Implementing Plan C – conservation, curtailment and cooperation

NewSolutions

Community Solutions℠

July 2012 Number 20

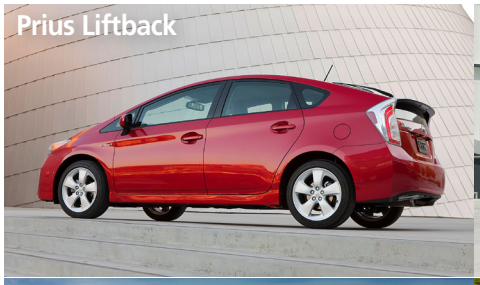
The New Saviors! – Plug-In-Electric Vehicles – Are They Hype or Reality?

This two-part New Solutions *on the electric car also appears on our new website, PlugInScam.org, where research director Pat Murphy's white papers and blogs go into more detail.*

Recent climate information indicates that our atmospheric situation is worsening rapidly. Governments make marginal suggestions to mitigate the coming crisis. Everyone hopes for a series of technological breakthroughs that will allow our consumer lifestyle to continue without end. This paper points out that much more efficient high-MPG cars have been available for more than a decade and should be the consumer choice.

Without political clarity, people should not wait for yet another technical breakthrough before beginning the change to less polluting products. It is high time people became aware that most of the high tech solutions currently proposed will not be successful and begin to make selections from the best options available now to reduce their CO_2 emissions.

Part 1: The Prius Proposal



U.S. automakers have tried unsuccessfully over the last thirty years to develop new powertrain technologies that significantly improve miles per gallon (MPG) or reduce carbon dioxide (CO_2) emissions. These unsuccessful efforts include fuel-cell vehicles (FCVs), diesel hybrid technology (Partnership for a New Generation of Vehicles), battery electric vehicles (BEVs), and plug-in hybrid electric vehicles (PHEVs). The only new technology that has improved MPG (and reduced CO_2 emissions) significantly has been the hybrid electric vehicle (HEV) first developed in Japan in the late 1990s by Toyota (Prius) and Honda (Insight). The most successful HEV has been the Toyota Prius; 50% of hybrid shipments in the U.S. have been of this single model. Most of the 38 different available or discontinued HEVs offer only marginally better MPG than equivalent conventional models, with the exception of Toyota's and Honda's HEVs. The fuel economy improvement for the best HEVs is in the range of 30-40% compared to the equivalent conventional vehicle.

Rather than continue looking for some new future technical breakthrough, particularly through vehicle electrification via plug-in battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV), the nation would be wise to commit to the HEV as the best alternative to conventional powertrains and do whatever it takes to make this the future standard powertrain technology for most cars. This powertrain technology can also be utilized in smaller lighter cars, coupling the fuel economy improvement from the hybrid technology with fuel savings from downsizing our cars.

At the time of this writing in July, 2012, more media reports have begun to question the concept of the plug-in car, either the pure battery electric vehicle (BEV) or the plug-in hybrid electric vehicle (PHEV).[1,2,3] The technical reasons have been described in detail in other white papers on pluginscam.org. The deliberate "hyping" of battery cars by the Environmental Protection Agency (EPA) and the Department of Energy (DOE), both of which compute MPG with data that ignore the energy cost of producing electricity, has been described. The first-year sales of plug-ins compared to HEVs have been disappointing. This is to some extent a repeat of the late 1990s and early 2000s, when the success of the Prius and the Insight led to the demise of the first-generation plug-ins, such as the GM EV1.

MPG performance for cars has been

increasing at the rate of 1-2% per year for many decades. Such improvements will continue, using smaller and more efficient engines, lighter materials, mechanisms such as start-stop capability, and technologies such as turbo-charging. But hybrid technology is a major change, a new powertrain architecture that provides a sizable "step function" from the normal rate of historical improvement. It is a new higher base from which to improve MPG at the traditional rate. It behooves us to embrace the HEV technology and make it the standard powertrain for the near future.

HEV History – Shipments Update

In a previous white paper, I showed the U.S. hybrid shipment history from the initial deliveries in 1999 through the year 2010.[4,5] Table 1 adds the 2011 sales of HEVs, as well as the MPG for each car.[6]

Fifty-one percent of all hybrid cars sold in 2011 in the U.S. were Priuses. Toyota's other hybrid models accounted for another 15% of Toyota's U.S. sales in 2011. Of the 38 models listed in Table 1, only five had a fuel economy above 40 MPG.

Status Report – Prius and Toyota in 2012

Yoshi Inaba, President of Toyota North America, spoke to the Economic Club of Chicago in February, 2012.[7] He announced that Toyota will launch 19 new or updated products this year under Toyota, Scion, and Lexus brands and that nearly half will be hybrids or electric vehicles. Inaba said that the company's current product line began a decade and a half ago, when the Prius was introduced to the United States. At that time, many people thought that a car with both an electric motor and a gas engine was a silly idea. Today, hybrids are mainstream products; the company now offers nine different Toyota and Lexus hybrids. Recently, Prius sales in the U.S surpassed the one-million mark, and there are more than three million hybrid vehicles on the road worldwide. Inaba said that if one sees a hybrid car on the streets of a city like Chicago today, chances are one in two that it's a Prius and seven in ten that it's a Toyota or Lexus. He further noted that Toyota hybrids get about twice as many miles per gallon (MPG) as conventional cars.

Inaba then discussed some of the newest products, including the Prius Plug-in,

Table 1: U.S. Hybrid Sales 1999-2011

Vehicle	1999/ 2002	2003/ 2004	2005/ 2006	2007/ 2008	2009/ 2010	2012/ 2011	Total
Honda Insight-42mpg	10,747	1,783	1,388	0	41,534	15,549	71,001
Toyota Prius-50mpg	41,237	78,591	214,868	339,795	280,610	136,463	1,091,564
Honda Civic-44mpg	13,700	47,371	57,115	63,872	22,455	4,703	209,216
Ford Escape-32mpg		2,993	38,946	38,559	25,969	10,089	116,556
Toyota Highlndr.-28mpg			49,474	41,493	18,542	4,549	114,058
Lexus RX400/450-30mpg			42,619	34,814	30,357	10,723	118,513
Toyota Camry-41mpg			31,341	100,749	37,474	9,241	178,805
Nissan Altima-33mpg				17,207	16,067	3,236	36,510
Lexus LS600hL-20mpg				1,844	387	84	2,315
Chevy Tahoe-21mpg				3,745	4,726	519	8,990
GMC Yukon-21mpg				1,610	3,154	598	5,362
Cadillac Escalade-21mpg				801	3,168	819	4,788
Ford Fusion-39mpg					36,370	11,286	47,656
Lexus HS 250h-35mpg					17,362	2,864	20,226
Sierra/Silverado-21mpg					3,991	1,165	5,156
BMW ActiveHEV7-20mpg					102	338	440
BMW X6-18mpg					205	43	248
Ford Lincoln MKZ-39mpg					1,192	5,739	6,931
Honda CR-Z-35mpg					5,249	11,330	16,579
Mazda Tribute-32mpg					570	484	1,054
Mercedes S400-21mpg					801	309	1,110
Porsche Cayenne-21mpg					206	1,571	1,777
Buick Lacrosse-19mpg						1,801	1,801
Hyundai Sonata-37mpg						19,673	19,673
Lexus CT 200h-42mpg						14,381	14,381
Buick Regal-29mpg						123	123
Infinti M35h-29mpg						378	378
porsche pnamera-25mpg						52	52
VW Toureg Hybrid-21mpg						390	390
Honda Accord-28mp		1,061	22,424	3,601	0	0	27,086
Mercury Mariner-27mp			4,172	6,051	2,583	0	12,806
Saturn Vue-26mp				7,323	2,706	0	10,029
Saturn Aura-27mp				1,057	581	0	1,638
Chevy Malibu-27mp				2,093	4,567	0	6,660
Chrysler Aspen-21mp				46	33	0	79
Dodge Durango-21mp					9	0	9
Mercury Milan-39mp					2,884	0	2,884
Mercedes ML450-22mp					627	1	628
Total	**65,684**	**131,799**	**462,347**	**664,660**	**564,481**	**268,501**	**2,157,472**

