A Clean and Quiet Revolution

By Steve Heckeroth, May 2006

The technologies exist to clean the air, stabilize the climate and maintain our standard of living all at the same time. By relying on clean renewable technologies we can eliminate much of the US trade deficit and the reason for war while achieving energy independence.

A quick study of the chart below shows the overwhelming advantages of plug-in hybrid (PHEV) and battery electric vehicles (EV). EVs are zero emission and can be charged from zero emission renewable energy sources like the sun and wind. By adding more batteries to hybrid electric vehicles (HEV) plug-in hybrids (PHEV) can be built which offer the range of gas vehicles (400 Mi.) with the environmental benefits of electric vehicles for short trips.

Vehicle Type	$ Gas 50 Mi. /Day	kWh 50 Mi. /Day	fuel/Year 50 Mi. /Day	Tons of CO2/Year Tailpipe	+Tons of Upstream CO2/Year*
10 MPG Gas	17.50	200	$6400	21	27.3
20 MPG Gas	8.75	100	$3200	10.5	13.6
30 MPG Gas	5.85	67	$2130	7	9.1
40 MPG HEV	4.40	50	$1600	5.2	6.8
50 MPG HEV	3.50	40	$1275	4.2	5.5
40 MPG PHEV with 25 Mile EV Range	1.75 for 25 miles	10 for 25 miles	$820	2.5	3
PHEV with 50 Mile EV Range		22	$396	0	.4
EV-1, 120 Mile Range (built & crushed by GM)		12	$216	0	.2
Solar Charged Ultra-light Pedal Electric Hybrid		1	0	0	0

The main assumptions used to produce the values in the chart are:
1. The average cost of gasoline over the next year will be approximately $3.50/gallon.
2. The Time of Use (TOU) rate for nighttime charging is approximately $0.05/kWh.
3. There are about 40 kWh of energy in a gallon of gasoline.
4. Burning 1 gallon of gasoline produces approximately 23 lbs of CO_2.

* This column includes upstream CO_2 emissions for exploration, extraction, transport, refining and distribution of gasoline, as well as CO_2 emissions from the California mix of power plants that produce electricity to charge electric vehicles.

Transportation Efficiency and Reducing Greenhouse Gas Emissions

Most people don't realize that they use more energy to power their cars than they use to power their homes. For comparison, an energy-efficient home uses about 10 kWh/person/day for lights and appliances and contributes < 200 lbs of CO2/year from the California mix of power plants. Increasing transportation efficiency is clearly the best place to focus our efforts to reduce greenhouse gas emissions. Experts suggest that in order to stabilize Climate Change the US population must reduce its total CO2 emissions to below 2.5 tons/person/year. Even this low number of 2.5 tons assumes that most developing countries will keep their CO2 emissions below 1 ton/person/year. PHEVs offer zero emission for every day commuting and the convenience of traveling 400 miles on one tank of fuel for trips over the battery's capacity. Long trips are relatively infrequent, so PHEVs can decreased fuel consumption by 90% which increases the feasibility of using fuels like ethanol and hydrogen (H2) produced from renewable sources. H2 produced from solar, wind or Hydro is the fuel of choice because no CO2 is generated in its creation or combustion. Of course the best way to cut CO2 emissions is to build and redevelop energy-efficient communities for people instead of cars but that is a topic for another day.

As we approach the peak of world oil production (extraction) it is important to reflect on how it came to pass that the developed world would base its entire economy on finite resources. It is also important to realize that corporations are not conscious beings and, for the most part, are incorporated for one reason: to make money. This gives us, the consumers, the ultimate power to be the corporate conscience by choosing how we spend money. It is also up to us to insure that laws and regulators protect essential resources like air, water and soil.

Sun to Wheel

Biofuels may provide a transition to zero emission fuels but over-harvesting forests and/or agricultural lands led to the decline of most civilizations over the last 7000 years. Maintaining production on diminishing soil resources now requires ever increasing amounts of fossil nutrients and fuels. As we bump up against the finite limits of fossil nutrients and fuels, feeding a growing population will not be possible much less a growing number of internal combustion engines (ICE).

Ultimately all energy on the Earth comes from the Sun so fuel efficiencies should be measured from the Sun. Fossil fuels are inherently very inefficient because of the millions of years of solar energy it took to produce them. Photosynthesis is about 1% efficient at producing carbohydrate energy from solar energy. The efficiency of producing liquid fuel from carbohydrates varies widely depending on the process and the distance to the use. Then there is the efficiency of the ICE which yields an overall efficiency for biofuels from Sun to drive shaft of 0.01- 0.03%.

