# Vehicle Technology Programs

Thomas J. Gross
Deputy Assistant Secretary
Office of Transportation Technologies
Office of Energy Efficiency and Renewable Energy

Solid State Energy Conversion Alliance Workshop
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# Presentation Outline

- OTT Mission
- Vehicle Technology Programs
  - Light-Duty Vehicles
  - Heavy-Duty Vehicles
- Fuels R&D
- Fuel Cell Program
- SECA-Related R&D

# OTT Mission

...support the development and use of advanced transportation vehicles and fuels which will reduce energy demand, particularly for petroleum; reduce greenhouse gas emissions; and enable United States transportation to sustain a strong competitive position in domestic and world markets.

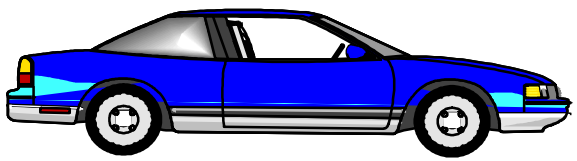
# Partnerships Are Key to Success

Clean Cities

Bioenergy Initiative

California Fuel Cell Partnership

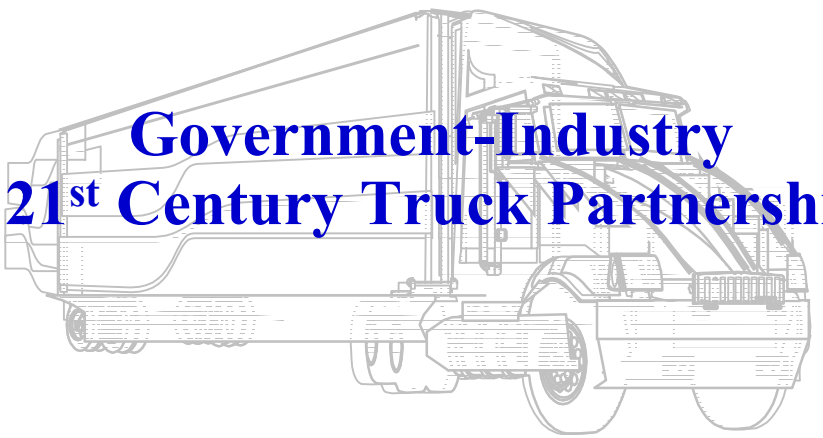
DRIVING FOR THE FUTURE



USAMP

PNGV℠

PARTNERSHIP FOR A NEW GENERATION OF VEHICLES



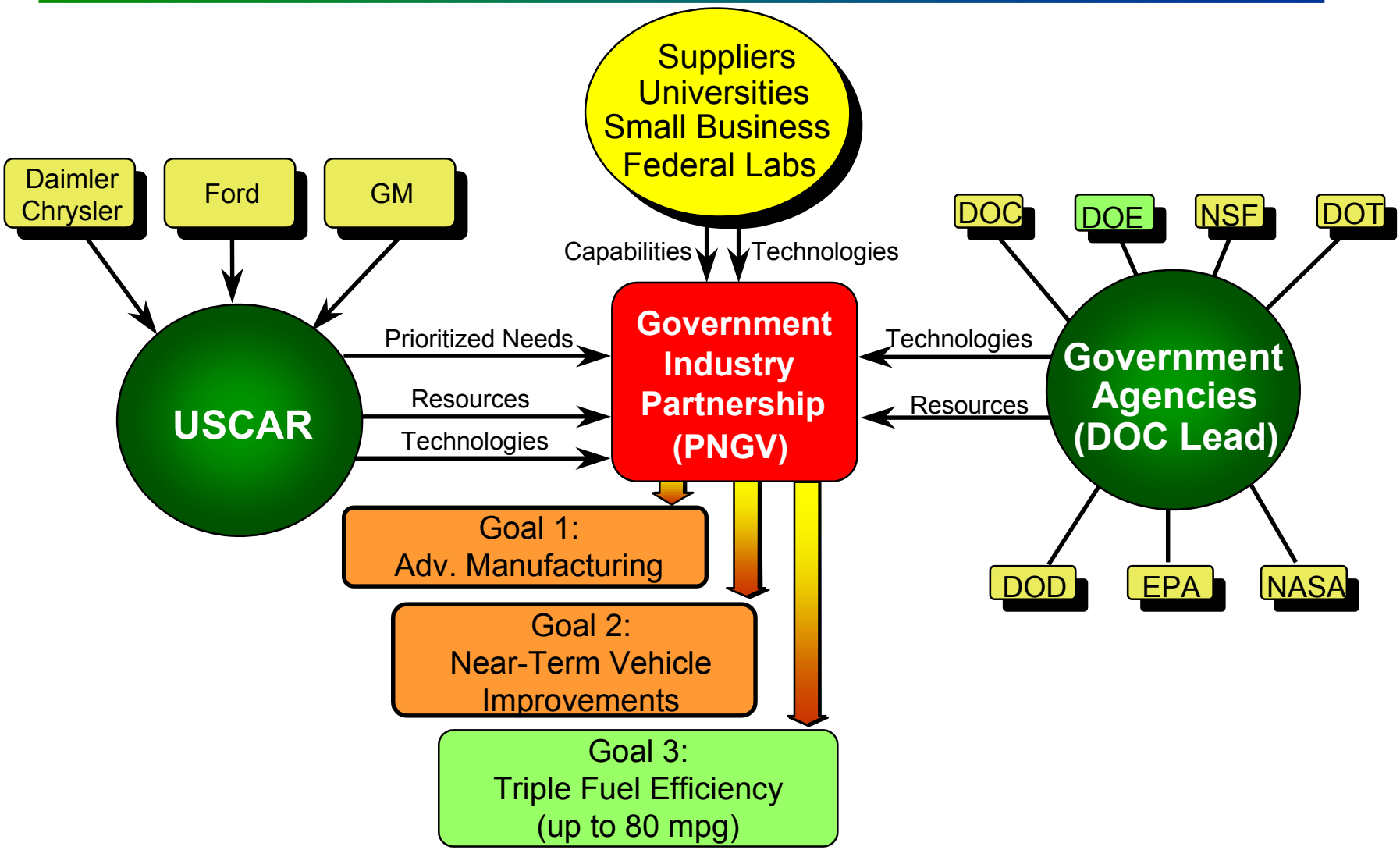
Government-Industry
21st Century Truck Partnership

