Vehicle Technologies Program

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Deep-Dive

September 22, 2009

Mission, Goals, Targets & Budget

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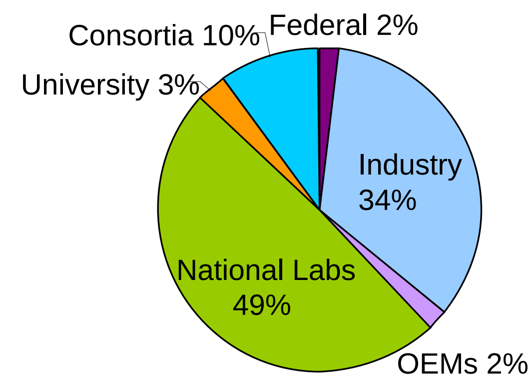
Mission: Develop clean highway transportation technologies to enable America to use less petroleum and lower greenhouse gas emissions

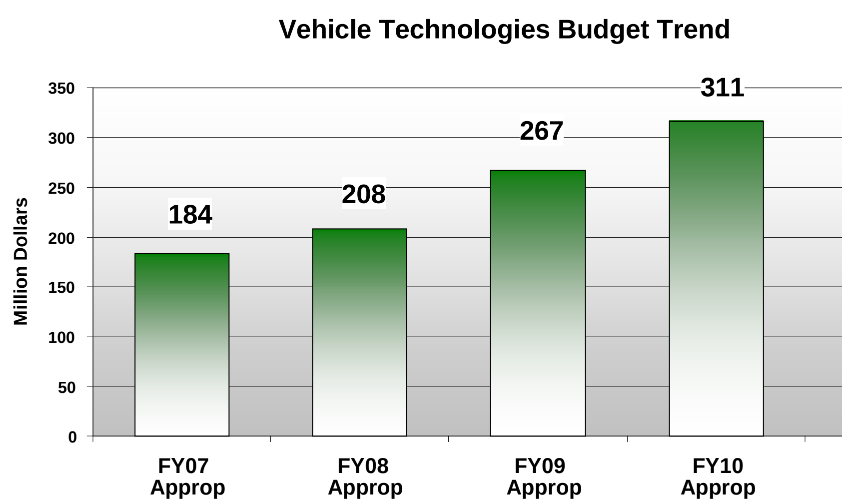
Key Administration Goals Relevant to Vehicle Technologies

- One million PHEVs on the highway by 2015
- Reduce oil use in 10 years by an amount equivalent to today's imports from the Middle East and Venezuela (~3.5 mbpd). The transportation share of this goal is estimated as ~1.75 mbpd.

Status	Target
Lower cost of electric-drive enables consumer adoption	
Electric drive cost at $19/kW power elec. and motor combined	Power Electronics: $12/kW; 15 yr life; 55 kW peak for 18 sec & 30 kW constant
Li-ion R&D: PHEV - < $1000/kWh – HEV cost at $625-850 for 100,000 units/year; life at 10-15 yr	Battery: PHEV – $300/kWh; 15 yr life; durability; 100 kWh/kg – HEV discharge power of 25 kW for 18 sec; storage at 300Wh; cost of $500 per sys
Efficiency reduces oil use and CO2 emissions	
Achieved engine efficiencies in lab testing of 43% for cars and 50% trucks	Combustion Efficiency: passenger vehicle up to 45% and commercial vehicles 55% at today's cost
Lightweighting improves efficiency of all vehicles	
Demonstrated 30% weight reduction of body and structure and lower cost carbon fiber	Material weight reductions up to 50% in body in white and component parts

Distribution of Funding





Market

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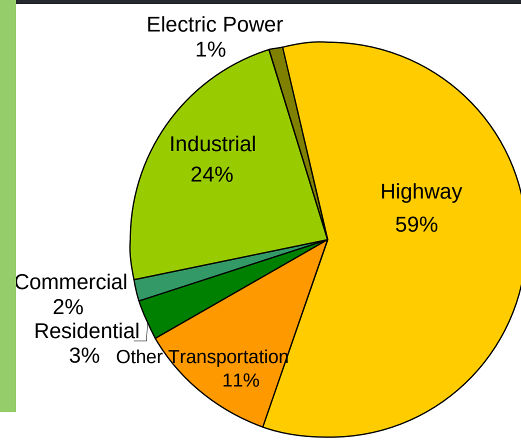
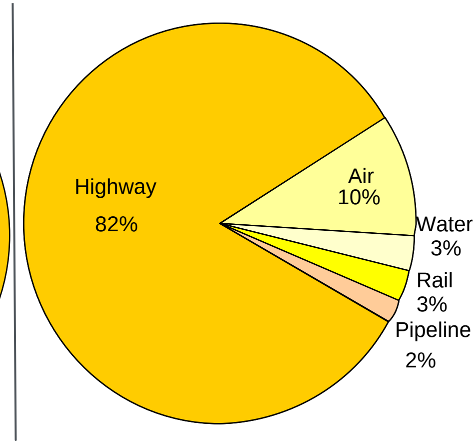
U.S. Vehicle Market