Hybrid technology is a major change, a new powertrain architecture that provides a sizable "step function" from the normal rate of historical improvement.

which is expected to achieve an estimated 95 miles per gallon equivalent (MPGe) in combined city and highway driving. He described the new Prius c as a small, sporty, fun-to-drive hybrid with the highest city miles per gallon (53 MPG) and the lowest price of any hybrid (under $20,000). Two battery electric vehicles (BEVs) are to be added to the company's product line, the first an all-electric version of the popular RAV4 and the second a Scion iQ EV, a micro-car aimed at short-range urban driving and car-sharing programs.

Inaba emphasized that hybrids will remain the core powertrain technology for Toyota's future vehicles and that hybrids can easily be adapted to other kinds of fuels. He noted that Toyota currently builds its Camry hybrid at its Georgetown, Kentucky, factory and will build the Highlander SUV hybrid at its plant in Princeton, Indiana. He acknowledged that car companies are forming alliances and partnerships. Toyota forged an alliance with Tesla in order to rapidly bring to market the electric RAV4 and has teamed with Ford to develop hybrid systems for pickup trucks and large SUVs.[8] Inaba predicted more automotive alliances, such as the previous swap of patents on hybrid powertrains by Toyota and Ford.[9]

In the same month, Toyota Group Vice President and General Manager Bob Carter, along with Prius c Chief Engineer Satoshi Ogiso, and car expert Dave Lee of the University of Toyota,[10] a training school for Toyota employees, gave a series of talks on the Prius family, including specific information on the new Prius c.[11,12] Carter pointed out that 8,399 Prius v's were sold in the U.S. in the first ten weeks on the market, about the same as the number of Volts sold in the U.S. for all of 2011. He projected 220,000 U.S. sales of all Prius models in 2012, up from 136,000 in 2011. The mix is expected to include roughly 75% Liftbacks, the new brand name for the conventional Prius. Prius c and Prius v U.S. sales are estimated to be at 33,000-44,000 vehicles (15-20% of sales). The Prius Plug-in sales are estimated at about 11,000, or around 5% of the mix.

Toyota has recovered from the Japanese earthquake and tsunami that occurred on March 11, 2011. Toyota's new hybrid announcements are impressive, and its commitment to fuel-saving hybrids remains strong. The company will also compete for PHEV and BEV business, but acknowledges that the powertrain of the future is the standard hybrid. We believe that Toyota hybrid models will increasingly cut into the sales of plug-ins.

New Metrics for Plug-ins

More fuel economy information is now available, based on the experience of a full year (2011) of plug-in sales. There are three sources of this information, which I will cover in this section. First, some new information is available from the EPA website, fueleconomy.gov, which still does not include complete and accurate MPGe information. Second, the EPA publishes a yearly summary of changes in light-duty vehicles; the most recent one contains useful information. Third, a recent life-cycle report from Carnegie Mellon provides a good summary of the economics of plug-ins compared to those of conventional and hybrid cars.

EPA fueleconomy.gov

The fueleconomy.gov website now includes an Energy and Environmental section, described in detail in my previous white paper, "Reviewing EPA's Fueleconomy.gov Plug-In Emissions."[13] This website provides some limited capability for comparing CO_2 emissions. The grams per mile for the Prius are 178, for the Leaf 239, and for the Volt 260. It would be helpful if this function were made more accessible and the information for plug-in cars more comprehensive.

EPA Light-Duty Vehicle Trends

The EPA publishes a yearly summary of trends in technology, CO_2 emissions, and fuel economy.[14] The most recent report shows characteristics of seven model years of cars and light trucks in the U.S. which are detailed in Table 2. The Prius CO_2 emissions rate of 178 grams/mile is less than half of the 2011 U.S. car and light-truck fleet rate of 391 grams/mile. There was a significant reduction in CO_2 emissions during the twelve-year period from 1975 to 1987, a decrease of 40%. In the twenty-four year period from 1987 to 2011, CO_2 emissions declined only about 3.0%, showing the decreasing concern with fuel economy in recent decades.

Life-cycle Report

Table 3 summarizes a recent life-cycle analysis that compares total costs to build and operate conventional vehicles (CVs), hybrid electric vehicles (HEVs), PHEVs with an electric-only range of 20 kilometers, PHEVs with an electric-only range of 60 kilometers, and BEVs with no range given.[15] A PHEV20 is equivalent to a car that can go 12.5 miles on a charge; a

Table 2: MPG and CO_2 for U.S. Cars and Light Trucks, 1975-2011

	1975	1987	2004	2008	2009	2010	2011
Adjusted CO_2 Emissions (g/mi)	681	405	461	424	396	394	391
Adjusted Fuel Economy (MPG)	13.1	22.-	19.3	21.0	22.4	22.6	22.8

Table 3: Cost Analysis for Different Powertrains

	CV	HEV	PHEV20	PHEV60	BEV
Base vehicle cost	$23,019	$24,800	$25,666	$25,729	$20,497
Initial battery cost	$0	$2,068	$2,632	$8,730	$31,395
Battery replacement cost	$0	$0	$0	$0	$0
Gasoline cost	$12,396	$8,847	$7,189	$6,226	$0
Electricity cost	$0	$0	$788	$2,314	$5,282
Scheduled maintenance	$4,380	$3,962	$3,235	$3,235	$2,232
Charger installation	$0	$0	$1,200	$2,400	$2,400
Net cost	**$39,786**	**$39,677**	**$40,709**	**$48,635**	**$62,364**

PHEV60 is equivalent to a car that can go 37.5 miles on a charge. The electric-only range of the new Prius Plug-in is 11 miles; the electric-only range of the Volt is 35 miles.

