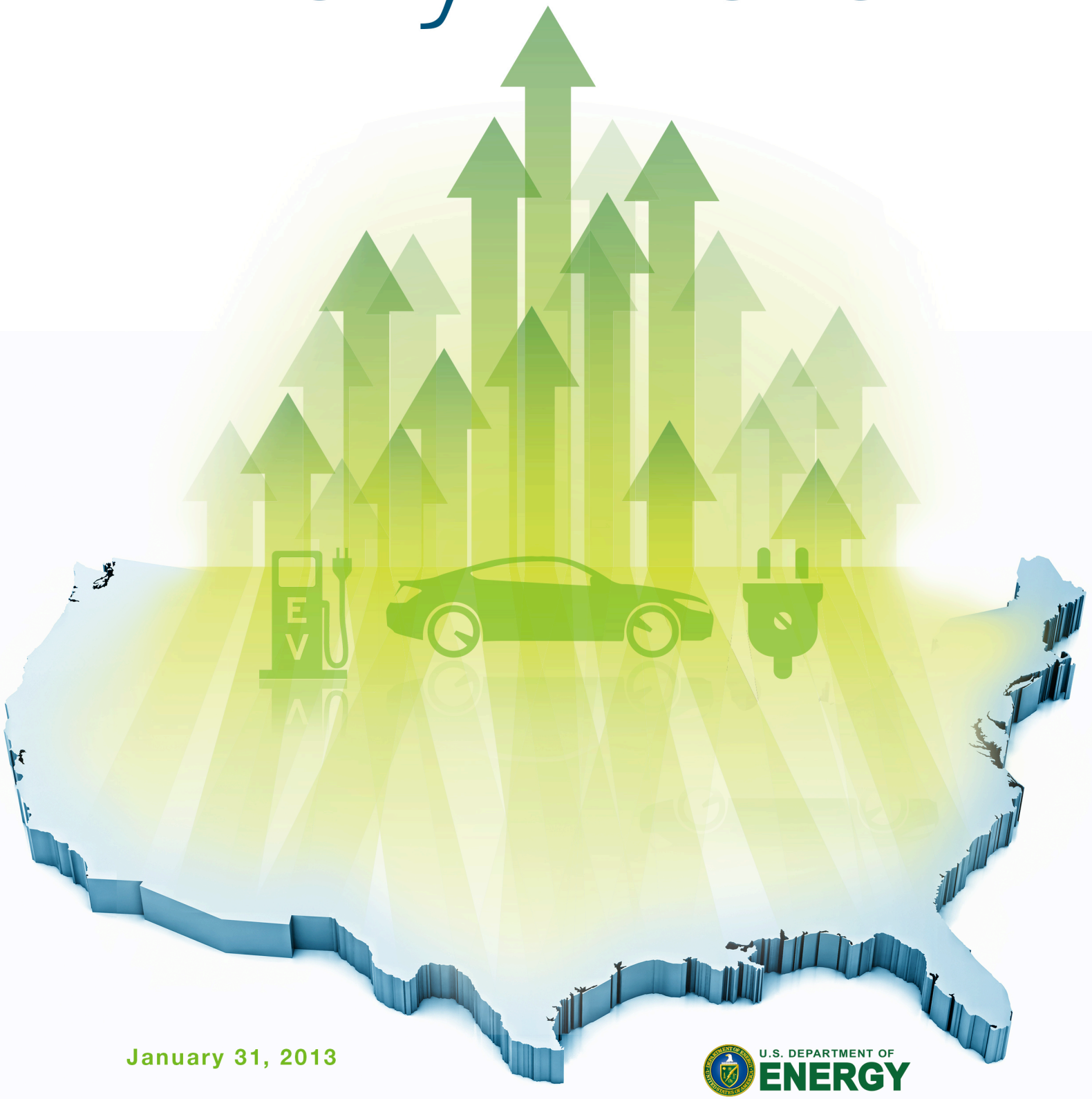
EV Everywhere

grand challenge blueprint



January 31, 2013

U.S. DEPARTMENT OF ENERGY

A Message from the Assistant Secretary

Every challenge presents an even greater opportunity, and the *EV Everywhere Grand Challenge* is no exception. The need for clean energy solutions drives the most important economic development race of the 21st century, providing opportunity for America to invent, manufacture, and export clean energy technologies.

Dr. David T. Danielson
Assistant Secretary for Energy Efficiency and Renewable Energy

Recognizing that vehicle electrification is an essential part of our country's "all-of-the above" energy strategy, President Obama issued the *EV Everywhere Grand Challenge* to the nation in March 2012 with the bold goal to enable plug-in electric vehicles (PEVs) that are as affordable and convenient for the American family as gasoline-powered vehicles by 2022.

I am more convinced now than ever that we can capture this opportunity, and I am committed to making the strategic investments necessary to get there. These investments will: 1) improve the competitive position of U.S. industry and create jobs through American innovation; 2) enhance energy security by reducing our dependence on foreign oil; 3) save money by cutting fuel costs for American families and businesses; and 4) protect our health and safety by mitigating the impact of energy production and use on climate change.

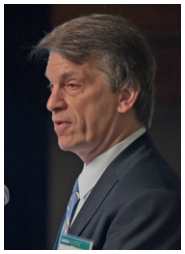
This is not just a DOE effort; this is a nationwide effort. In order to win this Challenge, we must work together. We are agents of change, helping to forge a prosperous future where energy is clean, abundant, reliable, and affordable. DOE will not accomplish these things alone. A task such as this requires partnership among the private sector, the Federal government, Congress, states and communities, national laboratories, universities, nongovernmental organizations, and individual citizens.

