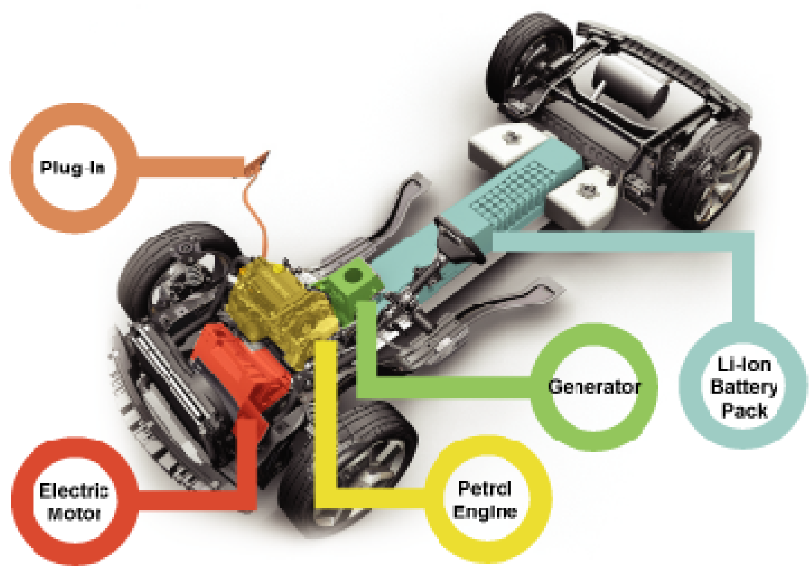
2008

Federal Policy Recommendations for Creation of a Plug-In Hybrid Electric Vehicles Industry in the United States



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EXECUTIVE SUMMARY

While it should be one part of a comprehensive strategy to reduce our emissions, there are fewer technological opportunities that could do more to help the U.S. simultaneously address the problem of emissions, an ailing domestic automotive sector, and dependence on foreign oil than a transition to electric drive trains in passenger vehicles. Enabled by incremental improvements in the energy and power density of advanced battery technologies, Plug-In-Hybrid Vehicles (PHEV's) will soon provide breakthrough advances that will also be able to meet consumer expectations of price, range, top speed, and acceleration. Likewise, these vehicles may also provide ancillary benefits, such as distributed storage that could help balance the electric loads of utilities.

PHEV's will receive a portion of their energy from the electric grid, with the remainder being supplied by an on-board generator that runs on fossil fuels. This could equate to a gasoline savings of 75% with a battery pack that provides a range of 40-45 miles under normal driving conditions, such as in the Chevy Volt. Depending upon energy source provided by the grid CO_2 emissions could be expected to be 20%-50% of a conventional vehicle. (Electric Power Research Institute, 2007)

PHEV's are needed because they represent the best near-term technological possibility to:

1) Reduce CO2 emissions from transportation
2) Reduce dependency upon foreign oil
3) Export technological advances to the rest of the world to improve our current account deficit

PHEV's with an all-electric range of 40 miles are currently technically achievable at an estimated cost of $30,000 - $40,000. The greatest challenge lies in finding the appropriate ways in which to bring down the upfront costs of PHEV's, and especially in the battery packs, which make up close to 75% of the additional costs associated with hybrid configurations in most models (Anderman, 2007). Operating PHEV's are cheaper and more environmentally friendly than operating gasoline or diesel vehicles at almost every comparable level of fuel and electricity prices. However, policies are needed in order to drive developments in PHEV technology in order to:

1) Reduce cost of the vehicle (primarily in the battery pack)
2) Increase vehicle range by increasing energy and power density of the batteries
3) Improve the infrastructure available for charging & recharging

In order to drive development of PHEV technology it will take a sustained effort, an increase in federal contribution to R&D around battery technologies, and a mix of policies to smooth the adoption of this technology for producers and customers (Schafer, 2003). It is necessary to stimulate not only the consumption of these vehicles, but also to stimulate the production of key technologies within the United States. This is not only critical to job creation, it is critical to energy security. If the United States pays for the transition to an electric vehicle infrastructure then it should do its best to protect the IP that is developed in the process. The best way of doing this is to manufacture within the borders of the U.S..

Because of the massive raw materials costs, the federal government should consider providing support either for the production of these materials in the U.S., or structuring of more favorable subsidies for battery chemistries that use more raw materials that can be produced in the U.S. at scale. Furthermore, the global supply of certain raw materials should be evaluated to ensure that chemistries that utilize more rare metals would be scalable to production of several million vehicles per year. Without some thought given to planning ahead, the U.S. could end up in a situation whereby reducing the dependence on foreign oil it increases dependence on some imported commodity metal used in the battery packs in PHEV's. With policies based on evaluation of the entire value chain for production of PHEV's, the U.S. will be able to stimulate production of batteries used in PHEV's in a way that will reduce U.S. dependence on foreign oil, reduce carbon emissions, and have large percentage of the value created within U.S. borders. PHEV's offer tremendous potential to the future of personal transportation and U.S. industry but it will take smart policy to optimize these benefits for the U.S.

State of PHEV Technology and Future Potential

A plug-in hybrid electric vehicle (PHEV) is defined as any hybrid electric vehicle which contains at least:

1) A battery storage system of 4 kWh or more, used to power the motion of the vehicle;
2) A means of recharging that battery system from an external source of electricity; and
3) An ability to drive at least ten miles in all-electric mode, without consuming any gasoline (IEEE, 2007).

This is distinguished from hybrids that are currently being mass-marketed, such as the Toyota Prius, which do not use any electricity from the grid.

State of Technology

The Chevy Volt is the first plug-in hybrid with a 100% electric drive-train advertised to be released commercially, with a targeted release date of 2010. Toyota is also planning to release a plug-in version of the Prius in 2010, but this will have dual gas and electric drivetrains. The Volt is considered a greater technological advance for this reason, and it will also be the first vehicle to incorporate lithium-ion batteries. Toyota has not committed to whether they will incorporate lithium ion batteries or if they will stick with the nickel-metal hydride batteries currently being used in the Prius, which are heavier and have a lower energy density. The plug-in Prius will only be able to travel 7 miles in all-electric mode in comparison to the 40 miles the Volt is claiming it will offer (after a 6-hour charge).

Hybrid-Electric Vehicles (HEVs) sales made up over 0.7% of total global new car production in 2006, 60% of which were in the U.S. market, where it accounted for 1.3% of total car sales. Hybrid technology has spread to fifteen car models across several vehicles classes. (Anderman, 2007)

Environmental Assessment of PHEV Adoption

A recent study performed by the Electric Power Research Institute and the NRDC showed that adoption of PHEV's would reduce emissions of greenhouse gases, NOx, VOC's, SO2, ozone, and particulate matter.

The study's GHG analysis included evaluating several scenarios of PHEV fleet penetration and electric sector CO2 intensity. Significant reductions in CO2 were found in each of nine different scenario combinations. Cumulative reduction in GHG emissions from 2010 to 2050 due to adoption of PHEV's could range from 3.4 to 10.3 billion metric tons.

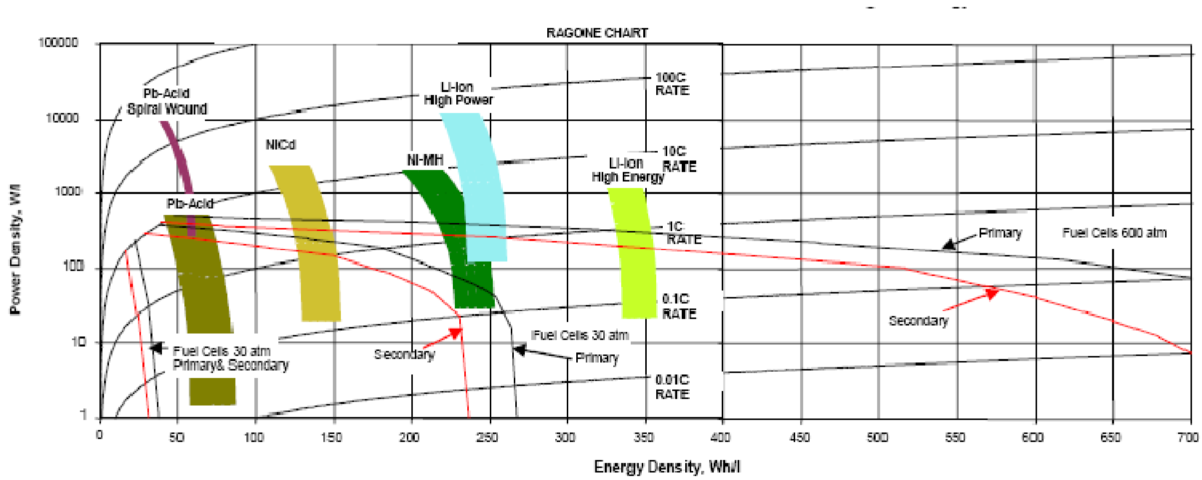
Annual greenhouse gas emissions reductions from PHEVs in the year 2050.