- 240 million vehicles on the road
- Approximately 9M new cars & light trucks for 2009. Average is 15.7 M/yr 2002-2007
- Hybrid vehicles now approaching 3% of sales
- 13 Million cars and light trucks taken out of use per year
- 11.5 Million barrels of oil per day consumed by on-road vehicles

2009 Oil Use in the U.S. (19.4 MBPD)

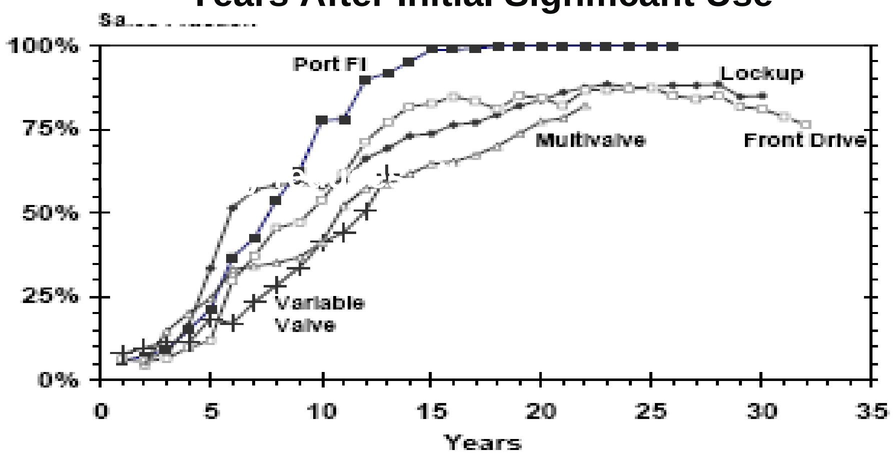


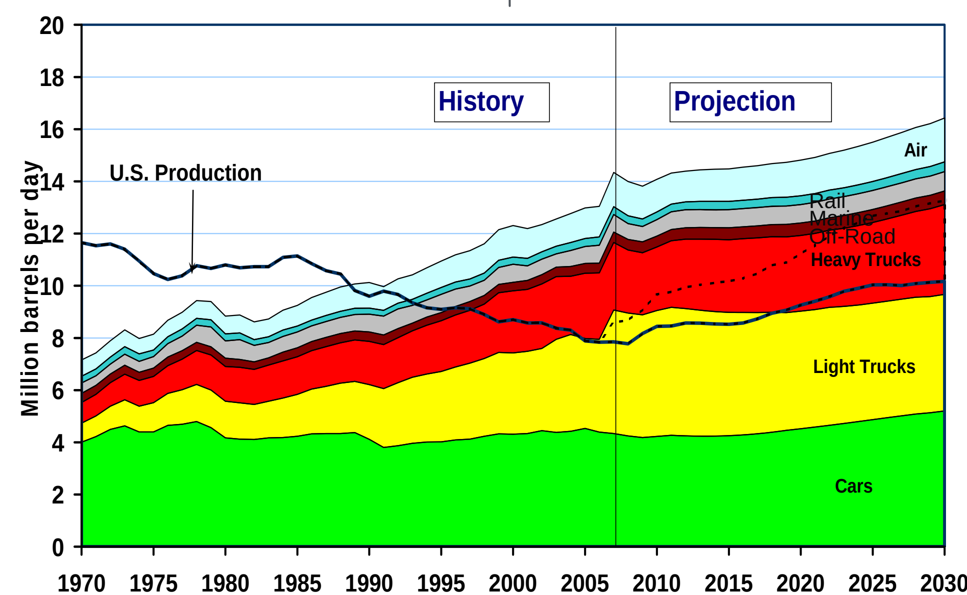
2007 Trans. CO2 Emissions 32% of Total U.S.



