Electrify Transportation Briefing Book
January 2007

Electrify Transportation in Washington

By:
Richard A. Feldman, Apollo Alliance of Washington
206-441-4968 feldman@apolloalliance.org

Patrick Mazza, Climate Solutions
206-443-9570 x22 patrick@climatesolutions.org

On behalf of:
The Electrify Transportation in Washington Group

Electrify Transportation Briefing Book
January 2007

Funding for this publication by the Edwards Mother Earth Foundation.
Research assistance by Shayle Kann, Pomona College.

What is electrified transportation and where is it employed?

Photo: King County Metro

Electrified transportation is the use of electrical power to run transportation vehicles and related facilities. Electricity has long been used to power transportation in the Seattle area where 150 King County Metro electric trolley buses serve 14 routes covering 115 miles. Now electrical power options are spreading to port facilities, medium-duty trucks, school buses and truck stops. Most importantly, electricity is emerging to power cars and light-duty vehicles in the form of gasoline-electric hybrids and plug-in hybrid vehicles (PHEVs) which can use grid power and run longer on batteries than regular hybrids. These options are all explored in this briefing.

What benefits does electrified transportation provide?

Electrification provides several key advantages:

1. ***Reduces oil use***– Transportation demand accounts for over 70% of total U.S. oil use, 61% of which is used to power the light duty vehicle fleet.[1] Nationally, less than 3% of electricity is produced with oil. Shifting from oil to electricity directly cuts oil use. If by 2025 35% of Washington's light duty vehicle fleet were PHEVs able to go 20 miles on a charge, 580 million of gallons of oil could be saved per year.[2] The full build out of a Truck Stop Electrification network on the West Coast and the retrofit of 15,000 trucks with on-board idle reduction kits would save close to 100 million gallons of oil per year.[3]

2. ***Reduces energy imports*** - Electrification firms up national and state economies by replacing imports with domestic energy production. The U.S. imported oil bill for 2006 is estimated at $329 billion, more than one-third the total trade deficit.[4] Washington State in 2006 paid an estimated $9.29 billion for oil from beyond state boundaries. That compares to $9 billion spent on public K-12 education, and $5.8 billion in farm cash receipts.[5]

3. ***Increases national energy security*** – By diversifying transportation fuels, electrification reduces vulnerability to oil shocks and price rises due to natural disruptions such as hurricanes and political disruptions from unstable and unfriendly countries. A Stanford

[1] "2005 Annual Energy Outlook", U.S. Energy Information Agency, Table 11 and 7.
[2] Based on modeling in R. Grahm, "Comparing the Benefits and Impacts of Hybrid Electric Vehicle Options," Electric Power Research Institute, July 2001, Table A-2.
[3] Personal communication from Frank Van Haren, Air Quality Program, Wash. Department of Ecology.
[4] James K. Jackson, "US Trade Deficit and the Impact of Rising Oil Prices," Congressional Research Service, July 2006, p2 and 4. www.ncseonline.org/NLE/crs/abstract.cfm?NLEid=1565
[5] Sightline Energy Counter - http://www.sightline.org/daily_score/archive/2006/05/02/giant-sucking-sound, projected 2006 energy costs; Public Education Finances 2004, US Census Bureau March 2006, p1, http://ftp2.census.gov/govs/school/04f33pub.pdf; USDA Economic Research Service, Farm Income: Data Files, http://www.ers.usda.gov/data/farmincome/finfidmu.htm , 2005 figures.

University Energy Modeling Forum study for the U.S. Department of Energy analyzed the probability of severe oil shocks over the next decade. Summarizing the study results Stanford's Hillard Huntington testified that, "Your odds of drawing a club, diamond or heart from a shuffled deck of playing cards are three out of four. In the EMF study, the participants found that the odds of a foreign oil disruption happening over the next 10 years are slightly higher at 80 percent." In addition, Huntington noted, "...oil price shocks preceded nine of the last 10 recessions in the United States."[6]

4. ***Reduces air pollution*** – Use of electricity reduces transportation air pollutants that have serious impacts on human health including particulates and volatile organic compounds. For example, replacing diesel with electricity has important health benefits. Clean Air Task Force notes, "Fine particle pollution from diesels shortens the lives of nearly 21,000 people each year. This includes almost 3,000 early deaths from lung cancer."[7]

5. ***Protects our climate*** – Electrically powered vehicles operate with significantly lower emissions of heat-trapping gases, especially carbon dioxide. Electrical drive is more efficient than mechanical drive, so even when fossil-fuel generated electricity is used to power vehicles, heat-trapping emissions are still reduced when using the Northwest power grid mix.

What is a plug-in hybrid electric vehicle (PHEV)?

Photo: CalCars.org

"A PHEV is like having a second fuel tank you always use first. You fill up at home from an ordinary socket at a cost equivalent to less than $1 per galllon."

-- Felix Kramer, Founder of CalCars

From being a concept known mainly only by a few even as recently as several years ago, plug-in hybrid electric vehicles (PHEV) are now being seen by an increasing number of transportation technologists and policy-makers as a near-term solution for reducing petroleum consumption and emissions of greenhouse gases.[8]


Chelan County Port District's WhiteBird PHEV conversion

Current hybrid vehicles are 100% gasoline fueled with a small battery for power assist and regenerative braking. The next stage is the PHEV, which also will charge from on-board systems but adds capability to plug into the power

[6]Prepared Statement by Hillard Huntington, Executive Director, Stanford University Energy Modeling Forum, U.S. Senate Foreign Relations Committee, March 30, 2006.
http://www.senate.gov/~foreign/testimony/2006/HuntingtonTestimony060330.pdf
[7]Clean Air Task Force, "Diesel and Health in America: The Lingering Threat."
http://www.catf.us/publications/view/83
[8] Mike Millikin, "Plug-ins Progress," September 29, 2006.
http://www.greencarcongress.com/2006/09/plugins_progres.html

grid. By adding batteries and the ability to recharge the car from an ordinary 120-volt household circuit, the car substitutes electricity for local miles.

Unlike current hybrids, PHEVs will be able to travel significant distances on electricity, ranging from 20 to 60 miles. Puget Sound Regional Council notes, "From 1960 to 1990, the average Puget Sound driver increased daily driving from 9.3 miles to 22.2 miles (about where it has remained since)."[9] So drivers will use substantially less oil fuels than even today's highly efficient hybrids. Modeling studies and real-world experience with prototypes show that PHEVs can run 100 mpg or more of gasoline.

UC Davis Professor Andy Frank modified a 2000 Chevrolet Suburban to PHEV. http://www.team-e.net/team.htm

PHEV technology is applicable to all light duty vehicles (comprised of passenger vehicles, light trucks under 8,500 lbs, vans and SUVs). These vehicles account for over 93% of the total fleet. Additionally, light duty vehicles have an average vehicle life of 15 years, as opposed to 28 years for heavy duty vehicles.[10]

Who supports electrified transportation nationally?

