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ANL/ESD/TM-137

CONF-9611153--

U.S. Department of Energy Workshop on Future Fuel Technology for Heavy Vehicles

Energy Systems Division

Argonne National Laboratory

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United States Department of Energy

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ANL/ESD/TM-137

U.S. Department of Energy Workshop on Future Fuel Technology for Heavy Vehicles

by Argonne National Laboratory with Energetics, Inc., and Antares Group, Inc.

November 20-21, 1996

Workshop sponsored by the United States Department of Energy,
Office of Transportation Technologies, Office of Heavy Vehicle Technologies

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ACKNOWLEDGMENTS

The workshop described in this technical memorandum is one in a series that the U.S. Department of Energy, Office of Heavy Vehicle Technologies, is conducting to develop a common industry/government vision of the heavy vehicle industry of the future. We acknowledge the valuable guidance provided by Rob Davidson of Ethyl Corporation, as well as the suggestions regarding attendees and format from Brent Bailey, National Renewable Energy Laboratory; Bob Carling, Sandia National Laboratory; Ron Graves, Oak Ridge National Laboratory; Don Lyons, University of West Virginia; and Frank Stodolsky, Argonne National Laboratory. We also appreciate the efforts of Kevin Stork, Argonne National Laboratory, who was responsible for organizing the workshop, and of the many people who contributed to make this workshop a success, in particular: Joan Brunsvold and Marianne Adair of Argonne National Laboratory for workshop administration, and René Abarcar and Christina Gikakis of Energetics, Inc., and David Gelman and Peter McCallum of Antares Group, Inc., for preparing the group summary reports. The speakers in the plenary session are commended for their excellent presentations. Special thanks are due to the workshop facilitators, who guided a diverse group of participants through challenging discussions. Finally, we wish to thank the attendees for their participation and their continuing input into the plans for the Fuels and Lubricants Program in the Office of Heavy Vehicle Technologies.

James J. Eberhardt, Director
Office of Heavy Vehicle Technologies
U.S. Department of Energy

Stephen J. Goguen
Team Leader, Fuels and Lubricants Technology
Office of Heavy Vehicle Technologies
U.S. Department of Energy

December 20, 1996

U.S. DEPARTMENT OF ENERGY WORKSHOP ON FUTURE FUEL TECHNOLOGY FOR HEAVY VEHICLES

by

Argonne National Laboratory with Energetics, Inc.,
and Antares Group, Inc.

ABSTRACT

The objective of the workshop described in this report was to develop consensus on a program strategy for use of alternative fuels in heavy vehicles. Participants represented fuel providers, additive suppliers, the trucking industry, engine manufacturers, and government or national laboratory staff. Breakout sessions were co-facilitated by national laboratory staff and industry representatives.

1 BACKGROUND

The goals of the workshop, sponsored by the U.S. Department of Energy (DOE), Office of Transportation Technologies (OTT), Office of Heavy Vehicle Technologies (OHVT), were to (1) work toward a consensus on the research aims of the OHVT fuel program with respect to the use of fuels in heavy vehicle engines and (2) provide customer input to the multiyear planning for the Office.

Engine manufacturers, fuel providers, additive suppliers, trucking industry representatives, alternative fuel advocates, consultants, and government/national laboratory staff were present at the meeting.

2 GOVERNMENT AND INDUSTRY PERSPECTIVES

The first day of the workshop was devoted to overview presentations by government and industry representatives. The final agenda is provided in Appendix A; the presentation materials are reproduced in Appendix B. Each of the presentations is described briefly below.

James J. Eberhardt, Director, DOE/OTT/OHVT, delivered the welcoming address and described the mission of OHVT's fuels program. His presentation, entitled "Crafting a Common Vision on Fuels Technologies for the Heavy Vehicle Industry of the Future," placed the workshop in the broader context of a continuing series of OHVT workshops. The strategy of the OHVT program is to focus on the diesel engine in developing a fuel-flexible, low-emitting vehicle engine that can be used in all vehicle size classes. He also described the goal of achieving a shared vision among industry and government to help guide the OHVT's research goals.

Kevin Stork, Argonne National Laboratory, explained the procedural details of the workshop, presented breakout group assignments and breakout questions, and furnished a count of participants by industry/affiliation.

Stephen Goguen, Fuels and Lubrication Team Leader, DOE/OTT/OHVT, gave a summary of a panel discussion on heavy vehicle fuel technology that was held at the Customers' Coordination Meeting (CCM) and further elaborated the goals of the current workshop.

William H. Peerenboom, Vice President — ATA Foundation, presented a trucking industry perspective on alternative fuels. He emphasized that, for the trucking industry to accept alternative technologies, it needs transparent technology, an existing infrastructure, and a cost comparable with that of diesel fuel.

Vinod K. Duggal, Director — Alternative Fuels Product Development, Cummins Engine Company, spoke on engine manufacturers' perspective on alternative fuels for heavy vehicles. He emphasized that increasing stringency in emissions standards will increase the attractiveness of alternative fuels to heavy vehicle engine manufacturers, but availability and cost of fuels remain major barriers.

John Nepywoda, Manager — Market Development, Amoco Petroleum Products, spoke primarily about liquefied natural gas. He emphasized that there must be market drivers for alternative fuel use in heavy vehicles, because these vehicles are not mandated to use them. The emissions and energy-security benefits are secondary to the economic benefits.

Robert I. Davidson, Assistant Director, Fuels Research and Development, Ethyl Corporation, gave a fuel-additive supplier's perspective on future fuels for heavy vehicles,

emphasizing the use of additives for conventional diesel fuels to improve vehicle performance, reduce emissions, and reduce petroleum consumption. He also noted that fuel-additive suppliers may need a wide range of additives to accommodate fuels other than diesel and will not be able to finance the development of additives for all types of fuels.

Mike Ansell, Alternative Fuels Program Leader, Exxon Research and Development Laboratories, spoke on Fischer-Tropsch diesel fuel processed from natural gas.

3 BREAKOUT SESSIONS

On the second day of the workshop, participants were divided into four groups and asked to consider the following questions:

1. What do you foresee as the fuel mix for the first decade of the twenty-first century?

2. What barriers prevent the use of nonpetroleum fuels in heavy vehicles in the near term?

3. Do you envision emission standards as the driver for choices among fuels?

4. What do you foresee as the fuel mix of the mid-twenty-first century?

Each group consisted of as broad a mixture of participants as possible. The compositions of the breakout groups, with names and affiliations, are included in Appendix C.

After the breakout sessions, each group made a brief report to the reconvened attendees.

4 SUMMARY

Several points emerged independently from all of the groups. Detailed notes on each discussion, as recorded by the scribe for each group, are included as Appendix D to this report.

There seemed to be a general consensus on the following issues:

- Alternatives to traditional fuels must surmount *economic* barriers to gain acceptance. Cost and availability of fuels and the engines to use them were the most consistently cited impediments to change.

- The compression-ignition (CI) engine platform will continue to dominate heavy vehicles. In the near term, diesel fuel will be predominant. In the long term, diesel fuel was seen as continuing to play a major role, but the CI engine was perceived to be the right engine for alternative fuels — particularly those that physically resemble conventional diesel fuel (e.g., Fischer-Tropsch diesel, biodiesel).

- Most of the groups agreed that emissions standards would be *a* driver, though not the *sole* driver, of future fuel technology.[1] While reformulated diesel fuel with engine modifications could potentially allow diesel engines to meet the U.S. Environmental Protection Agency/California Air Resources Board (EPA/CARB) targets cited for the year 2004 (2 gm/hp-hr NO_x, 0.1 gm/hp-hr particulate matter), some nonpetroleum fuels were cited as having the potential to reduce new engine emissions *below* this level.

- It was suggested that future research should be in the areas of multifuel-capable CI engines ("flex fuel") and liquid fuel blends containing a mix of petroleum and nonpetroleum feedstocks that are compatible with the CI engine cycle.

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[1] The summary for Group B does not provide an explicit answer to question 2, but the table of issues presented in the group's summary suggests that the per-gallon cost of fuel and infrastructure capital cost would be major unknowns for any alternative to diesel fuel (see Appendix D).

APPENDIX A:

MEETING AGENDA

AGENDA

Workshop on Future Fuel Technology for Heavy Vehicles

Ramada Plaza Hotel O'Hare
6600 N. Mannheim Road
Rosemont, Illinois

Wednesday, November 20

1:00-2:00 p.m.	**REGISTRATION**
2:00-2:30 p.m.	**WELCOME**
	Crafting a Common Vision on Fuel Technology for the Heavy Vehicle Industry of the Future *Dr. James J. Eberhardt*, Director - Office of Heavy Vehicle Technologies
2:30-2:40 p.m.	**Call to Order and Statement of Workshop Objectives** *Kevin Stork*, Argonne National Laboratory (Workshop Organizer)
2:40-3:00 p.m.	**Customers' Coordination Meeting Panel Discussion Summary** *Steve Goguen*, Office of Heavy Vehicle Technologies
3:00-3:20 p.m.	**COFFEE BREAK**
3:20-3:40 p.m.	**Trucking Industry Perspective on Alternative Fuels for Heavy-Duty Vehicles** *William H. Peerenboom*, Vice President - ATA Foundation, American Trucking Associations
3:40-4:00 p.m.	**Engine Manufacturer Perspective on Alternative Fuels for Heavy-Duty Vehicles** *Dr. Vinod K. Duggal*, Director - Alternative Fuels Product Development, Cummins Engine Company
4:00-4:20 p.m.	**Alternative Fuels for Heavy-Duty Vehicles** *John Nepywoda*, Manager - Market Development, Amoco Petroleum Products
4:20-4:40 p.m.	**Fuel Additive Suppliers Perspective on Future Fuels for Heavy-Duty Vehicles** *Robert I. Davidson*, Assistant Director, Fuels Research and Development, Ethyl Corporation
4:40-5:00 p.m.	**Natural-Gas Based Fuels for Diesel Engines** *L.L. (Mike) Ansell*, Alternative Fuels Program Leader, Exxon Research and Development Laboratories
5:00-6:00 p.m.	**RECEPTION**
6:00-7:30 p.m.	**DINNER**

Thursday, November 21

7:00-8:00 a.m.	**CONTINENTAL BREAKFAST**
7:30-8:00 a.m.	**REGISTRATION**
8:00-8:10 a.m.	**Breakout Session Instructions**
8:10-2:00 p.m.	**Breakout Sessions (4 Simultaneous Sessions)**
10:30-10:45 a.m.	**COFFEE BREAK**
Noon	**WORKING LUNCH**
1:30-2:30 p.m.	**Summary and Reports from Breakout Sessions** Breakout session facilitators make reports, 15 min. each, maximum
3:00 p.m.	**Adjourn**

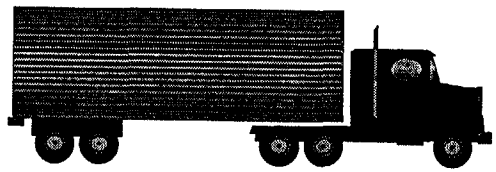
APPENDIX B:

PRESENTATION MATERIALS

Workshop on Future Fuel Technology for Heavy Vehicles

Kevin Stork
Argonne National Laboratory

Ramada Plaza O'Hare
November 20-21, 1996



Agenda

Day 1: Overview

2:40-3:00 CCM Panel Discussion Summary
Steve Goguen, Office of Heavy Vehicle Technologies

3:00-3:20 Coffee Break

3:20-3:40 Trucking Industry Perspective on Alternative Fuels for Heavy Vehicles
William H. Peerenboom, Trucking Research Institute

3:40-4:00 Engine Manufacturers Perspective on Alternative Fuels for Heavy Vehicles
Dr. Vinod K. Duggal, Cummins Engine Company

4:00-4:20 Alternative Fuels for Heavy-Duty Vehicles
John J. Nepywoda, Amoco Petroleum Products

Agenda (cont'd).

