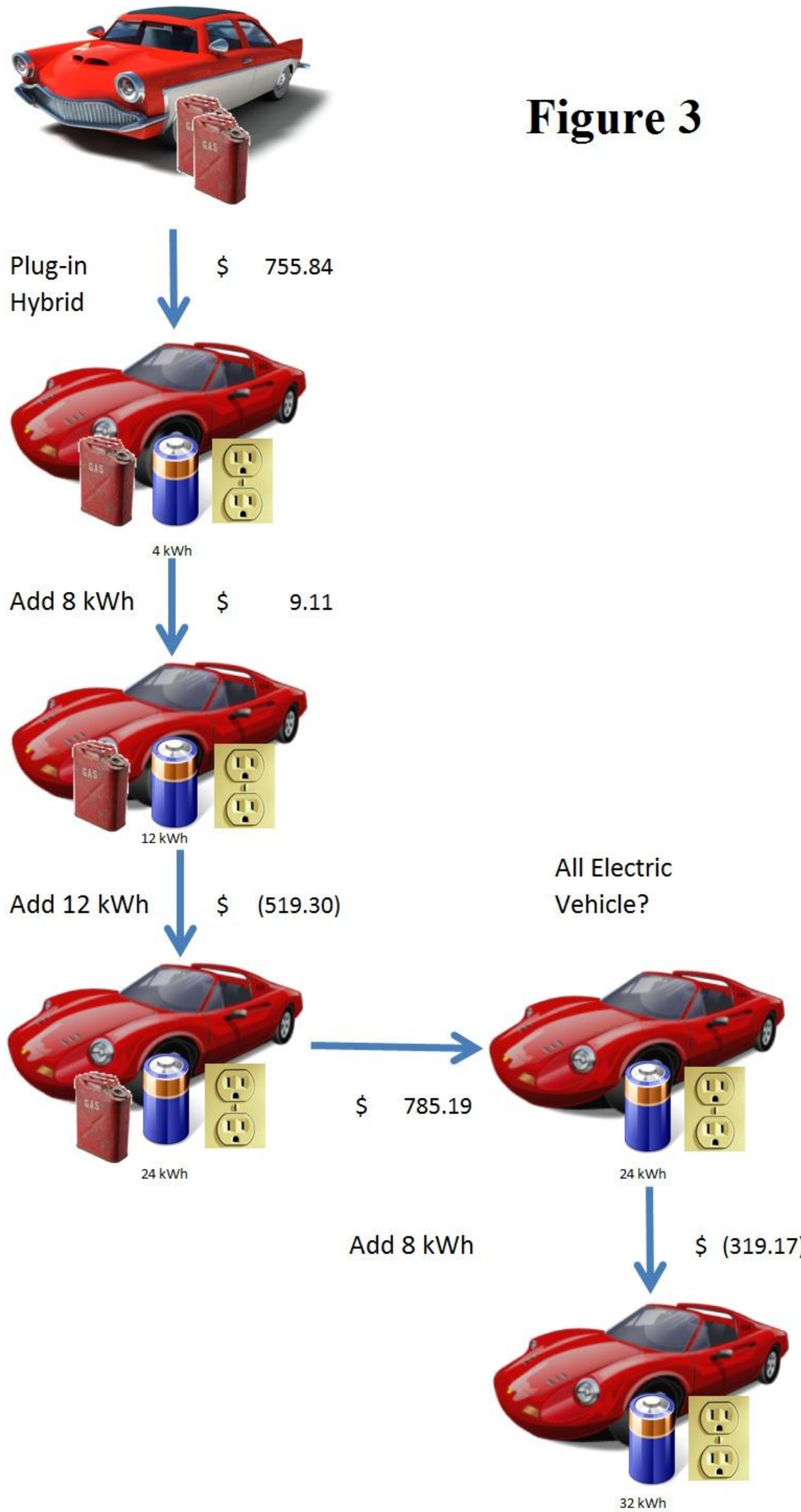
Figure 3 on page 7 illustrates the consumer's set of decisions as he or she moves from petroleum to electricity as a fuel.

As we see, adding additional batteries is favorable, although only marginally. Moving from 4 kWh to 12 kWh increases the range of the vehicle using electricity to 36 miles. Adding more storage actually loses money, since the cost of the battery is not always recovered across longer daily trips.

