Overview of the U.S. DOE Vehicle Technologies Program

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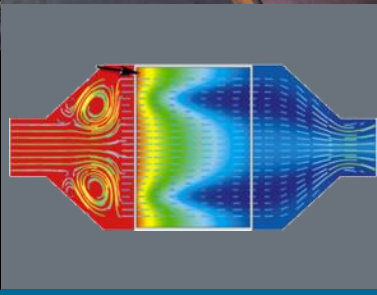
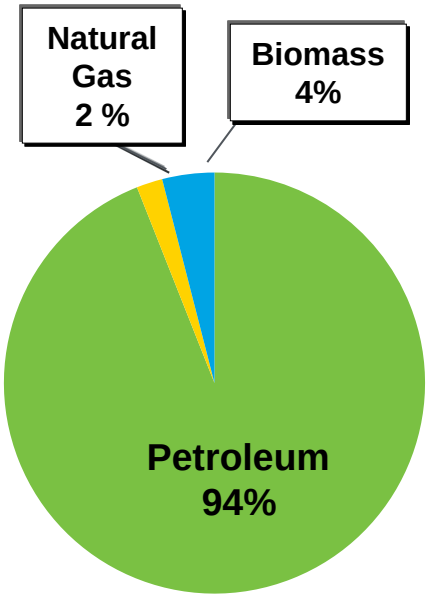
Office of the Vehicle Technologies Program
Energy Efficiency and Renewable Energy
U.S. Department of Energy

U.S. DEPARTMENT OF ENERGY
DEER 2012 DEARBORN
DIRECTIONS IN ENGINE-EFFICIENCY AND EMISSIONS RESEARCH CONFERENCE

18TH CONFERENCE ON ENGINE-EFFICIENCY AND EMISSIONS RESEARCH
October 15-19, 2012
HYATT REGENCY DEARBORN | DEARBORN, MICHIGAN



Transportation is Highly Dependent on Oil



U.S. Transportation Fuel Share (2010)

- Transportation is responsible for over 2/3 of our petroleum usage
- On-road vehicles responsible for ~80% of transportation petroleum usage
- About 1/3 of U.S. GHG emissions from transportation

Oil Dependency

World Oil Production Has Grown Slowly

2005: 84.58 mbpd
2006: 84.54 mbpd
2007: 84.40 mbpd
2008: 85.37 mbpd
2009: 84.24 mbpd
2010: 87.30 mbpd
2011: 88.40 mbpd

- Economic security
- Energy security
- Environmental Stewardship

The Cost of Oil is Not Just Monetary

U.S. DOE/EERE Is Investing in Five Main Technologies

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Electric vehicles

Advanced ICEs

Natural gas

Advanced biofuels

Hydrogen fuel cells

Vehicle Technologies Program

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Batteries and Electric Drive
- Advanced Batteries
- Advanced Power Electronics,
- Electric Motors & Traction Drive Systems

VSST
- Validation
- Aerodynamics, Rolling Resistance & Accessory Loads
- Modeling
- Codes & Standards