In an effort to recruit and inspire America's best and brightest individuals to join us in this Challenge, DOE held a series of workshops across the country—the first, the *EV Everywhere Grand Challenge* Framing Workshop, was followed by others with specific technology focus areas including Electric Drive Components, Batteries, Consumer Acceptance & Charging Infrastructure, and Vehicle Design. These workshops provided important stakeholder input which is reflected in this *EV Everywhere Grand Challenge* Blueprint. This document serves as a "living strategic framework" that will guide DOE's investments in the Challenge going forward. Throughout the document are key findings gained from the workshops, the public comment period, as well as direct comments from workshop participants. We highly value this feedback, and it has been integral to defining the focus and strategies of the *EV Everywhere Grand Challenge* Blueprint.

Dr. Steven Chu

As we move forward, our Challenge is clear—to make the many advantages of electric vehicles affordable for the average American by 2022. By working together as a nation and rising to this *EV Everywhere Grand Challenge*, America can become a global leader in the transition to a clean energy economy.

Secretary Steven Chu has been our leader and guiding force in shaping *EV Everywhere*. David Sandalow, Under Secretary of Energy (Acting) throughout the *EV Everywhere* workshops and a leader on electric vehicle policy for many years, has played a central role in shaping our program. I thank both of them for their tremendous support. In the following pages, you can learn about what has been done so far, our plans for the future and what all of us can do to move our communities and country forward to meet the *EV Everywhere Grand Challenge*.



David Sandalow

Dr. David T. Danielson

Assistant Secretary for Energy Efficiency and Renewable Energy
U.S. Department of Energy

EV Everywhere

Grand Challenge Blueprint

Vision

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. Today, this process is well underway. America is the world's leading market for electric vehicles and is producing some of the most advanced PEVs available today. Consumer excitement and interest in PEVs is growing—PEV sales in the U.S. tripled in 2012, with more than 50,000 cars sold, and a plug-in electric vehicle (the Chevrolet Volt) beat all other vehicle models in *Consumer Reports'* owner satisfaction survey for the second time. PEVs have won critical acclaim with awards such as 2011 World Car of the Year (Nissan Leaf), 2013 *Motor Trend* Car of the Year (Tesla Model S) and 2012 Green Car Vision Award Winner (Ford C-MAX Energi). To maintain this leadership, strong growth in the U.S. PEV sector will need to continue.

President Obama in Mount Holly, NC for the *EV Everywhere Grand Challenge* announcement.

Realizing the promise of PEVs is one of the grand challenges of this era. Today, our transportation system is still dependent on internal combustion engines and oil. In fact, 93% of our transportation fuel is derived from petroleum and much of this is imported.[1] PEVs can decouple personal mobility from oil, cut pollution and help build a 21st Century American automotive industry that will lead the world.

This "Blueprint" provides an outline for the Department of Energy's (DOE) technical and deployment goals for electric vehicles over the next five years. DOE will pursue these targets in cooperation with a host of public and private partners.

The technical targets for the DOE PEV program fall into four areas: battery R&D; electric drive system R&D; vehicle lightweighting; and advanced climate control technologies. Some specific goals include:

- Cutting battery costs from their current $500/kWh to $125/kWh
- Eliminating almost 30% of vehicle weight through lightweighting
- Reducing the cost of electric drive systems from $30/kW to $8/kW

These numbers represent difficult to reach "stretch goals" established in consultation with stakeholders across the industry—including the *EV Everywhere* workshops held during the summer and fall of 2012. When these goals are met, the levelized cost[2] of an all-electric vehicle with a 280-mile range will be comparable to that of an ICE vehicle of similar size. Even before these ambitious goals are met, the levelized cost of most plug-in hybrid electric vehicles —and of all-electric vehicles with shorter ranges (such as 100 miles)— will be comparable to the levelized cost of ICE vehicles of similar size. Although there is little evidence that levelized cost plays an important role in vehicle purchase decisions for most consumers, there is substantial evidence that initial purchase price plays an important role—and meeting

Terminology

Here's a guide to terms and abbreviations in this Blueprint:

- All-electric vehicle (AEV): a vehicle with plug-in capability whose driving energy comes entirely from its battery.
- Plug-in hybrid electric vehicle (PHEV): a vehicle with plug-in capability whose driving energy can come from either its battery or liquid fuel.
- Plug-in electric vehicle (PEV): any vehicle with plug-in capability. (An AEV or a PHEV.)
- Hybrid electric vehicle (HEV): a vehicle without plug-in capability but with an electric drive system and battery, whose driving energy comes only from liquid fuel.
- Internal combustion engine vehicle (ICE): a vehicle whose driving energy comes only from liquid fuel.