This table illustrates the very high costs of long range plug-ins and BEVs. Note that the Base Vehicle Cost (row 1) is relatively close for all models. As the battery increases in size, the Initial Battery Cost (row 2) increases. For the BEV in this example, the battery cost is half the total car cost. It is this factor that calls into question the viability of high–range cars like the PHEV60 and the BEV. The better options are the HEV and a small improvement like the PHEV20 that adds a relatively small cost.

Embodied Energy Considerations

Some believe that a new high-MPG car purchase should be avoided because it will take many years of driving it to save enough energy to make up for the energy expended in its manufacture. But the fact of the matter is that new cars are made and bought every year. Since much more efficient ones can be made, that is what we should focus on. Most older cars, even ones made a short time ago, are energy-inefficient. Thus, if one chooses to keep an inefficient car on the basis of avoiding the manufacture of a new car, then one is choosing to maintain the existing unsustainable rate of CO_2 generation. That idea is economically and ecologically unsound.

It would help if consumers became aware of Lifecycle Assessment (LCA) or Lifecycle Energy Consumption. The EPA defines lifecycle assessment[16] as follows:

Lifecycle assessment is a "cradle-to-grave" approach for assessing industrial systems. "Cradle-to-grave" begins with the gathering of raw materials from the earth to create the product and ends at the point when all materials are returned to the earth. LCA evaluates all stages of a product's life from the perspective that they are interdependent, meaning that one operation leads to the next. LCA enables the estimation of the cumulative environmental impacts resulting from all stages in the product lifecycle, often including impacts not considered in more traditional analyses (e.g., raw material extraction, material transportation, ultimate product disposal, etc.). By including the impacts throughout the product lifecycle, LCA provides a comprehensive view of the environmental aspects of the product or process and a more accurate picture of the true environmental trade-offs in product and process selection.

The most important thing about LCA for cars is that it includes the amount of energy required both to build and to operate the car. Figure 1 shows that 85% of the energy consumed over the lifetime of a car is for the gasoline or diesel fuel that it requires.[17]

As cars become more efficient, the percentage distribution of manufacturing energy (embodied energy) and operating energy changes. The more fuel-economical the car, the higher the percentage of total energy used to build the car. Nonetheless, the total energy used decreases over its lifetime.

Figure 1: Lifecycle Energy Analysis for Cars

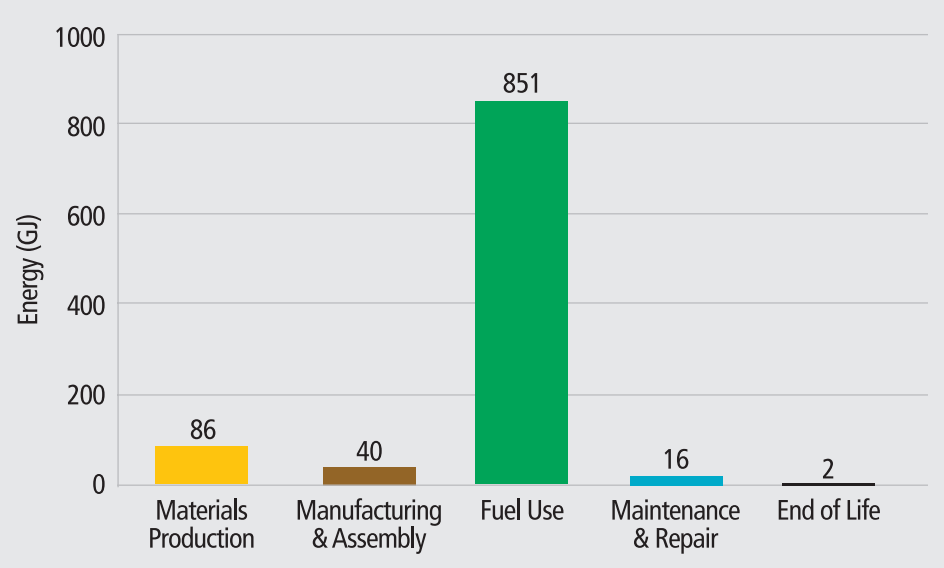
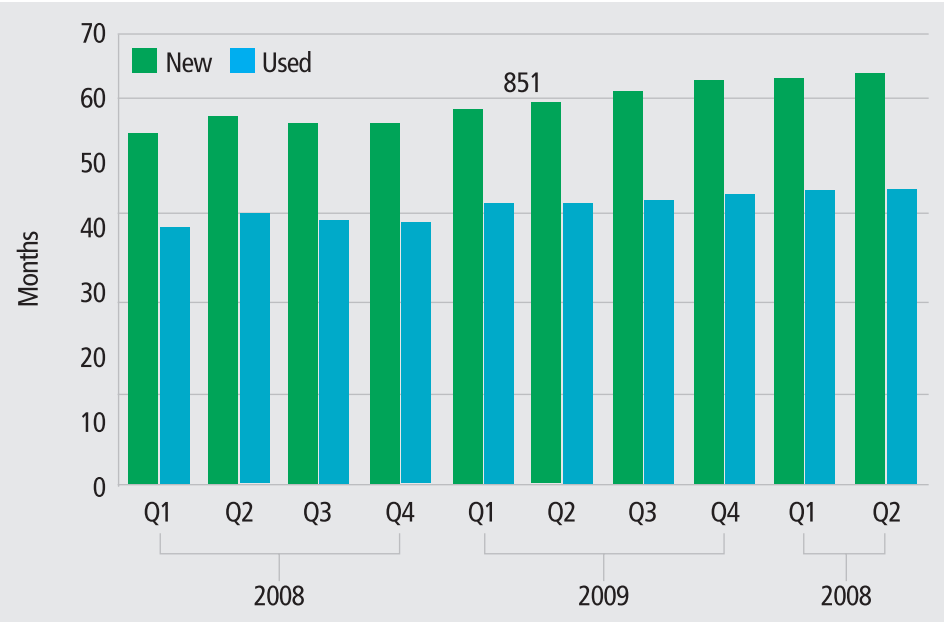


Figure 2: Average Length of Vehicle Ownership by Quarter, 2008-2010



It is also important to consider behavioral changes regarding how long consumers keep their cars. Figure 2 shows that the number of months that new- and used-car buyers keep their cars has increased over the years.[18]

The length of time that a new vehicle is kept by its U.S. purchaser has increased each quarter since 2008, to an average of 64 months by the 2nd quarter of 2010. By that quarter, the average used vehicle had been kept for 46 months. The most recent U.S. data suggests that new cars are kept 71.4 months and used cars 49.9 months.[19]

An Important Insight

The main obstacles to major change are cultural. The consumer paradigm underlying our society is focused on bigger, faster, and more wasteful products with endless and unnecessary style and fashion changes. Today, our cultural measures of success are based on how much we consume, not on how little energy we use and how little CO_2 we emit.

But I am writing from a different perspective, one that says we must curtail our energy use drastically. It has become clear to me that the Prius HEV technology currently offers the best approach to energy reduction for personal transportation. So promoting the purchase of Prius hybrids makes good sense from an economical, ecological, and ethical point of view.