Automotive Technology Penetration

Years After Initial Significant Use





Analysis Informs Strategy

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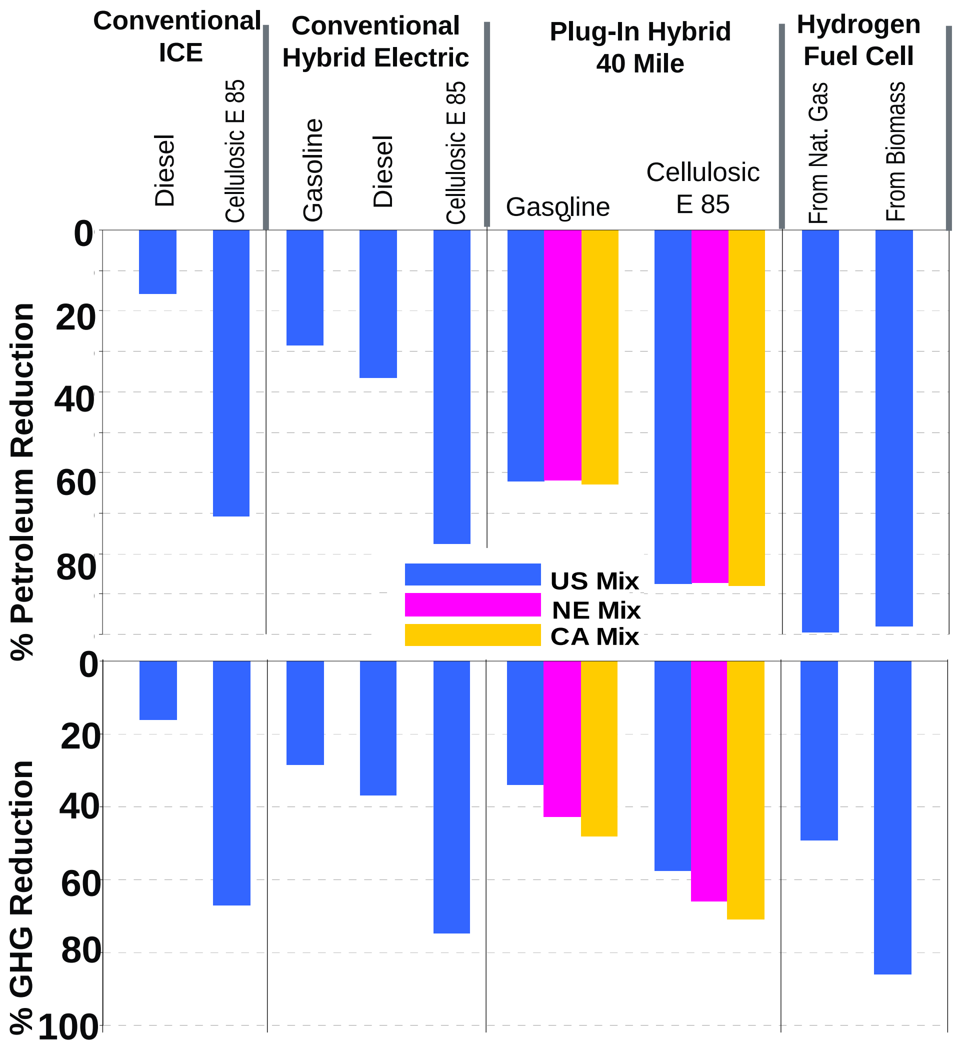
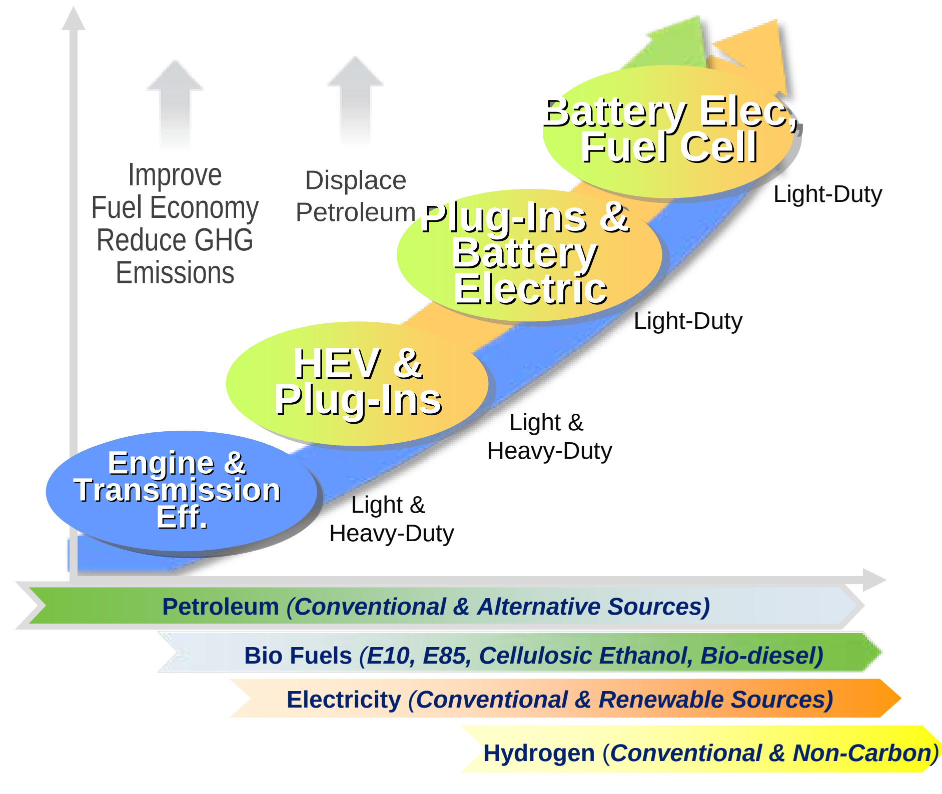
Well-to-Wheels Petroleum/GHG Reduction By Vehicle Type





