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PHEV Market Introduction Study

Pre-Workshop Discussion Paper

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1. INTRODUCTION

The Oak Ridge National Laboratory (ORNL) and Sentech, Inc., are conducting a Market Introduction Study to identify action items that are critical to creating and sustaining a market for plug-in hybrid electric vehicles (PHEVs). Supportive policies, regulations, and temporary incentives are likely to be key enablers for a successful market debut. The study will identify candidate actions to foster the PHEV market and assess their impact. Also, possible pinch points during market growth will be identified. Results will be used to recommend an action plan aimed at successfully transitioning what has begun as a grassroots industry into a thriving market by 2030.

The first milestone in this study is a private workshop, jointly facilitated by Energetics, Inc. and Sentech, Inc., to be held in Washington, D.C., on December 1-2, 2008. The objective of this workshop is to discuss and expand upon the preliminary findings outlined in this discussion paper, including:

- Actions (e.g., policies, incentives and regulations) taken in support of preceding alternative fuel vehicles (AFVs) during their market introductions;
- Preliminary efforts taken thus far in support of light-duty PHEVs;
- Potential supply chain and infrastructure pinch points that may emerge while ramping up PHEV production;
- Future actions that may be taken in support of PHEVs to boost this nascent market; and
- Anticipated effectiveness of these potential actions.

It is presumed that Federal R&D will be underway between now and 2030 to help move the industry forward from a technical perspective. This paper is designed to stimulate discussion among workshop participants and provide a platform for brainstorming and prioritizing of potential policies, incentives, regulations or marketing strategies that may accelerate the initial market growth and commercialization of PHEVs. After the workshop, the results will be input into a consumer preference model developed at ORNL to assess the probable effectiveness of candidate market introduction strategies. Results may also be analyzed by consumer preference models developed at the University of Michigan Transportation Research Institute (UMTRI), with support from analysts at the Pacific Northwest National Laboratory (PNNL).

Representatives from varied stakeholder organizations have been invited to participate in the workshop to share their expertise on various aspects of the emerging PHEV market. Among those in attendance will be members of the Guidance & Evaluation Committee, comprised of executives and entrepreneurs from the automotive, energy storage, utility and regulatory arenas. Select policy experts, government officials, university professors, and national laboratory researchers have also been invited to attend.

2. SUPPORTIVE ACTIONS FOR PRECEDING AFVS

A broad range of policies, regulations, and incentives have been proposed and implemented in recent decades to enhance the introduction and sustainability of AFVs and their associated fuels as they emerged into the market. Such actions include various tax credits, rebates, fuel and fleet mandates, non-monetary perks and more. This section highlights many of these efforts, broken down into Federal, state/local or private initiatives.

A. FEDERAL

Alternative Motor Vehicle Tax Credit

- Summary: A tax credit is available for individuals and businesses that purchase new advanced cars and trucks that meet the specifications defined below. The tax credits range from $400 to $4,000, depending on fuel economy and vehicle weight.
- Eligibility: Applicable to qualifying advanced lean burn technology vehicles and hybrid vehicles described below.
- Status: Full tax credit is available for vehicles purchased on or after January 1, 2006 through December 31, 2010, or until a credit enters the one year phase out period.
- Origin: Energy Policy Act of 2005, Section 1341; replaced the Clean Fuel Tax Credit, which expired December 31, 2005.

a. Advanced Lean Burn Technology Vehicle Credit

- Eligibility: Vehicles with an internal combustion engine (ICE), using direct injection, that are designed to use more air than necessary for complete fuel combustion (e.g., clean diesel engines). Certain additional requirements must also be met.
- Status: This credit went into effect on January 3, 2006, and is subject to a one year phase out after the U.S. vehicle manufacturer (or U.S. distributor if a foreign vehicle manufacturer) reaches 60,000 vehicles sold after 2005.
- Source: Reference 26 U.S. Code 30B

b. Hybrid Vehicle Credit

- Eligibility: Vehicles that draw propulsion energy from energy stored onboard in the form of 1) an ICE or heat engine that uses consumable fuel and 2) a rechargeable energy storage system. Certain additional requirements must also be met.
- Status: This credit went into effect on January 3, 2006, and is subject to a one year phase out after the U.S. vehicle manufacturer (or U.S. distributor if a foreign vehicle manufacturer) reaches 60,000 qualified hybrid vehicles (weighing 8,500 lbs or less and sold after 2005).
- Source: Reference 26 U.S. Code 30B

- **Qualified Alternative Fuel Motor Vehicle Tax Credit**
  - Summary: An income tax credit of up to $4,000 is available to qualifying AFVs. These vehicles may be new original equipment manufacturer (OEM) vehicles or vehicles that have been converted by aftermarket companies to operate on alternative fuels.
  - Eligibility: Vehicles that are fueled completely by compressed natural gas, liquefied natural gas, liquefied petroleum gas, hydrogen, fuel comprised of at least 85 percent methanol, or a mixture of one of these fuels with a petroleum-based fuel. Certain additional requirements must also be met.
  - Status: Applicable to AFVs purchased or placed into service between January 1, 2006 and December 31, 2010.
  - Source: Reference 26 U.S. Code 30B

