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Energy Efficiency and Renewable Energy

freedomCAR & vehicle technologies program

Vehicle Technologies Overview

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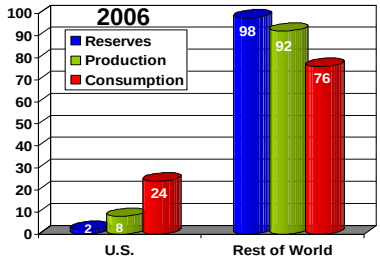
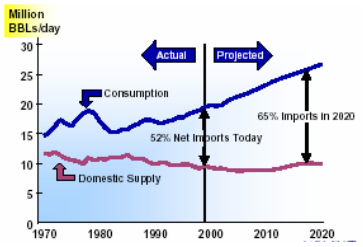
DOE Has a Transportation R&D Program Because the Nation Has an Oil Problem

- The current high oil prices reflect the increasing global demand for a limited energy resource: China is number 2 in oil use and India is 6th…and growing
- The U.S. consumes more oil than it has and demand is growing



Reliance on domestic oil is not sustainable.
We cannot drill our way out of the problem.



Historically, we have underestimated' the magnitude of the oil problem.
We already import more than 60%.

- Oil is predominately a transportation energy problem, with economic, environmental, and geopolitical concerns for the nation
- Oil is an energy security issue

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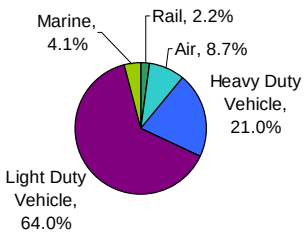
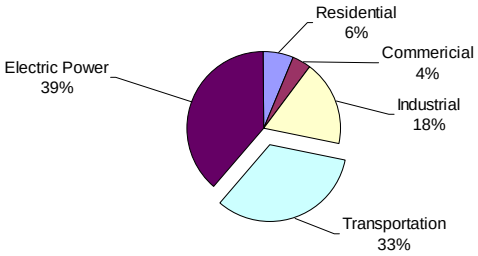
The Challenge

Transportation Petroleum Consumption by Sector



The transportation sector accounts for 2/3 of the oil use in the U.S. and is the fastest growing petroleum consuming sector.

Carbon Dioxide Emissions by End Use Sector



The transportation sector accounts for 1/3 of the CO2 released in the U.S. and one of fastest growing contributors to global warming.

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Strategic Considerations

- **Diversity:** Don't trade petroleum dependency for dependency on another resource.
- **Efficiency:** Large increases in efficiency lowers overall energy consumption.
- **Addressing greenhouse gas emissions and criteria pollutants**
- **A vehicle/fuel combination that the market will accept:**
  - Cost effective
  - Meets all typical expectations
  - Offers other advantages besides energy benefits
- **A solution capable of serving a HUGE market**
  - Current consumption 9-10MBD and growing
  - Requires multiple feedstocks/energy sources

To achieve a solution requires working with the industries that can commercialize the technology and serve the market.

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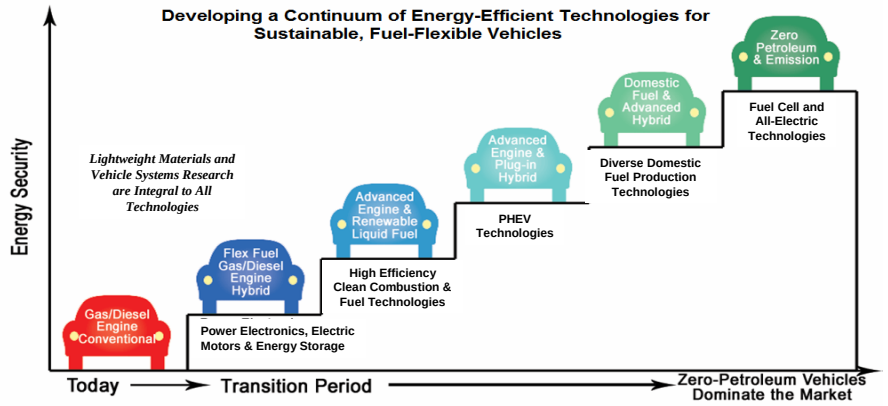
Strategic Approach to Transportation Energy Security



The FreedomCAR and Fuel Partnership is "… a very effective way to develop technologies that will satisfy all of the requirements for the deployment of radically new systems in the marketplace on a large scale."