Producing electricity from solar energy using photovoltaics (PV) is from 5-20% efficient and solar thermal generation can reach over 35% efficiency without counting the cogeneration possibilities. Current battery charge/discharge efficiency varies from 80-95%. Electric motors are over 90% efficient including line and motor controller losses. Total efficiency from Sun to electric motor drive shaft is between 3-30%. This gives solar charged electric vehicles an advantage 10 to 300 times greater then burning biofuels.

The obvious question is: Why aren't we all driving zero emission battery electric vehicles?

Of course for EVs to be clean the electricity used to charge their batteries must be generated from zero emission renewable sources. If EVs are charged with power generated from fossil fuels or radioactive material the cost of our mobility will be passed on to future generations in the form of poor air quality, depleted resources, climate change and radioactive waste.

The History of EVs

The following pages will explore some of the history of zero emission vehicles (ZEVs) and the barriers to their widespread use. My hope is that readers will use this information to take responsibility for the long term effects of their transportation choices and demand vehicles that can be fueled by unlimited clean renewable energy.

Inventors first started tinkering with small EVs right after the invention of the electric motor in 1833. It wasn't until 1859 that the development of the first rechargeable lead acid battery made it possible for EVs to be more than a novelty. In the 1880s the first electric cars were patented by inventors in the US and Europe. In 1890 the first golden age of electric cars started in Des Moines, Iowa when William Morrison's electric car traveled 182 miles on a single charge. For the next two decades electric vehicle manufactures like GM, GE, Studebaker, Baker and scores of relatively unknown companies led the race for the successor to the horse as the preferred mode of transportation. EVs held the land speed record until 1902 and many of the inventions that made gas cars popular, like rack and pinion steering and pneumatic tires, were introduced on electric cars.

Quiet, clean EVs out-sold loud, smoke-belching gas cars at the turn of the century and were assumed by most to be the car of the future. In 1900 Thomas Edison started work on a new alkaline battery and by 1909, using much of his own fortune he was manufacturing nickel iron cells that had almost double the power to weight ratio of the lead acid batteries of the day. Having the strength to turn the crank to start the engine was a prerequisite for driving Henry Ford's Model T. So almost all of the cars that rolled off the assembly line in 1908 at the low price of $850 were purchased and driven by men. Ironically, it took the invention of the electric starter motor in 1912 to convince 'respectable people' that longer range was worth giving up the elegant silence of electric automobiles. Edison stopped his work on batteries and then GM made its last electric truck in 1916; a cloud of smoke became a symbol of power and progress.

Electric street cars and light rail continued to develop as clean and convenient ways to get around in and between towns and cities until the Great Depression. In the 1920s the auto industry, along with the oil industry that fueled it and the tire industry that gave it wheels, became the most powerful companies on earth. In the late 20s GM, Standard Oil and Firestone Tire collaborated in a plan to eliminate all forms of transportation that competed with rubber tired, fossil fueled vehicles. They lobbied all levels of government to eliminate public funding for electric rail projects, and at the same time supported funding of vast road building projects. After the quality of rail service declined because of lack of funds, the oily cabal offered to buy out the transit systems. They sometimes promised to improve service but in the end they always ripped up the tracks as soon as the sale was final.

By 1940 the rubber tire alliance had systematically ripped up nearly every light rail system in the country, forcing everyone into private pollution machines. Never mind that rail can be zero emission and that it is hundreds of times more efficient than 8 lanes of traffic idling on the freeway. From a business point of view ripping up the tracks was an effective way of eliminating competition. From a social point of view it was a sea-change that triggered suburban sprawl and a life style that encouraged the US, representing 4% of the world population, to use 25% of the world's petroleum resources. Please see the film "The End of Suburbia" for a more complete understanding of the ramifications.

By the 1960s a cloud of smoke was engulfing most American cities. I was born and raised in Southern California in the late 40s through early 60s. As a young boy I thought smog was a natural phenomenon. I remember my lungs and eyes burning when I ran track and cross country alongside a freeway in high school and thinking that the pain was not natural. I helped organize the first Earth Day events in 1970 at Arizona State University where I was studying Architecture. Earth Day shook me out of the smoky haze

in which I was raised. It forever changed the way I perceived the definition of the word finite and the importance of air, water and soil quality. I made reducing dependence on finite resources my life's work. When the oil embargos hit in 1973 & 1979, it was the writing on the wall and it seemed that a national effort to improve battery technology and switch to renewable energy would be the only rational next step. After all… domestic oil discoveries had been falling since the 1930s and domestic oil production (extraction) had peaked in 1970. Worse yet, there was a cartel that controlled 80% of world oil reserves and was organizing into a force to be reckoned with. About a dozen start-up EV manufactures in the US and Europe went into limited production mostly for commercial delivery use. The surprising fact was that the nation who landed people on the moon and safely returned them to earth had done little to improve EV performance since the turn of the previous century. In fact the improvements that Edison had made 80 years before on battery technology were almost all but forgotten.