Key Focus Areas

- Improved Eff. of engines (25-40%)
- Powertrain Electrification (2.5X current MPG)
- Lightweighting to Improve Efficiency (30%)
- Alternative Fuel Utilization (2B gallons/yr by 2020)

Hybrid-Electric Systems

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Petroleum Displacement through Fuel Substitution and Improved Efficiency

Administration Goal: 1 Million PHEVs by 2015

Types of Vehicles and Benefits

HEV →

Toyota Prius → **50 MPG**

- 1 kWh battery
- Power Rating: 80kW
- System Cost: $3000

PHEV →

Chevy Volt → **~100 MPGe**

- 16 kWh battery
- Power Rating: 170kW
- System Cost: est. $16,000

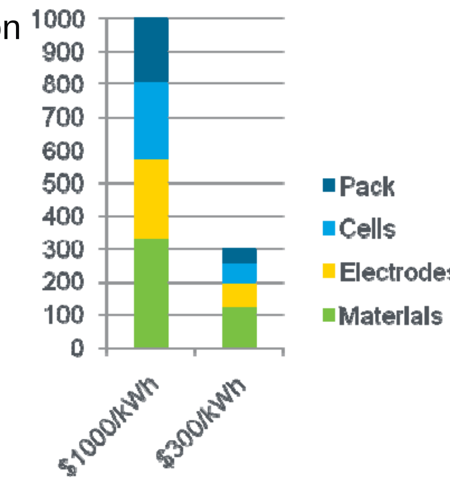
EV →

Nissan Leaf → **All Electric**

- ≥ 40 kWh battery
- Power Rating: ≥ 110kW
- System Cost: est.$36,000

Battery Cost Reduction

- Cell materials & fabrication represents about 3/4 the cost for PHEV batteries
- For significant cost reduction, new materials with increased energy density are needed to reduce:
  - material needs
  - cell count, and
  - cell/pack hardware



Status and Targets

2009 Status	*Targets*
Status: $8000-$12,000 for a PHEV 40-mile range battery **Status:** Current cost of the electric traction system is $40/kW	***2014 PHEV***: Battery that has a 40-mile all-electric range and cost $3,400 ***2015 PEEM***: Cost for electric traction system no greater than $12/kW peak by 2015

Battery Chemistry Comparison

Lithium Ion Chemistry	Type I	Type II	Type III	Type IV
Life	🙂	☹	😐	😐
Power	😐	🙂	😐	🙂
Energy	🙂	😐	😐	☹
Abuse tolerance	☹	😐	🙂	🙂
Materials cost	😐	😐	☹	😐
Nominal Voltage	3.6	3.8	3.3	2.5

Increasing engine efficiency is one of the most cost-effective approaches to increasing fuel economy

Benefits All Vehicle Classes

Light-Duty

Cars
- Power Rating: 100-300hp


Trucks
- Power Rating: 200-400hp

25-40% Improvement

Heavy-Duty

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



Up to 50% Improvement

Targets

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

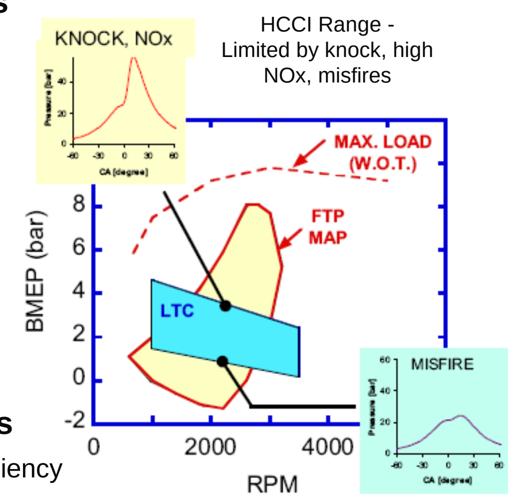
2015 Commercial Engine: Improve commercial engine efficiency by more than 20%; compared to 2009 baseline

