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*Replacing Oil with Electricity and Biofuels in Transportation:
The Convergence of Technology and Public Policy*

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*Replacing Oil with Electricity and Biofuels in Transportation:
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“To reduce oil dependence, nothing would do more good more quickly than making cars that could connect to the electric grid.”— Brookings Institution Report, January 22, 2007

*“Widespread adoption of plug-in hybrid electric vehicles could cut U.S. greenhouse gas emissions at a scale equivalent to removing one-third of today’s vehicles from the road”
-- National Resources Defense Council and the Electric Power Research Institute, July 19, 2007*

Introduction

The primary purpose of this paper is to underscore the point that the transition from oil to electricity as an alternative transportation fuel (along with biofuels) is proceeding faster than most electric power utilities and their regulators imagine. With long planning horizons, the industry, with some exceptions, is often slow to adapt to comparatively rapid changes in either technology or in public policy. In this case there is a convergence of remarkable technological change and a major shift in policy.

A secondary purpose is to suggest steps that should be taken early in the transition to optimize the benefits for the power and transportation systems and to mitigate some potentially costly consequences.

Electricity as an Alternative Transportation Fuel—Developments in Technology

Over 97% of all U.S. transportation depends on oil for fuel. The U.S. must import 60% of the oil it uses, adding to greenhouse gases, undermining national security and adding to trade deficits at nearly a billion dollars a day pace. The price of oil has gone from \$25 a barrel five years ago to over \$70 a barrel now.

By contrast, the electric power industry, which before the 1970’s relied on oil to generate nearly 30% of U.S. electricity, uses oil to generate less than 3% today. The question has become, how can we replace foreign oil with domestic power in transportation?

A year ago plug-in electric vehicles were mostly a concept. Professor Andy Frank and Felix Kramer among others showed that it was possible to make a plug-in hybrid electric car that gets more than 100 miles a gallon, significantly reduces greenhouse gases and helps free America from its addiction to oil. But no major auto maker had plans to make them. Much has happened in a year.

On July 18, 2006 Toyota was the first to announce plans to make plug-in electric hybrid vehicles. Unlike its existing Prius and other gas-electric hybrid cars, Toyota's plug-in hybrid will recharge its larger batteries from a standard household outlet. Toyota said it would be able to "travel greater distances without using its gas engine, it will conserve more oil and slice smog and greenhouse gases to nearly imperceptible levels."

On August 2nd New York Governor George Pataki announced a \$10-million program to convert New York State's gas-electric hybrid vehicle fleet to plug-in hybrids and for a state-of-the-art alternative fuel research laboratory. Under the program, 600 state hybrid vehicles will be converted to plug-in hybrids. The state will make conversions available to private vehicle owners through a competitive process.

In September, Ford named Alan Mulally as its new CEO, and in December he flew to Toyota for "talks on the environment, hybrid car development and manufacturing efficiencies."

On December 1st, GM's CEO, Richard Wagoner, announced GM was developing a plug-in version of its existing Saturn Vue Green Line gas-electric hybrid, calling it "a major priority." Asked about his "worst" business decision, Wagoner said "Axing the EV1 electric car program and not putting the right resources into hybrids." (David Kirsch, *A Battery-Powered Run Down*, Science, Oct. 20, 2006, at 124)

On December 11th, the Department of Energy's Pacific Northwest National Laboratory in Richland, Washington evaluated the impact of plug-in hybrid electric vehicles on foreign oil imports, the environment, electric utilities and the consumer. If recharging were limited to night and other "off peak" times, the study estimated significant savings for the economy and a potential for lowering greenhouse gases substantially. The study said idle capacity of the electric power grid "is an underutilized national asset that could be tapped to vastly reduce our dependence on foreign oil."

On December 13th, the California Energy Commission funded a plug-in hybrid electric vehicle research center to "serve as a magnet for innovative research by advancing and demonstrating technology which will greatly reduce our dependence on petroleum." The research center will identify strategies to accelerate the commercial adoption of plug-in hybrid electric vehicles, and an advisory council will provide strategic direction.