My wife and I have been committed to driving fuel–efficient, high-MPG cars for many decades. We initially bought a Volkswagen Squareback, and later purchased a Honda Civic Hatchback with a fuel economy rating of about 40 MPG.[20,21] In 2004 we bought a used 2001 Honda Insight with automatic transmission which got 48 MPG. (Stick shift Insights can get more than 60 MPG.) Ours was the original two-seat version made from 1999 to 2006. In 2006 we bought a used Toyota 2001 Prius (42 MPG). And in 2008 we traded in the Honda Insight for a 2006 version. Our current combined MPG average for our two cars is about 45 MPG, about twice the national average. In addition, our average yearly number of miles driven is much less than the national average.

It is necessary to go for a deep cut to make fundamental energy-reducing changes. Our cars are a clear target.

In the fall of 2010, our friend Eric Johnson, editor of our popular 2006 film, *"The Power of Community - How Cuba Survived Peak Oil,"* was looking for a way to further reduce his CO_2 emissions. Both of us were members of the Yellow Springs Energy Board at that time, and both of us had previously made major changes to our homes to reduce energy consumption. Eric's efforts included installing new triple-pane windows, doing extensive air sealing, and adding more insulation to his attic and basement, cutting his energy use in half.

He was evaluating a ground-source heat pump when I suggested he consider buying a Prius instead. I made this suggestion after reading a Kiplinger magazine article[22] that compared several very different modes of saving energy, including the Prius, fluorescent light bulbs, and other dissimilar products. After considering the article, Eric bought a 2011 Prius rather than make more home-energy improvements. He concluded he had reached the "point of diminishing returns" in CO_2-reducing changes to his home.

In the spring of 2011, I was interviewed by several radio shows concerning the Federal Trade Commission's (FTC) proposal for new *Green Guides*.[23] Their *Green Guides* were first issued in 1992 to ensure that the claims of so-called green marketers were true and substantiated. The *Green Guides* were revised in 1996 and 1998. The FTC was proposing more stringent rules for such claims to offset the "greenwashing" that had already become popular.

The purpose of the series of interviews was to discuss green products, greenwashing, and effective ways of reducing CO_2 emissions. On a radio show in Boulder, Colorado, the interviewer, who had apparently absorbed all the information on our organization's website (www.communitysolution.org), asked me what to do next. I determined that her current car was a Japanese model with gas mileage of around 26 MPG. I suggested she buy a Prius, pointing out that she would probably still be driving a car in 14 years, the average lifespan of a car. I emphasized that, if she was an average driver in terms of miles driven yearly, she would be spending far less for gasoline and reducing her CO_2 generation from travel to the lowest level possible. For both Eric and this interviewer, the point was to look past the conventional view of financial benefit or payback time to society's need to cut energy emissions deeply and rapidly. These cuts have to be significant.

Going after the "low-hanging fruit," such as changing light bulbs, is a small step and not very effective unless done rapidly on a nationwide basis. It is necessary to go for a deep cut to make fundamental energy-reducing changes. Our cars are a clear target. We tend to philosophize about bicycles or mass transit, but progress has been very slow in these two areas with no fundamental change in sight. A change in cars can be made immediately and can dramatically reduce CO_2 emissions.

My important insight is that the cars we need are already here and available. Unfortunately, there are only a handful of high-MPG hybrids on the market. Most of the thirty or so that were marketed in 2011 are not much better than conventional cars.[24] Many of these others can be viewed as "placeholders" until their manufacturers get more serious about fuel economy. But the environment cannot continue to wait for new kinds of car technologies, such as the PHEVs. Nor can it wait while automakers gradually add token hybrid models with low MPG until it is convenient for them to build high-MPG versions. We need to move our driving now to the high-MPG cars that are already using reliable technology, most notably the Prius.

Selecting a Prius involves the sacrifice of excessive speed, size, and styling. It is a commitment to a rigorous reduction in CO_2 generation. It also involves the physical risk of driving a smaller car in a road environment dominated by SUVs and large cars. But for those with strong societal and ecological commitments, the Prius technology solution is a "no-brainer."

The Prius(eqv)* Proposal

(*45-50 miles per gallon)

I have previously shown that the Toyota Prius is far and away the best car for reducing CO_2 emissions.[25] Thus, it is the most ecologically sound car available. It is also the most economical car that can be purchased, in terms of total costs. Of the 300 cars currently marketed in the U.S., it typically takes first or second place in both categories each year. It is a midsize car, not full size, and not an SUV. If every U.S. car were replaced overnight with a Prius, our automobile CO_2 emissions would be reduced almost 60%, and the average consumer would begin saving on gasoline costs, as shown in Table 3 (page 3).

It is hard to compare the Prius to a standard car since it is a unique brand name and there is no conventional version of the Prius. So I will compare the 2012 Camry Hybrid and the 2012 Camry Conventional Vehicle, which respectively get 41 MPG and 28 MPG. The Camry Hybrid gets a bit more than 40% more miles from a gallon of gas on the same frame and engine size as the conventional Camry. This is a remarkable number. I know of no change in the last fifty years that has provided such a sizable jump in performance. Thus, the hybrid represents the best MPG improvement of any recent change in automobile technology.

The Prius(eqv) Proposal assumes that a very large number of people, numbering in the tens of millions, might be willing to standardize on a particular powertrain – the Toyota Hybrid Synergy Drive (HSD), as well as its future derivatives. Current derivatives include versions of the HSD used in the Prius v (first shipped in 2011), the Lexus CT200h (first shipped in 2011), the Prius c (city) small car (first shipped in March 2012), and the 2012 version of the Toyota Camry. If every new car purchased from now on utilized an HSD powertrain, the nation's fuel costs and CO_2 emissions for car-based transport could be cut by more than half within the current average lifespan of 14 years for cars. When Americans concerned with climate change eventually understand this, many will forego the comfort and convenience (as well as the cost and CO_2 emissions) of a larger car for the guarantee of a CO_2-reducing midsize car.

This proposal does not mean that each car would have to be an actual Prius or a member of the Prius family, although that would typically be the case. As noted, the HSD is also used in the Lexus and Camry brands. This proposal would include other manufacturers who are using the HSD, such as Mazda, which is buying HSD components from Toyota to be used in a forthcoming HEV.[26,27] Nissan, which has used the HSD drive, will soon use an in-house hybrid powertrain.[28] This Prius(eqv) Proposal suggests an MPG level, one to which many people would commit, that is close to 50 MPG and certainly at least a mid-40s MPG. Of the thirty-eight HEV models that have been sold in the U.S., there are currently only four that fit this requirement – Prius, Lexus CT 200h, Civic, and Insight.[29]

Ford Motor Company might soon have a model that will join the category of Prius(eqv). Note that Ford is third in terms of total historical U.S. hybrid sales, having sold 183,000 units compared to Honda's 324,000 and Toyota's 1,540,000 (see Table 1). As recently as 2000, Ford had ten patents that it classified as hybrid technology. By 2002, Ford had approximately 30 hybrid patents. Today, Ford has nearly 500 hybrid patents, many used in its forthcoming new Fusion Hybrid,[30] which is anticipated to deliver 47 MPG city and 44 MPG highway.[31] Additionally, its 2012 Lincoln MKZ hybrid almost reaches the 40+ MPG range, currently getting 39 MPG.