FY 2012 Budget - $330M

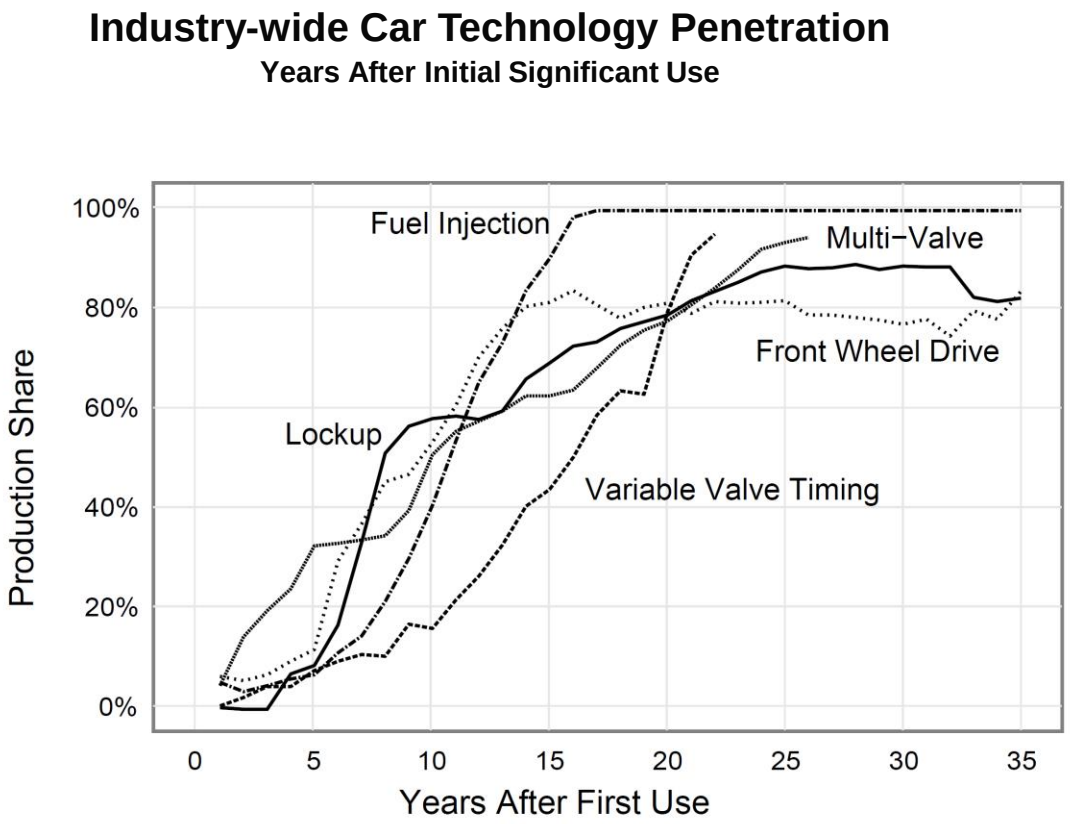
Outreach, Deployment and Analysis
- Deployment – Clean Cities
- EPAct/EISA
- Rulemaking
- Student Competitions
- Graduate Automotive Technology Education

Materials Technology
- Lightweight low cost structural composites
- Lightweight metals improved properties, processing, cost
- Predictive tools
- Multimaterial enabling: joining, corrosion
- Materials enabling higher efficiency propulsion systems

Advanced Combustion Engine R&D
- Combustion R&D (low temperature combustion, lean-burn, direct injection)
- Emission Controls and Aftertreatment
- Light- & Heavy-Duty Engine Efficiency
- Solid State Energy Conversion

Fuels Technology
- Drop-In Biofuels
- Clean/Efficient Combustion Fuel Characteristics
- Synthetic/Fischer-Tropsch Fuels
- Advanced Lubricants

Realizing Benefits of Vehicle Technology Takes Time



U.S. Vehicle Market

- About 240 million light-duty vehicles on the road
- Approximately 12.7M new cars & light trucks sold in 2011; ~11M sold through September for 2012.
- Hybrid vehicles at 3% of sales
- Sales of plug-ins showing significant growth

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 2011, EPA420-R-10-023, 2012, p. 72

EV Everywhere Grand Challenge

Goal: Enable U.S. companies to produce electric drive vehicles that are as affordable and convenient for the average American family as today's gas-powered vehicles within the next 10 years (by 2022).

- Midsize sedan, majority of miles driven on electricity,
- < 5 year payback
- Sufficient range and fast charge capability for widespread adoption

- EV-Everywhere Framing Document is under development.
- Stakeholder workshops have been completed
- Roll Out of Initiative details expected in the Fall 2012