USABC

SECA

# PNGV: An Historic Collaboration Between Industry & Government

PARTNERSHIP FOR A NEW GENERATION OF VEHICLES

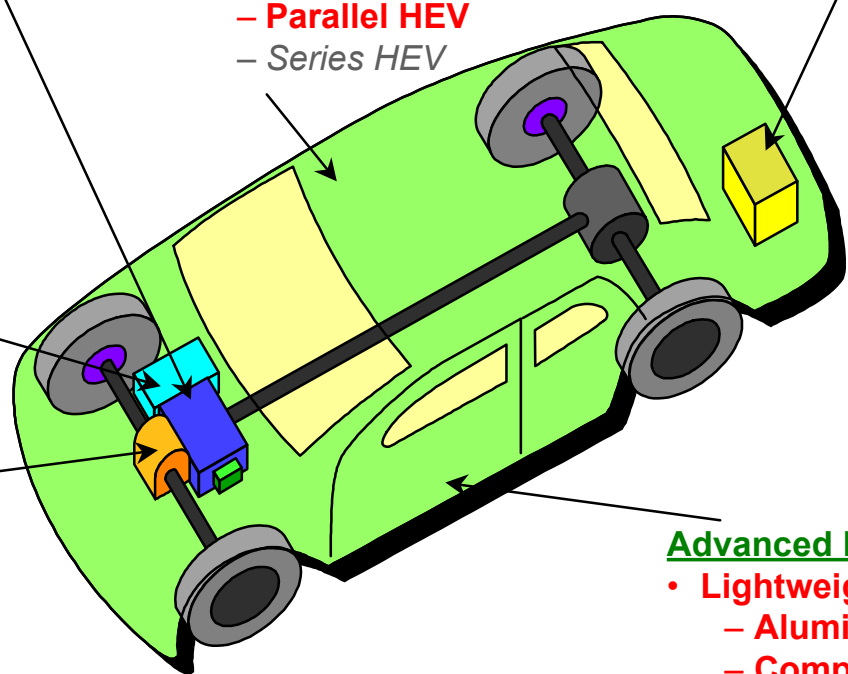


# Technology Portfolio Continues to Evolve

PARTNERSHIP FOR A NEW GENERATION OF VEHICLES

**Engine/Power Sources**
- **Advanced Heat Engines**
  - **DI Engines**
  - *HCCI*
  - *VCR*
- **Combustion and Aftertreatment**
  - **Lean NOx Catalyst**
  - **EGR**
  - **Traps**
- **Fuel Cell**
- **Batteries**
  - **NiMH Battery**
  - **Lithium Battery**
- *Pneumatic/Hydraulic Storage*
- **Power Electronics**
  - **Invertors/Controllers**
  - **Motors**
  - **Ultracapacitors – Electric**

**Systems Development**
- **Aerodynamics**
- **Rolling Resistance – Tires**
- **Accessory Loads – HVAC**
- **Powertrain Configuration**
  - **Parallel HEV**
  - *Series HEV*



**Fuels Utilization**
- **Gasoline**
- **Diesel Fuels and Blends (<30 ppm sulfur)**
- **Natural Gas**
  - **Methanol**
  - **Fischer-Tropsch**
  - *Dimethyl Ether*
- **Ethanol**
- *Hydrogen*

**Advanced Materials**
- **Lightweight Materials**
  - **Aluminum/Composite BIW**
  - **Composite BIW**
- **Propulsion Materials**

Most promising options

*Other technologies*

# 2000 PNGV Concept Vehicles

PARTNERSHIP FOR A NEW GENERATION OF VEHICLES

## Ford Prodigy

- Lightweight materials reduce vehicle body structure weight 50%*
- Integrated starter/alternator*
- 33% reduction in aerodynamic drag
- Advanced diesel engine with 35% efficiency improvement projected to exceed 70 mpg (gasoline equivalent)*
- High-power battery *

## DaimlerChrysler ESX3

- Body system weighs 46% less*
- Efficient diesel engine, motor, and battery projected at 72 mpg (gasoline equivalent)*
- Cost penalty halved to $7500

## GM Precept

- Vehicle body weight reduced 45% *
- World's most energy efficient vehicle lighting system
- Lowest drag coefficient ever recorded for a 5-p sedan
- Dual-axle parallel hybrid achieves 79.6 mpg (gasoline equivalent)