2050 Annual GHG Reduction (million metric tons)		Electric Sector CO_2 Intensity		
		High	Medium	Low
PHEV Fleet Penetration	Low	163	177	193
	Medium	394	468	478
	High	474	517	612

Opportunities for Technological Advancement

The current generation of hybrids contains almost exclusively Ni-MH batteries. The major automakers have committed to developing high- powered Li-ion batteries for the next generation of hybrids. All-electric vehicles like the Tesla Roadster generally have enough power available due to the size of the pack and choose to go with Li-ion high energy cells in order to extend the total vehicle range.

However, this chart only shows the technical specifications of batteries, where the price per Wh is often the key component, and where lithium-ion currently has a much higher cost per Wh (generally though to be in the $2-$5 per Wh range). Potential to develop batteries with comparable energy density and power density to lithium-ion cells exists at a much lower $ per Wh range. In theory, zinc-air batteries offers some of the best potential to achieve this cost effectively on the basis of power and energy density but would require additional battery-servicing infrastructure due to shorter cycle life and the potential need to swap out batteries or to replace the contents of the batteries with zinc pellets. While it appears certain that lithium-ion will be the next major transition in battery chemistries it is unclear where that direction will be headed in ten years time, although it is certain that reducing the cost per Wh of capacity will be a key driver.



Battery Manufacturing Value Chain

One serious consideration that any policy surrounding PHEV's should consider is the source of the batteries, and materials incorporated in the batteries, within PHEV's that are being supported by government regulation or subsidies. Currently, Japanese suppliers provide over 60% of the world's lithium-ion battery demand, with Korean and Chinese suppliers sharing the bulk of the remaining 40%.

In automobiles, two Japanese battery producers, Panosonic EV Energy, a joint venture between Toyota and Panosonic, and Sanyo share over 95% of the $600MM HEV battery market (nearly all of which are NiMH). Cobasys is the only U.S. supplier of batteries to the HEV market, supplying the Saturn Greenliner. Both of these large Japanese battery giants are developing lithium-ion batteries for the emerging HEV and PHEV automotive market, where over twelve companies are expected to be competing. A123 Systems, a U.S.-based company recently received some good news when it was disclosed that they will be one of two suppliers to the Chevy Volt, the first mass-produced PHEV slated to be released.

While the U.S. and Europe have significantly capabilities around battery research, these Asian countries have established a serious gap in the knowledge around advanced battery manufacturing, which has been described as a combination of art and science. The manufacturing of high-volume, low-cost high-powered lithium ion batteries with high levels of reliability is expected to be extremely challenging. Incentives should be provided to begin establishment of this manufacturing knowledge in the U.S. in addition to the research and development that is used to develop the materials being used. (Anderman, 2007)

Raw Materials Value Chain

Battery chemistries should be evaluated for the source and availability of their raw materials in addition to other factors when they are being considered for federal grants or production subsidies. The ideal raw materials will have sufficient global resources and will be available in the U.S. or from a wide variety of international sources. A scale-up of advanced batteries should not lead to anticipation to a spike in materials costs that would suddenly make the cost of the battery pack rise by more than 10-20%.

NICKEL- Nickel is an expensive commodity. Prices have ranged from $10,000 to $50,000 per ton over the past few years. The U.S. also did not have any active nickel mines in 2007. Nickel should be avoided as a material in energy storage technologies unless a significant advantage can be established.

COBALT- The United States did not mine any cobalt in 2007 but has estimated resources of about one million tons. In November 2007 the price of cobalt cathode increased to nearly $40 per pound. Cobalt is not an ideal choice for battery materials from a geo-political and economic perspective.

MANGANESE- Manganese is also used in steel production. Steel-grade Manganese can generally be obtained for only a few dollars per ton. South Africa is though to contain the vast majority (80%) of the world's reserves.

ZINC- Zinc is commonly used in galvanizing, bronze, and alloys, as well as in the agriculture, chemical, paint, and rubber industries. Global reserves of zinc are estimated at 1.9 billion metric tons, with the using containing 90 million metric tons. Global zinc resources are well dispersed.

LITHIUM- It is hotly disputed as to if future prices of lithium will increase or decrease with the growth in demand due to lithium-ion batteries. The U.S. does have a supply of lithium but the vast majority of lithium is available in Chile and Bolivia. However, there could be some issues with availability of groundwater used in production, where groundwater is currently being mined in these deserts to produce vast quantities of lithium at a relatively low cost.

EXAMPLE VEHICLE: THE CHEVY VOLT

The Chevy Volt is said to have a battery pack of 16kWh, and the U.S. Advanced Battery Consortium says that cars will need packs that hold 40kWh of energy before electric-only cars become acceptable to consumers at a meaningful scale. The Volt's battery pack will weigh 400 pounds. Assuming a price of $2 per Wh, this pack would cost $32,000. Also, Compact Power, one of the two named battery suppliers to the Chevy Volt, has been said to have settled on a manganese spinel blend, which has a higher power density (but somewhat lower energy density) then some of the other available chemistries. (Gustafson, 2008)

EXISTING POLICY CLAIMS FOR PHEV'S

Barack Obama's presidential campaign policy included a "New Energy for America" plan that set the goal of putting 1 million PHEV's on the road by 2015 that will be built in America, which will be supported by a specific focus on R&D in advanced battery technology. This policy plan also included a $7,000 tax credit for the purchase of advanced vehicle technology vehicles as well as conversion tax credits. Current hybrid subsidies amount to $2,000 per vehicle. Finally, the policy included a pledge to convert the entire White House fleet to plug-ins within one year of becoming president, and for half of all cars purchased by the federal government to be plug-in hybrids or all-electric vehicles by 2012. (Senator Barack Obama Campaign, 2008)

STRATEGY AND POLICY TO SUPPORT DEVELOPMENT & ADOPTION OF PHEV TECHNOLOGY

The United States should pursue policies that will drive adoption of PHEV technology within its borders, but with policies that look beyond the creation of this market and look to creating it in a way that is most beneficial to the United States. PHEV's should also be seen as a potential first step towards a long-term pathway to transition to vehicles powered by hydrogen fuel cells. The key drivers for PHEV policies should be:

- Reduced pollution, including greenhouse gases
- Reduced dependence on foreign commodities, including oil AND valuable metals used in PHEV batteries such as cobalt, nickel, and manganese
- Building up the weakened U.S. automotive and manufacturing sector by making the U.S. the key dispensers of cutting-edge PHEV and EV technology for domestic use and export
- Enabling of a long-term transition to fuel-cells or ultra-efficient lightweight vehicles as part of a pathway to long-term environmental sustainability

Promoting the adoption of PHEV's is an important component of reacting to all of these drivers but additional policy measures are necessary in order to maximize the economic security and benefit to the United States. If U.S. taxpayers are willing to adopt policies that promote PHEV's, there should be some consideration of this adoption as something that will benefit the U.S. economy in the long term. Therefore, efforts should be made to stimulate production of each piece of the PHEV value chain that is possible, within economic reason.

Promote adoption of PHEV's

While PHEV's have great potential to help the United States solve its transportation energy problem in the long term, government policy is needed that will send clear regulatory and economic signals to consumers and automakers that the future of personal transportation will shift to PHEVs and electric vehicles.

Taxes that create a higher floor on the price of liquid fuels

The recent spike in gasoline prices helped to establish that U.S. consumers will react to high price signals for gasoline by purchasing smaller, more fuel efficient vehicles. This is compounded with long-term development planning, where long commutes are designed into the built environment under the premise that consumers will not calculate this additional cost into the price they are willing to pay for a home that is further away from their work. The U.S. government should gradually phase in additional taxes to raise the floor price of gasoline and diesel to $4 per gallon. The additional revenue that is generated should be used to reduce in equal proportion other taxes that bring in revenue for the federal government, such as income taxes and payroll taxes. A positive unintended consequence of this policy would be that reducing the number of large vehicles on the road will help to reduce the safety-related worries that consumers have when they are considering purchase of their own smaller vehicles.

Tax credits for purchase of PHEV's

The government should provide a tax write-off of $2000 to any business that purchases a qualified PHEV from 2010 until 2018. Qualified PHEV's must have their battery cells certified as being manufactured in the United States.

Mandatory utility investments in distributed storage technology

The federal government should require all regulated utilities serving over 1,000,000 customers to provide Advanced Metering Infrastructure and charging stations to any customer that requires it by 2015, including commercial customers.

Increase the fuel standards set by CAFE and give PHEV's maximum credit

The hybrid electric vehicle emerged as part of a strategy to vastly increase the total fleet efficiency for Toyota. Increased fuel economy standards would also promote further investment in PHEV's. However, there is some danger that CAFE requirements could stimulate a market that does not yet exist if fuel prices remain low or if there is not simultaneous progress made on development of charging infrastructure. Awarding PHEV's that have a range of at least 40 miles with a mpg rating of at least 100 mpg would reward automakers for investing in this technology as part of their CAFE requirements.

Opportunity for Electric Utilities to Participate

Federal utility regulation should be reviewed that may prohibit utilities from owning battery packs in vehicles and adjusted so that utilities can carry customers battery packs on their books as assets. This would allow utilities to invest in battery packs and achieve a reasonable return, because utilities make profits on the basis of total assets under management rather than a high price. This would also enable utilities to undertake additional infrastructure investments such as charging stations and information for incorporated distributed storage into the grid. Allowing utility participate would also ease the consolidation of the information systems necessary to make an AMI-PHEV system efficient.