2015 HEV & PHEV Improvements:
Could provide >70 MPG HEV

R&D Focus

Advanced Combustion Regimes (HCCI / low temp combustion)

- Demonstrate diesel-like efficiency (>45%) with less than 0.07 g/mi NOx emissions
- Complex combustion modeling for fuels -reduce reaction paths from thousands to less than 100
- Computational fluid dynamics (CFD) engine models for HCCI - reduce processing time by 90% for use by industry

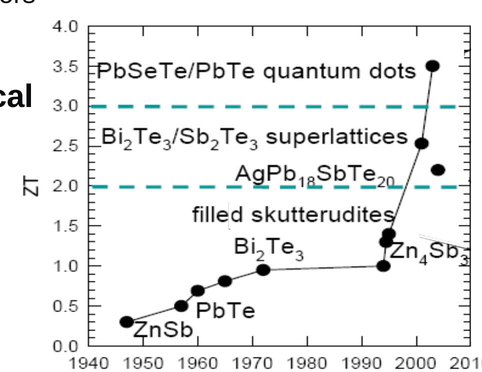


Emissions Control Technologies

- Improve NOx catalyst conversion efficiency by 50%. Integrate four after-treatment components into one and reduce cost by 50%.
- Develop on-board diagnostics and sensors such as 50ms response NOx sensors

Waste Heat Recovery – Mechanical and Thermoelectric Devices

- Increase practical ZT from 1.2 (current) to >2 for 20% conversion efficiency
- Increase durability of the thermoelectric systems for 15 year life
- Develop capability to process 12K tons/yr of thermoelectric material



"Support improved mileage performance of internal combustion engines…" – Secretary of Energy Steven Chu

Advanced & Alternative Fuels

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Direct Displacement of Petroleum and Enabling Advanced Engine Technology

Ethanol “Blend Wall” is approximately 11-15 billion gallons per year with E10

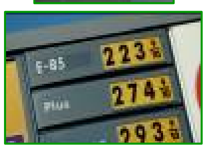
Technologies and Benefits

LD Fuels

- 7B gallons displaced in 2008
- Renewable and synthetic fuels, such as E85 and F-T
- Little consumer sacrifice and currently available
- Opportunity for greater optimization with some blends

HD Fuels

- 250M gallons displaced in 2008
- Biodiesel & 3rd Generation Renewable Fuels
- Easier deployment with larger fleets`



Advanced Conventional Fuels

- Fuel savings not direct displacement
- Enabling technology for advanced engine technologies
- Mostly compatible with existing infrastructure

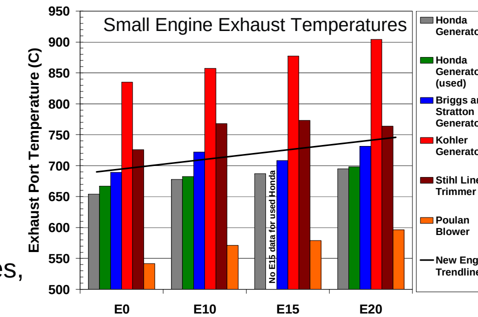
Targets and Status

2009 Status	*Targets*
2009: Intermediate blends testing in support of E15 waiver on-track to finish 2010. **2009:** Approximately 10.5 billion gallons of renewables used	**2011 Target:** Have definitive answer on viability of E15 and B20 **2022 Target:** Attainment of RFS II mandate – 36 B gallons/year including expanded E85 use

R&D Focus

i-blends:
Can legacy vehicles run on Intermediate EtOH blends

- Emissions results looks similar to E0. Catalyst temperature increase seen.
- Testing 79 vehicles (26 models) up to 120,000 miles - long-term durability effect on NMHC, CO, NOx, and toxics
- $38M project includes emissions, durability, driveability, and materials compatibility for vehicles, small engines, and infrastructure

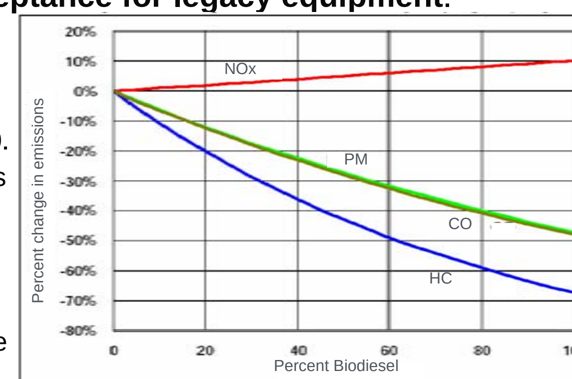


E85 Optimized FFV Engines – Increase use of E85 by decreasing the fuel economy penalty of ethanol

- Eliminate half of energy content penalty by taking advantage of higher octane
- Utilizing turbo-charging, variable valve timing, direct injection, and compression ratio increase to achieve 15% increase in fuel efficiency with E85

Biodiesel - Increase acceptance for legacy equipment.