The concept of electrifying vehicles and accelerating market growth of PHEVs is driving a broad, bipartisan movement. Plug-In Partners is a national movement promoting PHEVs. (www.pluginpartners.org) Launched early in 2006, Plug-in Partners already has been endorsed by close to 500 cities and other government bodies, environmental and other nonprofit organizations and businesses including the American Public Power Association and Edison Electric Institute, and national security groups including Institute for the Analysis of Global Security and the Set America Free Coalition. Set America Free includes national security experts such as former CIA Director James Woolsey and former National Security Advisor Robert McFarlane. (www.setamericafree.org) Additionally, the campaign has gained more than 8,000 "soft" fleet orders for these vehicles when they are available.

PHEVs are supported in Congress with the proposed bipartisan Vehicle and Fuel Choices for American Security Act and the Clean Edge bill sponsored by the Senate Democrats. PHEV funding is included in the President's Advanced Energy Initiative.

AutoNation, the country's largest auto retailer, is urging automakers to produce plug-in hybrids.

[9] "Regional Review: Monitoring Change in the Central Puget Sound Region," Puget Sound Regional Council, Sept. 1997, p16.
[10] S Davis, S Diegel. "Transportation Energy Databook: Edition 24" Oak Ridge National Laboratory, ORNL-6973 (2004).

In New York State, Governor George Pataki and Senate Majority Leader Joseph Bruno announced a new $10 million State program to convert 600 vehicles in the State fleet to plug-in hybrids.
In September 2006, Riverside California Mayor Ronald Loveridge, a member of the California Air Resources Board (CARB), called for a Plug-in California campaign and recommended that the State commit to purchase plug-ins, offer incentives for manufacturers and provide $5 million for plug-in vehicle research and development.

In December 2006, the California Energy Commission Awarded $3 Million to UC Davis for a PHEV research center.

IC Corporation, the nation's largest school bus manufacturer, will build 19 plug-in hybrid school buses to be used in 11 states as part of a consortium organized by Advanced Energy, a Raleigh, N.C.-based nonprofit corporation. Chelan and Seattle School districts are raising funds to purchase one bus each.

Who is working on electrified transportation in Washington State?

Washington has one of the largest representations of Plug-In Partners members of any state. They include the cities of Seattle and Wenatchee, King County, the Port of Chelan County, Wenatchee Valley Transportation Council, Chelan County PUD, Cowlitz County PUD, Douglas County PUD, Energy Northwest, Lewis County PUD, Pacific County PUD #2, Pend Oreille County PUD, Seattle City Light, Snohomish County PUD, Washington Public Utility Districts Association and the Apollo Alliance of Washington.

In Summer 2005, a consortium including the Port of Chelan County sponsored the Advanced Vehicle Initiative (AVI) Summit, which was held in Wenatchee and featured national leaders in technology and advocacy for plug-in hybrid technology. The AVI effort was conceived to establish North Central Washington as a catalyst and center for development, demonstration, and deployment of flex-fuel plug-in hybrid electric vehicles.

UC Davis Prof. Andy Frank and former CIA Director James Woolsey both spoke at the Future Trends Conference in June 2006 at Microsoft's Redmond Campus. Photo: CalCars.org

On June 1, 2006, the Cascadia Center held the "Future Trends in Energy, Technology & Transportation" conference co-sponsored with Microsoft. It brought together national experts as well as U.S. Senators Cantwell and Brownback and former CIA Director James Woolsey to address the potential of plug-in hybrid vehicles to increase energy independence. The Seattle Times, KCPQ-FOX TV, KING TV, KUOW, and MSNBC covered the event.

In June 2006, the Apollo Alliance of Washington and Climate Solutions helped launch the Electrify Transportation in Washington Group to support and put in motion efforts that will greatly increase the contribution electricity makes in powering Washington State transportation. Current membership includes representatives from: City of Seattle, Cascadia Center, King County, Puget Sound Clean Air Agency, Washington PUD Association, Seattle City Light, Climate Solutions, Apollo Alliance of Washington, Port of Chelan County, Washington State Dept. of Ecology, and Washington State Community Trade and Economic Development.

What can state and local governments do to promote electrified transportation?

1. Create a State Electrified Transportation Task Force that includes representatives of key state and local agencies, ports, private and public electrical power utilities as well as key stakeholders. Minnesota led the nation in 2006 by creating the first state plug-in hybrid task force.[11] Assign the task force to:
    - Map out ways the state can promote all forms of transportation electrification including cars and light-duty vehicles, port electrification and truckstop electrification.
    - Review existing state laws, regulations, tariffs and policies with an impact on transportation electrification and plug-in adoption.
    - Map out how public agencies can most rapidly bring plug-ins into their fleets, and potential cost savings this might yield.
    - Identify potential partners for pilot projects that test controlled charging of plug-in hybrids, to minimize grid impact, and the use of parked plug-ins for power grid energy storage and support (so-called vehicle-to-grid services).
    - Identify how Washington state industries can participate in development and manufacture of plug-ins, charging control and vehicle-to-grid technologies (eg., power electronics, lightweight materials, wireless telecommunications to control charging times) and develop a plan for realizing those opportunities.
2. Fund plug-in conversion kits for hybrids owned by state and other public agencies.
3. Fund port acquisition of prototype plug-in hybrid short haul container trucks and other port-related vehicles working in conjunction with Pacific Northwest National Laboratory and other West Coast jurisdictions and ports.
4. Fund acquisition of plug-in hybrid school buses prototypes by three school districts, including one eastern Washington, one large urban and one suburban district.
5. Fund a Truck Stop Electrification network.
6. Fund public electric utilities to carry-out controlled charging and vehicle-to-grid test projects including the use of power electronics and wireless technologies to regulate charging and discharging of plug-in vehicles.
7. Establish a plug-in demonstration program involving state and local jurisdictions.
8. Pass a legislative resolution urging automakers to mass produce plug-ins, along with binding legislation committing state and local governments to use a certain percentage of plug-ins in their fleets when vehicles become available at an appropriate price.

[11] "Kicking Our Oil Addiction: Minnesota Becomes First State to Endorse an Electric-Alcohol Strategy," Press Release, The Institute for Local Self Reliance, June 8, 2006. http://www.ilsr.org/columns/2006/060806.html

9. Make state commitments to purchase a specific number of PHEVs when they become available at a specified price by filling out soft fleet vehicle orders or participating in regional projects that develop specifications for PHEVs and place hard orders via an RFP.
10. Join Plug-in Partners national effort to bring on mass produced plug-ins.
11. Eliminate sales tax on PHEV conversion kits or battery portion of mass produced PHEVs.

Why should state and local government fund conversions of existing hybrids to PHEV?