On January 7, 2007 GM announced its Chevy Volt plug-in hybrid car that could travel up to 40 miles on batteries alone and recharge itself with an onboard generator—or by plugging into a standard household outlet. Robert Lutz, GM's vice chairman for product

development, estimated that for 78 percent of commuters in the United States whose daily trip to work is 40 miles or less, the Chevy Volt would make the commute using only the battery “without burning a drop of petroleum.”

On January 17, 2007, PG&E’s CEO, Peter Darbee in accepting an award from the National Resource Defense Council (NRDC) said PG&E planned to partner in the promotion of plug-in hybrid vehicles: “More efficient cars have the obvious benefit of reducing oil use. But this technology could also help the power grid. When the cars are not in use, energy from the batteries could be uploaded back to the system, reducing the need for peak power generation. This is important, because peak power often comes from the least efficient and least clean resources on the grid.” PG&E also announced support for Governor Schwarzenegger’s low carbon fuel standard saying: “This is a positive step to accelerate adoption of plug-in hybrids, as well as other cost effective ways to reduce oil dependence and address climate concerns.”

On May 1, 2007 in testimony before a U.S. Senate Finance Committee, David Vieau, CEO of A123Systems, a leading lithium-ion battery developer and manufacturer, unveiled plans for large scale conversions of existing gas-electric hybrids into plug-in vehicles. A123Systems is an MIT spin off company that has also acquired Hymotion, a company that makes lithium-ion battery conversion modules. According to press accounts, the module contains all of the necessary components including the batteries, power electronics, crash sensors, charger, battery management systems and safety sensors. It can be installed in less than two hours in a stock Prius without any other changes except the installation of the plug in the rear bumper. See full testimony at www.finance.senate.gov/sitepages/hearing050107.htm.

On May 16th A123Systems announced a new more powerful and durable lithium ion battery that will allow automakers to build PHEVs with a battery pack lasting more than 10 years or 150,000 miles.

On June 18th Google’s foundation announced grants for its “RechargeIT” initiative and “teamed with Pacific Gas & Electric to demonstrate the bi-directional flow of electricity between plug-ins and the electric grid,” sometimes called vehicle to grid or V2G. Dr. Larry Brilliant, Executive Director of Google.org, said “Clean energy technology can dramatically shift how we make and use energy for our cars and homes... This approach can quadruple the fuel efficiency of cars on the road today and improve grid stability.” Experiments have started with a Toyota Prius “that has been converted to allow two-way flows of electricity. PG&E will send wireless signals to the car while it is parked and plugged in to check its state of charge. It can then recharge the batteries or draw out the power.”

On July 9, 2007 Ford’s CEO Alan Mulally and John Bryson, CEO of Southern California Edison (SCE) announced “a joint electric transportation initiative designed to explore way to advance plug-in hybrid technology for the U.S. market.” This is the first such partnership between a major automaker and a major utility. Initial plans are for Ford to

provide versions of its Ford Escape SUV for testing by customers of Southern California Edison.

Mulally said plug-in hybrids are a “high priority” for Ford’s research and development staff. SCE, with 13 million customers, has been a vocal advocate for the development of electric vehicles. Bryson is also a member of the Boeing board of directors and worked with Mulally when he was in charge of the development of the new fuel efficient Boeing 787 Dreamliner.

At the press conference, Bryson held up a standard 110V extension cord and said: “We need to make the future as simple as this... [Electricity] is the only alternative fuel with an infrastructure that has already been built.” The project will also test vehicle to grid (V2G) technology and will explore the potential residual value of PHEV battery packs when used for bulk energy storage after the packs reach the end of their useful lives in a vehicle.