Day 1, cont'd.:

4:20-4:40 Fuel Additive Suppliers Perspective on Future Fuels for Heavy-Duty Vehicles
Robert I. Davidson, Ethyl Corporation

4:40-5:00 Natural-Gas Based Fuels for Diesel Engines
Mike Ansell, Exxon R & D Laboratories

5:00-6:00 Reception -- Plaza 4

6:00-7:30 Dinner -- Plaza 4

Agenda (cont'd).

Day 2: Breakout Sessions

8:00-8:10 Breakout Session Instructions -- Salon C

8:10-1:30 **Breakout Sessions**

Group A -- Salon C

Group B -- Room D-11

Group C -- Room D-12

Group D -- Room D-23

Noon Lunch in Salon C

1:30-2:30 Reconvene in Salon C for Breakout Summaries

~2:30 Adjourn

Who are We?

Industry:	
Engines:	7
Components:	2
Trucking Cos.:	1
Major Oil Cos.:	5
Additive Makers:	3
Alternative Fuels:	3
Government:	10
Nat'l Labs:	11
Associations:	5
Consultants:	9

Heavy-Vehicle Fuel Workshop

Breakout-Session Questions:

(1) What do you foresee as the fuel mix for the first decade of the twenty-first century?

(2) What barriers prevent the use of non-petroleum fuels in heavy vehicles in the near term?

(3) Do you envision emissions standards as the driver for choices among fuels?

(4) What do you foresee as the fuel mix of the mid-twenty-first century?

Crafting a Common Vision on Fuels Technologies for the Heavy Vehicle Industry of the Future

Dr. James J. Eberhardt, Director
Office of Heavy Vehicle Technologies
U.S. Department of Energy

Presented at the Workshop on
Future Fuels Technologies for Heavy Vehicles

Chicago, Illinois
November 20 - 21, 1996

Crafting a Common Vision on Fuels Technologies for the Heavy Vehicle Industry of the Future

Outline

- Purpose of Workshop
- Who Are We?
- Program Rationale
- OHVT Strategy
- Crafting a Common Vision on Fuels Technologies for Heavy Vehicles
- Summary

Industry/Government R&D Collaboration for the Heavy Vehicle Industry of the Future

Purpose

To create a shared Industry/Government (DOE) vision and contribute to developing consensus on the nature of future fuels technologies for heavy vehicles

Who Are We?

- The U.S. Department of Energy - Secretary
  - Efficiency and Renewables - Deputy Assistant Secretary, Transportation Technologies
    - **Office of Heavy Vehicle Technologies**

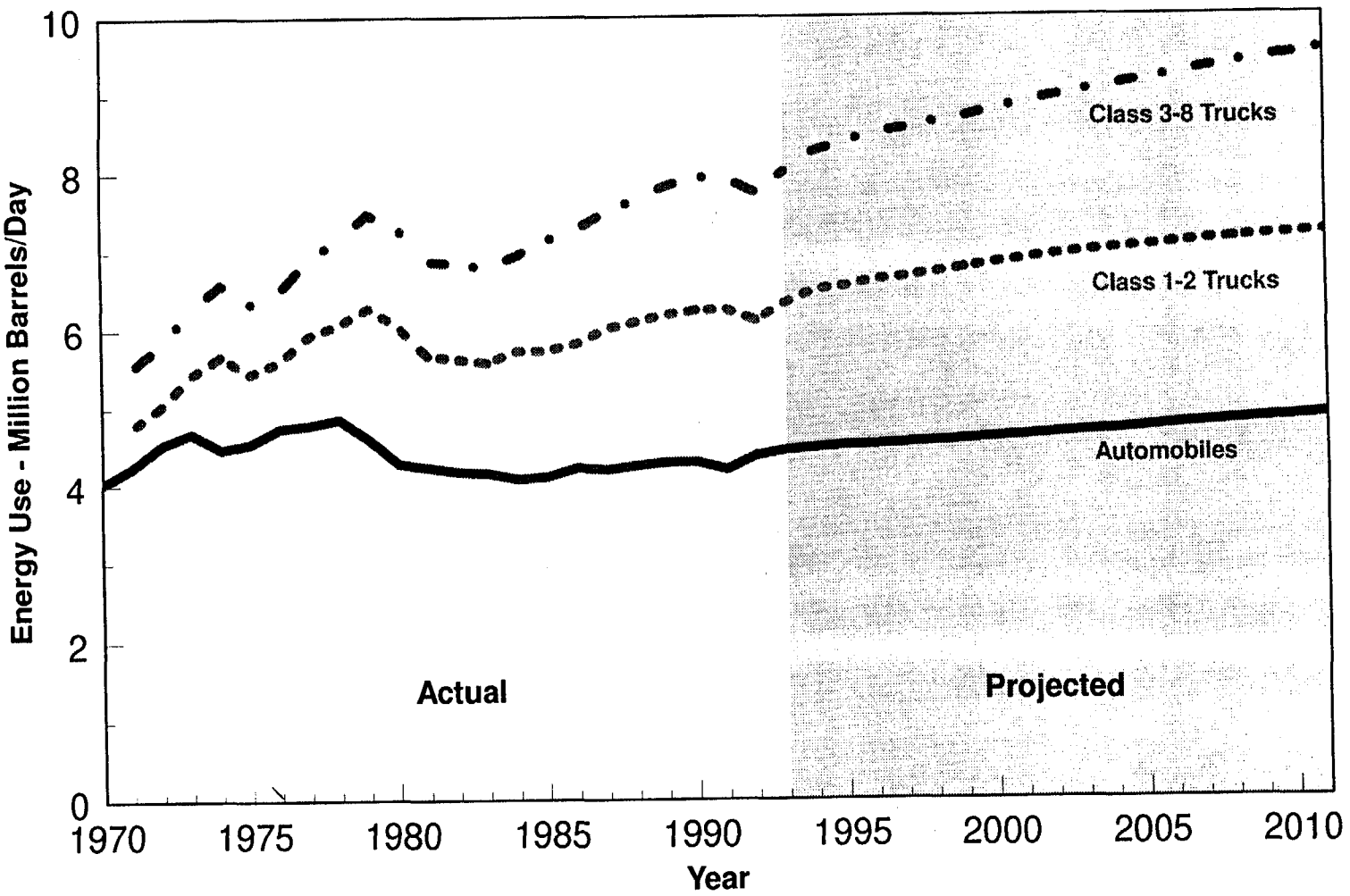
Dr. James J. Eberhardt, Director
Office of Heavy Vehicle Technologies
phone: (202) 586-9837
voicemail: (202) 586-1694
fax: (202) 586-1600
e-mail: james.eberhardt@hq.doe.gov

DOE/Heavy Vehicle Technologies

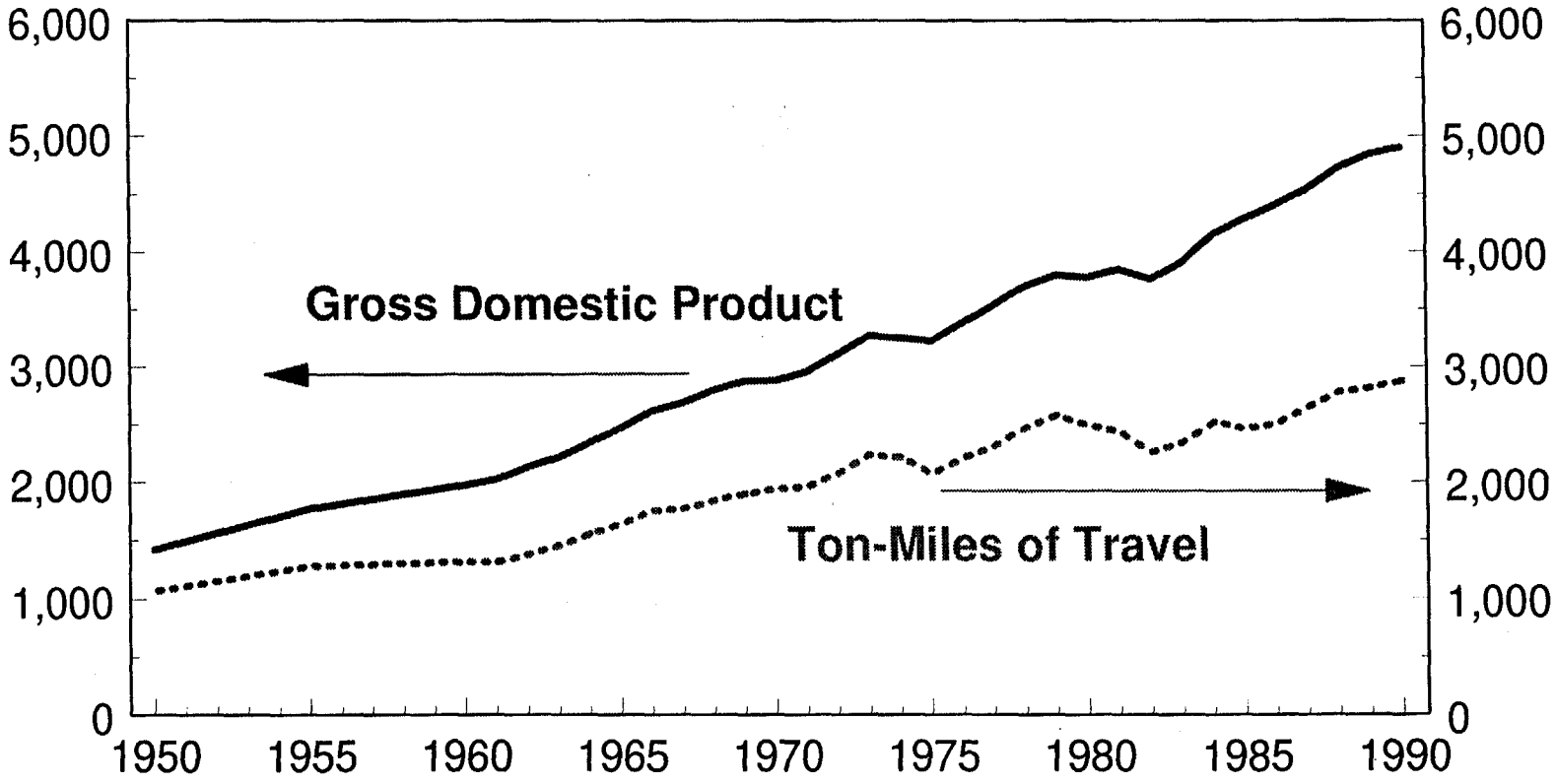
Mission Statement

To conduct in collaboration with our heavy vehicle industry partners and their suppliers, a customer-focused national program to research and develop technologies that will enable trucks and other heavy vehicles to fully exploit the energy efficiency and alternative fuel capabilities of the diesel engine while simultaneously reducing emissions.