Battery R&D

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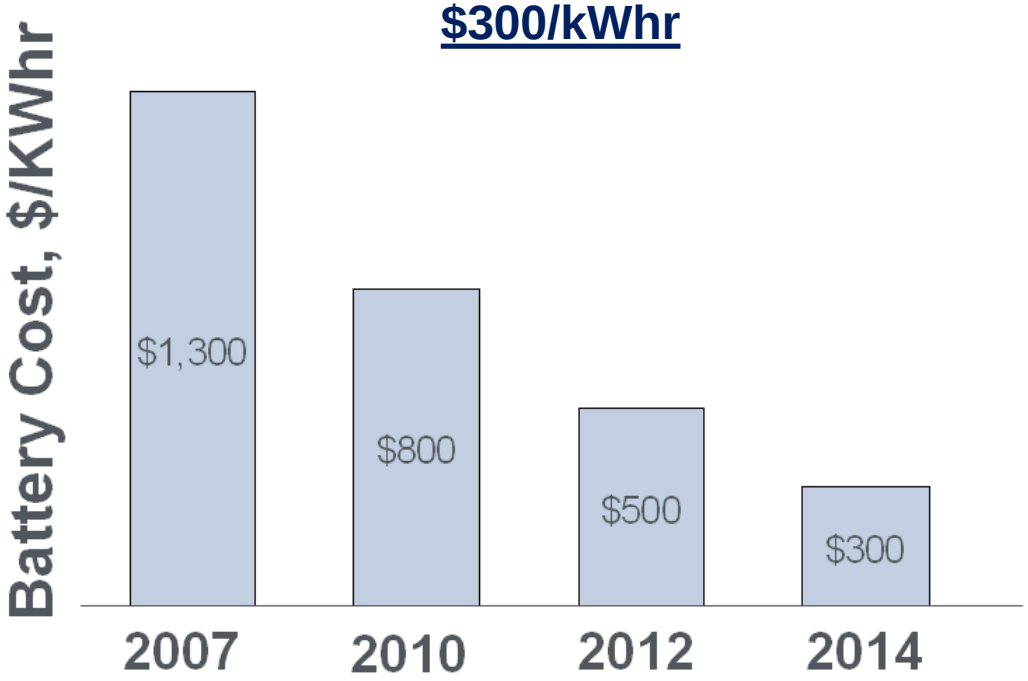
Plug-In Hybrid Battery Cost on Track to Meet 2014 Goal of $300/kWhr



Future Direction

- Emphasize cost reduction, durability, safety, and increased specific energy:
  - Innovative development efforts and manufacturing improvements with potential to reach cost goals.
  - Continue development of high voltage, high capacity cathodes and high voltage electrolytes
  - Develop Silicon Composite & Metal alloy materials and cells
  - Expand focus on beyond-Lithium-ion technology

Goal: By 2015, reduce the cost of a PHEV40 battery to $300/kWh; to $150/kWh by 2020

Status:
- On track to meet cost target of $500/kWh in FY12.
- Calendar life up to 10-15 years
- Cycle life between 3,000-5,000 deep discharges

Advanced Power Electronics and Electric Motors R&D

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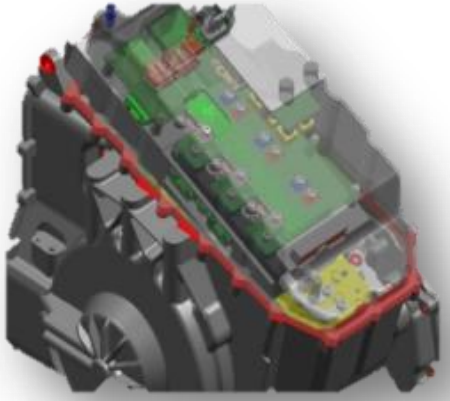
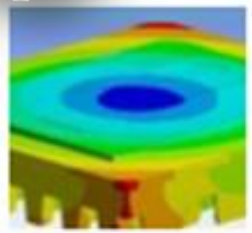
Accomplishments

- Integrated Electric Traction System (ETS) developed with GM exceeded 2010 R&D targets
- Assessed 29 technologies; filed 41 patents
- Working with suppliers, detailed component specifications were developed which led to lower cost components and increased available supplier base





	2010	GM
Cost, $/kW	<19	<16
Specific power, kW/kg	>1.06	>3
Power density, kW/L	>2.6	>5
Efficiency	>90%	>90%

Goal: By 2015, reduce cost of technologies for electric traction drive to $12/kW; and to $8/kW by 2020.