*Government supported technologies

# The National Research Council Conducts Annual Reviews of PNGV

- Outstanding effort in meeting the concept car milestone in 2000
- Substantial technical progress noted in:
  - Vehicle engineering
  - Structural materials
  - 4-stroke, direct-injection engines
  - Fuel cells
  - Batteries
  - Power electronics
- Major barriers: costs, emissions, fuels
- Significant progress also observed for Goals 1 and 2


**"Considering the magnitude of the challenges facing the program, PNGV is making good progress"**

-- NRC Sixth Report of the PNGV

PARTNERSHIP FOR A NEW GENERATION OF VEHICLES

# Technology Is Migrating into New U.S. Vehicles

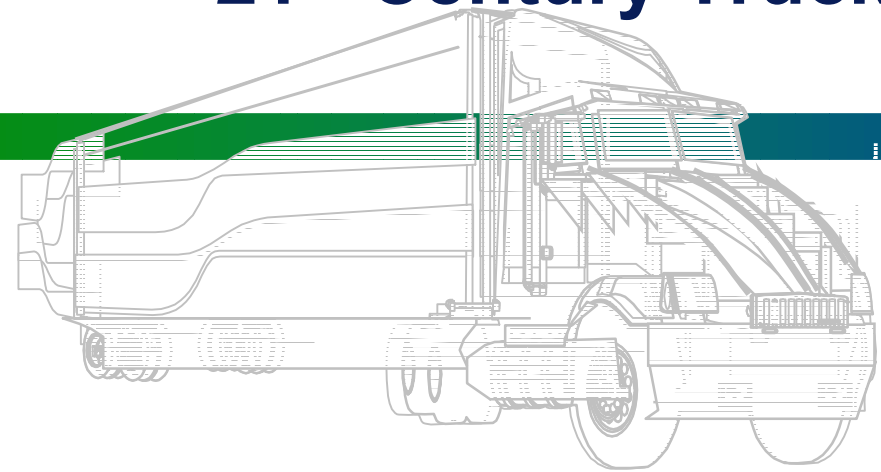
PARTNERSHIP FOR A NEW GENERATION OF VEHICLES

- Hybrid-electric drives scheduled for:
  - Dodge Durango in 2003
  - Ford Escape in 2003
  - Chevrolet Silverado in 2004
  - and Ford Explorer in 2005
- 412 pounds of lightweight aluminum in the 2000 Lincoln LS
- Aluminum used for door, deck, and hood panels for Cadillac, Oldsmobile, and Chevrolet vehicles
- 50-pounds lighter composite pickup truck box on the 2001 Chevrolet Silverado
- Production of a new, lighter, recyclable thermoplastic hardtop for the Jeep Wrangler in 2001

# Difficult, but Surmountable, Research Challenges Remain to Achieve Very High Fuel Economy

- **Hybrid Systems:** Parallel configuration offers best option to meet 80 mpg. Series configuration may be used with fuel cells. Cost, weight, and packaging remain as challenges.
- **CIDI Engines:** Mature technology with 44% efficiency, but NOx and particulate emissions remain as challenges.
- **Fuel Cells:** Lowest onboard emissions and potential for highest efficiency, but cost, systems integration, and fueling infrastructure are major challenges.
- **Energy Storage:** Considerable progress in developing high-power battery; focus now on cost and cycle life.
- **Power Electronics:** Progress on cost, power-to-weight ratios, and efficiencies needed
- **Light Materials:** Significant weight reductions achieved. Major issues are cost, manufacturability, joining, recycling, and repair.
- **Fuels:** Fuel impacts on infrastructure must be addressed. Thorough evaluation is needed of the effects of fuel composition and physical properties on CIDI and fuel systems' performance.

# 21st Century Truck Partnership



**Industry Participants**

Allison Transmission
BAE SYSTEMS Controls
Caterpillar
Cummins
DaimlerChrysler
Detroit Diesel
Eaton Corporation
Freightliner
General Motors
Honeywell
International Truck and Engine
Mack Trucks
NovaBUS
Oshkosh Truck
PACCAR
Volvo Trucks North America

**Department of Energy**
DOE/EE/OTT Heavy Vehicle Technologies R&D

**Department of Defense**
Army/TACOM NAC Military Vehicle R&D

**Department of Transportation**
Intelligent Vehicle and Highway Safety R&D

**Environmental Protection Agency**
Vehicle Emissions Regulations

# 21st Century Truck Partnership Declaration of Intent

**Trucking industry's future depends on ability to produce affordable, high quality, safe, environmentally sensitive products.**

- **Innovation needed** for U.S. truck manufacturers and suppliers to remain competitive worldwide;
- New truck and bus technologies will help truck owners and operators, and their customers, **cut fuel and operating costs and increase safety;**
- DOD would share gains and benefit from **reduced logistic costs** of transporting fuel during operations.