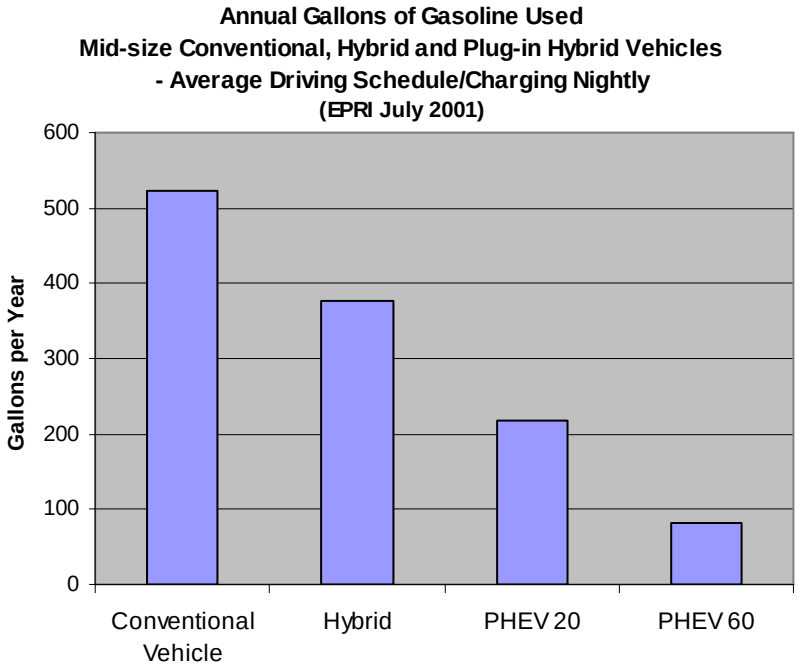
Mike Millikin with Green Car Congress reporting on the September 2006 California Air Resources Board symposium on PHEVs notes:

> The nature of the electrode materials and the electrolytes can all make a difference in terms of tilting the battery toward the power or the energy ends of the spectrum. While that customization is possible from the battery manufacturers' points of view, what they need are targets to hit: the specifications from the automakers. And one of the best ways to achieve that—aside from the simulation work underway—is to get more trials out on the road that then feed back into shared project knowledge…
>
> So while the conversions of existing hybrids to plug-in operation might not represent the optimal in terms of battery technology or systems design, they do represent an extremely valuable potential source of real world data that needs to be fed back to battery makers and to automakers.[12]

[12] Mike Millikin, "Plug-ins Progress," http://www.greencarcongress.com/2006/09/plugins_progres.html

What oil savings will PHEVs provide?

EPRI projections and real world conversion experience show plug-ins can achieve 100 mpg and over in terms of liquid fuel.[13]



The chart above summarizes modeling done by EPRI.[14] Relative to a conventional mid-size hybrid vehicle, gasoline consumption is reduced by about 42 percent for a mid-size PHEV 20 (having a 20-mile all-electric range) and by 78 percent for a mid-size PHEV 60 (having a 60-mile all-electric range).

A University of California-Berkeley study finds that every 500 kWh used to charge plug-in hybrids would displace one barrel of oil.[15]

What reductions of heat-trapping gases and other air pollution will PHEVs provide?

A PHEV environmental analysis calculates air pollutants from gasoline consumption and electrical generation and is called a well-to-wheel analysis. Numerous factors can increase or decrease the pollution estimates, including fuel efficiencies of PHEVs and time of day for

[13] Electric Power Research Institute, "Comparing the Benefits and Impact of Hybrid Electric Vehicle Options," Report No. 1000349, July 2001.
[14] R. Grahm, "Comparing the Benefits and Impacts of Hybrid Electric Vehicle Options," Electric Power Research Institute, July 2001, Table A-2.
[15] Jenn Baka1, Frank H. Ling, and Daniel M. Kammen, "Towards Energy Independence in 2025", University of California, Berkeley, March 2006, p14.

charging. A basic assumption for an environmental analysis of PHEVs is that the majority of charging is done off peak.

In September 2006, the American Council for an Energy Efficient Economy released a study on PHEVs that included an assessment of environmental impacts.[16] They used projections by the US Energy Information Agency's National Energy Modeling System to determine the mix of electric generation sources over time including the Western States Coordinating Council/Northwest Power Pool Area (WSCC-NPP).

Based on the ACEEE study, a PHEV 40 operating under a 2005 Northwest power generation mix, would reduce CO2 emissions by 55% over today's hybrid [2006 Toyota Prius hybrid]. This compares to a 15% reduction of CO2 emissions relative to a Prius under the U.S. average power generation mix. In California, the PHEV would reduce CO2 emissions by one-third relative to a hybrid, while in the East Central Area CO2 emissions would be about the same for the PHEV as for the hybrid. ACEEE cautioned that their numbers are first order estimates and should not be regarded as conclusive**.**

ACEEE's estimates for total annual emissions of the major air pollutants Carbon Dioxide, Sulfur Dioxide and Nitrogen Oxide for a PHEV 40 that is charged on the Northwest Grid compared to conventional vehicles and a hybrid are shown below:

Total Annual Air Emissions of a PHEV 40 Charged on the NW Grid vs Conventional and Hybrid Vehicles for years 2005 & 2020

Emissions	PHEV 40 2005 WSCC-NPP	PHEV 40 2020 WSCC-NPP	Conv. Vehicle Bin 8[17]	Conv. Vehicle Bin 5[18]	Hybrid Vehicle Bin 3[19]
CO2 (lbs)	2,668.6	2,434.7	10,000	10,000	6,000
SOx	3.3	2.4	7.0	7.0	4.2
NOx	4.3	3.6	20.1	16.5	11.8
Mercury	0.021	.00012	0	0	0

In September 2006, preliminary results of a comprehensive study on PHEV environmental impacts undertaken by the Charles Clark Group and EPRI were presented before the