- **Fuel Cell Motor Vehicle Credit**
  - Summary: Tax credit of up to $8,000. A similar tax credit is available to medium- and heavy-duty fuel cell vehicles, based on the vehicle weight.
  - Eligibility: Vehicles that run via energy created in at least one cell by directly converting chemical energy to electricity (combination of oxygen with hydrogen fuel). Certain additional requirements must also be met.
  - Status: Credit went into effect on January 3, 2006 and expires December 31, 2014; after December 31, 2009, the tax credit decreases to $4,000.
  - Source: Reference 26 U.S. Code 30B

- **Alternative Fuel Infrastructure Tax Credit**
  - Summary: A business tax credit of up to $30,000 is available to cover 30 percent of the cost to install alternative fueling equipment. A residential tax credit of $1,000 is available to buyers of residential refueling equipment.
  - Eligibility: Infrastructure required for natural gas, liquefied petroleum gas, hydrogen, electricity, E85 or diesel fuel blends with a minimum of 20 percent biodiesel. Purchases put into service after December 31, 2005, are eligible.
  - Status: Went into effect January 1, 2006 and will expire December 31, 2010 (infrastructure purchases for hydrogen expire in 2014).
  - Origin: Amended in the Energy Improvement and Extension Act of 2008; previously updated the Energy Policy Act of 2005, Section 1342, which replaced the Tax Deduction Timeline for the refueling property tax deduction found in the Working Families Tax Relief Act of 2004.

- **AFV Fleet Requirements**
  - Summary: In January 2007, President Bush announced the following AFV fleet requirements in an attempt to reduce the consumption of imported oil. This order also has the objective of increasing the markets for AFVs, alternative fuels and alternative fuel infrastructure.
  - Eligibility: Federal government agencies that operate a fleet of twenty or more motor vehicles must (relative to the fleet's fiscal year 2005 baseline):
    - Reduce the fleet's total consumption of petroleum products by 2 percent annually through the end of fiscal year 2015,

- Increase the total fuel consumption that is non-petroleum-based by 10 percent annually, and
- Use PHEVs once commercially available at a cost reasonably comparable, on the basis of life-cycle cost, to non-PHEVs.

- Status: Agencies are beginning to assess how to meet requirements of the order.
- Origin: Executive Order 13423 "Strengthening Federal Environmental, Energy and Transportation Management"

Hybrid High-Occupancy Vehicle (HOV) Waiver

- Summary: A waiver was passed allowing states to open HOV lanes to certified hybrid vehicles.
- Eligibility: Hybrid vehicles with a U.S. Environmental Protection Agency rating of at least 45 mpg or hybrid vehicles with at least a 50 percent increase in fuel efficiency in the city and a 25 percent increase in fuel efficiency (combined city/highway miles) relative to the non-hybrid model.
- Status: Signed into law on August 8, 2006 and is currently set to expire on September 30, 2009.
- Origin: 2005 Transportation Equity Act and SAFETEA-LU provision.

Volumetric Biodiesel and Ethanol Excise Tax Credit

- Summary: Biodiesel and ethanol producers can receive a tax credit based on volume of fuel sold.
- Eligibility: Producers of waste-grease biodiesel are eligible for a $0.50 per gallon credit (or $0.005 for each percentage point if mixed with other fuel(s)). Producers of agribiodiesel (including biodiesel created from biomass) are eligible for a $1.00 per gallon credit (or $0.01 for each percentage point if mixed with other fuel(s)). Producers of ethanol are eligible for a $0.51 per gallon credit of ethanol of 190 proof or higher (or $0.0051 for each percentage point if mixed with other fuel(s)).
- Status: This credit is available through December 31, 2009.
- Origin: Originally established in the American Jobs Creation Act of 2004 (Public Law 108-357); biodiesel credit extended in Energy Policy Act of 2005, Section 1344 and again in the Energy Improvement and Extension Act of 2008.

Small Agribiodiesel Producer Tax Credit

- Summary: A tax credit of $0.10 per gallon of agribiodiesel is available to small agribiodiesel producers.
- Eligibility: Agribiodiesel producers that make less than 60 million gallons annually are eligible for this credit.
- Status: This credit is applicable for the first 15 million gallons produced annually through December 31, 2009.
- Origin: Originally established in the Energy Policy Act of 2005, Section 1345; extended in the Energy Improvement and Extension Act of 2008.