Rationale: Trucks Account for Increasing Highway Transportation Energy Use

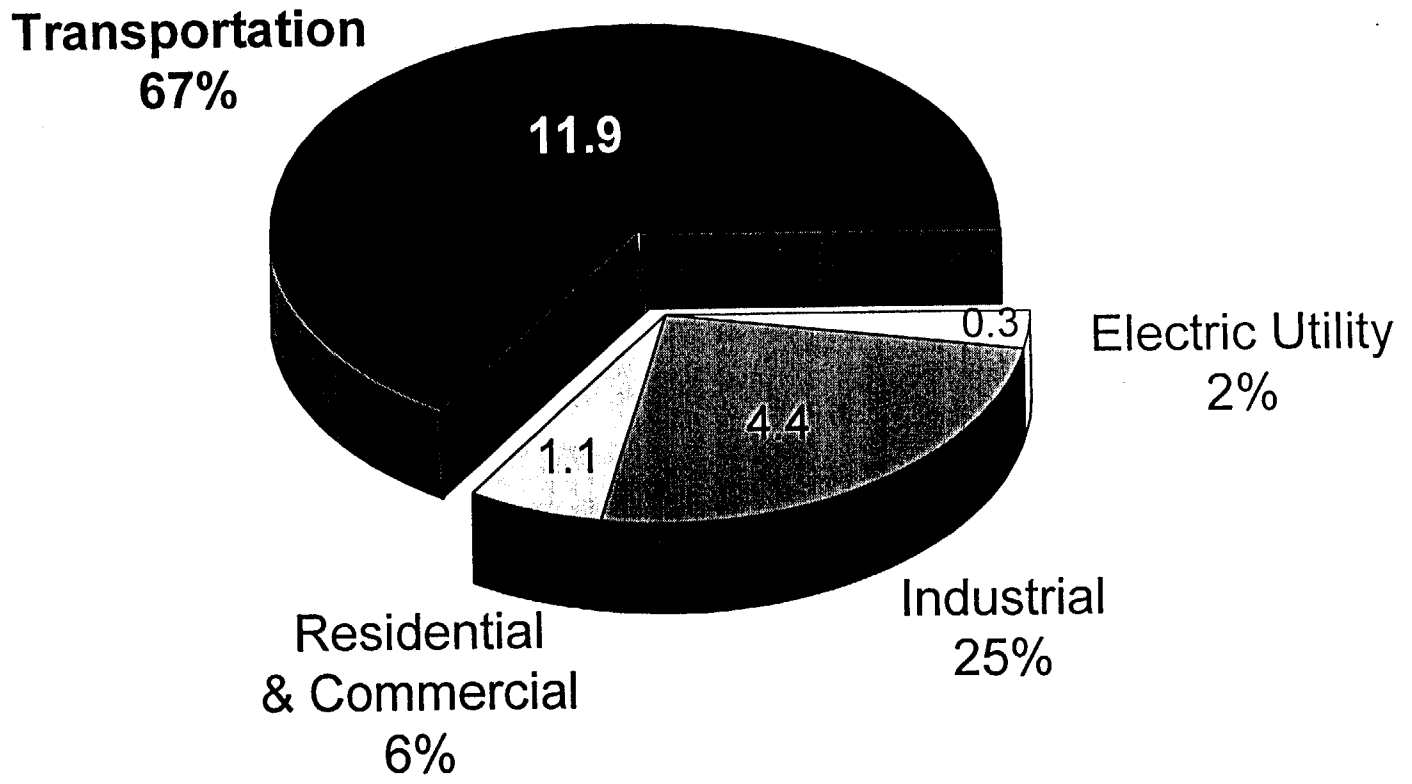


The Nation's Economy is Linked to Efficient Heavy Vehicle Transportation



U.S. Petroleum Dependence, 1995
Transportation Sector Is Key Contributor

Total U.S. Petroleum Use: 17.7 Million Barrels Per Day



Source: Monthly Energy Review, March 1996
Energy Information Administration

Impact of Transportation on the U.S. Economy

On the U.S. Economy (1992)	• Approximately 17% of GDP ($1,013 billion in gross domestic product)
On the Nation's Trade Deficit (1993)	• $45 billion in oil imports • $50 billion in net motor vehicles and parts imports
On the Nation's Consumers (1993)	• 11.3% of household expenditures • $91 billion in new auto costs • $104 billion in fuel and oil costs
On the Nation's Health	• An estimated $45 billion in health costs attributable to air pollution

Economic Impacts
Heavy Transportation Vehicles

On the U.S. Economy (1995)

- Approximately 4.8% of GDP ($348 billion in GDP, all trucks)

On the Nation's Trade Deficit (1995)

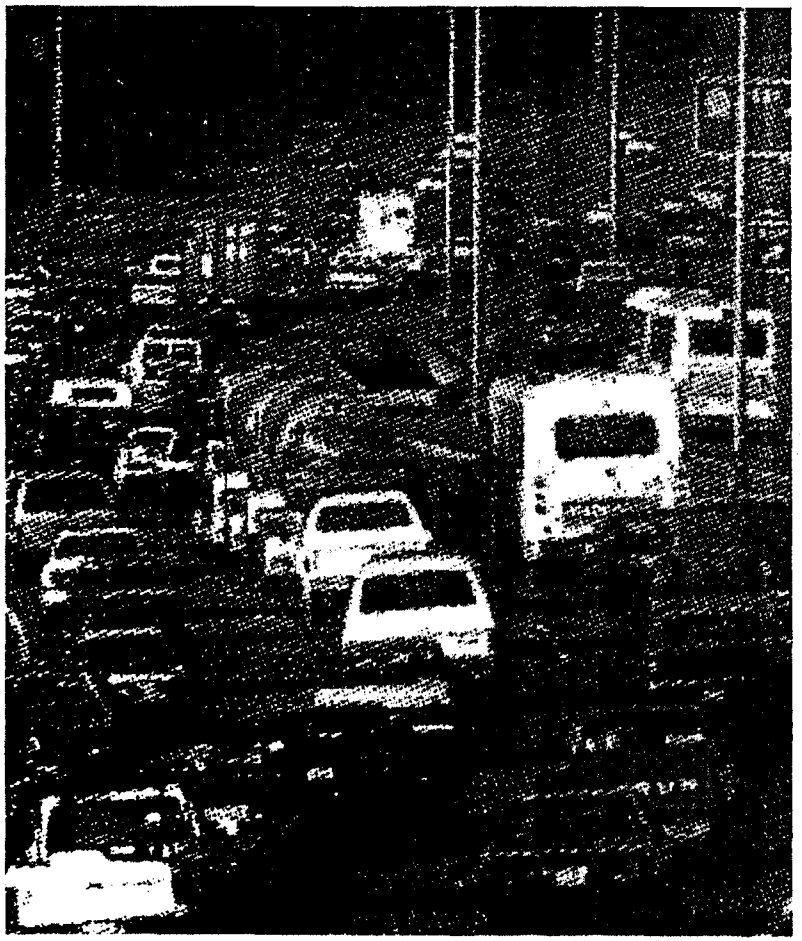
- $25.7 billion in net oil imports (all trucks, 1994)
- $0.5 billion in net Class 3-8 exports
- $5.5 billion in net Class 1-2 imports
- 17.6% of total merchandise trade deficit (all trucks)

On the Nation's Business & Consumers (1994)

- $46 billion in sales of new class 3-8 vehicle costs
- $77 billion in sales of new class 1-2 vehicle costs
- $69 billion in diesel/gasoline costs (all trucks)

Source: ENO Transportation
AAMA Facts & Figures 95
US DOE Transportation Energy Databook - Edition 16
U.S. Department of Commerce

Problem: Transportation Energy Demand Is Increasing



Source: Transportation Energy Data Book, May 1994.

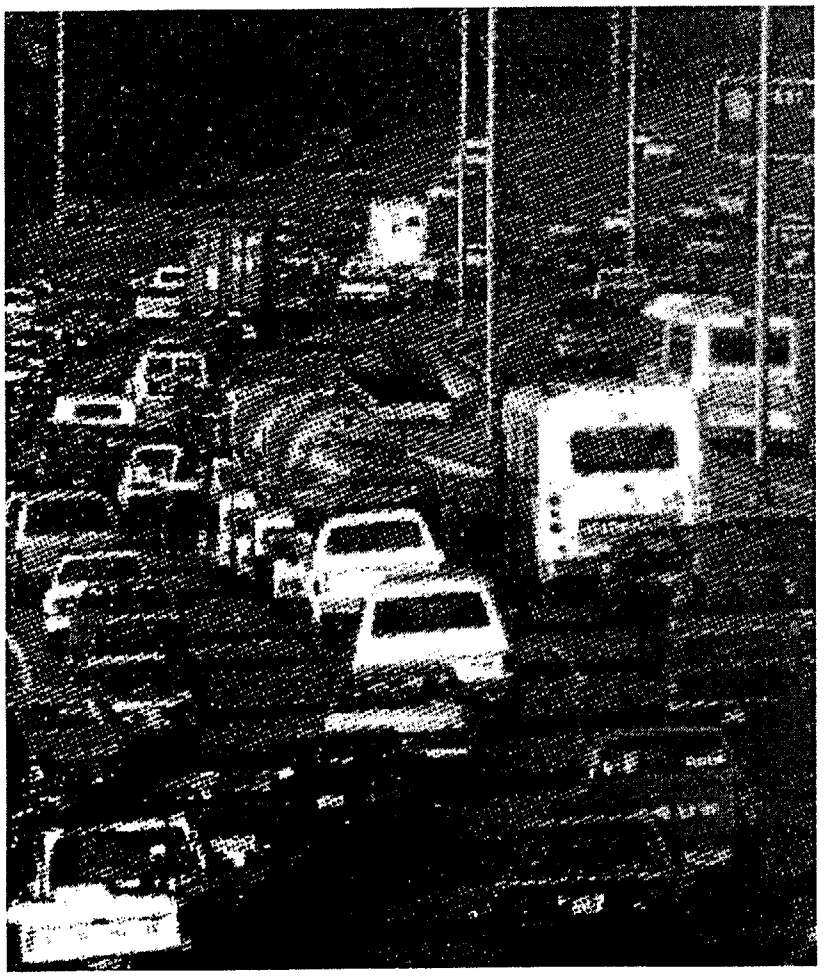
FACT:

- Since 1980, MPG efficiency for all passenger cars increased 39%; and
- Real fuel cost per mile has declined 59%.

RESULT:

- The real operational cost of driving has dropped 50%;
- Vehicle miles traveled increased 43%; and
- Transportation energy consumption increased 14%.

Energy Pollution Is A Public Health Issue



- 54 million Americans live in counties that regularly violate air quality standards.
- 80% of the pollution in urban areas comes from the energy used by transportation systems.
- The American Lung Association estimates that Americans spend $50 billion a year on health care as a result.

Office of Heavy Vehicle Technologies

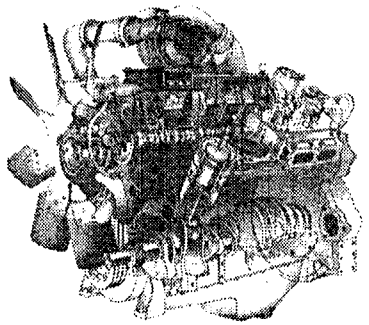
Heavy Vehicle Industry of the Future

Vision

The development of a **fuel-flexible**, energy efficient, near-zero emissions, heavy-duty U.S. **diesel engine** technology devolving into all heavy vehicle applications is a real and viable strategy for reducing energy requirements of commercial transport services and the rapidly growing multi-purpose vehicle market (pick-ups, vans, and sport utility vehicles).