Unexpectedly, competition may also come from China. On July 12th, Frank Gaffney, CEO of the Center for Security Policy, testified before the House Select Committee on Energy Independence and Global Warming: “China will shortly be introducing to the U.S. and other export markets the Chery, a car that could sell for as little as \$10,000. Some believe the Chinese intend to translate their competitive advantage in battery technology to offer a plug-in hybrid electric variant of their vehicle as a price to consumers of \$13,000-\$15,000.” The full testimony is available at www.setamericafree.org/gaffney071207.pdf

On July 25th Toyota announced it has developed a plug-in hybrid vehicle for public road tests in Japan and also plans tests for the United States and Europe. The New York Times reported that “Toyota is the first manufacturer to receive government approval to conduct tests for a plug-in hybrid on Japanese public roads.” The article said “other major automakers, including [General Motors Corp.](#) and [Ford Motor Co.](#), are developing plug-in hybrids, a key technology that reduces the gases causing [global warming](#)... Plug-in hybrids, including Toyota’s, generally have batteries that power an electric motor, with an internal combustion engine for use when the batteries run low. The batteries can be recharged by plugging them into a standard wall outlet.”

In summary, in the space of a year, major automakers have gone from no commitment on producing plug-in hybrid electric vehicles, to what is shaping up to be a race to see which company can successfully bring a PHEV to the consumer market first.

Competition for the major automakers is also coming from another source. On the all electric side, the Tesla Motor Company announced it has pre sold over 540 Tesla Roadsters that will travel 250 miles on a charge. It is capable of speeds up to 135 miles per hour and can go from zero to 60 in under four seconds. Crash tests and other certifications are nearly complete and delivery will begin this fall. Among the first ten customers to receive delivery are George Clooney and California Governor Arnold Schwarzenegger. According to Tesla’s CEO Martin Eberhard, “It’s about proving that

plug-in technology can work, that electric cars do not have to be frumpy and dull.” The Tesla is designed to compete with other high performance cars and is expensive. But, as Eberhard recently told a U.S. Senate Finance Committee: “Almost any new technology has high cost before it can be optimized, and this is no less true for electric cars.” Tesla also plans a family car for \$50,000 in 2009 at a plant it is building in New Mexico, followed by a third model that “will be more affordable still.” Tesla has an excellent website with background engineering details and comparisons to other alternative fuel vehicles.

The Public Policy Consensus to Replace Oil with Electricity and Biofuels

At the national, regional and state level, there is a strong and growing bipartisan public policy consensus pushing to reduce as fast as possible our nation’s “addiction to oil.” Because our dependence on oil for transportation undermines national security, creates greenhouse gases and is a major portion of our trade deficit, political alliances have formed that cut across party lines.

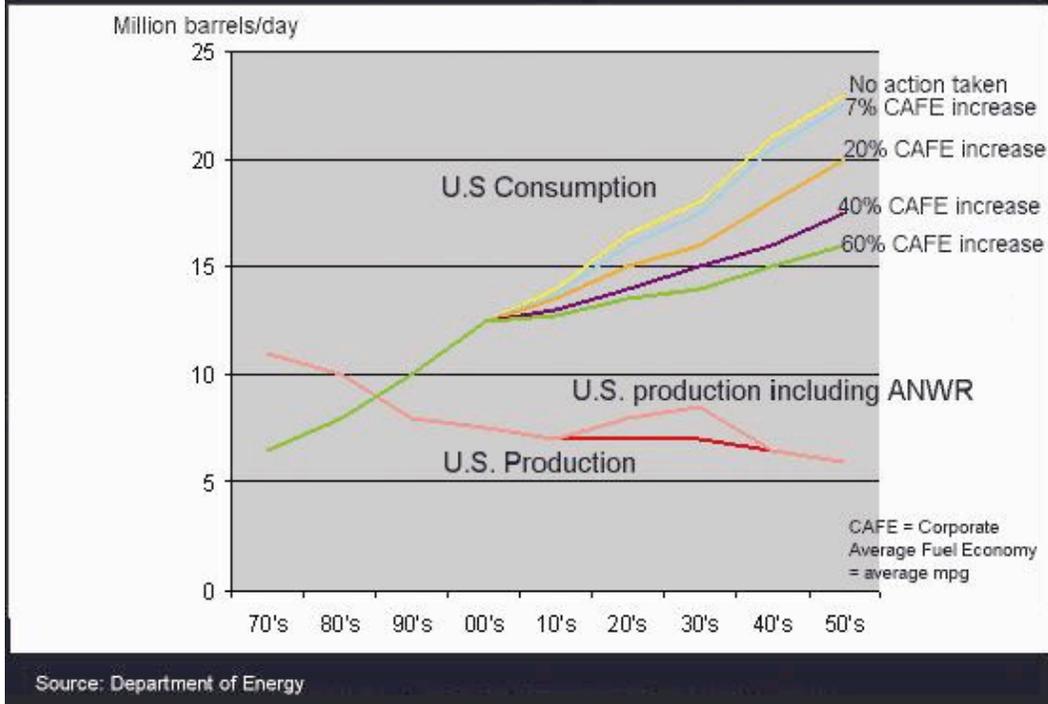
The basic facts behind the growing public policy consensus are now well recognized: Over 60 percent of U.S. oil is imported, adding to record trade deficits. The U.S. will borrow over \$320 billion a year to finance the purchase of foreign oil, making the U.S. less competitive.

