

# U.S. Department of Energy Vehicle Technologies Program Overview

Annual Merit Review and Peer Evaluation Meeting  
May 9-13, 2011

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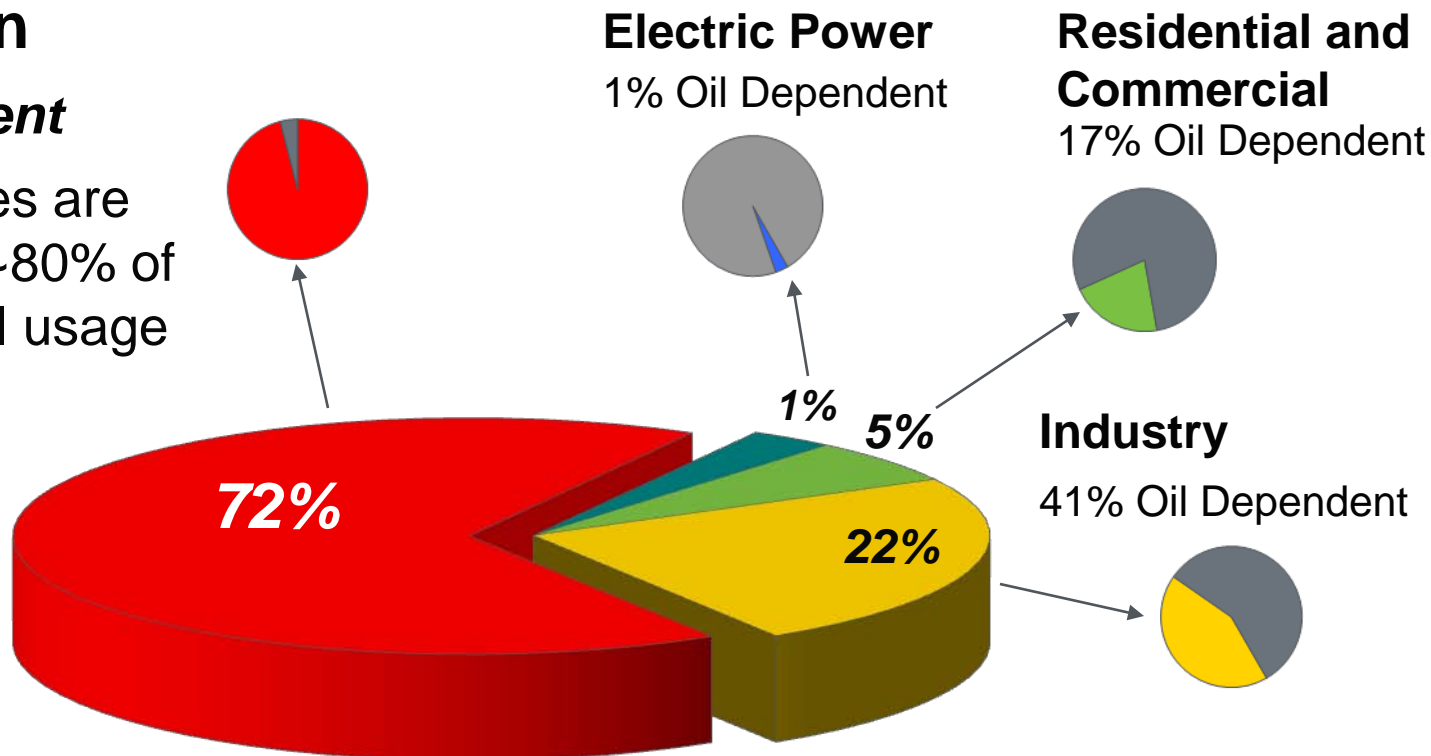