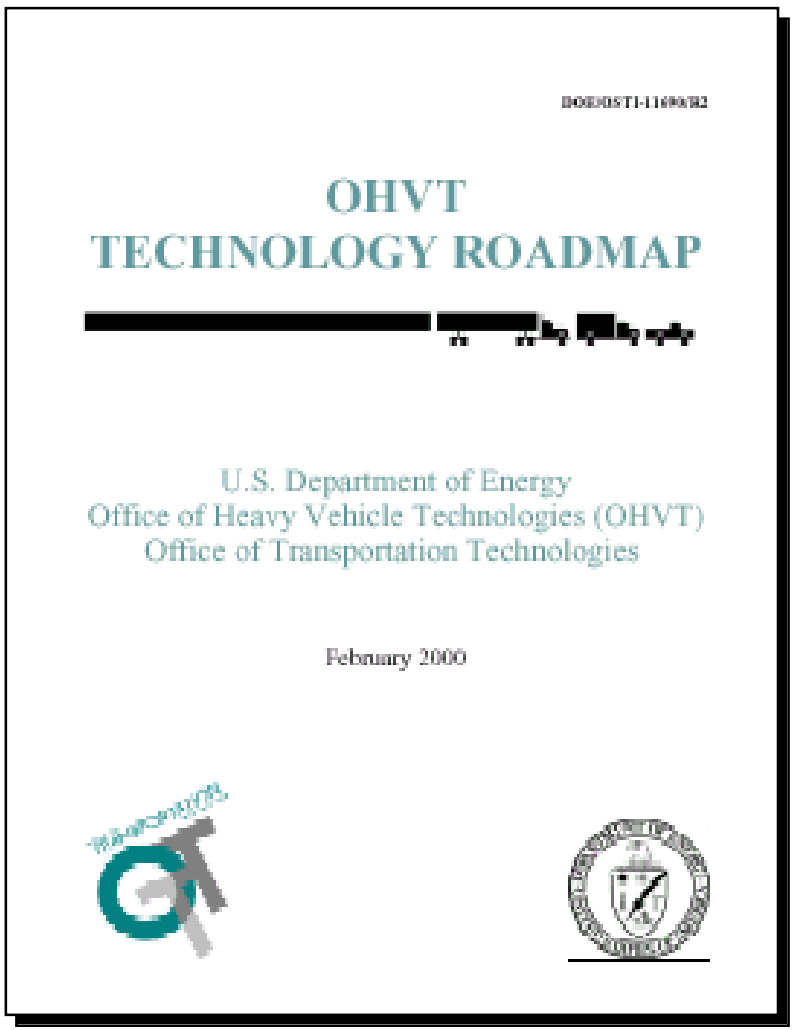
# 21st Century Truck Partnership Declaration of Intent

Develop production prototype vehicles that:

- **Improve fuel efficiency, specifically, by 2010;**
  - double the Class 8 long-haul truck fuel efficiency*;
  - triple the Class 2b and 6 truck (delivery van) fuel efficiency*; and
  - triple the Class 8 transit bus fuel efficiency*;
- **Exceed expected emissions standards for 2010;**
- **Meet or exceed motor carrier safety goal of reducing truck fatalities by half in ten years; and**
- **Enhance affordability, and maintain or enhance performance.**

* on a ton-mile per gallon basis

# Heavy Vehicles Technology Roadmap




## *R&D needs of three groups of trucks are addressed*

- Class 7 and 8, heavy-duty on-highway trucks
- Class 3-6, medium duty trucks such as urban delivery vans and transit buses.
- Class 1 and 2 light trucks (pickups, vans, and sport utility vehicles)

**Independent review conducted by the National Research Council.**

# Heavy Vehicle Technologies R&D Goals

## Heavy (Class 7-8) Trucks

To develop by 2004, the enabling technologies needed to achieve a fuel efficiency of at least ***10 miles per gallon*** *(at 65 miles per hour)* and ***meet*** emissions standards prevailing in 2004, using petroleum-based diesel fuel.