OHVT Strategy: Focus on the Diesel Engine

Efficiency 55% or Higher



Alternative Fuels/ Flexible-Fuel

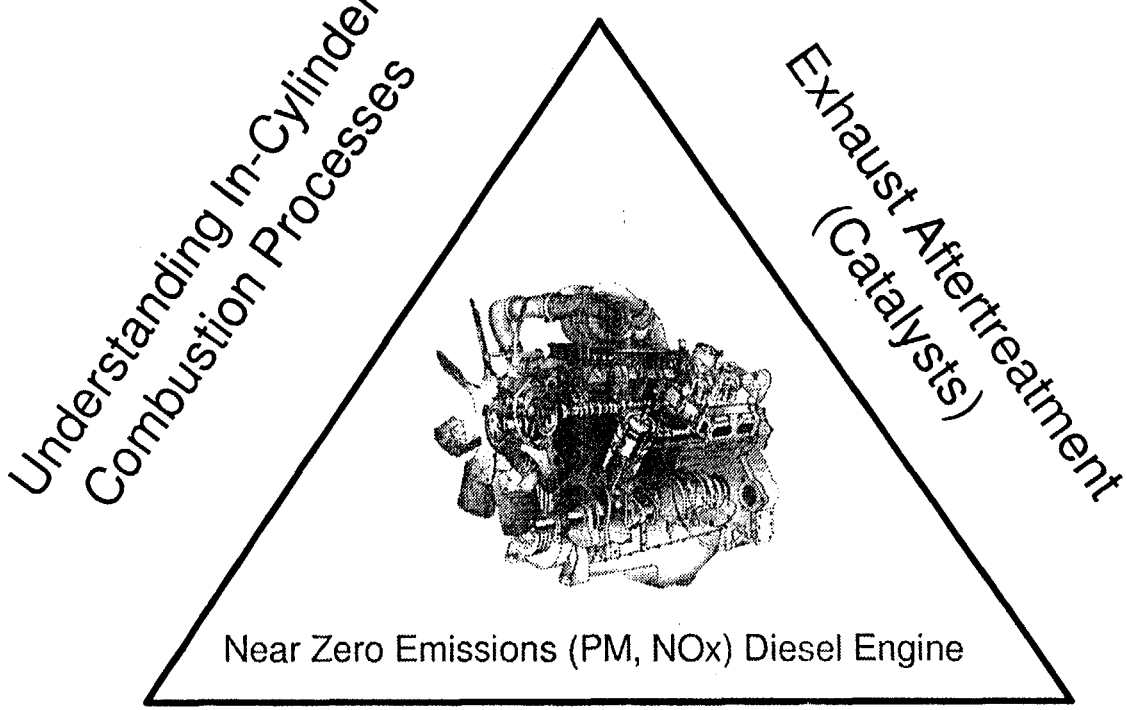
Emissions Control is the Key Enabling Technology

Ultra-Low/ Near-Zero Emissions

Benefits

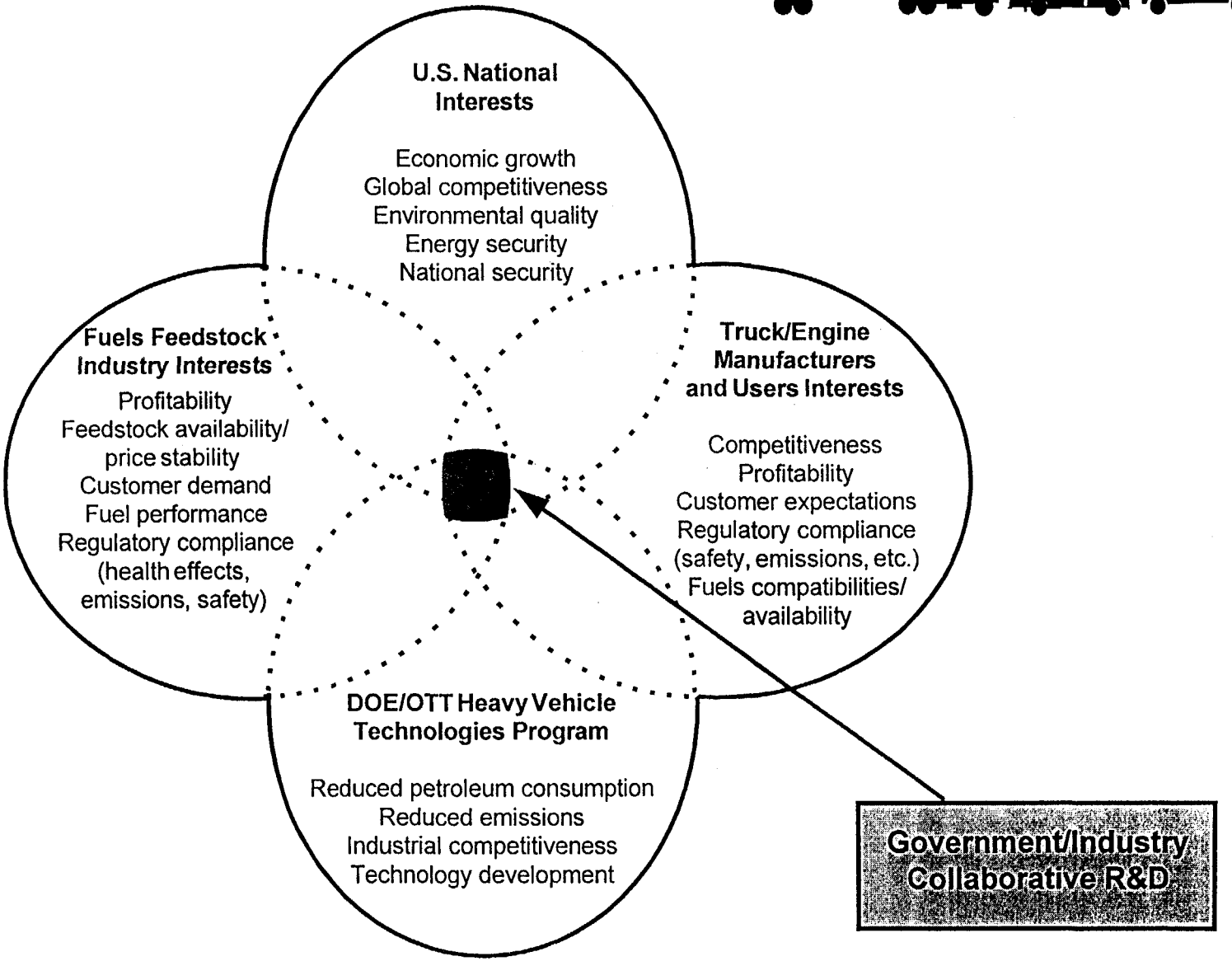
- Highway Energy Use Reduction
- Enhanced Energy Security
- CO_2 Reduction
- Environmental Impact Reduction
- Mitigation of Health Effects

Diesel Engine Emissions Control Strategy



Optimizing all three elements in the diesel cycle engine is necessary to meet ***near zero emissions without sacrificing engine efficiency***

DOE/Industry Collaborative R&D Efforts Target Common Interests



Workshops and Meetings Soliciting Customer Input

- **DOE/SAE Workshop on Energy Efficient Heavy Vehicle Technologies for Reducing Fuel Costs: Leveraging DOE's R&D Capabilities**
  Romulus Michigan, April 17 - 18, 1996
- **DOE/Office of Heavy Vehicle Technologies Customer Focus Workshop**
  Golden, Colorado, May 14 - 15, 1996
- **SAE Truck and Bus Council Meeting**
  Miami, Florida, June 24 - 25, 1996
- **DOE/OHVT Workshop on Applications of Carbon Products for Efficient Operation of Heavy Trucks, Buses, and Other Commercial Vehicles**
  Chicago, Illinois, September 4 - 5, 1996
- **1996 SAE International Truck and Bus Meeting and Exposition**
  Detroit, Michigan, October 14 - 16, 1996
- **DOE Automotive Technology Development Customers' Coordination Meeting**
  Detroit, Michigan, October 28 - November 1, 1996
- **Workshop on Future Fuels Technologies for Heavy Vehicles**
  Chicago, Illinois, November 20 - 21, 1996
- **Workshop on Improving Heavy Vehicle Aerodynamics**
  January 1997
- **Workshop on Diesel Engine Emissions Reduction**
  San Diego, California, July 1997

Office of Heavy Vehicle Technologies

R&D Agenda on Future Fuels Technologies for the Heavy Vehicle Industry

Consensus

?

"Strawman" Proposal for Future Fuels Technologies for Heavy Vehicles

Strategy

Diversity of Feedstocks

- Petroleum
- Natural Gas
- Coal
- Biomass

TO

Common Fuel Requirements

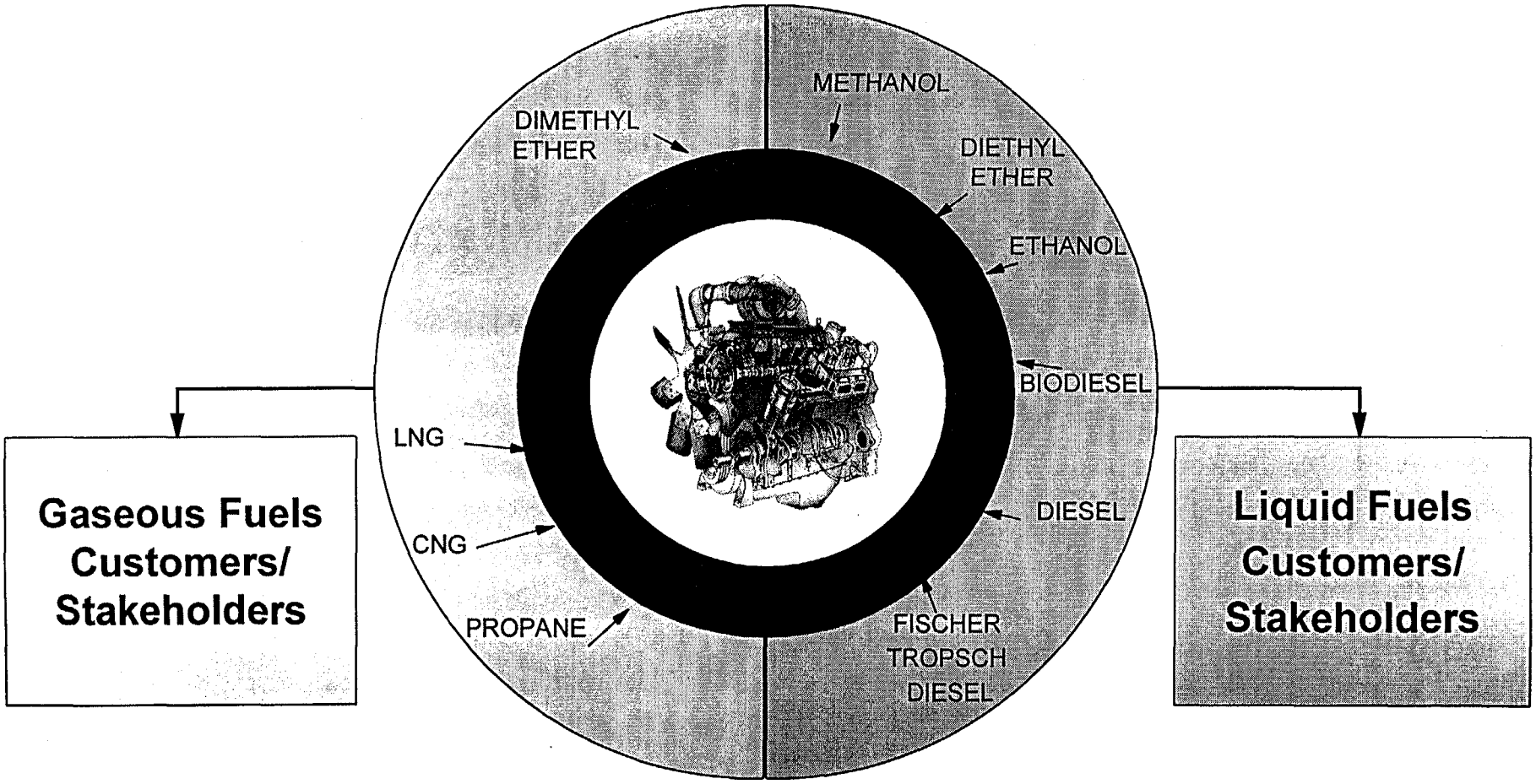
- Cetane number
- Energy density
- Emissions characteristics
- Cost competitive