- **Renewable Diesel Tax Credit**
  - Summary: The biodiesel tax credit has been broadened to include renewable diesel fuel created from biomass regardless of process used. A credit of $1.00 per gallon is available for renewable diesel. A $0.50 per gallon tax credit for diesel fuel created by co-processing biomass with additional feedstocks, such as petroleum, is also available.
  - Eligibility: Renewable diesel must be used for residential heating oil or for vehicle or aviation jet fuel.
  - Status: Credit is applicable to fuel sold or used after December 31, 2005; no longer applicable to biodiesel imported or sold for export after May 15, 2008.
  - Origin: Energy Policy Act of 2005, 1346

- **Renewable Fuels Standard (RFS)**
  - Summary: The RFS requires gasoline sold by refiners, importers and blenders to include an increasing volume of renewable fuel (e.g., biodiesel, ethanol).
  - Eligibility: Refiners, importers and blenders that sell gasoline in the U.S.
  - Requirements: Increases from 9 billion gallons in 2008 and to 36 billion gallons in 2022.
  - Origin: Originally established in the Energy Policy Act of 2005; amended in the Energy Independence and Security Act of 2007 (H.R. 6).

B. STATE/LOCAL

- **HOV Lane Access**
  - Summary: Multiple states allow hybrid electric vehicles (HEVs) to drive in HOV lanes regardless of the number of passengers.
  - States: AZ, CA, CO, FL, GA, NJ, NY, TN, UT, VA
  - Example: In California, HEVs with at least 45 mpg fuel economy that meet SULEV regulations can receive a California Clean Air Vehicle decal, allowing them to use the HOV lanes regardless of number of passengers. The Toyota Prius, Honda Insight and Honda Civic hybrid are eligible for the decal in the state.

- **Emission Testing Exemption**
  - Summary: Electric vehicles (EVs) and HEVs are exempt from emission testing in multiple states.
  - States: ID, CO, MD, NV, NY, WA
  - Example: EVs and HEVs are exempt from the vehicle emission inspection and maintenance program.

- **Parking Fee Exemptions or Discounts**
  - Summary: Many cities offer free or discounted parking to HEVs and/or zero emission vehicles (ZEVs) that meet certain requirements.
  - Cities: San Jose, Los Angeles, and Port of San Diego, CA; Aspen and Manitou Springs, CO; New Haven, CT; Miami Beach, FL; Baltimore, MD; Ferndale, MI;

Bozeman Public Library, MT; Albuquerque, NM, Westchester and Huntington, NY; Austin and San Antonio, TX; Salt Lake City, UT.

- Example: The city of Los Angeles, CA, allows Toyota Prius, Honda Civic hybrids, Honda Insight and Ford Escape hybrid and hybrid vehicles with a California Clean Air Vehicle decal to park in any metered parking space for free.

Incremental Cost Rebate

- Summary: Many state programs will offer a rebate to cover a certain percentage of the incremental cost of purchasing an AFV or to convert a vehicle to operate on specified alternative fuels. A maximum rebate amount is typically established.
- States: IL, PA
- Example: The Illinois Alternative Fuels Rebate Program provides rebates for 80 percent of the incremental cost for activities listed above (HEVs not included).

Business and Residential Energy Tax Credits

- Summary: Oregon offers business and individual tax credits to purchasers of HEVs or dual fuel vehicles.
- States: OR
- Example: Oregon offers a Business Tax Credit of 35 percent of the incremental cost of the system or equipment over a five year period to HEV or dual fuel vehicle owners. Oregon also offers a Residential Tax Credit of up to $1,500 for the purchase of or $750 for the conversion to an HEV or dual fuel vehicle.

Motor Vehicle Excise Tax Credit or Reimbursement Grant

- Summary: Cities and states may provide a tax credit or reimbursement grant to cover all or part of an AFV's excise tax.
- States: DC, MD, MA, NM, WA
- Example: Washington, D.C., has a "Hummer/Hybrid" Tax, which exempts HEVs and other AFV owners from paying their vehicle excise tax while increasing the regular excise tax rates for heavy passenger vehicles (exceeding 5,000 pounds) from 7 percent to 8 percent.

License Registration Rebate and Reduced Annual Vehicle License Tax

- Summary: Some states or cities offer rebates or reductions on vehicle license registration fees or annual vehicle license taxes to HEV owners.
- States/Cities: Aspen, CO; Frankfort and Wilmette, IL
- Example: Aspen, Colorado, offers a $100 rebate on vehicle license registration to HEV owners.

Sales Tax Exemption, Reduction or Rebate

- Summary: Purchasers of HEVs benefit from sales tax exemption, reduction or credit in some states.
- States: CT, SC, WA
- Example: In Connecticut, purchasers of HEVs with fuel economy above 40 mpg were exempt from the state's 6 percent sales tax through 10/1/08.

- **Vehicle Purchase Rebate**
  - Summary: Some cities and states have set aside funding to provide direct rebates to AFV purchasers.
  - States: CA; CO; IL; PA; City of Parkland, FL
  - Example: Illinois' new "Green Rewards" program has pledged $2 million in rebates ($1,000 rebate per purchaser) to Illinois residents to help make high-mileage HEVs more affordable.