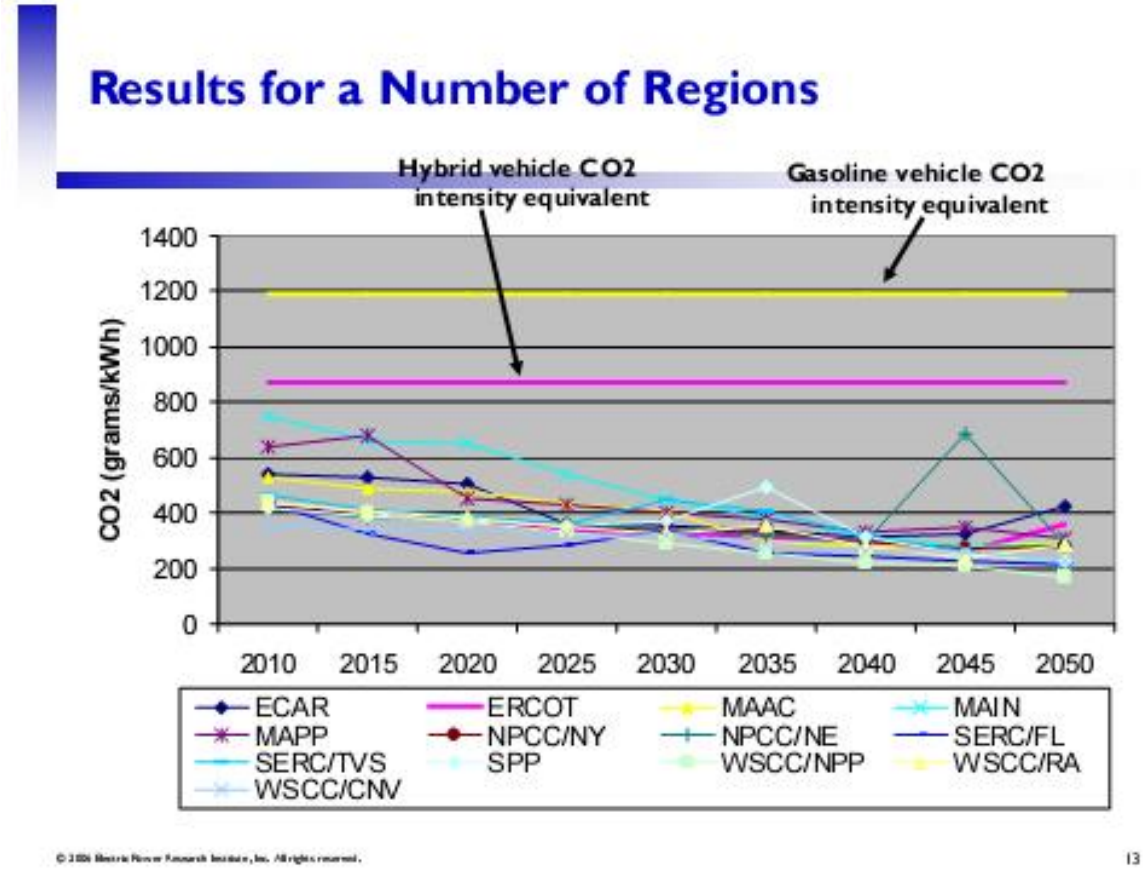
[16] James Kliech and Therese Langer, "Plug-In Hybrids: An Environmental and Economic Outlook," ACEEE, Report Number T061, September 2006. ACEEE assumed that a PHEV with 40 miles all-electric range will reduce gasoline consumption 50% relative to a comparative standard gasoline-electric hybrid and that 3,000 kWh were consumed annually by the PHEV (12,000 miles at 4 mile/kWh) and a 9% transmission and distribution loss for the grid power.

[17] Assumed to have a combined city/highway economy of 30 miles per gallon and meeting EPA Emission Standard for Light Duty Vehicles Tier 2 bin 8.

[18] Assumed to have a combined city/highway economy of 30 miles per gallon and meeting EPA Emission Standard for Light Duty Vehicles Tier 2 bin 5.

[19] Assumed to be a 2006 Toyota Prius with a combined city/highway economy of 50 miles per gallon and meeting EPA Emission Standard for Light Duty Vehicles Tier 2 bin 3.

California Air Resource Board.[20] This study used EPRI's model of the entire U.S. power grid (with detailed characteristics of every generating plant), a worst-case 30%-peak/70%-off-peak charging regime, and scenarios for PHEV penetration, regulatory climate and other factors. The Charles Clark Group study found positive results for all regions when comparing PHEVs' CO2 output compared to hybrid or conventional vehicles. In the chart below, the WSCC/NPP is the grid that serves the NW.



What will be the impacts on the power grid of charging a substantial fleet of PHEVs?

A study by Pacific Northwest National Laboratory to be released in January 2007 finds that there is sufficient idle electrical capacity today in the PNW grid to power 20% of the regions current vehicles in a 24 hour window with base and intermediate generation.[21]

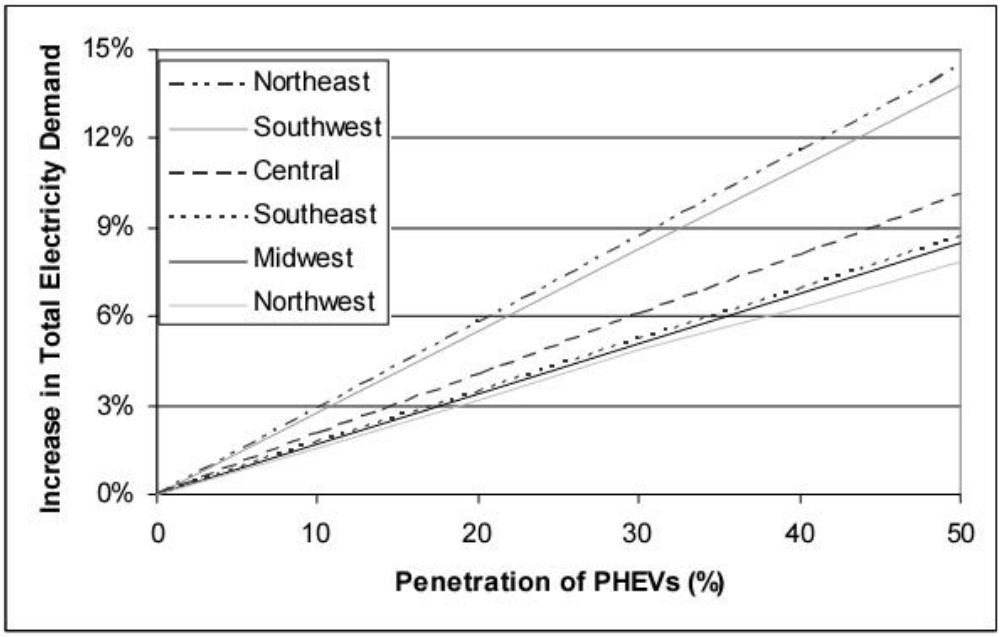
In Fall 2006, Seattle City Light carried out an evaluation of PHEVs based on preliminary data and found assuming a gradual increase in the number of these vehicles that:

[20] Charles Clark Group for EPRI, "The Environmental Benefits of Plug-in Hybrid Electric Vehicles," CARB ZEV TECHnology Forum presentation, September 27, 2006.
[21] Michael Kintner-Meyer, Kevin Schneider and Robert Pratt, "Impacts Assessment Of Plug-In Hybrid Vehicles On Electric Utilities and Regional U.S. Power Grids," PNNL, January 2007.

> …PHEVs have potential benefits for the utility in terms of better use of its distribution infrastructure and as a potential source of greenhouse gas offsets, for the region in terms of reduced pollution and greenhouse gas emissions, and for the consumer in terms of lower per-mile costs. Furthermore, the impact on customer rates, whether positive or negative, is likely to be very small. On the face of it, this technology deserves further investigation.[22]

In July 2006, the U.S. National Renewable Energy Lab (NREL) completed an evaluation of the impact of PHEVs on the electrical grid in six regions including the Northwest. The modeling of the Northwest was based on Portland General Electric's electrical generation profile. This study concluded that:

> …large-scale deployment of PHEVs will have limited, if any, negative impacts on the electric power system in terms of additional generation requirements. As demonstrated by utility system load duration curves, current electric power systems have large amounts of underutilized capacity. This excess capacity could potentially provide electricity to PHEVs provided the utilities have some control over when charging occurs.[23]



P. Denholm and W. Short, NREL, July 2006, Figure 9: Increase in Total Electric Demand as a Function of PHEV Penetration

[22] Seattle City Light, Environmental Affairs, "Evaluating Plug-In Hybrid Vehicle Concepts," Fall 2006.
[23] P. Denholm and W. Short, "An Evaluation of Utility System Impacts and Benefits of Optimally Dispatched Plug-In Hybrid Electric Vehicles," NREL, NREL/TP-620-40293, July 2006.

