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The *EV Everywhere* Grand Challenge

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Abstract

In March 2012, President Obama announced the *EV Everywhere* Grand Challenge—to produce plug-in electric vehicles (PEVs) as affordable and convenient for the American family as gasoline-powered vehicles by 2022. The U.S. Department of Energy developed a framing document and conducted a series of public workshops to obtain input on the plan, leading to an *EV Everywhere* Blueprint issued in January 2013. DOE released a funding opportunity announcement for up to $50 million of R&D to support *EV Everywhere* in March 2013. The solicitation sought projects on advanced batteries, electric motors and power electronics for electric drive systems, vehicle lightweighting, climate control technologies, and charging infrastructure. This paper describes the specific technical targets set forth and describes the areas of research to be undertaken to achieve the targets and goals.

Keywords: EV (electric vehicle), PHEV (plug-in hybrid electric vehicle), battery, motor, charging, infrastructure

1 Introduction

The *EV Everywhere* Grand Challenge is a U.S. Department of Energy (DOE) initiative with the goal of enabling U.S. companies to produce plug-in electric vehicles (PEVs) that are as affordable and convenient for the average American family as today's gasoline-powered vehicles within the next 10 years. President Obama announced the *EV Everywhere* Challenge on March 7, 2012 [1]. The goal of the aggressive *EV Everywhere* Grand Challenge is to enable American innovators to rapidly develop and commercialize the next generation of vehicle, component, and charging infrastructure technologies to achieve sufficient PEV cost, range, and charging infrastructure to assure widespread PEV deployment without subsidies. Broad deployment of PEVs will dramatically decrease American dependence on foreign oil, will provide stable and low fuel prices for American families with the convenience of plugging in at home, and will reduce the environmental impact of the transport sector. Achieving the *EV Everywhere* Challenge will also help establish manufacturing the next generation of advanced PEVs and PEV components, creating high paying jobs and stimulating the American economy.

PEVs can offer consumers significant advantages over gasoline-powered vehicles, including savings on fuel costs, added convenience, and reduced maintenance costs. Driving on electricity is cheaper than driving on gasoline – equivalent to less than $1 per gallon of gasoline equivalent – and consumers are able to conveniently fuel up at home. Electric vehicles can also offer the same or better driving performance compared to today's gasoline-powered vehicles. Furthermore, recent analysis by DOE in its inaugural Quadrennial

Technology Review shows that EVs can achieve a dramatic reduction in petroleum energy use and a significant reduction in life-cycle greenhouse gas (GHG) emissions [2]. The initiative is focused on addressing major challenges to widespread deployment of electric drive vehicles [3].

2 Scope

DOE put forward the following initial key parameters for the *EV Everywhere* Challenge:

- A mid-size 5-passenger vehicle
- Majority of vehicle-miles-traveled powered by electricity under standard drive cycles
- Simple payback time of 5 years vs. equivalent gasoline powered vehicle
- “Vehicle range/charging infrastructure” scenarios where the majority of consumers are willing to consider purchasing the PEV as a primary vehicle
- No reduction in grid reliability

While there are many various combinations of vehicle types and infrastructures, for the purpose of setting initial targets, DOE examined in detail three specific “vehicle/infrastructure” scenarios, namely:

1. A plug-in hybrid electric vehicle with a 40-mile all-electric range (PHEV-40) with limited fast-charge infrastructure;
2. An all-electric vehicle with a 100-mile range (AEV-100) with significant intra-city and inter-city fast charge infrastructure; and
3. An all-electric vehicle with a 300-mile range (AEV-300) with significant inter-city fast charge infrastructure.

Each of these framing “vehicle/infrastructure” scenarios would provide a majority of vehicle-miles-traveled powered by electricity, but the vehicle costs and the infrastructure costs (both public charging and home charging) would be quite different in each scenario.

Other key requirements for the *EV Everywhere* Challenge include:

- Secure Materials Supply: Technologies should be based on materials without major supply/availability barriers and risks when deployed at large scale. This is required to meet cost goals, to eliminate foreign material resource dependence, and to ensure large-volume scalability.
- Safety: Technologies/solutions should meet all applicable safety and environmental standards and must meet or exceed Federal Motor Vehicle Safety Standards (FMVSS) and SAE–J2929 Battery Safety Standard [4].
- Recycling: Technologies should also be capable of full recycling. Recycling can provide a financial value and thereby contribute to overall affordability and sustainability, can conserve material resources, and can reduce the costs and environmental concerns of vehicle and component disposal at end of life.
- No Reduction in Grid Reliability: The charging technologies and charging infrastructures considered must be deployable without compromising the reliability of the electric grid and local distribution networks.