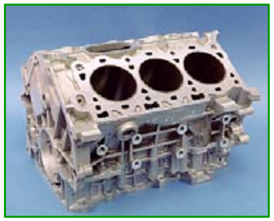
- Determining effect of B20 on emissions and after-treatment systems → 12% / 48% reduction -in PM for B20/B100.
- Developing codes & standards for acid value, cloud point, water interfacial tension, etc.
- B20 recently approved for use in 2011 Ford light-duty trucks (46% U.S. diesel market share in 2009



Materials Development

Vehicle lightweighting is one of the most cost effective ways of reducing fuel consumption resulting in a 6-8% improvement in fuel economy with every 10% reduction in vehicle weight

Types of Materials and Benefits



Magnesium

25-35% Lighter than a Aluminum Engine Block and 45-55% Lighter Compared to Cast Iron

Carbon Fiber

50-60% Lighter than a Standard Steel Body in White

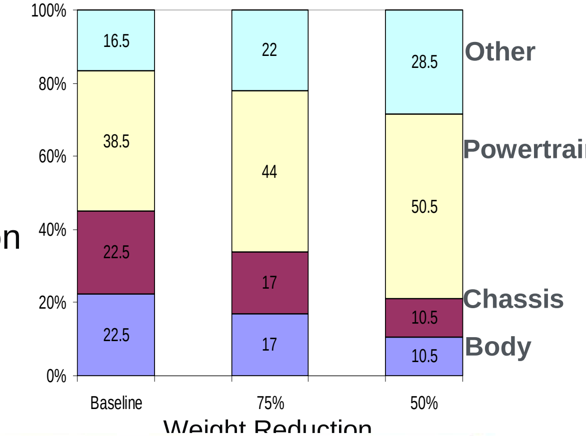
Targets and Status

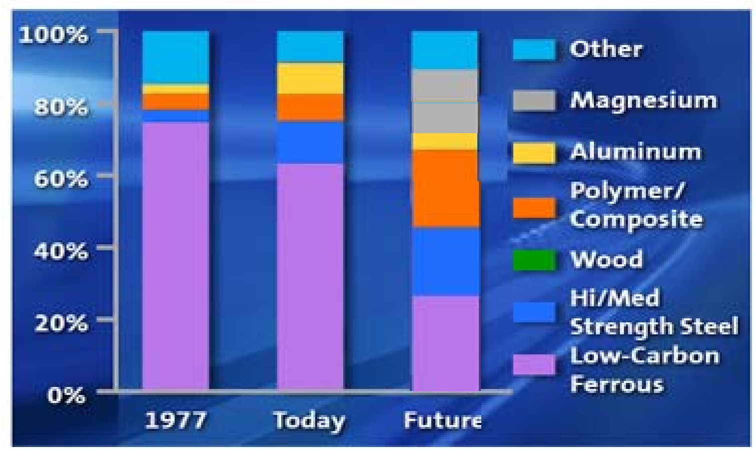
2009 Status:
Modeling demonstrated that body and chassis weight reduction goal of 40% could be achieved, *but not at cost parity*.

2010 Target:
Cost-effectively reduce the weight of passenger vehicle body and chassis by 50% in high volume applications compared to 2002 vehicles.

Weight Reduction of 50% Possible

- Through weight decompounding only 20-25% of primary weight reduction required
- Key Materials: Carbon fiber, Mg alloys, high strength steel
- Changes vehicle weight distribution





Weight Decompounding is an iterative solution: Lower overall weight reduces the engine size required, which in turn reduces weight, which in turn allows the vehicle structure to be reduced, etc.