## U.S. Oil Consumption by End-Use Sector *19.1 Million Barrels per Day (2010)*

### Transportation

#### **94% Oil Dependent**

- On-Road vehicles are responsible for ~80% of transportation oil usage



Source: DOE/EIA Annual Energy Review, April 2010

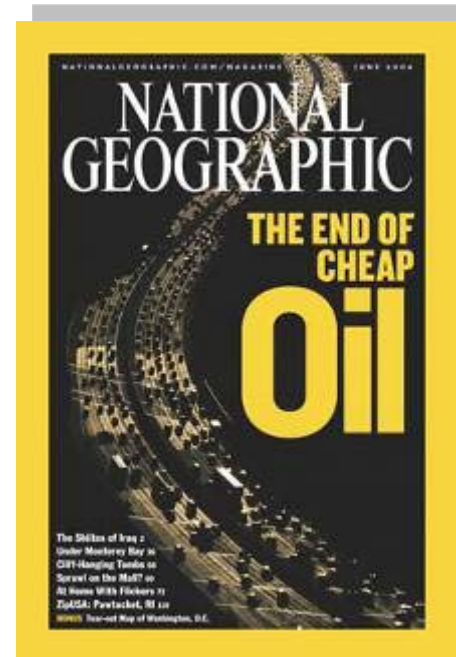
# New Oil Reserves are Harder to Find

- Global discovery of new oil fields peaked in 1966.
- U.S. oil *production* peaked in 1971.
- World oil production has hardly grown at all since 2005.
- >\$1B/day for imported petroleum.

Source: Jeff Rubin, "Why the World is About to Get a Whole Lot Smaller"

## World Oil Production

2005: 84.58 mbpd  
2006: 84.54 mbpd  
2007: 84.40 mbpd  
2008: 85.37 mbpd  
2009: 84.24 mbpd  
2010: 87.3 mbpd



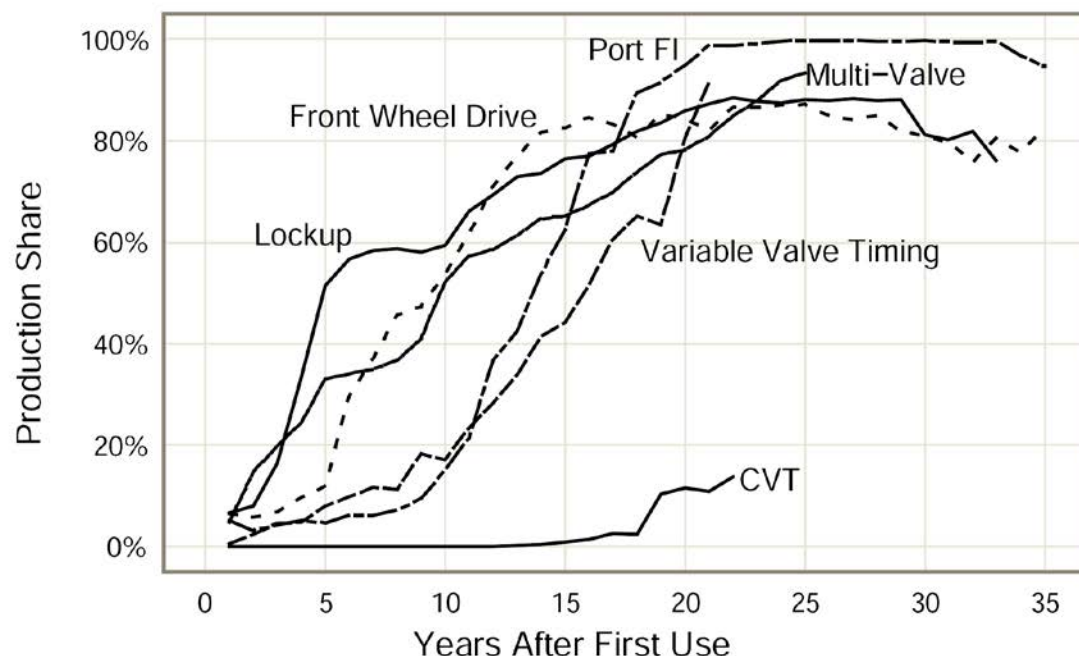
## *The Cost of Oil is More than Monetary*