Nearly 66 percent of the world’s oil comes from the Middle East, and much of the rest comes from unstable or unfriendly regimes. And as former CIA Director James Woolsey has said, we are essentially financing both sides of the war on terror at the gas pump.

Although we have only 3% of the world’s oil reserves, we use 25% of the world’s oil output and consume half of the world gasoline production. Burning petroleum for transportation is one of the largest sources of U.S. carbon dioxide emissions.

China, India and other developing countries increase world demand for oil, and production has not kept pace. The use of oil for U.S. transportation far outstrips U.S. production, even if ANWR is included:

The Oil Gap in the Transportation Sector



Thomas Friedman, author of “*The World is Flat*,” compared U.S. dependence on foreign oil to the iceberg that sank the Titanic: “Energy, broadly defined, has become the most important geostrategic and geoeconomic challenge of our time—much as the Soviet Union was during the cold war.” (*The New York Times*, April 28, 2006, “*Gas Pump Geopolitics*.”)

National Public Policy Developments

At the national level coalitions of Republicans, Democrats and independents concerned about our national addiction to oil and its effect on national security, global climate change, and the economy have joined to press for solutions. Senators Orrin Hatch, Barack Obama and Maria Cantwell joined to introduce legislation to create incentives for flex-fuel, plug-in hybrid vehicles. Senators Lieberman, Brownback, Bayh and Coleman introduced a detailed measure called the DRIVE Act, major portions of which were recently passed by the Senate. Similar legislation is pending in the House, including measures for regional pilot projects for plug-in hybrid vehicles supported by U.S. Representatives Jay Inslee and Dave Reichert. Both addressed a Cascadia/Microsoft conference on May 7th called “Jump Start to a Clean, Secure Energy Future.” (www.cascadiaproject.org and at TVW archives).

These Congressional coalitions share an urgency that puts energy independence above partisanship. They understand that we need to accelerate and integrate the production of vehicles capable of dramatically reducing our use of oil.

The Administration is also taking steps to accelerate the technology. The President, who first used the phrase “addiction to oil” in the 2006 State of the Union address, returned to the issue in this year’s State of the Union address:

“For too long our Nation has been dependent on foreign oil. And this dependence leaves us more vulnerable to hostile regimes, and to terrorists – who could cause huge disruptions of oil shipments ... raise the price of oil ... and do great harm to our economy.

...
America is on the verge of technological breakthroughs that will enable us to live our lives less dependent on oil. These technologies will help us become better stewards of the environment – and they will help us to confront the serious challenge of global climate change.”

Regarding replacing oil in transportation he said: “We need to press on with battery research for plug-in and hybrid vehicles, and expand the use of clean diesel vehicles and biodiesel fuel.”

The following day, on January 24th the President issued an Executive Order that among other things required federal agencies to buy plug-in hybrid vehicles for their agency fleets when commercially available on a life cycle cost basis comparable to conventional vehicles. The President has toured plug-in battery manufacturing plants, reviewed plug-in vehicles on the White House south lawn and has directed the U.S. Department of Energy to accelerate its plug-in research and related programs.