Allocation of Federal Highway Dollars

A portion of the federal highway budget should be directed to reward urban areas that promote adoption of PHEV's through investment in charging infrastructure, HOV lane policies that allow greater access to PHEV's, and parking policies or congestion-price policies that reward vehicles with electric drive-trains. Metropolitan regions with air-quality problems should be keen to adapt PHEV's.

Promote security of PHEV energy and the value chain

It is not in the best economic interests of the United States to substitute oil that is purchased abroad for battery packs that are produced abroad. Also, it is not productive for the United States to invest in R&D around advanced batteries if it is not willing to support an advanced battery manufacturing industry. Therefore, some strategic thought should be given to the future raw materials flows that will be involved in choosing different battery chemistries, the long term impact that massive adoption of PHEV's will have on metals prices, and the ability to maintain a diversified (or U.S.-based source) of key materials inputs for advanced batteries being used in PHEV's.

Production tax credits for advanced batteries

Rather than reward the production of the finished PHEV, production tax credits should seek to reward the manufacturing and assembly of battery cells and packs in the U.S., similar to existing incentives aimed to reward production of wind and solar equipment in the U.S. This is necessary in order to build the necessary battery manufacturing capability in the United States.

Establishment of a permitting-fast track for advanced battery manufacturing

A special unit should be established to grant all necessary federal environmental and regulatory permits for advanced battery producing facilities. This unit will be available to provide feedback on short notice to companies who are applying for permits. All federal permits for advanced battery production will be required to be turned around within 45 days.

Mandatory recycling of battery packs by the OEM

In order to qualify for production tax credits, all OEM's will be required to provide take-back stations for battery packs sold in their HEV and PHEV vehicles throughout their dealer networks by 2012. By 2015 all packs should be removable and replaceable by OEM-certified replacement models. This will minimize the amount of new metals that needs to be mined or imported, maximizing the reserves of these metals that are available. It is recommended that a potential shift of subsidies from battery production to battery recycling be examined in 2012 to determine the optimal economics based on known costs of battery recycling. A vibrant advanced battery recycling industry must be established.

Mandatory battery-pack charging stations at gas stations

Gas stations should be required to provide charging stations equivalent to 20% of their fuel pump, or at least one charging station, whichever is greater. This should be done by 2015.

Promote research of critical technologies for PHEV's and an EV future

The U.S. does not allocate enough of its federal R&D budget to energy. When considering the magnitude of the problems the U.S. faces with energy, which is a $1.8 trillion annual market in the United States, (15% GDP) that is on par with healthcare industry. However, only $1 billion (0.1% of GDP) is spent per year on energy R&D, versus $28 billion on health. Furthermore, energy technologies that are produced in the U.S. are more likely to be exported than many healthcare related products, which are often not supported by the public medical systems of other nations.

Research and development in advances in battery recycling technologies

The federal R&D budget for research in energy technologies should be increased dramatically as-is. A portion of this increase should be in recycling processes surrounding advanced batteries.

Research and development in mineral extraction technologies for Cobalt, Lithium, and Manganese

Although materials costs make up a large portion of the net cost of a lithium-ion battery cell, little research is put into new processes that could extract these materials more cost effectively. Furthermore, the global metals and mining industry invests a very small proportion of their revenues into R&D. Still, possibility for more efficient processes may exist, especially for metals that will see their net consumption grow at least 50% due to advanced batteries, such as lithium and potentially cobalt. Processes combining minerals extraction with geothermal energy production are one area where the federal government should increase their R&D expenditures.

Research and development of Zinc-Air battery technologies

The government should commit to spending at least $200MM per year on research and development of zinc-air battery technologies, which is still too immature to be developed for electric vehicle usage but which has potential to become commercialized before hydrogen fuel cells. Another advantage of this technology for future energy security is that unlike nickel, cobalt, or manganese, the United States has a supply of zinc that is on par with other nations. Zinc deposits are also thought to be distributed relatively evenly throughout the world, which could help to reduce global commodity power asymmetries. For reference, the price of zinc is often 1/10 the price of nickel. (London Metal Exchange, 2008)

Alternate Policy Scenarios

Reduction of dependence on foreign oil with no environmental consideration

In this scenario, liquid coal produced with CCS could be used in fuel-efficient vehicles, which would result in lifecycle GHG emissions of approximately 330 grams/mile. This is *ten times* the amount of CO2e that would be produced by a PHEV operating on electricity generated in a coal-fired power plant equipped with CCS (Greene, 2007). While this scenario may provide for acceptable levels of energy security, it is clearly disastrous from an environmental standpoint. Also, it would make it more difficult to transition to advanced battery technologies in the future once liquid coal made it far enough down the cost curve.

Market-based reduction of GHG's without technology direction

In this scenario the U.S. puts a price on GHG's. We will assume a price of a range of $20-$40 per ton of CO2e, which is the equivalent of ~$0.15 to $0.30 per gallon of gasoline. The U.S.A maintains the current level of funding for R&D and does not attempt to pick technology winners beyond the current rebate for hybrid vehicles. The result is that a pure carbon tax will have minimal effect on transportation, and will have a much greater effect on the cost of electricity first.

Stimulation of PHEV's without strategic value-chain planning

In this scenario the U.S. promotes consumption of PHEV's without taking any measure to ensure that production of the batteries remain in the U.S. The result is an industry with the raw materials in the battery packs being produced internationally and shipped to Asia, where the batteries are produced before they are shipped to the U.S. Therefore, most of the potential subsidies available to offset the costs of the battery packs goes beyond U.S. borders without much conversion into U.S. employment.

Business as Usual

In this scenario the U.S.A continues to maintain a relatively low gas tax in comparison to the rest of the world, and does not enforce a cap-and-trade system for GHG's or a carbon tax. The U.S.A maintains the current level of funding for R&D and does not attempt to pick technology winners beyond the current rebate for hybrid vehicles. The result is an unclear direction for investors, which would translate to a lack of investment in developing the technologies needed for efficient and cost-effect electric vehicles. Furthermore, if all of the current investments in battery technologies and fuel cells are allowed to crash and burn it will serve as a warning that will prevent more investments in cleantech in the future.

Alternative Vehicle Pathways

Biofuels can help to reduce emissions of the overall fleet but biofuels will not replace fossil fuels in vehicles because of limitations by how much sunlight can be converted into usable biomass. Biofuels produced from algae may be the only truly scalable biofuels technology that would be able to provide a majority percentage of liquid fuels before being limited by land availability. However, it will be many years before liquid fuels can be produced cost-effectively from algae at scale, if ever. Biofuels will remain important to the aerospace industry in the long term, as electric-storage will never be the ideal technology for flight. R&D should be increased in the area of producing biodiesel and jetfuels from algae, and most significantly in the areas of algae biological engineering, controls for maximizing algae yields, and potential open ocean systems for growing and harvesting algae.

STANDARD HYBRIDS (HEV'S) provide a significant improvement in fuel economy in comparison to standard vehicles powered strictly by liquid fuels. Hybrid vehicles to date have shown an improvement of 16 to 47 percent in fuel economy in comparison to their non-hybrid counterparts. In comparison, PHEV's could reduce the consumption of liquid fuels by at least 70 percent compared with conventional cars (IEEE, 2007).

DIESEL vehicles do achieve greater fuel efficiency due to a higher energy density of the fuel. While the rest of the world chose a greater penetration of diesel, the U.S. remains almost purely upon unleaded gasoline for its light vehicle fleet, because of emissions regulations put on diesel in the 1970's. While diesel engines currently have greater fuel economy & do not have the same emissions problems that were present in the 1970's, they are also about $3,000-$4,000 more expensive and are heavier. Diesel vehicles should be supported but do not need any economic stimulus from the federal government at this point.

FUEL CELLS offer a potential hope for a long-term solution for a transition to a 100% reduction in emissions and reliance upon foreign oil. However, fuel cells are still incredibly expensive and nowhere near commercialization, despite decades of R&D invested by both the federal government and major automakers. A transition to fuel cells will require serious investment in the creation of a hydrogen infrastructure in addition to a source of electricity in order to produce the hydrogen to charge them.

CONCLUSIONS

The U.S. should encourage cost-effective production and consumption of PHEV's within the United States in a manner that attempts to build the core of this industry, the research and manufacturing capabilities for advanced batteries and battery-management systems, in the U.S. as well. Although we can suggest several policies that could do this in a cost-effective manner, what policies can be achieved and maintained politically over the time period necessary to seed this progress is another question. Much of these political difficulties will be managing interest group policies, with the scale of the problem being addressed reflecting the quantity and magnitude of the interest groups likely to become involved. Perhaps the greatest difficulty, if it is possible, will be in getting the U.S. public to accept higher gas prices that are propped up by a higher gas tax, even if this tax was used to offset other taxes affecting individual consumers, like income taxes, or to provide health care assistance for average Americans. In economic terms, higher fuel prices are the most efficient means of reducing fuel consumption in the long run because it also provides incentive for consumers to alter their behavior, in addition to providing an added layer of certainty for investors who are making bets on technologies that do better in higher fuel price scenarios, such as alternative fuels and PHEV technology.