HEVs, while far ahead of PHEVs and BEVs, have not penetrated deeply into the car and light-truck market. Total U.S. hybrid sales over the lifetime of the technology from 1999 to 2011 were 2.2 million vehicles (see Table 1). During this same period of time, 199 million cars and light trucks were shipped.[32] Thus, in this twelve-year period, hybrids captured 1% of the market. In 2011 total car sales were 12.7 million units compared to 233,000 hybrids, giving the hybrids about 2% of the market that year. Concern over climate change is still not enough to make a very big impact on hybrid sales.

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New perspectives on transportation are needed when one considers a Prius(eqv) paradigm shift. The main qualification is to understand that the private car as we know it – large, expensive, stylish, fast, etc. – cannot continue to be the basis of personal transportation. The Prius(eqv) Proposal is simple and profound. It suggests buying a car based primarily on its MPG rating, with secondary advantages being resale value and repair record. This implies that little value will be given to power, size, comfort, style and prestige. Prius People, as I call those who adopt this proposal, realize that the consumption of transportation energy must be radically curtailed. They are not able at this point to see a way to live without a car. Bicycles appear very dangerous for U.S. riders; mass transit is a concept that has been talked about for a half century and one that may take another half century to develop. A Prius person accepts the fact that he or she will have to drive a few more decades and wants to minimize the damage done by driving. A Prius person simply acknowledges that the car is a destructive device that cannot yet be totally dispensed with. A Prius purchase is a step in the right direction, a move from fashion to function.

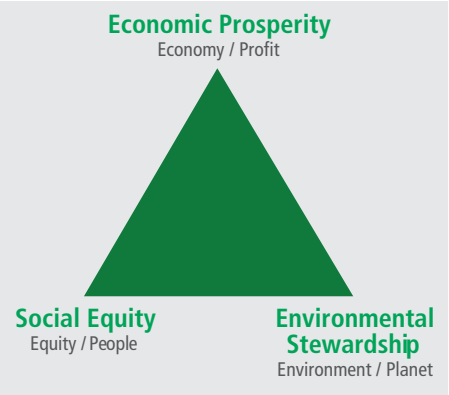
Buying a New Prius(eqv) – An Ethical Choice

How can society get tens of millions of Prius(eqv) HEVs on the road rapidly? The obvious answer is for tens of millions of people to buy one. There is no question that the Prius family includes the most economical and ecological cars available. Changing the existing consumer paradigm requires a change in consciousness from personal gratification to long-term human survival. A Prius appears to be the most

ethical car choice one can make.

The famous Triple Bottom Line[33] of the sustainability movement, based originally on the report of the 1987 Brundtland Commission, has for some time been divided into Economic Prosperity, Environmental Stewardship, and Social Equity. This division has been shortened to Economy, Environment, and Equity and in another form, the 3Ps – Profit, Planet, and People (profit for economy, planet for environment, and people for equity) as shown in Figure 3.

Figure 3: Triple Bottom Line [34]



Somehow in this definition and even in its placement on the triangle, Economic Prosperity takes precedence, with less recognition of the environment and even less recognition of people and social equity. In practice, this perspective is more focused on corporations than on people. The P for profit is not referring to profit for people but profit for automakers. In general, profit is not a term used by most people to describe the nature or goals of human beings. Most people do not prepare a profit and loss statement annually. In a personal vein, relative to the term profit, there is the familiar religious statement "What doth it profit a man if he gains the whole world, and suffers the loss of his own soul?"[35] One might paraphrase this today as "What doth it profit a man if he gains the wealth of the whole world, and suffers the loss of this habitable world?"

Another perspective is to determine what is most economical for people rather than for automakers. For automobile companies, larger cars and SUVs provide more profit than midsized, compact, or subcompact cars. They are marketed as having the most "sex appeal." But the resulting negative environmental effect injures the planet and all the people. Thus the first P (profit) is in conflict with the second and third.

The P for planet (environmental or ecological) can be greatly simplified to reduced CO_2 generation. This is a simple measure for society at large, including cars and buildings. The social equity or the people component can best be served by removing larger cars and SUVs, banning many cars that don't get high MPG and moving the focus from cost savings to ethical issues. The question is not comfort or payback but the moral question of what each driver is doing to the future of our children and grandchildren. I suggest a reordering to ethical, ecological, and economical. The most ethical thing to do is to drive cars that have little environmental and personal effect. Ecologically, this means that the car would generate the minimum amount of CO_2.

In this way, the moral issue and the guidepost of Prius People may be the "precautionary principle." This principle states that, if an action or policy has a suspected risk of causing harm to the public or to the environment, the burden of proof that it is *not* harmful falls on those taking the action. This is needed, even in the absence of scientific consensus that the action or policy is harmful.

Conclusion – Buy a Prius – Now!

The unrestricted growth in the car population in the rest of the world, particularly China, may well lead to climate calamity. But that is not an excuse to avoid action. Action is needed now, not later, and we can't wait for someone else or some other country to lead. Saving the climate is a good reason for buying a new Prius, which is to bring into the world a 50-MPG car to replace a 23-MPG car. The more midsize Priuses that are purchased, the fewer SUVs and large cars will be made. Over some period of time, the car fleet as a whole will increase its MPG rating. Whether the Prius purchase causes the scrapping

The question is not comfort or payback but the moral question of what each driver is doing to the future of our children and grandchildren.

of an older gas guzzler is immaterial – we can only choose the cars we drive and not worry about what happens to our previous car when it enters the resale market. It is important to note that a new Prius will eventually also go into the used-car market. If a current car with relatively high MPG is replaced by a Prius, as a secondary benefit, the older car, with its good gas mileage, will then be available in the current used-car market.

Begin by assuming that most people will be drivers for a long time, maybe from the ages of 16 to 76, possibly a 60-year period. We can also assume that younger people often drive used cars and older people often can afford new cars. A choice is made each time a car is bought.

When we consider the instability of the climate, our concerns should be major. Many of the early purchasers of the Prius were environmentalists and purchased the cars for that reason, taking on the risks of early adopters. As hybrid sales increase, we see that more and more people are making an ecological choice. Media often criticize the Prius as a rich yuppie car. But per-mile costs are very low; the justification for purchase can be either for environmental or economic reasons. ■

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Part 2: A Review of the Union of Concerned Scientists EV Report

In April, 2012 the Union of Concerned Scientists (UCS) published a report entitled "*State of Charge: Electric Vehicles' Global Warming Emissions and Fuel-Cost Savings across the United States.*"[36] The report discussed the electrical generation and distribution system in the US, that is, the "grid," relative to plug-in cars. Early in the report, the power grid network is shown divided into 26 grid regions (Figure 4). UCS grades the 26 regions relative to the efficiency of electric cars because different areas of the country have different fuel sources for their electricity, resulting in different amounts of CO_2 emissions for the same amount of electricity generated. For example, coal generates more CO_2 for a kilowatt/hour of electricity than natural gas. In areas with a high percentage of hydroelectric power, for example the Pacific Northwest, there is much less CO_2 generated for a kWh of electricity than in the rest of the country.