A detailed study of future electrical generating capacity and potential penetration rates of PHEVs is required to fully understand the potential impacts on the NW grid. The tables below provide an analysis that simply calculates the electricity required to charge PHEVs at two potential penetration rates of estimated total passenger vehicles in 2023.[24]

PHEV 20 Load for Washington State

4 miles/kWh
14 miles of all electric range per day
5,489,780 Group 1 Passenger Vehicles registered 2023[25]

Percent of 2023 Fleet	35%	10%
Number of PHEV 20s	1,921,423	548,978
Electric Powered Miles/year	9,818,471,530	2,805,277,580
MWh/year	2,454,618	701,319
Average Load MW assuming 10 hours to charge	667	191

PHEV 60 Load for Washington State

4 miles/kWh
28 miles of all electric range per day
5,489,780 Group 1 Passenger Vehicles registered 2023[25]

Percent of 2023 Fleet	35%	10%
Number of PHEV 60s	1,921,423	548,978
Electric Powered Miles/year	19,636,943,060	5,610,555,160
MWh/year	4,909,236	1,402,639
Average Load MW assuming 10 hours to charge	1,335	381

Based on these tables, if close to 2 million PHEV 20s were being charged, 667 MW of capacity would be required. If close to 2 million PHEV 60s were being charged, 1,335 MW of capacity would be required. For purposes of comparison, the Northwest Power and Conservation Council in their Fifth Power Plan estimated that there are 700 average megawatts of cost-effective conservation acquisitions available from 2005 through 2009.[26] Currently, the Northwest power supply is about 2,400 megawatts in excess of average annual demand.[27]

[24] This methodology is from Dan Greenberg, "Plug-in Hybrids: Electrifying Transportation," ET Currents, July 2005, p5. All electric range for a PHEV 20 and PHEV 60 are based on EPRI modeling.
[25] "Annual Vehicle Registrations, FY 2006-2023," September 2006 Forecasts, Washington State Transportation Revenue Forecast Council, p56.
[26] Northwest Power and Conservation Council, Fifth Power Plan, May 2005, AP-2.
[27] Northwest Power and Conservation Council http://www.nwcouncil.org/library/releases/2006/1017.htm

What will be the benefits for the power grid of charging a substantial fleet of PHEVs?

Thermal power plants are sized to accommodate peak loads and need to be shut down during off-peak periods. By reducing the number of shut-downs and start-ups known as cycling, wear and tear is decreased on the power plant. The National Renewable Energy Lab (NREL) found that charging PHEVs off-peak has an important benefit for the grid by increasing overnight minimum load thereby decreasing cycling. "This reduction in cycling will translate into decreased power plant start-up and operations and maintenance (O&M) costs."[28]

Photo: Brennan Jordan

In addition, various researchers and futurists like Lester R. Brown of the Earth Policy Institute are projecting that PHEVs with large batteries and the ability to discharge power back into the grid based on signals from the utility could provide electrical storage beneficial for the integration of intermittent renewable energy, such as wind or solar, into the grid.[29]

How will utilities have some control over when PHEV charging occurs?

The current thinking by Austin Energy, the founder of Plug-in Partners, is that the PHEV should come from the manufacturer with a replaceable plug. The local utility could provide a replacement plug for the vehicle that has an embedded smart chip that would allow the utility to control when the time of charging occurs. The utility could provide some rebate possibly as cash or discounted rates to the utility's customer.

In the future, as control mechanisms and communication protocols become standardized, auto manufacturers can be given incentives to build charging intelligence into vehicles.

Are batteries well enough developed for PHEVs?

According to George Schultz and James Woolsey in a policy paper for the Committee on the Present Danger, batteries for PHEVs "will require some development – although nothing like years that will be required for hydrogen fuel cells…Such development should have the highest research and development priority because it promises to revolutionize transportation economics and have a dramatic effect on the problems caused by oil dependence."[30]

---

[28] P. Denholm and W. Short, "An Evaluation of Utility System Impacts and Benefits of Optimally Dispatched Plug-In Hybrid Electric Vehicles," NREL, NREL/TP-620-40293, July 2006.

[29] This concept is known as Vehicle-to-Grid (V2G) and a detailed discussion is beyond the scope of this document. For more information see: Lester R; Brown, "The Short Path To Oil Independence," October 13, 2004. http://www.earth-policy.org/Updates/Update43.htm Also see: W. Short and P. Denholm "A Preliminary Assessment of Plug-In Hybrid Electric Vehicles on Wind Energy Markets," NREL, April 2006. http://www.nrel.gov/docs/fy06osti/39729.pdf

[30] George P. Shultz and R. James Woolsey, "Oil & Security." May 2005. http://www.fightingterror.org/newsroom/050610.cfm

All hybrids currently produced employ a Nickel Metal Hydride (NiMH) battery. NiMH batteries are considered "non-hazardous waste" and are recyclable. (Toyota has had a hybrid battery recycling program since 1998.) According to CalCars, NiMH batteries have been proven to be safe over many years of use in hybrids and could go into PHEVs today – the batteries would be designed more like the ones Toyota put in its 2002 RAV4 EV compact all-electric SUV than like current hybrid batteries.

A 2004 EPRI study on batteries concluded that:

> NiMH batteries from top manufacturers today appear to exceed projected cycle life and durability expectations. For example, 5-year old Toyota RAV 4 Electric Vehicles, in real world driving, have traveled over 100,000 miles on the original NiMH battery with no appreciable degradation in battery performance or vehicle range. These batteries are projected to last for 130,000 to 150,000 miles. … In addition, life cycle laboratory bench tests of Saft NiMH batteries between 80% and 20% state of charge demonstrated 2841 to 2922 cycles. Battery test data presented by Ford Motor Co. at the Advanced Automotive Battery Conference show considerably more than 2000 cycles between 100% and 20% state of charge and also confirmed that shallower discharge cycling between 80% and 20% state of charge results in even greater cycle life."[31]

NiMH is generally considered an interim battery technology, soon to be eclipsed by the Lithium Ion battery, which packs more energy capacity per pound. DaimlerChrysler is using this battery technology in some of its prototype PHEV Sprinter commercial vans. Valence Technology's Li-ion batteries used in EDrive Systems' Prius conversions include a phosphate additive that makes it nearly impossible for them to burn or explode.[32] Nanotechnology is being used to improve Li-ion batteries by such companies as Altairnano and A123. In addition, other technologies such as Zebra Battery's sodium nickel chloride and EEstor's high-power-density ceramic ultracapacitors are receiving attention for PHEV applications.