# Realizing Benefits of Vehicle Technology Takes Time

## Vehicle Technology Penetration

Years After Initial Significant Use

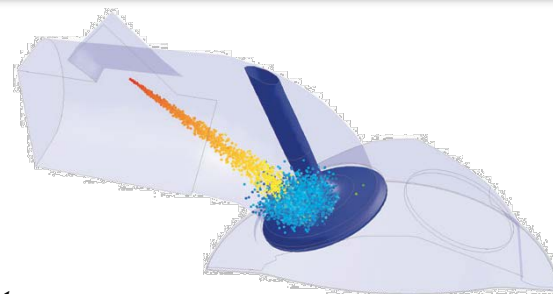


*It has taken about 15 – 20 years for a technology to reach maximum market penetration.*

Light-Duty Automotive Technology and Fuel Economy Trends: 1975 Through 2010, EPA420-R-10-023, November 2010, p. 69

## U.S. Vehicle Market

- About 240 million light-duty vehicles on the road
- Approximately 11.5M new cars & light trucks sold in 2010; the average was 15.7 M/yr from 2002-2007
- Hybrid vehicles at about 3% of sales





President highlights National Clean Fleets Partnerships as part of his goal of reducing America's imported oil



President calls out goal of 1 million PHEVs on the road by 2015 in State of the Union address



Vice President Biden announces 200M for community infrastructure project



# The President's Plan for Transportation



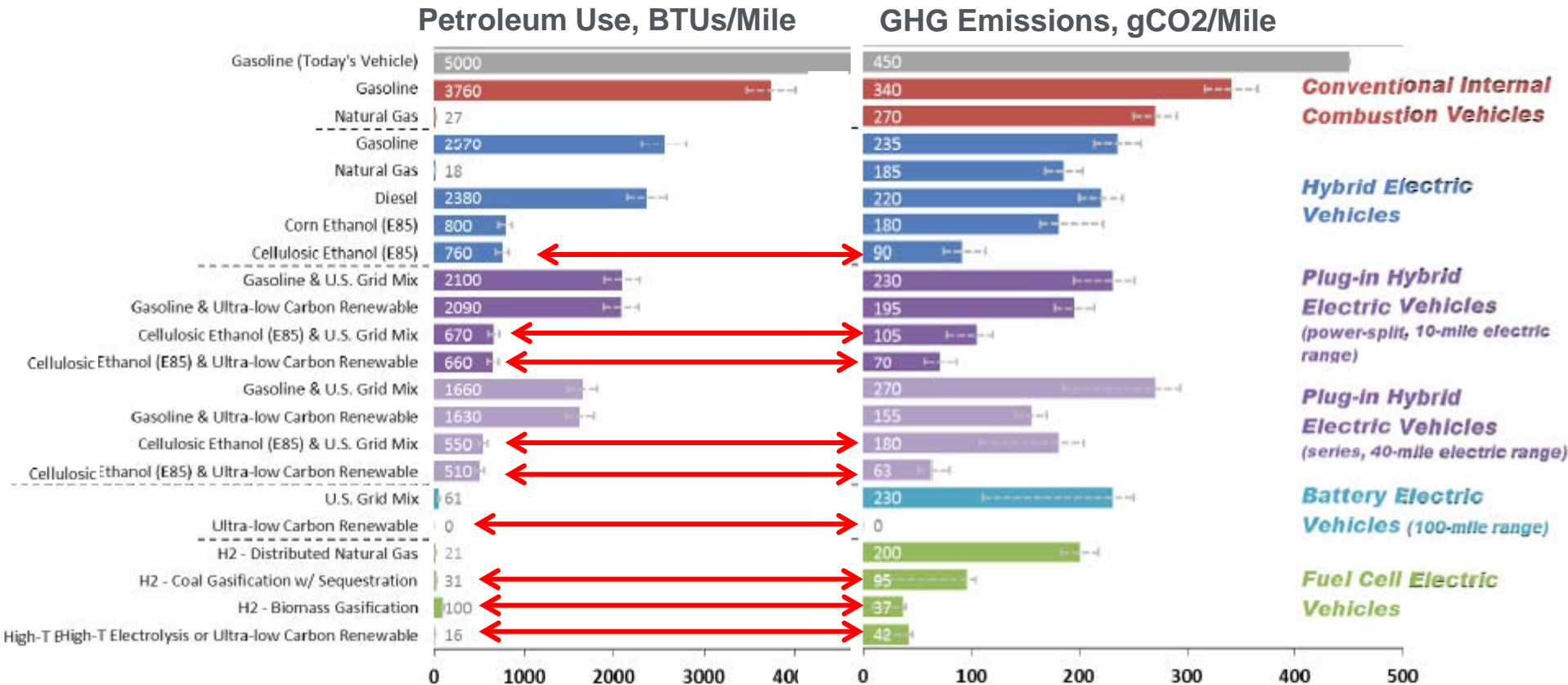
*“With more research and incentives, we can break our dependence on oil with biofuels, and become the first country to have a million electric vehicles on the road by 2015”*