- **State Income Tax Credit**
  - Summary: Some states offer a state income tax credit for AFV conversions and/or the incremental cost to purchase an AFV.
  - States: CO, LA, MD
  - Example: Louisiana offers a state income tax credit worth 20 percent of the vehicle conversion cost to operate on an alternative fuel or 20 percent of the incremental cost of purchasing an AFV from the OEM.

- **Vehicle Acquisition Requirements**
  - Summary: State agencies and state universities are often required to purchase HEVs for their fleets.
  - States: MN, MS
  - Example: State universities in Mississippi are required to purchase HEVs.

- **State Alternative Fuel Requirements**
  - Summary: Some states require a minimum percentage of alternative or biofuels to be in gasoline sold in state.
  - States**:** CA, FL, HI, IA, LA, MN, MO, MT, OK, OR, WA
  - Example: Hawaii requires 85 percent of its gasoline to contain at least 10 percent ethanol**.**

C. PRIVATE

- **Interest-Free Loans, Leases**
  - Summary: Auto dealers may offer interest-free loans or leases to boost sales.
  - Example: For a limited time, Toyota offered interest free loans for 24 months and three year leases as low as $219 a month on the Prius. Ford dealers in Washington, D.C., and California previously offered five year, zero percent financing on Escape Hybrids (not to be combined with any purchase rebate).

- **Reduced Car Insurance**
  - Summary: Select insurance companies offer discounted rates in many states for HEV owners.
  - Example: Travelers Companies and Farmers Insurance Group offer a 10 percent insurance discount in most states to HEV owners.

- **Hotel Discounts**
  - Summary: Some hotels offer discounted room rates and/or parking for HEVs.
  - Example: The Fairmont Hotel in San Jose offers free parking for HEV drivers.

- **Vehicle Purchase Rebates**
  - Summary: Select auto OEMs offer rebates to purchasers of certain hybrids.
  - Example: Ford offered a rebate package totaling up to $1,000 nationwide for purchasers of the Escape Hybrid (applicable 3/16/06 - 4/6/06).

- **Reduced Parking Costs**
  - Summary: Select parking agencies offer discounts to drivers of certain AFVs.
  - Example: In Oregon, the Oregon Environmental Council and City Center parking partnered to provide HEV owners (35 mpg or higher) a $15 per month discount on monthly parking.

- **Toll Payment Discounts**
  - Summary: Select toll agencies offer discounts to owners of certain AFVs.
  - Example: The Port Authority of New York and New Jersey offers a $2 E-ZPass discount for three hybrid models.

- **Private Purchaser Perks**
  - Summary: Countries may offer a monetary award to early purchasers of certain vehicles to stimulate vehicle sales and use.
  - Example: In Sweden, private purchasers of the Toyota Prius receive SEK 10,000 (~$1,700 USD) after six months of ownership.

- **Congestion Fee Exemption**
  - Summary: Cities outside the U.S. have offered congestion fee exemptions to hybrid vehicles that travel into congested city areas.
  - Example: Hybrid vehicles are exempt from the £8 daily congestion fee in London, England.

- **Corporate Employee Incentives**
  - Summary: Many corporations will offer some sort of incentives (e.g., reimbursements, credits) to promote AFV purchases by employees.
  - Example: Bank of America will reimburse full- and part-time (over 20 hours per week) employees $3,000 if they choose to purchase a new hybrid vehicle.

3. PRELIMINARY ACTIONS THUS FAR IN SUPPORT OF PHEVS

As PHEVs near mass production, government agencies and corporations are beginning to take preliminary measures that will encourage consumers to purchase or lease PHEVs through financial incentives as well as consumer outreach efforts. In some cases, these entities have chosen to jointly launch initiatives that will educate consumers on how to optimize PHEV benefits, such as recharging at night when off-peak rates are available. Below is a sample of early actions taken in support of PHEVs.

- **PHEV Purchase Tax Credits**
  - Summary: A tax credit ranging from $2,500 to $7,500 is available to purchasers of PHEVs (passenger vehicles and light trucks) based on battery size.
  - Type: Federal
  - Status: Full tax credit is available until total number of qualified PHEVs sold in the U.S. exceeds 250,000. After threshold, a phase out period will begin.
  - Source: Energy Improvement and Extension Act of 2008

- **Austin Plug-In Hybrid Incentive Program**
  - Summary: Austin Energy and the City of Austin, Texas, have created a PHEV incentive program that promotes mass production of PHEVs. Local utilities have committed to provide funds that make hybrids more affordable. Local government, businesses and universities have agreed to buy hybrids for fleets.
  - Type: City and private collaboration
  - Status: "Plug-In Austin" was kicked off in August of 2005.
  - Source: Resolution 050301-48 passed by Austin city council on March 3, 2005.