[1] http://www.eia.gov/energy_in_brief/article/major_energy_sources_and_users.cfm

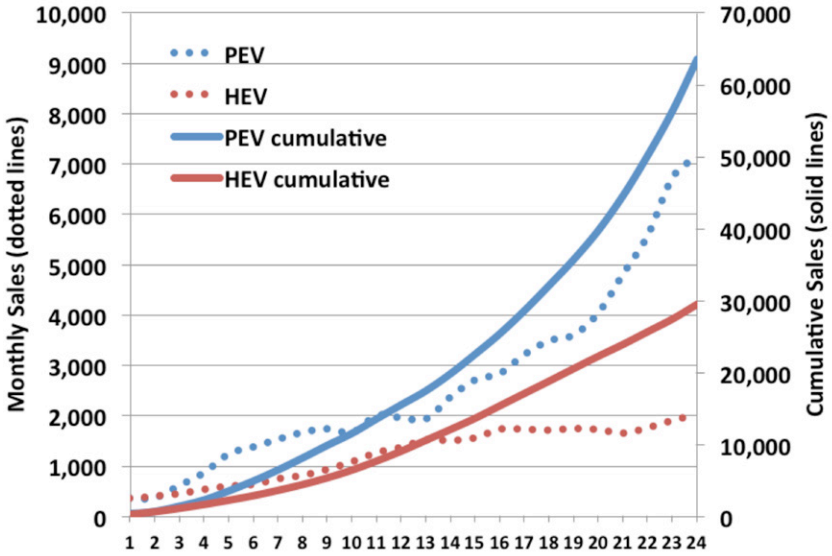
[2] Levelized cost = purchase cost + operating cost

these targets will help to reduce the purchase price for plug-in electric vehicles. In light of uncertainty concerning consumer preferences and manufacturer plans for PEVs, DOE is selecting ambitious technical goals for this program.

The electric-drive vehicle market is growing quickly. Popular PEV models are outselling more than half of all vehicle models in the U.S. PEV sales are climbing more rapidly than sales of hybrid-electric vehicles when HEVs were first introduced roughly a decade ago, as shown in the chart at right.

Individual consumers benefit from PEVs in the form of savings on fuel costs, added convenience, quiet operation, instant torque, responsive performance and reduced maintenance costs. Driving on electricity is cheaper than driving on gasoline—generally comparable to roughly $1 per gallon of gasoline equivalent—and consumers are able to conveniently recharge at home, at public places such as shopping malls and grocery stores, or increasingly, at their workplaces and fast charging locations. However, many drivers and vehicle purchasers are unaware of the benefits of PEVs. Greater awareness of these benefits can play an important role in accelerating PEV deployment. In addition, sales of AEVs may be limited by concerns about becoming stranded without access to a charger when batteries run low (although this is not an issue with PHEVs).

New PEV sales compared to HEV sales over their respective 24 month introductory periods



PEV sales 12/2010 through 11/2012, HEV sales 12/1999 through 11/2001

This document also discusses *EV Everywhere* deployment programs related to charging infrastructure and consumer education. Efforts to promote home, workplace, and public charging can also help speed PEV deployment.

To summarize the *EV Everywhere Grand Challenge* vision, realizing PEVs that meet or exceed the performance of ICE vehicles on the basis of cost, convenience, and consumer satisfaction will require the combined efforts of technological push (R&D), operational enablers (charging infrastructure), and market pull (consumer adoption and incentives).

PEVs have already established a foothold in a world long dominated by gasoline vehicles. As technology

> "We want Americans and politicians to see why EVs are so critical for energy security, the economy, everything. This is the smartest thing this country could ever do."
>
> *— Comment from EV Everywhere Workshop Participant*

> This industry will either succeed together or fail together. Everyone has their own philosophy on winning technologies and business models, but we need to work together.
>
> *— Comment from EV Everywhere Workshop Participant*

Key elements needed to meet the *EV Everywhere* Challenge

improves and production scales, batteries and electric drive systems will become less expensive and better performing. DOE's goal is to work with leaders in the private sector, state and local governments, non-governmental organizations (NGOs), and academia to accelerate these trends.