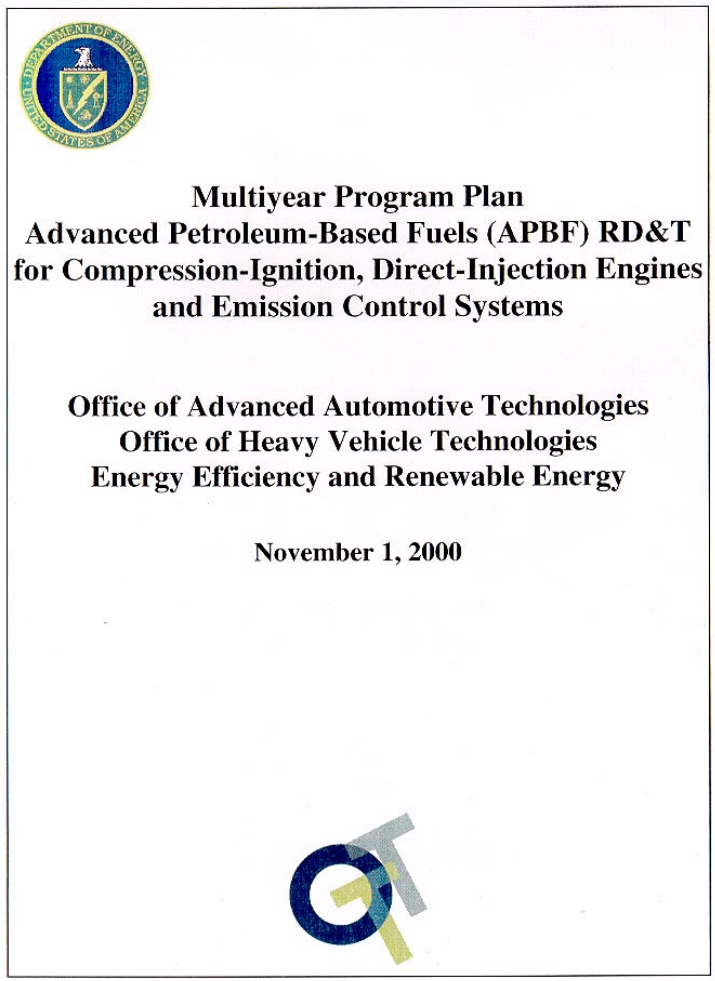
## Medium (Class 3-6) Trucks

By 2004, to develop and demonstrate commercially viable vehicles that achieve, on an urban driving cycle, at least ***double the fuel economy*** of comparable current (1999) vehicles, and as a *research goal*, reduce criteria pollutant emissions to at ***least 30 percent below*** EPA standards prevailing in 2004.

## Light (Class 1-2) Trucks

To develop by 2004 the enabling technologies for clean diesel engines to be competitive with and ***at least 35-percent more fuel efficient*** than equivalent gasoline engines for light trucks, while meeting Federal and state emissions standards prevailing in 2004.

# OHVT/OAAT Advanced Petroleum-Based Fuels Program



Multiyear Program Plan
Advanced Petroleum-Based Fuels (APBF) RD&T
for Compression-Ignition, Direct-Injection Engines
and Emission Control Systems

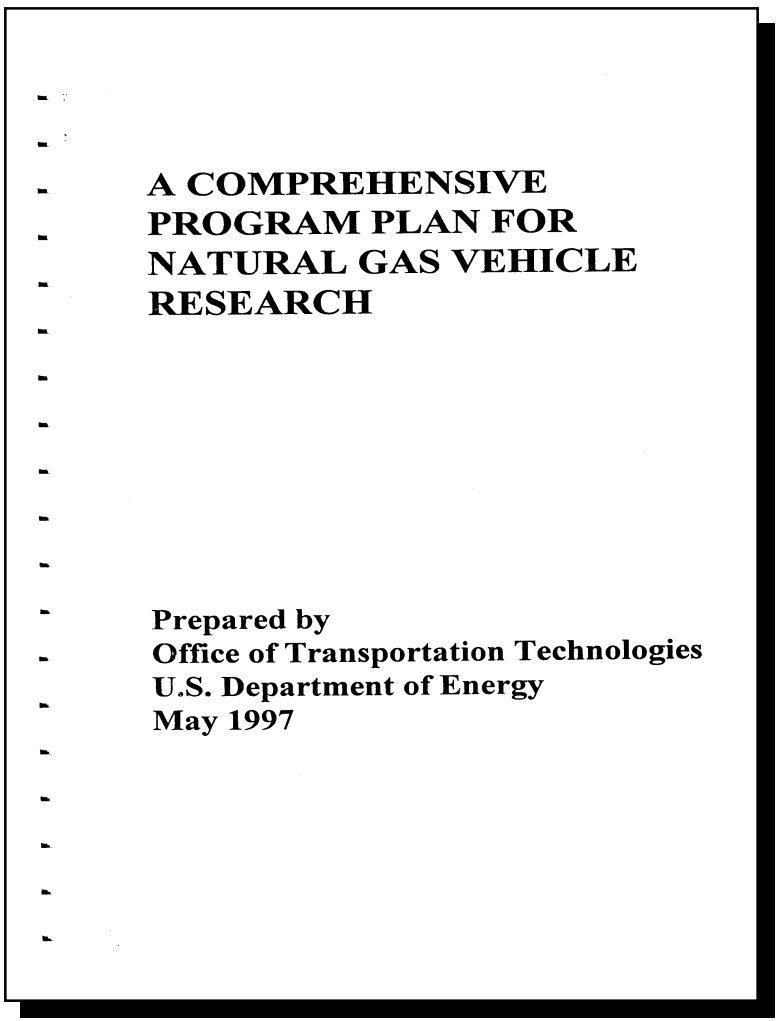
Office of Advanced Automotive Technologies
Office of Heavy Vehicle Technologies
Energy Efficiency and Renewable Energy

November 1, 2000

***Mission*** Undertake, with partners in the energy and transportation industries, research and development which will result in competitive, high performance, low emission fuel options for transportation vehicles.

***Goals*** Identify, develop, and test new fuel formulations for automotive and truck engines that will be needed to simultaneously achieve high fuel economy and low emissions.

# Alternative Fuels Program




## *Goals*

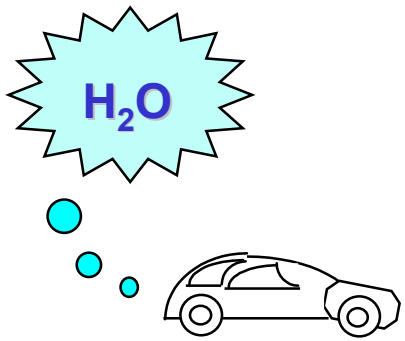
- Develop production-ready prototype vehicles – one Class 3-6 CNG and one Class 7/8 LNG – achieving 2007 emission standards and fully competitive with conventionally fueled counterparts.
- Develop enabling fueling infrastructure technology to promote use of CNG and LNG in medium- and heavy-duty engines.
- Attain capital cost of $70 per DGE for LNG tank.
- Improve average thermal efficiency of NG engines to approach that of diesel engines.
- Understand atmospheric impacts of the use of petroleum-based and alternative transportation fuels.