-President Barack Obama  
2011 State of the Union

*“To make sure we stay on this goal we’re going to need to do more — by offering more powerful incentives to consumers, and by rewarding the communities that pave the way for the adoption of these vehicles”*

-President Barack Obama  
Remarks on Energy Security  
Georgetown University, March 30, 2011

## Only Options That Achieve Very High Petroleum Reductions and Very Low Carbon Emissions Combine Electric Drive With Low Carbon Fuels



# Vehicle Technologies Program Goals

## Decrease petroleum dependency

## Reduce greenhouse gases

Develop more energy efficient and environmentally friendly highway transportation technologies that enable America to use less petroleum. The long-term aim is to develop technologies that will provide Americans with greater freedom of mobility and energy security, with lower costs and lower impacts on the environment.





Program Focus: Strategic research, development, and deployment activities supporting the goal of 1 million electric drive vehicles on U.S. roads by 2015

## Budget Request

Activity	Funding (\$ in thousands)	
	FY 2010 Current Appropriation <sup>a</sup>	FY 2012 Congressional Request
Batteries and Electric Drive Technologies	98,566	188,000
Vehicle and Systems Simulation and Testing	43,732	58,000
Advanced Combustion Engine R&D	55,987	49,000
Materials Technologies	49,303	38,000
Fuels Technologies	23,421	18,503
Outreach, Deployment & Analysis	33,214	236,500
<b>TOTAL</b>	<b>304,223</b>	<b>588,003</b>

<sup>a</sup> SBIR/STTR removed.

Pursuing advanced vehicle technologies to reduce petroleum use and carbon emissions.

**Battery and Electric Drive Technologies (\$188.0M):** Battery technology and prototype systems that provide full electric drive vehicle performance and reduce cost to \$300/kWh. Motor designs that minimize or eliminate use of rare earth materials.

**Vehicle and Systems Stimulation & Testing (\$58.0M):** Wireless charging, high efficiency HVAC systems and vehicle thermal load reduction, codes and standards for communications and power management between vehicles, chargers, grid.

**Advanced Combustion Engine R&D (\$49.0M):** With the Off. of Science, develop predictive simulation computer model to optimize engine efficiency & reduce emissions and cost.

**Materials Technology (\$38.0M):** Multi-material vehicle validation of 50% weight reduction of body and chassis.

**Fuels Technology (\$18.5):** Expand work on engine and transmission lubricants to demonstrate 2% fuel efficiency improvement from improved lubricants (2015).

**Outreach, Deployment, & Analysis (\$236.5M):** Support community based EV deployment initiatives focusing on competitive awards to establish infrastructure, local policy incentives and streamlined permitting processes.