Still, these political challenges provide the opportunity for true leadership. Finding a sustainable and secure means of transportation is one of the major challenges for this generation, and it will not come easy. At the highest level we do not necessarily need policies that pick battery chemistries, or even drivetrain technologies. However, it is wise to realize which technologies are left underfunded by business as usual, and to pull the correct economic levers to jumpstart research and production of those technologies when it is deemed to be appropriate for society. Furthermore, promoting PHEV production and consumption in the U.S. should be thought of as building a strategic industry, and careful thought should be given to each piece of the value chain, from the raw material stage up to the eventual recycling of the vehicle and the battery pack. With this approach and cooperation between government, automakers, utilities, and research organizations the U.S. could be a leader in PHEV and EV design and production for the next 50 years. However, an approach that is not adequately thought out could lead to either the lack of, or the offshoring of the majority of the technological developments needed to build a PHEV industry, either of which would be a tragedy.

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APPENDIX

Table 3. U.S. apparent consumption of raw materials used in the transportation sector, 1975–2000

[In metric tons. NA, not available. Source: Kelly and Matos, 2004]

Year	Aluminum	Copper	Iron and steel	Lead	
				Gasoline additives	Storage batteries
1975	663,000	190,000	NA	189,000	635,000
1980	868,000	240,000	15,000,000	128,000	645,000
1985	1,100,000	280,000	13,000,000	46,000	841,000
1990	1,110,000	260,000	11,400,000	16,000	1,020,000
1995	1,990,000	280,000	13,300,000	NA	1,330,000
2000	2,760,000	310,000	14,600,000	NA	1,490,000

Table 4. U.S. passenger-miles of travel by mode, in millions, 1985–2000

[Source: U.S. Bureau of Transportation Statistics, 2004c]

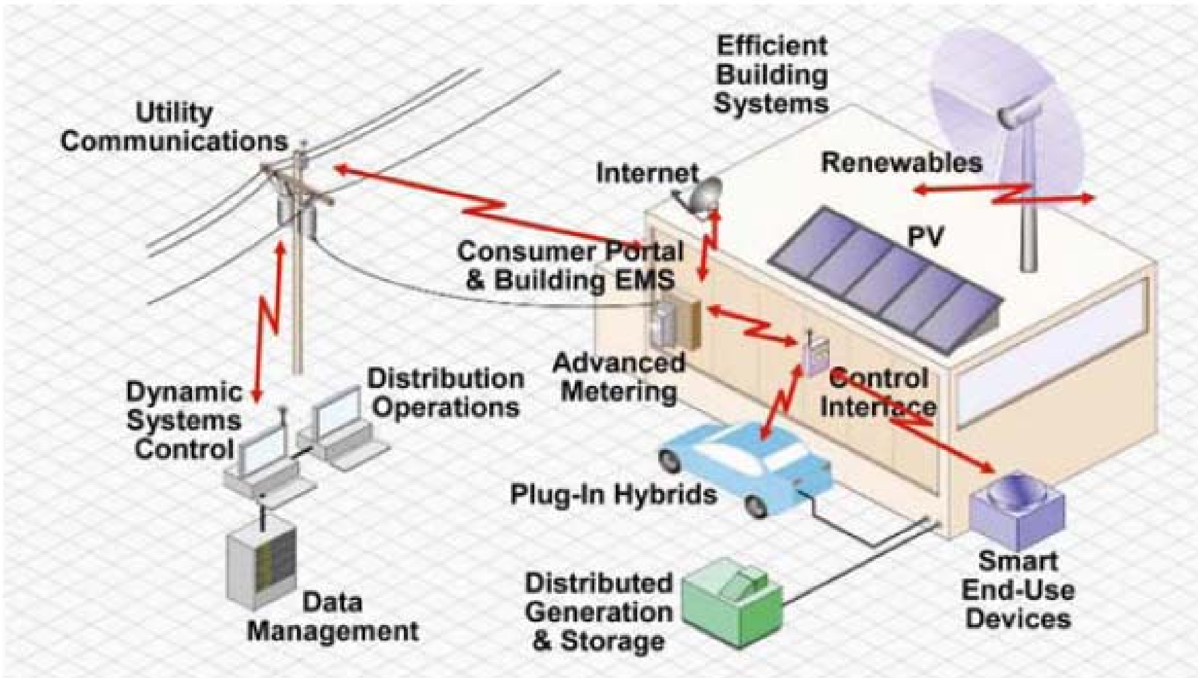
Mode	1985	2000	1985–2000 percentage change	2000 percentage of total
Air total	290,136	531,329	83.1	11.2
Highway total[1]	2,889,449	4,184,556	44.8	88.1
Bus[2]	94,925	160,919	69.5	3.4
Light truck	688,091	1,467,664	113.3	30.9
Motorcycle	11,812	11,516	-2.5	0.2
Passenger car	2,094,621	2,544,457	21.5	53.6
Transit total[3]	18,420	26,425	43.5	0.6
Rail, Amtrak	4,825	5,498	13.9	0.1
Total[4]	3,202,830	4,747,808	48.2	100

[1]Excludes heavy trucks because their function is to transport goods.

[2]Comprises all travel by bus including intercity, transit, and school bus.

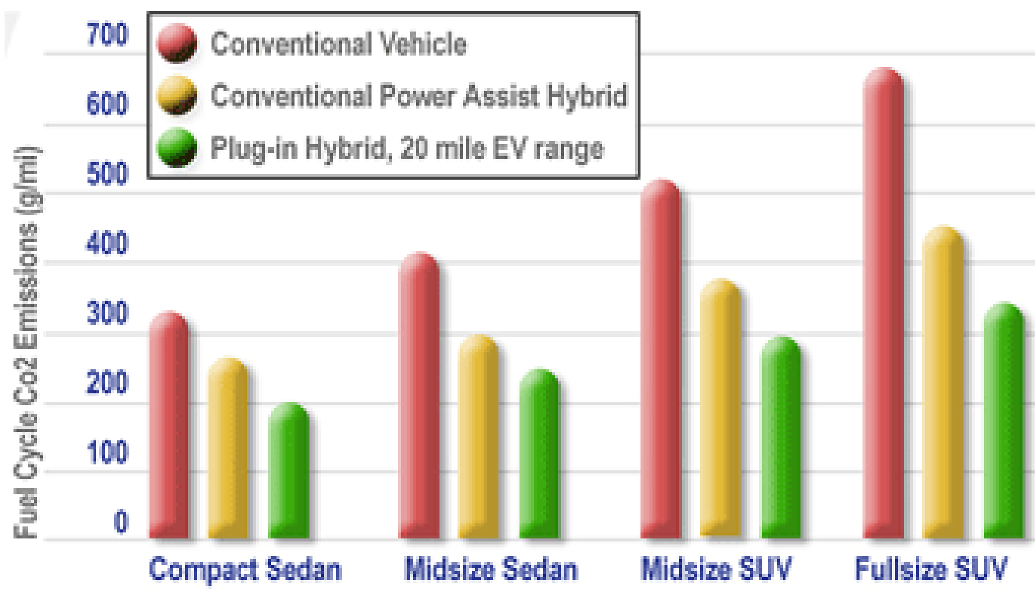
[3]Excludes bus and includes travel by commuter, heavy, and light rail, ferry boat, and others.

[4]Excludes passenger-miles of travel by bicycle, walking, and boat because national estimates are not available on an annual basis.