What will PHEVs cost?

At the September 2006 California Air Resource Board ZEV Technology Forum, automotive consultant ASG Renaissance's Max Kapadia, working with engineering services firm Ricardo, presented detailed data modeling for mid-size sedan PHEV-20 production costs, retail price equivalents, fuel and maintenance savings.

The projected additional first cost over a similar internal combustion vehicle, manufactured in mass-production quantities, came in well below the $10,000+ numbers currently cited by automakers -- but above the $4,100-$6,000 projected in 2001-2002 by the EPRI HEV Working Group. Acknowledging that the data were preliminary, both the author and audience pointed to many factors that could be added to the study to further reduce cost. The study

[31] "Advanced Batteries for Electric-Drive Vehicles: A Technology and Cost-Effectiveness Assessment for Battery Electric, Power Assist Hybrid Electric, and Plug-in Hybrid Electric Vehicles," EPRI, Palo Alto, CA:2003. 1001577.
[32] http://www.valence.com/saphion.asp

adopted the analytic approach used by automakers and showed PHEVs priced at 300,000/year volume levels with a less than three-year payback time when fuel cost savings are taken into account.[33]

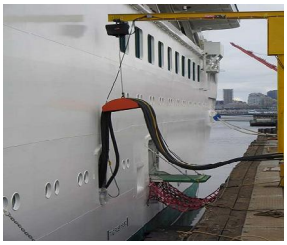
What are electrified transportation options for rail?

Hybrid technology is ideal for locomotives, due largely to the absence of weight constraints. One application is rail yard car switchers. Switchers are deliberately designed to be heavy to gain maximum traction, but they operate in an inefficient 'stop-go' manner that is hard on the large engines of conventional diesel units. One example of hybrid switchers is the RailPower GG Series which have small diesel gensets and large banks of long-life, recyclable batteries, so diesels do not idle. This yields 40-60% reduction in fuel use and greenhouse gas emissions (depending on duty cycle), and 80-90% reduction in nitrogen oxides (NOx) and diesel particulate emissions. Hybrid switchers are ideal for rail yards in emissions constrained airsheds.[34]

What are electrified transportation options for port operations?

Among emerging options:

1. ***Alternative Marine Power***, also known as cold ironing, shore power or hoteling- One of the methods to control ship emissions while a ship is in port is to use shore-supplied electricity to run the ship's lights, refrigeration, heating, air conditioning and hot water. The Port of Seattle has been plugging in docked cruise ships since 2005. Seattle City Light worked closely with the Port and the cruise lines, and have electric service agreements in place that ensure the connection and use of shore power goes smoothly. Hoteling provides phenomenal pollution and oil use reductions. The Puget Sound Clean Air Agency calculates that just eight hours of hoteling cuts on-board oil burning by 2.85 metric tons. Cruise ship air emissions are reduced by about 30 percent. The reduction in emissions is equal to taking 1,100 cars of the road for a full year.[35] Cold ironing is less appropriate at this point for container and cargo ships that call at NW Ports until this technology is adopted more broadly at all West Coast ports.



2. ***Drayage trucks*** and ***terminal operations***- Plug-in hybrid electric short-haul container trucks offer the potential to significantly reduce all truck diesel emissions, NOx, SOx, PM and CO2. EPRI will be funding the development of a plug-in yard hostler. The Port of

[33] "Progress or Breakthroughs at California Symposium on Zero Emission," CalCar News, Oct 5, 2006. http://calcars.org/calcars-news/539.html

[34] http://www.railpower.com

[35] "Cruise Ships Plug In to Shore Power at Port of Seattle," Press Release, Port of Seattle, July 23, 2005.

Tacoma and Port of Seattle have replaced a number of diesel cranes with electric powered cranes. The Port of Tacoma is looking to fully-electric vehicles for many uses, including operations, maintenance and personnel transport. It hosted, in August 2006, a demonstration of electric vehicle technology, performance, capability and utility by several electric vehicle manufacturers.[36]

What electrified transportation options are emerging to reduce diesel truck idling?

Photo: Shurepower

Each night, thousands of truckers idle their diesel engines during government mandated rest periods to power heating, air conditioning, and appliances for their sleeper cabs. Unfortunately, engines running at idling speed also cause undue wear on machinery, emit harmful local and global air pollutants, and increase noise levels for drivers and neighboring communities. They also cost truckers lots of money.

Key strategies for reducing idling are: on-board idle reduction kits (such as small diesel fueled auxiliary power generators, shore power capable retrofits and battery packs) and truck stop electrification (TSE) where truckers can shut down the truck's main engine and plug into land based grid electrical power to operate cab amenities. The potential of truckstop electrification is huge. A California Energy Commission petroleum reduction study in development projects that truckstop electrification could reduce 2025 state fuel use by 250 million gallons per year, for a 6 percent reduction in overall California diesel consumption.[37]

The states of Washington, Oregon, and California are working together to create a network of idle-free truck stops along the I-5 corridor and other corridors from Mexico to Canada. A study from the National Cooperative Highway Research Program determined that there are 15,870 commercial truck parking spaces in Washington, Oregon and California.[38] Washington passed SSB 6512 to provide a business and occupation tax deduction and a sales tax exemption for on-board or stand-alone truck electrification systems.

The federal Environmental Protection Agency (EPA) has awarded grants to agencies in Washington and Oregon to establish an initial set of electrified parking spaces at truck stops. The federal grants are being supplemented with state and private money and funds from the Climate Trust of Oregon, a non-profit organization dedicated to reducing green house gases. This money will be used to establish 75 electrified parking spaces at three truck stops in Washington, and 200 spaces at four truck stops in Oregon. Shurepower, LLC, will install the pedestals and provide the service. (www.shurepower.com) If the 275 electrified parking

[36] Todd Matthew, "Electric vehicles draw attention from Port of Tacoma" Tacoma Daily Index, August 4, 2006.
[37] Personal communication from Gary Yowell, California Energy Commission. Draft report slated for release mid-December 2006.
[38] Jeffrey W Trombly, "Dealing with Truck Parking Demands", NCHRP Synthesis 317, Transportation Research Board, Washington D.C., 2003.

spaces are used just 50 percent of the time, over a five-year period diesel fuel consumption will be reduced by more than six million gallons and savings to truck or fleet owners will be more than twelve million dollars in fuel costs.[39]

The full build-out of a West Coast TSE network along with on-board idle reduction kits is not yet funded. This project envisions retrofitting 15,000 trucks with on-board idle reduction kits and installing a total 14,866 electrified parking spaces and over a five-year period. Under this plan, 7,156 parking spaces will be installed in California, 5,105 installed in Oregon and 2,605 in Washington. The fully built-out project has the potential to save close to 100 million gallons of diesel per year.[40]

What are electrified transportation options for medium-duty trucks?