U.S. Supreme Court Developments

On April 2, 2007, the U.S. Supreme Court ruled in *Massachusetts v. Environmental Protection Agency*, that carbon dioxide and other greenhouse gases are pollutants under the Clean Air Act and thus subject to regulation by the U.S. Environmental Protection Agency (EPA). The Administration had taken the position that the EPA had no authority to regulate greenhouse gases under the Clean Air Act. Carl Pope, national director of the Sierra Club said: “This ruling is probably the most important Supreme Court environmental ruling in history.”

Writing for the 5-4 majority, Justice Stevens said the Clean Air Act allows carbon dioxide to be regulated because it defines a pollutant as “any physical, chemical...substance or matter which is emitted into the air.” The decision said “EPA can avoid taking further action only if it determines that greenhouse gases do not contribute to climate change or if it provides some reasonable explanation as to why it cannot or will not exercise its discretion to determine whether they do.”

The Wall Street Journal said the “court’s decision sets the stage for aggressive new regulation of auto emissions, a primary source of carbon dioxide.” (D. Treftz, J. Fialka, *Court Rulings Could Hit Utilities, Automakers*, Wall Street Journal, April 3, 2007)

The decision may also have an effect on California’s efforts to impose more stringent requirements on auto emissions, which require a cut of 30% in carbon dioxide emissions in passenger vehicles by 2016. A dozen other states including Washington State have enacted laws adopting the California standard. Before the standards take effect, California needs a waiver from the EPA, which the auto industry has opposed. Governor Schwarzenegger said: “I am very encouraged by the U.S. Supreme Court ruling today that greenhouse gases should be regulated by the federal government. We expect the U.S. EPA to move quickly now in granting our request for a waiver.” (F. Barringer, *Ruling Undermines Lawsuits Opposing Emission Controls*, New York Times, April 3, 2007)

Although the theory has yet to be tested, the ruling could have an effect on Environmental Impact Statements and consultations necessary for federal and state road and transportation projects, unless it is shown that future vehicles will be produced that substantially reduce or eliminate carbon dioxide emissions.

State and Regional Public Policy Developments

A number of states believe that the federal government is neither doing enough nor moving fast enough to limit auto and other greenhouse gas emissions. Although national security concerns due to oil dependence are not addressed at the state and local level, increasingly states and cities are taking the initiative on reducing auto emissions.

As mentioned in the section on the Supreme Court ruling above, California has adopted far more stringent measures to limit auto emissions than Congress has enacted to date. This year, on January 9th, California Governor Schwarzenegger established a “Low Carbon Fuel Standard” through an executive order to “reduce the carbon intensity of California vehicle fuels.” Schwarzenegger said: “Transportation accounts for 40% of California’s annual greenhouse gas emissions, and we rely on petroleum-based fuels for 96 percent of our transportation needs. This petroleum dependency contributes to climate change and leaves workers, businesses and consumers vulnerable to price shocks from an unstable global energy market.” Later, in his state of the state message he said: “Our country has been dependent on foreign oil for too long.”

The Governors of Washington, California and Oregon “have approved a series of recommendations for action to combat global warming and directed their staffs to continue working on state and regional goals and strategies.” A staff report to the three governors stated:

"Global warming will have serious adverse consequences on the economy, health and environment of the West Coast states. These impacts will grow significantly in coming years if we do nothing to reduce greenhouse gas pollution. Fortunately,

addressing global warming carries substantial economic benefits. The West Coast region is rich in renewable energy resources and advanced energy-efficient technologies. We can capitalize on these strengths and invest in the clean energy resources of our region."

The report was prepared as part of the West Coast Governors' Global Warming Initiative, initially launched by the Governors in September 2003. (For further details see www.climatechange.ca.gov/westcoast/index.html).