The report divides the country into good, better, and best categories. The middle of the country is mostly designated good (purple color); the South and mid-Atlantic are mostly designated better (dark blue color); and the two coasts are mostly designated best (light blue color). Forty-five percent of the population lives in light blue, (best regions) where CO_2 emissions from a plug-in car would be less than those from the most efficient gasoline hybrid, the Prius.

Another graphic from the UCS report (Figure 5) shows that there is a wide range of emission rates for the 26 regions of the country. The highest emission rate is more than twice the lowest emission rate.

Americans are used to a simple mile-per-gallon (MPG) metric for fuel economy. The idea of different rates of emissions and miles-per-gallon for different regions of the country may be a new idea. In fact, compared to the conventional car, a plug-in vehicle may have an advantage or a disadvantage that is based on the owner's location in the country.

Calculating the fuel economy of an electric vehicle using MPG has proved difficult. The Environmental Protection Agency (EPA) developed a new designation of MPGe which stands for MPG equivalent. The EPA methodology is described later in this report.

In the UCS report, the term MPG-ghg is introduced, which is analogous to MPGe in that it estimates mileage from some other measure. MPGghg stands for MPG greenhouse gas equivalent. Since the formula for converting the CO_2 emissions to MPGghg is not explained in the UCS report, I requested it. Co-author Don Anair[37] provided the following information:

MPG equivalent (MPGghg) = (1/Emissions intensity)*(1/electric vehicle efficiency) *grams of CO_2 equivalent per gallon of gasoline.

Two parameters that are necessary to evaluate this formula are:

- Electric vehicle efficiency = 0.34 kWh/mile (Nissan Leaf)
- Grams CO_2 eq./gallon of gasoline = 11,200 (GREET*)

(*GREET stands for the "Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model" and was developed by Argonne National Laboratory.)

Don also provided the national average Emissions Intensity for all regions, which is 684 gCO_2/kWh. This converts to about 48 mpg, using the formula above. He also explained that the figure of 11,200 grams of CO_2 per gallon of gasoline includes the extraction and refining of oil, as well as the transport of oil and gasoline. A direct comparison of CO_2 from a gallon of gasoline, not considering these factors, is 9,300 grams/gallon rather than 11,200.

Table 4 is taken from the report. It shows the information in Figure 4 and Figure 5 in a tabular format. I have added a column to this table at the far right that illustrates how the MPG (really MPGghg) in Figure 4 was derived for the 26 different regions. This column, labeled "MPGghg 33000/EI" (Emissions Intensity), uses the number 33,000, which is derived by dividing 11,200 (grams of CO_2eq in a gallon of gasoline) by .34 (electric vehicle efficiency measured in kwH per mile for the Nissan Leaf). Thus the new entries in the added column are obtained by dividing 33,000 by the value in the Emissions Intensity column. For example, the 46 MPGghg for the first entry is calculated by dividing 33,000 by 717. I also added a row at the bottom of the table that shows the national average for Emissions Intensity provided by Don Anair.

Figure 4: The 26 U.S. Electricity Regions shown as MPG Ratings

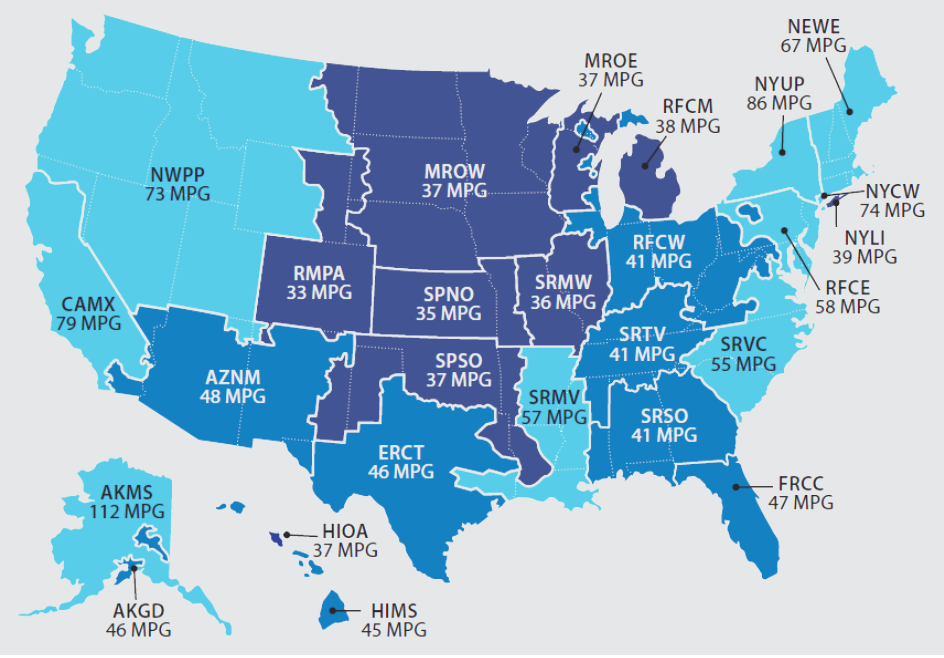


Table 4: Grid Mix By Region

Region Name	Emissions Intensity (gCO2e/kWh)	MPGghg 33000/EI
ASCCAlaskaGrid	717	46
ASCCMiscellaneous	293	113
ERCOTAll	712	46
FRCCAll	702	47
HICCMiscellaneous	737	45
HICCOahu	879	38
MROEast	885	37
MROWest	893	37
NPCCLong Island	838	39
NPCCNewEngland	493	67
NPCCNYC/Westchester	446	74
NPCCUpstate NY	383	86
RFCEast	572	58
RFCMichigan	870	38
RFCWest	808	41
SERCMidwest	923	36
SERCMississippiValley	583	57
SERCSouth	794	42
SERCTennesseeValley	806	41
SERCVirginia/Carolina	594	56
SPPNorth	936	35
SPPSouth	880	38
WECCCalifornia	419	79
WECCNorthwest	451	73
WECCRockies	991	33
WECCSouthwest	682	48
Nationwide Average	**684**	**48**