# Fuel Technology R&D Challenges

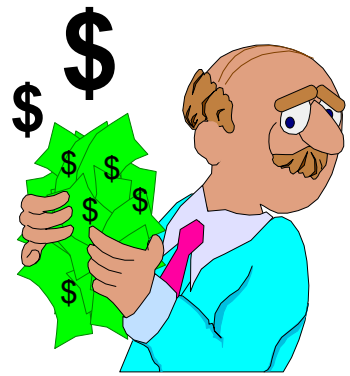
***Alternative Fuels***

- **Vehicle Integration**
  - A clean-sheet design of Class 3-6 and Class 7-8 trucks will ensure full integration of CNG and LNG technologies in vehicles.
- **Engine Efficiency**
  - Natural gas engines must overcome part-load and throttling efficiency losses to achieve diesel-like efficiencies.
- **Fueling Infrastructure**
  - Advances are needed in cost-reduction, ease of handling, and safety to have full customer acceptance.
- **On-board Storage**
  - Natural gas will have to be stored on-board at considerably lower pressures than current technology to address space and safety concerns.

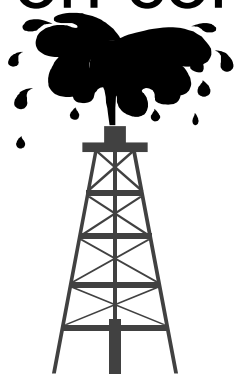
# Fuel Cells For Transportation Program Goal

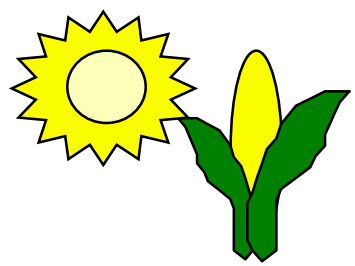



***More MPG***

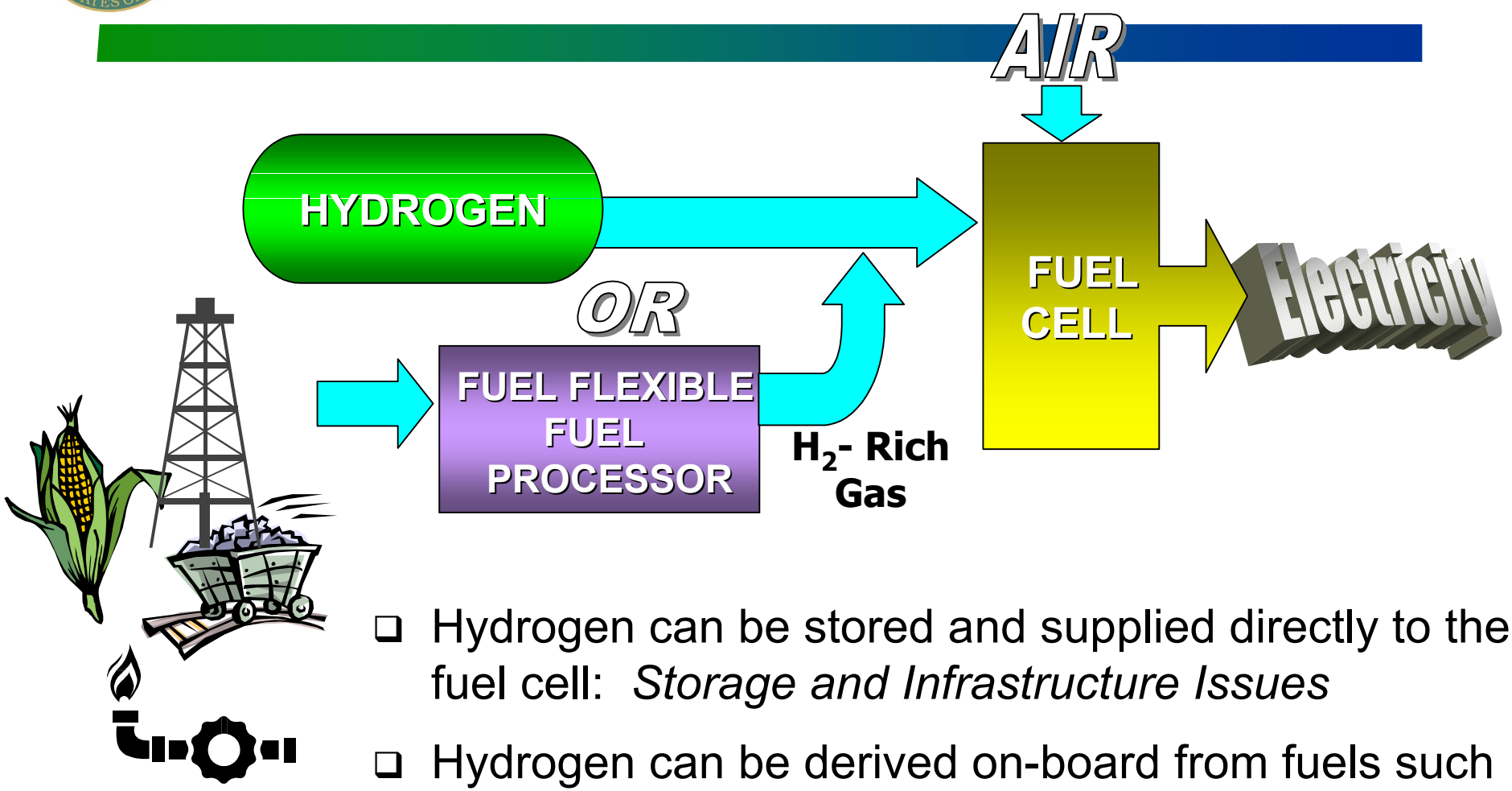



Develop highly efficient, low- or zero-emission, cost-competitive automotive fuel cell power system technologies that operate on conventional & alternative fuels.