The Gas Guzzler Tax and the EV Renaissance

In 1978, the federal gas guzzler tax that levied a fee on cars with poor fuel economy, along with continued higher gas prices, made more efficient foreign cars increasingly popular. Japanese car sales increased dramatically and for the first time oil use and imports decreased in 1979 and the early 80s. Just as it seemed a smooth transition to renewable energy might be possible a new president captured the election and the 80s turned into the dark ages as the solar collectors were taken off the White House and the nation that once prided itself on its independence went deeper and deeper in debt to pay for its increasing dependence on foreign oil. When Reagan made statements like "Our oil in the Middle East" hopes for world peace also evaporated.

The only bright spots for clean transportation in the 80s were Stanford Ovshinsky, Paul MacCready and Professor Andrew Frank. Ovshinsky invented the Nickel Metal Hydride Battery, which is now used in almost all hybrid and pure electric vehicles. Ovshinsky's accomplishments also include the Triple-Junction Thin-film Amorphous Solar Cell which can be used to charge the batteries in an EV. Paul MacCready engineered the Gossamer Albatross, a pedal powered flying machine and later the sun-powered Solar Challenger. Both successfully flew across the English Channel to capture prize money and the imaginations of a new generation of engineers. Professor Frank very quietly started working with his students at the University of California at Davis to build what we now call Plug-in Hybrid Electric Vehicles (PHEV). Ovshinsky was named a "Hero of the Planet" by Time Magazine and MacCready was named Engineer of the Century by the American Society of Mechanical Engineers. Andy Frank's inventions have not yet received the national attention they deserve, but the idea that over 90% of vehicle miles could be zero emission while still allowing hybrid drive for long trips, will make him one of the heroes of this century.

In 1988 Alec Brooks at AeroVironment, Paul MacCready's small R&D firm, sold the idea of developing a prototype EV to middle management at GM. Bob Stempel, who would later take over as GM's CEO and is now the CEO of ECD, the company founded by Stan Ovshinsky, was the primary advocate of the EV project. Brooks headed the EV prototype team and pushed the GM designers to let styling be determined by aerodynamics, which was a very novel idea at the time. Alan Cocconi, another talented young engineer at AeroVironment, who now makes the most advanced electric cars in the world, worked alone on the electronics. The inverters he built would take the car from 0 - 60 mph in 8 seconds and also provide regenerative breaking, as well as act as a battery charger. The Delco Remy division of GM worked on an 850 pound advanced sealed lead-acid battery pack that would give the car a range of 124 miles at 55 mph. The prototype was completed in January of 1990 and got rave reviews at the opening of the LA auto show. It was easily the most efficient car ever built with funding from an American auto manufacturer.

The California Zero Emission Mandate

After seeing that EVs were possible, the California Air Resourse Board (CARB) announced the Zero Emission Vehicle (ZEV) Mandate later in1990. As originally conceived, the program required that at least 2 % of new car sales by the major manufacturers would be zero-emissions by 1998. The requirement would be 5% by 2001 and 10 % by 2003. The ZEV mandate provided a long term vision that spurred technology development around the world and started an epic battle between the state of California and the auto industry.

It took a while for opposition to get organized but hope for auto industry leadership on fuel efficiency and zero emissions dimmed when Bob Stempel's term as CEO at GM was cut short in part because of his support for the EV-1. The auto industry instead started heavily promoting passenger trucks (SUVs and Vans) for several reasons: 1. Passenger vehicles that qualified as trucks were not included in calculating the percentage of ZEVs manufacturers were supposed to build; 2. The 1978 Gas Guzzler tax did not apply to trucks; 3. Trucks did not have to qualify for the same fuel economy, safety or emission standards as cars; 4. If the passenger trucks were heavy enough there were almost no standards at all; and 5. These heavy trucks (Excursion, Hummer, etc) qualified for federal tax credits that would essentially make them free to anyone with a large enough tax burden.