Figure 5: Grid Regions Comparisons of Emissions Rate

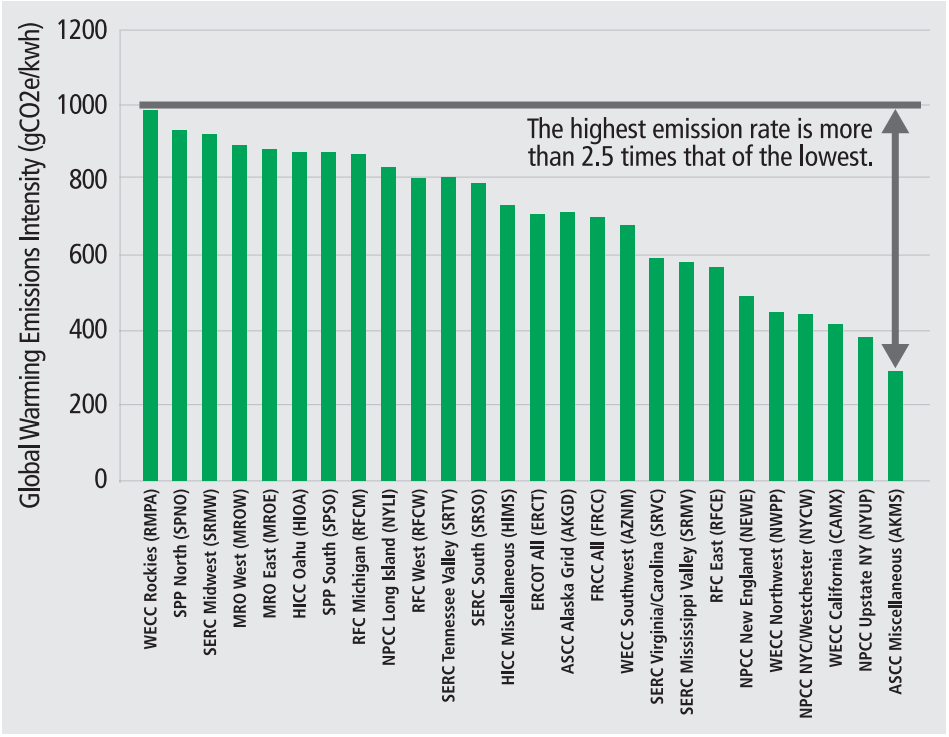
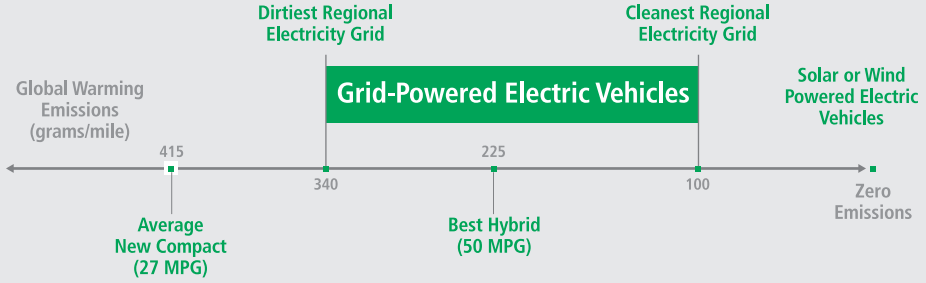


Figure 6: Best, Worst, and Prius



Note that this table is for a single car, the Leaf; a different table would have to be generated for cars with different electric vehicle efficiency. Such tables could be made simpler, for example, by eliminating the distribution of fuel sources.

There are important concepts and useful information in the UCS report, such as the new MPGghg. The maps of the country also provide a quick look at how effective a plug-in would be in different parts of the country. The algorithm provided by one of the authors for obtaining MPGghg is also important.

Comparing the Prius and the Leaf

The UCS report concentrates on comparing electric cars, particularly the Leaf, to a conventional car that gets 27 MPG and generates 415 grams of CO_2 per mile (gCO_2/mile). The Prius and other conventional hybrids are discussed, but many of the financial advantages of plug-ins in the report are derived from comparisons to a basic 27-MPG car rather than to a 50-MPG car like the Prius. In other papers, I have pointed out that the main competitors to plug-ins are conventional hybrids, not conventional gasoline cars. Over half the hybrids sold in the U.S. in the last thirteen years have been the Prius model. Thus, a more detailed comparison to a Prius would be useful. The UCS Executive Summary provides a useful graphic (Figure 6) showing how the Prius relates to the cleanest and dirtiest regional grids.

The EPA fueleconomy.gov website recognizes that the total emissions for a car must consider the "upstream" as well as the "tailpipe" emissions. The term "upstream" is equivalent to the emissions from a power plant or an oil refinery, along with the transmission of electricity or transportation of gasoline. The "tailpipe" emissions correspond to the emissions generated by driving the car. According to the EPA, the Prius has a CO_2 emission rate of 222 gCO_2/mile (see Figure 7). (Both EPA and UCS use "g/mile" but I prefer to add a "CO_2" subscript as a reminder of what is being measured.) As a check, if one uses the 50 mpg of the Prius from fueleconomy.gov and divides that into 11,200, the result is

224 gCO_2 /mile, very close to the number in Figure 7.

The emissions for the 50-MPG Prius are taken from the main page of the fueleconomy.gov website. The CO_2 emissions for the Leaf and other plug-in cars are found at a special part of the fueleconomy.gov website.[38] From the homepage, this is accessed first by selecting "About EPA Ratings" from the horizontal menu across the top. When the drop-down menu appears, the option of "Beyond Tailpipe Emissions" is displayed at the far left under the heading "New Window Stickers." Clicking this option displays the "Greenhouse Gas Emissions for Electric and Plug-In Hybrid Electric Vehicles" choices. This part provides data on several plug-in cars, including the Leaf. The result for a Leaf is shown in Figure 8. Note that the emission rates include a national average as well as the value for a particular region. This is the same approach used by UCS, except that EPA uses zip codes and UCS uses the 26 grid regions.

The UCS report includes another table, which is a summary of the MPGe from EPA (see Table 5).[39] I have previously shown that the Prius and Leaf are almost the same, relative to CO_2 (230 versus 222 gCO_2/mile). But Table 5 shows that the Leaf fuel economy measured by MPGe is about twice that of the Prius (99 MPGe versus 50 MPG). The reader might be puzzled by the fact that the Leaf gets 48 MPGghg based on CO_2 emissions while it gets 99 MPGe based on electricity consumed.

The difference, which I covered extensively in a white paper on pluginscam.org, *History and Status of the Battery Electric Vehicle,*[40] comes from the EPA method of deriving the MPGe for a plug-in vehicle. The EPA formula uses a value of 33.7 kWh per gallon of gasoline, which does not account for the energy burned at the power plant and energy lost in electricity transmission. The appropriate value is 12.3 kWh per gallon of gasoline, as explained in the white paper. To determine the more accurate measure, one need only multiply the EPA MPGe by a correction factor of .36 (12.3 kWh per gallon/33.7 kwH per gallon). Table 6 shows the application of this correction factor to the 99 MPGe, which results in a more accurate 36 MPGe.