- **South Carolina Hybrid Sales Tax Rebate and Credit**
  - Summary: Purchasers of PHEVs are eligible for sales tax rebates in South Carolina. $300 (phased over five years) is available for in-state purchases or leases of PHEVs, and $500 is available for equipment purchases required to convert an HEV to a PHEV. In addition, a $2,000 tax credit is available for PHEVs (with at least a nine mile all electric range) purchased or leased in between 2007 and 2011. A $200,000 cap exists for this PHEV tax credit.
  - Type: State
  - Status: Applicable to PHEV purchases or leases beginning after June 30, 2008 and ending before June 13, 2013. Bill introduced in Senate on January 9, 2007; Governor vetoed final bill but it was overridden by legislature on June 19, 2007.
  - Source: South Carolina General Assembly, S 243, Section 10, Chapter 63

- **California "Driving Alternatives" Vehicle Rebate Program**
  - Summary: PHEV purchasers or leasers are eligible for vehicle incentive grants of up to $5,000 under California's "Driving Alternatives" vehicle rebate program.
  - Type: State
  - Status: Rebate is applicable for purchasers or leasers of PHEVs between May 24, 2007, and March 31, 2009.
  - Source: California Assembly Bill 1811

4. CRITICAL PINCH POINTS DURING PHEV MARKET INTRODUCTION

One aspect of this study is to identify possible pinch points in which small supply deficiencies could have potentially large effects on the success of the PHEV market. Such pinch points may exist in technology readiness, supply chain insufficiencies, infrastructure development, and attaining necessary workforce. This section highlights several (but not all) potential pinch points that must be addressed to ensure the introduction of PHEVs is as seamless as possible. A significant portion of the workshop will be focused on expanding this list and offering suggestions on how to minimize the potential effects of these constraints.

- **Battery Production**

  Achieving ample production of affordable PHEV batteries may be the single greatest challenge to large-scale commercialization of PHEVs. In order to produce batteries that meet the required levels of durability, quality and safety at a reasonable cost, many facets of the battery industry must continue to mature. These facets include (but are not limited to) technology maturation, supply chain development, increased domestic production, and market readiness.

  From a technology standpoint, PHEV batteries must demonstrate key performance and safety standards. For instance, batteries need to perform for the anticipated lifetime, maintain thermal stability, and tolerate a reasonable level of abuse. To ensure these qualities, increased Federal research and development (R&D) funding for industry, universities, national laboratories and domestic battery manufacturers may be necessary. Beyond the R&D phase, a steady source of raw materials (e.g., lithium) must be identified – a supply that may become strained by the demands of international customers.[*]

  Domestic battery manufacturers must strive to establish a competitive edge and leadership role within the PHEV industry in order to avoid replacing imported oil with imported batteries. To attain this level of leadership in an international marketplace, a sufficient supply of key technology components must be available. Incentives and access to additional capital to make domestic production both appealing and worthwhile to battery manufacturers may also be necessary. Battery manufacturing facilities must reach a level of versatility that enables scaling to rapidly match demand, and modularity to quickly transition between technology generations.

  Finally, an attractive market must exist to encourage consumers to purchase PHEVs that are primarily operated by batteries and that will likely cost more to purchase than competing vehicles. Consumers must be assured that these batteries will be safe, reliable and easy to service. A rapid recharging time, mobile power, eventual vehicle-to-building (V2B) or vehicle-to-grid (V2G) capabilities, and potential recycling credit

[*] DOE's PHEV Value Proposition workshop held in Washington, DC, December 11-12, 2007, identified potential shortages of lithium and limited world-wide battery manufacturing capacity as major impediments to achieving a viable market size for PHEVs.

are characteristics that consumers may also come to expect from their PHEV batteries.

- **Power Electronics and Electric Motors (PE&EM)**
  Similar to batteries, the PE&EM components in early generation PHEVs must demonstrate key performance standards at an affordable cost. PE&EM components must perform for the anticipated vehicle lifetime while maintaining proper operating temperature. Volume and weight reduction of PE&EM components will also likely be needed. Beyond technology improvements, a steady source of raw materials that comprise PE&EM components must be identified to effectively compete with international players.

  For domestic PE&EM manufacturers to become leaders in an international marketplace, a sufficient supply of key technology components must be available. Incentives and access to additional capital to make domestic production both appealing and worthwhile to manufacturers may also be necessary. Manufacturing facilities must also reach a level of versatility that enables scaling to rapidly match demand, and modularity to quickly adapt as more advanced technologies are introduced in PHEVs. High volume automation will need to be integrated into the manufacturing process to efficiently produce sufficient supply.

  Again, consumers must be encouraged to purchase vehicles with PE&EM components that add value to the vehicle but also contribute to increased vehicle purchase price. Proof of safety, reliability and ease of service will be key factors for encouraging consumers to choose vehicles with these components. Incentives or subsidies that help reduce the cost of PE&EM components to consumers may help to boost market introduction.

- **Charging Stations and Locations**
  A critical need for the success of PHEVs is the availability of charging locations for the vehicles. A rough rule of thumb is that one third of households have garages or carports where vehicles could be charged on the owner's property; and a third of households are in apartments or condominiums where parking is available but out of the vehicle owner's control. The remaining one third of households is in locations without assigned or controlled parking available.