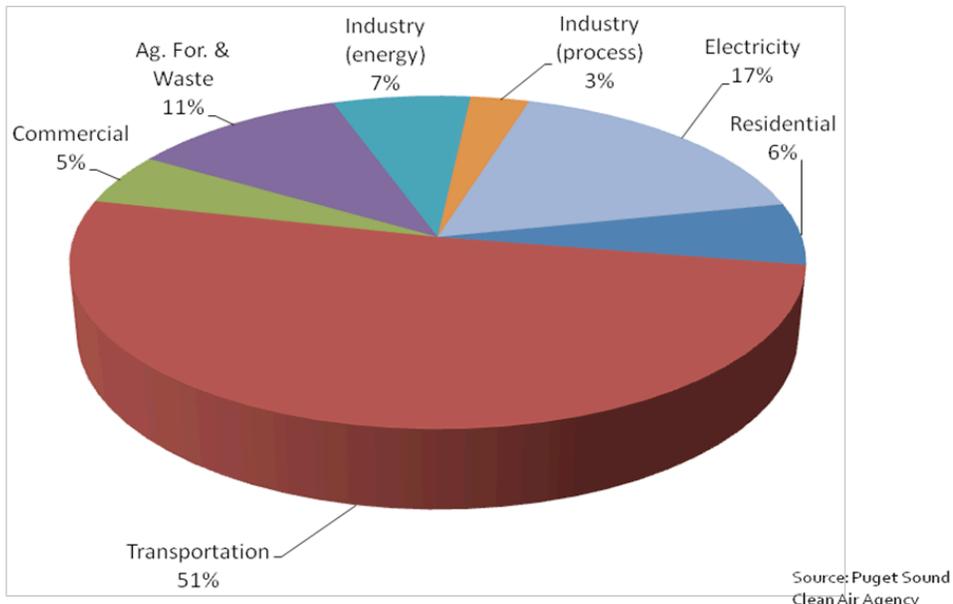
More recently, the Premier of British Columbia, Gordon Campbell has joined with Governor Schwarzenegger to create a "green block" along the Pacific. (D. Struck, *California to Create a Green Block Along Pacific*, Washington Post March 18, 2007)

Washington State is also taking action on its own. The legislature has enacted some of the same auto emission limitation measures California enacted and is looking at adopting more. In addition, the Governor and the legislature have set goals that start with reducing greenhouse gas emissions to 1990 levels in less than 13 years—by 2020. In order to develop proposals to meet those goals, the Governor created a Climate Action Team. (see www.ecy.wa.gov).

Washington has a high percentage of low carbon and renewable resources producing its electric power thanks to our state's hydro-electric resource heritage and to the Bonneville Power Administration sales of hydro and nuclear power. On average utilities in Washington State produce electricity with some of the lowest percentages of carbon dioxide emissions of utilities anywhere in the United States.

As a result, transportation is by far the single largest source of greenhouse gas emissions in Washington State. Washington State vehicles burn more than 3.6 billion gallons of gas a year. In the Puget Sound area, more than half of all greenhouse gases are from transportation:

Greenhouse Gas Emissions for the Puget Sound Region



The Transportation Working Group for the Climate Action Team is looking at several options for reducing greenhouse gas emissions including one that would provide incentives to accelerate and integrate flex-fuel, plug-in hybrid electric vehicles.

As the Governor's letter to the Climate Action Team notes, Washington state drivers spend over \$9 billion a year on petroleum for vehicles—more than the state spends on K through 12 education (see www.ecy.wa.gov)—and most of those dollars leave the state. Replacing gas with Washington state biofuel crops and Washington state generated electric power would keep a significant portion of that \$9 billion in the state economy.

The combination of Washington State's comparatively clean existing electric power system, coupled with the Renewable Portfolio Standards adopted by voters in 2006 and other limitations enacted by the legislature earlier this year, mean that the electric fuel for PHEVs and battery powered vehicles now and in the future will continue to be as low as or lower than any other state.

In other states without our relatively clean power production, the news is still positive -- plug-in vehicles have the potential to dramatically reduce greenhouse gas emissions.

Two studies released on July 19th by the Natural Resources Defense Council (NRDC) and the Electric Power Research Institute (EPRI) show that widespread adoption of plug-in hybrid electric vehicles (PHEVs) in the United States could reduce greenhouse gas

(GHG) emissions “by more than 450 million metric tons annually in 2050—equivalent to removing 82.5 million passenger cars from the road,” which is a *third* of the total vehicle fleet.