Future Direction

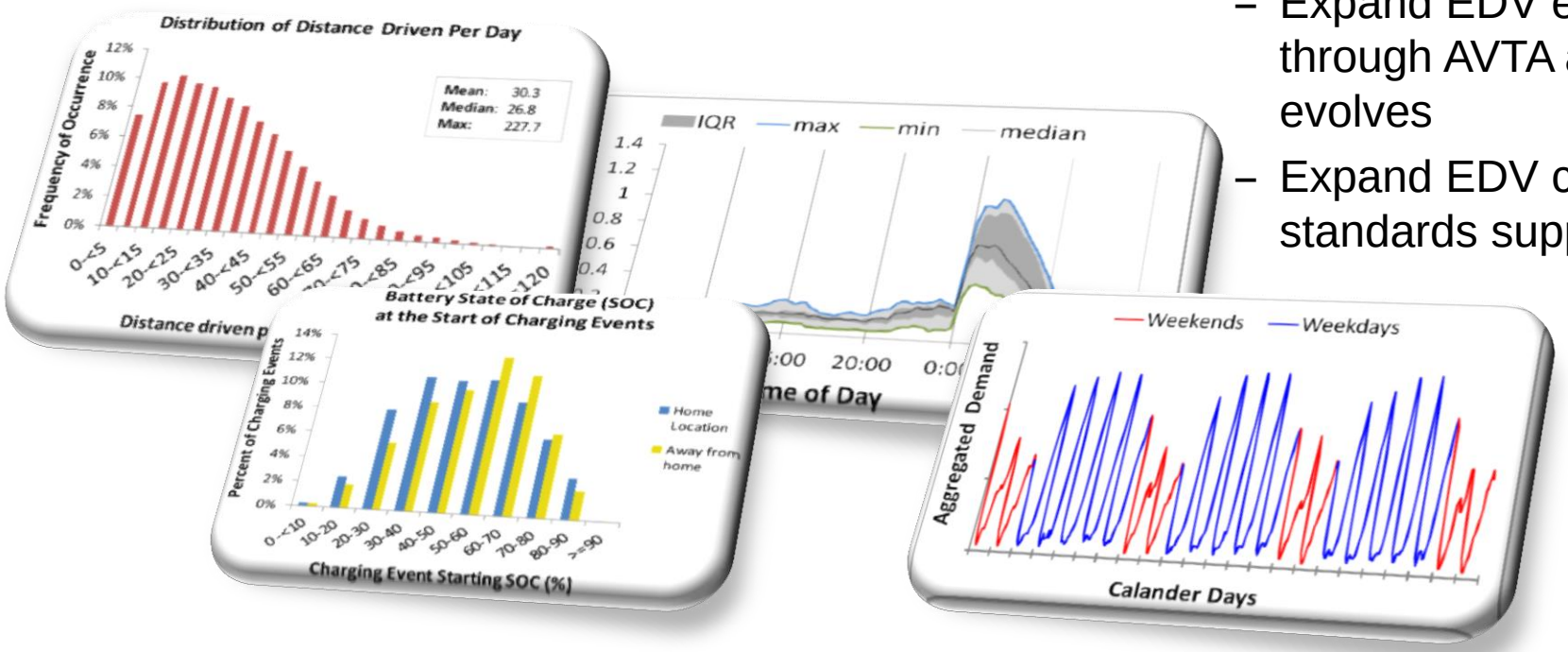
- Emphasize cost reduction of electric traction drive systems:
  - Non-rare earth motors
  - Wide bandgap based designs to increase switching frequency, efficiency, and operating temperature
  - Manufacturability
  - Thermal management
  - Reliability

Status:

- On track to meet cost target of $17/kW in FY12
- Met cost target of $18/kW in FY11
- Achieved FY10 traction drive system cost goal - GM traction drive system development

Vehicle & Systems Simulation & Testing

- Use data on 13,000 vehicles and 20,000 charging locations:
  - 130,000 PHEV/EV test miles and 5,000 charging events documented each day
  - Full details of every charging event and vehicle trip are captured
  - http://avt.inel.gov/index.shtml



Future Direction

- Support electric-drive vehicle (EDV) market transformation:
  - Wireless Charging RD&D
  - Auxiliary load reduction / Advanced HVAC RD&D
  - Expand EDV evaluations through AVTA as market evolves
  - Expand EDV codes & standards support