  Many businesses have parking available for employees and customers. Similarly, apartment buildings and complexes may have parking for tenants. These businesses may be able to install charging equipment in selected spots in their lots, expanding the number available as needed. Selling electric power may be difficult for businesses because of franchise laws and the transaction costs for what will be relatively small individual sales. Pass-through of the purchases from the utility may solve this, but communications between the charger and utility for billing purposes will be necessary. Providing power to employees or tenants may be easier, with the cost of power absorbed by the company as an employee benefit or built into a periodic parking fee. An added complication may be that many businesses lease their space

from a separate company; the parking lots may be under the control of a separate entity, either the building's landlord or a parking company.

Public charging stations have been available in the past in limited locations. In France, EdF has been active in developing charging stations and has found that a key requirement is to keep it simple. Various companies have developed charging stations that allow customers to use their credit cards or other transaction mechanism to purchase power. Communications are required between the charger and the utility to authorize purchases. Cities may be able to combine the charging station with their parking meters to provide street-level charging. Security and damage-resistance will be key factors for this equipment.

An alternative paradigm for recharging has been the dedicated charging station that could either quick-charge the vehicle's battery or quick-swap the battery with a fully charged one. This may provide a recharge method for those who do not otherwise have access to power or have depleted their batteries while still traveling and wish to refill. In the latter example, this capability is less crucial for PHEVs than for battery electric vehicles because the gasoline engine will still provide PHEV power. There are several hurdles to this method. Rapid swap of batteries will require vehicle designs that allow this and the variability in battery condition may make customers leery of accepting an unfamiliar battery. Rapid recharging will potentially require very high power levels at a station, on the order of megawatts, to reduce the waiting time to an acceptable level. This could require significant stiffening of the distribution system from the utility's substation to the charging station.

Charging technology will need to be standardized so that vehicles will not need different plugs for different locations, and utilities will not need different charger designs for different vehicle brands.

- **Smart Metering Technology / Infrastructure**

Smart meters are not essential to operation of PHEVs; customers could purchase power from standard plugs using current "dumb" rates. However, smart grids allow utilities and customers to maximize their benefits from PHEV technology. The smart grid includes not just smart meters, but a large amount of infrastructure technology that integrates information flow with power flow for decision-making both at the customer and utility level.

Smart meters will be the visible face of the smart grid to customers. They will enable customers to respond to variable prices, optimize their electricity use, and discover inefficient or abnormal equipment operation within their homes. With its discretionary charging schedule, the PHEV will likely be the appliance deriving the largest beneficiary from smart grid technology, but other home equipment will also benefit. However, all of these will need to be able to receive and transmit information on their status to be able to take maximum advantage. Standardized protocols will be needed for communication among appliance, meter, and utility. Steps are being taken to address this issue, but competing technologies may slow over-all acceptance.

Conversely, too-early finalization of protocols can lock in obsolete technologies or limit flexibility for control of chargers or application of V2B or V2G capabilities.

Any utility implementing smart grid technology will need to reconfigure not just its metering system, but most or all of its accounting, billing, and customer information technology. Instead of a single power usage data point per month per customer, utilities will need to monitor and record energy use of multiple circuits (at a minimum, the PHEV charger and the rest of the house) and will need to record kWh consumption by rate period (e.g., peak, shoulder, off-peak times). The costs of the needed equipment, the change in utility procedures, and the regulatory requirements for new price structures will all be large hurdles to utilities seeking to implement a smart grid. This may be most difficult for the thousands of small, publicly-owned utilities across the country: municipals, utility districts, and electric cooperatives.

Since utilities prefer to use multiple sources for commodity equipment such as meters, it will be necessary for meter manufacturers to develop compatible data storage protocols, numbers of electronic "registers" provided, and communications protocols. While Time of Use (TOU) meters generally have achieved that level of interoperability, initial attempts to develop common TOU meter specifications (e.g., the California TOU Meter Specification) were not successful. Metering architecture for PHEVs may need to account for multiple circuits and record demand level and demand response in addition to TOU-consumption characteristics. Past experience introducing TOU meters to the utility industry may be indicative of the difficulties in developing a PHEV metering infrastructure. Conversely, lessons learned from TOU metering may help expedite PHEV metering.

- **Skilled Technicians to Service PHEVs**

  While today's car is a modern marvel of mechanical engineering, tomorrow's car will also be a modern marvel of electrical and electronics engineering. Ideally, a sustainable high-volume PHEV market will be one that is seamlessly integrated with the grid. Accordingly, the auto industry must undertake an ambitious effort to transition toward the manufacturing, sales, and servicing of electronically-powered products. While the transition from HEVs to PHEVs will provide the auto industry with a substantive learning experience, the educational system can accelerate the transition by training increased numbers of electrical engineers and technicians skilled in servicing the batteries and electrical systems that will be introduced in future PHEV powertrain and charging systems.