At 24 kWh, the consumer is well advised to shift to an all-electric vehicle and eliminate the use of gasoline and the costly gasoline engine altogether. The problem will be the question of convenience. A 24 kWh battery provides 72 miles of range or much more, for a well-equipped all-electric like the Nissan Leaf. For trips longer than 72 miles, the consumer will have to use another vehicle or add additional battery kWh. Since the tax credit is "used up" at 24 kWh, the consumer's value of convenience must be weighed against additional cost.

The following chart uses a 1% real discount rate, $4.00 gasoline, $.06/kWh electricity, and assumes that the electric vehicle will be driven up to its range on electricity and then another vehicle – fueled by electricity – will be used for longer trips.

Figure 3


Plug-in
Hybrid
$ 755.84
4 kWh
Add 8 kWh
$ 9.11
12 kWh
Add 12 kWh
$ (519.30)
All Electric
Vehicle?
24 kWh
$ 785.19
24 kWh
Add 8 kWh
$ (319.17)
32 kWh

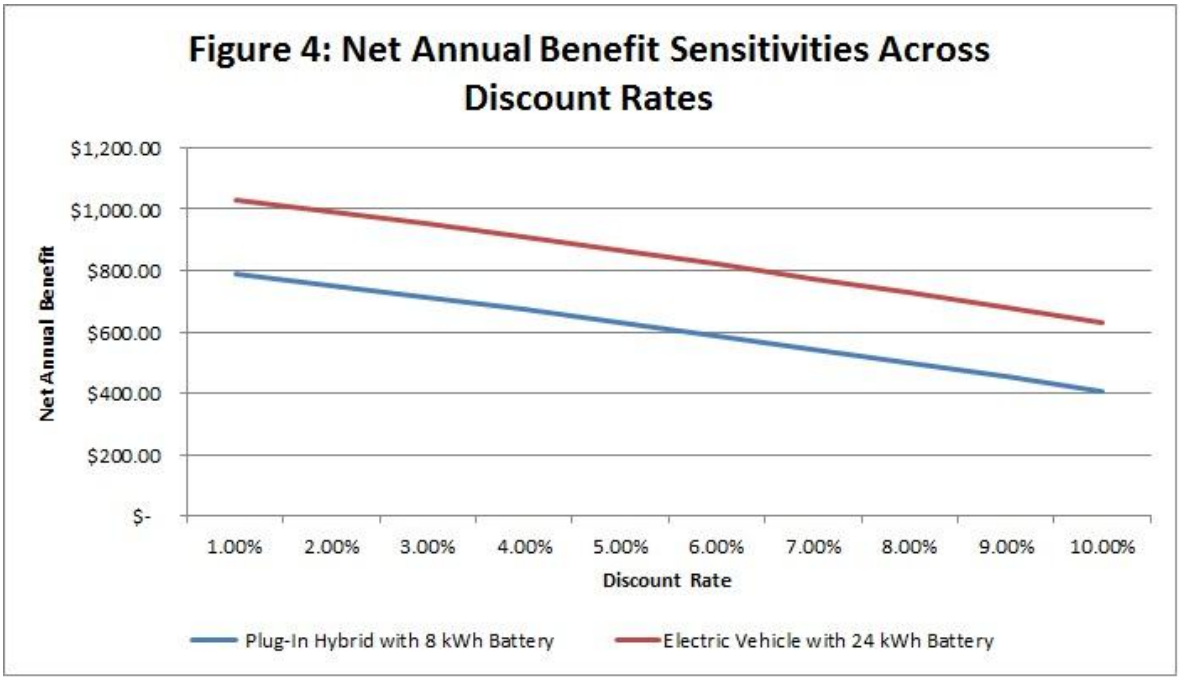
II. Sensitivities

Our results differ sharply from the CBO's, primarily due to the use of a more realistic discount rate, as the following four figures show.