FOR

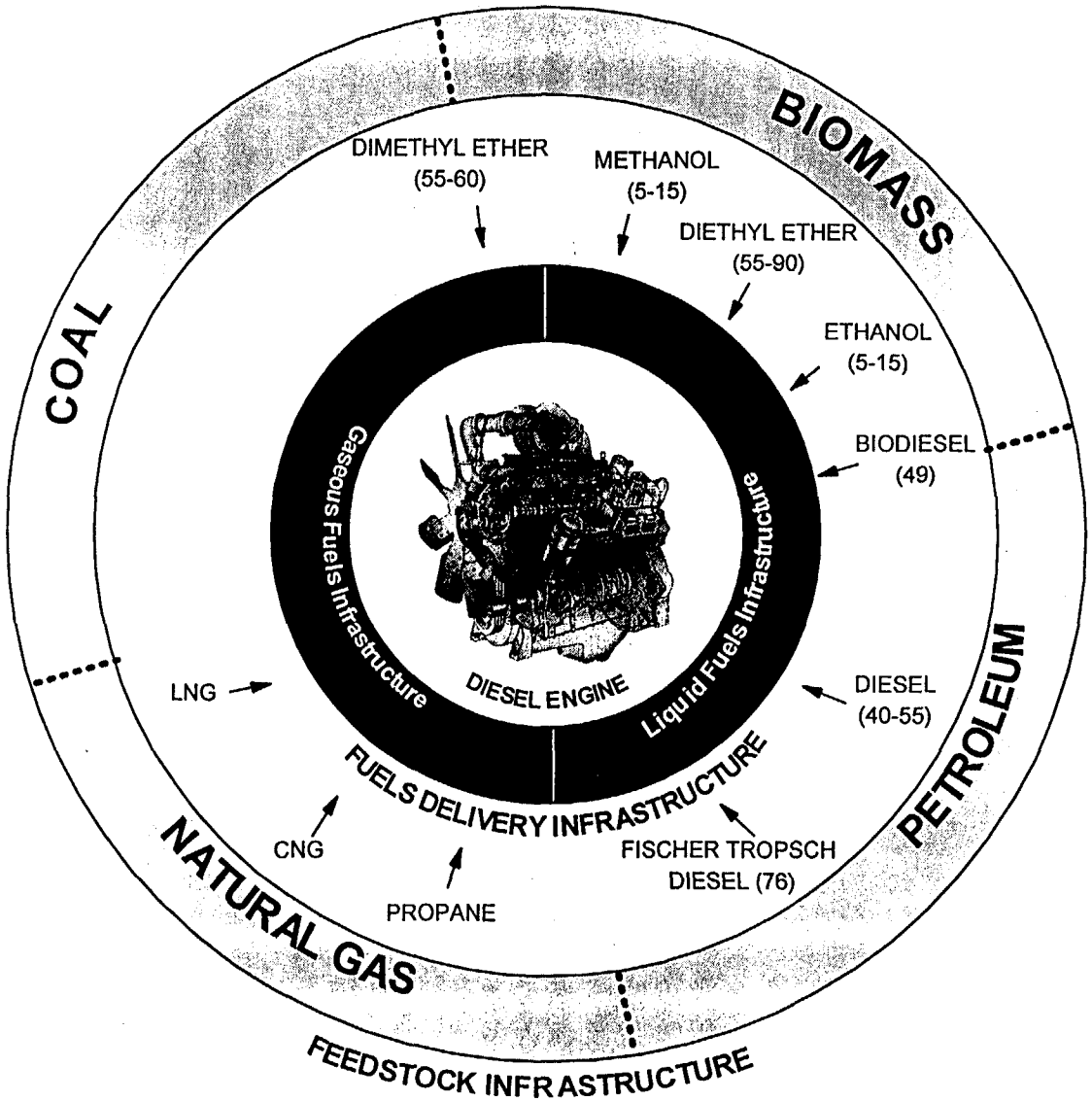
One Energy Conversion System

- Diesel Engine

Future Fuels for Heavy Vehicles: Exploiting Present Fuels and Feedstock Infrastructures



Diversity-of-Feedstocks Strategy: Exploiting Present Fuels and Feedstock Infrastructures



Heavy Vehicle Industry of the Future

Truck Operators/Customers Concerns Regarding Engines and Fuels

- Minimize operating cost
- Fuel supply and distribution infrastructure
- Uninterrupted fuel supply for life of vehicle
- Return on large investment in trucks and engines
- Maintenance (frequency and cost) of alternative fuel systems
- Lack of experience base of alternative fueled engines
- Additional parts and inventory required for differently fueled engines

Summary

- Heavy vehicle (truck) highway transportation energy use continues to grow both in the U.S. and the world.
- OHVT's "focus on the diesel engine" could serve as the confluence of energy efficiency, fuels flexibility, and near-zero emissions for the heavy vehicles industry.
- This workshop is a first step in formulating a shared government-industry vision of future fuels technologies for the heavy vehicle industry of the future.

Some Questions for Consideration

For Diesel Engines:

- How important a property is cetane number from the emissions and engine efficiency perspectives?
- Is there a well understood relationship between fuel average cetane number and emissions characteristics?
- Can very high cetane number "alternative fuels" (e.g., DEE) be incorporated easily (i.e., solubility characteristics well understood) into regular diesel fuel?
- Does such blending confer any engine efficiency, performance, emissions, and/or economic benefits compared to conventional blended diesel fuels?

Some Questions for Consideration (continued)

For Diesel Engines:

- Are the health damaging effects of particulates from diesel engines greater or less than those from spark ignition engines?
- Can biodiesel fuel be used to reduce toxicity of diesel to aquatic organisms?
- Can the production cost of biodiesel be significantly reduced?

Some Questions for Consideration (continued)

For Diesel Engines:

- Can DME be produced from pipeline gas at a cost nearly equal to that of LNG from pipeline gas?
- What future fuels are compatible with present pipeline distribution infrastructure?
- Are there issues of concern to the feedstock/fuels producers that should be addressed by DOE/OHVT?

CUSTOMERS' COORDINATION MEETING (CCM)
PANEL DISCUSSION SUMMARY

TRANSPORTATION TECHNOLOGIES

STEVE GOGUEN

U.S. DEPARTMENT OF ENERGY

OFFICE OF HEAVY VEHICLE TECHNOLOGIES

CCM PANEL PARTICIPANTS

PANELISTS INCLUDED REPRESENTATIVES FROM:

- CATERPILLAR
- NAVISTAR
- JOHN DEERE
- CUMMINS
- DETROIT DIESEL
- AVL POWERTRAIN
- BROOKHAVEN NATIONAL LABORATORY

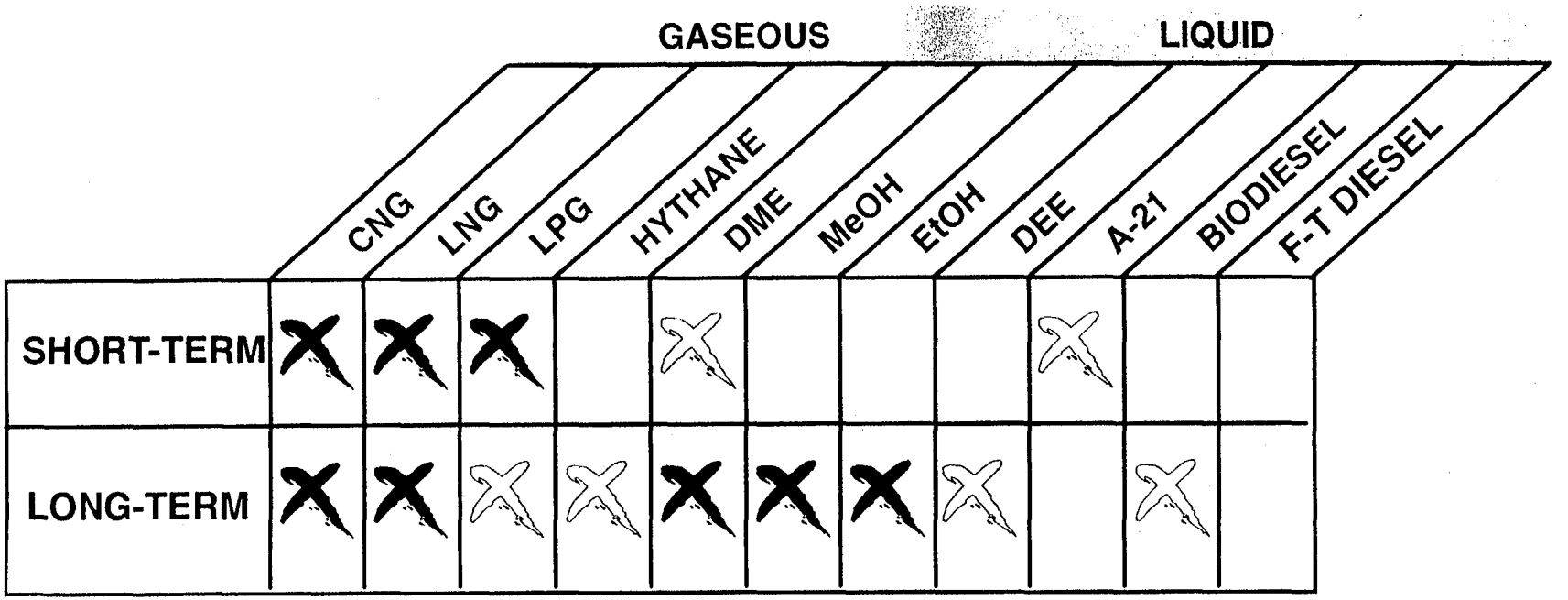
CCM PANEL INSTRUCTIONS

DISCUSS DEVELOPMENT OF TECHNOLOGIES FOR FUTURE FUELS

- SHORT-TERM VS. LONG-TERM
- VISION
  - CURRENT ACTIVITIES
  - FUTURE ACTIVITIES

CCM PANEL RESULTS

CHARACTERIZATION OF FUELS



CCM PANEL ISSUES

SHORT-TERM

FUELS:	CNG, LNG, & PROPANE
ENGINE DEVELOPMENT:	IMPROVEMENT OF ENGINE EFFICIENCY AND ON-BOARD STORAGE UTILIZING GASEOUS FUELS

CCM PANEL ISSUES

LONG-TERM

FUELS:

- CNG, LNG, DME, MeOH, EtOH

ENGINE DEVELOPMENT:

- RADICAL IMPROVEMENT IN GASEOUS FUEL ENGINE EFFICIENCY
- LOW PRESSURE STORAGE OF GASEOUS FUELS
- DEVELOP FUEL FLEXIBILITY OF THE DIESEL ENGINE INCLUDING THE CAPABILITY TO RUN ON BLENDED FUELS

Q: WHY IS DOE ASKING ALL THESE QUESTIONS? WHY ARE WE HERE TODAY?