  In addition to needed manpower, diagnostic equipment specific to PHEV operating systems will be necessary to properly service these vehicles. Technicians and engineers will need to be certified in order to service PHEVs while avoiding any unnecessary issues that could potentially tarnish the public's perception of PHEVs early in the market introduction phase. PHEV repair and service locations will likely also require certification to ensure that protocol is followed.

5. POTENTIAL POLICIES, INCENTIVES AND REGULATIONS FOR PHEVS

The previous chapters have touched on past efforts that have been successfully implemented by government and private entities with the shared goal of boosting market introduction of AFVs, alternative fuels, and alternative fuel infrastructure. While many of these actions may be applicable to PHEVs during their introduction, novel and creative strategies will also likely be necessary given the unique characteristics of PHEVs, such as the unprecedented level of fleet interaction that is anticipated with the grid. Qualitatively, policies, incentives and regulations for PHEVs would ideally:

- Be simple for consumers to use,
- Be easy for entities (Federal, state/local, or private) to administer,
- Offer great enough value to entice consumers to buy PHEVs rather than conventional vehicles,
- Require minimal or no amount of funding to implement (particularly with respect to Federal resources),
- Accelerate the capability of manufacturers (preferably domestic) to produce PHEVs that are competitive without subsidies, and/or
- Cut greenhouse gas emissions and petroleum use.

The primary goal of the workshop is to identify and prioritize policies, incentives and regulations that are applicable to PHEVs. These may include actions that have been applied to preceding AFVs (e.g., various tax credits, HOV lane access, emission testing exemption), but a significant portion of the breakout sessions will be focused on brainstorming new ideas that are unique to PHEVs (e.g., special charging rates, V2G or V2B benefits). Furthermore, initial actions should contribute to reduced reluctance associated with acquiring PHEVs, particularly the initial purchase price premium and uncertainties in the consumer's mind about reliability and servicing/maintenance.

To initiate workshop discussion, a few sample ideas are presented below; these attempt to address the characteristics of effective policies, incentives and regulations listed in the above bullets. Feedback from workshop participants will be used to expand this list.

Electric Utility Leasing of PHEVs

- Summary: Electric utilities – either voluntarily or in response to regulations – would acquire PHEVs. The PHEVs would then be leased by the utilities to customers at a cost competitive to the cost of conventional vehicles. The incremental cost for the PHEV would be paid by the utility. The agreement between the utility and the lessee could be structured such that all or a portion of the fuel cost reduction is returned to the utility. The program could be designed so that the incremental vehicle costs could be included in the utility's rate base. This initiative could get started with one or two pilot programs involving major utilities that have already indicated an interest in PHEVs.
- Eligibility: Electricity customers would be eligible for the lease program. The program could also be set up to give priority for leases to fleet vehicles.
- Advantages: Vehicle lessees (electric utility customers) would not have to pay the incremental PHEV costs, which are expected to be large during the next 10-15

years. The incremental vehicle costs during the early PHEV commercial introduction phase could be added to the utility's rates for electricity, and thus spread across all the utility's electricity customers. The electric utility could also receive carbon credits for the acquisition of PHEVs. With control of the leased vehicles, the utility could establish and implement a protocol to acquire information on characteristics and performance of PHEVs. It could also specify battery recharging times, equipment, etc., in its agreements with those leasing vehicles. Higher productivity of electricity production facilities would benefit all electricity customers and offset the incremental cost of vehicles not covered by lease charges. Energy sold for PHEVs may also have to be exempt from state RPS requirements.

- Disadvantages: Resistance by utilities may exist. Vehicles are not in their mission and not part of their personnel's expertise. Increased costs for electricity by a utility's customers may also be a concern.

Restaurants or Retail Stores Provide Free Charging to Customers

- Summary: Restaurants or retail stores may choose to install charging stations in premium parking spaces as a way to promote business among PHEV and EV drivers. If quick-charging technology is available at these charging stations, PHEVs parked in these spaces will likely be fully recharged by the time customers are ready to leave.
- Eligibility: PHEV or EV drivers that are dining at the restaurant or shopping at retail stores would be allowed to park in these spaces and plug in.
- Advantages: Restaurants and shopping centers are convenient locations to charge PHEVs. This is particularly beneficial to PHEV owners that drive more than the vehicle’s all-electric range or do not have access to a garage at home. In addition, consumers may choose to visit a place of business over a competitor because it offers free charging.
- Disadvantages: The installation cost of charging stations and the operating costs associated with charging PHEVs for free may take a considerable amount of time to turn a profit from restaurant or retail businesses.

PHEV Priority for Available Resources

- Summary: PHEVs could be given priority for existing Federal, state and local resources and support for initiatives. For example, there are technology deployment funds in the U.S. Department of Energy’s (DOE) Energy Efficiency and Renewable Energy budget for promoting alternative fuels and energy-efficient vehicles. Some of these funds support activities of Clean Cities coalitions across the country, which could be more focused on PHEVs. This initiative would not add to the Federal, state or municipal budget requirements beyond those already available for reducing the consumption of conventional transportation fuels. It would, however, direct a larger portion of those funds for the specific support of PHEVs.
- Eligibility: Government funds would be provided to entities based on their proposals, including the degree to which government funds could be leveraged, to advance the commercialization of PHEVs.