# Advanced Technologies for High Efficiency Clean Vehicles



## **Batteries and Electric Drive**

- Advanced Batteries
- Power Electronics
- Inverters
- Controllers & Motors

## **VSST**

- Aerodynamics, Rolling Resistance & Accessory Loads
- Validation

## **Advanced Combustion Engine R&D**

- Low Temp. Combustion R&D
- Emission Controls
- Light- & Heavy-Duty Engines
- Solid State Energy Conversion
- Health Impacts

## **Fuels Technology**

- Bio-Based Fuels
- Clean/Efficient Combustion Fuel Characteristics
- Fischer-Tropsch Fuels & Blendstocks
- Advanced Lubricants

## **Outreach, Deployment and Analysis**

- EPA/EA/EISA
- Rulemaking
- Deployment
- Student Competitions
- Graduate Automotive Technology Education
- Safety, Codes, & Standards

## **Materials Technology**

- Lightweight Structures
- Composite Development
- Processing/Recycling/Manufacturing
- Design Data Test Methods
- High Temperature Materials Laboratory

# Hybrid-Electric Systems




Petroleum Displacement via Fuel Substitution & Improved Efficiency




Energy Efficiency & Renewable Energy

Administration Goal: 1 Million PHEVs by 2015

## Types of Vehicles and Benefits

HEV		Toyota Prius 50 MPG
PHEV		Chevy Volt 100 MPGe
EV		Nissan Leaf All Electric

## System Cost

PHEV Battery Cost per kW·h		APEEM Cost per kW
\$1,000 - \$1,200		\$22
\$700 - \$950		\$19

## Targets and Status

<b>2014 PHEV:</b> Battery that has a 40-mile all-electric range and costs \$3,400	<b>Status:</b> \$8,000-\$11,000 for a PHEV 40-mile range battery
<b>2015 PEEM:</b> Cost for electric traction system no greater than \$12/kW peak by 2015	<b>Status:</b> Current cost of the electric traction system is \$40/kW

## Benefits all Vehicle Classes, HEV and PHEV

**Cars**  
Power Rating: 100-300hp



Light-Duty

**Trucks**  
Power Rating: 200-400hp



**25-40%  
Improvement**

**Class 2b-8**  
Power Rating: 250-600hp



Heavy-Duty



**Up to 30%  
Improvement**

## Accomplishments

- Demonstrated light-duty dual-fuel combustion engine concept with 77 percent higher efficiency (UW and ORNL)
- Demonstrated 45 percent efficient light-duty multi-cylinder diesel engine (ORNL)
- Demonstrated 15 percent increase in heavy-duty engine efficiency: in-cylinder improvements and organic Rankine cycle (Cummins)
- Developed more efficient models to simulate combustion and emission control processes (LLNL, LANL, SNL, ORNL, PNNL)
- Developed tubular thermoelectric waste energy recovery generator for Ford Fusion and BMW X-6 (BSST)

## Targets and Status

**2015 Passenger Vehicle:** Improve gasoline vehicle fuel economy by 25%, diesel vehicle fuel economy by 40%, compared to 2009 baseline

**Status:** Current fleet average fuel economy of 29.2 mpg; six ATP-LD cooperative awards to demonstrate fuel economy goals by 2015

**2015 Commercial Engine:** Improve commercial diesel engine efficiency by >20% compared to 2009 baseline, 30% by 2018

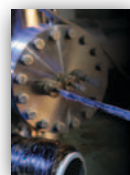
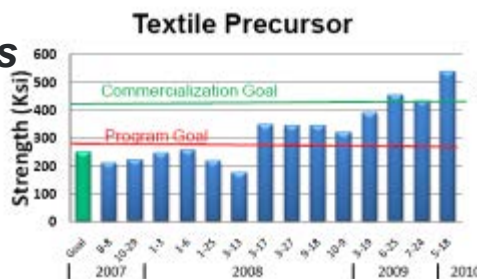
**Status:** Current commercial engine efficiency is up to 42%; three SuperTruck awards to demonstrate 50% efficiency in Class 8 trucks by 2015



*For 10% reduction in vehicle weight the result is 6-8% improvement in fuel economy*

## Weight Reduction Demonstrations

- Using textile precursor, demonstrated carbon fiber with strength 540 KSI (goal 250 KSI), modulus 38 MSI (goal 25 MSI)
- Validated that cost for high volume manufacturing of textile precursor would be \$5.74/lb (goal \$5.00/lb)



## Targets and Status

**2010 Target:** 50% cost-effective weight reduction of the passenger vehicle body and chassis systems compared to 2002 vehicles.

