SENTECH, INC.

Plug-In Hybrid Electric Vehicle Value Proposition Study

White Paper for Oak Ridge National Laboratory's PHEV Value Proposition Dec 07 Workshop

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WHITE PAPER FOR ORNL'S PHEV VALUE PROPOSITION WORKSHOP

OVERVIEW

Plug-In Hybrid Electric Vehicles (PHEVs) have gained interest over the past decade for several reasons, including their high fuel economy, convenient low-cost recharging capabilities, potential environmental benefits and reduced use of petroleum, contributing to President Bush's goal of a 20% reduction in gasoline use in ten years, or "Twenty in Ten." PHEVs have also been suggested as a technology to improve the reliability and efficiency of the electric power grid. However, PHEVs will likely cost significantly more to purchase than conventional or other hybrid vehicles, in large part because of the cost of batteries. In spite of the potential savings to the consumer and value to other stakeholders in the long run, the initial PHEV cost presents a major market barrier to their widespread commercialization.

On December 11-12 in Washington, D.C., the Oak Ridge National Laboratory (ORNL) is ***hosting a workshop to brainstorm potential business models*** that will lead to PHEVs that are competitive with conventional drive vehicles by reducing consumer costs and/or increasing consumer value. This workshop is the initial phase of an in-depth study by ORNL, SENTECH, Inc, General Electric, and Electric Power Research Institute to identify the benefits, barriers, opportunities, and challenges of grid-connected PHEVs. The "value propositions" to be determined at this workshop could consist of ways to operate (charge and discharge) PHEVs, capabilities or functions of the PHEVs, different methods for financing or leasing PHEVs or their batteries, and types of recognition or non-monetary incentives that would be valued by PHEV owners (such as access to HOV carpool lanes). Are there capabilities or value propositions that may be combined into a new business model for PHEVs that will establish a sustainable market that can thrive without the aid of Federal incentives or subsidies?

This workshop is anticipated to be highly interactive, and ***each participant is encouraged to bring his/her knowledge on PHEVs*** to help optimize takeaways from the breakout sessions. Workshop participants will include project team members, a broad group of other stakeholders, and a Guidance & Evaluation Committee. This Guidance Committee is composed of representatives from various stakeholder organizations, including executives and entrepreneurs from the automotive manufacturing and retail, energy storage, utility, and finance arenas. A complete list of Committee members along with the workshop agenda, logistical information, registration details, and reference materials can be found at www.sentech.org/phev.

WHAT IS A PHEV?

Like conventional hybrids, PHEVs contain both an electric motor and a conventional gasoline motor. However, PHEVs have much larger battery packs that can be recharged by plugging into a standard power outlet. Currently, PHEVs are envisioned to have 10 miles' to 40 miles' worth of additional stored electricity compared to conventional hybrids. When the stored power is depleted, the vehicle will revert back to conventional hybrid mode until recharged. Since the average driver only commutes a little over 30 miles a day, the capability to store this much electrical charge is expected to dramatically reduce visits to the gas station. In some areas of the country, charging with electricity from the grid during off-peak hours would be equivalent to roughly $0.70-0.80/gallon gasoline.

Increased fuel efficiency is the most important of the anticipated benefits associated with the introduction of PHEVs; this reduced need for gasoline would reduce our Nation's petroleum dependence and thus improve national security. There are, however, other significant benefits. With PHEVs expected to emit approximately 30% less pollutants than conventional cars, greenhouse gases and local air emissions would be reduced significantly. The carbon emissions would be especially lowered if some of the electricity for recharging were generated via renewable sources, such as hydroelectric or wind power. If recharging mostly occurs at night, utilities would benefit from off-peak sales using their most efficient and lowest cost generation or generators fueled by renewable energy sources. PHEVs could also be used as a source of distributed or emergency power, acting as a local generator to keep homes and businesses up and running when the conventional power grid is unable to or when it is too costly to rely on central station power.

Some basic operational and business models for PHEVs are described below. There could be multiple value propositions that derive from these or other models.

Unidirectional Electricity Flow

In this model, power is supplied strictly from the grid to the PHEV. This means that the power system is used to charge the PHEVs, but the PHEVs are never called upon to provide power to other facilities or to support the grid. The PHEV may be charged only at night, or it might be charged whenever the marginal cost of electricity is low enough to be price-competitive with gasoline usage when the vehicle is in conventional hybrid mode (i.e., additional low variable cost electric generator capacity is available). If the utility is given some control of the charging time and power level, it can use this interruptible load as reserves in case of emergency.