- Advantages: Government funds could be efficiently used by involving committed, knowledgeable people and organizations to manage expenditures, create coalitions, provide education and training, etc. A number of Clean Cities coalitions have already joined the Plug-in Partners campaign, are working with electric utilities and others, and are developing in-depth knowledge of PHEVs and their potential. This initiative could require competition for available resources and leveraging of Federal funds by state, local and private expenditures. For example, the state of California, the South Coast Air Quality Management District and Austin Energy have funds dedicated to advancement of PHEVs.
- Disadvantages: By giving priority to PHEVs for the use of taxpayer funds, government organizations would be "picking winners." There would be strong resistance from proponents of other fuel-saving technologies and alternative fuels. Funds currently available for technology deployment are relatively small, unless resources devoted specifically to advancing other technologies/fuels (e.g., ethanol) were instead to be directed for the benefit of PHEVs.

Federal Gas Taxes As a Driver for Actions (including PHEVs) to Reduce Consumption

- Summary: Gasoline could be strategically taxed to maintain its price at some agreed-on minimum level (e.g., $3 per gallon nationwide average). The minimum level could be raised over time. Additional gasoline taxes could be used to pay for tax credits, rebates, and/or other incentives for vehicles/fuels that reduce gasoline use, including PHEVs. Limits on incentive payments using gasoline taxes would be set on the number of vehicles funded, incentive per vehicle, types of vehicles/fuels, and time periods associated with the expenditure of resources from this additional tax. (See value propositions 2a and 2b from the December 11-12, 2007 PHEV Value Proposition Study workshop.)
- Eligibility: Incentives, including for PHEVs, funded by the gasoline tax could accrue to vehicle manufacturers, vehicle customers/users, or possibly others, including vehicle dealers/lessors.
- Advantages: Raising the price of gasoline is the most economically efficient way of reducing its consumption. Putting a floor under the price of gasoline is an efficient mechanism to protect the investments made in alternatives to gasoline use, including alternative fuels and vehicle fuel use efficiency improvements. Significant funds could be generated to support PHEV commercial introduction initiatives, without putting further stress on the Federal budget. The program could be structured to be "revenue-neutral", similar to a "feebate" approach.
- Disadvantages: A gas floor would be considered further government interference in the "marketplace." Any proposal for increasing taxes on gasoline is likely to be completely unacceptable politically. Most elected officials campaigned on reducing gasoline prices, even though higher prices would be more economically "efficient" than regulations and/or acquisition mandates as a means to lower gas consumption.

6. MARKET IMPACT ASSESSMENT METHODOLOGY

Once potential action items from the workshop have been compiled and prioritized, they will be provided to analysts at ORNL to be input into its PHEV consumer choice model. With this model, the project team will be able to evaluate which action items are likely to have the greatest impact on overall PHEV sales nationwide. Workshop data may also be sent to analysts at UMTRI/PNNL to be input into one of its PHEV consumer preference models.

The ORNL PHEV model was developed during a six month project, in response to the need of DOE for analytical tools for evaluating the potential of PHEV technology to contribute to energy security and climate change mitigation. The model simulates competition of PHEVs against several other vehicle technologies, including gasoline and diesel ICE vehicles, HEV, battery EV, and fuel cell vehicles, and projects PHEV sales for a given scenario of oil price, technology advancement, and policy.

ORNL's PHEV model is currently a functioning Excel spreadsheet model of PHEV vehicle choice by light-duty vehicle consumers in the U.S. over the period of 2005 to 2050. Within the model, the U.S. is disaggregated into nine geographic census divisions. Each census division is further disaggregated into three area types – central city, suburban and outside metropolitan statistical areas (MSA). The model considers three consumer types—early adopters, early majority and late majority – and treats cars and light trucks separately.

A large number of factors can potentially affect consumer decisions to choose PHEVs among all available vehicle technologies. The choice of factors to be included in a consumer choice model often comes down to consideration of policy needs, data availability and project resources. In ORNL's PHEV model, the following factors have been incorporated:

- Vehicle attributes
  - purchase price
  - performance
  - fuel economy
  - fuel price
  - vehicle capacity
  - battery cost
  - range
- Range of choice among makes and models
- Value of home refueling
- Availability of refueling infrastructure
- Subsidy and tax credit
- Housing type
- Vehicle and component supply constraint
- Consumer attitudes toward new technology
- Technology learning by doing
- Driving behavior among area types and among census divisions

Additionally, efforts are been made to expand the model to consider the following issues.

- V2G consideration
- Time-of-day electricity prices
- Fleet purchases
- Various monetary and non-monetary incentive policies
- Policy by geographic scope (Federal vs. state)