Materials Technology

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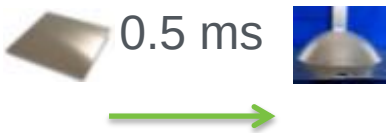
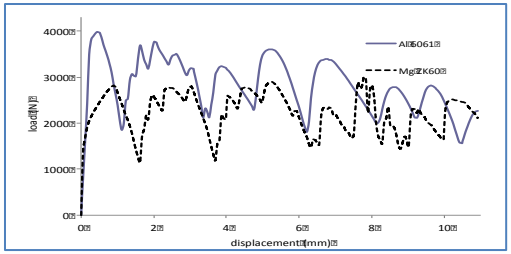
Accomplishments

- **Multimaterial joining** – Mg laser-assisted self piercing rivet and friction stir weld (USAMP)
- **Room temperatures processing of Al alloys lowers cost -**Pulse pressure forming enables **2.5x to 6x** increase in safe strains (PNNL)
- **Non-Rare Earth Mg alloy provides good properties using domestically available materials -** Significantly improve crash energy absorption (PNNL)
- **Propulsion Material-** SS alloy provides greater strength at higher temperatures (>750C), and lower cost by 33% (ORNL/Honeywell)

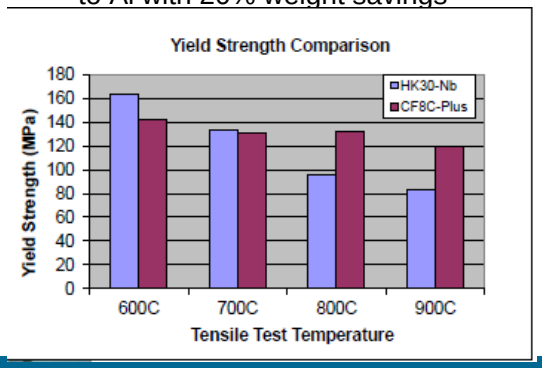
Joining demonstration: laser assisted (left) self piercing rivet and FSW (right)



Al RT Pulse Pressure Forming



Mg alloy with comparable crash energy to Al with 20% weight savings



Future Directions

- Predictive modeling of carbon fiber composites
- Predictive modeling of advanced steels
- Advanced alloy development for automotive and heavy-duty engines

Goals:

By 2015, validate cost-effective weight reduction of body and chassis systems by 50%

By 2016, develop pathway to 10% weight reduction in HDV suspension

Fuels Technology

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Accomplishments

- Initiated new industry and university R&D efforts:
  - Longer lifted-flame combustion
  - Expansion of RCCI engine operations
  - Reduced-friction, advanced base engine oils
  - Supplementary alcohol injection for improved combustion efficiency
- Completed 4-year testing program on intermediate ethanol-gasoline blends.
- Co-funded, with California state agencies, development of 3 medium-duty CNG engines.

Goal:

By 2015, demonstrate cost effective lubricant with 2% fuel economy improvement

Future Direction

- Increase emphasis on lubricant research:
  - Develop retrofittable low-friction lubes for use as drop-in replacement in existing vehicle engines
- Expand understanding and exploitation of fuel-controlled combustion
  - Example: RCCI
- Continue fit-for-service evaluations of candidate “drop-in” biofuels

Status:

Demonstrated greater-than-50% reduction in boundary friction in bench-top tests

VTP Deployment – Clean Cities
(leveraging people & resources)

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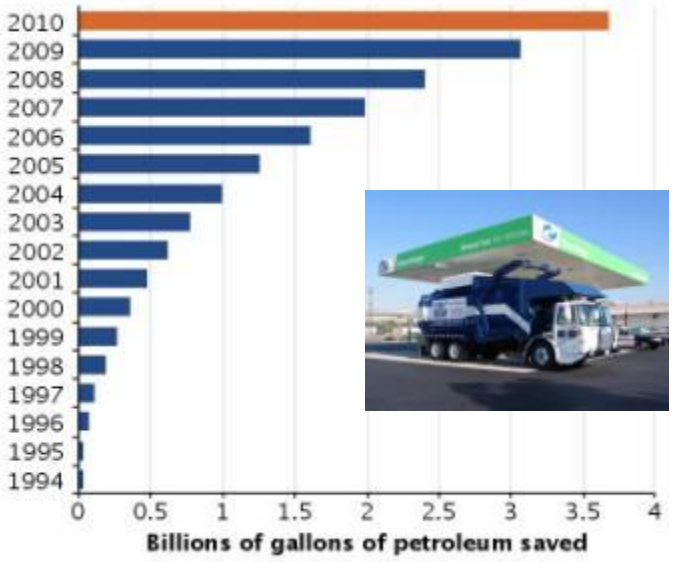
Accomplishments