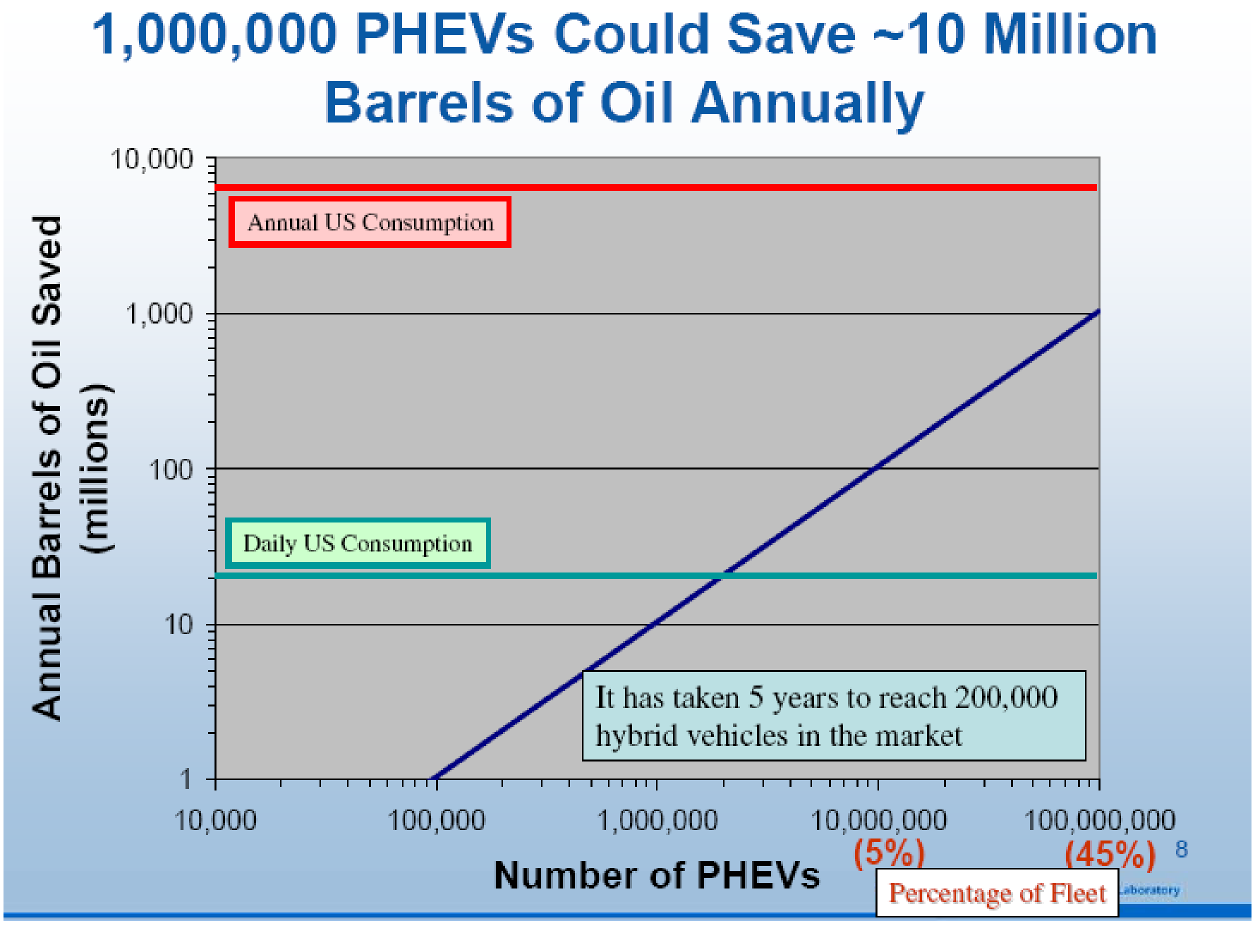


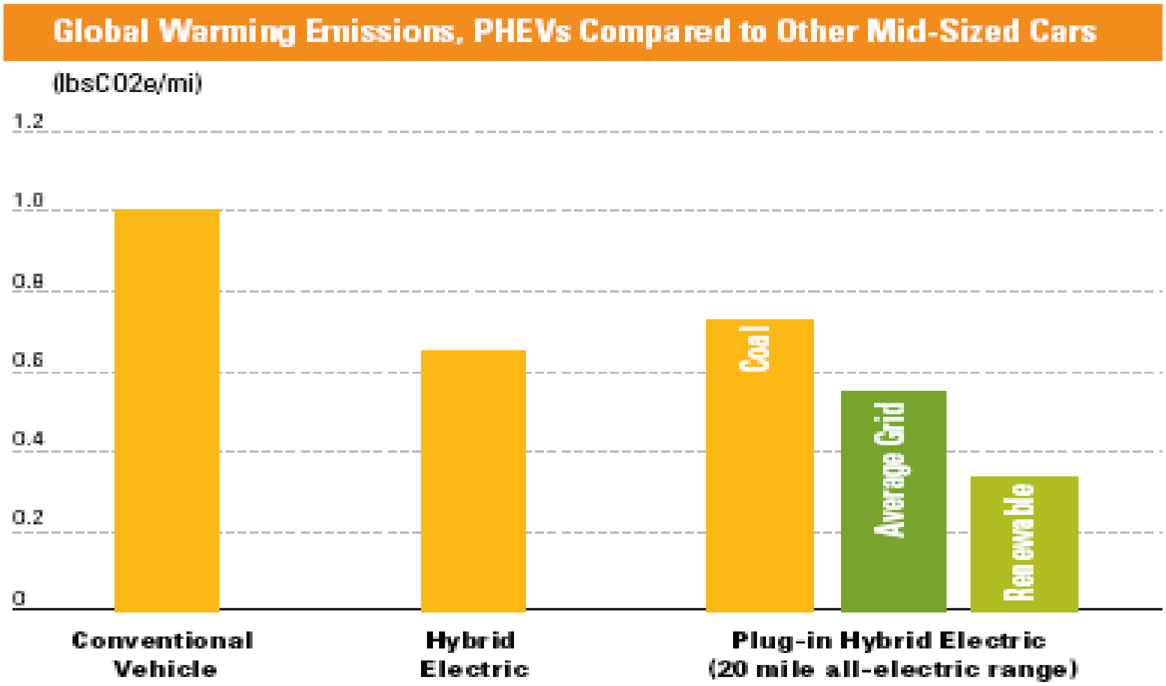
Tomorrow's Intelligent Power Delivery Infrastructure Must Enable PHEV