A: OHVT FUELS AND LUBRICANTS TEAM IS IN THE PROCESS OF DEVELOPING A MULTI-YEAR PLAN FOR TECHNOLOGY DEVELOPMENT FOR FUTURE FUELS

F&L
MULTI-YEAR
PLAN

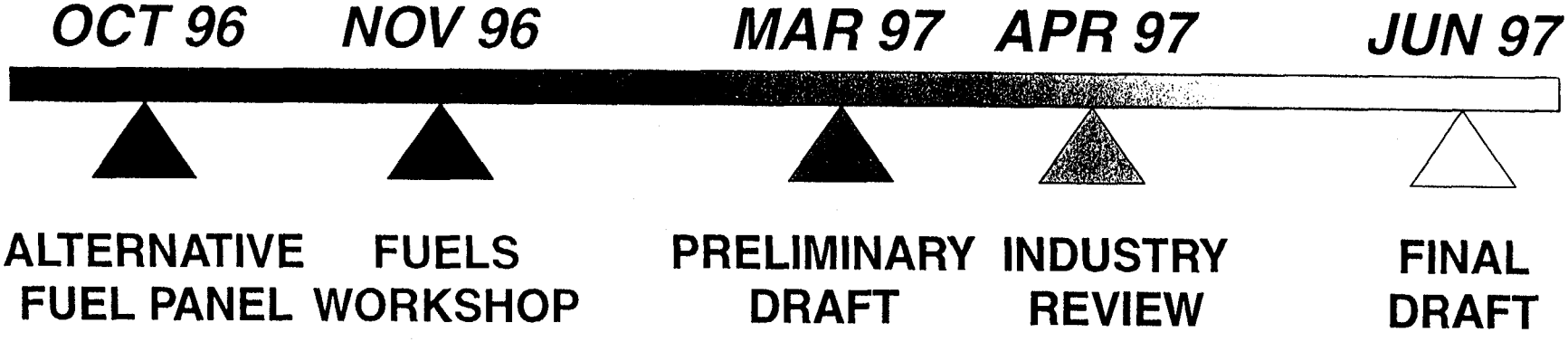
OHVT

MULTI-YEAR PLAN

SHORT-TERM: 3 YEARS

LONG-TERM: 4 - 10 YEARS

SCHEDULE


OCT 96
NOV 96
MAR 97
APR 97
JUN 97
ALTERNATIVE FUEL PANEL
FUELS WORKSHOP
PRELIMINARY DRAFT
INDUSTRY REVIEW
FINAL DRAFT

ATA FOUNDATION TRI

ALTERNATIVE FUELS

➥ Trucking Industry Perspective

ATA FOUNDATION TRI

BACKGROUND

- Mandates - 1980's
- ATA Foundation Industry Study
  - No significant activity
  - No OEM truck activity
- Demonstrations
  - Alcohol Fuels (ethanol)
  - Biodiesel
  - Natural Gas Vehicles

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Trucking Industry Needs

- Transparancy
- Infrastructure
- Comparable Cost
  - Economic Incentive (?)
- Highway Trust Fund Support

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TRUCKING MARKET

- 185,000 Class 8/year
- 25 Billion Gallons Diesel/year
- 13% Growth (Vehicles) - 2004

V.K. Duggal

Cummins Engine Company, Inc.

Presentation Materials Not Available for Publication

John J. Nepywoda

Amoco Corporation

Presentation Materials Not Available for Publication

Fuel Additive Suppliers Perspective on Future Fuels for Heavy Duty Vehicles

Rob Davidson
Ethyl Corporation

Presentation Outline

- Introduction
- Diesel Fuel Additives for "Conventional" Fuel
  - Cetane improvers
  - Detergents
  - Lubricity Additves
  - Combustion Improvers
  - Others
- Additives for Future Fuels

Role of Fuel Additives in "Conventional" HDV Fuels

- Improve Vehicle Performance
- Greater Utilization of Crude Oil
  - Reduce fuel cost
  - Decrease dependence on oil imports
- Reduce Emissions

Diesel Fuel Additives

- Cetane improvers
- Detergents
- Lubricity Additives
- Combustion Improvers
- Antioxidants
- Corrosion Inhibitors
- Demulsifiers
- Cold Flow Improvers

Higher Cetane Number Fuel

- Environmental Benefits
  - Hydrocarbons
  - Particulates
  - Carbon monoxide
  - Nitrogen Oxides
- Engine Performance Benefits
  - Cold Start
  - Misfire
  - White Smoke
  - Noise

[redacted].

Two Options for Increasing Cetane

Hydrotreating	Cetane Improver
► Expensive	► Inexpensive
► Lowers fuel density	► No change in physical properties
► Lowers fuel economy	

[redacted].

Diesel Detergents

- Major contributor to emissions control
  - Provide emissions "maintenance"
  - Insure proper fuel delivery
  - Smoke, fuel economy benefits
- Impact most obvious in field applications
  - Vehicles can be kept "Like New"
  - Difficult to show in dyno tests

[redacted].

Diesel Lubricity Additives

- Lubricity performance needed for fuel pump protection
- Severe hydrotreating removes sulfur and aromatic compounds which provide lubricity benefits
- Additives can restore lubricity performance

[redacted].

Diesel Fuel Combustion Improvers

- Complement detergents and cetane improvers
- Deliver small amount of combustion catalyst
- Can significantly reduce emissions
  - Particulate, smoke, & PAH
- Work later in combustion cycle
  - (Cetane improvers work early in cycle)
- Two application methods:
  - Direct (oxidize soot or produce hydroxyl radicals)
  - After-treatment (catalyze oxidation in a trap)

[redacted].

Diesel Fuel Additive Packages

- Consist of multiple components formulated to maximize performance
- Require extensive testing to demonstrate both the benefits and "no harm" performance
  - Laboratory tests
  - Engine dynamometer testing
  - Fleet testing
- Packages must be optimized for different fuels
- Package development is expensive

[redacted].

Additive Packages for Future Fuels

- Future fuels will require additives to provide performance at least comparable to current optimized diesel fuels
- Different additive packages will likely be required
  - Corrosion inhibitors for fuels containing water or alcohol
  - Stability additives for vegetable oil-derived fuels
  - Gaseous fuels ?
  - Expensive no harm testing will be required
- Fuel additive suppliers can not afford to develop and test additive packages for all fuel types

[redacted].

Diesel Additives
Summary and Conclusions

- Additives can convert a "conventional" diesel fuel into an "alternative" diesel fuel
  - Decrease U.S. oil requirements
  - Decrease HDV emissions
  - Improve vehicle performance
- Non-traditional diesel fuels need to perform comparably to optimized current fuels for broad usage
- Alternative fuels will require different fuel additives

[redacted].

L.L. (Mike) Ansell

Exxon R & D

Presentation Materials Not Available for Publication

APPENDIX C:

BREAKOUT GROUP MEMBERS

Breakout Group A

Vinod K. Duggal, Facilitator	Cummins Engine Co., Inc.
Harvey Drucker, Co-Facilitator	Argonne National Laboratory
René B. Abarcar, Scribe	Energetics, Inc.
Christopher F. Blazek	Institute of Gas Technology
Dan T. Daly	The Lubrizol Corp.
Frederick L. Dryer	Princeton University
Stephen J. Goguen	U.S. Department of Energy
Nabil S. Hakim	Detroit Diesel Corp.
Jill N. Hamilton	National Alternative Fuels Hotline
Steve A. Howell	National Biodiesel Board
Gilbert R. Jersey	Mobil Technology Co.
Richard Mastronardi	Thermo Power Corp.
William Siegel	U.S. Department of Energy
Susan L. Willis	U.S. Environmental Protection Agency

Breakout Group B

L. L. (Mike) Ansell, Facilitator	Exxon Research
Dennis L. Siebers, Co-Facilitator	Sandia National Laboratory
Peter McCallum, Scribe	Antares Group, Inc.
Ray Costello	U.S. Department of Energy
James H. Garrett	SW Research Institute
Alfred K. Jung	Texaco, Inc.
Donald W. Lyons	West Virginia University
Michael R. Marelli	Mesa Pacific
Donald J. McAlister, Jr.	Quantum Energy Technologies
Alissa J. Oppenheimer	Gas Research Institute
Bernard G. Richards	Caterpillar, Inc.
Cindy Sullivan	South Coast Air Quality Management District
Richard Wares	U.S. Department of Energy
James Wegrzyn	Brookhaven National Laboratory

Breakout Group C

Robert I. Davidson, Facilitator	Ethyl Corporation
Brent K. Bailey, Co-Facilitator	National Renewable Energy Laboratory
David J. Gelman, Scribe	Antares Group, Inc.
Joan C. Axelrod	Mobil Technology Co.
Rodica A. Baranescu	Navistar International Transportation Corp.
Reda M. Bata	West Virginia University
George W. Kalet	Minnesota Valley Engineering
Bernhard J. Kraus	Exxon Research & Engineering Co.
Norm Marek	Illinois Department of Commerce
Henry J. Modetz	Institute of Gas Technology
Jules L. Routbort	Argonne National Laboratory
Gurpreet Singh	U.S. Department of Energy
Sean H. Turner	Natural Gas Vehicle Coalition
Nick White	NGV Technology

Breakout Group D

William H. Peerenboom, Facilitator	Trucking Research Institute
Ronald L. Graves, Co-Facilitator	Oak Ridge National Laboratory
Christina E. Gikakis, Scribe	Energetics, Inc.
Glenn R. Bower	University of Wisconsin-Madison
Daniel Butler	Los Alamos National Laboratory
Stephen J. Enger	Greenfuels/NIPSCO
John Fairbanks	U.S. Department of Energy
Barbara Goodman	National Renewable Energy Laboratory
Madan R. Goyal	Deere Power Sys. Group
Michael Gurevich	U.S. Department of Energy
Robert J. Last	FEV Engine Tech., Inc.
John Nepywoda	Amoco
Gary L. Pope	Praxair
Ram D. Srivastava	BRSC Department of Energy-Pittsburgh
George M. Sverdrup	Battelle
J. Tom Vachon	Caterpillar, Inc.

APPENDIX D:

BREAKOUT SESSION NOTES

by

René Abarcar, Energetics, Inc. (Group A)
Peter McCallum, Antares Group, Inc. (Group B)
David J. Gelman, Antares Group, Inc. (Group C)
Christina E. Gikakis, Energetics, Inc. (Group D)

Workshop on Future Fuel Technology for Heavy Vehicles
November 20-21, 1996

Breakout Session Summary — Group A

Participants

Vinod Duggal, Cummins Engine Co., Inc. (Facilitator)
Harvey Drucker, Argonne National Laboratory (Co-Facilitator)
René Abarcar, Energetics, Inc. (Scribe)
Christopher Blazek, Institute of Gas Technology
Dan Daly, The Lubrizol Corporation
Frederick Dryer, Princeton University
Stephen Goguen, DOE/Office of Heavy Vehicle Technologies
Nabil Hakim, Detroit Diesel Corp.
Jill Hamilton, National Alternative Fuels Hotline
Steve Howell, National Biodiesel Board
Gilbert Jersey, Mobil Technology Co.
Richard Mastronardi, Thermo Power Corp.
William Siegel, DOE/Office of Heavy Vehicle Technologies
Susan Willis, EPA/Office of Mobile Sources, Fuel Studies & Standards

Overall Summary (presented by Vinod Duggal to the whole group)

Diesel engine technology (especially the heavy-duty diesel) will continue to be the mainstay for commercial applications; 10 to 50 years into the future, it (or a similar engine with diesel-like efficiency) will still be the powerplant.