- Saved nearly 4 billion gallons of petroleum (GGE) since 1993
- Created the National Clean Fleets Partnership with 20 large fleets
- Recent awards helped deploy over 1,500 stations and 8,500 vehicles

Future Direction

- Remove barriers and accelerate deployment of alt-fuel vehicles
- Focus on community readiness and sustainability, policy development, and removing market barriers



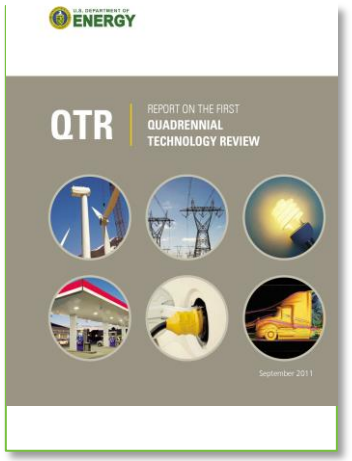
Clean Cities
U.S. Department of Energy

Near to Mid-term Opportunity for Reducing Transportation Oil Use

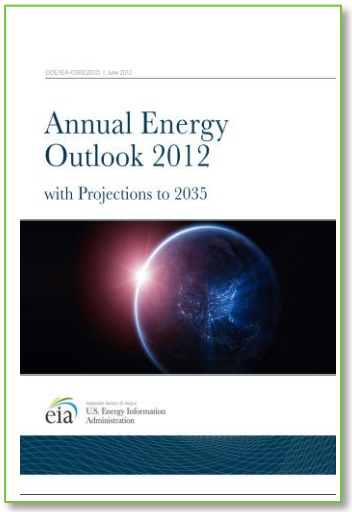
"The performance, low cost, and fuel flexibility of ICEs makes it likely that they will continue to dominate the vehicle fleet for at least the next several decades. ICE improvements can also be applied to both hybrid electric vehicles (HEVs) and vehicles that use alternative hydrocarbon fuels." DOE QTR 2011[1]

"…The internal combustion engine will be the dominant prime mover for light-duty vehicles for many years, probably decades …" NRC Report 2010[2]

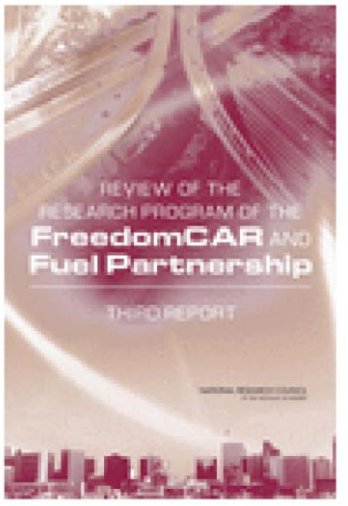
The EIA AEO 2012 reference case scenario projects that even by 2035, *99% of light- and heavy-duty vehicles sold will have ICEs.*[3]