A. Discount rate

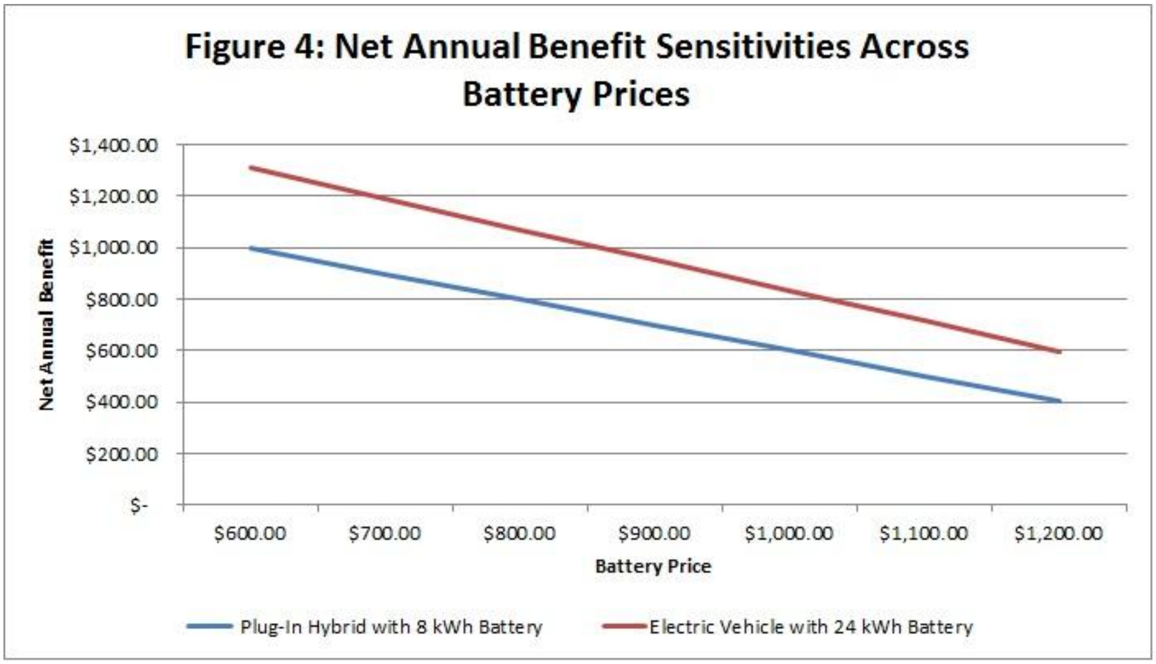
Assuming a 10% real discount rate rapidly discounts future fuel savings and wipes out most projected savings.

The following chart shows the annual net benefit for the best choices -- an 8 kWh plug-in hybrid and a 24 kWh electric vehicle – across a range of discount rates:



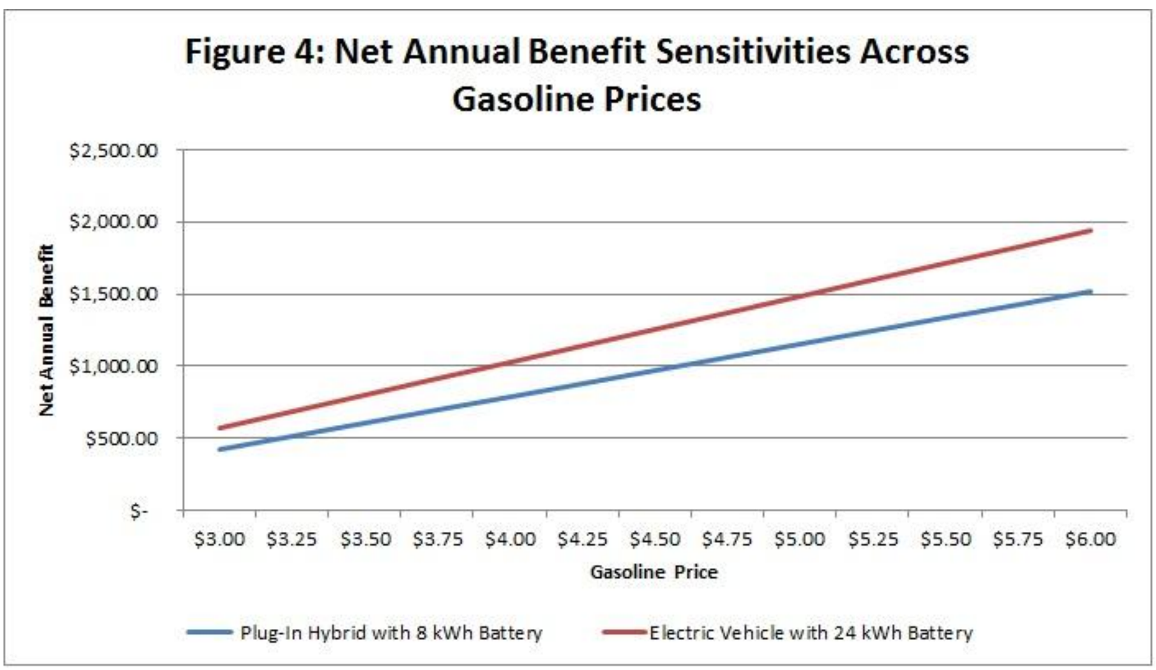
B. Battery cost

The next most important assumption involves the cost of batteries. The CBO's battery pricing would also appear to be high compared to the prices offered on the Tesla. Although the Tesla prices are speculative – Tesla deliveries are just starting – they are market prices as opposed to estimates. Tesla offers battery upgrades from 40 kWh to 60 kWh for $10,000 – about$500/kWh.