This was a mid-range projection “based on quantitative modeling taking into account multiple scenarios for technology change in the power and auto industries, as well as electric load and capacity growth.” The study also concluded that “pluggable cars would use 7 to 8 percent of grid energy, while reducing petroleum consumption by 3 million to 4 million barrels per day.” (For the full reports see www.epri-reports.org)

The use of biofuel PHEVs and battery electric vehicles would produce even lower GHG emissions, depending on the source of the biofuels.

Washington State Opportunities for Regional and National Cooperation

Washington State enacted legislation that provides initial funding for a plug-in hybrid pilot project. Our state is also an important part of the national equation. There is an effort underway for our region to work with the federal government to design a pilot program to determine how best to integrate plug-in hybrids into our power grid and the existing transportation system.

An essential first step is to implement a well-designed regional pilot program in cooperation with the federal government to determine how best to integrate plug-in hybrids into our power grid and the existing transportation system. If we are going to recharge hybrid batteries from the power grid, how can we optimize existing power generation as contemplated in the PNNL report? If we want to intelligently integrate plug-in hybrids into our other transportation planning, how do we make sure we have thought through the options and opportunities? Should we provide recharging at bus park and ride lots and transit centers? Provide “green lane” incentives? What replaces gas tax revenues if and when flex-fuel hybrids cut gas consumption and thus gas tax revenues? Is it time to test congestion pricing as a substitute?

Federal Energy Regulatory Commission member Jon Wellinghoff has proposed a “cash back hybrid,” that would link the vehicle to grid with two way power flows. Imagine an owner of a PHEV being able to drive to a park and ride lot, park and plug in his or her car and get free recharging and a small check at the end of the month simply for being connected to the grid and able to supply ancillary services or standby peak power. How would that concept be tested? A Northwest pilot project could test and refine, for example, the use of a utility-controlled chip for allowing recharging at optimum times and for Vehicle to Grid (V2G) services.

Much as Thomas Edison’s Pearl Street project in Manhattan demonstrated that the electric light bulb was part of a larger and necessary system of electric power production and delivery, we need a similar demonstration for flex-fuel, plug-in hybrids as part of an overall transportation and power *system*.

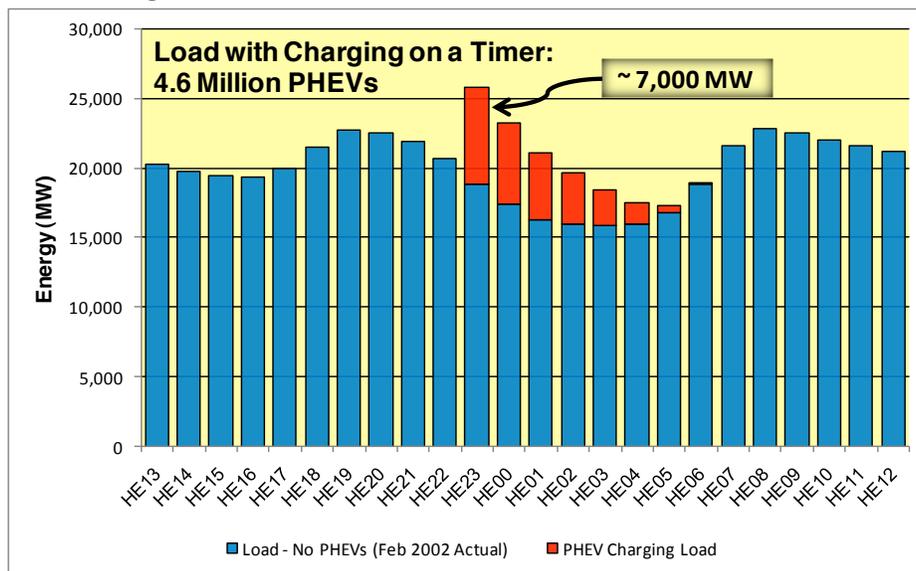
We are well suited in the Northwest to develop a pilot project with the federal government. The Department of Energy has two national labs, the Pacific Northwest National Lab in Richland, run by Battelle, and the Idaho National Lab in Twin Falls. Our state department of transportation has an excellent working relationship with the federal Department of Transportation and could be the lead state agency in designing a pilot project with the federal government. We have other institutions and traditions of federal/state coordination exemplified by Energy Northwest, the Bonneville Power Administration, and the Northwest Power and Conservation Council. Finally, we have forward-thinking regional leaders who are motivated to work together to reduce our reliance on oil for the sake of national energy security, the economy and our environment.