DOE 2011



EIA/AEO 2012

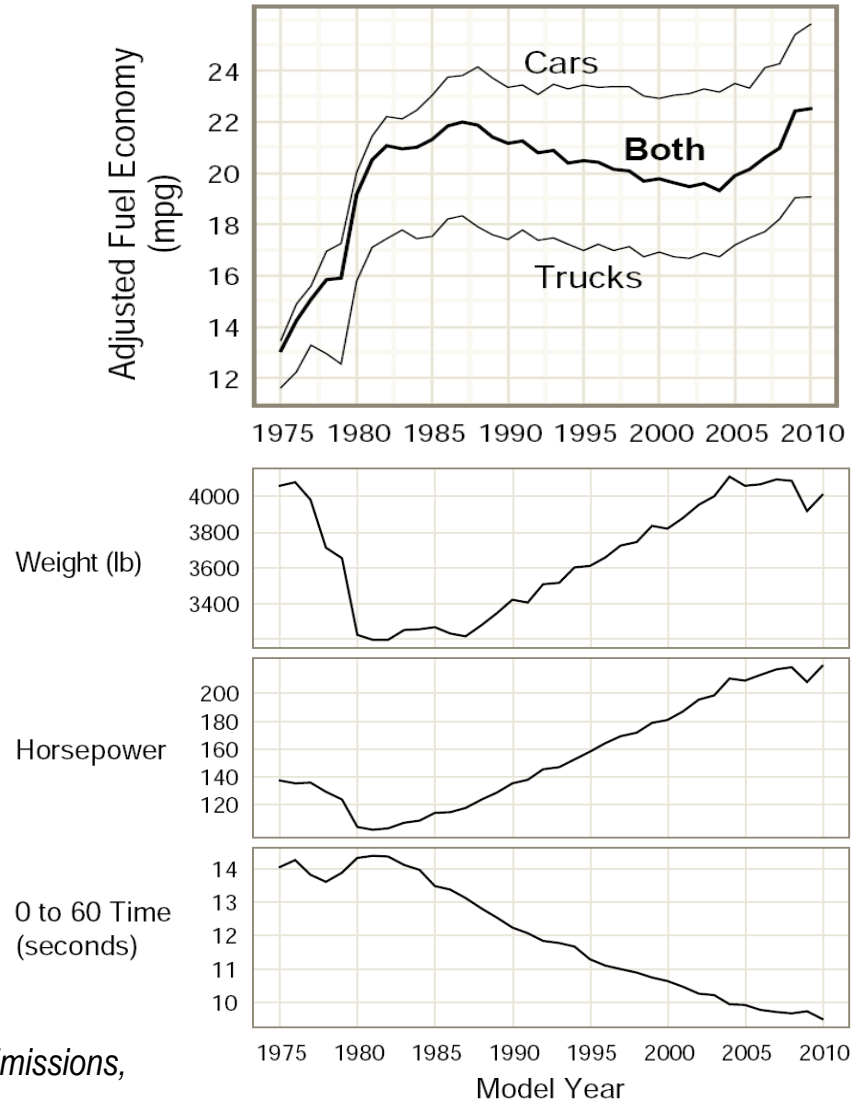


NRC 2010

[1] Quadrennial Technology Review, DOE 2011
[2] *Review of the Research Program of the FreedomCAR and Fuel Partnership: 3rd Report,* NRC 2010
[3] Energy Information Agency, *Annual Energy Outlook 2012,* June 2012.

Passenger Vehicle Fuel Economy Trends

Improvements in internal combustion engine performance (increased horsepower with smaller engines, reduced 0 – 60 mph acceleration time) largely responsible for maintaining or increasing vehicle fuel economy ***in spite of increases in vehicle weight and size***



Source: *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2011*, EPA 2012.

Advanced Combustion Engine R&D

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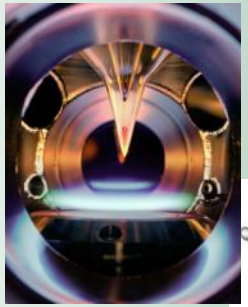
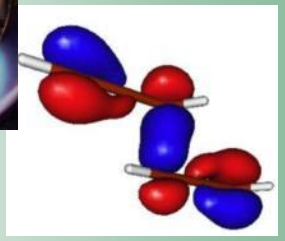
Basic Science

BES
Sustained support in 2 areas

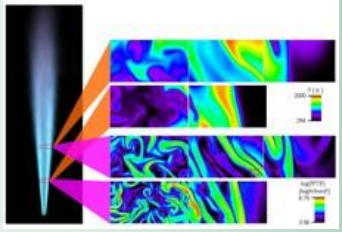
Development of predictive chemistry in model flames



Computational kinetics and experiments



Advance laser diagnostics applied to model flames

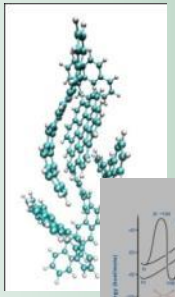


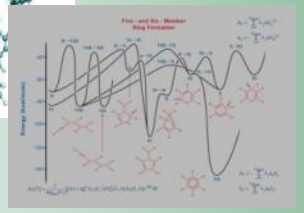
Laser-based chemical imaging

Applied R&D

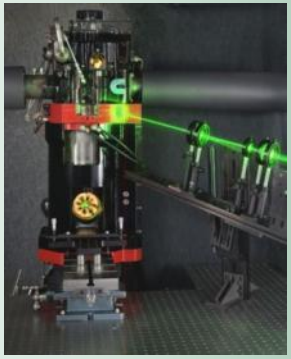
→ **EERE/VT/ACE R&D** →

Applications of chemistry and diagnostics to engines





Predictive chemical models under realistic conditions



Laser diagnostics of diesel fuel sprays in engine cylinders

Manufacturing/ Commercialization

Cummins and Dodge

Cummins used simulation tools and improved understanding of diesel fuel sprays to design a new diesel engine with reduced development time and cost and improved fuel efficiency.