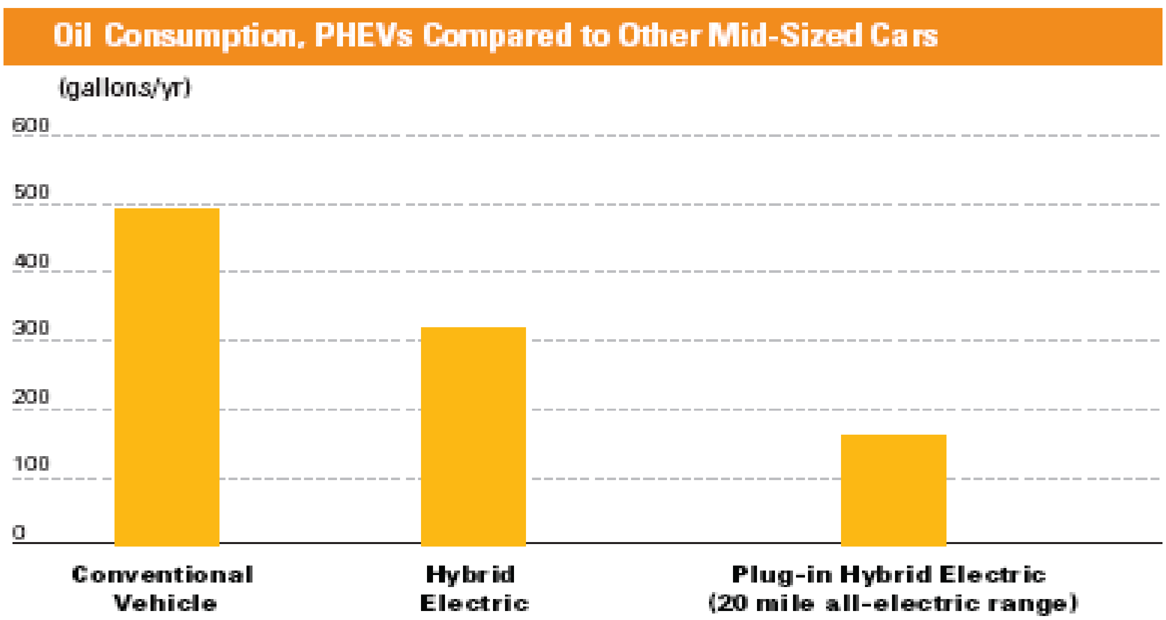
Source: EPRI



Electric Power Research Institute

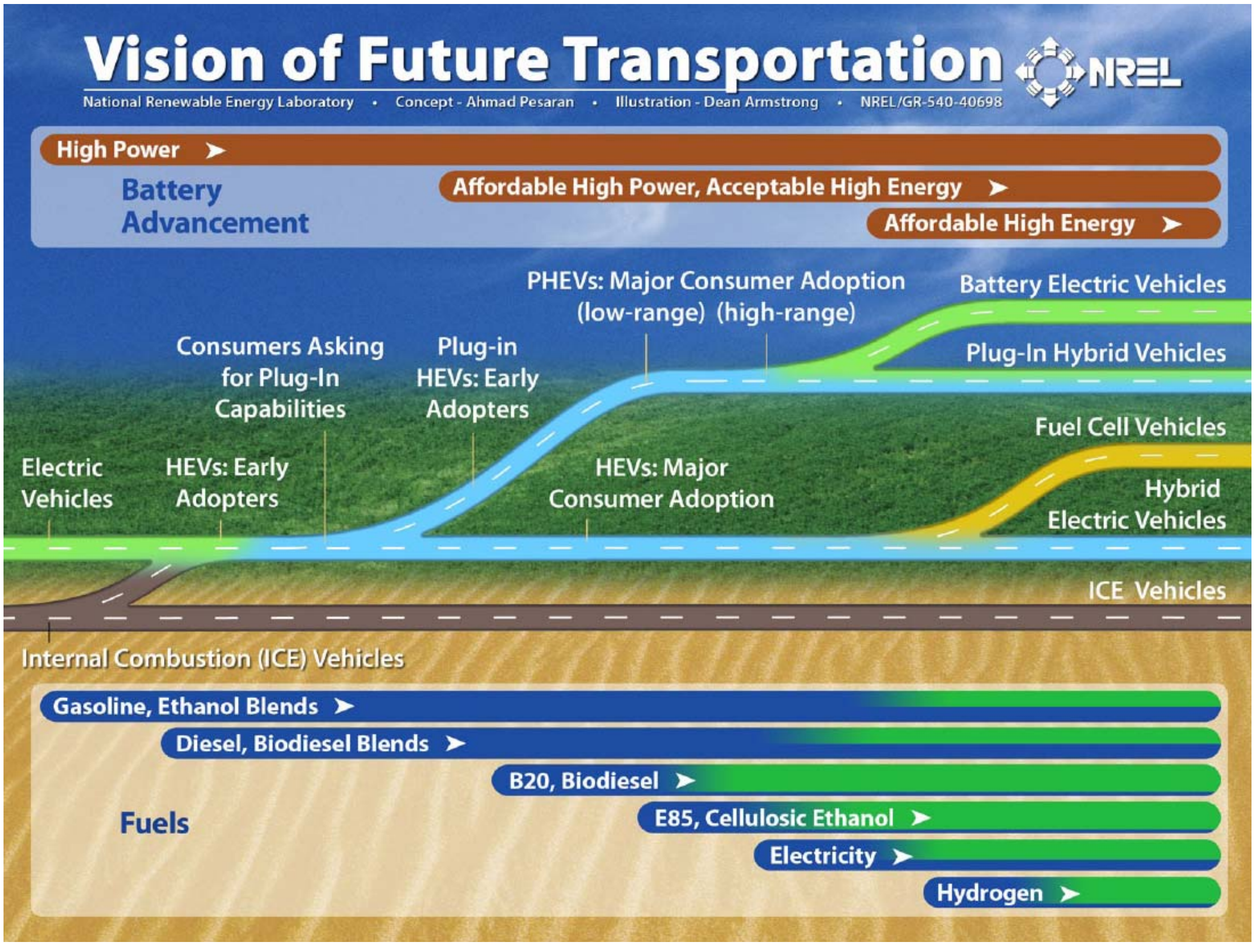

1,000,000 PHEVs Could Save ~10 Million Barrels of Oil Annually
Annual US Consumption
Daily US Consumption
It has taken 5 years to reach 200,000 hybrid vehicles in the market
Annual Barrels of Oil Saved (millions)
10,000
1,000
100
10
1
10,000
100,000
1,000,000
10,000,000
100,000,000
(5%)
(45%)
Number of PHEVs
Percentage of Fleet
8

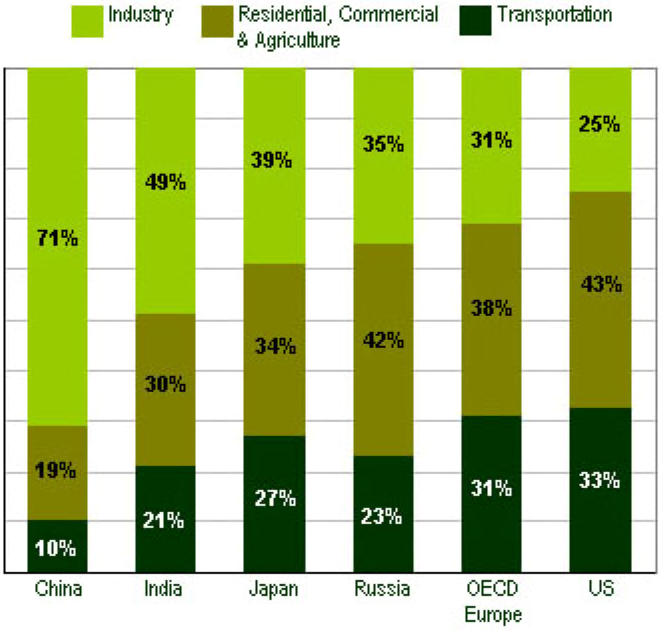




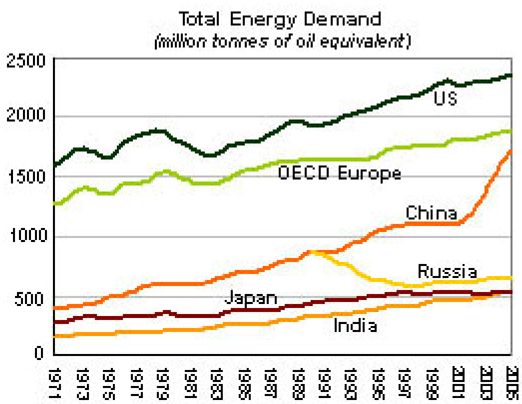
Source: EPRI-NRDC Joint Technical Report, *Environmental Assessment of Plug-In Hybrid Electric Vehicles, Volume 1: Nationwide Greenhouse Gas Emissions* (1015325), July 2007.

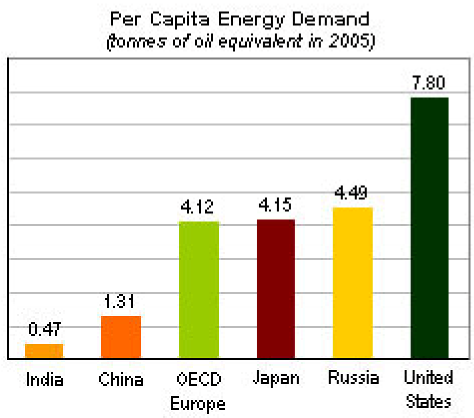
- For PHEVs, per mile global warming emissions are greatly affected by what is used to charge them. Today's typical pulverized coal power plant (2.5 pounds CO2e/kWh) results in the highest emissions. The average grid (1.3 pounds CO2e/kWh) is a mix of generation sources of mainly coal, natural gas, nuclear and large hydro. Non-emitting renewable electricity sources such as wind, geothermal, and solar provide the lowest emissions per mile.
- We assume all vehicles travel 12,000 miles per year. On-road efficiency for conventional vehicles 24.6 miles per gallon while hybrid drivetrains achieve 37.9 mpg on gasoline. PHEV electrical efficiency is 3.2 mi/kWh and 49 percent of the PHEV miles are using stored grid electricity.


Vision of Future Transportation
NREL
National Renewable Energy Laboratory • Concept - Ahmad Pesaran • Illustration - Dean Armstrong • NREL/GR-540-40698
High Power
Battery Advancement
Affordable High Power, Acceptable High Energy
Affordable High Energy
PHEVs: Major Consumer Adoption (low-range) (high-range)
Battery Electric Vehicles
Consumers Asking for Plug-In Capabilities
Plug-in HEVs: Early Adopters
Plug-In Hybrid Vehicles
Fuel Cell Vehicles
Electric Vehicles
HEVs: Early Adopters
HEVs: Major Consumer Adoption
Hybrid Electric Vehicles
ICE Vehicles
Internal Combustion (ICE) Vehicles
Gasoline, Ethanol Blends
Diesel, Biodiesel Blends
B20, Biodiesel
Fuels
E85, Cellulosic Ethanol
Electricity
Hydrogen



[1]

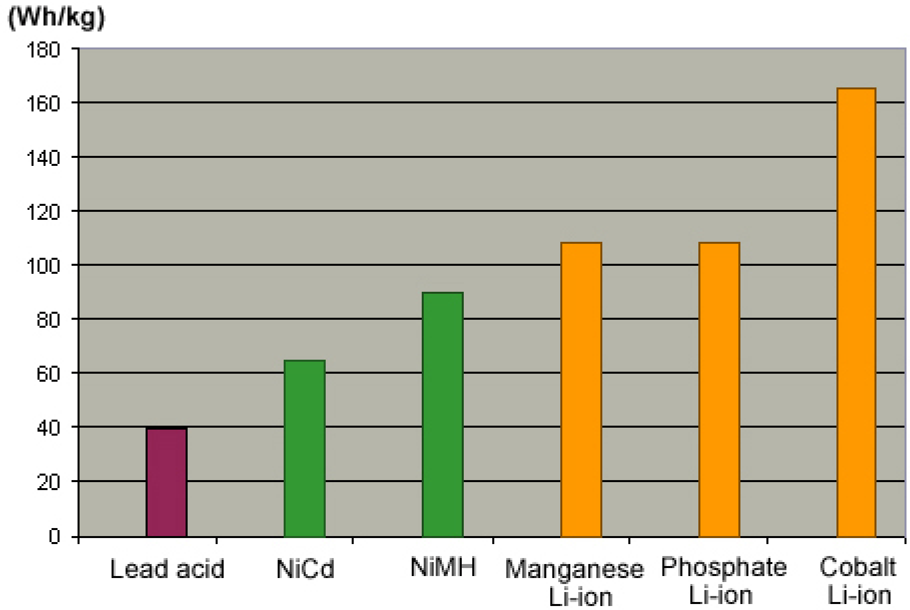




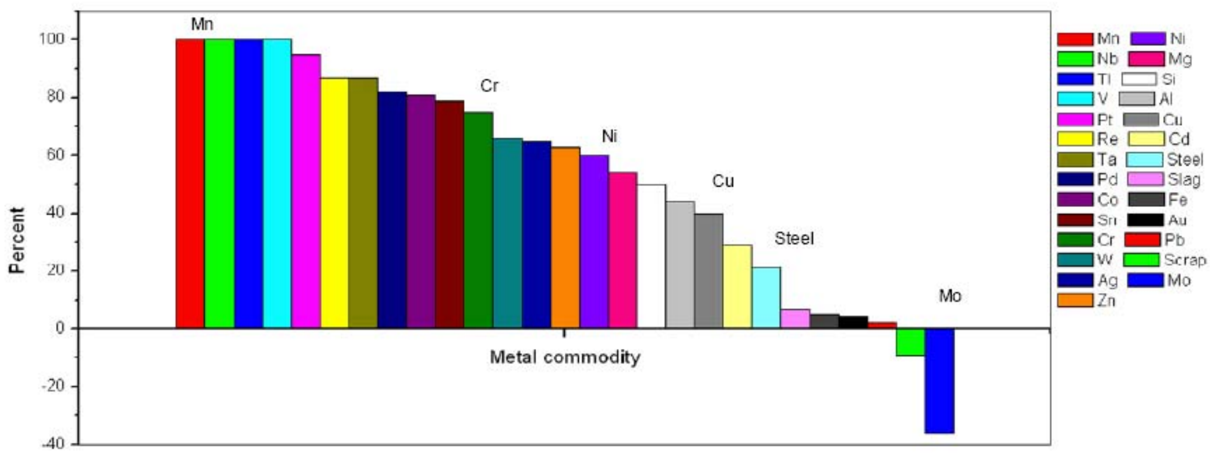
[2]