Bidirectional Electricity Flow

The "vehicle-to-grid" (V2G) model allows for sharing of energy between PHEVs and a utility. PHEVs can supply stored power back to the grid to help balance the load to prevent overloads on power distribution equipment or simply sell power to the utility whenever the utility may be willing to pay a premium price for it. The assumption is that the PHEVs would then be recharged during off-peak hours at cheaper rates while helping to absorb otherwise unused generation capacity at night. Net power usage by individual vehicles could be tracked by Advanced Metering Infrastructure, one of the technologies of the "Smart Grid."

A second alternative within bidirectional flow is the "vehicle-to-building" model. In this model, the PHEV's stored energy may be used as emergency power for the home owner or sold to a facility during a grid power outage.

A third alternative within bidirectional flow is the ancillary services model. The electric grid requires other products for its reliable operation besides just energy; reactive power and spinning reserves are just two of the services that PHEVs may supply. In this model, the PHEV is requested to provide these services to the utility through one or several advanced communication networks.

Battery leasing or ownership by a third party

Frequent deep cycle discharges in V2G operating mode may shorten battery lifetime. While the utility would pay a premium for emergency power supplied to it by a PHEV, the hidden "costs" to the vehicle owner may still make the transaction inequitable. One possible financial solution would be to have the utility or a third party own the battery and lease it to the vehicle owner. This may address concerns about battery maintenance cost and life by the car-buying public. It may also enable bulk battery purchasing that would lower battery costs and better manage battery disposal and recycling. Since the entire power grid would benefit from accessing the PHEVs as a resource, incorporating PHEV batteries in the utility's base rate would spread the costs among all utility customers, decreasing the premium an individual PHEV buyer would have to pay.

Alternatively, the utility could take possession of the batteries once they have completed their useful life within the vehicle. The batteries may still have useful capacity as a stationary source and utilities (or third parties) could use them in battery banks for peaking capacity.

WHAT IS A VALUE PROPOSITION?

The first step in evaluating a "value proposition" is to define and specify it. A value proposition offers additional benefits which will ultimately cause the consumer to see PHEVs as multi-functional products that provide value (monetary or non-monetary), making PHEVs more competitive with other vehicles on the market. This additional value could be accrued by the electric utility, the vehicle owner, or a third party. Value propositions consist of three primary elements:

1. The type of entity providing the value (e.g., government agencies, utilities, car makers),
2. The nature of the deal (monetary and non-monetary) being offered (e.g., direct payments, special features, special privileges, financing assistance), and
3. A resulting tangible benefit to the consumer.

Below are three examples of a value proposition:

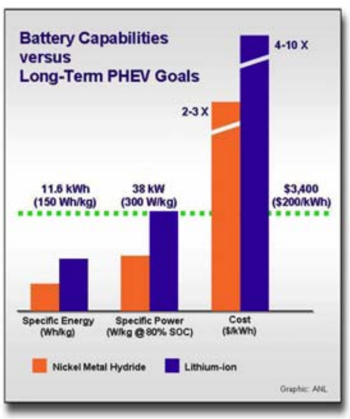
> **Value Proposition**: *With permission from PHEV owners, the utility can draw on some of the energy stored in the PHEV batteries for load leveling, congestion relief, other ancillary services or as an emergency power source. In return, the utility will pay premium rates for the energy used.*
>
> 1. Type of entity providing value: *Utility*
> 2. The nature of the deal being offered: *Electricity at strategic points in time to the utility and direct payments to PHEV owners, reflected in utility service contracts to the consumer*
> 3. A tangible benefit to the consumer: *Reduced peak loads to utility prevent rate increases, and the utility makes premium payments for electricity to the PHEV owner.*
>
> **Value Proposition**: *PHEV owners can have access to High Occupancy Vehicle (HOV) Lanes.*
>
> 1. Type of entity providing value: *Government agency*
> 2. The nature of the deal being offered: *Special Privileges*
> 3. A tangible benefit to the consumer: *HOV access for single occupancy vehicles.*
>
> **Value Proposition**: *A financial corporation owns the batteries and leases them to PHEV owners.*
>
> 1. Type of entity providing value: *Financial corporation*
> 2. The nature of the deal being offered: *Financing assistance and management of battery recycle/reuse.*
> 3. A tangible benefit to the consumer: *PHEV owners experience reduced initial cost for PHEV and less uncertainty about battery maintenance costs.*

Feedback from workshop participants will be used to develop a broad list of potential business models. In addition to enumerating the potential value propositions, the workshop will establish a framework for continuing dialogue, where the project team will seek input from the workshop participants on:

- Metrics to be used to evaluate the value propositions.
- Data and modeling procedures to be used for evaluation.
- Identification to whom benefits would accrue and the nature of those benefits.
- Regulatory, organizational, or physical prerequisites (e.g., power system interconnection infrastructure) needed to realize each value proposition as well as technical or other barriers that must be overcome.
- Market segments most likely to respond to each value proposition.
- What incentives are recommended for market introduction of this value proposition
- Suggestions on which options or scenarios would be most likely to foster a sustainable PHEV market.