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Demonstrate a 50% improvement in freight efficiency by 2015

Heavy-duty trucks use 20% of the fuel consumed in the United States.
Fuel economy improvements in these trucks directly and quickly reduces petroleum consumption

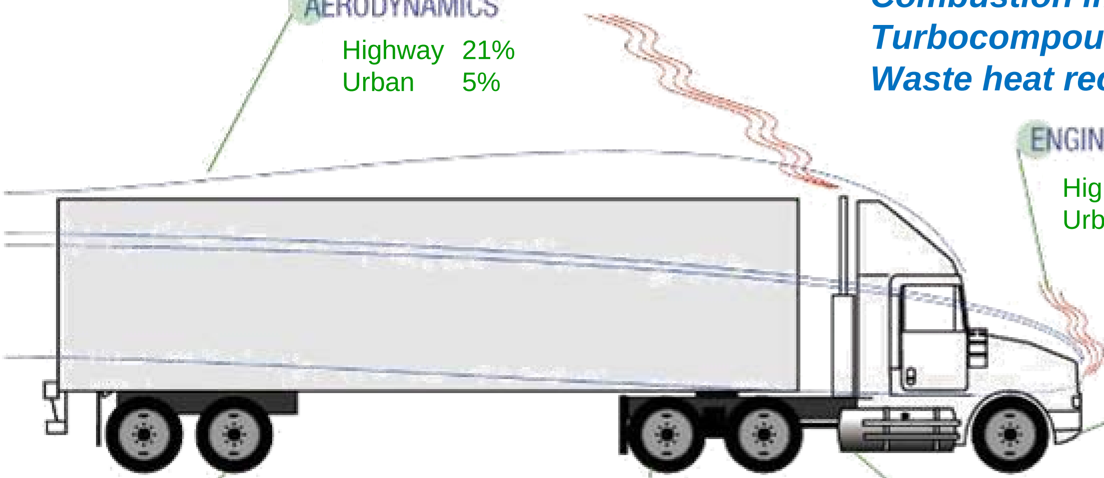
Energy losses in Class 8 trucks and opportunities for efficiency improvements

Trailer skirts
Gap reduction
Tractor/trailer integration (major redesign)

AERODYNAMICS
Highway 21%
Urban 5%

Combustion improvements
Turbocompounding
Waste heat recovery

ENGINE
Highway 59%
Urban 58%



AUXILIARIES
Highway 2%
Urban 7%

Electric accessories

ROLLING RESISTANCE
Highway 16%
Urban 9%

New generation wide base single tires
Tire rubber compound
Central tire inflation

INERTIA/BRAKING
Highway 0%
Urban 16%

Hybridization

DRIVETRAIN
Highway 2%
Urban 5%

Reduced drivetrain friction
Automated manual transmissions

Outreach and Deployment

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Providing a new generation of engineers with knowledge/skills in advanced vehicle technologies

Advanced Vehicle Competitions

Since 1987, DOE has sponsored more than two dozen university-level competitions, providing engineering students an opportunity to conduct hands-on research and development. EcoCAR has 17 teams pursuing a variety of advanced vehicle technologies

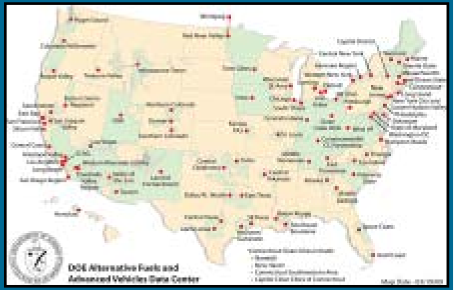
EcoCAR The NeXt Challenge | U.S. DEPARTMENT OF ENERGY | GM | Argonne | Government of Canada | Gouvernement du Canada

Graduate Automotive Training Education

Eight Centers of Excellence

University of California-Davis, Virginia Tech, Pennsylvania State University, The Ohio State University, University of Michigan-Dearborn, University of Tennessee, University of Illinois, Champaign-Urbana, University of Alabama-Birmingham

Clean Cities



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

Focus

- Petroleum & Emissions Reduction
- Vehicles and Infrastructure
- Education and Outreach
- Economic Opportunities

Unique Assets

- Local Strategy Advances Nat. Goal
- Coordinators
- Coalitions
- Technical Information/Resources