[1] http://earthtrends.wri.org/images/energy_demand_by_sector.jpg

[2] http://www.calcars.org/images/epri-emissions-sm.gif



Metal commodity net import reliance as a percent of apparent consumption



Source: Mineral Commodity Summaries 2007

LITHIUM

(Data in metric tons of lithium content unless otherwise noted)

Domestic Production and Use: Chile was the leading lithium chemical producer in the world; Argentina, China, Russia, and the United States also were major producers. Australia, Canada, and Zimbabwe were major producers of lithium ore concentrates. The United States remained the leading consumer of lithium minerals and compounds and the leading producer of value-added lithium materials. Because only one company produced lithium compounds from domestic resources, reported production and value of production data cannot be published. Estimation of value for the lithium mineral compounds produced in the United States is extremely difficult because of the large number of compounds used in a wide variety of end uses and the great variability of the prices for the different compounds.

Although lithium markets vary by location, global end-use markets are estimated as follows: batteries, 20%; ceramics and glass, 20%; lubricating greases, 16%; pharmaceuticals and polymers, 9%; air conditioning, 8%; primary aluminum production, 6%; and other uses, 21%. Lithium use in batteries expanded significantly in recent years because rechargeable lithium batteries were being used increasingly in portable electronic devices and electrical tools.

Salient Statistics—United States:	2003	2004	2005	2006	2007[e]
Production	W	W	W	W	W
Imports for consumption	2,200	2,910	3,580	3,260	4,000
Exports	1,520	1,690	1,720	1,500	1,400
Consumption:					
Apparent	W	W	W	W	W
Estimated	1,400	1,900	2,500	2,500	3,300
Employment, mine and mill, number[e]	100	100	100	100	100
Net import reliance[1] as a percentage of apparent consumption	≤50%	>50%	>50%	>50%	>50%

Recycling: Insignificant, but increasing through the recycling of lithium batteries.

Import Sources (2003-06): Chile, 69%; Argentina, 29%; and other, 2%.

World Mine Production, Reserves, and Reserve Base:

	Mine production		Reserves[2]	Reserve base[2]
	2006	2007[e]		
United States	W	W	38,000	410,000
Argentina[e]	2,900	3,000	NA	NA
Australia[e]	5,500	5,500	160,000	260,000
Bolivia	—	—	—	5,400,000
Brazil	242	240	190,000	910,000
Canada	707	710	180,000	360,000
Chile	8,200	9,400	3,000,000	3,000,000
China	2,820	3,000	540,000	1,100,000
Portugal	320	320	NA	NA
Russia	2,200	2,200	NA	NA
Zimbabwe	600	600	23,000	27,000
World total (rounded)	[3]23,500	[3]25,000	4,100,000	11,000,000

World Resources: The identified lithium resources total 760,000 tons in the United States and more than 13 million tons in other countries.

NICKEL

(Data in metric tons of nickel content unless otherwise noted)

Domestic Production and Use: The United States did not have any active nickel mines in 2007. Limited amounts of byproduct nickel were recovered from copper and palladium-platinum ores mined in the Western United States. On a monthly or annual basis, 111 facilities reported nickel consumption. The principal consuming State was Pennsylvania, followed by Kentucky, West Virginia, and North Carolina. Approximately 52% of the primary nickel consumed went into stainless and alloy steel production, 34% into nonferrous alloys and superalloys, 10% into electroplating, and 4% into other uses. End uses were as follows: transportation, 30%; chemical industry, 15%; electrical equipment, 10%; construction, 9%; fabricated metal products, 8%; household appliances, 8%; petroleum industry, 7%; machinery, 6%; and other, 7%. Estimated value of apparent primary consumption was $4.19 billion.

Salient Statistics—United States:	2003	2004	2005	2006	2007[e]
Production, refinery byproduct	W	W	W	W	W
Shipments of purchased scrap[1]	137,000	133,000	141,000	147,000	207,000
Imports: Primary	125,000	136,000	143,000	153,000	125,000
Secondary	11,500	18,800	15,500	20,300	15,100
Exports: Primary	6,330	8,000	7,630	8,050	13,000
Secondary	47,300	48,300	55,600	59,300	103,000
Consumption: Reported, primary[2]	90,400	102,000	100,000	124,000	113,000
Reported, secondary[2]	101,000	103,000	101,000	108,000	119,000
Apparent, primary	117,000	128,000	135,000	144,000	112,000
Total[3]	218,000	232,000	236,000	252,000	231,000
Price, average annual, London Metal Exchange:					
Cash, dollars per metric ton	9,629	13,823	14,738	24,244	37,744
Cash, dollars per pound	4.368	6.270	6.685	10.997	17.121
Stocks: Consumer, yearend	11,700	11,900	13,500	14,100	14,100
Producer, yearend[4]	8,040	6,580	5,940	6,450	6,500
Net import reliance[5] as a percentage of apparent consumption	45	49	48	49	17

Recycling: About 119,000 tons of nickel was recovered from purchased scrap in 2007. This represented about 52% of reported secondary plus apparent primary consumption for the year.

Import Sources (2003-06): Canada, 41%; Russia, 16%; Norway, 11%; Australia, 8%; and other, 24%.

World Mine Production, Reserves, and Reserve Base: Estimates of reserves for Canada and New Caledonia and the reserve base for the United States were revised based on new mining industry information.

	Mine production		Reserves[6]	Reserve base[6]
	2006	2007[e]		
United States	—	—	—	150,000
Australia	185,000	180,000	24,000,000	27,000,000
Botswana	38,000	35,000	490,000	920,000
Brazil	82,500	75,300	4,500,000	8,300,000
Canada	233,000	258,000	4,900,000	15,000,000
China	82,100	80,000	1,100,000	7,600,000
Colombia	94,100	99,500	830,000	1,100,000
Cuba	75,000	77,000	5,600,000	23,000,000
Dominican Republic	46,500	47,000	720,000	1,000,000
Greece	21,700	20,100	490,000	900,000
Indonesia	140,000	145,000	3,200,000	13,000,000
New Caledonia[7]	103,000	119,000	7,100,000	15,000,000
Philippines	58,900	88,400	940,000	5,200,000
Russia	320,000	322,000	6,600,000	9,200,000
South Africa	41,600	42,000	3,700,000	12,000,000
Venezuela	20,000	20,000	560,000	630,000
Zimbabwe	8,820	9,000	15,000	260,000
Other countries	34,300	41,000	2,100,000	5,900,000
World total (rounded)	1,580,000	1,660,000	67,000,000	150,000,000

World Resources: Identified land based resources averaging 1% nickel or greater contain at least 130 million tons of nickel. About 60% is in laterites and 40% in sulfide deposits. In addition, extensive deep-sea resources of nickel are in manganese crusts and nodules covering large areas of the ocean floor, particularly in the Pacific Ocean.

MANGANESE

(Data in thousand metric tons gross weight unless otherwise specified)

Domestic Production and Use: Manganese ore containing 35% or more manganese was not produced domestically in 2007. Manganese ore was consumed mainly by eight firms with plants principally in the East and Midwest. Most ore consumption was related to steel production, directly in pig iron manufacture and indirectly through upgrading ore to ferroalloys. Additional quantities of ore were used for such nonmetallurgical purposes as production of dry cell batteries, in plant fertilizers and animal feed, and as a brick colorant. Manganese ferroalloys were produced at two smelters, although one operated sporadically throughout the year. Construction, machinery, and transportation end uses accounted for about 24%, 10%, and 10%, respectively, of manganese demand. Most of the rest went to a variety of other iron and steel applications. The value of domestic consumption, estimated from foreign trade data, was about $730 million.

Salient Statistics—United States:[1]	2003	2004	2005	2006	2007[e]
Production, mine[2]	—	—	—	—	—
Imports for consumption:					
Manganese ore	347	451	656	572	610
Ferromanganese	238	429	255	358	322
Silicomanganese[3]	267	422	327	400	390
Exports:					
Manganese ore	18	123	13	2	2
Ferromanganese	11	9	14	22	33
Shipments from Government stockpile excesses:[4]					
Manganese ore	28	172	34	73	5
Ferromanganese	28	37	36	56	66
Consumption, reported:[5]					
Manganese ore[6]	398	441	368	365	300
Ferromanganese	248	315	267	296	280
Consumption, apparent, manganese[7]	643	1,030	773	1,050	910
Price, average value, 46% to 48% Mn metallurgical ore, dollars per metric ton unit contained Mn, c.i.f. U.S. ports	2.41	2.89	4.39	3.51	3.32
Stocks, producer and consumer, yearend:					
Manganese ore[6]	156	159	337	159	115
Ferromanganese	20	16	30	31	31
Net import reliance[8] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Manganese was recycled incidentally as a minor constituent of ferrous and nonferrous scrap; however, scrap recovery specifically for manganese was negligible. Manganese is recovered along with iron from steel slag.