**2015 Target:** Commercial introduction of thermoelectric coolers/heaters to replace vehicle A/C systems

**2010 Status:** Modeling shows that weight reduction of 50% is achievable but, *but not at cost parity*.

**2010 Status:** Using materials by design, new low cost/high performance thermoelectric materials were made and performance verified

Lightweighting improves fuel economy and reduces the demands on the powertrain and ancillary systems (e.g., braking)

*Renewable Fuels Standard: 36 Billion gallons per year by 2022*

## Accomplishments

- Completed DOE Intermediate Ethanol Blends Test Program – Primary data source for EPA waiver decision.
- Partnered with seven automotive companies and MIT to lower friction in the engine power-cylinder.



## Future Directions

- Lubricant research – retrofit solution for vehicles in use.
- E15 deployment – develop retrofit fuel dispenser technology.
- Fuel effects research – enable advanced combustion regimes and next-generation fuels.

## Targets and Status

**2015 Fuel Target:** Expand operational range of low-temperature combustion to 75% of light-duty Federal Test Procedure operating range.

**2015 Lubricant Target:** Demonstrate cost effective lubricant with 2% fuel economy improvement.

**Status:** E15 approved for 2001 and newer light-duty vehicles. Several hurdles to overcome to enable widespread deployment.

**Status:** Over 13 Billion gallons of renewable fuels used in 2010 – primarily ethanol with some biodiesel.

**Over 90% of gas stations in the US currently dispense E10 year round**

***The Partnership provides a forum for frequent and detailed pre-competitive technical information exchange among experts in government and industry***

- *Accelerates technical progress by leveraging expertise*
- *Avoids duplication of effort*
- *Ensures industry commercialization needs inform DOE R&D targets*

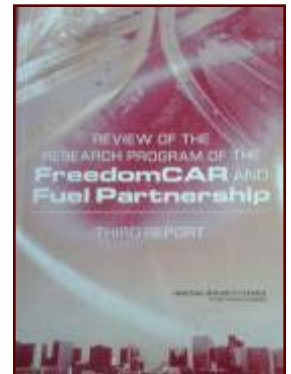


## 2010 Highlights of Technical Accomplishments Report (Mar 2011):

- [www.vehicles.energy.gov/about/partnerships/freedomcar/index.html](http://www.vehicles.energy.gov/about/partnerships/freedomcar/index.html)
- 70 key accomplishments demonstrating significant progress toward Partnership goals and targets

## Third Biennial National Academies' Review (July 2010):

- [www.nap.edu/catalog.php?record\\_id=12939](http://www.nap.edu/catalog.php?record_id=12939)
- "There has been considerable progress...results since the program began in 2002 have been very significant"
- "The FreedomCAR and Fuel Partnership government/industry collaboration is working well...such precompetitive collaborations should be continued"



## Systems Level Technology Development, Integration, and Demonstration for Efficient Class 8 Trucks

Awardees
Cummins, Inc.
Daimler Trucks North America
Navistar, Inc.



- ❑ All teams on schedule with their plans
- ❑ Base heavy-duty engines selected and benchmarked; scoped out pathways to achieving brake thermal efficiency target
  - Downselected engine modification strategies
  - Significant progress in developing waste heat recovery systems
- ❑ Baseline vehicle tested on specified routes and operational profiles.
  - Vehicle improvement targets for engines, aerodynamics, hybridization, APUs, and lightweighting defined for vehicles and trailers based on simulation. 50% improvement is achievable.
  - CFD and scale-model wind tunnel testing point to radically different truck and trailer integration.