On future fuel, only two fuels will be available: petroleum fuels and natural gas (and other derivatives of natural gas).

Diesel cycle engines will be around in the timeframe 0-10 and 10-50 years; there will be no basic change until 2004, when small changes will occur and the engine will definitely get better.

In 10-50 years, the fuel mix will change but diesel fuel will still be a significant part; another part will consist of fuel mixtures (maybe derived from synfuels, alternative fuels, etc.).

(Nabil Hakim added that the future engine will continue to be based on the diesel cycle, with evolutionary developments to improve efficiency and reduce emissions.)

Summary of Discussions

Question 1: What do you foresee as the fuel mix for the first decade of the twenty-first century?

The fuel will substantially be diesel fuel and diesel fuel blends (blending with nonpetroleum fuels will be as high as fuel properties will allow, to reduce the amount of diesel).

Emissions, economics, and energy policy are the drivers that will determine the fuel mix.

The group generally agreed that:
- present diesel engines may not meet 2004 standards
- fuel blends with present diesel engines might meet the 2004 standards
- redesigned diesel engine might meet the 2004 standards.

Although diesel fuel blends can lower emissions of some older diesel engines, it is not certain that these engines can meet the 2004 standards, especially for NO_x. Also, because diesel fuel blends can reduce emissions in both new and old engines, the total tonnage of NO_x and PM will be reduced as a consequence.

The majority opinion is that the fuel mix to the year 2010 will be 95% diesel fuel and 5% blends (including gaseous fuels).

Question 2: What barriers prevent the use of nonpetroleum fuels in heavy vehicles in the near term?

The group listed the barriers perceived for each of the nonpetroleum fuels considered:

CNG
- storage (volume/range)
- cost
- weight
- infrastructure
- safety
- engine efficiency
- warranty/reliability/wear

LNG
- taxation
- storage
- infrastructure
- engine efficiency
- safety

Biodiesel
- availability
- fuel properties (cold flow)
- cost
- competition (fuels vs. food and fiber)

Question 3: Do you envision emissions standards as the driver for choices among fuels?

The group was in agreement that emissions standards are one driver; other drivers have been discussed in conjunction with Question 1.

Question 4: What do you foresee as the fuel mix of the mid-twenty-first century?

The group generally agreed that 50 years from now, the diesel cycle engine will remain the heavy-duty prime mover. There will be only two fuels, diesel fuel and natural gas/natural-gas-derived fuel (optimistic estimate is as high as 50% share for natural gas/natural-gas-derived fuel).

Workshop on Future Fuels Technology for Heavy Vehicles
November 20-21, 1996

Breakout Session Summary — Group B

Participants: Ansell (Exxon Research)[Facilitator], Siebers (Sandia)[Co-Facilitator], Garrett (SwRI), Jung (Texaco), Lyons (WVU), Marelli (Mesa Pacific), McAlister (Quantum Energy Technologies, Inc.), Oppenheimer (GRI), Richards (Caterpillar), Sullivan (SCAQMD), Wares (DOE), Wegrzyn (Brookhaven Nat'l Lab), Costello (DOE), McCallum (Antares Group)[Scribe]

Introduction

SCAQMD — Consider "consensus" fuel selections named by S. Goguen yesterday; look at each in near and long terms.
Near term: CNG, LNG, LPG
Long term: DME, MeOH, EtOH, F-T liquids

DOE — DEE also a long term option.

Exxon — How can we approach the task of ordering R&D priorities for all fuels?

GRI — Can we establish a benchmarking matrix for fuels using the most important criteria?

Cat — How about:
- fuel processing economics
- fuel handling systems
- engine technologies,

all examined in near and long terms?

DOE — Energy security contribution of alternative fuel is paramount. Environmental impact and national economic stability contribution are also important.

Antares — Need the alternative fuel offer distinct environmental advantages over petroleum?

DOE — No, as good as petroleum is OK.

Cat — Should we consider tax and regulatory effects on fuel economics?

Texaco — What about infrastructure cost? Development of new infrastructure can be multi-billion dollar undertaking.

SCAQMD — Is existing infrastructure even usable for some alternative fuels?

Texaco — Transition use of blends (alternative fuels with petro distillates) could help solve infrastructure problem.

Sandia — Stick with the diesel engine (high efficiency) in the long term.

Consensus — Use following benchmarking criteria:

A. Energy security contribution (domestic availability, significant quantities)
B. Environmental performance (ability to meet 2.5 g/bhp-hr NO_x + HC)
C. Economics (compete with DF2 at $0.60/gal, on an energy equivalent basis)
D. Infrastructure (cost/difficulty of establishing new, adapting existing storage and distribution systems)

Exxon — Near and long terms were defined differently yesterday in Steve Goguen's remarks and today in the charge to the breakout groups.

	NG	LPG	Meth	Eth	DME	DEE	BD	H2	A-21	F.-T.
A- nt	+	+	+	+	+	+	+	+	-	+
A-lt	?	-	?	+	?	+	+	+	-	+
B-nt	+	+	+	+	+	?	?	+	+	0
B-lt*										
C-nt	+	-	-	-	-	-	-	-	-	-
C-lt*										
D-nt	-	0	0	0	?	?	?	-	-	0
D-lt*										

Notes: Natural gas considered as one fuel; CNG and LNG taken together, because resource is the same and both are consumed as gas by the engine.

+ and - indicate advantage/ improvement and disadvantage/deterioration.

? indicates not known at present.

0 indicates no obvious advantage/disadvantage.

**Long-term ranking of fuels is less well-defined due to unpredictable influence of economic factors and time frame selected to represent the long term.*

R&D Priorities

Natural gas (CNG and LNG)

- bulk storage improvements
- vehicle storage improvements (density, safety, and cost)
- CNG compression systems
- long-term: improvements in engine efficiency (direct injection gas engine) [Cat: DING engine can follow diesel BMEP and BSFC]
- LNG delivery and production (purpose-built LNG facilities vs. current peak-shaving, N_2 rejection, etc.)
- incremental improvements to SING engines in the short term (these engines may be near the limits of their BMEP and BSFC potential at their current stage of development)

Liquefied Petroleum Gas (LPG)

- fuel specification - consistency of quality for engine use
- demonstration of actual emissions potential
- long-term: DI engine application

Methanol

- short term: no clear R&D needs
- long term: DI diesel (current technology)
- R&D on blends of MeOH with petroleum diesel fuel

Dimethyl ether (DME)

- production cost studies
- study use of existing natural gas infrastructure for distribution, etc.
- study use of DME as blending agent? (LNG)
  [Cat: DOE would be wasting money on DME engine work; production economics is the key. Let Europeans spend the engine development money. U.S. engine builders could readily respond with hardware if production economics prove attractive.]
- long term: contingent on results of above, short-term work

Diethyl ether (DEE) - short term

- characterization for safety and engine performance

Biodiesel (BD) - all short term

- emissions, fuel spec(s)
- use of alternative feedstocks (waste oils and fats, etc.)
- use as a petroleum diesel fuel additive

Fischer-Tropsch (F.-T.) Liquids

- short term - U.S.-based production processes
  [Exxon: Other U.S. oil companies have expressed interest in Exxon's F.-T. technology]

Workshop on Future Fuel Technology for Heavy Vehicles
November 20-21, 1996

Breakout Session Summary — Group C

Participants: Davidson (Ethyl) [Facilitator], Bailey (NREL) [Co-Facilitator], Axelrod (Mobil), Baranescu (Navistar), Bata (WVU), Kalet (Minn Valley Engineering), Kraus (Exxon), Modetz (IGT), Routbort (ANL), Singh (DOE), Turner (NGVC), Marek (Ill. Dept. of Commerce and Community Affairs), Gelman (Antares Group) [Scribe]

Introduction

All relevant fuels should be considered — instructions refer to fuels for *diesel cycle* engines, not just diesel fuels.

WVU — There is no single magic fuel. Look at what makes sense regionally.

ANL — This is for forming a plan/roadmap, to take us toward reducing dependence on foreign petroleum.

NGVC — Should we be limited to diesel cycle?

ANL — It's the most efficient cycle.

NGVC — If you're talking lab vs. "real world."

Navistar — Some natural gas engines are spark-ignited (SI). So do we talk heavy-duty engines only?

ANL — No. Also light trucks and sport utility vehicles (SUVs).

Addressing Steve Goguen's Questions

Question *1:* What do you foresee as the fuel mix for (the heavy vehicle sector in) the first decade of the twenty-first century?

Discussion

Mobil — Petroleum-based dominate, except where incentives exist.

Exxon/IGT	Economics drive it.
NREL	What about LNG?
Exxon	Where its use is near its source. If talking economics, crude oil products are still the cheapest to *make*. They might not be the cheapest to the user, depending on taxes.
IGT	The engines are already out there for this time-frame.
Ethyl	EPA's 2004 standards could have some impact.
Mobil	Cost of petroleum fuel will be higher. This helps alternative fuels.
MVE	Helps sway economics. Look at tomorrow's requirements — 2004 standards.
IGT	But companies are not doing R&D on alternative fuels as much — they're worrying about 2004 compliance (for conventional fuel engines).
Navistar	Diesel fuel engines can make it.
NGVC	EPA won't write regulations that diesel can't make.
Ethyl	The Engine Manufacturers Association says it needs help.
Navistar	So what we see is LNG when it's near source, high mileage vehicles, transit buses; niches. We also see conventional/petroleum fuels — diesel plus gasoline, some reformulated. CNG/LNG, plus a small amount of LPG.
NGVC	Probably not MeOH, but a little EtOH (if costs come down, such as from DOE programs). Biodiesel is still a question — perhaps a little from 2000-2010.
Navistar	Some potential for biodiesel blends up to B20 for conversions of older urban fleets — no advantage in new engines (because no smoke reduction needed), plus cost, long-term durability, NO_x, and lubricity issues. No warranties on new engines, although we're helping some existing customers.
Exxon	If every Btu cost the same in 2010 — what engine would you choose?
Navistar	Diesel fuel probably. Natural gas is still SI, so lower efficiency. Technology is not ready for stratified charge, etc.

IGT	Shell shelved their program on it.
Navistar	Look at the customer. He can achieve his needs on petroleum.
Mobil	Experience says cost of diesel won't skyrocket, though there will be some cost increases due to reformulating.
NGVC	Technology on the road is what you have to look at, not what's in the lab. For SI engines, fuel economy is within a few percent of diesel. Can get closer to cost-competitive.
MVE	Look at the big picture — meet needs on a *national basis*, then look at fuel mix.
IGT	Might be some regional market for EtOH and biodiesel — some fleets use centralized fueling.
ILLDCCA	Some niche markets are developing — the infrastructure is key.
Exxon	So, what fuels would you supply engines for?
Navistar	Highest efficiency, infrastructure existing, highest energy density — other events might change this (like a disruption).
WVU	Develop the diesel engine to accept other fuels.
NGVC	Should alternative fuels be limited to an engine type developed for diesel fuel?
DOE	There will be a redesign transition if there's a disruption.
IGT	Should DOE look at a natural gas or diesel engine to burn natural gas?
Navistar	We built a natural gas engine, starting with commonality to diesel.
DOE	Some overdesign in that approach, but that's probably okay.
NREL	What if there were no cost differences? Fischer-Tropsch diesel and DME?
Navistar	Diesel fuel is preferred, if you don't have to go below 2g NO_x — after that, alternative fuels compete. DME has lower emissions

Consensus—Answer/Reasons for Question 1

Reasons: The time period is not far away. Many of the vehicles for the 2000-2010 time period are already in use. Preparations are already in place for the vehicles/engines to be offered in that time-frame, too. If there are no critical events, there will be no significant changes, and no major disruptions are foreseen. In addition, there are no major investments being made in changing the system, especially for infrastructure and technology development. No major cost changes (to fuels) are foreseen either.