NAS/NRC Review of the Research Program of the FreedomCAR and Fuel Partnership, August 2005

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Vehicle Technologies Program Budget

	FY 2008 Current Appropriation	FY 2009 Request
Hybrid Electric Systems	94,135	103,361
Advanced Combustion Engine	44,591	33,600
Materials Technology	39,636	36,903
Fuels Technology	17,836	16,122
Technology Integration	16,845	31,100
Total, Vehicle Technologies	213,043	221,086

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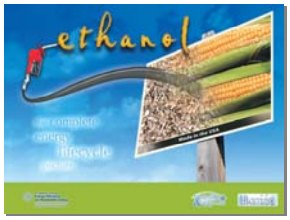
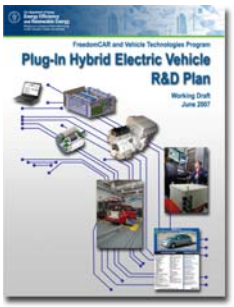
Opportunities to Reduce Petroleum Use

- Two major thrusts:
  - More efficient vehicles
  - Vehicles that use non-petroleum fuels
- DOE's Vehicle Technologies R&D portfolio
  - Advanced combustion engines
  - Fuels and lubricants
  - Energy storage
  - Power electronics and electric machines
  - Lightweight materials
  - Hybrid vehicle systems
  - Deployment activities
- Two promising directions
  - Ethanol: corn today, cellulosic tomorrow
  - Plug-in hybrid vehicles





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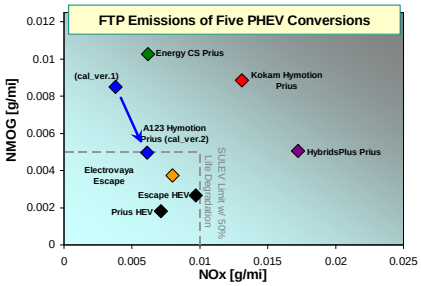
Plug-in Hybrids

- **DOE stakeholder meeting in May 2006 helped stimulate aggressive industry R&D**
- **Lessons learned in the lab and from modeling and simulation**
  - Validated that conversions can meet SULEV emissions level
  - Blended mode can be preferable to EV mode followed by charge sustaining mode
  - Electrical accessories (e.g., air conditioning) can greatly reduce AER or MPG
  - Battery energy more important than power for petroleum displacement
  - Knowing trip lengths in advance could save some additional fuel
  - Substantial petroleum displacement shown
    - 100% in EV mode, obviously
    - Up to 78% in blended mode demonstrated in lab
  - Fuel economy testing protocol needed
    - DOE lab leading the protocol procedure
    - J1711 balloting expected in summer 2008
- **Barriers to commercialization**
  - Batteries, batteries, and batteries
    - Cost
    - Safety
    - Calendar life and cycle life
  - Power Electronics
    - Cost
    - Weight
    - Volume



Data collected at Argonne National Lab

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Current PHEV Activities

- Issued a solicitation to conduct a large scale technology demonstration of PHEVs; initial award announcements soon.
- Solicitation issued for the development of advanced battery materials and manufacturing technology.
- Initiated a PHEV Value Proposition Study that will identify, characterize, and quantify several plausible business cases that can accelerate PHEV commercialization.
- Conducted detailed laboratory tests of every existing PHEV conversion available.
- Awarded ten R&D contracts totaling $36.2 million for development of high energy batteries, power electronics and electric motors for PHEVs. Industry cost share will bring the total funding of these projects to $77 million.

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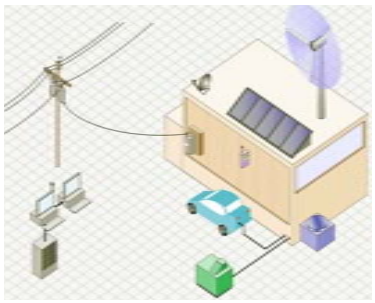
Utilities and States will need to support Plug-In Hybrids

- **AMI: Advanced Metering Infrastructure**
  - **– 2-way communication portal between grid and homes**
  - **– Enables load management, e.g. turning on/off Plug-In Hybrid Electric Vehicle (PHEV) charging**



- **Differential rate structures allow time of use metering and enable PHEVs to take advantage of lower rates at night and "valley-filling"**
- **Updates of utility codes and standards**

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Energy Storage

- **Lithium-ion batteries** are being aggressively pursued globally for EV/HEV applications, including several different electro-chemical and mechanical designs
  - Focus is on system integration, cost, and life
  - Safety and recycling remain to be demonstrated (for millions of laptop batteries as well)
  - Saft Li-ion technology (DOE supported R&D) will be produced in volume (TBD) for mild hybrids
  - Available technology does not meet the Administration's 40-mile electric range target for PHEVs
- **Capacitor combinations** with other battery chemistries (e.g., NiMH, Pb-Acid) are being evaluated – for potentially lower cost and shorter electric range