3 Considerations for Widespread Consumer Adoption of Plug-In Electric Vehicles

3.1 Where we are today

The 2011 DOE Quadrennial Technology Review concluded that electric drive vehicles (HEVs, PHEVs, and AEVs) offer a significant opportunity to reduce petroleum consumption, lower greenhouse gas emissions, reduce air pollution, and build a competitive U.S. industry within the next decade. Electric drive vehicles in which the majority of miles driven under standard drive cycles can be powered with electricity include plug-in hybrid electric vehicles (PHEVs) and battery-powered all electric vehicles (AEVs).

American automakers and automotive suppliers are currently pioneering the way forward in getting the first wave of electric vehicles into the hands of a significant number of U.S. drivers. But today, the prices of these cars are still out of reach for the majority of American families.

The Tesla Roadster, with a range greater than 200 miles, was the first production automobile to use lithium-ion batteries, and more than 2,000 Tesla Roadsters have been sold since 2008. Tesla utilized a DOE loan to bring the full-sized Model S battery electric sedan to market in 2012. In 2010, GM delivered the first mass-produced PHEV

(Chevrolet Volt) and Nissan delivered the first mass-produced AEV (Nissan Leaf). In addition, PHEV and AEV models have been Ford, Toyota, and many others.

DOE is supporting the establishment of manufacturing capability for batteries and electric drive components through Recovery Act grants. By 2015, manufacturers will have the domestic capacity to produce batteries at a production rate of 500,000 units per year (based on 10 kWh average battery size). DOE is also supporting early adoption of PEVs by conducting technology validation through vehicle testing and data collection, public outreach through the Clean Cities/Clean Fleets programs, and infrastructure development through Recovery Act funded deployment of 13,000 PHEVs and AEVs and 23,000 chargers in more than 20 cities around the country.

3.2 Electric Vehicle Purchase Decisions

Vehicle purchase decisions are the result of many factors. For individual consumers, "identity statements" and style play central roles. Electric vehicle attributes such as instant torque, quiet drive and home recharging may be attractive to many purchasers. At present, there is limited data to evaluate the role of these factors in electric vehicle purchase decisions in the years ahead.

One constraint on electric vehicle adoption is likely to be the additional purchase price associated with battery costs. Reducing those costs will likely speed adoption. Additional amounts paid at purchase will likely be recovered over time, since the cost of driving a vehicle on electricity is often much less than the cost of driving a vehicle on gasoline. As battery costs come down, the "payback period" associated with the additional purchase price of an electric vehicle will likely shorten. At present there is limited data on the impact of shorter payback periods on consumer purchase decisions, but shorter payback periods may also help speed consumer adoption.

With that in mind, the following may be helpful:

- Current hybrid electric vehicles, which use no grid electricity, currently have a payback period of about 2-6 years. DOE estimates that the current payback time for a third-generation mid-size hatchback Prius HEV is 2 years, based on gasoline at $4/gallon, 15,000 annual miles, and a $2,180 price difference between a third-generation Prius hatchback and a comparably equipped Toyota Camry automatic. Similarly, DOE estimates the payback time for a Ford Fusion hybrid, compared to a comparably equipped Ford Fusion SEL 4-cylinder, is 2.4 years using the assumptions above. [5]
- Edmunds compared the mid-sized Leaf priced at $36,050 ($28,550 after including the $7,500 federal tax credit) with the compact gasoline-powered Nissan Versa (priced at $19,656) and calculated a subsidized payback period of 7 years at $4 per gallon. [6]
- U.S. EPA estimates the Nissan Leaf's annual fuel cost at $612 while the Nissan Versa's annual fuel cost is $1,860. (EPA estimates are based on 45% highway and 55% city driving, over 15,000 annual miles; gasoline price of $3.72 per gallon and electricity price of $0.12 per kWh [7].) Thus, the EV's annual fuel saving under these assumptions is $1,248. Under these assumptions, over a five-year period, the fuel savings would offset a purchase price premium, before discounting for present value, of $6,240. Thus, for *EV Everywhere* to achieve a 100-mile EV with affordability comparable to a conventional vehicle, the unsubsidized purchase price would need to be reduced by about $10,000 from $36,050 currently to $25,896 as a first approximation.