Framing Workshop Recommendation

- **Maximizing "electric miles driven" should be a key goal for DOE.**

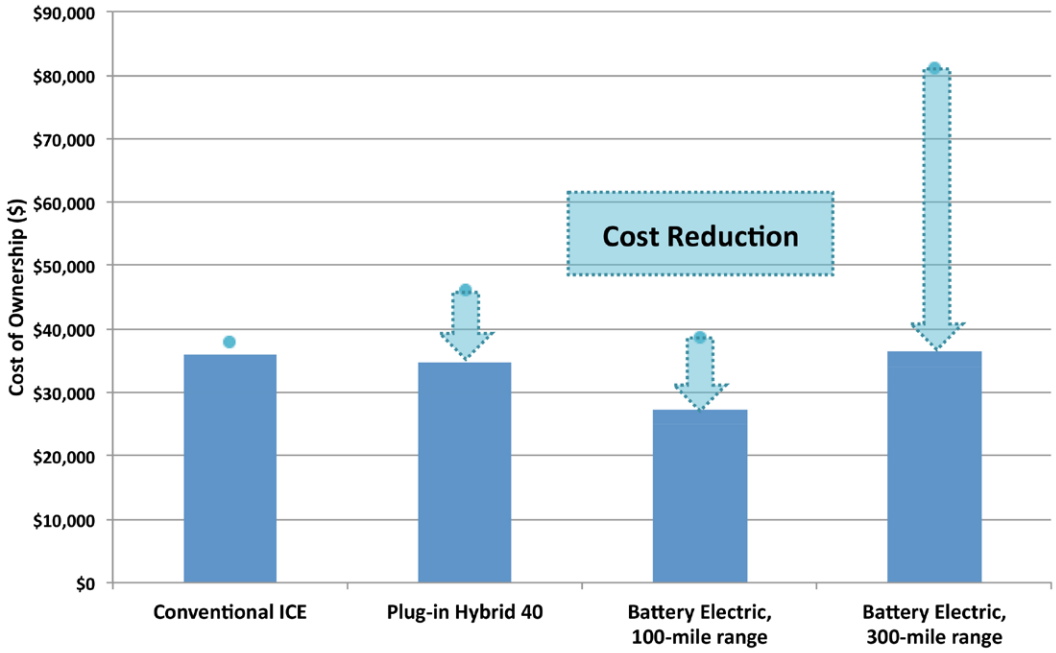
EV Everywhere R&D Strategy

Dramatic improvements in PEV performance and cost will require a well-coordinated effort with America's most innovative researchers and companies. The technical targets presented in this section represent "stretch goals" established in consultation with stakeholders across the industry who acknowledge that innovations in PEV technology will only occur as a result of collaborative efforts in scientific investigations and technology development. Achieving *EV Everywhere* technology performance and cost targets described below will reduce the combined battery and electric drive system costs of a PEV by up to 50%.

EV Everywhere's focus on cost reductions and performance improvements in several platform technology areas—batteries, electric motors, power electronics, lightweight materials and vehicle structures, and fast-charging technologies—logically shaped the method for setting targets. The evaluation framework focused on the first three technology areas of interest since R&D can contribute directly to their advance. Additional social science research is required to better understand consumer preferences regarding vehicle structures and fast-charging technologies.

> One thing about shooting for the moon was that it was a stated objective, so I'm glad that DOE is setting these visions. Let's try to move towards that objective. It's good we have a target like that.
>
> *— Comment from EV Everywhere Workshop Participant*

Meeting *EV Everywhere* targets will significantly lower PEV 5-year cost of ownership (vehicle cost plus fuel)[1]

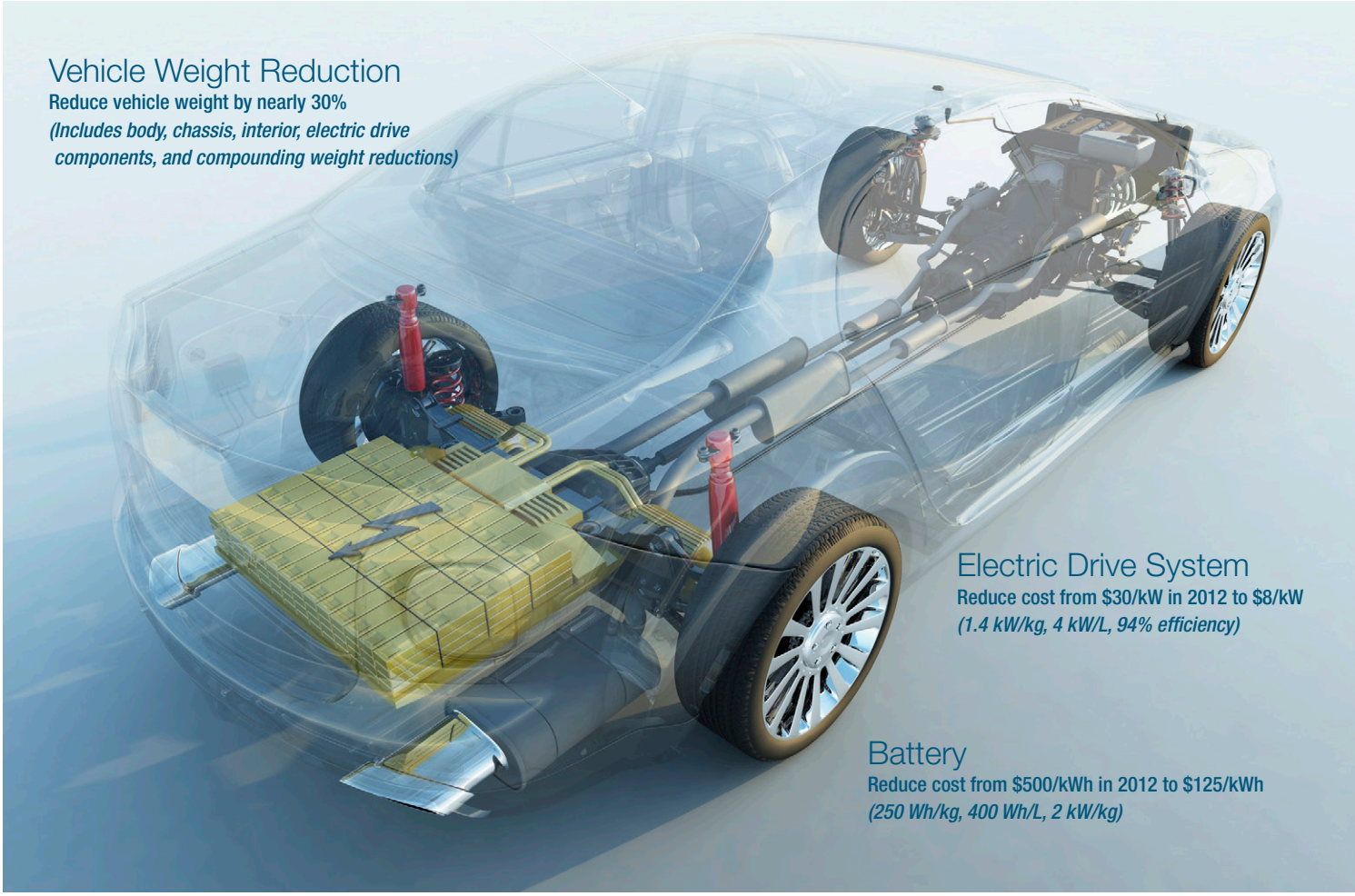


[1] 2022 vehicle cost, plus 5-year fuel (EIA AEO 2013 Reference Cost) expressed in 2012 dollars