WHY ARE VALUE PROPOSITIONS NEEDED?

The Office of Energy Efficiency and Renewable Energy has established a success indicator that, "By 2020, vehicles are available that double fuel economy at an incremental cost that is paid back within three years through fuel cost savings."[1] PHEVs are capable of achieving double the fuel economy; however, in the near term, the cost premium of a PHEV will likely exceed the fuel saved over a reasonable ownership period for the average driver. For example, current high energy lithium batteries most likely to be used in PHEVs offer an electric range up to ~25 miles but add $9,000-15,000 to current hybrid vehicle prices. To lower these initial costs, the Office has set long term R&D goals for specific PHEV components, including battery capabilities and power electronics & electric motors (PEEM) systems demonstrated in the Figures 1 and 2 below. Based on these targets, a 50 kW PEEM system would cost $1,650. Combined with a $3,400 battery system, the PHEV components will add over $5,000 to the cost of the vehicle. Even at $3.00/gallon for gasoline, the vehicle would have to save nearly 1,700 gallons of fuel to recover the component cost.



PEEM Development Targets (FreedomCAR program)

		2010	2015	2020
***Integrated Electric Propulsion System** (Motor and Power Electronics Inverter/Controller)*				
Requirements	Peak Power (18 seconds), kW	55	55	55
	Continuous Power, kW	30	30	30
	Life, years	15	15	15
Targets	Spec. Power at Peak Load, kW/kg	>1.06	>1.2	>1.4
	Vol. Power Density, kW/L	>2.60	>3.5	>4.0
	Cost, $/kW	<19	<12	<8
Desired	Coolant Temperature, °C	90	105	105
	Efficiency (10-100% speed, 30% torque)	>90	>93	>94
***Vehicle Power Management** (Bidirectional DC/DC Converter)*				
Targets	Spec. Power at Peak Load, kW/kg	0.8	>1.0	>1.2
	Vol. Power Density, kW/l	1.0	>2.0	>3.0
	Cost, $/kW	<75	<50	<25
Desired	Coolant Temperature, °C	90	105	105
	Efficiency (10% to 100% speed, FTP)	92	95	96

Figures 1-2: FreedomCAR PHEV components goals for battery capabilities (left) and PEEM systems (right).

Once these goals have been reached, PHEVs may still need to provide more value than fuel savings alone to achieve commercial viability. This study will determine how much (if any) added value of PHEVs is desired by the vehicle owner, utility, building (facility) owner, energy services company or load aggregator, and/or local or national government.

NEXT STEPS

Selection and Evaluation of Value Propositions

Potential business models collected at the workshop will be prioritized, and the highest priority model will be evaluated in Phase 1 of the study; the second and third

[1] Department of Energy, *Office of Energy Efficiency and Renewable Energy Strategic Plan.* 2002. http://www.nrel.gov/docs/fy03osti/32988.pdf.

highest priority models will be evaluated in Phase 2. Prior to evaluation, case study locations for each of the three business models will be selected, including the utility system (or subsystem), PHEV market segment, and facilities/buildings.

Determination of Data, Models and Analysis Procedures

The data, models and analysis procedures required to evaluate each of the three highest priority potential business models will be determined. This may involve modifications to existing battery, vehicle, facility, utility, or energy sector models to perform the analyses and establish relationships between costs and value to the respective owners.

To realize the full potential benefits of PHEVs, the vehicle must not only achieve certain cost and performance targets; the necessary grid interconnect infrastructure, institutional incentives or roles, and business opportunities, and tax or other regulatory incentives may also have to be put in place. These cost, organizational, or regulatory requirements must be identified for each candidate value proposition.

The selected business models must address the power system of 2020 and beyond, when it is presumed that a significant PHEV fleet exists. For example, the value of PHEVs to the electric grid must be evaluated in terms of the generation mix and the targeted PHEV fleet of 2020 – not today's. Nevertheless, the strategy to get there must postulate an evolution of technical, economic, business and regulatory developments that will result in a PHEV fleet-compatible electric grid in the future.

Barrier Identification

Technical, regulatory, or economic requirements and any barriers that must be overcome to achieve market success will also be identified for economically attractive PHEV business cases. A qualitative risk/benefit assessment of the technical barriers and research required to achieve the conditions required for the positive value added will provide guidance to DOE on the best strategies to overcome such barriers, the likelihood of success, and stakeholder-specific risks and benefits of such barrier-mitigation activities.

Application to National and Regional Assessments

Analysis of the case studies, load profile changes, and utilization of generating capacity will provide key indicators of what local/regional characteristics or parameters determine the viability of specific business models. A culminating report that parameterizes these results will be delivered to DOE, who may use its input to refine ongoing national or regional PHEV assessments.