AESC = NEC + Nissan JV

Subaru

Saft/JCS

Photos by KSH

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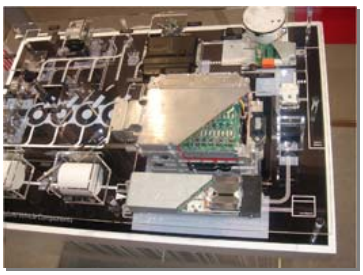
Power Electronics

- **Smaller, integrated systems**
  - Applications ranging from motorcycles to luxury cars
  - Integrated motors and power electronics available in small (motorcycle) systems
- State-of-the art power electronics is the **Denso converter** (Lexus 600h)
- Denso targeting **Silicon Carbide** (SiC) converter production for 2015+
  - Claims wafer production with the smallest level of defect density in the world, "hundreds per cm^2"
  - Cost must be reduced 50%



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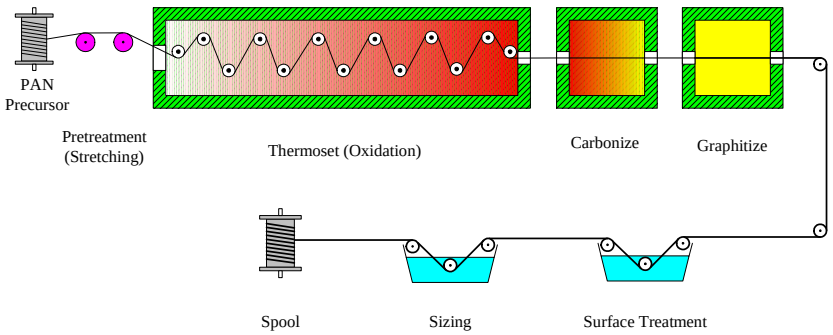
Low Cost Carbon Fiber



Typical processing sequence for PAN and pitch –based carbon fibers

Major Cost Elements	
Precursor	43%
Oxidative stabilization	18%
Carbonization	13%
Graphitization	15%
Other	11%

- Automotive cost target is $5 - $7/lb

  Tensile 250 ksi, 25 Msi, 1% ultimate strain
- Oak Ridge National Laboratory (ORNL) is attempting major technological breakthroughs for major cost elements

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Advanced Combustion and Emission Control R&D

Goal: Remove critical technical barriers to mass commercialization of high-efficiency, emissions-compliant internal combustion engine (ICE) powertrains

Primary directions

- ICE efficiency improvements for cars, light- and heavy-duty trucks through low-temperature combustion and minimization of thermal and parasitic losses
- Aftertreatment development integrated with combustion strategies for emissions compliance and minimization of efficiency penalty
- Coordination with fuels R&D to enable clean, high-efficiency engines

Goals	2010 (light-duty)	2013 (heavy-duty)
Engine brake thermal efficiency	45%	55%
Powertrain cost	< $30/kW	
NOx & PM emissions	Tier 2, Bin5	EPA 2010

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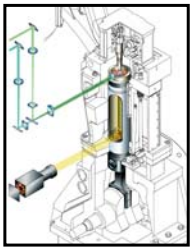
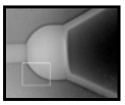
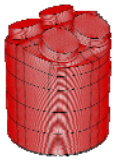
Research Approach

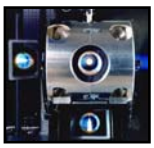
- Close collaboration between industry, national labs and universities
  - Research guided by industry needs
  - DOE/industry prototype engine projects
- Close coupled modeling and experiments
  - Multi-/single-cylinder engines & simulators
  - Advanced diagnostics
    - Optical-, laser-, and x-ray- based techniques
  - Multi-dimensional computational models
- Cross-cuts heavy-duty research


Optical Engine


Nozzle Sac X-Ray Image

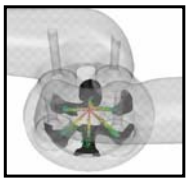

3-Million Cell LES Grid


Automotive HCCI


LTC Simulator


H2 Engine


Multi-Cylinder Diesel


Engine Simulation

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Expanding E85 Infrastructure

- We continue to support the expansion of the use of E85… *by focusing its deployment in areas in which it makes the most sense!*
  - Concentrated development of distribution/fueling infrastructure near production
  - High-traffic corridors
- Cooperative agreements and national laboratory projects focus on reducing or eliminating the fuel economy penalty associated with using E85
  - Awarded 7 E85 Engine Optimization Contracts
- Clean Cities consumer education and technical advice for retail fueling station operators and fleet managers

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20 in 10/EISA Goals Cannot be Met Solely Through Expansion of E10 Gasoline