Technical Targets

DOE defined *EV Everywhere* technology targets using an analytical framework that evaluated the performance of component technologies as well as vehicle cost and performance. We synthesized data about future vehicle potential by using expert projections of component technology to create virtual vehicles of the future via computer modeling and simulation. The range of vehicle costs and efficiencies made possible a comparison of the degree to which the portfolio of these technologies must progress, in both performance and cost terms, to yield PEVs that are cost-competitive, as measured by the initial vehicle purchase price and the fuel expenditure accrued over a 5-year ownership period. Ultimately, an analysis of this balance yielded technical targets at the technology progress frontier: *EV Everywhere* targets are consistent with what experts see as very aggressive but still possible within the *EV Everywhere* timeframe.

2022 technology performance and cost targets for key PEV technical areas



Batteries

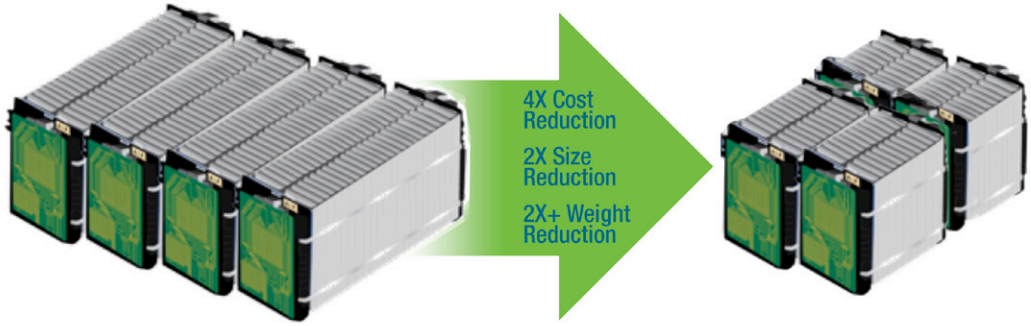
An important step for the electrification of the nation's light duty transportation sector is the development of more cost-effective, long lasting, and abuse-tolerant PEV batteries. The cost of today's batteries is over four times too high. In addition, PEV design optimization and performance is often hindered by the size and weight of the battery. The figure below shows the battery performance advancements that are needed to enable a large market penetration of PEVs. A well-coordinated effort across all of the DOE complex and with America's most innovative researchers and companies is required in order to achieve these dramatic improvements in battery performance and cost.

Current battery technology is very far from its theoretical energy density limit. In the near-term (2012 – 2017), with advances in lithium-ion technology, there is an opportunity to more than double the battery pack energy density from 100 Wh/kg to 250 Wh/kg through the use of new high-capacity cathode materials, higher voltage electrolytes, and the use of high capacity silicon or tin-based intermetallic alloys to replace graphite anodes. Despite current promising advances, much more R&D will be needed to achieve the performance and lifetime requirements for deployment of these advanced technologies in PEVs.

In the longer term (2017 – 2027), "beyond Li-ion" battery chemistries, such as lithium-sulfur, magnesium-ion, zinc-air, and lithium-air, offer the possibility of energy densities that are significantly greater than

Battery Challenge

Battery advancements needed to enable a large market penetration of PEVs



2012 Battery Technology

$500/kWh, 100 Wh/kg, 200 Wh/l, 400W/kg

Lithium-ion batteries in today's electric drive vehicles use a combination of positive active materials based on nickel, manganese, or iron; matched with a carbon or graphite negative electrode.

2022 Battery Technology

$125/kWh, 250 Wh/kg, 400 Wh/l, 2000 W/kg

New battery technologies may meet the challenges of *EV Everywhere*. New concepts in lithium-ion technologies have the potential to double the performance and significantly reduce the cost. "Beyond lithium-ion" technologies (lithium metal, lithium-sulfur, and lithium-air) may also meet the challenge.

> "Lithium-ion is a young technology; it has changed the way we use battery devices. As a young industry, the opportunity for innovation is significant."
>
> *— Comment from EV Everywhere Workshop Participant*

current lithium-ion batteries as well as the potential for greatly reducing battery cost. However, major shortcomings in cycle life, power density, energy efficiency, and/or other critical performance parameters currently stand in the way of commercial introduction of state-of-the-art "beyond Li-ion" battery systems. Breakthrough innovation will be required for these new battery technologies to enter the PEV market.