# Fuel Strategy for Automotive Fuel Cells




- Hydrogen can be stored and supplied directly to the fuel cell: *Storage and Infrastructure Issues*
- Hydrogen can be derived on-board from fuels such as ethanol, methanol, natural gas, gasoline or FT fuels: *Complexity, Cost, and Start-up Issues*

# Program is Focused on Critical Technical Challenges

**Significant technical and economic challenges will keep fuel cell vehicles from making significant market penetration for up to 10 years.**

**Major Challenges for Automotive PEM Fuel Cells:**

- **Cost**
- **Efficiency (Higher Cell Voltage)**
- **Air Management (Compressor Technology)**
- **Startup (Fuel Processor Thermal Mass)**
- **Thermal/Water Management**

# Projects and Funding by Budget Category

## Systems

- Plug Power/Nuvera
- International Fuel Cells
- Energy Partners, Honeywell
- A.D. Little (Cost Analysis)
- ANL (System Analysis)

**FY01: $7.6M**

## Fuel Processing

- Nuvera
- Hydrogen Burner
- McDermott
- Honeywell
- ADL/Acurex
- ANL, LANL, PNNL

**FY01: $21.5M**

## Stack Subsystem Components

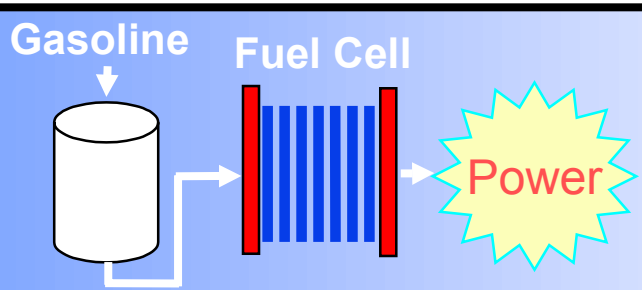
- Energy Partners, AlliedSignal, IFC, Plug Power
- Gas Technology Institute
- 3M, SwRI/Gore, Foster-Miller
- Vairex, A.D. Little, AlliedSignal, Meruit
- LANL, LBNL, NRL, JPL