Consequences for the Failure to Plan

Once a driver buys a plug-in hybrid electric vehicle, it is likely to become the daily car of choice. At current Northwest electric rates the cost of electric “fuel” is about 50 cents a gallon equivalent compared to \$3 a gallon or more for gas. For the driver of a plug-in, the operating costs will be from 1 to 2 cents a mile compared to 12 cents or more for a gas engine car.

Drivers will want to recharge their cars wherever they are and will want to charge quickly. This presents a challenge to utilities

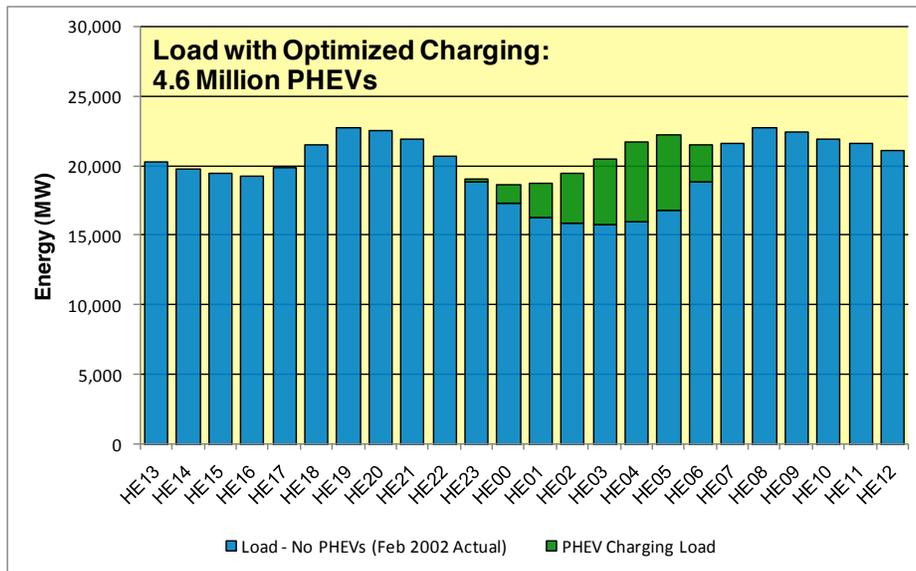
As shown in the attached article from the Northwest Public Power Association PHEVs could place about 7,000 MW of load on Northwest utilities assuming a timer or time of day pricing incentive was used to delay charging to 10 pm. As noted, 10 pm is the latest charging can start and still be certain that each PHEV was fully charged prior to the next morning’s commute. After the first hour, charging load diminishes as PHEV batteries reach their full charge.



The above chart assumed charging at standard 110 volts. If charging is 220, the load increase from 7,000 additional megawatts to 28,000. Some manufactures, such as the Phoenix Car Company are looking at even higher voltages for faster recharging. Whether it is 7,000 or 28,000 megawatts, recharging PHEVs in a static manner even at night or with time of day pricing would significantly increase Northwest peak load which in turn would drive new power plants and transmission line construction.

However, as the article points out, if PHEV charging load is actively managed, the same amount of energy can be delivered to each PHEV without exceeding the native load's peak demand, thus not requiring additional new power plants to meet peak loads. It is important to start this active load management when the commercial sales of PHEVs first begin so that vehicle owners understand that management of PHEV charging is part of the deal of purchasing these vehicles.

A major reason for a Northwest Pilot Project is to explore the ways in which this load can be managed. If managed properly, the load might look as follows:



Electric utilities need to prepare for the mobile customer driving PHEVs. Mobile customers have different needs than static customers. Utilities will need to allow PHEVs to plug in anywhere: at home, at work, when shopping, and when visiting friends and family whether they are across town, across the state, or across the nation.