Renton-based PACCAR, whose Kenworth and Peterbuilt lines are truck world leaders, plans to market medium-duty hybrid trucks by 2008 and has targeted a 30 percent fuel savings in selected medium-duty applications over seven years. In Oyster Bay, Long Island three diesel recycling trucks are being converted to plug-in hybrid electric vehicles by Odyne Corporation with a federal grant of $264,000. Expected diesel savings are 2,670 gallons per year.[41]

International Truck and Engine Corporation and Eaton Corporation have developed a hybrid medium-duty utility truck that is being produced in limited quantities. The trucks are being deployed in fleets across the country as part of a demonstration and field assessment program. The initial trucks showed between 40 and 60 percent improvement in fuel economy. The Northwest Hybrid Truck Consortium has formed to bring these trucks to this region. The Consortium has received grant funds to help offset the incremental cost of these trucks and plans to purchase nine of the trucks in 2007.

[39] "Focus on Reducing Engine Idling at Truck Stops," Wash Dept of Ecology, October 2005.
[40] Personal communication from Frank Van Haren, Air Quality Program Washington State Department of Ecology. Report for West Coast Diesel Emissions Reduction Collaborative: Idle Reduction Projects Plan for Long-Haul Trucks in WA, OR and CA.
[41] "Odyne Corp Awarded Municipal and Utility Projects," Press Release, Odyne Corporation, November 9, 2006. www.odyne.com/pdf/11-09-06-TOB-KEYSPAN.pdf

What are electrified transportation options for school buses?

Several cities and agencies led by Advanced Energy have formed a national consortium called the Hybrid Electric Bus Project, and International has been awarded the contract to produce 20 prototype buses for this consortium. Among the consortium members are: Lake Chelan School District, Little Rock School District, Arkansas and Austin, Texas. Seattle can also buy a prototype school bus. The prototype PHEV school bus will cost $220,000 compared to approximately $65,000 for a traditional diesel-fueled school bus. As currently proposed, the school bus will be owned and operated by the Seattle Public School District which will select a bus route (or routes) to use the technology efficiently and will work with the manufacturer to track the performance and capacity of the bus.

Advanced Energy's vehicle performance modeling (with DOE's ADVISOR model) indicates that plug-in hybrid school buses dramatically increase fuel economy to 18.0 miles per gallon - a 140% increase over a conventional bus. For a typical school bus driven 12,000 miles per year, each plug-in hybrid could save nearly 1,000 gallons of diesel fuel per year and $2,000 in energy costs, including the additional cost of electricity. If this technology were used in every school bus in the nation, this project could save over 480 million gallons of diesel fuel per year from being imported and save school districts over $960 million in annual operational costs. Such buses will reduce operational costs, decrease students' exposure to harmful pollutants, and improve ambient air quality.[42]

[42] http://www.advancedenergy.org/corporate/initiatives/hybrid_electric_bus.html

Appendix – Recent Local Op-Eds

Sunday, July 2, 2006

Time for Washington State to Declare Clean Energy Independence

By Patrick Mazza and Richard Feldman

An economic earthquake is poised to shake the globe. By making preparations now for a future of scarce world oil supplies, we can build an economy with a more resilient foundation for jobs and prosperity.

As economics guru Alan Greenspan recently told the Senate Foreign Relations Committee, "Even before the devastating hurricanes of last summer, world oil markets had been subject to a degree of strain not experienced for a generation. Today . . . the buffer between supply and demand is much too small to absorb shutdowns of even a small part of the world's oil supply."

The American economy is now like a car without shock absorbers. The next hurricane that slams into the Gulf Coast could send prices up at the pump again. But the next car bomb that successfully explodes at a major Saudi oil facility could send fuel pump prices above $5 or $6 per gallon. A doubling of oil prices from such a shock could cause a 2-5 percent slump in GDP, for one of the worst recessions since World War II.

While U.S. energy policy has seemed like a deer petrified in the headlights of oncoming calamity, leaders spanning the spectrum are now moving serious proposals for greater energy self-reliance. Just as President Kennedy challenged our nation to land on the moon within a decade, citizens across the country – trade unionists, farmers, security hawks, entrepreneurs, and state and local officials – are by word and deed challenging our nation to implement a new Apollo Project – to achieve clean energy independence within a decade. The farmer led 25x'25 movement is calling for agriculture to produce 25% of U.S. energy by 2025.

Bipartisan federal legislation aims to cut oil consumption seven million barrels by 2025. Washington State has been a pioneer in these efforts. Just this year, Gov. Gregoire united farmers, unions, environmentalists, Republicans, and Democrats to sign into law a bill sponsored by Rep Jenea Holmquist that sets a state-wide standard to promote renewable fuels to replace some of the gasoline we now import from the Middle East and other troubled regions.

There is more, however, that we in Washington State can do to help reduce oil use by a transportation system 97 percent dependent on oil. So doing, we can help lead America toward clean energy independence that protects our economy, our environment and our security. The following five -point plan could help us achieve that goal:

1. Set an oil savings goal.
First, we should set an oil savings goal. A California plan targets a 15% lower oil use in 2020 than 2000. Senator Maria Cantwell has introduced legislation to reduce U.S. oil imports 40 percent below 2025 projections. Hawaii Gov. Linda Lingle is pushing to cut state oil imports by 2020. Washington consumes roughly 3.6 billion gallons of oil per year in transportation fuels, with a typical annual growth rate of 1.7 percent for the past 25 years. State leaders should set firm goals and dates, first to halt increasing oil use and then to significantly reduce it, appointing an Oil Savings Task Force to map strategies.

2. Promote vehicles that reduce oil use.
Cost-effective, off-the-shelf motor vehicle technologies could improve fuel efficiency by 60 percent in 10 years without reducing vehicle size or weight, says the Union of Concerned Scientists. State and local governments can promote better mileage by public fleet purchases, and tax and license fee incentives. Requiring replacement tires to be as efficient as new car tires can improve mileage by three percent. Public education on proper tire inflation could have a real impact.

At least 100,000 Washington motorists are driving flex fuel vehicles capable of running on home-grown "E85" – 85% ethanol fuel -- instead of gasoline, yet there is only one retail E85 fuel pump in the entire state. State and local governments can provide incentives for station operators to install E85 pumps and make sure their own flex fuel vehicles run on E85.

3. Build up transit and transit-friendly communities.
Public transportation uses half the oil per passenger mile as cars and SUVs, reports the Center for Transportation Excellence. Investing in bus and rail transit systems that provide frequent, reliable service is vital. Building compact communities provides the population base that makes frequent transit service feasible. Smart transit-oriented development could reduce oil use up to 10 percent by 2020, a California Energy Commission study shows.