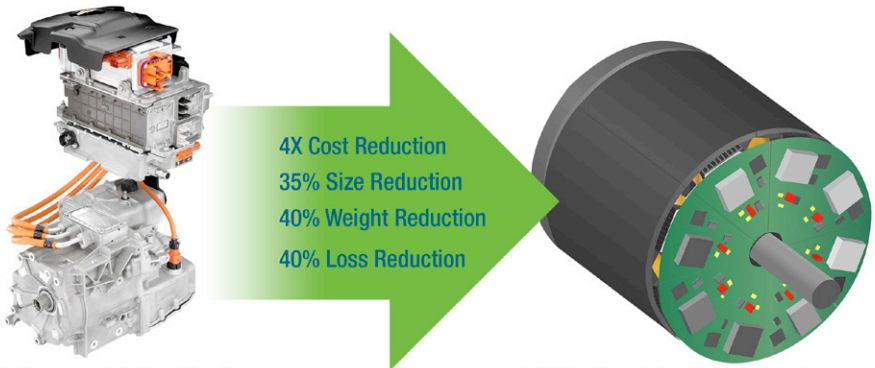
The energy density increases described above will be critical to achieving the *EV Everywhere* cost and performance targets. Additional R&D efforts including pack design optimization and simplification, manufacturing improvements at the cell and pack level, materials production cost reduction, and novel thermal management technologies will also contribute to battery cost reduction. Also, achieving the *EV Everywhere* battery power density target (2000 W/kg) is important to assure that technology breakthroughs meet the discharge power requirements for a wide range of PEV architectures and to enable the battery to be rapidly charged. Fast charging may be important for consumer adoption of certain PEVs.

Select Battery Workshop Recommendations

- *EV Everywhere* should pursue a balanced battery R&D portfolio focused on aggressive Li-ion (80%) and beyond Li-ion (20%), given the probability that Li-ion can achieve the *EV Everywhere Grand Challenge*.
- *EV Everywhere* should develop lower-cost processes for materials production (cathode, anode, electrolyte, and separator) since these represent a large portion of battery cost.

Electric Drive System Challenge

Advancements needed for an electric drive system to support meeting *EV Everywhere* targets



2012 Electric Drive System
$30/kW, 1.1 kW/kg, 2.6 kW/L
90% system efficiency

55kW SYSTEM COST OF $1650
Today's electric drive systems use discrete components, silicon semiconductors, and rare earth motor magnets.

2022 Electric Drive System
$8/kW, 1.4 kW/kg, 4.0 kW/L
94% system efficiency

55kW SYSTEM COST OF $440
Future systems may meet these performance targets through advancements such as fully integrating motors and electronics, wide bandgap semiconductors, and non-rare earth motors.

Select Electric Drive Workshop Recommendations

- *EV Everywhere* should leapfrog silicon devices for power electronics, and focus on silicon carbide and wide bandgap materials.
- Electric motor development should focus on concepts that reduce or eliminate rare earth materials.

Electric Drive Systems

Electric drive system R&D is needed to accelerate the development of advanced power electronics and electric motors to enable a large market penetration of PEVs. Developing advanced power electronic, electric motor, and traction drive system technologies that will leapfrog current on-the-road technologies, with a system-level emphasis to improve fuel efficiency and reduce cost, are key to meeting the *EV Everywhere Grand Challenge*.

Achieving *EV Everywhere* targets will require cutting-edge R&D in several areas including permanent magnet materials, non-rare earth magnets, advanced capacitors, thermal and electrical packaging, wide bandgap (WBG) semiconductors, and motor laminations. The R&D strategy to achieve the *EV Everywhere* cost and performance targets in this technology area includes:

- **ELECTRIC MOTORS:** Develop new low-cost and highly efficient motor designs, alternative magnetic materials with reduced rare earth content, and improved motor manufacturing methods. Long-term emphasis on non-rare earth motor architectures will reduce motor costs and mitigate rare earth market uncertainties for the original equipment manufacturers and their suppliers.
- **POWER ELECTRONICS:** Develop affordable WBG devices, high-temperature capacitors, advanced packaging, high voltage operation, and new circuit topologies. Designs using WBGs will increase as manufacturing processes enable improved device yield and performance. In addition, this research includes advancements in thermal management such as low cost heat transfer technologies, thermal stress and reliability, and thermal systems integration.
- **TRACTION DRIVE SYSTEM:** Integrate power electronic and motor technologies along with traction drive control strategies, innovative integrated system designs, and thermal management.
- **ON-BOARD CHARGERS:** Reduce the cost for on-board chargers, followed by overcoming packaging and thermal limitations.

Select Vehicle Lightweighting Workshop Recommendation

▶ Modeling and simulation of advanced alloys/materials (aluminum, steels, composites, magnesium, and advanced materials) for improved performance and cost is needed, including modeling techniques that can integrate with objectives for both materials property improvement and cost reduction to address a path towards performance and cost needs in each material system.

Vehicle Lightweighting

Reducing the weight of a PEV can extend its electric range, reduce the size and cost of the battery, or achieve a combination thereof. In order for vehicle lightweighting to provide these benefits, lightweight metals and composites must be an attractive choice by meeting both cost and structural requirements. Materials properties related to mechanical behavior, crash response, and durability of vehicle structures must be improved. Moreover, techniques for predicting material behavior must be integrated with design methods to enable reduced cost, such as by minimizing input material quantities or decreasing cycle time.

The focus of these targets is to enable cost effective weight reduction for each of the systems of the vehicle that combined with compounding weight reduction in other systems and weight reduction for batteries and electric drive systems leads to a total vehicle weight reduction of almost 30%. For example, by 2022 we are seeking to reduce weight by 35% for the body structure, 25% for the chassis and suspension, and 5% for the interior.

To achieve these targets for weight reduction, lightweight materials efforts must:

- improve mechanical characteristics,
- lower cost,
- facilitate manufacturability,
- provide solutions for cost effective joining and corrosion protection of multimaterial structures,
- validate safety of lightweight designs, and
- support design tools to facilitate faster development of new materials.