Answer: Predominant fuels will be petroleum-based diesel and gasoline, though possibly more will be reformulated. Natural gas (compressed and liquefied) will have some applications that make sense, plus possibly a little bit of LPG. Lower blends of biodiesel (less than 20%) and some ethanol could penetrate some markets (Midwest) toward the latter part of the period, but only if fuel production costs are significantly reduced.

Question 2: What barriers prevent the use of nonpetroleum fuels in heavy vehicles in the near term?

Discussion

Group A. First barrier is *cost*, including:

- Delivered cost per Btu of fuel (including taxes)
- Incremental purchase price or cost of conversion
- Infrastructure investment
- Maintenance/repair parts
- Training cost
- Education

B. Availability of fuels — amount or route to customers

- Feedstock/resource, production capability/capacity, distribution system to where required
- Engine technology? Supply/demand, fuel flexibility (could use variable compression ratio technologies)
- Public acceptance — often based on experience, safety concerns [education]
- Too hard to blend most alternative fuels — could just use gasoline with oxygenates

C. Momentum of diesel engine/diesel fuel technologies
[Jim Eberhardt's point — what role can alternative fuels play in improving diesel engines/fuels?]

- Alternative fuels stimulated diesel engine/fuel development to get better emissions — maybe through alternative fuels causing regulators to lower (make stricter) standards.

D. Regulations — especially consistent regulations and policies

E. Need or lack of incentives

F. Special interests — Each group has its favorite, resulting in a lack of focus. Thus, you have competing interests, which end up segmenting the market for technologies (especially engines). This raises the cost of each segment (because none achieve economies of scale).

G. No ideal multifuel engine exists with current technologies. We need a new engine that is truly multifuel, but still has strong commonality. Right now, the technologies for the fuels are too different, resulting in performance compromises.

Question 3: Do you envision emissions standards as the driver for choices among fuels?

Discussion

NGVC — No.

Navistar — If going below 2g NO_x, Yes.

NGVC — But EPA won't write regulations diesel can't meet.

NREL — For light-duty vehicles (pickups/SUVs), emissions will be set too low for diesels.

ILLDCCA — Global warming issues, maybe.

MVE — Economics is the real driver.

Exxon — There might be some incentives from the regulations — Clean Fuel Fleet, for example — which make them more attractive.

IGT — Might affect choices *among* alternative fuels.

Navistar If doing low emission engine, you'd try DME, not biodiesel.

NGVC But no differentiation, really. It all comes back to cost.

Exxon So, for parts of the world, yes.

Ethyl CARB made it so — reformulated diesel.

Answer to Question 3

Emissions can be *a* driver, but probably won't be *the* driver.

Question 4: What do you foresee as the fuel mix of the mid-twenty-first century?

Discussion

Assumptions

- Worst case could be no imported petroleum available; probably, limited availability of imported petroleum
- Emissions standards are not significantly lower
- Higher efficiencies for vehicles
- Better alternative transportation systems/freight — but, higher mass moved
- New engine technologies mature to market readiness
- New alternative fuel sources available
- U.S. energy consumption goes up, but per capita goes down

Answer to Question 4

Fuel resources include:

- Move to coal-derived fuels (higher energy density), as well as shale and tar sands
- Biofuels — renewables (crops, municipal solid waste, wind, PV), although all have lower energy densities
- Nuclear for electricity
- Petroleum and natural gas

Further Discussion

ANL What kind of R&D should DOE do?

Navistar EMA concerns — developing technology for universal heavy-duty fuel. Feedstocks are different, but you want the basic requirements in the fuel.

ANL Can you get more energy density from fuel without adding too much more energy in?

Exxon Not really. For crude, you could add more of the bottom end, but that hurts emissions.

Discussion of Fuels, with Focus on Utilization

Fuels discussed: A-21, CNG, LNG, LPG, EtOH, MeOH, biodiesel, F-T diesel, DME, DEE, H_2 (fuel cell or internal combustion engine), electricity

Utilization Issues:

1. Properties/specification
2. Cost
3. Stability/storage and thermal stability
4. Fuel/engine compatibility
5. Carbon and hydrogen in normal or ISO chains
6. Liquid

	On-Board Storage	Safety	Fuel Quality	Cost	Engine Efficiency	Emissions	Materials Compati-bility	Energy Security	Durability/ Reliability	Tribology
1.CNG/LNG	+	+	+	0	+	0	0	0*	+	+
2.Alcohols	0	+	+	++	0	+	+	0 EtOH +MeOH	+	+
3.Biodiesel	+	0	++	++	0	+	+	0	+	0
4.LPG	+	+	+	0	+Dedicated 0Pilot Injn	0Dedicated +Pilot Injn	0	+	+	+
5.Ethers	+	+	0	++	0	0	+	0*	0	0
6.F-T Diesel	0	0	0	++	0	0	0	0	0	0
7.Petrodiesel	0	0	0	0	0	+	0	++	0	0

++ Major issue
+ Issue
0 Not an issue (similar to diesel as baseline, except for emissions and energy security)

* Depends on use levels

Technology Development Activities/Research Needs (identified from above)
[No particular order]

1. Combustion/injection approaches and systems
2. Metering natural gas
3. Natural gas storage - on-board
4. Fuel quality sensors
5. Multi-fuel engine (liquid or gas or both) — long-term
6. Perfect blend for fuel
7. Emissions — alcohols and biodiesel
8. Low-cost infrastructure? Compressors, LNG storage, etc.
9. Tribology — ethers, LPG, natural gas, alcohols
10. Valve seats for gaseous fuels
11. After-treatment
    - Aldehydes - alcohols
    - NO_x reduction - diesel, biodiesel, F-T diesel
    - Oxygen catalyst for CO - natural gas
    - Particulate traps?
12. Fuel blending — diesel/alcohol, polyesters, A-21, DME/MeOH/H_2O for existing diesel engines
13. "Demonstrations" for durability/reliability/data generation?

Workshop on Future Fuel Technology for Heavy Vehicles
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Breakout Session Summary — Group D

Participants

William Peerenboom (Facilitator), Trucking Research Institute
Ronald Graves (Co-Facilitator), Oak Ridge National Laboratory
Christina Gikakis (Scribe), Energetics, Inc.
Glenn Bower, University of Wisconsin-Madison
Daniel Butler, Los Alamos National Laboratory
John Fairbanks, U.S. Department of Energy
Barbara Goodman, National Renewable Energy Laboratory
Madan Goyal, Deere Power Systems Group
Michael Gurevich, U.S. Department of Energy
Robert J. Last, FEV Engine Technologies
John Nepywoda, Amoco
Gary Pope, Praxair
Ram Srivastava, BRSC Dept of Energy - Pittsburgh
George Sverdrup, Battelle
Tom Vachon, Caterpillar, Inc.
White, Natural Gas Canada

Question 1: What do you foresee as the fuel mix for the first decade of the 21st century?

Near-term (1997-2000)

- No substantial change. In 1 to 3 years there could not be substantial impact on the market of new fuels. Current evolution in fuels (e.g., reformulated fuels) would continue.

- Liquid fuel that may come to market would be blended with existing fuels (additives).

- Diesel and gaseous fuels will continue to be offered and limited gaseous fuels
  - NG stock available but no infrastructure (CNG possible niche)
  - Blends with alcohols and ethers, etc.

- Some lesser liquid fuels (ethanol, methanol) present in mix.
- Demonstrations of alternative fuels would continue.
- If there was a major interruption in fuel supply, new infrastructure could not be put into place in this time period. Response would be limited to blending fuels or fuel additives.

Midterm (2000-2010)

Class 5-8 (>150 hp)

- LNG — meaningful penetration given modifications to get production infrastructure in place (group defined "meaningful penetration" as 1% or approximately 250 M gal fuel).
- Probability for Fischer-Tropsch diesel is a function of petroleum cost. (Fisher-Tropsch diesel has a high cetane number and can be used with existing infrastructure and engines; however, processing is costly.)

Class 1-4

- CNG and propane >1%.
- Problems with diesel-powered light-duty engines meeting the more stringent 2004 emissions standards.

Question 2: What barriers prevent the use of nonpetroleum fuels in heavy vehicles in the near term?

The group discussed the general barriers to the use of nonpetroleum-based fuels, including:

- Cost (fuel, equipment, etc.)
- Infrastructure
- Driving range
- Technical barriers
- Public perception/acceptability
- Human health effects
- Safety
- Emissions

Cost, infrastructure, technology, and acceptance barriers specific to LNG, CNG, and LPG were discussed (items in italics refer to Question 2a):

	LNG	CNG	LPG
Cost	Fuel *Tax* *Equipment* Tanks *Engine* Accounting/costing Operating costs Time Warranty	Quality/ consistency Equipment Testing to enter market *Tax* Operational Warranty	Similar to CNG
Infrastructure	*Physical— no infrastructure available*	Inconsistent fueling equipment	Less of a problem
Technology	*Engine efficiency* *Fuel storage* *Engine durability (DI engines)* *Fuel chemistry (undeveloped solution to problems)* *Measuring/ metering*	*Engine efficiency* *Fuel storage— weight, volume materials* *Engine durability* *Metering/measuring* *Low-cost materials for components*	*Component reliability* *Measuring* *Engine efficiency* *Engine durability*
Acceptance	Safety Education Regulatory Transparency—no inconvenience	*Safety* Regulatory	Safety Regulatory Transparency

Question 2a: DOE's role
What should the DOE/OHVT role be in alternative fuels and diesel engine technologies?

Items in the table above that appear in italics refer to the group's responses.

Question 3: Do you envision emissions standards as the driver for choices among fuels? What do you see as the drivers?

Emissions are a driver, but secondary to economics. Economics is the underlying driver.

Every future fuel will need to meet current emission levels. This is a constantly moving target.

DOE needs to ensure options so that as nonrenewable supply diminishes, renewables are feasible. DOE should ask for lists of processes (from industry) that could become feasible.

Question 4: What do you foresee as the fuel mix of the mid-21st century (long term - 2050)?

Diesel
Fischer-Tropsch diesel
Biodiesel
Other diesel (e.g., shale)
Natural gas and derivatives (LNG, CNG, LPG)
Hydrogen
Alcohol and esters
Ethanol
Methanol
Dimethyl ether

The fuel mix would change depending upon availability of certain fuels and feedstocks, and emissions standards would affect which fuels were available.

The group chose not to predict percentages of each fuel because 2050 was too far in the future to give meaningful predictions.

Additional Question: What is the proper role of DOE versus industry in future fuels technology?

- Make sure that the best available technology is available to industry
- Generate new technologies consistent with national goals
- Identify emerging technologies
- Conduct R&D on emerging technologies and develop them to proof-of-concept

- Intelligence

  - determine the possibilities
  - determine if we can make them work cheaply and economically

- Research and development — more emphasis on the "R" than the "D"

- Work together with industry to develop long-term strategy for replacing imported oil — implementation strategy must be developed

- Benchmarking

APPENDIX E:

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