Trucks were cheaper to build than cars because the fuel economy, safety or emission standards were low or non-existent, and it was relatively easy to make people think they were getting more for their money because they were huge. The average suggested mark-up over manufactured cost on cars is about $3000. On passenger trucks the mark up is as much as $20,000. Once customers got used to the high prices the $5,000 cash back deals seamed too good to pass up. Only when the carnage from rollovers and high bumpers made front page news did people consider that bigger may not be better. The book *High and Mighty* gives statistics that suggest SUV drivers are 3 times more likely to die in single car accidents than mid-sized car drivers, because of rollovers. And in multi-car accidents between an SUV and a mid-sized car, fatalities are almost 3 times more likely than in accidents between two mid-sized cars, because the bumpers on SUVs are at the head height of people in cars. Whenever sales sagged the federal government stepped in with ever bigger tax write-offs up to $100,000 for the biggest passenger trucks and luxury SUV's.

In 1990, only 4% of the passenger vehicles sold in America were classified as trucks. By 2003, passenger trucks made up over 50% of the new cars sold. For the same period, passenger vehicle fuel economy had gone from nearly 30 mpg down to the low 20's. As gas prices continue to rise, those who can afford to buy new, more efficient cars will dump their old SUV's onto second hand buyers, like first time drivers. Driving defensively will take on a new meaning.

The 1994 bi-annual ZEV Mandate hearing in California was attended by an overflow crowd evenly split between young environmental lawyers and well-spoken citizen advocates on one side and 'good old boy' corporate executives and high paid industry 'consultants' on the other. There was a lot of speculation that the newly appointed CARB chair was going to do his best to stop the Mandate. The politicians spoke first at length on both sides of the issue. Next, the industry testified, taking as much time as they needed, to point out the disastrous consequences of the Mandate. Representatives from every major auto manufacturer pointed out the shortcomings of batteries, EV technology in general, the huge costs that would have to be passed on to the consumer, the lack of customer support, and the importance of letting the free market work its magic unencumbered with mandates. The oil industry, through its slick hired guns, was much more threatening. Their long polished speeches were filled with the results of studies they had funded, which claimed everything from 'There was no problem' to 'The Mandate would increase pollution.' They would usually close with something like 'You mandate, we sue.'

By the time industry was through, it was late afternoon and the new CARB chairman instituted the 3 minute rule. The young lawyers from environmental organizations spoke next passionately about the risks from increased greenhouse gas emissions and threats to human health from car exhaust. The crowd was thinning and the press was gone by the time the environmental organizations were through speaking and the citizens who had missed a day of work were told to return the next day if they wanted to be heard. The next day the hearing continued with a bare quorum of the board members and no press but a room full of citizens who came to speak from their heart about what many thought were the most critical issues facing humanity. Every citizen that testified supported the Mandate and was anxious to purchase an EV when they were available. That evening the board voted to uphold the Mandate to the cheers of those who stayed through the two days of testimony. Overnight it seemed like a dam had burst and new companies offering better EV components and conversion kits were popping up every day from all around the world. Michael Hackleman's second book on EVs, *The New Electric Vehicles,* came out at the end of '95 with hundreds of photos of exciting new products and projects.

The $30 Million Ad Campaign that kept America Addicted to Oil

It usually takes at least three years for an auto manufacturer to bring a completely new model from concept to production. If the auto manufacturers were to be ready with ZEVs to meet the 2% mandate in the 1998 model year they would have to start designing them at the very latest in 1995. In the spring of '95 the Western States Petroleum Association and the California Manufacturers Association kicked off a well-funded media campaign to turn the public against electric vehicles. The first phase of the campaign had already started by identifying politicians, scientists and universities whose statements and research could be influenced by very large sums of money. In early spring cover stories started appearing in newspapers, magazines and even scientific journals. The articles quoted what looked like reputable studies to make the point that the EV Mandate would ruin California's economy, raise the cost of every car sold in America by $5,000, and that batteries would cause terrible pollution and blow up and spew acid in an accident. It was later discovered that all the studies the articles referred to were as reliable as the WMDs in Iraq. For example, the battery study was based on statistics from lead-acid battery factories that operated at the turn of the last century and were totally unregulated. They also assumed that the batteries were going to be dumped in landfills. Never mind that 99% of car batteries are now recycled and new totally non-toxic Nickel Metal Hydride and lithium Ion batteries were already in use. The retractions were always buried in small print somewhere at the end of the publication.

Over a six-month period in the summer of '95 every elected or appointed public official in California, from the local Chamber of Commerce to the State legislature, received anti-Mandate propaganda in official-looking yellow envelopes filled with information from what appeared to be some concerned citizen groups. Inside the envelopes were letters from concerned citizens, clippings of the negative articles, pictures of people with acid burns and lists of civic organizations that were against EVs and the Mandate. There were special packets for fire, police and emergency workers that focused on the difficulties of dealing with hydrogen explosions, acid spills and toxic cleanup resulting from EV accidents.