**FY01: $12.4M**

# Progress in Gasoline Fuel Cell Systems

***Full Scale Gasoline Systems Are Being Demonstrated***

**1997:**

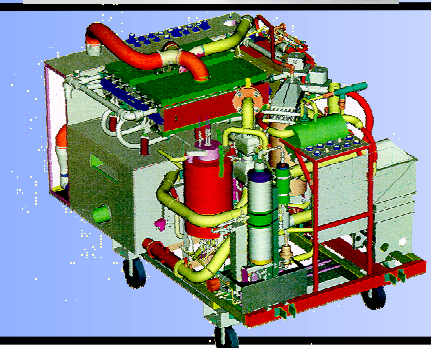



**World's First Demonstration of PEM Fuel Cell Power from Gasoline - <1kW**

**1999:**

**Plug Power & Epyx (NUVERA) Demonstrate 10kW System on Multiple Fuels Including Gasoline, Methanol, and Ethanol**

**2000:**

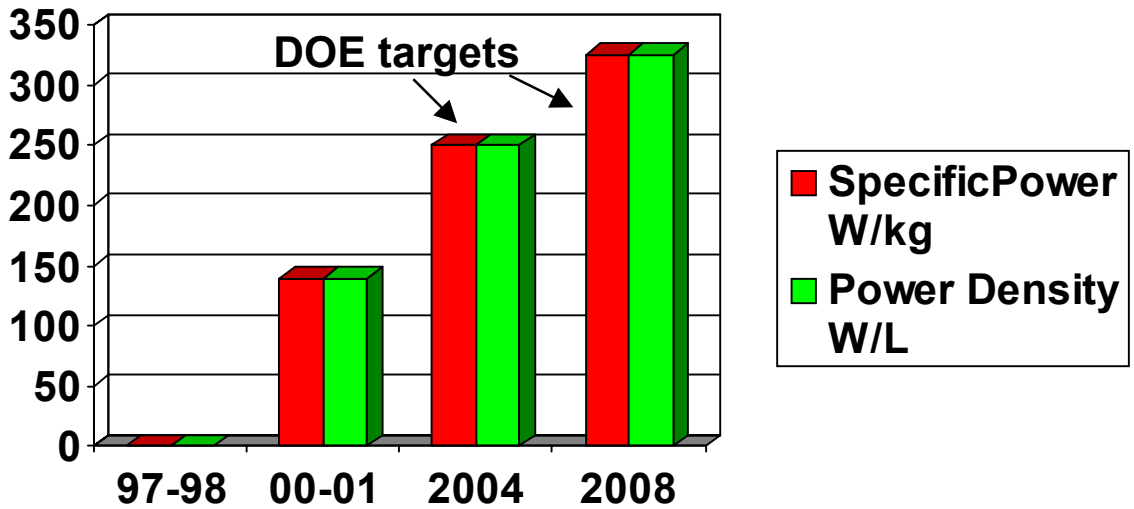


**IFC Demonstrates 50 kW, Automated System on Gasoline**

# Significant Improvements in Fuel Cell System Size and Weight Have Been Made in the PNGV/DOE Program

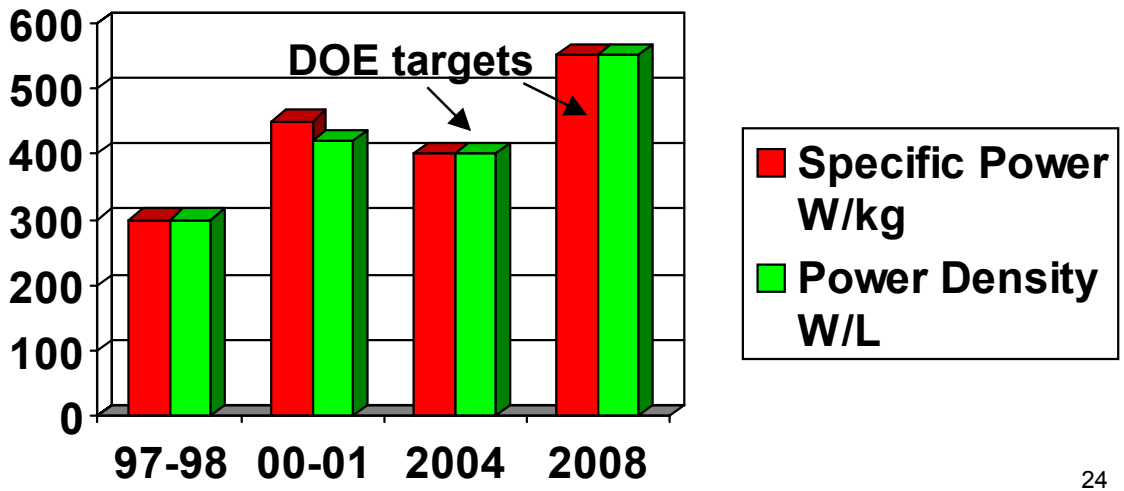
**50kW Gasoline Fuel Cell Power System***

- includes stack system, fuel processor, BOP
- gasoline systems and data unavailable in 1997-98




**50kW Direct Hydrogen Fuel Cell Power System****

- includes stack, air/water management
- targets are for stack subsystem, i.e. excludes fuel processor, hydrogen storage




*Based on Plug Power
** Based on IFC

# DOE is a Member of the CALIFORNIA FUEL CELL PARTNERSHIP

California FUEL CELL PARTNERSHIP
DRIVING FOR THE FUTURE

## Goals

- Demonstrate vehicle technology
- Demonstrate the viability of alternative fuel infrastructure technology
- Explore the path to commercialization
- Increase public awareness

## Members

- State of California (CARB/CEC/SCAQMD)
- Auto Manufacturers (DaimlerChrysler/Ford/Honda/Hyundai/Nissan/ Volkswagen/General Motors/Toyota)
- Energy Providers (BP/Shell Hydrogen/Texaco/ExxonMobil)
- Fuel Cell Companies (Ballard/IFC/XCELLSiS)
- Associates (Air Products/Methanex/Praxair/Hydrogen Burner/Pacific G&E
- Proton Energy/Stuart Energy/AC Transit/SunLine)
- Federal agencies (DOE/DOT)

# SECA-Related R&D

**OTT is developing fuel cells for auxiliary power units (APUs) in diesel trucks, and addressing the related technical challenges:**

- **Diesel Reforming**
  - eliminate carbon formation
  - remove sulfur and/or develop sulfur tolerant catalysts
- **Solid Oxide Fuel Cells**
  - develop rugged, low cost cell materials
  - reduce startup time

**Current R&D efforts are being carried by LANL, NETL, and ANL under the Transportation Fuel Cell Program.**
**Small businesses and universities will carry out R&D through the Cooperative Automotive Research for Advanced Technology (CARAT) Program.**
**Analyses of APUs for light and heavy vehicle applications will be conducted.**

# Summary

- DOE's Office of Transportation Technologies is addressing the key technical challenges in the development of fuel-efficient vehicles for both light duty and heavy duty applications.
- Government-Industry partnerships are critical to the success of OTT's Vehicle Technology Programs.
- OTT's Fuel Cell Program has made tremendous progress; however, major technical challenges remain which prevent the introduction of fuel cell vehicles today.
- The Fuel Cell Program is developing fuel cell and fuel processing technologies in support of SECA.

**For more information, visit the OTT Web Site:**
**www.ott.doe.gov**

# Back-Up Slides

# EE Stationary Fuel Cell Program

**Program Goal**

Develop and demonstrate a 50-kW PEM fuel cell for a commercial building by 2005

- operating on natural gas
- operating at high-temperature (120-140C)

**R&D Focus**

- High-temperature membranes
- Natural gas reforming
- System design