*Improving the speed and scale of market penetration for alternative fuel vehicles and infrastructure*

*Results: 3 Billion Gallons of Petroleum Fuels Displaced Since 1993*

*Goal: 2.5 Billion Gallons/year by 2020*

~100 coalitions Serving  
78% of the US population



*Thousands of stakeholders from businesses, city & state governments, transportation industry, community organizations, fuel providers*



Recent Deployment Awards:

Vehicle Deployment - More than 10,000 alt-fuel and EVs, displacing an estimated 38 million gal of petroleum fuels/year

Infrastructure - More than 1,250 new fueling and charging stations

Education - Hundreds of workshops, community events, workforce training and public outreach efforts

NREL photo



*National Clean Fleet Partners:  
(deployment with hi-impact national fleets)*

## Progressive Automotive X PRIZE:

Winners were announced in September 2010, the winner, Edison 2, achieved 102 mpg. Competition also included an educational outreach program aimed at teaching K-12 students and the public in about advanced, energy-efficient vehicles.



## Green Racing

A DOE, EPA and SAE International initiative, adopted by the American Le Mans Series in 2009, that encourages the transfer of cleaner, more fuel-efficient vehicle technologies from the racetrack to the driveway. Biobutanol, cellulosic ethanol and hybrid powertrains were introduced in the 2009 and 2010 seasons.



*Inspiring the design of a new generation of super-efficient vehicles that dramatically reduce oil dependence and greenhouse gas emissions*

# EcoCAR Competitions

U.S. DEPARTMENT OF  
**ENERGY**

Energy Efficiency &  
Renewable Energy

- DOE has a 23-year history of sponsoring Advanced Vehicle Technology Competitions
- EcoCAR is one piece of the Department's broad commitment to educate the next generation of American innovators and support America's transition to a more efficient transportation sector.
- EcoCAR2 succeeds EcoCAR, and is a three-year collegiate level engineering competition that challenges teams of students to design vehicles that are both fuel efficient and meet strict emissions standards, without sacrificing performance, consumer appeal, or safety



***The EcoCAR Competition  
Finals will be held in June  
2011 in Washington DC.***



# EcoCAR2 Participants

U.S. DEPARTMENT OF  
**ENERGY**

Energy Efficiency &  
Renewable Energy



University  
of Victoria



UNIVERSITY OF ONTARIO  
INSTITUTE OF TECHNOLOGY



**EMBRY-RIDDLE**  
Aeronautical University



**PURDUE**  
UNIVERSITY





- Autonomie release
- Launch of the Geo EVSE Forum
- \$5M Communities based infrastructure pilot solicitation released



***EDTA Innovation Motorcade***



***Secretary Chu Launches  
the Geo EVSE Forum***

# Recovery Act :> \$2.8 Billion

**\$1.5 Billion in funding to accelerate the manufacturing and deployment of the next generation of U.S. batteries**

**\$500 Million in funding for electric-drive components manufacturing**

**\$400 Million in funding for transportation electrification**

Recovery Act will fund 48 new projects in advanced battery and electric drive components manufacturing and electric drive vehicle deployment in over 20 states: Directly resulting in the creation tens of thousands of manufacturing jobs in the U.S. battery and auto industries.



**Facilities and Equipment Upgrade up to \$105 Million:** User Centers, offer expert staff and unique equipment capabilities that no one industrial entity can afford to maintain.  
**Solicitation closed on 8/10/2009**



**Clean Cities: Petroleum Displacement through Alternative Fuel Vehicles and Expanded Alternative Fuel Infrastructure**

**SuperTruck and Advanced Combustion R&D**  
**\$104.4 Million Solicitation:**

Heavy-duty trucks are emphasized because they rapidly adopt new technologies and account for 20% of the fuel consumed in the United States.

**Solicitation closed 9/9/2009**



**We are on target to meet the administration's goals  
of 1 million PHEVs on the road by 2015.**

- 21 new battery or battery component plants opening or expanding due to ARRA funding
- 18 vehicle electrification component plants opening or expanding due to ARRA funding



Governor Granholm at Toda,  
Battle Creek, MI



Secretary Steven Chu marks the production  
of the first Chevy Volt battery off the line



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