C. Gasoline prices

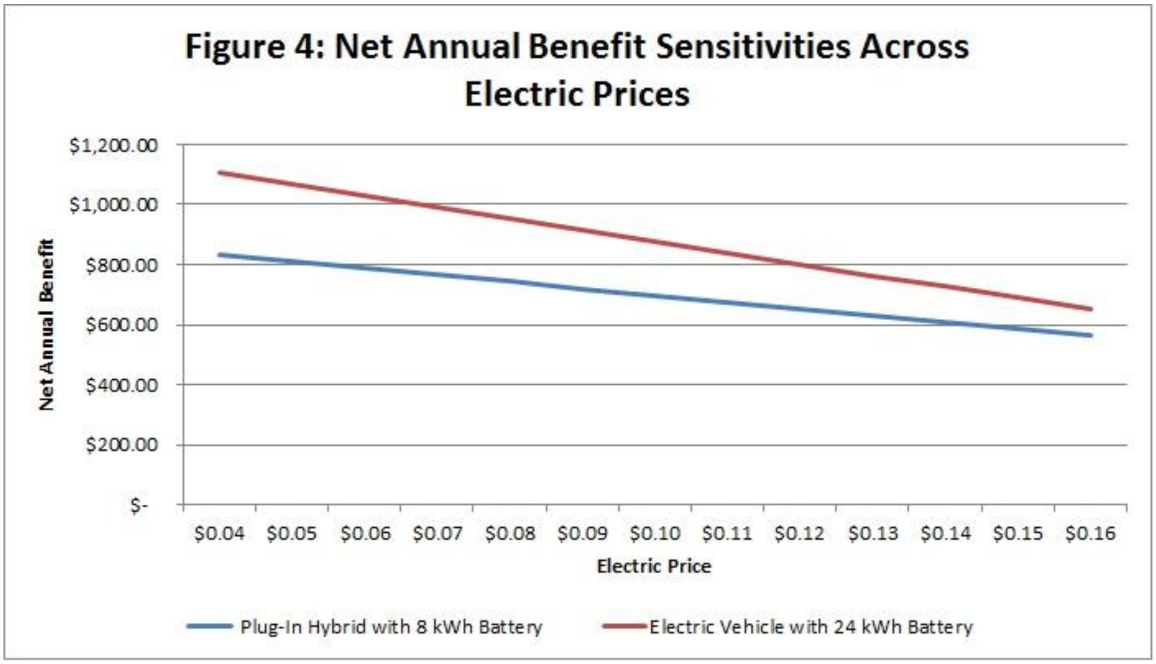
Gasoline prices are the next most critical assumption. California gasoline prices have been particularly volatile this year ranging from $3.51 to $4.66/gallon.[15]



[15] www.gasbuddy.com.

D. Electricity costs

The final sensitivity is surprising until one considers how little electricity costs relative to gasoline. Varying electric prices has little impact on the net annual benefit.



III. What have we learned?

The policy implication from this exercise in varying the assumptions in the CBO study is that the impediment – and there seems to be one – blocking purchase of electric vehicles lies in the perceived cost of financing for consumers and not in the vehicles themselves.

Once that assumption is corrected, plug-in hybrids and all-electric vehicles should be considered cost-effective across broad ranges in the price of batteries, gasoline, and electricity.

There are many reasons why adoption of this new technology has been slow. The most obvious involves convenience – range and the availability of recharging stations. Vehicles with relatively low ranges will require recharging stations to be ready and waiting before the consumer will invest in the vehicle. This is currently not the case, although the situation is rapidly improving. Consumer skepticism is also a factor. Promises from manufacturers are often discounted in purchasing decisions, while actual experience has more credibility. Hybrid vehicles now have that level of credibility. The arrival of substantial numbers of plug-in hybrids and electric vehicles will replace promises with actual experience in years to come. ■