In the same white paper, the Prius MPG is corrected to take into account the upstream use of energy in a manner similar to that used by UCS in its report. This correction factor is also explained in the white paper. To determine a more accurate measure, the EPA MPG for conventional cars and hybrids must be multiplied by a correction factor of .83 (9,300 grams of CO_2 per gallon/11,200 value grams of CO_2 per gallon). This will give an MPGe for gasoline and diesel cars that reflects refinery and petroleum energy losses. The UCS approach is more accurate from a scientific perspective than the EPA plug-in fuel-economy methodology. Table 6 shows a corrected MPGe from the referenced report.

Figure 7: Prius from MPG and CO_2 – fueleconomy.gov

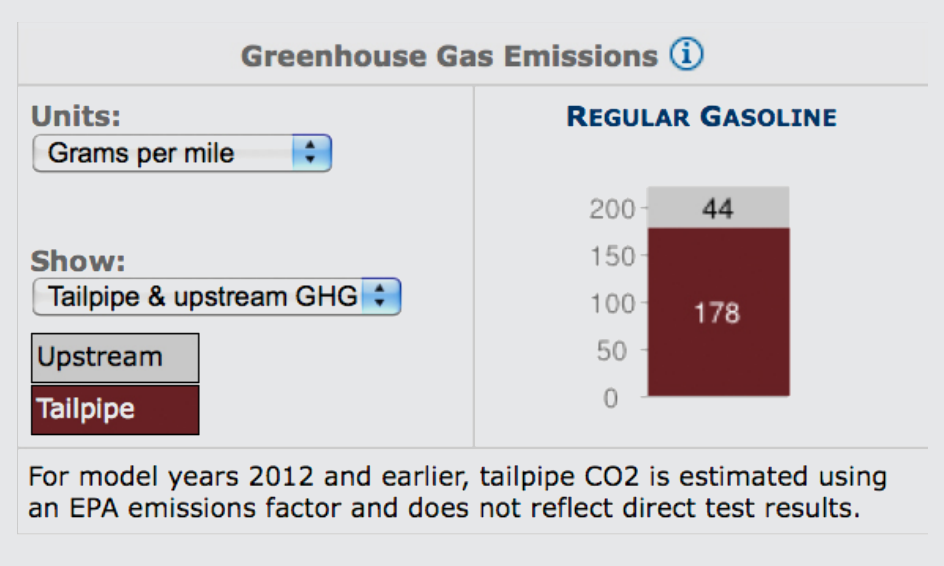


Figure 8: Leaf EV CO_2 Emissions from fueleconomy.gov

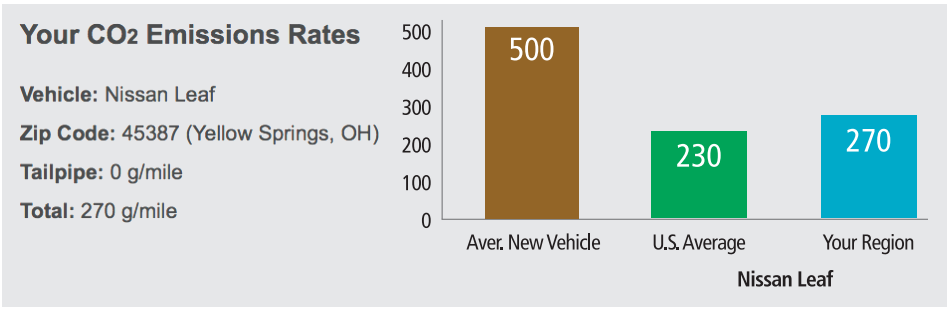


Table 5: EV MPGe from UCS Report [4]

2012 Models	Mitsubishi "i"	Ford Focus EV	Nissan Leaf	Chevy Volt
Electric Efficiency (kWh/mile)	0.3	0.32	0.34	0.36
Energy Efficiency Rating (miles per gallon of gasoline equivalent)	112	105	99	94

Table 6: Leaf and Prius MPGe Comparison

Car	Quoted MPG	Correction Factor	Actual MPGe
Leaf	99MPGe	0.30	30 MPGe
Prius	50 MPG	0.83	42 MPGe

In summary, the Prius has roughly the same MPGghg as the Leaf, while its corrected MPGe is somewhat better than the corrected MPGe of the Leaf.

The UCS report has provided two useful tools. First, the report gives an algorithm for determining MPGghg, which is similar to the EPA MPGe but more accurate, in that it accounts for the emissions from energy used to obtain gasoline. The argument about the efficiency of the

power plants is overlooked by EPA since it does not do an analysis equivalent to that done by UCS; the EPA report thus provides misleading measures. Second, the UCS report shows the map of the country with its regions, including the MPGghg data. Unfortunately, the UCS report does not maintain the MPGghg designation throughout. But the visual representation for the country in Figure 4 is very useful.

On a national basis, the Leaf has no advantage over the Prius relative to CO_2. However, there are major sections of the country with large populations where the Leaf does have a significant advantage, since much of the electricity comes from hydroelectric sources rather than coal or natural gas. The UCS report adds a key dimension to the HEV vs. plug-in debate by showing that regional considerations must be evaluated. For a student or other person concerned about energy and CO_2, this report is extremely useful.

Finally, I have not addressed here the question of capital and operating cost, which is covered extensively in the UCS report. I may analyze this in the future in a blog entry on pluginscam.org. ■

Even though electric vehicles can provide significant CO_2 emissions reductions in certain areas of the country, they are unlikely to generate significant sales because the battery cost is still prohibitive in most cases and thus for most people.

The only revolutionary product that has come forth in the last 40 years is the conventional hybrid car. Fuel cell cars, electric vehicles and plug-in hybrids are technologies that have not been proven, in spite of repeated efforts. Citizens who wish to address their CO_2 emissions should be purchasing the highest MPG hybrid car they can afford.

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Postscript: July 11, 2012

As we were going to press, the sales for the first six months of 2012 became available. Hybrids took a significant jump in this period compared to the second half of 2011. There were 82,000 hybrids added to the car fleet compared to 6,422 PHEVs and BEVs. The percentage of plug-ins compared to conventional hybrids declined in the first six months of 2012 from 8.18% to 8.05%. The full report on this can be read on **PlugInScam.com** under Blogs.

Car Sales	First half 2011		Second half 2011		First half 2012	
	Sales	% of All Cars	Sales	% of All Cars	Sales	% of All Cars
All Cars	**6,333,313**	**100.00%**	**6,401,043**	**100.00%**	**7,248,893**	**100.00%**
Prius Hybrids	66,520	1.05%	69,943	1.09%	122,316	1.69%
All Hybrids	**133,114**	**2.10%**	**135,693**	**2.12%**	**217,701**	**3.00%**
Volt PHEV	2,745	0.04%	4,926	0.08%	8,817	0.12%
Leaf BEV	3,875	0.06%	5,799	0.09%	3,148	0.04%
Prius PHEV	0	n/a	0	n/a	4,333	0.06%
Other PHEV/BEVs	87	0.00%	381	0.01%	1,230	0.02%
All PHEV/BEVs	**6,707**	**0.11%**	**11,106**	**0.17%**	**17,528**	**0.24%**
PHEV/BEV % of Hybrids		**5.04%**		**8.18%**		**8.05%**

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