Lightweight material systems include carbon fiber composites, magnesium alloys, advanced high strength steel, and aluminum alloys; and techniques to join combinations of these materials in a cost effective manner are also critical. Specific milestones seek to validate both that the material performance meets the system requirements and the cost to implement the material per pound of weight saved is acceptable. The image below illustrates the weight reduction targets for each structural system of the vehicle by 2022.

2022 targets for weight reduction for materials lightweighting

> The industry has discovered that electrification is going to be a growing part of all our portfolios. The issue is the volatility of [vehicle markets], the incredible cost, and how long it takes to get to that sustainable business model. We need the pull to continue to invest in EVs.
>
> *— Comment from EV Everywhere Workshop Participant*

Efficient Climate Control Technologies

Using less energy in PEVs to achieve comfortable climate control will allow for a smaller, less expensive battery, and thus contribute to lowering the cost of PEVs. Currently, these climate control loads on a PEV can double vehicle energy consumption, effectively halving vehicle range. *EV Everywhere* will focus on the following specific research areas:

- **ENERGY LOAD REDUCTION AND ENERGY MANAGEMENT** strategies can minimize energy consumption by reducing the thermal loads that the systems must address. Advanced windows and glazing, surface paints, advanced insulation, thermal mass reduction, and ventilation and seating technologies can better control heat transfer between the passenger cabin and the environment, minimizing the thermal loads that the Heating, Ventilation and Air-Conditioning (HVAC) systems must address to ensure passenger comfort.
- **ADVANCED HVAC EQUIPMENT,** such as advanced heat pumps or novel heating/cooling subsystems, can reduce the auxiliary loads. Innovative heating and cooling concepts to achieve passenger comfort, such as infrared and thermoelectric devices and phase change materials, can also reduce energy requirements.
- **CABIN PRE-CONDITIONING** while the vehicle is connected to the grid can reduce the amount of energy needed from the battery upon initial vehicle operation to either pull-down (hot conditions) or raise (cold conditions) the temperature in the cabin. Another approach to cabin pre-conditioning is to utilize waste heat generated within the battery and/or charging circuit during charging.

Select Auxiliary Load Reduction Workshop Recommendation

- ***EV Everywhere*** **should focus on advanced climate control technologies (passenger comfort and window defrost/defog) that use less energy to achieve the same level of climate control, allowing for a smaller, less expensive battery.**

Charging Infrastructure

Today, half of the vehicles in the U.S. park overnight at locations with access to plugs. However, workplace and public parking lots are only beginning to offer access to chargers. Participants from DOE's workshops recommended that the Department focus attention on workplace charging in particular, since so many Americans drive their cars to work each day. Following up on that recommendation, DOE is launching the *EV Everywhere* Workplace Charging Challenge with a goal of increasing the number of employers in the U.S. offering workplace charging by tenfold in five years. Participants also recommended that DOE help convene diverse stakeholders including utilities, charging equipment providers, and local governments to ensure smooth operation and grid reliability.

Widespread PEV charging infrastructure will help promote rapid scale-up of PEVs in the years ahead. (This is especially important for AEVs, which rely on charging infrastructure for refueling, unlike PHEVs.) A wide range of stakeholders will need to engage in cross-cutting work to address the issues that *EV Everywhere* participants identified. These issues are discussed below.

Charging Infrastructure Siting: Data from existing stations and charging events can inform the development of improved siting guidance and help to ensure public PEV charging is available in locations most useful to drivers. While the infrastructure requirements for different vehicles will vary, local

Stakeholder collaboration is necessary to develop charging infrastructure

> "You can't dabble in this. You have to invest in the technology enough to get ready for mass market. It is a long term investment. You have to make a decision at a certain point in time to join in, and you hope you have a competitive advantage. We all make those bets every day in the industry."
>
> *— Comment from EV Everywhere Workshop Participant*

> I'd like to see consumers realize that they could plug in at home and at work, and that they don't need chargers everywhere. It's important to demonstrate that EVs aren't as complicated as they seem.
>
> *— Comment from EV Everywhere Workshop Participant*

decision-makers must also help determine the optimal placement of charging infrastructure relative to vehicle deployments, regional characteristics, and traffic patterns. DOE is collecting use data from existing infrastructure to help guide future build-out, and has supported community siting planning efforts.

Codes & Standards Development for Charging:
A comprehensive set of codes and standards addressing the interface between PEVs and charging infrastructure is essential. These include physical interfaces, power flow, communications, test procedures, and installation/permitting processes. Although some standards already exist, further progress is needed on standards to address current issues around DC fast charging to ensure that all consumers have safe, seamless access to this important charging capability. DOE will remain active supporting the full breadth consensus standards activities.

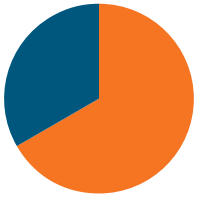
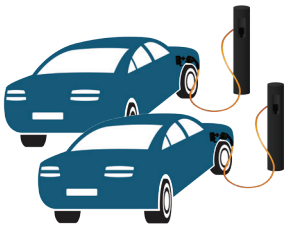
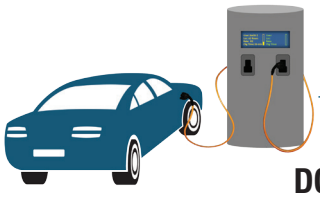
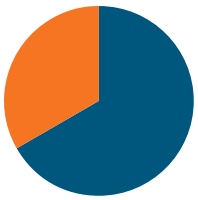
PEV Charging Station Permitting:
Permitting for PEV charging station installation varies significantly by region, and costs and delays associated with permits continue to be a barrier to PEV charging station deployment. Developing efficient permitting and inspecting procedures will reduce time and costs for PEV charging station installation. DOE's Clean Cities program will continue to expand resources that aid in station permitting. Currently available resources include a permit template and a Residential Charging Installation Video.