ISB 6.7 liter Cummins diesel engine first marketed in the 2007 Dodge Ram pickup truck; more than 100,000 sold/year

Advanced Combustion Engine R&D

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Accomplishments

- Demonstrated pathway to combustion that could improve passenger vehicle fuel economy by over 50%. (SNL, UW)
- Demonstrated diesel-like efficiencies and low emissions on gasoline. (ANL)
- Ford's 2011 Super Duty diesel pickup truck utilizes DOE supported emission control technology.
- Heavy-duty multi-cylinder engine w/bottoming cycle reached 49% brake thermal efficiency.
- 1st gen. thermoelectric generators produced over 500 Watts on vehicle tests. (GenTherm)

Future Direction

- High-efficiency low temperature combustion technologies and lean-burn gasoline.
- Simulation codes that reduce design iterations and engineering design tools for validation of simulation models.
- Increase efficiency of NOx, PM and HC emission control systems focusing on low-cost base metal catalysts.
- High efficiency thermoelectric generators to improve vehicle fuel economy.

Goals:

Passenger Vehicles: By 2015, improve gasoline vehicle fuel economy by 25%, diesel vehicle fuel economy by 40%, compared to 2009 baseline; 35% and 50% improvements by 2020.

Commercial Vehicles: By 2015, improve commercial diesel engine efficiency by >20% compared to 2009 baseline, 30% by 2020.

SuperTruck Initiative at Halfway Point

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Status of 50% engine efficiency:

- 49% engine efficiency has been demonstrated
- Additional technologies identified
- Component tests being conducted

SuperTruck Concept

Status of 50% freight efficiency improvement:

- First generation demonstration tractors completed
- Aerodynamic designs for trailers completed
- Additional sub-systems including parallel hybrid, auxiliary power units, etc. developed and under test

Goals:

- **Demonstrate 50% engine efficiency at 65 mph and a pathway to 55%.**
- **Increase overall freight efficiency by 50% measured in ton-miles per gallon**

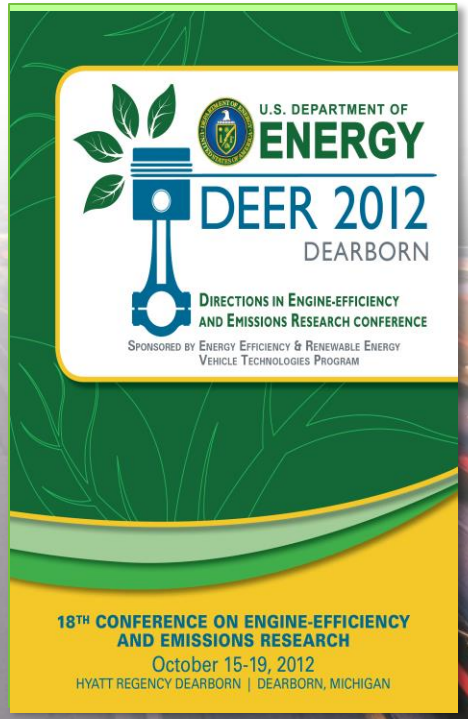
Participants: Cummins, Daimler, Navistar, and Volvo

2012 DEER Conference

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

The Premier International Engine Technology Conference: Featuring High-Level Speakers, Peer-Selected Papers, and Exhibits

- Grown from 50 attendees in 1993 to over 900 attendees each year since 2009.
- About 70 technical presentation over three days and over 50 poster presentations highlighting recent advances in engine technology.
- Ride and Drive of advanced technology vehicles.
- Provides opportunity for networking.
- DEER 2012 is 18th in the series.



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