As the 1996 CARB ZEV bi-annual review approached, the auto and oil ('autoil') industry media campaign went into high gear with new and even more effective techniques. Political campaign style TV ads started appearing between sexy SUV commercials. The ads again appeared to be produced by concerned citizen groups and suggested that unnecessary government regulation was going to cost the California tax payer $28 billion and force everyone into cars that would leave people stranded on the road when their toxic batteries died. The industry even managed to turn EVs into a class and race issue. They convinced unsuspecting civic leaders in poor communities that the poor and people of color were going to bear the burden of higher bills so that rich white folks could drive expensive electric cars.

The over $30 million spent in the ad campaign only amounted to a few minutes of the 'autoil' industry annual revenue but had an effect that surpassed even their expectations. The hundreds of start-up companies that were gearing up to produce EV components and kit cars started going out of business.

At the '96 ZEV Bi-annual Review Hearings, CARB eliminated the 2% requirement for '98 and the 5% requirement for 2001 and tried to save face by leaving the 10% ZEV requirement in place for 2003. GM had chartered buses to bring activist from poor communities to testify against the Mandate creating a confrontational and chaotic atmosphere very different from previous hearings. CARB was characterized as the big bad government regulator taking money from the poor to pay for rich people's toys. It was clear, however, that the results of the hearing had been determined months before by an unchallenged negative media campaign. The hoped for clean transportation, charged from renewables, would have to remain a dream for a while longer.

At the 1998 Hearings, CARB continued to ask the auto makers to make a limited number of ZEVs available for lease to the public and fleet operators, but allowed partial ZEV (PZEV) credits for very low emission vehicles that were not pure ZEVs. Toyota started leasing the RAV4 EV to fleets and GM, not to be outdone, finished development on the EV-1. Soon after, Honda came out with the EV Plus.

By 2000, the auto industry was again in the position of having to start the design of vehicles to meet the 2003 10% Mandate. At the hearings that year there was a split in the auto industry. Ford had never been very outspoken at previous hearings, but now under the new leadership of Henry's grandson Bill, Ford was willing to try and meet a revised 2003 requirement. GM on the other hand made a series of announcements that culminated in the recall and crushing of all the EV-1s and electric S10 trucks in California and the end of GM's EV design and production program.

At another hearing in January 2001 CARB reduced the requirement from 10% to 2% ZEVs but maintained the 2003 deadline. Soon after the hearing, GM announced a lawsuit against the State of California. The suit made the allegation that CARB could find more cost-effective ways to reduce air pollution than by imposing the burden of producing battery electric vehicles on the auto industry. The other auto manufacturers moved to comply with the reduced requirements, but Toyota was the only manufacturer to offer an EV for sale to the public. Unfortunately, it was only available for a very brief period to about 200 customers. We purchased our RAV4 EV at the beginning of 2002 and installed a 3 kW PV roof to offset the electricity used to charge our EV.

Toyota RAV4 EV in front of 3.5 kW PV roof Charging Station

The Lawsuits that Increased the Pace of Global Climate Change

GMs suit was modified and joined by the Federal Government in June 2002. A federal judge soon issued an injunction that prevented CARB from enforcing the 2001 requirements. The expanded suite asserted that only the Federal Government had the right to set fuel economy standards. Never mind that the Federal Government wasn't doing its job or that California was regulating emissions, not fuel economy standards.

In April 2003, CARB abandoned the ZEV Mandate to eliminate the federal injunction and then adopted a hydrogen program that required manufacturers to build 250 fuel cell vehicles by 2008. Instead of hundreds of thousands of competitively priced zero-emission EVs by 2003, we now have a few dozen multi-million dollar fuel cell vehicles with less range than EVs and GM started recalling and crushing all the EV-1s

Recalled EV-1s waiting to be crushed

The end for best car ever built by GM.

Last year, in response to increasing concerns about Green House Gas emissions and Global Warming, California passed limits on CO2 emissions from cars. Again the Bush administration and this time all auto makers including Toyota, thinking short-term profits are more important than long-term health, filed suit against the State of California. Seven Eastern States have also opted to adopt the new California standards. This move by States is part of a growing grass roots effort by local governments and citizen groups to deal with issues like 'Peak Oil' and Climate Change caused by human activity. When greed wins everyone loses. It was greed that created the SUV profit bubble and now, as oil prices continue to rise, the bubble will burst, causing plant closures and lay-offs.

The next phase of EV development is being assembled by Professor Andy Frank and his students at UC Davis. It's called a Plug-in Hybrid Electric Vehicle (PHEV). Hopefully this time around enough people will be able to see through the smoke and demand transportation choices that can be fueled by unlimited clean renewable energy. Then the clean and quiet revolution can begin.