4.Commercialize advanced biofuels.
Building on our Renewable Fuels Standard, Washington should invest in the R & D necessary to develop the next generation of bio-fuels – so-called "cellulosic ethanol" based on Washington's abundant supplies of plant waste from its farms, forests and municipalities as well as specialized crops such as switchgrass. New technologies will produce cellulosic biofuels at costs competitive with gasoline.

Washington State University calculates the state annually generates 15 million dry tons in cellulose wastes. With near future technologies each million tons could displace 50 million gallons of petroleum fuels. Washington also has 14 million acres of croplands. Crops such as switchgrass could displace 200 million gallons per million acres. While only a portion of those tons and acres will be practical for fuel production, these figures indicate massive

prospects. State farmlands also can grow oil crops capable of producing at least 50 million gallons of biodiesel annually, perhaps several times that much. And a substantial chunk of the $9 billion that we annually pay to oil companies will wind up in Washington farmer wallets.

5. Electrify transportation.
Outcompeted by gasoline in the early days of the car, electricity is now returning in the form of gasoline-electric hybrids that significantly reduce fuel use. The next stage is the plug-in hybrid charged not only by car systems, but also by standard wall sockets. Because plug-ins run on electric charge longer than most people drive daily, liquid fuel use could drop as much as 85 percent. A Prius converted by the CalCars group gets over 100 mpg of petroleum. A flex fuel plug-in car could be nearly oil free. Plug-In Partners is a national grass-roots initiative working to demonstrate to automakers that a market for flex fuel plug-ins exists today.

Plug-ins could make a big dent in global warming pollution. A University of California-Berkeley study finds that every 500 kWh used to charge plug-in hybrids would displace one barrel of oil. Since plug-ins would be charged at night during off peak hours, they would use generating capacity that is otherwise wasted. Plug-ins could be virtually carbon free if Washington develops its significant undeveloped renewable power and energy efficiency resources. Passage of I-937, the Clean Energy Initiative, this fall would help ensure that Washington taps its clean power potential.

A State Plug-In Hybrid Task Force could help advance demonstration projects and identify opportunities for state businesses in plug-in manufacture. Significant oil reductions can also be made by electrifying truck stops, and running port cranes and docked ships on electricity as is being done increasingly at our ports.

When America's founders came together at Independence Hall 230 years ago they knew it was time to take the future in their hands. We would either hang together or hang separately, they told each other. Now we are called to secure our independence from politically unstable regions and oil companies with a long record of resistance to alternatives. Disruptive oil shocks are barreling down on us. We will either hang economically as individuals or join in a bold agenda to replace petroleum fuels. Washington state has the public leadership, entrepreneurial vision and energy resources to lead this new American energy revolution. In upcoming elections citizens should ask candidates – What is your plan for dissolving the bonds of oil addiction and declaring clean energy independence?

Patrick Mazza is Research Director for Climate Solutions, www.climatesolutions.org. Rich Feldman is Coordinator for Apollo Alliance of Washington, www.apolloalliance.org and Executive Director of the Worker Center-King County Labor Council, AFL-CIO. For more on the Apollo Challenge campaign, visit www.apollochallenge.com.

The Seattle Times
seattletimes.com

Plug-In Energy Independence

By: Steve Marshall and Bruce Agnew
May 23, 2006

Imagine a car that gets more than 100 miles a gallon, reduces greenhouse gases and helps free America from its reliance on foreign oil. There is growing bipartisan support and interest for just that kind of car — a plug-in, flexible-fuel hybrid vehicle. And on June 1 at the Microsoft Conference Center, policymakers and the public will be able to see actual plug-in hybrid cars that can get 100 mpg, and hear experts discuss steps to help "end our addiction to foreign oil."

Like hybrids on the road today, such as the Toyota Prius, plug-in hybrid cars run on electric power with a gasoline (or biofuel) engine backup. The difference is that a plug-in hybrid can top off its batteries by plugging into the electric power system instead of using the gasoline engine for recharging. For shorter trips, such as commuting to work, the plug-in hybrid can get 100 miles to the gallon or more because it hardly needs to use the gas engine. The gas engine itself can become a "flexible fuel" engine running on ethanol blends or biodiesel blends, further reducing oil dependence.

A relatively small shift to plug-in hybrids could save Puget Sound drivers millions of gallons of gas a year and reduce carbon-dioxide emissions by more than a million tons a year. Topping off hybrid batteries from the electric power grid is far more efficient than recharging from gasoline engine power — which is why carbon-dioxide emissions drop so much with plug-in hybrids.

But, it is the immediate threat to national security from foreign oil dependence that is finally driving strong bipartisan support for plug-in hybrid cars and similar measures. At next week's conference, former CIA Director James Woolsey and Sen. Sam Brownback, R-Kan., will be among those describing the national-security risk from reliance on unstable oil-producing nations; Brownback and others have sponsored legislation, backed by a coalition of labor and environmental groups, to accelerate production of plug-in hybrid vehicles. Sen. Maria Cantwell, D-Wash., will also speak on the coalition's efforts.

In his State of the Union address, President Bush also called for an end to our foreign oil addiction, and has rolled out initiatives including support for plug-in hybrid vehicles.

We can work to pull together an integrated Puget Sound transportation solution that would dramatically reduce gasoline use, increase transportation efficiency and cut greenhouse gases — and reduce our dependence on foreign oil. There are three steps we need to take now to get ahead of the curve.

First, we need to convene state and regional leaders in transportation, electric utilities and government to work together on a set of overall recommendations. For example, a cellphone-

type chip could be required that allows recharging only during off-peak hours, in order to use our electric power system more efficiently. Hybrid bus transportation, including school buses, could be encouraged. (A few Washington state school districts have joined a national school bus plug-in hybrid campaign.) Corporate and government vehicle fleet purchases could be linked to the national "plug-in partners" campaign. Parking garages and park-and-ride lots could incorporate recharging stations.

Second, we need to encourage a Washington state-based transportation-technology industry to advance solutions such as using strong, lightweight composite materials for trucks and buses and shifting to complete electric-drive vehicles to save weight. Boeing is a world leader in composites and we have high-tech research centers such as Battelle and Energy Northwest to help develop technology solutions. Paccar last month announced an initiative to incorporate lightweight material and hybrid technologies in its trucks.
Biofuels, using renewable Washington state farm and forest products, can be further encouraged. Like biotech, transportation tech can become a hallmark of the Northwest economy.

Finally, we need to move fast. Plug-in hybrids can be ready to roll well within the planning horizon for regional transportation and power organizations. We need a thoughtful, integrated transportation approach now before we lose a once-in-a-generation chance at an integrated transportation solution.

Such a solution will also require thoughtful leadership to make sure we have the domestic electric power to move away from our dependency on oil while solving our commuting problems, especially in the Puget Sound basin.

Steve Marshall is chairman of the Municipal League of King County. Bruce Agnew is director of the Discovery Institute's Cascadia Center, which is working on regional transportation solutions. The Cascadia Center and Microsoft are co-sponsoring the June 1 conference in Redmond with government, transportation and energy leaders.