PEV Charging Station Signage:
Consistent and abundant charging station infrastructure signage will help consumers not only navigate to public fueling opportunities, but also draw attention to the availability of charging infrastructure for potential PEV drivers.

Grid Integration:
Effective grid integration will enable PEVs to be managed as dispatchable loads by utilities, and allow consumers to charge based upon the best available utility rates. It will also lay the groundwork for bidirectional power flow through vehicle-to-grid (V2G) technologies, so that PEVs may become an asset to the grid. Additionally, a mature PEV market could be an enabler for variable distributed generation such as wind and solar photovoltaic (PV) systems. Controlling PEV charging so that it coincides with renewable electricity generation could provide value to consumers, through favorable electricity rates, and to utilities, by providing demand for this generation. DOE addresses vehicle-related grid integration primarily through the U.S. DRIVE government-industry partnership.

Select *EV Everywhere* Workshop Finding

▶ **Wireless charging could enhance consumer acceptance of PEVs, and the potential offered by the technology presents an opportunity for innovation. In the near term, static (stationary) wireless charging may provide convenience to the PEV driver.**

	Charging Level	Setting	Supply Power	Representative Example	Where Charging Occurs
	**AC Level 1**	Residential/ Parking Lot 5 mi/hour @ 1.7 kW	120vac/20A (16A continuous)		RESIDENTIAL  2/3 of charging
	**AC Level 2 (minimum)**	Residential/ Commercial 10 mi/hour @ 3.4 kW	208/240vac/20A (16A continuous)		
	AC Level 2 (maximum)	Commercial (up to) 60 mi/hour @ 19.2 kW	208/240vac/100A (80A continuous)		
	**DC Level 1**	Commercial up to 500v @ 80Adc (up to) 120 mi/hour @ 40 kW	208vac/480vac 3-phase (input current proportional to output power; ~20A-200A AC)		COMMERCIAL  1/3 of charging
	DC Level 2	Commercial up to 500v @ 200Adc (up to) 300 mi/hour @ 100 kW	208vac/480vac 3-phase (input current proportional to output power; ~20A-400A AC)		

Charging levels and resulting charging times

Education & Policy

In addition to R&D to overcome technologies barriers, consumer education and exposure, innovative PEV ownership incentives, and increased adoption by government and private fleets will help grow the market and drive down PEV costs to achieve the *EV Everywhere Grand Challenge* goal.

PEVs offer the driver many benefits, including ease of home recharging, quiet drive, durability, performance and instant torque. Providing consumers with opportunities to experience PEVs, learn about these benefits and share their experiences will further the adoption of these vehicles.

Federal and State PEV tax credits can increase domestic manufacturing capability and PEV market penetration, while promoting a U.S. vehicle fleet that is less dependent on petroleum. Taxpayers currently receive a Federal tax credit from $2,500-$7,500 for qualified PEVs. Policy mechanisms, such as transferring the Federal tax credit to the point-of-sale, can reduce consumer PEV purchase barriers. In addition to monetary incentives, non-financial incentives such as HOV lane access and/or preferential parking for PEVs must be explored to help motivate consumer adoption.

Realizing the vision of *EV Everywhere* will require action by many stakeholders. Cities and states have the power to promote deployment in their own communities; research labs will pioneer and refine battery technologies that will be critical to achieving these goals; and automakers will apply their enormous expertise to engineer these new technologies into low-cost, commercially viable products.

The electric vehicle market is growing rapidly. We must work with industry, cities and states, NGOS and researchers to support a robust U.S. PEV market today, and in the years to come, and ultimately accomplish our goal: *EVs Everywhere*.

Publishing support services provided by Argonne National Laboratory.

EV Everywhere grand challenge blueprint

For further information, contact:
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The R&D and deployment activities in support of the *EV Everywhere Grand Challenge* are carried out through a variety of DOE organizations that help to remove technology and institutional barriers, enabling a faster transition of PEVs into the marketplace.

- OFFICE OF SCIENCE seeks to provide the foundations for new energy technologies to DOE's missions in energy, environment and national security. The Office of Science is the single largest supporter of basic research in the physical sciences in the United States. (http://science.energy.gov/)
- ARPA-E empowers America's energy researchers with funding, technical assistance and market readiness. ARPA-E funds energy technology projects that translate scientific discoveries and cutting-edge inventions into technological innovations. (http://arpa-e.energy.gov/)
- EERE VEHICLE TECHNOLOGIES PROGRAM develops more energy efficient and environmentally friendly highway transportation technologies that enable America to use less petroleum. VTP aims to provide Americans with greater freedom of mobility and energy security, with lower costs and lower impacts on the environment. (http://www.eere.energy.gov/)
- CLEAN CITIES has served as DOE's alternative transportation deployment initiative since 1993, saving more than 3 billion gallons of petroleum since its inception. Clean Cities' mission is to advance the nation's economic, environmental, and energy security by supporting local decisions to adopt transportation practices that contribute to the reduction of petroleum consumption. The mission is carried out by 10,000+ stakeholders in nearly 100 Clean Cities coalitions across the country. (http://cleancities.energy.gov)