www.fueleconomy.gov

http://www.afdc.energy.gov/afdc/

External Review/Strategic Input

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2009 Annual Merit Review

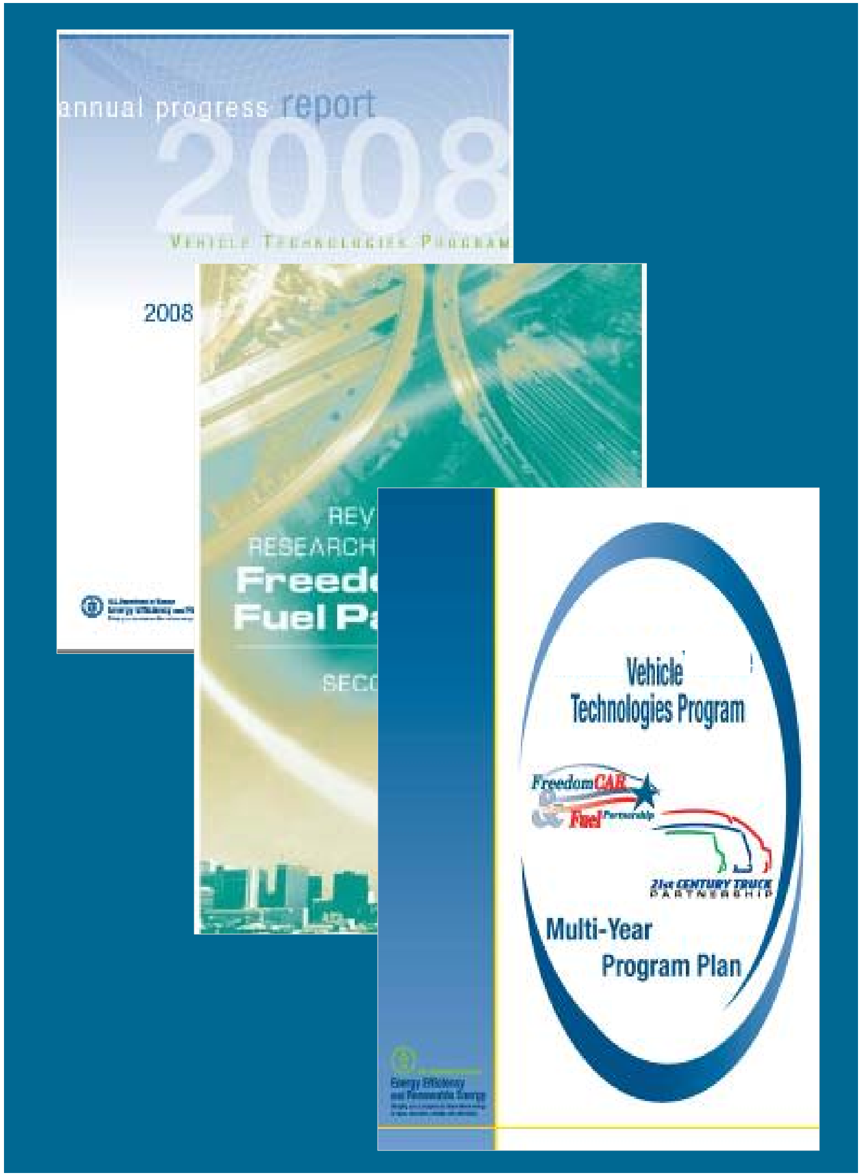
- Every project is reviewed at least every other year (2/3 of all projects reviewed every year). 2009 review included more than 140 reviewers, including internationally recognized experts from consultancies, government, industry, laboratories, trade organizations and academia.

NAS Review of FreedomCAR & Fuel Partnership

- *NAS 2nd review of the partnership completed in April of 2008*
- 3rd review is currently underway. Review committee includes 19 recognized experts from academia and industry.

Multi-Year Program Plan

- VT Program Plan was last published in 2007. Vehicle Technologies has launched a revision process, with an updated plan scheduled for publishing in 2010.
- 2010 Plan will be written internally and vetted through a public comment process.



Collaborations

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Hybrid-Electric Systems ($125M)

General Motors•Brigham Young U•Lawrence Berkeley National Laboratory •MIT•A123•State U. of New York, Binghamton & Stony Brook•U.C, Berkeley•U. of Michigan•Chrysler•U of Pittsburgh•Argonne National Laboratory•U of Texas•U of Utah•Johnson Controls•Embry Riddle Aeronautical U.•Georgia Tech•Howard U.•Michigan Technological U.•EnerDel• Mississippi State U.•Missouri U. of Science and Technology• Brookhaven National Laboratory•3M•North Carolina State U.•The Ohio State U.•Pennsylvania State U.•National Renewable Energy Laboratory•SAFT•Rose-Huleman Institute of Technology•Texas Tech U.•U. of Ontario Institute of Technology •U. of Victoria•U. of Waterloo•U. of Wisconsin•West Virginia U. •UC Berkley•Oak Ridge National laboratory•Ford Motor Co.

Combustion R&D ($41M)

Fuels Collaborations

Materials Collaborations

Automotive Composites Consortium•Ford•University of Tennessee Chrysler•Chinese Ministry of Science and Technology United States Automotive Materials Partnership •Argonne National Laboratory •Mississippi State University• Natural Resources Canada•Auto/Steel Partnership • University of Virginia•the Vehicle Recycling Partnership •Virginia Tech•Plastics Division of the American Plastics Council•Pacific Northwest National Laboratory•the American Foundrymens Society•General Motors•Oak Ridge National Laboratory•the North American Die Casting Society

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.

Clean Cities: Petroleum Displacement through Alt 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.