3.3 Regulatory and Policy Factors

Regulatory and policy issues can have a large impact, either positive or negative, on the deployment of PEVs. The *EV Everywhere* Challenge will seek to identify and address critical regulatory and policy barriers that affect the rate of deployment of PEVs.

Some of the key policy issues that may impact PEV adoption include:

- Increased CAFE standards for light-duty vehicles through 2025
- Advanced Technology Vehicle Manufacturing (ATVM) loan program
- Manufacturing tax credits (48c)
- Federal and State tax credits for vehicle purchases
- Government fleet EV/PHEV purchases

- HOV lane access and/or preferential parking for PEVs

Some of the key regulatory issues that can impact PEV affordability and convenience include:

- Vehicle and infrastructure safety regulations
- Charging infrastructure permitting
- Standardization of vehicle components for safety and charging
- Standardization of electric vehicle supply equipment (charging standards)

4 Technical Targets

To achieve the *EV Everywhere* Grand Challenge, dramatic advances will be required in batteries, power electronics, motors, lightweight materials and vehicle structures, and fast-charging infrastructure technology.

Affordability and the 5-year payback period identified in the Grand Challenge imply a method for relating up-front vehicle purchase cost and subsequent fuel expenditure during vehicle operation, and, most importantly, the role that technology progress can play in that relationship. Specifically, according to the preliminary Grand Challenge key parameters, the technologies supported through the *EV Everywhere* Grand Challenge should enable sufficient range/rechargeability to eliminate daily PEV driving limitations and must reduce the initial PEV cost such that any incremental cost above today's equivalent gasoline-powered vehicles is more than compensated by fuel savings (using electricity in an PEV is much less costly than using gasoline in a conventional vehicle) over a standard passenger vehicle drive cycle in 5 years or less.

EV Everywhere specifically targets dramatic performance and cost improvements in several platform technology areas: batteries, electric motors, power electronics, light-weight materials and vehicle structures, and fast-charging technologies. A combination of performance improvement and cost reduction across these technologies will result in electric vehicles that satisfy the Challenge of an affordable (5-year payback) and convenient electric vehicle within 10 years. DOE's Vehicle Technologies Program (VTP), with input from U.S. DRIVE industry partners, developed a framework within which one can evaluate the degree to which the portfolio of these technologies must progress—in both performance and cost terms—to satisfy the 5-year *EV Everywhere* payback challenge.

The set of component technology performance and cost assumptions that together yield the 5-year payback period established in this Challenge is the portfolio of technology targets which *EV Everywhere*-supported technologies shall strive to achieve. These values are listed by component technology in the Tables 1 – 4 below.

Table 1: Energy Storage 2022 Targets

		Current Status	Target
Battery Cost	$/kWh usable	500	125
Pack Specific Energy	Wh/kg	80-100	250
Pack Energy Density	Wh/L	200	400
Pack Specific Power	W/kg	500	2000

Table 2: Electric Drive System 2022 Targets

		Current Status	Target
System Cost	$/kW	30	8
Specific Power	kW/kg	1.1	1.4
Power Density	kW/L	2.6	4.0
Peak Efficiency	%	90	94

Table 3: Vehicle Lightweighting 2022 Targets

	Body	Interior	Chassis/ Suspension	Total Vehicle
Weight Reduction	35%	5%	25%	30%

Table 4: Vehicle Charging 2022 Targets

		Current Status	Target
Charger Cost	$/kW	150	35

5 Research Program

DOE released an *EV Everywhere* Grand Challenge Blueprint on January 31, 2013 [5]. This document sets forth the specific targets in five technical areas that are key to achieving the EV Everywhere goals -- batteries, electric drive systems, vehicle lightweighting, climate control technologies, and charging infrastructure. The Blueprint indicates that climate control loads on an EV can double energy consumption, and calls for research in load reduction/management, advanced equipment and cabin pre-conditioning.

The Blueprint also addresses the issues involved in developing charging infrastructure, including siting, permitting, codes and standards, signage and grid integration. It presents the *EV Everywhere* Workplace Charging Challenge [6], an initiative that involves electric vehicle supply equipment manufacturers and installers, charging station hosts, utilities, community planners and local governments, with a goal of increasing the number of employers offering workplace charging by tenfold in five years.

DOE released a Funding Opportunity Announcement [7] in support of the *EV Everywhere* Grand Challenge on March 5, 2013. Up to $50 million of DOE funding is being made available for research projects supporting the *EV Everywhere* Grand Challenge.

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