Import Sources (2003-06): Manganese ore: Gabon, 65%; South Africa, 19%; Australia, 7%; Ghana, 2%; and other, 7%. Ferromanganese: South Africa, 51%; China, 14%; Mexico, 6%; Republic of Korea, 5%; and other, 24%. Manganese contained in all manganese imports: South Africa, 35%; Gabon, 22%; Australia, 8%; China, 7%; and other, 28%.

	Mine production 2006	Mine production 2007[e]	Reserves[10]	Reserve base[10]
United States	—	—	—	—
Australia	2,190	2,200	62,000	160,000
Brazil	1,370	1,000	35,000	57,000
China	[e]1,600	1,600	40,000	100,000
Gabon	[e]1,350	1,550	20,000	160,000
India	[e]811	650	56,000	[11]150,000
Mexico	133	130	4,000	9,000
South Africa	2,300	2,300	100,000	[11]4,000,000
Ukraine	[e]820	820	140,000	520,000
Other countries	1,360	1,360	Small	Small
World total (rounded)	[e]11,900	11,600	460,000	5,200,000

World Resources: Land-based manganese resources are large but irregularly distributed; those of the United States are very low grade and have potentially high extraction costs. South Africa accounts for about 80% of the world's identified manganese resources, and Ukraine accounts for 10%.

COBALT

(Data in metric tons of cobalt content unless otherwise noted)

Domestic Production and Use: The United States did not mine or refine cobalt in 2007; however, negligible amounts of byproduct cobalt were produced as intermediate products from some mining operations. U.S. supply comprised imports, stock releases, and secondary materials, such as cemented carbide scrap, spent catalysts, and superalloy scrap. One of two U.S. producers of extra-fine cobalt powder ceased operations in late 2006. The remaining U.S. powder producer used cemented carbide scrap as feed. Seven companies were known to produce cobalt compounds. Sixty-five industrial consumers were surveyed on a monthly or annual basis. Data reported by these consumers indicate that 45% of the cobalt consumed in the United States was for use in superalloys, which ar used mainly in aircraft gas turbine engines; 9% was for use in cemented carbides for cutting and wear-resistant applications; 14%, for various other metallic applications; and 32%, for a variety of chemical applications. The total estimated value of cobalt consumed in 2007 was $600 million.

Salient Statistics—United States:	2003	2004	2005	2006	2007[e]
Production:					
Mine	—	—	—	—	—
Secondary	2,130	2,300	2,030	2,010	2,000
Imports for consumption	8,080	8,720	11,100	11,600	9,700
Exports	2,710	2,500	2,440	2,850	3,100
Shipments from Government stockpile excesses	2,380	1,630	1,110	260	600
Consumption:					
Reported (includes secondary)	8,030	8,990	9,150	9,270	9,300
Apparent[1] (includes secondary)	10,000	9,950	11,800	11,100	9,200
Price, average annual spot for cathodes, dollars per pound	10.60	23.93	15.96	17.22	30.20
Stocks, industry, yearend	1,010	1,210	1,190	1,150	1,150
Net import reliance[2] as a percentage of apparent consumption	79	77	83	82	78

Recycling: In 2007, cobalt contained in purchased scrap represented an estimated 22% of cobalt reported consumption.

Import Sources (2003-06): Cobalt contained in metal, oxide, and salts: Norway, 21%; Russia, 19%; Finland, 10%; China, 9%; and other, 41%.

World Mine Production, Reserves, and Reserve Base: U.S. reserves were estimated based on reports from two companies.

	Mine production 2006	Mine production 2007[e]	Reserves[5]	Reserve base[5]
United States	—	—	33,000	860,000
Australia	7,400	7,500	1,400,000	1,700,000
Brazil	1,200	1,200	29,000	40,000
Canada	7,000	8,000	120,000	350,000
China	2,300	2,300	72,000	470,000
Congo (Kinshasa)	28,000	22,500	3,400,000	4,700,000
Cuba	3,800	4,000	1,000,000	1,800,000
Morocco	1,500	1,500	20,000	NA
New Caledonia[6]	1,900	2,000	230,000	860,000
Russia	5,100	5,000	250,000	350,000
Zambia	8,000	7,000	270,000	680,000
Other countries	1,300	1,300	130,000	1,100,000
World total (rounded)	67,500	62,300	7,000,000	13,000,000

World Resources: Identified cobalt resources of the United States are estimated to be about 1 million tons. Most of these resources are in Minnesota, but other important occurrences are in Alaska, California, Idaho, Missouri, Montana, and Oregon. With the exception of resources in Idaho and Missouri, any future cobalt production from these deposits would be as a byproduct of another metal. Identified world cobalt resources are about 15 million tons. The vast majority of these resources are in nickel-bearing laterite deposits, with most of the rest occurring in nickel-copper sulfide deposits hosted in mafic and ultramafic rocks in Australia, Canada, and Russia, and in the sedimentary copper deposits of Congo (Kinshasa) and Zambia. In addition, millions of tons of hypothetical and speculative cobalt resources exist in manganese nodules and crusts on the ocean floor.

ZINC

(Data in thousand metric tons of zinc content unless otherwise noted)

Domestic Production and Use: The value of zinc mined in 2007, based on zinc contained in concentrate, was about $2.59 billion. It was produced in 7 States at 14 mines operated by 8 companies. Alaska, Missouri, Montana, and Washington accounted for about 99% of domestic mine output; the Red Dog Mine in Alaska accounted for about 77% of total U.S. production. One primary and 12 large- and medium-sized secondary smelters refined zinc metal of commercial grade in 2007. Of the total zinc consumed, about 55% was used in galvanizing, 21% in zinc-based alloys, 16% in brass and bronze, and 8% in other uses. Zinc compounds and dust were used principally by the agriculture, chemical, paint, and rubber industries. Major coproducts of zinc mining and smelting, in order of decreasing tonnage, were lead, sulfuric acid, cadmium, silver, gold, and germanium.

Salient Statistics—United States:	2003	2004	2005	2006	2007[e]
Production:					
Mine, zinc in ore[1]	768	739	748	727	740
Primary slab zinc	187	188	182	113	120
Secondary slab zinc[2]	150	139	139	139	128
Imports for consumption:					
Ore and concentrate	164	231	156	383	380
Refined zinc	758	812	668	851	693
Exports:					
Ore and concentrate	841	745	786	825	789
Refined zinc	2	3	1	3	11
Shipments from Government stockpile[3]	7	32	27	30	7
Consumption:					
Apparent, refined zinc	1,110	1,170	1,020	1,130	936
Apparent, all forms	1,340	1,410	1,260	1,380	1,180
Price, average, cents per pound:					
Domestic producers[4]	40.6	52.5	67.1	158.9	159.0
London Metal Exchange (LME), cash	37.5	47.5	62.7	148.5	151.0
Producer and consumer stocks, slab zinc, yearend	64	63	61	56	58
Employment:					
Mine and mill, number[5]	860	935	978	1,120	1,470
Smelter primary, number[e]	600	600	600	246	246
Net import reliance[6] as a percentage of apparent consumption:					
Refined zinc	70	72	68	78	73
All forms of zinc	58	60	55	64	58

Recycling: In 2007, an estimated 420,000 tons of zinc was recovered from waste and scrap; about 30% was recovered in the form of slab zinc and the remainder in alloys, oxide, and chemicals. Of the total amount of scrap recycled, 370,000 tons was derived from new scrap, and 50,000 tons was derived from old scrap. About 103,000 tons of scrap was exported, mainly to China (80%), and 23,000 tons was imported, most of which came from Canada (60%).

Import Sources (2003-06): Ore and concentrate: Peru, 67%; Mexico, 14%; Ireland, 9%; Australia, 9%; and other, 1%. Metal: Canada, 64%; Mexico, 17%; Australia, 4%; and other, 15%. Waste and scrap: Canada, 83%; Mexico, 15%; and other, 2%. Combined total: Canada, 50%; Peru, 17%; Mexico, 16%; Australia, 5%; and other, 12%.

World Mine Production, Reserves, and Reserve Base: Reserves data, and where appropriate, reserve base data were revised based on updated resource information published by companies with mines in Australia, Canada, Kazakhstan, Mexico, Peru, and the United States.

	Mine production[10]		Reserves[11]	Reserve base[11]
	2006	2007[e]		
United States	727	740	14,000	90,000
Australia	1,380	1,400	42,000	100,000
Canada	710	680	5,000	30,000
China	2,600	2,800	33,000	92,000
Kazakhstan	400	400	14,000	35,000
Mexico	480	480	7,000	25,000
Peru	1,200	1,500	18,000	23,000
Other countries	2,500	2,500	49,000	87,000
World total (rounded)	10,000	10,500	180,000	480,000

World Resources: Identified zinc resources of the world are about 1.9 billion metric tons.