- Ethanol markets are not able today to absorb the ethanol volumes specified by the Energy Independence & Security Act (36B gallons)
  - Today, blended gasoline used in standard vehicles (non-FFVs) is limited to 10 percent ethanol (E10).
  - More than 99 percent of the ethanol produced today is used in E10 blends; a tiny fraction is used to produce E85 for FFVs.
  - E10 markets are likely to saturate by 2012, 2013, possibly sooner, as production capacity approaches 14B gallons (~10% of all gasoline sold).
- There are two paths to increase ethanol markets beyond 14B gallons:
  - Path A: Saturate E10 markets – and significantly expand E85 markets at an accelerated pace
  - Path B: Certify "intermediate blends" of gasoline to use up to 15 or 20% ethanol (E15, E20) and let market forces drive ethanol supply distribution
- DOE is investigating the impact of Path B on the existing "legacy" fleet of vehicles and non-road equipment

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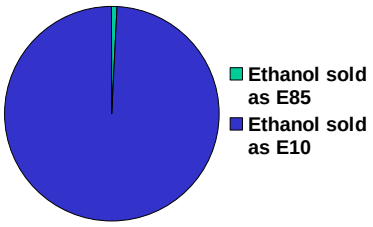
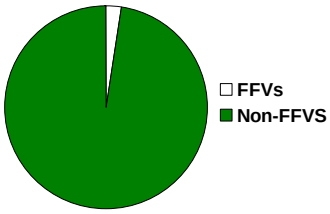
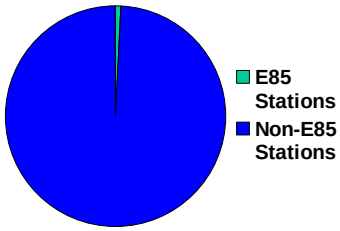
Nation has limited E85 Infrastructure







E85 Route to Solution:

For example, in order for E85 market to absorb 25 billion gallons of ethanol per year by 2017 we estimate that the US would need :

- 10 billion gallons per year of E85, 250X more than today.
- 100 million FFVs vs 6 million FFVs today.
- 60,000 E85 stations vs 1,200 today.

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DOE is Testing Intermediate Blends in Legacy Equipment

- The purpose of the testing is to determine what effects intermediate blends may have on existing vehicles and equipment
- This testing could aid EPA in their regulatory role regarding RFS2
- Published testing results will help EPA in considering potential future requests for "sub-sim" waivers

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Clean Cities *A voluntary, locally based government/industry partnership*

Mission: To advance the energy, economic, and environmental security of the U.S. by supporting local decisions to adopt practices that contribute to the reduction of petroleum consumption in the transportation sector.

TECHNOLOGIES

- **AFVs**
- **Fuel Economy**
- **Idle Reduction**
- **Fuel Blends**
- **HEVs**

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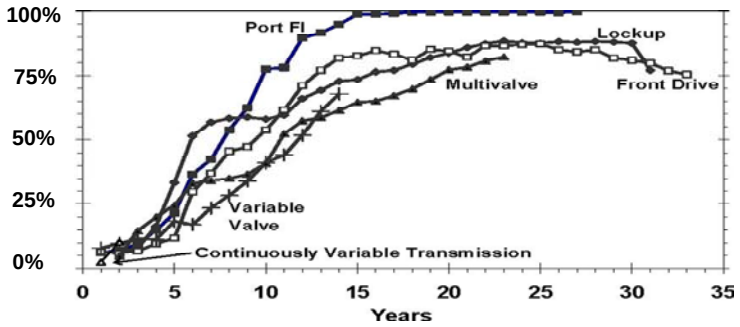
Faster Market Penetration

Through early R&D investments

It takes about 15 years for a technology to reach maximum penetration in new vehicle sales and another 15 years for the technology to be ubiquitous.



Policy and incentives can accelerate market penetration.

Light-Duty Automotive Technology and Fuel Economy Trends: 1975 Through 2006, EPA420-R-011, July 2006, p. 62

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Major Technology Success Stories

Deployed Technologies	Technology Partners	Policy Implications	Market Impact
Low Sulfur Diesel Fuel	NREL	Informed EPA of sulfur effects from fuel research	40B gallons of low sulfur diesel fuel used annually
Nickel Metal Hydride Batteries	Cobasys	Royalty payments to Treasury	Every US Hybrid Vehicle sold has IP from this battery research
Quick Plastic Forming of Aluminum	GM PNNL ORNL	Higher Energy Efficiency	Chevrolet Malibu MAXX 2004, Cadillac and GM Vehicles
Light Duty Diesel Engine	Cummins ORNL SNL	Higher Energy Efficiency for Light Vehicles	Agreement with DaimlerChrysler for 2009 volume production

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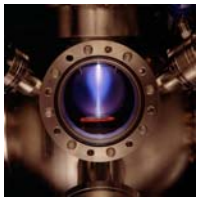
Office of Energy Efficiency and Renewable Energy

http://www.eere.energy.gov



Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable