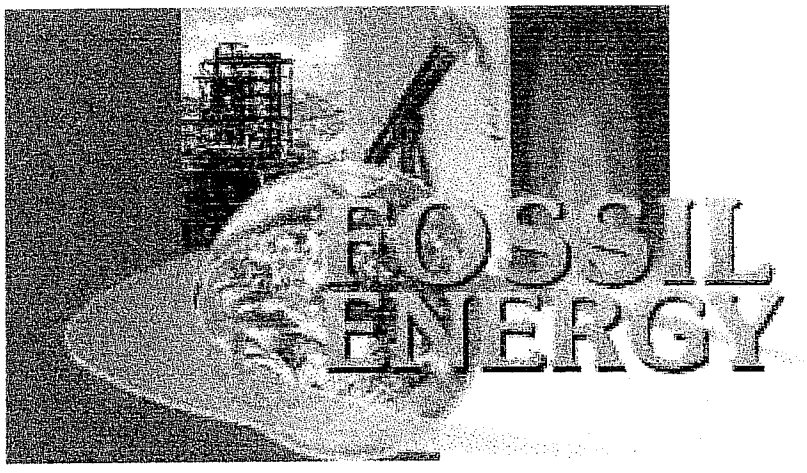
Industry-Government Workshop On Ultra-Clean Fuels for the 21st Century

June 30 - July 1, 1999
Dallas, Texas



WORKSHOP PROCEEDINGS

Presented by

The Federal Energy Technology Center
and
The National Petroleum Technology Office
Office of Fossil Energy
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I. EXECUTIVE SUMMARY

A. BACKGROUND

The DOE Office Fossil Energy's Coal Transportation Fuels & Chemicals, Natural Gas Processing, and Petroleum Processing programs have formed a strategic partnership with a common mission: "Partner with industry to ensure a stable, affordable supply of energy for the U.S. by assisting in the development and deployment of technologies to produce ultra-clean burning, high performance transportation fuels by the year 2010." To help establish a new fuels industrial base by 2010, this partnership will be issuing a solicitation early in fiscal year 2000, to develop "Ultra-Clean Fuels for the 21st Century." In the interim, comments and recommendations from industry are being actively pursued through public meetings such as this workshop, and separate discussions with individuals and organizations.

The workshop was a one and a half day facilitated meeting that took place June 30-July 1 at the Adam's Mark Hotel in Dallas, Texas. The workshop brought together 34 senior managers from industry (19), national laboratories (4), DOE Fossil Energy (7), DOE Energy Efficiency (2), DOD Army (1) and EPA(1). Invited participants represented a cross-section of companies that produce fuels and chemicals and perform systems engineering, and federal personnel involved in research, program, and policy development and establishing environmental regulations.

B. WORKSHOP SUMMARY

Generally, industry participants were supportive of the need for a Government role in the development of next generation ultra-clean fuels; were interested in actively participating in the debate over what the public role should be in the technology development arena; and were excited at the prospect of playing a major part in the design and development of a competitive program targeted at deploying advanced fuels technologies that are at present too unproven, too risky, and too expensive for the industry to develop on their own.

Energetics, Incorporated facilitated three breakout groups, each of which addressed the same topics: Vision and Goals, Barriers (technical and policy), R&D Priorities, and Other Actions.

One spokesperson from each breakout session summarized the comments and recommendations from their respective groups.

Vision and Goals

The groups were asked to comment on the following DOE Vision and Goals:

Vision:

"The vision of the Joint DOE Fossil Energy Program is to partner with industry to ensure a stable, affordable supply of energy for the United States, by fostering the development and deployment of

technologies to produce ultra-clean burning, high-performance transportation fuels from domestic fossil resources by the year 2010. These fuels will:

- Be compatible with existing transportation system infrastructure
- Produce lower emissions
- Enable the efficiency of the current vehicle fleet to be more than doubled when used in advanced engine systems
- Be cost competitive"

Goals:

- By 2005, establish data and processes that will help the oil industry meet projected clean fuel requirements

- By 2010, establish an industrial base that will produce clean fuels from domestic resources not now being exploited for fuel production (natural gas, petroleum by-products, and coal)

- By 2020, establish a new U.S. fuels industry that produces 5MM BPD from alternative domestic resources and provides technology enabling 10MM BPD domestic and 10MM BPD imported oil to meet ultra-low emissions specifications

1. **Group B made a strong point that seemed to summarize many comments made by all three groups:**

"Simply stated, the (DOE) Vision lacks excitement, clarity and mention of the benefits to business. CEOs would not generally be ready to commit resources to an enterprise with a vision as currently written. It should include mention of global market opportunities and not limit itself solely to the domestic side. There should not be a goal for oil imports, since this is much more a DOE policy than an industry concern. There should be goals for development of the clean fuels infrastructure and supply chain. There should be a goal related to the positive economic well-being of industry." Supporting comments include:

"The Vision statement is authored solely by DOE; appropriate input by industry is needed (i.e., from the management and strategic levels)"
"The Vision statement is lacking an international component"
"The Vision and goals give the impression of the government wanting to re-create a major coal-to-liquids program. The 5MM BPD of domestic production probably can't be met with gas (and petroleum by-products) and would mean a large crash effort for coal."

2. **Another major concern shared by the industry is the schedule for deploying the fuels technologies:**

"The Vision statement contains a schedule that is untenable"
"There is a disconnect in the time frame. The Vision addresses relatively long-term considerations and aims at 2010. Yet, the Tier II rules from EPA — will need to be met by 2005. As a practical matter, there is not enough time for the government to launch a RD&D program — that would produce products in time to meet near-term targets."

Group A prepared a revised Vision statement:

"Work effectively with industry to meet the growing demand for cleaner transportation fuels in a manner that strengthens the competitive position of the U.S. energy industry while serving other national goals."

Barriers

The barriers to achieving DOE's vision and goals can be categorized as follows:

1. Policy/Regulatory

"The U.S. does not have a long-term energy policy — which prevents industry from achieving DOE FE's goal of producing 5MM BPD of fuels from domestic resources." (Paraphrased)
"Industry views this (the ultra-clean fuels initiative) as an environmental/policy-driven activity and (industry) is geared toward responding to what the law requires. There is inherent reluctance to 'get out in front' of the regulators."
"Industry believes that closer discussions between EPA and industry may have led to a more reasonable goal for 2004."
"The greatest government barrier is the lack of adequate domestic resources (other than coal) to meet the 5MM BPD goal."

2. Government-Industry Partnership

The industry participants were generally negative toward the government - industry consortium approach. This is because several major players have already teamed with others who share common interests and have begun to develop competitive technology solutions addressing the resources and reserves they have under their control. As a result, they do not believe that companies are willing to share their intellectual property with potential competitors in the consortium. They would be more likely to partner through formation of separate teams to pursue commercialization of specific technologies, perhaps in a manner similar to that of the Early Entrance Coproduction Plant initiative. One team also commented that: "Implementation of industry-government consortia is typically a complex and cumbersome undertaking."

There is much concern over the intellectual property issue: "Rules regarding the treatment of intellectual property need to be spelled out in considerable detail and must be acceptable to both sides of the partnership."

3. Technical

Two teams noted that there is no proven commercially viable sulfur removal technology — will require new technology.
"There is a lack of breakthrough ideas — and when one is identified, commercialization moves at an inherently slow pace."
"There is a lack of knowledge about emissions-efficiency trade-offs; in some areas, basic understanding of chemistry is lacking."
"The greatest engineering barrier is the need to scale-up and demonstrate (at the proof-of-concept scale), but this is high risk (and high cost)."

4. Marketing/Economics

"Because of the relatively weak market outlook for clean fuels, industry does not have the incentive to launch major RD&D initiatives to develop them, and the government has difficulty gaining sustained public support for clean fuels RD&D programs."

Participants also noted that the combination of very-high capital costs to produce 5MM BPD (approximately $100B) and the perceived continuation of low oil prices constitutes a major barrier to establishing a new fuels industry.

R&D Priorities and Other Actions

The following comments are grouped according to the categories created by Group C:

1. Funding and Policy

"The U.S. must develop a long-term energy policy and continue to foster dialogue with industry."
"Try to determine what industry needs but is not doing."
"Rethink program goals — domestic resources, near- and long-term goals and feedstocks."
"Retool the vision and goals to include industry input."
"Coordinate the goals of this activity (ultra-clean fuels) with other government programs so the distinctions are made crystal clear."
"Alternative capital funding to reduce capital investment risk is needed to promote innovative technologies for producing ultra-clean fuels."
Intellectual Property: "Rules need to be well-defined, — make the rules clear before the solicitation is issued."

2. Basic and Applied Research

All three teams agreed on the need for economic sulfur removal technology.
"F-T technologies need to be enhanced, especially in the areas of attrition-resistant, more efficient catalysts, catalyst/wax separation and nanotechnologies for iron catalysts."
For refineries: "Develop more efficient hydrogen separation technology — and evaluate short-term processing options through RD&D."
"Optimize fuel and engine design."

3. Systems Analysis

"A comprehensive analysis should be conducted of the entire clean fuel cycle and supply chain."
"Focus on the most cost-effective global technology solution (fuel type, location, diversification, etc.)".
"Integrate new technologies into existing plants (power, chemicals, hydrogen, etc.) — to lower capital cost barriers and provide for more efficient use of energy and resources."

C. CONCLUSIONS

- The DOE vision should be global-oriented, i.e., strengthen the U.S. energy industry's competitive position in producing clean fuels from the world's fossil resources.

- The DOE's 5MM BPD target from domestic resources is too aggressive and unrealistic considering the very-high capital cost that would have to be invested to produce that amount of ultra-clean fuel. Significant economic and environmental advantages for the U.S. can result if only half of this goal is achieved.

- The ultra-clean fuels RD&D program probably will not help industry meet near-term Tier II regulations, although there will be a continuing need for advanced fuel technologies. The government should work with industry to define their needs, then embark on a mid- to long-term research program that strengthens U.S. competitiveness and also helps meet national policy goals.

- Industry is generally not in favor of a government-industry consortium. Companies, who have begun to develop their own technology solutions, do not want to share intellectual property rights with potential competitors. The purpose of the ultra-clean fuels initiative should be to assist industry in mitigating the substantial risk and capital investment required to scale-up and test technologies. A competitive teaming approach with multiple projects, each with its own industry lead team, is strongly supported and preferred by industry. The Early Entrance Coproduction Plant initiative may serve as a good model for this latter approach.

- There is a weak market for clean fuels, thus industry doesn't have the incentive to launch major RD&D initiatives and support high-risk, high-payoff technology scale-up and testing.

- The main R&D priority is to develop economic means for sulfur removal. Other research needs include:

  - Development of better F-T catalysts and hydrogen separation technology
  - Evaluating refinery processing options for short-term implementation of clean fuels production
  - Analyzing the entire clean fuel cycle and supply chain and integration of new fuel technologies into existing power, chemicals, etc. plants to provide for more efficient use of energy and resources.

- There is a general lack of breakthrough ideas, which implies a need for more emphasis on basic research.

- The participants agreed strongly with DOE's plan to hold more meetings with industry prior to release of the ultra-clean fuels solicitation

II. WORK-GROUP PRODUCTS

A. OVERVIEW

This section presents the raw results of the small-group facilitated sessions. Each group followed the same process. They first reviewed the draft vision and goals presented in the plenary vision, providing comments, clarification, or rewritten statements. Based on this, the groups then brainstormed on the question: What are the barriers to achieving this vision and goal? Analysis and prioritization resulted in a high-priority set of barriers. These were the basis for a subsequent brainstorming session to answer the question: What are the actions (RD&D and others) to remove these barriers?

B. GROUP A: DISCUSSION SUMMARY

Comments on Visions and Goals

- The Vision Statement is authored solely by DOE; appropriate input by industry is needed (i.e., from the management and strategic level of industry)
- The Vision Statement contains a schedule that is untenable
- The Vision Statement is lacking an international component – either by design or by accident
- The Vision Statement should clearly identify the high-risk/high-payoff elements that justifies government involvement or industry investment
- On a positive note, the Vision Statement recognizes the need for alternative fuels
- A revised Vision Statement prepared by Group A reads: "A DOE that is working effectively with industry to meet the growing demand for cleaner transportation fuels in a manner that strengthens the competitive position of the U.S. energy industry while serving other national goals.
- The goals were perceived to be congressional goals that simply referenced laws, regulations, and statutes
- There is no mention in the goals of reducing sulfur
- There was a general belief that the goals sounded too much like vision statements
- Some believed that the goals were to ambitious, especially given the time constraints posed by the current EPA Tier II requirements

Barriers

- The greatest barrier on the part of the <u>public</u> is their willingness as consumers to pay for environmental benefits

- The greatest government barrier is the inadequate domestic resources (other than coal) that can meet the target goals

- The greatest barrier from the industry standpoint is issues of intellectual property and proprietary positions. Many felt, however, that this might be a matter of communicating up front (or before the issuance of any RFPs) how intellectual property can be maintained

- The two greatest technological barriers are (1) the ability to remove sulfur and aromatics from diesel will require new technology, and (2) catalyst performance and life

- The greatest engineering barrier was believed to be the fact that high-risk scale-up and demonstration (proof-of-concept) has not been done

- Two economic barriers were identified: (1) there is a finite time until refinery investment decisions can be made, and (2) the required capital for 5 MM barrels/day is too high

RD&D and Other Actions

- There were two primary and two secondary actions related to overcoming barriers through technological, engineering, or scientific means. The two primary actions are

  1. Develop a separation technology for more efficient hydrogen use in refineries. This action arises from the belief that it is unclear whether or not the technology exists or (if it does) whether it is even cost effective.
  2. Develop a short-term program aimed at refinery processing options. This action could be implemented through the (cost) augmentation of demonstration programs and R&D.

  The two secondary actions are

  1. Develop an innovative catalyst for sulfur/nitrogen removal from crude/resid.
  2. Develop a heavy distillate and resid sulfur removal technology.

- There were four primary and two secondary actions related to overcoming barriers from an institutional, program, or design standpoint. The four primary actions are

  1. For intellectual property (IP) issues, make the IP rights clear before the RFP is issued.
  2. Try to find out what industry wants but is currently not doing. This will
     a. be a good use of DOE money
     b. encourage high-risk and long-range activities
     c. encourage consortia (such as the membrane consortium)
     d. allay capital risk
  3. Rethink the program goals related to independent domestic resources. These actions can include
     a. identify near-term goals and feedstocks
     b. identify long-term feedstocks (coal)
  4. Focus on the most cost-effective global technology solution (i.e., fuel type, location, diversification, etc.)

The two secondary actions are

1. Retool the vision and goals to include industry input and reflect the DOE/FETC roles and responsibilities
2. Get oil company feedback on needs for technologies related to ultra-low sulfur fuels

The following tables presents the products of the group's discussions:

- Table 1 - Group A: Comments on Vision and Goals
- Table 2 - Group A: Barriers
- Table 3 - Group A: R&D and Other Actions to Overcome the Barriers

Table 1 - Group A: Comments on Vision and Goals

COMMENTS ON VISION	COMMENTS ON GOALS
"Economically" producing	"Congressional" goals per regulations/statutes/litigation
Does not recognize market viability	Sulfur? no mention (implied?)
Disconnect re: timing	Need overarching high-risk high-payoff goals
Domestic focus is constrained	Targets too ambitious
(+) Alternative fuels focus by government	Too general - sounds like vision statement
Lack of "high-risk/high-payoff" element (long-term)	
International component (lack of)	
Too "DOE driven"	
Need industry-driven vision	
"Significant improvement to vehicle fleet . . . " not in vision	

Suggested Vision Statement: A DOE That is working effectively with industry to meet the growing demand for cleaner transportation fuels in a manner that strengthens the competitive position of the U.S. energy industry and serves other national goals

Table 2 - Group A: Barriers

(✪ = Votes for Priority Topic)

INSTITUTIONAL, PROGRAM DESIGN				PROCESS		ECONOMICS
POLITICAL	PUBLIC	GOVERNMENT	INDUSTRY	TECHNOLOGY	ENGINEERING	
Politically incorrect to consider coal ✪✪ Strong political lobbiers, i.e., coal, ADM, etc.	Consumer: People's willingness to pay for environmental benefits ✪✪✪✪✪ Convincing the public that the program is needed	Inadequate domestic resources (other than coal) to meet target ✪✪✪✪✪✪ Institutional Process: Too much DOE "design"/not enough DOE "listen" and "facilitate" DOE "disconnects" re: fuel choices Predetermined "answers" (from government) Not invented here Potential barrier: Short-term actions not compatible with long-range goals	Crowding out of advanced technology by compliance technology - Resources - Capital Institutional: Intellectual property/ proprietary positions ✪✪✪✪✪✪ DOE objectives at odds with industry objectives ✪✪ Economics: DOE competing with private industry ✪	Removing sulfur and aromatics in diesel requires new technology ✪✪✪✪ Ultra-low sulfur fuel technology is costly and inefficient ✪✪ Use Fischer-Tropsch product slate in the refinery Fundamental understanding: [materials, models (CFD)] Catalysts! catalysts! catalysts! Catalyst performance and life ✪✪✪	High-risk scale-up and demonstration (POC) high-risk not been done ✪✪✪ **SCIENTIFIC** Firm scientific basis for regulatory requirements ✪ Health issues (toxicity)	Limited time until refinery investment decisions ✪✪✪ Required capital for 5 MM barrel too high ✪✪✪ Economics, all alternatives to oil must compete (refineries doing cogeneration, etc.) ✪✪ Will not happen if oil prices stay low ✪ Clear understanding of oil vs. gas solutions ✪ Cost-competitive fuels may be a long shot Pay the price vs. reduce the cost (e.g., methanol)

Table 3 - Group A: Actions (R&D and Other) to Overcome Barriers

TECHNOLOGY, ENGINEERING, SCIENTIFIC	INSTITUTIONAL, PROGRAM, DESIGN
Innovative catalyst for sulfur/nitrogen removal from crude/resid ✪✪ Develop heavy distillate and resid sulfur removal technology ✪✪ Separation technology for more efficient hydrogen use in refineries ✪✪✪✪ - Is technology there? - Is it cost effective? Keep feedstock and process options open Short-term program aimed at refinery processing options ✪✪✪✪ - Augment demonstration programs - R&D Longer-term gas-to-liquids program Very long-term: coal-to-liquids program	Restructure contracting process to address intellectual property issues Barrier: Intellectual property issues - Action: make clear IP nights <u>before</u> RFP ✪✪✪✪✪✪ Do what industry wants - but is not doing (at current level) ✪✪✪✪ - Good use of DOE $ - High-risk, long-range - E.g., membrane consortium - Allay capital risk Get oil company feedback on needs for technology for ultra-low sulfur fuels ✪✪✪ EPA/DOE/Government-wide convergence on regulations and timing ✪✪ Work toward DOE/government/coordination (EE/FE/EPA etc.) ✪ Retool the vision and goals ✪✪ - Industry input - Reflect DOE/FETC/roles/accountability Barrier: Too much DOE design already done on the program. Go back to vision statement and start from there ✪ - More pieces of the "value chain" - Tap into existing conferences (API, e.g.) Barrier: Independent Domestic Resources - Action: Rethink program goals ✪✪✪✪✪ - Identify near-term goals and feedstocks - Identify long-term feedstocks (coal) Focus on most cost-effective global technology solution (i.e., fuel type, location, diversification, etc.) ✪✪✪✪ Tap into Europe/Japan efforts on diesel technologies, emissions Look outside domestic resources for solutions to limit oil imports growth - Diversification

C. GROUP B: DISCUSSION SUMMARY

Comments on Vision and Goals

- There was some confusion about the audience for the vision and goals. There were two main points of view: 1) a government-led program in need of strong industry participation, and 2) an industry-driven activity. Those who held the industry-driven view saw many shortcomings in the vision and goals. Simply stated, the vision lacks excitement, clarity, and mention of the benefits to business. CEOs would not generally be ready to commit resources to an enterprise with a vision as currently written. It should include mention of global market opportunities and not limit itself solely to the domestic-side. There should not be a goal for oil imports, since this is much more of a DOE policy than an industry concern. There should be goals for development of the clean fuels infrastructure and supply chain. There should be goals related to the positive economic well being of industry.

- There is a disconnect in the time frame. The vision addresses relatively long-term considerations and aims at 2010. Yet, the Tier II rules from the EPA, if enacted in their current form, will need to be met by 2005. Perhaps the vision could be structured in two parts with both near and long term components. The relationship between government and industry will be radically different in each of these components. For example, industry, if mandated to do so, will meet the Tier II requirements and as a practical matter there is not enough time for the government to launch a RD&D program (which may not even be funded until fiscal year 2001) that would have the chance of producing usable products in time to meet the near-term targets.

- The vision and goals give the impression of the government wanting to re-create a major coal-to-liquids program. The 5 MMBPD of domestic production probably cannot be met with gas and would mean a large crash effort for coal.

- There were questions about the overall scope and what should and should not be included. Several wondered why vehicle efficiency was a part of the vision and goals since it was covered extensively in other programs. If it is, there is need for extensive industry representation from that segment. Several wondered why stationary uses of clean fuels, particularly in chemical production but also heat and power generation, was not included in the vision and goals.

Barriers

- The economics of creating a clean fuel industry don't exist today and the major policy and market drivers are not pushing toward conditions where clean fuels will be hotly desired by consumers unless the costs can be reduced substantially.

- Because of the relatively weak market outlook for clean fuels, industry does not have the incentive to launch major RD&D initiatives to develop them and the government has difficulty gaining sustained public support for clean fuels RD&D programs. Industry views this as an environmental-policy driven business activity and is geared toward responding to what the law requires. There is inherent reluctance to get "out-in-front" of the regulators on this issue.

- There is a lack of breakthrough ideas in this area despite considerable levels of RD&D over the past 20 years. Even if identified, the commercialization process moves at an inherently slow

pace in this industry because the capital stock turnover is relatively slow and facilities tend to be large, capital-intensive assets.

- There is a lack of knowledge about emissions and efficiency trade-offs in the use of clean fuels. In some areas, basic understanding of the chemistry is lacking.

- Implementation of industry-government consortia is typically a complex and cumbersome undertaking. Rules regarding the treatment of intellectual property need to be spelled out in considerable detail and must be acceptable to both sides of the partnership.

RD&D and Other Actions

- Fischer-Tropsch technologies need to be enhanced particularly in the area of attrition resistant catalysts. Research needs include resolving the Fischer-Tropsch iron catalyst/liquid separations problem and in the use of nanotechnologies for iron catalysts that are rdier, more efficient, and have a longer useful life.

- There is also need for new technologies that reduce the sulfur content of fuels economically.

- Effort is needed to coordinate the goals and objectives in the implementation of this activity with other government program so that the distinctions between this and related programs are made crystal clear. Technology development priorities should be well-aligned with expected EPA requirements. EPA should fully understand technology opportunities and limitations and set regulations accordingly.

- Rules for intellectual property need to be well-defined and accepted by the key participants.

- A comprehensive analysis should be conducted of the entire clean fuel cycle and supply chain.

The following tables present the products of the group's discussions:

- Table 4 - Group B: Comments on Vision and Goals

- Table 5 - Group B: Barriers

- Table 6 - Group B: RD&D and Other Actions to Overcome the Barriers

Table 4 - Group B: Comments on Vision and Goals

(✪ = Votes by Government ★ = Votes by Industry)

COMMENTS ON THE VISION	COMMENTS ON THE GOALS
To get industry buy-in and CEO-level support: make it much more saleable, desirable, marketable, needed ✪★	Do not be too specific on Tier II: not final yet
Possible wording: To develop technologies that will allow U.S. industry to make decisions on building power plants for generating 10 MMBPD of alternative fuels economically by 2020 to meet national needs ✪	If industry vision no need for an oil-import goal
Can domestic production really reach 10 MMBPD in 2020? ✪★	More reliable foreign oil sources
Tier II takes effect in 2005 - vision does not address this ✪✪✪✪★★	Global oil markets in 2020 less friendly
Include clean-up to meet near-term requirements	Need energy-efficiency goal for conversion
5 MM BPD domestic looks unrealistic for gas-to-liquids: Requires expanded use of coal	Why is industry group being asked to set energy policy? - Oil import a DOE, not industry goal
Should include coal-to-fuel supply chain	Develop technologies that meet specifications cost-effectively
Needs business model for coal-to-fuel infrastructure ✪	U.S. refiners hurting, past and new regulations costly - Losing $ from added investment for clean
In today's economics, coal-to-trans-fuel not cost effective	"Positive economic impact on refiners"
Global markets a reality: vision should be more than just domestic challenge ✪✪✪★	Delete fleet from wording of efficiency goal
Energy prices do not reflect value	Vehicle efficiency not part of this - Can you make a fuel to increase efficiency? - Will this increase industry participation? - Not linked to vision
Business opportunities abroad for U.S. industries should be part ✪★	Add goal covering stationary plant use of clean fuels
Not clear who vision is for - As stated hard to attract industry participation	
Tried before did not work before; why now? - Looks like syngas conversion crash effort	

Table 4 - Group B: Comments on Vision and Goals *(continued)*

(✪ = Votes by Government ★ = Votes by Industry)

COMMENTS ON THE VISION (CON'T)	COMMENTS ON THE GOALS
Joint EPA-DOE vision would be stronger for engaging industry ★ Domestic resource issue not top industry priority Re-focus on health of industry and development of clean technology ✪✪✪★ - Jobs, economics, business growth Should cover stationary fuel use ✪★★ Include Kyoto and efficiency gains on demand side ★ Consider other products, e.g., gas to methanol Need replacement text to appeal to CEDs	

Table 5 - Group B: Barriers

(✪ = Votes by Government ★ = Votes by Industry)

IMPLEMENTATION ISSUES	ECONOMICS	GOVERNMENT POLICIES/ISSUES	INADEQUATE PERFORMANCE OF TECHNOLOGIES	LACK OF FUNDAMENTAL UNDERSTANDING	NEW TECHNOLOGY DEVELOPMENT
Inability of government-industry partnerships to meet near-term requirements ✪ Short-term focus of industry and government Consortium lacks industry "buy in" to elicit maximum number of participants ✪✪★ - One company may not support all parts of vision - Lack of integration of fuel stakeholders to share goals Handling of IP ✪★★★ - Proprietary technical information is not likely to be shared Lack of coal manufacture participation Tension between fuel makers and vehicle makers (cross purposes) Independent thinking of industry to avoid new ideas (not invented here) ★ New and innovative processes will not be adopted until demonstrated Lack of sufficient funding to meet time goals Complexity of control of R&D scope and pace Time it takes to go from start-finish	Economic drivers are and have been inadequate ★ Economics of fuel alternatives are not there ✪✪★★★★ Need for measurement of energy efficiency that makes scientific sense (2nd law) ★★ Lack of understanding of the very-low fuel efficiency in the U.S. (2nd law) ★ Lack of incentives to drive R&D ✪✪★ Liquid fuel price, value, and cost are not in alignment Experimental work comes at a high cost Lack of infrastructure for alternative fuels ★	Lack of support for - Kyoto - Sustainability - Eco-impact, etc. Lack of common set of "EPA" standards Lack of public support to fund government program to extent necessary ✪ Regulations developed without benefit of complete scientific understanding ★ - Lack of understanding of environmental benefit (economic) Regulatory uncertainty ✪	Technical barrier to convert coal synthesis gas to diesel ★★★ No known way for FT to make high-octane gasoline? ★ Sulfur reduction technologies ✪ - HDS The goal (coal for liquid fuel) is counter to thermodynamics Scarcity of hydrogen ✪ - Hydrogen content of liquid fuels vs. coal/resid C:H ratio - Economics of hydrogen manufacture ★ Direct coal liquefaction? ★ Gas-to-liquid plant costs are too high ★	Lack of understanding of fuel property effects on emissions and efficiency (CIDI and FC) ✪✪★★ For diesel (CIDI) lack of data on what sulfur level required for emission control (after treatment) effectiveness and durability ✪✪★ - Diesel lubricant sulfur additives may require replacement Lack of technical consensus among fuel/ engine/after-treatment industries Lack of understanding of impact of decreased lubricity from sulfur removal process (CIDI) Additives not understood Proper refining of gas-to-liquids naphtha Oxygenates not understood ✪✪ Petroleum resid chemistry: better understanding ✪	Technology: Different approaches to processing different feedstocks Lack of true breakthrough ideas ✪✪✪★★★★ Hydrogen storage and transportation ★★ Biodesulfurization technology development required ✪ Transportation fuel cells (?) ★★

Table 6 - Group B: RD&D and Other Actions to Overcome the Barriers

(✪ = Votes by Government ★ = Votes by Industry)

PROGRAMMATIC	FUELS DEVELOPMENT	TESTING, DEMO AND ANALYSIS	FISCHER-TROPSCH TECHNOLOGY	TECHNOLOGY PROCESS DEVELOPMENT	ECONOMICS
Make federal $$ go farther by higher % funding by DOE at higher risk points Focus on breakthrough ideas. Favor concepts that have reasonable chance of being commercial ★ Introduce chemicals industry into the program ★ Coordinate goals and objective with those of department/other offices ✪★★★ - Develop technologies to avoid future regulations! - Coordinate with regulatory (EPA) organizations up front on specs/time frames ✪ - Coordinate with other countries (e.g., Canada) on alternative fuels development Solicit R&D community for innovative technology ✪ Deal with intellectual property. DOE and industry 1) understand concerns, 2) jointly solve concerns ✪★★★★ - Define IP process and rules	Perform feasibility analysis of role of oxygenates. Do they have any future role as fuels/additives? ✪✪✪★ - Oxygenates; partial oxygenation of oil-derived transportation fuels using enzyme biotechnology - Explore low MW and high MW oxygenates as neat and component fuel stocks Evaluate DME as a future fuel Give some attention to all parts of the MW distribution to cover problems of naphtha and gas oil Demonstrate transportation market utilization for carbon Develop new "diesel" that can include part/all of FT naphtha ★	Think about second derivative consequences early, i.e., MTBE ✪✪★ Conduct well documented high utilization and instrumented fleet test of ultra-clean diesel in new trucks Conduct cost-analyses for developing new infrastructure ✪ Conduct pioneer plant demonstration of novel FT tech ✪★★ - Demonstrate transportable barge FT jet-fuel refinery Provide strong lab/field testing to evaluate candidate fuels early ★	Attrition resistant catalyst development for FT ✪✪★★★★★ - Nanotechnology for Fe catalysts for FT (sturdy, efficient, improved life) Develop/improve three-phase reactor technology for FT coal liquid fuel Find ways to reuse carbon dioxide as a raw material for Fischer Tropsch Resolve FT Fe cat/ liquid separation problem ★★ Conduct hydrodynamics study for scale up ✪	Develop S reduction technologies to produce fuel(s) economically ✪✪✪✪✪★ Develop data on new and different technology ideas with open mind Enhance hydrogen production ★ - Provide additional hydrogen for coal - liquid fuels via natural gas (C:H = 1:4) Conduct fundamental R&D at C1 level ✪✪ Enzyme technology for S, Ni, Va removal from oil ✪ Develop more efficient systems for fuels production Explore more means of processing for heavy feedstocks ✪ - Evaluate viscosity reduction for heavy oils via biotechnology	Redisplay the economics of alternative fuels to better define financial risks ✪★ Action: Guarantee market for MeOH and/or Fischer Tropsch ultra-clean fuel

Table 6 - Group B: RD&D and Other Actions to Overcome the Barriers *(continued)*

(✪ = Votes by Government ★ = Votes by Industry)

PROGRAMMATIC	FUELS DEVELOPMENT	TESTING, DEMO AND ANALYSIS	FISCHER-TROPSCH TECHNOLOGY	TECHNOLOGY PROCESS DEVELOPMENT	ECONOMICS
Comprehensive before-the-fact announcement of implementation to potential participants and potential objectors - Identify/advertise potential benefits (get buy-in) Disperse the "seed money" function broadly to promote identification of "breakthrough" ideas Conduct more/focused industry exchanges (API, etc.) to develop saleable vision/goals ✪ Develop improved organization structure(s) ✪** - Finalize industry/government roles - Remember the refiners - Involve more stakeholders (auto) in development of strategy - Form consortia with like companies to do R&D! Government agencies must publicize their integrated approach to *Fuels of the Future* to identify proper contacts ✪	Evaluate MeH as a fuel (conventional or fuel cell): technical, environmental, perceptions, etc. - Investigate importance of gas - liquid mass transfer in syngas - diesel (where?)	Examine the fuel production comprehensively from specifications to feedstock production to refining to utilization to emissions ✪✪✪★★		Develop cost efficient heavy oil conversion technologies development (catalyst ind.) ✪★★ Develop advanced fuels research focused on catalysis ✪✪ - Hydrogen storage - Innovative desulfurization - Highly efficient distillate HDS - Non-hydrogen desulfurization	

Table 6 - Group B: RD&D and Other Actions to Overcome the Barriers *(continued)*

(✪ = Votes by Government ★ = Votes by Industry)

PROGRAMMATIC	FUELS DEVELOPMENT	TESTING, DEMO AND ANALYSIS	FISCHER-TROPSCH TECHNOLOGY	TECHNOLOGY PROCESS DEVELOPMENT	ECONOMICS
Conceive aggressive risk oriented incentive program to facilitate commercialization ✪★ Develop R&D roadmap - Project goals established as soon as possible ★ Assist technology for ULE vehicle production Avoid diluting the program by going in too many different directions					

D. GROUP C: DISCUSSION SUMMARY

Comments on Vision and Goals

A revised set of suggested goals are listed in Table 7.

Barriers

The barriers are organized according to which goals they address. The topics within the goal areas are as follows:

- Barriers to 2004 Goal
  - Political / Policy
  - Technology / Economics

- Barriers to 2010 Goal and Barriers to 2020 Goals
  - Political / Policy
  - Technology / Economics
  - Science
  - Funding

- **2004**
  The primary technical barrier to meeting EPA Tier 2 emission standards is that there is currently no proven commercially viable sulfur removal technology. The technologies that currently exist are generally too expensive for widespread use. The primary political barrier to achieving the 2004 goal is that there is no clear agreed upon mechanism for industry-government partnership. Many individuals in industry are concerned about meeting the EPA standards in the currently set timeframe and believe that closer discussions between EPA and industry may have led to a more reasonable goal for 2004.

- **2010**
  The top priority barrier to commercializing alternative feedstock derived ultra-clean fuels with significantly improved conversion efficiencies is the high capital cost of clean fuels technology. It is currently difficult to fund alternative feedstock technologies due to the low price of petroleum. The combined low oil cost and high capital cost of installing new equipment in refineries leads to a lack of interest in innovation in a non-mandate environment.

- **2020**
  The U.S. currently does not have a long-term energy policy. The lack of policy and motivation is what is preventing the industry from producing the goal of 5 million barrels per day of fuel from alternative domestic feedstocks. Even if the price of domestic feedstocks increase in the coming years, imports are still expected to remain inexpensive. There no direct, low-cost conversion technologies to allow for the production of fuels from alternative feedstocks.

RD&D and Other Actions

The R&D is organized into four major groups and several subgroups as follows:

- Funding and Policy
- Systems Analysis

- Basic Research
  - Advanced Separations
  - New Approaches
  - Direct Conversion
  - Advanced Catalyst Research
- Applied Research
  - Fuel / Engine Technology
  - Reactors / Catalysts
  - Other

Funding and Policy

Alternative capital funding (such as non-recourse bonds) to reduce capital investment risk is needed to promote innovative technology for producing ultra-clean fuels. These funding sources will help to ensure that R&D efforts are focused and that the efforts remain sustained regardless of outside market forces such as low feedstock prices. The U.S. must also develop a long-term energy policy and continue to foster dialogue with industry.

Systems Analysis

Plant integration into various infrastructure such as power plants, chemicals, hydrogen, and desalination facilities can lead to more energy and resource efficient operations. Meshing new technologies with existing facilities could help lower the capital cost barriers inherent in implementing entirely new processes.

Basic Research

Direct conversion of a fossil-based feedstock to an ultra-clean fuel is theoretically the most efficient way of producing fuel. Fundamentally examining direct conversion mechanisms may lead to great advancements. One of the potential direct conversion mechanisms is the conversion of methane to methanol.

Applied Research

In the short term, there should be focused research on the removal of sulfur. This will help to meet EPA Tier 2 requirements. Another key research need is to optimize fuel and engine design. The idea of "designer fuels" is that the fuel and engine are developed to work together specifically.

The following tables present the products of the group's discussions:

- Table 7 - Group C: Revised Goal Statements
- Table 8 - Group C: What are the Barriers to Achieving the Goals?
- Table 9 - Group C: What R&D is Needed to Overcome the Barriers?

Table 7 - Group C: Revised Goal Statements

GOALS: 2004	GOALS: 2010	GOALS: 2020
• Meet EPA Tier 2 emission standards with improvements based on current refining technology	• Commercialize ultra-clean fuels from alternative feedstocks with significantly improved conversion efficiencies	• 5 million barrels per day from alternative domestic feedstocks • Commercialize direct conversion of fossil feedstock

Table 8 - Group C: What are the Barriers to Achieving the Goals?

(★ = Votes for High-Priority Topics)

2004		2010			
POLITICAL/POLICY	**TECHNOLOGY/ ECONOMICS**	**POLITICAL/POLICY**	**TECHNOLOGY/ ECONOMICS**	**SCIENCE**	**FUNDING**
No clear agreed upon mechanism for industry-government partnership ★★★★ Public-policy goals inconsistent with market focus Government has conflicting goals and policies Congressional action to slow process Public perception of need - no public support EPA loss of mandate via recent court case Enforcement mechanisms not strong enough Special interest groups do not accept Tier II as strong enough Court challenges to refinery modifications	Unproven sulfur removal technology (commercial viability) ★★★★ No available proven technology for sulfur removal Engines are not efficient enough Low refining margins (70c-1-5 $/barrel) cost for developing not there Cost/capital for up-grading existing plants Lack of cooperative efforts (problem too big for one industry to address) ★ Availability of $100B capital investment required to produce 5 mm BPD target Lack of economic hydrogen separation/ production technologies No inexpensive desulfurization technology Lack of EPC contractors - cannot build fast enough★	2015 Goal: Carbon dioxide generation per Kyoto accords ★ Known lack of domestic natural gas; remote reserves sufficient to produce significant quantities of natural gas liquids Lobbying for technology gas vs. oil vs. coal ★ American public not willing to pay incremental fuel costs ★★	Proven technologies not available (high risk) (high cost) Insufficient knowledge of catalysts/reactor hydrodynamics to warrant alternative feedstock conversion (too much risk) Capital cost of clean fuels technology is currently too high for broad commercialization ★★★★★★ New catalysts needed - Longer life - Improved selectivity, activity Expensive technology development and demonstration cost ★ Syngas plants too expensive 2005 and 2020 Goal: Conventional feedstock price uncertainty Globalization of world markets → satisfy needs, not develop technology ★	Lack of advanced materials for separations (Hydrogen, SO_x, carbon dioxide, oxygen separation) ★★★ Knowledge of reactor thermo-hydrodynamics	No identified funding mechanism for critical enabling technologies Low oil price scenario → no funding for novel technologies from alternative feedstocks ★★★ Significant public funding resources not available

Table 8 - Group C: What are the Barriers to Achieving the Goals?

(★ = Votes for High-Priority Topics)

2004		2010			
POLITICAL/POLICY	TECHNOLOGY/ ECONOMICS	POLITICAL/POLICY	TECHNOLOGY/ ECONOMICS	SCIENCE	FUNDING
			Little economic incentive for industry to invest in alternative technology ★★★ 2015 Goal: Improved, lower energy separations Research efforts below critical mass		

Table 8 - Group C: What are the Barriers to Achieving the Goals?

(★ = Vote for High-Priority Topic)

2020			
POLITICAL POLICY	**TECHNOLOGY/ECONOMICS**	**SCIENCE**	**FUNDING**
No long-term domestic energy policy ★★★★	No direct , low-cost conversion technologies ★ Economic barriers/cheap imports ★★★ Time to get to 5 mm BPD from initial commercialization is too short Best domestic feedstocks not available at low enough cost Lack of EPC contractors (cannot build fast enough) ★ Crude compatibility issues Capital investment economics/competition	Economic carbon sequestration technology BOCs not exist Lack of new catalyst formations Little or no effort now for direct conversion; need fundamental and applied studies ★★★	Insufficient resources currently devoted to alternative conversion technology Commercialize direct conversion of fossil feedstocks to clean fuels: low up-front government funding ★★★

Table 9 - Group C: What R&D is Needed to Overcome the Barriers?

(★ = Vote for High-Priority Topic)

Funding and Policy	Systems Analysis	Basic				Applied		
		Advanced Separations	New Approaches	Direct Conversion	Advanced Catalyst Research	Fuel/Engine Technology	Reactors/ Catalysts	Other
Alternative capital funding (non-recourse bonds) to reduce capital investment risk ★★★★★ Ensure that R&D efforts are focused at critical mass and sustained ★★ For long-term research, cost share to full funding Develop firm, consistent long-term domestic energy policy ★ Define depth of foreign involvement ★ Action: Continue government-industry dialogue on partnering mechanisms	Plant integration into various infrastructure (power plant, desalination, chemicals, hydrogen) ★★★★ Better refinery/ chemical/power system integration; "Energy Plex" optimization High capital cost barriers: Mesh new technologies with existing facilities ★★ Coordination of fuel, lubes, and hardware progress ★ Design, construct operate 200-300 BPD pre-commercial FT plant based on today's best	Catalytic membranes - Thermal stability - Selectivity - Lifetime Membranes for carbon dioxide separation ★ - Thermal stability - High selectivity - Facilitated transport Hydrogen and N_2 separation (non cryogenic); oxygen enrichment ★★★ - New materials - Hydrogen, N_2, oxygen, carbon dioxide, CO	Develop economic biologic processes for sulfur and metals removal from crude oil (and coal) Develop technology for removal of metals from heavy oils and coal Emphasize development of core, broadly enabling technologies Better (cheaper) syngas generation technology - Reactor design - Catalysts Develop economical carbon capture and sequestration technology	Increase emphasis on C_1 Chemistry R&D Focus on direct methane to methanol ★★★ Broadly fund fundamental look at breakthrough direct conversion processes ★★★★ Coal to gas or liquid fuels research (revolutionary approaches) ★ Action: Initiative R&D program targeted at direct conversion technology (key enabling technology focus) Move from direct hydrogen	- Direct conversion - Fischer-Tropsch - Deep desulfurization - Alkylation - Combinatorial - Sulfur resistant NO_x conversion Develop attrition resistant universal catalyst that works with a wide range of hydrogen to carbon ratio syngas Solid alkylation catalyst development ★★★ Develop sulfur resistant NO_x catalyst ★ Sulfur, heavy metals - tolerant catalysts	Understand environmental implications of "clean fuels" including additives Fuel/engine optimization: "designer fuels" ★★★★ Mechanism to optimize fuels - engine requirements Improved fuel and lube additives ★ Develop alternate oxygenates to replace MTBE for octane improvement 2004 Goal: R&D in the area of fuels formulation and catalysts	Action: Pilot testing of biodesulfurization for diesel production Reliable scale-up of monolith reactors Develop improved hydrogen separation materials/ technology★★★ - Hydrogen from mixed gas streams - Hydrogen from syn-gas Better FT liquefaction reactor design beyond fixed bed and slurry bed Improved current slurry reactor systems - Lower temperature - Lower pressure - Higher	Crude oil/ feedstock characterization (aromatics, PM) 2010 Goal: Pilot scale testing of promising technologies → Advanced reactor design, and separation processes Full exploration of alternate fuel technology (include biodiesel, fuel cells, etc.) ★

Table 9 - Group C: What R&D is Needed to Overcome the Barriers?

(★ = Vote for High-Priority Topic)

Funding and Policy	Systems Analysis	Basic				Applied		
		Advanced Separations	New Approaches	Direct Conversion	Advanced Catalyst Research	Fuel/Engine Technology	Reactors/ Catalysts	Other
Full coordination: DOD and industry ★ Action: Provide viable fuel technology options and facts to policy makers (government and industry) Micro/macro-economic impact of clean fuel plants (domestic and foreign) Action: Develop public awareness program Develop approach to overcoming attitude that direct oxidation "cannot be solved"	available technology ★★		Emphasize "out of the box" approaches to direct oxidation 2020 goal: Initiate novel concepts at exploratory level	use to direct CH_4 use	New catalysts - combinatorial materials discovery; high productivity ★ Deep desulfurization/ denitrogenation catalysts ★★★		conversion Focused research for the short-term for sulfur removal ★★★★	

III. SUMMARY SESSION

The session opened with "report-outs" from the three breakout groups. The detailed comments on vision and goals, along with the storyboards on barriers and actions developed by the groups have been presented in Section II. The following are selected highlights of the groups, as presented by group representatives.

A. GROUP A: REPORT-OUT

In general, the group was excited about the fact that there is an integrated effort across government agencies—it is the only way to get the right solution to this kind of a problem. The group thought they needed to take a step back and reassess the vision and goals. For example, the ability to meet the 5 MM barrel per day goal is questionable given the time frame, the level of capital investment required, and the resource mix required. Also, with this production target, coal would likely be the predominant resource. The group consensus was a vision with the government as an enabler of technologies in a manner that both strengthens the competitive position of the U.S. industry and serves other national goals.

With respect to the barriers, the group generally broke them into technology/engineering and institutional/program design issues. To see if there were substantive differences between viewpoints, the group elected to split their votes into industry and government. By and large, the two groups saw issues the same way. Generally, unless major policy and market drivers change, the economics for ultra-clean fuels do not exist today. A key technology barrier clearly is the ability to remove sulfur, particularly below 30 ppm. There is a general lack of breakthrough technologies and ideas that might lead to the necessary cost reductions. A key non-technical issue is intellectual property along with the often cumbersome nature of industry/government partnerships.

For solutions (RD&D and other actions), innovative catalysts for removing sulfur and separations technology are critical needs. An up-front understanding of how intellectual property agreements are going to work is critical in responding to any request-for-proposal. Another area is to ensure that government support is focused on longer-range, higher-risk technology. Also, to move the process forward and assure integration of fuels and engine development, the automakers should be involved. This is a key piece of the value claim.

B. GROUP B: REPORT-OUT

As with Group A, general comments on the vision and goals were the starting point. If 5 million barrels per day is the goal, the majority of that will have to come from coal. Moreover, the industry is looking at all resources, not simply domestic resources. There is a global market reality that must be recognized. There is a big difference between a policy to use domestic resources and one to diversify fuel resources in a world market. Also, there is probably a timing mismatch between the 2020 goals and the Tier II requirements, which are much more near-term. In general, the potential industry/government relationships are likely quite different for the two time frames. Industry response to Tier II requirements does not have the luxury of waiting for a R&D program.

With respect to barriers, key items included the need for improved understanding of the effects of fuel properties on emissions and the need for technology for economical conversion of coal, particularly

breakthrough technologies. With respect to policy, industry currently does not have the economic incentives for alternative fuels; the economics are simply not there without technology breakthroughs. As with Group A, intellectual property issues are critical.

For solutions, economic sulfur reduction technologies, better Fischer-Tropsch catalysts, testing and demonstration to analyze the entire fuel cycle, and feasibility analysis of the role oxygenates can play were key items. Also a comprehensive analysis of the entire fuel cycle would aid in delivering resource-process-performance options and opportunities.

C. Group C: Report-Out

The group had a lively discussion concerning the goals, including a global versus domestic focus and the respective roles of industry, DOE, and EPA. The group distributed the goals into three time frames: short (Tier II in 2004), medium (2010), and long (2020). In the short-term, EPA requirements must be met by improvements in current refining technology. In comparison, the long-term goal is to commercialize ultra-clean fuels from alternative feedstocks, including direct conversion technology.

Barriers included the lack of clear mechanisms for government/industry collaboration, the lack of proven sulfur-removal technology, the public's unwillingness to pay for environmental costs, and the lack of fundamental and applied studies for direct conversion. Under current low-price crude scenarios, industry simply does not have the incentive to look at most of this. Also, in the context of a global economy, clean fuels and use of domestic resources are quite different goals, though not mutually exclusive.

For solutions, the groupings were funding and policy, systems analysis, basic research, and applied research. Basic research topics included advanced catalysts, direct conversion and advanced separations. Applied research topics included cost-effective sulfur removal technology and the optimization of fuel and engine design. Systems analyses focused on developing technologies that can be integrated into existing infrastructure in an economic manner. Funding and policy actions included the alternative capital funding to reduce investment risk in new technology, and stable long-term energy policy to guide and promote longer-term work.

D. Closing Comments

Following the group report-out, a general discussion was held to get closing comments and final thoughts. Perspectives and observations from this include:

- In reaching 30 ppm sulfur, the issue is cost, not technology capability; the real issue is whether the public is willing to pay the price.
- To reach 5 ppm sulfur, however, is a much more difficult challenge—the technology is not there.
- If technology-driven, not policy-driven solutions are going to be the answer, industry and government are going to have to collaborate to find acceptable solutions.

- The issue of domestic vs. other production is strictly a government policy issue, not an industry-related decision; from the industry perspective, the economics of a global approach will prevail.

- If 5 million barrels per day is the goal, the vast majority of it (75-80%) would have to come from coal.

- There is a need to clearly distinguish between two models for a program: a government based one and a joint industry/government one. A basic question is whether (and how) a long-term relationship will be achieved between government and industry.

- What is the role of R&D in a world where environmental targets are politically motivated and constantly changing?

- Clear distinctions need to be made between short-term and long-term goals, and industry needs to help with roadmapping.

- Promising and breakthrough technologies need to be identified and pursued, especially as they relate to possible Tier II solutions.

- There is a need for DOE to more broadly share the program concept with a broader range of stakeholders, including industry leaders and decision makers.

- There is a general emphasis necessary on alternative fuels development; very novel ideas and basic science work is required for the significant breakthroughs needed for cost-effectiveness.

- The public benefits of accelerating technology development for environmental improvements need to be clearly specified. It must be recognized that they require a time frame quite different from what industry would do on its own for economic purposes.

- If one of the government's goals is to help industry move their technologies from the lab to market, then partnering through a [illegible] ortium is not the optimum strategy. The owners of a particular technology are not wi[illegible] share their intellectual property with others.

IV. PRESENTATIONS

GREGORY KAWALKIN
Senior Advisor, DOE-FETC

GLENN PASSAVANT
Senior Program Manager, EPA

DEXTER SUTTERFIELD
Technology Manager, DOE-NPTO

VENKAT K. VENKATARAMAN
Product Manager, DOE-FETC

JOHN WINSLOW
Product Manager, DOE-FETC

A. Presentation by:

GREGORY KAWALKIN

Senior Advisor, DOE-FETC

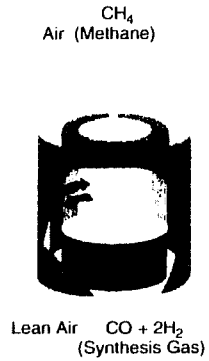
Office of Fossil Energy

Ultra-Clean Fuels for the 21st Century

Collaboration Models & Opportunities for RD&D

June 30, 1999

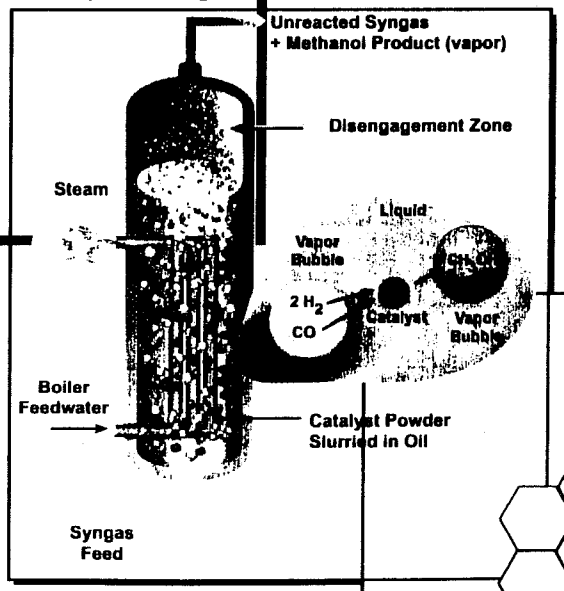
Ceramic Membrane Technology

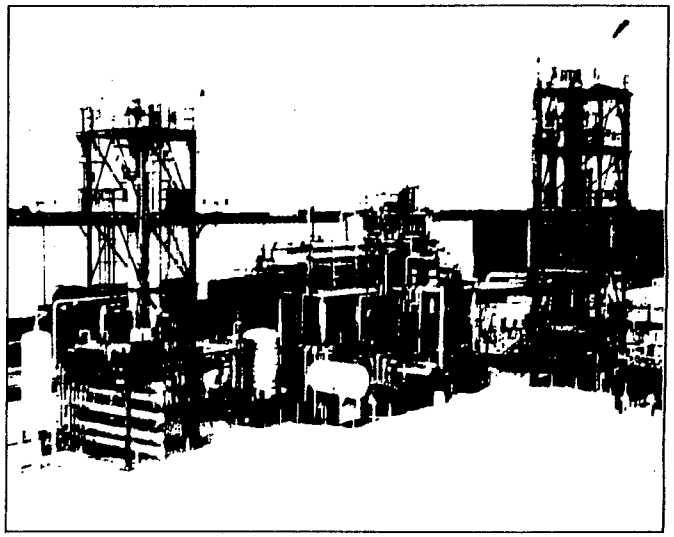


The partial pressure difference in oxygen that occurs between the air side and the methane side of the membrane when synthesis gas is formed facilitates oxygen ion transport through the membrane.

High Quality Transportation Fuels and Premium Chemicals

Hydrogen Production





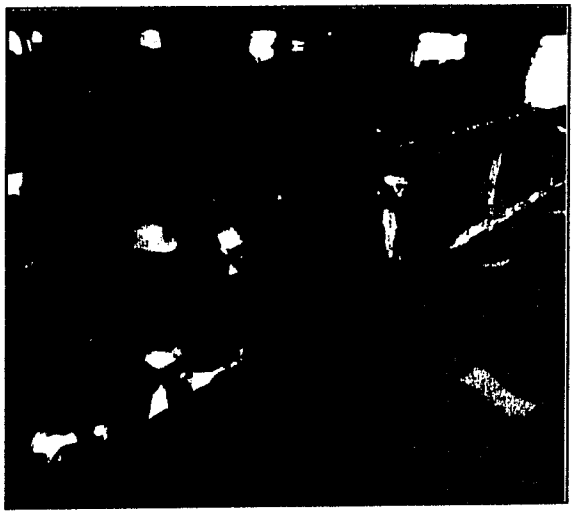
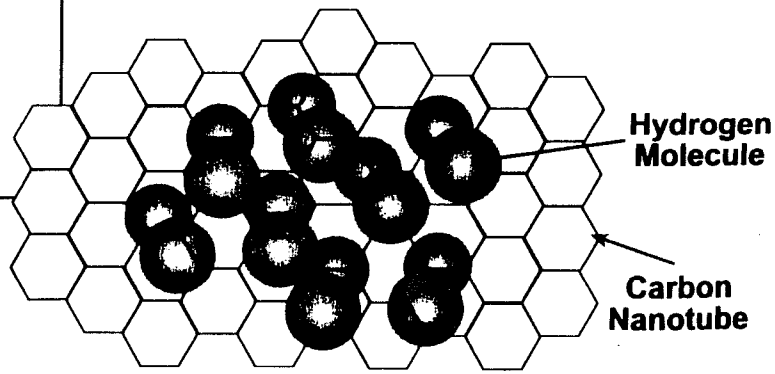


Illustration of Hydrogen Molecules in a Carbon Nanostructure



Collaboration Models & Opportunities for Ultra-Clean Fuels RD&D

Presentation Format

- **Goals**
- **Key Program Components**
- **Key Stakeholders**
- **Roadmap -- Ultra-Clean Fuels for the 21st Century**
- **A Vision of the Future -- Ultra-Clean Fuels for the 21st Century**
- **Program Objectives**
- **R&D Scope and Funding**
- **Potential Strategies (DOE/Industry)**
  - Multiple Award/Multiple Phase Downselection
  - Competitive Teaming Approach
  - Government/Industry Consortium
- **Trends, Goals, Barriers and R&D Opportunities**
- **DOE Collaborations (FE/EE)**
- **Supporting Information**

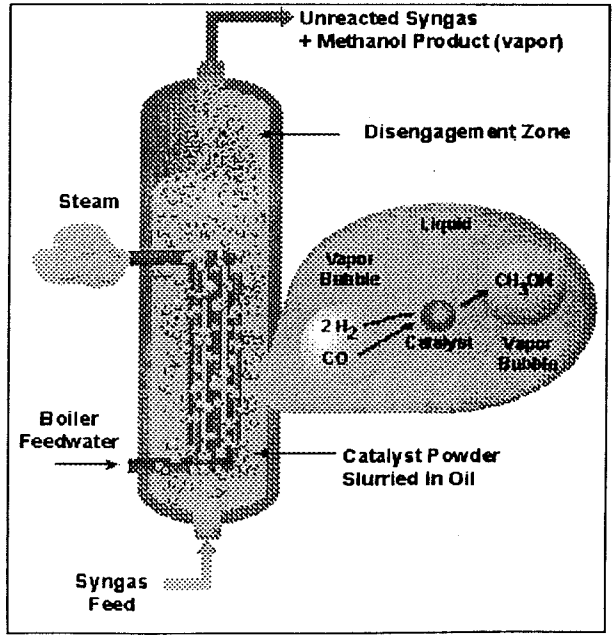
Ultra-Clean Fuels for the 21st Century Goals

- By 2005, establish data and processes to assist oil industry meet projected clean fuels requirements
- By 2010, establish an industrial base that will produce clean fuels from domestic resources not now exploited for fuel production: natural gas, petroleum by-products and coal
- By 2020, establish a new U.S. fuels industry that produces 5MM BPD from alternative domestic resources and provides technology enabling 10MM BPD domestic and 10MM BPD imported oil to meet ultra-low emissions specifications

Create strategic partnerships that will maximize the clean and efficient use of Fossil Resources as the Nation transitions to a sustainable energy economy

Ultra-Clean Fuels for the 21st Century
Key Program Components

- ***Ultra-Clean Fuels for the 21st Century***
- ***Early Entrance Co-production Technologies***



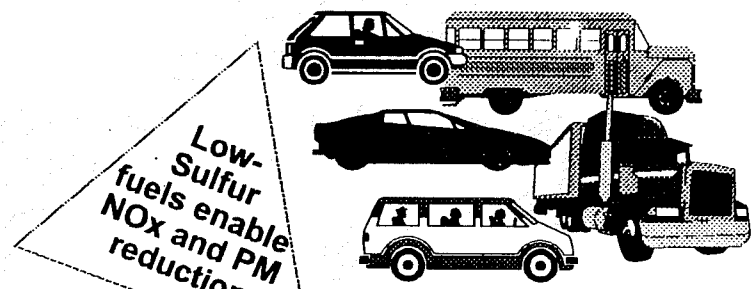
Advanced Clean Fuels Research
Key Stakeholders

- ***Petroleum Industry***
  - BP-Amoco, ARCO
  - Exxon,Mobil
  - Chevron, Texaco, Equilon
  - Conoco
  - Phillips
- ***Power Industry***
  - E. Kentucky Power
  - General Electric
  - PSI Energy
  - Tampa Electric
  - WMPI (IPP)
  - Global Energy
  - Dynergy
- ***Coal Industry***
  - Consol,
  - Western Energy
  - Usibelli
- ***Engineers & Constructors***
  - Bechtel
  - B&W
  - Kellogg-Rust
- ***Chemical Industry***
  - Air Products
  - Dow Corning
  - Eastman Chemical
  - Praxair
  - UOP
  - Methanex
- ***Carbon Industry***
  - Alcoa, Calgon Carbon, Pure Carbon, Duracell, Koppers, U.S. Steel, Bethlehem Steel

Ultra-Clean Fuels for the 21st Century Roadmap

As fuel sulfur approaches zero:

- Oil Processing Costs ↑
- Energy Losses ↑
- Technology Challenges ↑



Low-Sulfur fuels enable NOx and PM reduction

Petroleum/Gas/Coal

Petroleum/Gas

Petroleum

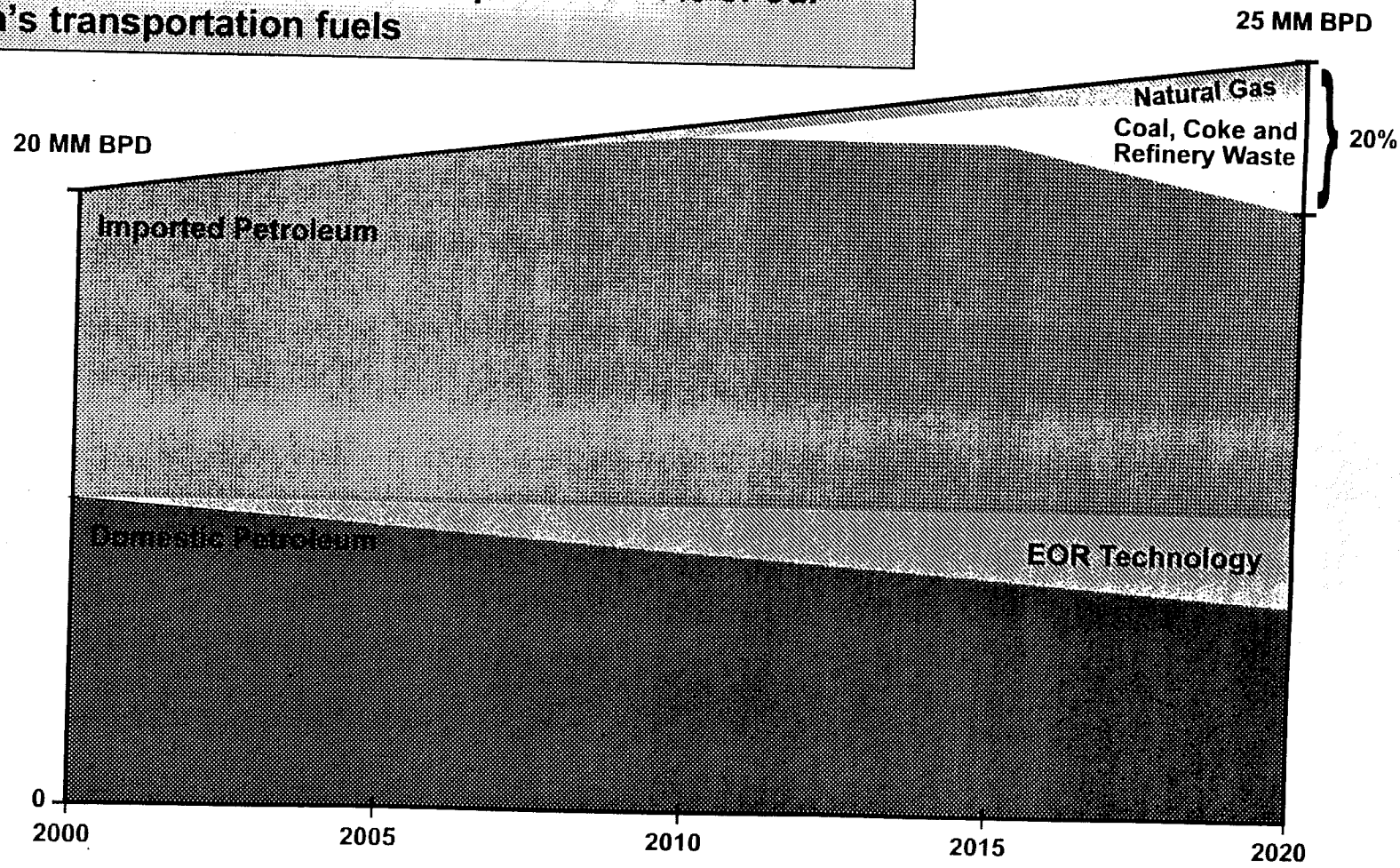
S in Fuel

2015	Zero-Sulfur neat fuels from domestic resources
2012	Zero-Sulfur blendstocks from domestic resources
2008	EPA Tier II 0.07 g/mile NOx 0.02 g/mile PM 0-30 ppm Sulfur
2004	EPA Tier II Phase-in Common Standard for all Fuels
Today	300-500 ppm Sulfur 4 gram NOx/hp-hr 0.1 gram PM/hp-hr

The first step toward a comprehensive FE Clean Fuels Program .... Coal, Petroleum and Natural Gas join forces to create a common strategy

Ultra-Clean Fuels for the 21st Century
A Vision of the Future

In 2020, clean, low-sulfur fuels from domestic petroleum play a significant role in U.S. transportation markets; alternative domestic feedstocks produce 20% of our Nation's transportation fuels



Ultra-Clean Fuels for the 21st Century Program Objectives

- **Develop a suite of technologies that:**
  - *assist the transportation industry meet Tier II standards and potentially more stringent future regulations*
  - *produce clean fuels that are complementary with the existing infrastructure*
  - *significantly reduce CO2 and other greenhouse gases by producing ultra-clean fuels for high-efficiency vehicles*
  - *provide the basis for a new U.S. industry producing 5MM BPD of premium fuels from alternative domestic resources by 2020*
  - *provide the basis for new technologies to improve the quality of fuels derived from domestic and imported petroleum*
  - *are cost competitive*

Ultra-Clean Fuels for the 21st Century
R&D Scope and Funding

- **Planning Level Program**

DOE	**$ 65MM**
Industry	**$115MM**
Total	**$180MM**

- **Implementation Mechanisms**
  - ***Government/Industry Consortium***
  - ***National Laboratory Partnership***

↓

U.S. technological base for production of ultra-clean fuels established

Ultra-Clean Fuels for the 21st Century
R&D Scope and Funding

- **Government/Industry Consortium**

DOE	**$ 50MM**
Industry	**$100MM**
Total	**$150MM**

- 5 Year Fast-Track Program
- Aggressive advanced fuels development & testing protocol
- Target design, construction and operation of a synthesis gas based innovative pre-commercial scale clean fuel production facility (200 -- 300 BPD) facility *capable of using multiple feedstocks*

U.S. technological base for production of ultra-clean fuels established

Ultra-Clean Fuels for the 21st Century
R&D Scope and Funding

- **National Laboratory Partnership**

	DOE	**$ 15MM**
	Industry	**$ 15MM**
	Total	**$ 30MM**

  - 5 Year Supporting Research Program
  - ***Petroleum Processing*** -- bio-processing heavy crudes, inorganic hydrogen separation membranes or other innovative technologies
  - ***Natural Gas Processing*** -- synthesis gas production, direct (one step) hydrogen production, catalyst/reactor development
  - ***Coal Transportation Fuels*** -- synthesis gas clean-up, hydrogen production, lab-scale fuel production for characterization and limited engine tests, systems engineering, economic/environmental analysis
  - ***Advanced Fuels Research*** -- C1 Chemistry, oxygenate production, hydrogen/carbon storage co-production

Ultra-Clean Fuels for the 21st Century Potential Strategies (DOE/Industry)

- **Multiple Award -- Multiple Phase Down-select Process**
  - ***Advantages***
    - Less expensive
    - Only best in class continue
  - ***Disadvantages***
    - Loss of support coincides with need for bigger budgets
    - Participants forced to follow parallel schedules

- *Multiple teams (3 to 5)*
- *Each with resource/facility owner, technology developer, end user*
- *Vertical integration among industry teams at project level*
- *Multiple phases (3 to 5)*
- *1--Concept Definition; 2--Technical, Economic Analysis; 3--Supporting R&D; 4--Engineering Development & Preliminary Design; 5--Detailed Design, Construction, Operation*
- *Evaluation and downselection at each phase end point*
- *No formal plan for horizontal integration at public level*

Ultra-Clean Fuels for the 21st Century Potential Strategies (DOE/Industry)

- **Competitive Teaming Approach**
  - ***Advantages***
    - No downselection at phase end points
    - All teams work at their own pace
    - Technology offered may vary in maturity
    - No loss of support at phase end points
  - ***Disadvantages***
    - Requires two procurement cycles to complete program

- *Multiple Teams*
- *Each with resource owner, technology developer, end user*
- *Multiple Phases*
- *Logical breakpoint in phased effort determined in advance*
- *All teams participate to end of phased program*
- *Vertical integration among industry teams at project level*
- *Horizontal integration at public level*

Ultra-Clean Fuels for the 21st Century Potential Strategies (DOE/Industry)

- **Government/Industry Consortium**
  - ***Advantages***
    - Significant financial leverage for each team member
  - ***Disadvantages***
    - Tends to work well when research is pre-competitive
    - Ownership/distribution of of intellectual property rights is difficult/complex
    - Requires an industry champion

- *Single team*
- *Multiple projects*
- *Participation across industry*
- *Horizontal/Vertical integration at industry/public level*
- *Program goals, technology challenges, research priorities, project definition, selection and schedule* ***all*** *reside with industry*

The First Step Toward a Comprehensive Fossil Energy Clean Fuels Program -- Petroleum, Natural Gas & Coal Join Forces to Create a Common Strategy

Ultra-Clean Fuels for the 21st Century
Trends, Goals, Barriers, R&D Opportunities

- **Industry Trends**
  - More restrictive emission standards
  - Lower sulfur fuels
  - Industry-wide NOx and PM regulations
  - Continued emphasis on CO2 reduction
  - Harder economic times for domestic refiners
  - Higher sulfur, heavier crude oil supply
  - Increasing oil imports
- **Goals**
  - By 2020, 5MM BPD from alternative domestic feedstocks
  - Significant improvement in vehicle fleet efficiency
  - Healthy domestic refinery industry
  - Eliminate need for increasing oil imports
  - Satisfy EPA Tier emissions standards (0.07 g/m NOx; 0.02 g/m PM)
- **Barriers**
  - Sustainable supply of natural gas feedstock
  - Environmental/economic constraints associated with alternative feedstocks
  - System integration requirements
- **R&D Priorities**
  - Innovative sulfur removal technology
  - Three phase slurry reactor technology
  - Improved, lower cost:
    - synthesis gas conversion catalysts
    - synthesis gas production
    - hydrogen production, storage, utilization
  - Middle of the pipe solutions
    - improved refinery conversion
  - Systems engineering:
    - technology integration
    - life cycle analyses
    - Infrastructure impacts

Ultra-Clean Fuels for the 21st Century
DOE Collaborations (FE/EE)

Fossil Energy Area of Primary Responsibility -- Fuel Production

↓

Area of shared Responsibility (collaboration) -- Fuels Characterization, Testing, and Evaluation

↑

Energy Efficiency Area of Primary Responsibility -- Engine and Exhaust Gas After-treatment Development

B. Presentation by:

GLENN PASSAVANT

Senior Program Manager, EPA

Overview of the Tier 2 Vehicle/ Gasoline Sulfur Control NPRM & Diesel ANPRM

June 30, 1999

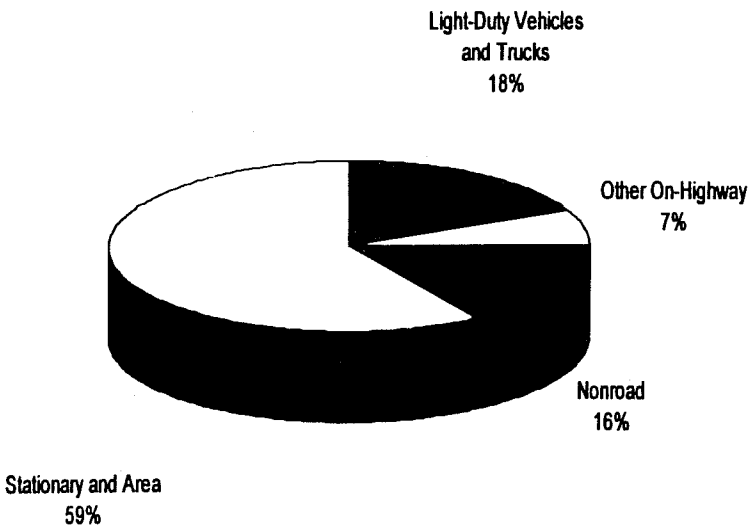
EPA Office of Mobile Sources

Background

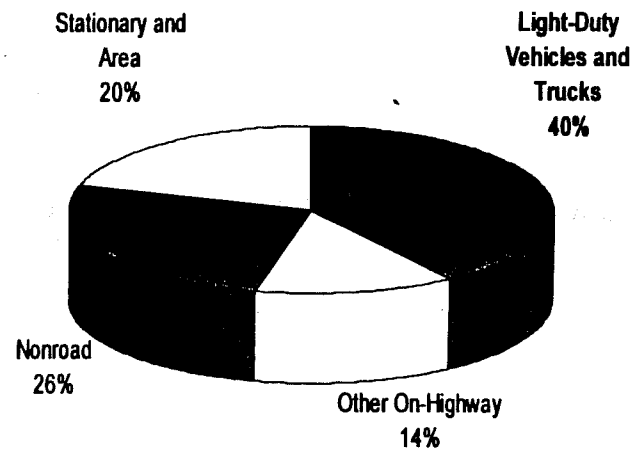
- Tier 2 called for by CAA section 202(i)
- Tier 2 study to address three areas:
  - air quality need for more control
  - technical feasibility of new standards
  - cost effectiveness of controls
- Study to Congress July 1998
- Strong evidence that we should pursue Tier 2 controls

LDV/LDT Contribution To NOx From All Sources Without Tier 2/Sulfur (2020)

47-State



Atlanta



EPA Overarching Principles

- Strong national program
- Vehicles and fuels are an integrated system
- Single set of emission standards for cars and light trucks regardless of fuel
- Encourage low emission & fuel efficient technologies
- Compliance flexibilities
- Sufficient lead-time

Industry Perspectives

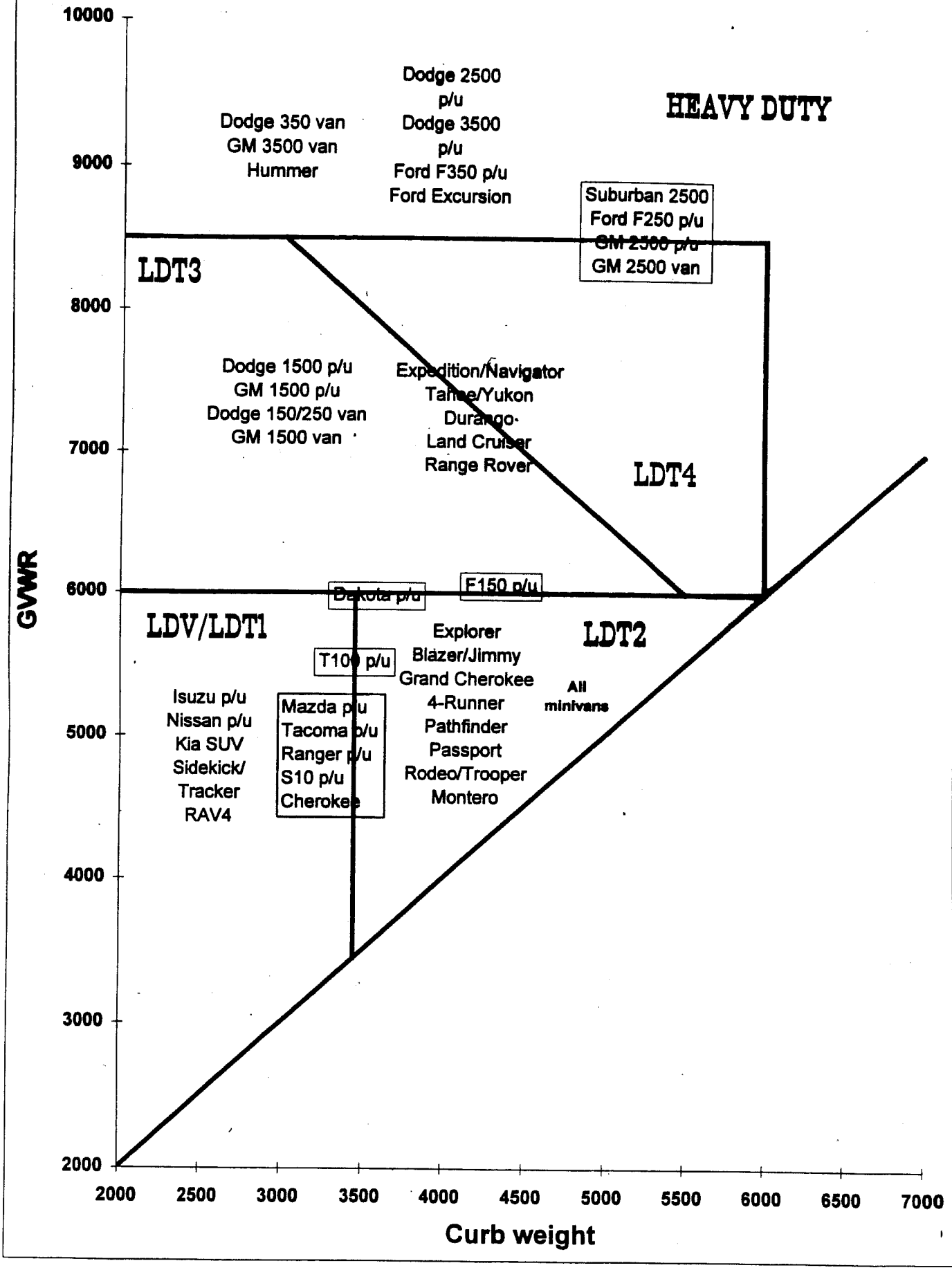
AUTOS

- vehicles/fuels are an integrated system - fuel quality matters
- do not preclude future technology
- different program needed for HLDTs
- flexibility is critical
- technology review

OILS

- regional program
- sulfur standards - consider vehicle technology and cost
- uniform standards within regions
- adequate lead-time
- resolve uncertainties

1999 MY Light Vehicle and Truck Classifications



Current Situation

- Passenger cars and light LDTs in NLEV
  - NMOG:0.09-0.13 g/mi
  - NOx: 0.30-0.50 g/mi
- Heavy LDTs
  - NMHC:0.46-0.56 g/mi
  - NOx:0.98-1.53 g/mi
- Gasoline Sulfur
- Conventional
  - 330 ppm avg
  - range:25-1000 ppm
- Phase II RFG
  - ~ 150 ppm
- Diesel sulfur
  - ~ 350 ppm avg(hwy)
  - ~3000 ppm (nr)

Overview - Tier 2 Vehicles

- Phase-in single set of exhaust emission standards for all LDVs and LDTs
- During phase-in apply interim standards that equal or exceed current requirements
- Same standards apply regardless of fuel
- Significant implementation flexibility
- Additional PM and evaporative emission controls

Tier 2 "Bins"

Full Useful Life Exhaust Emission Standards (grams/mile)

Bin No.	*NOx*	*NMOG*	*CO*	*Formaldehyde*	*PM*
7*	**0.20**	0.125	4.2	0.018	0.02
6*	**0.15**	0.090	4.2	0.018	0.02
5	**0.07**	0.090	4.2	0.018	0.01
4	**0.07**	0.055	2.1	0.011	0.01
3*	**0.04**	0.070	2.1	0.011	0.01
2	**0.02**	0.010	2.1	0.004	0.01
1	**0.00**	0.000	0.0	0.000	0.00

* Additional bins not in California's LEV II program.

Tier 2 and Interim Non-Tier 2 Averaging Sets

	2001	2002	2003	2004	2005	2006	2007	2008	2009 & later	Avg. NOx Std. (g/mi)
LDV/LLDT (Tier 2 + evap)	Early Banking **	**	**	25%	50%	75%	100%	100%	100%	0.07
LDV/LLDT (Interim)	NLEV	NLEV	NLEV	75%	50%	25%				0.30
HLDT (Tier 2)				Early Banking **	**	**	**	50%	100%	0.07
HLDT (Interim "A")	Tier 1	Tier 1	Tier 1	50%						0.60*
HLDT (Interim "B")	**	**	**	25%	50%	75%	100%	50%		0.20

* 0.60 NOx cap applies to balance of vehicles during the 2004-2006 phase-in years

** Alternative phase-in schedules permit manufacturers to deviate from the 25/50/75% 2004-06 and 50% 2008 phase-in requirement if they phase some vehicles in during one or more of these model years.

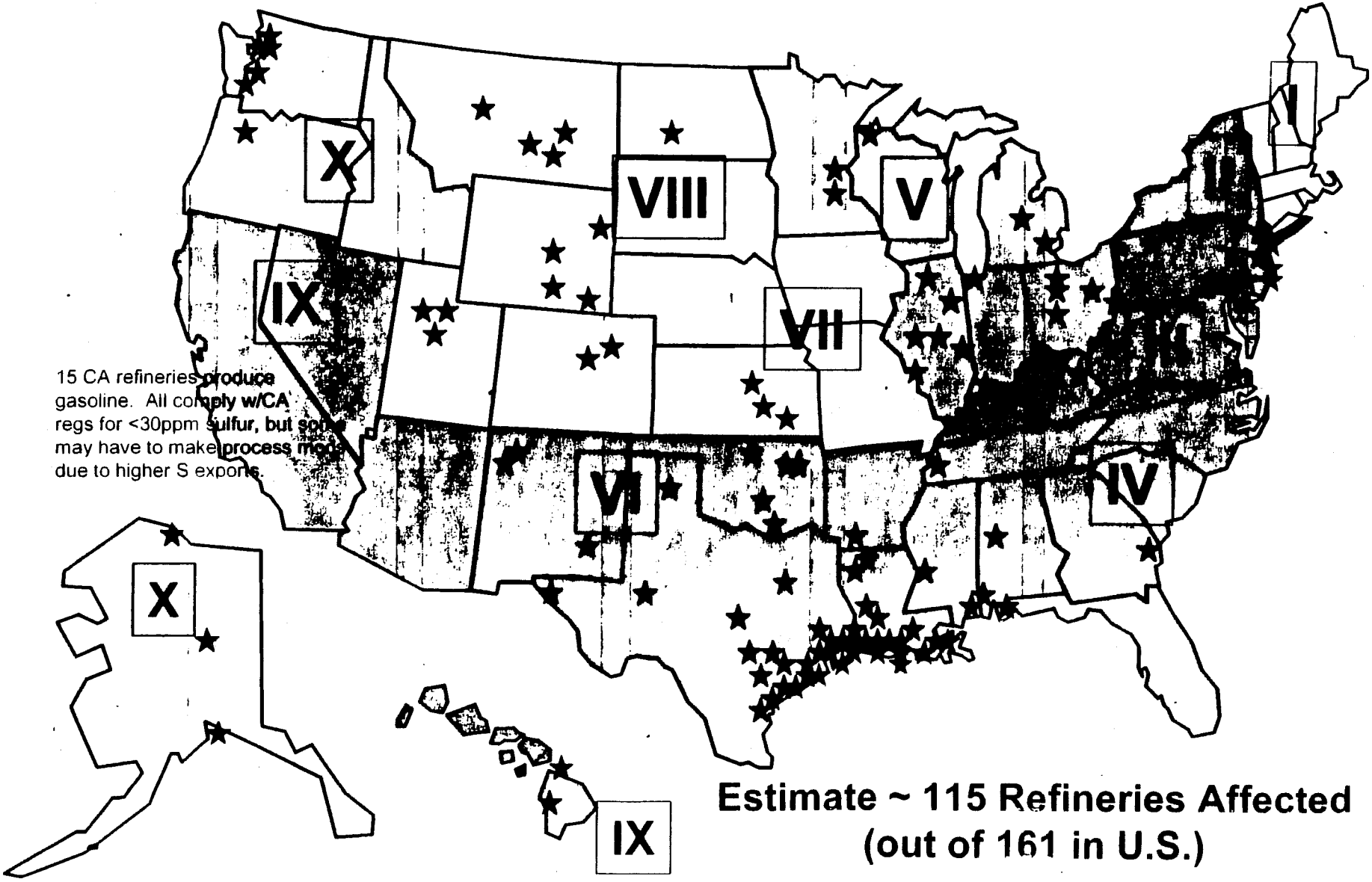
Overview - Fuel Sulfur

- Significantly reduce average gasoline sulfur levels nationwide
- Provide for flexible implementation by refiners
- Apply temporary, less stringent standards for certain small refiners
- Optimize emissions performance of current and future vehicles
- Diesel ANPRM

Key Issues - Gasoline Sulfur

- Stringency and Geographic Scope
  - sensitivity
  - irreversibilty
- Adequate lead-time
  - technology development
  - permitting and construction

U.S. Refineries Affected by Gasoline Sulfur Control by EPA Region



15 CA refineries produce gasoline. All comply w/CA regs for <30ppm sulfur, but some may have to make process mods due to higher S exports.

Estimate ~ 115 Refineries Affected (out of 161 in U.S.)

Proposed Gasoline Sulfur Standards

Compliance as of:	January 1, 2004	January 1, 2005	January 1, 2006+
Refinery Average, ppm	30	30	30
Corporate Pool Average, ppm	120	90	not applicable
Per-Gallon Cap, ppm	300	180	80

Gasoline Sulfur Program Flexibilities

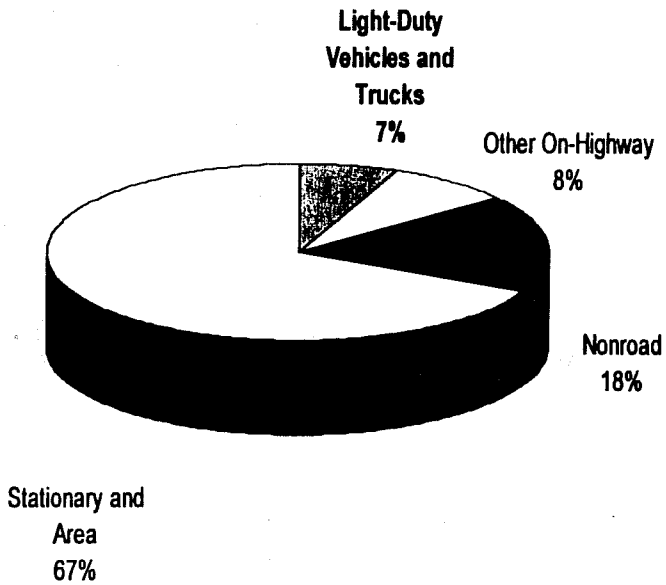
- Averaging, Banking, and Trading Program
- Small refiner relief provisions through SBREFA
- Permit streamlining

Proposed Gasoline Sulfur Program

2000	2000 - 2003	2004	2005	2006	2007+
Application for Credit Program Baseline due by July 1	Early Credit Generation for Gasoline with ≤ 150 ppm Sulfur				
		Credit Generation for ≤30 ppm Sulfur			
	Banking & Trading of Credits	Banking & Trading of Credits			
		Corporate Average Standards Apply			
		Compliance with 30 ppm Average Standard at the Refinery and Importer Level			
		Phase-in of Downstream Cap Standards			

LDV/LDT Contribution To NOx Emission From All Sources With Tier 2/Sulfur (2020)

47-State



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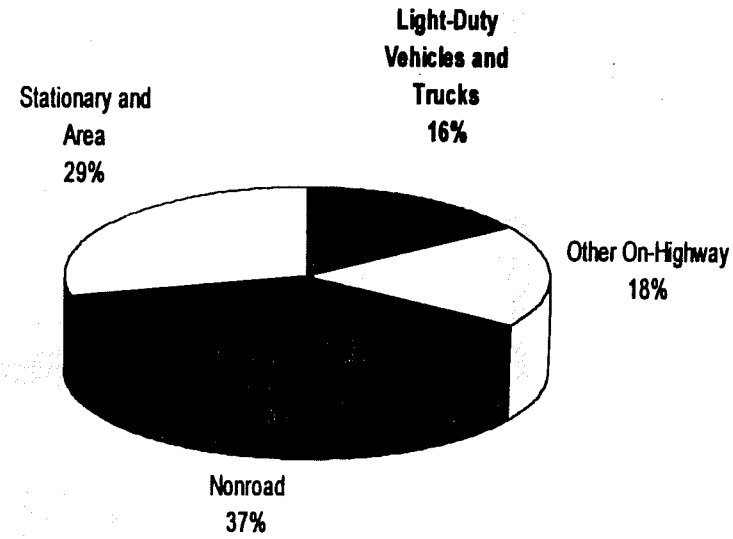
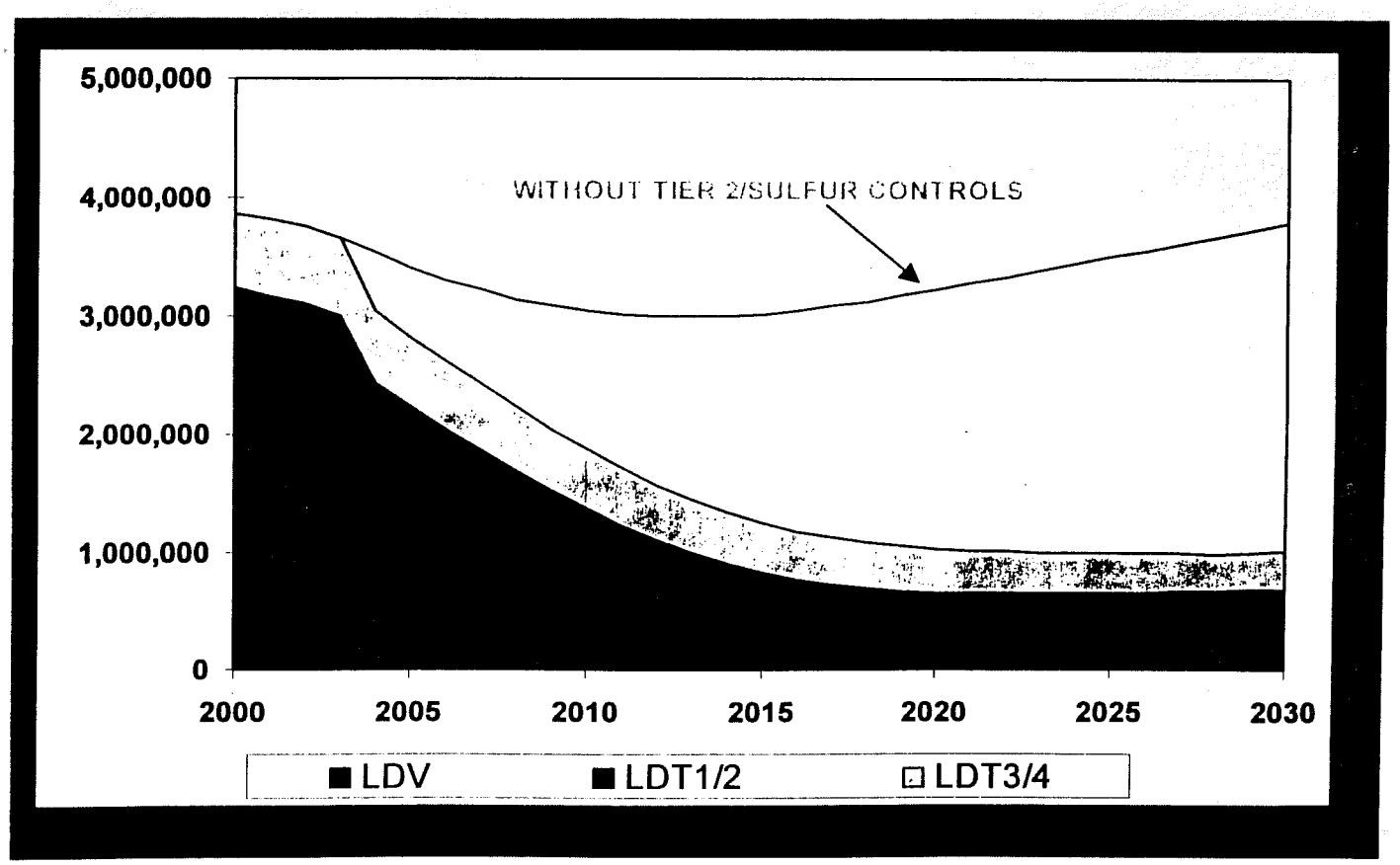
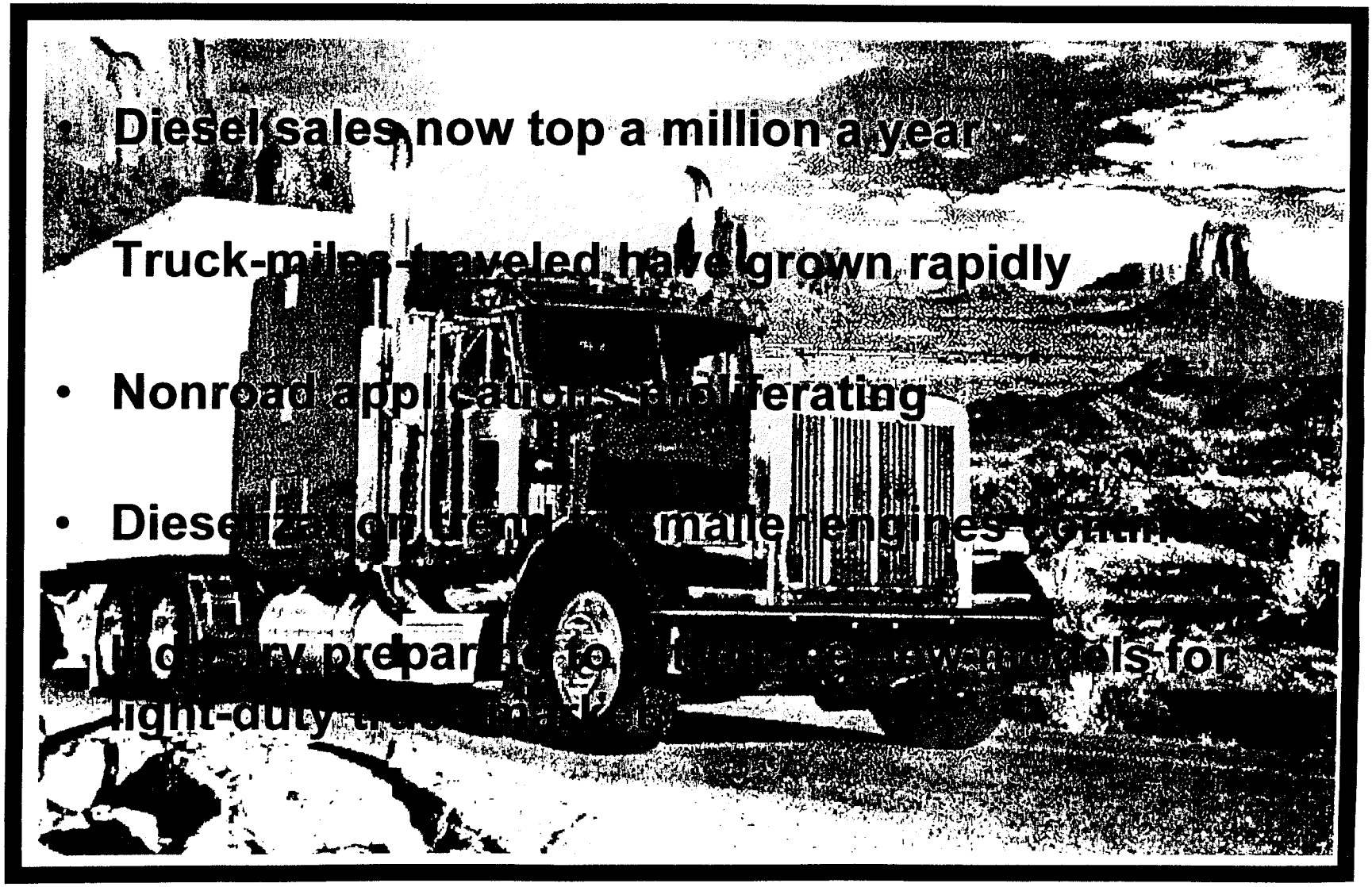


47-State LDV/LDT NOx Emissions With Proposed Tier 2/Sulfur Program (Tons)

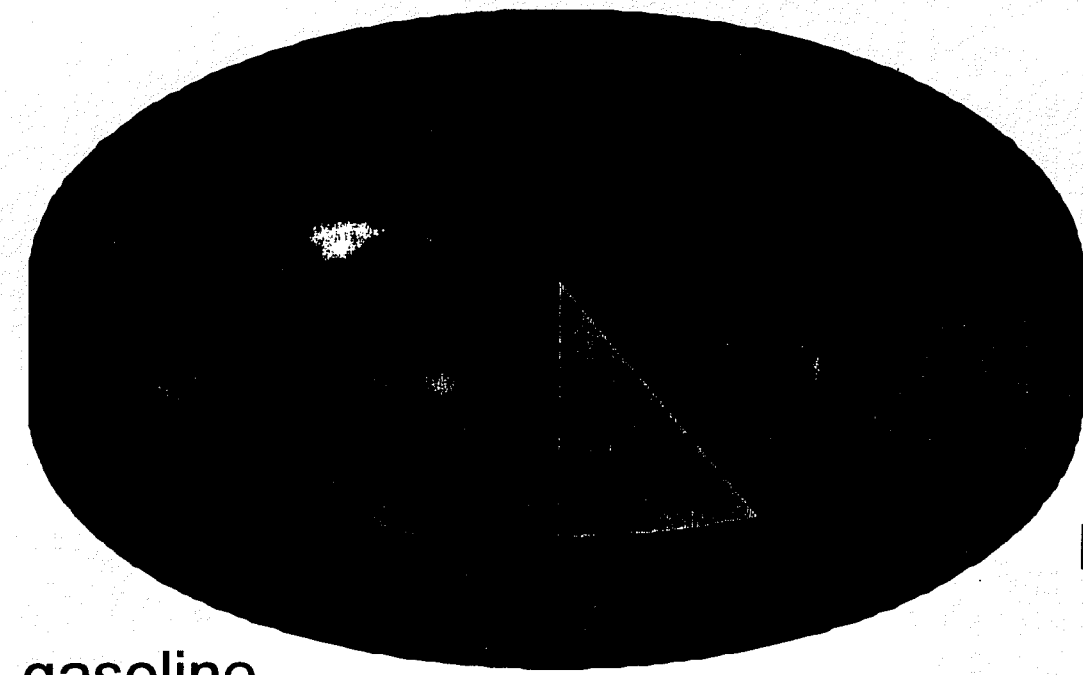


Diesel Popularity



- Diesel sales now top a million a year
- Truck-miles traveled have grown rapidly
- Nonroad applications proliferating
- Diesel [illegible] marine engines [illegible]
- [illegible] prepar[illegible] to [illegible] new models for light-duty [illegible]

U.S. Fuel Use



Diesels and Air Quality

Rapid progress in emissions control BUT…

- **NOx and PM inventories still large**
- **Diesel PM increasingly of concern**
  - **Fine PM (~all diesel PM is <2.5 microns)**
  - **Air toxics**

What Can Be Done?

- Diminishing returns with engine redesigns - -
- Emissions control focus is shifting to aftertreatment
- Potential for step change in emissions
- Similar to auto emissions control in 70's
- Likely need to remove most of sulfur from fuel to enable
  - sulfur reduction also enables better EGR
  - Also some direct PM and SOx benefits in existing fleet

How Can Diesel Fuel Be Improved?

Lots of candidate fuel spec changes

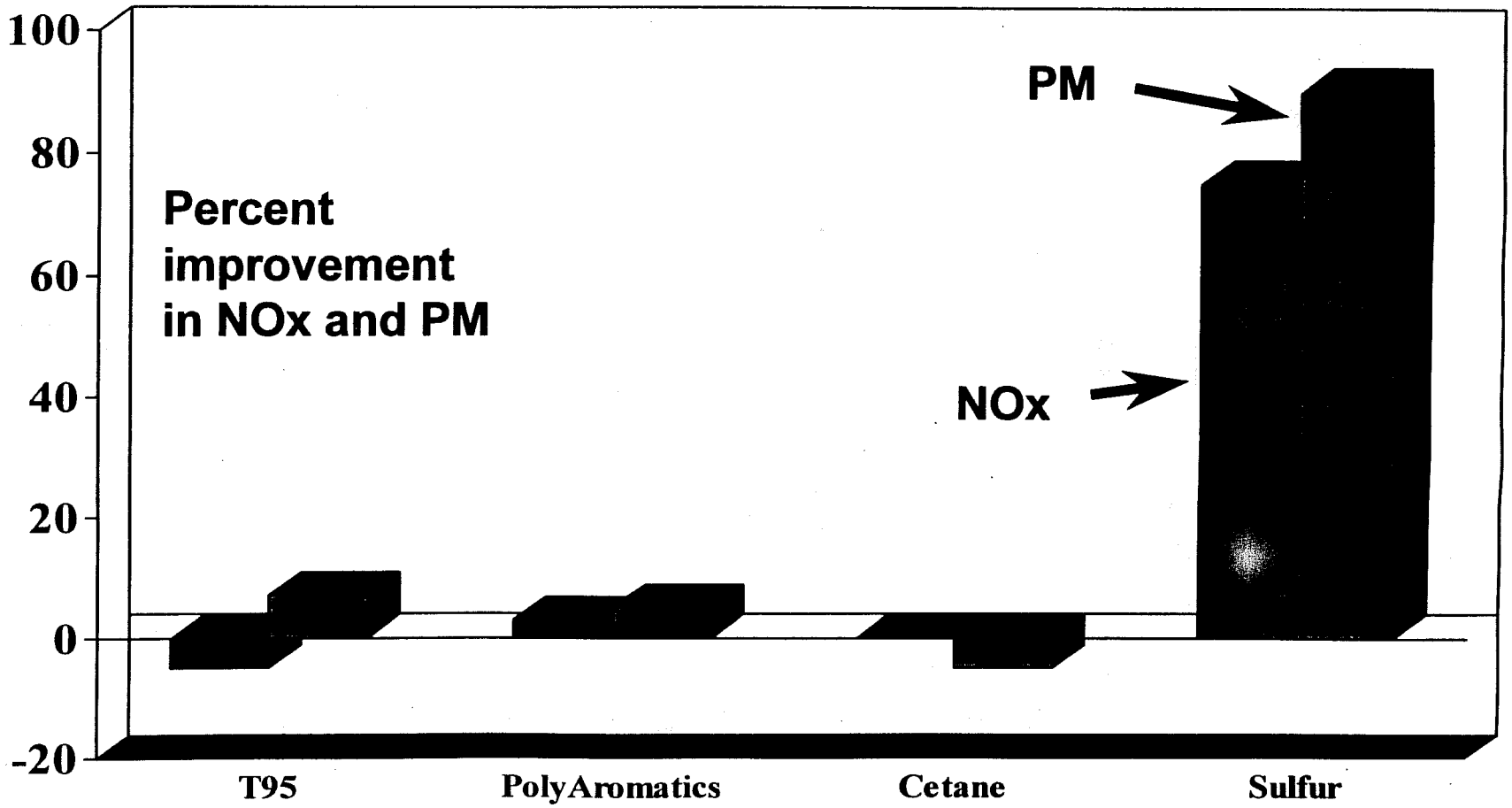
- polyaromatics
- Distillation characteristics (T90, T95)
- cetane
- sulfur
- oxygenates
- density
- total aromatics

Why Sulfur?

- ***PM traps***
  - designs have improved over the years
  - 80-90% efficiency, including superfine particles
  - some promising designs are **sensitive to sulfur**
- ***NOx catalysts***
  - high efficiency (50-75%) NOx adsorbers are **sulfur-sensitive**
- May need sulfur reduced to 30 ppm or less
- Also enables better EGR & oxidation cats
- Also some direct PM benefits in existing fleet

Why Sulfur?

Some Preliminary Data On Fuel Effects



(Technology enablement)

	Corporate Average NOx (grams/mile)	Highest-Emitting Certification Bin (grams/mile)	
		NOx	PM
LDV & Light LDT			
Interim	0.30	0.60	0.06
Tier 2	0.07	0.20	0.02
Heavy LDT			
Interim A	0.60*	0.60	0.06
Interim B	0.20	0.60	0.06
Tier 2	0.07	0.20	0.02

* Applies to all vehicles in category (not a corporate average).

	Model Year					
	2004	2005	2006	2007	2008	2009 & later
LDV & Light LDT						
Interim	75%	50%	25%			
Tier 2	25%	50%	75%	100%	100%	100%
Heavy LDT						
Interim A	75%	50%	25%			
Interim B	25%	50%	75%	100%	50%	
Tier 2					50%	100%

Diesels may need low-S fuel here

When Might Sulfur Reduction Be Needed?

- Tier 2:
  - Advanced technologies in 2006 or 2007 models years --
  - So fuel likely needed in mid part of next decade
- Heavy-duty highway:
  - Not likely needed for 2004 standards
  - Advanced technologies / new standards ~2007?
- Nonroad:
  - Tier 3 starts in 2006 (may require 500 ppm sulfur fuel)
  - Eventually advanced technologies for nonroad too?

ANPRM Key Issues

- Should pursue changes **other than sulfur**?
- **How feasible** are advanced sulfur-sensitive technologies?
- **What sulfur levels** are needed and when?
- What about a **phased approach**?
- Should desulfurize **nonroad fuel** to current highway levels?
- Should **Alaska** be exempted?

ANPRM Key Refiner Issues

- What would the refinery and distribution **costs** be?
- **How soon** can low sulfur fuel be made available?
- What would be the impact on **small refiners**?
- How can the program be made **flexible** for refiners and still be effective?

C. Presentation by:

DEXTER SUTTERFIELD

Technology Manager, DOE-NPTO

National Petroleum Technology Office (NPTO) Oil Processing Program

June 30, 1999

Planning Workshop

Ultra-Clean Fuels for the 21st Century

Oil Processing Program

- Environmental
  - Work with EPA and industry
    - PERF
      - How clean is clean
      - Bioavailability of hydrocarbon contaminants
      - Stack emissions
    - PM2.5
      - Characterization of particulates from petroleum
      - Indoor vs. outside PM

Oil Processing Program

- **Chemistry**
  - Chemical and physical data for design of processes
  - Data for sound scientific bases for regulatory compliance issues
  - Data for process options and verification

- **Processing**
  - Coker joint industry project (10 companies)
  - Supercritical Solid Alkylation
  - Plasma arc upgrading of heavy crudes
  - Membranes for hydrogen separation
  - Bio upgrading of heavy crude

Technology Roadmap: Bio-Upgrading of Heavy Crude (API <20)

Timeline	2 years			6 years		10 years
Technology Areas						
Heavy Oil Chemistry and Analytical Methods	Understand chemistry of Heavy Oil to identify targets 1. Literature Review 2. Workshop Select representative crude oil as standard	Develop fast, sensitive screening assays - SIM-DIST - Model Compounds Characterize higher molecular weight Sulfur compounds & develop quantitative techniques Identify target molecules for upgrading		Continue fundamental research to understand physical andchemical structure of asphaltene micelles		
Biotechnology	Understand existing biocatalyst capabilities 1. Literature Review 2. Workshop	Conduct Preliminary Screening for biocatalysts Collect organisms & enzymes for screening - Bug Hunt - Available Enzymes	Conduct Activity Screening -Breakdown large molecules -Remove S, N, Metals Conduct Stability Screening - high temp., pH, solvent, salinity	De-bottleneck enzyme pathway to improve rates Develop Cell hosts that ease emulsion breaking and cell recovery	Develop enz[illegible] from whole-[illegible] biocatalyst([illegible] Develop co-[illegible] regeneration capability	
Synergistic Physical & Chemical Processes	Understand Physical/Chemical Process To Make Asphaltenes Bioavailable - Physical Mixing, Electrical Forces, pH, Solvents, Thermal, Emulsification, partial oxidation/extraction		Develop combined Physical/Chemical Bio-Process			
Reactor Science				Design reactor to optimize bioavailability and avoid mass transport limitations	Develop [illegible] Reactor	
Separations Science				Develop separations: - reuse microbe/enzyme - break oil-water emulsion		
Process Engineering	Conduct "Reverse Engineering" to identify target process conditions from oil-field -> refinery			Evaluate effects of physical/chemical changes in oil on the downstream processing, and by-products		
Process Economics	Cost Benefit Analysis of Upgrading Options			Evaluate Economics - including cost of Biocatalyst	Evaluate Price Targets - here do we need to be?	

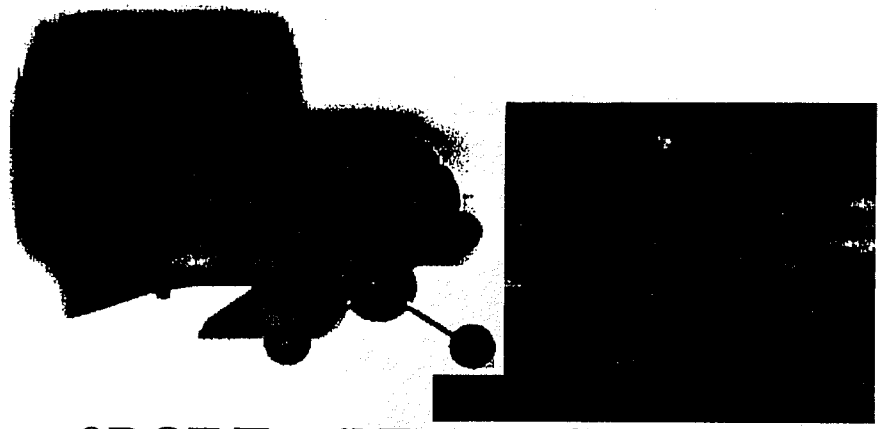
Oil Processing Program
Bio Upgrading Projects

- Biochemical upgrading of oils and petroleum products (BNL)
- Bioprocessing of high sulfur crudes (INEEL)
- Biological upgrading of heavy oils for viscosity reduction (LBNL)
- Enzymatic upgrading of heavy crudes (ORNL)
- Petroleum biorefining for pollution prevention (IGT)

D. Presentation by:

VENKAT K. VENKATARAMAN

Product Manager, DOE-FETC



Overview of DOE/Fossil Energy Gas-to-Liquids R&D Program Strategy

by

V. K. Venkataraman

Product Manager, Natural Gas Processing & Utilization

Presented at the

U.S. Department of Energy Industry-Government Workshop on Ultra-Clean Fuels for the 21st Century

Dallas, Texas - June 30, 1999

U.S. Department of Energy
Federal Energy Technology Center
Morgantown, WV 26507-0880

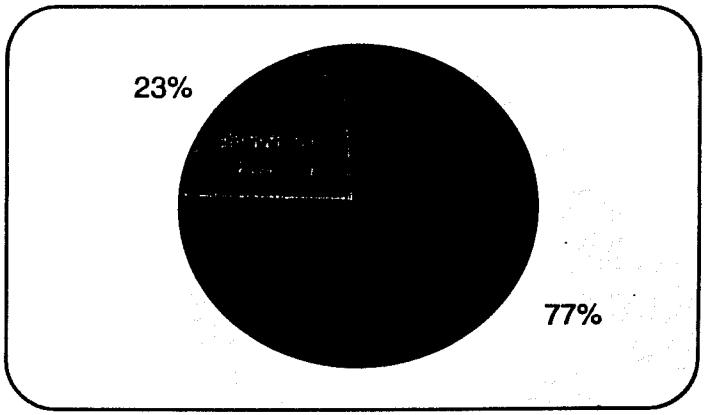
M990786 PPT

FETC

Gas to Liquids
Program Drivers

Federal Government Role:

- Provide science and technology leadership
  - Develop advanced technology for economic conversion of remote gas to easily transportable and clean liquids - liquefied natural gas, petrochemicals, fuels



23 % of gas resources are in remote locations
(Alaska and Deep Offshore Gulf of Mexico)

Gas to Liquids

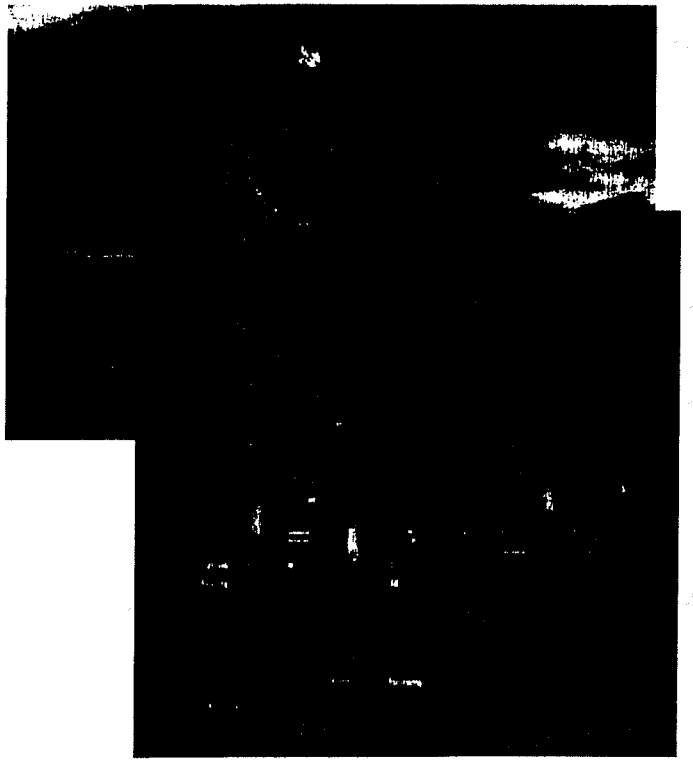
Impact of Technology

Advanced gas-to-liquids (GTL) technologies will allow conversion of remote gas to transportable fuels and petrochemicals

- Advances in separation technologies promise 25+% cost reduction breakthroughs for GTL conversion (from current technology $26-28/bbl to $18 - 22/bbl)

- Small-scale technologies of both LNG manufacture and GTL conversion can meet space and size limitations of remote offshore platforms and isolated, small gas deposits

Why Gas-to Liquids?



- GTL option allows use, and extends life, of existing Trans-Alaska oil pipeline -- leading to additional North Slope oil production
- Advanced GTL technologies will allow remote and deep gas to be converted to transportable liquid fuels and petrochemicals
- Diesel fuels made with gas-to-liquids technology have environmental and efficiency benefits over petroleum-derived diesel

Program Strategy

- Establish U.S. lead in Gas-to-Liquids Conversion Technologies for fuels and chemicals

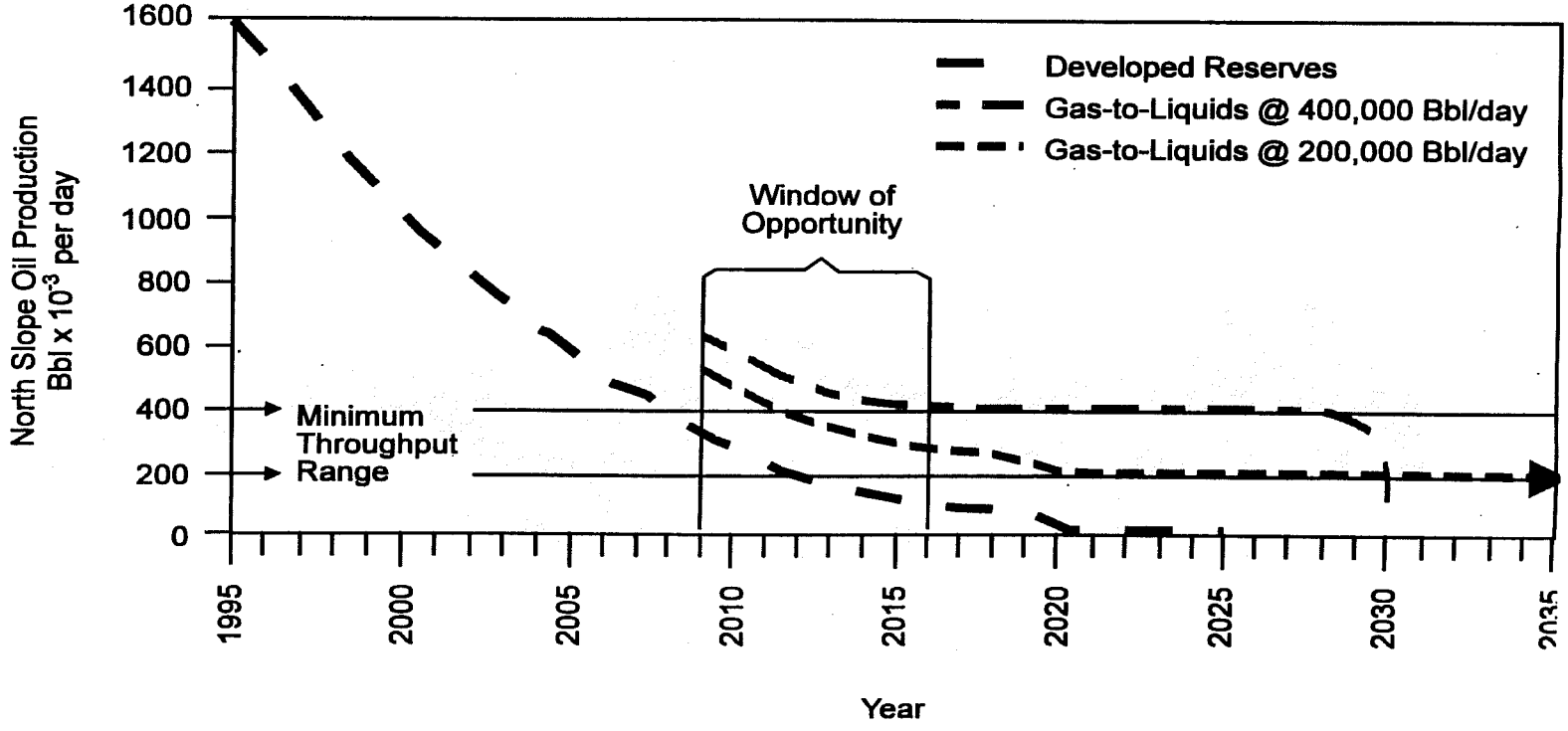
- Develop government/industry partnerships to stimulate deployment of technical commercial plants for mitigation of technology and market risks

- Partner with other FETC Product lines (Coal Transportation Fuels, Advanced Fuels) and other DOE offices (Energy Efficiency, Office of Transportation Technology) in an effort to leverage program funding

Program Benefits

- Enhanced utilization of on/offshore natural gas resources (1200 Tcf)
- Monetization of 100 Tcf of stranded gas resources in Alaska
- Continued operation of TAP transporting both petroleum and gas-derived fuels for at least 25 years
- Continued operation will result in recovery of an additional 1 billion barrels of petroleum
- Increase of domestic natural gas production by 1 Tcf per year for each 172 million barrels of fuel produced (Btu exchange basis)

Window of Opportunity (2009-2016)
Alaska



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FETC

Gas-to-Liquids
Technology Development Timeline

[redacted]

Explore	Bench and Engineering Scales	Entry Level	Demonstration Plants (10,000 - 50,000 Bbl/day)
1992	1996-2000	2004	2008 Alaskan North Slope U.S. Offshore/Onshore

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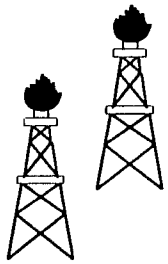
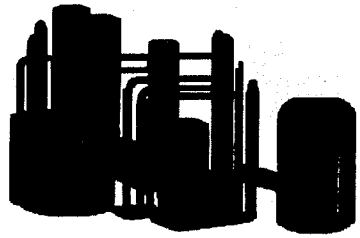
FETC

Indirect Conversion

Existing Process Cost Breakdown

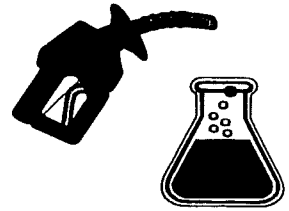


Gas



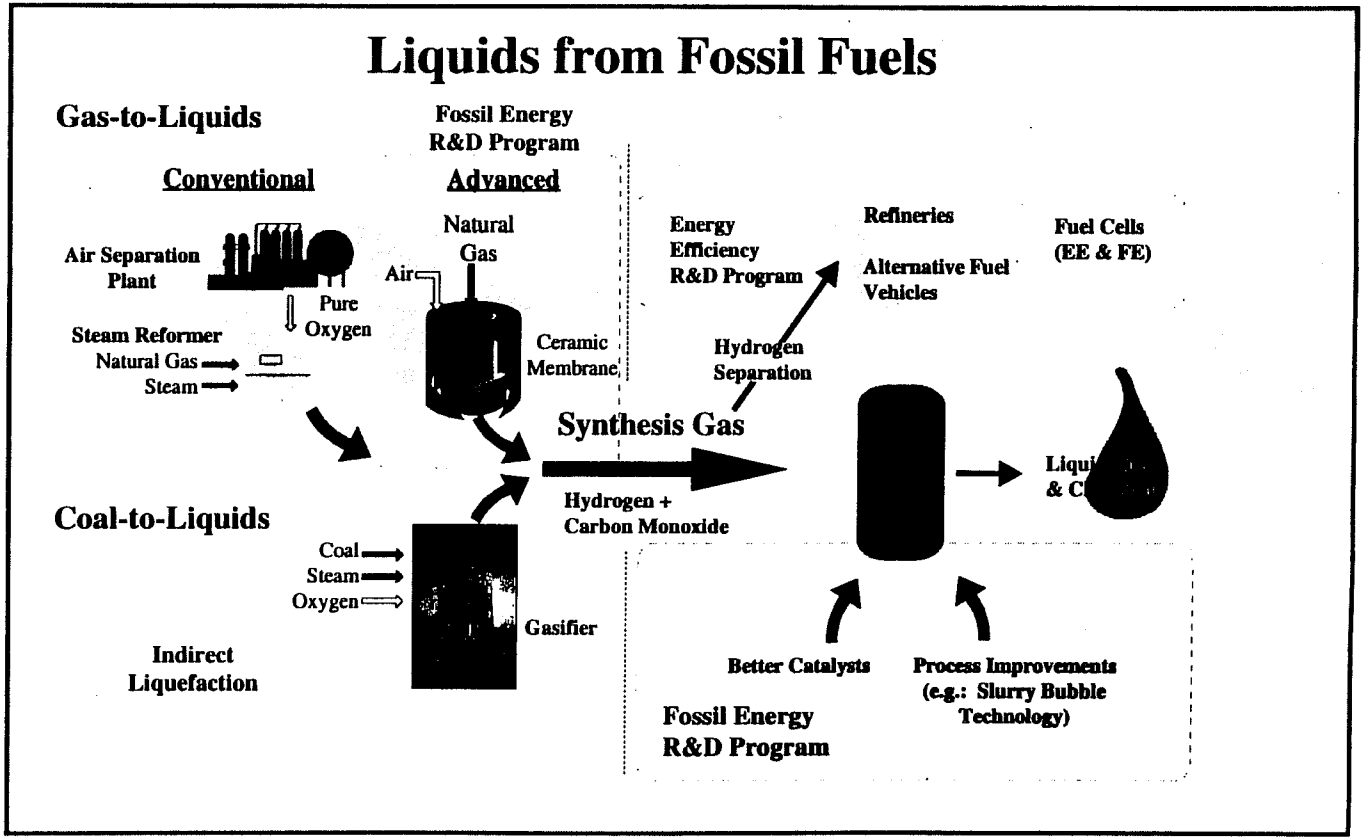
Synthesis Gas Generation 60%

Synthesis Gas Conversion 25-30%



Product Refining 10-15%

DOE Gas-to-Liquids Program



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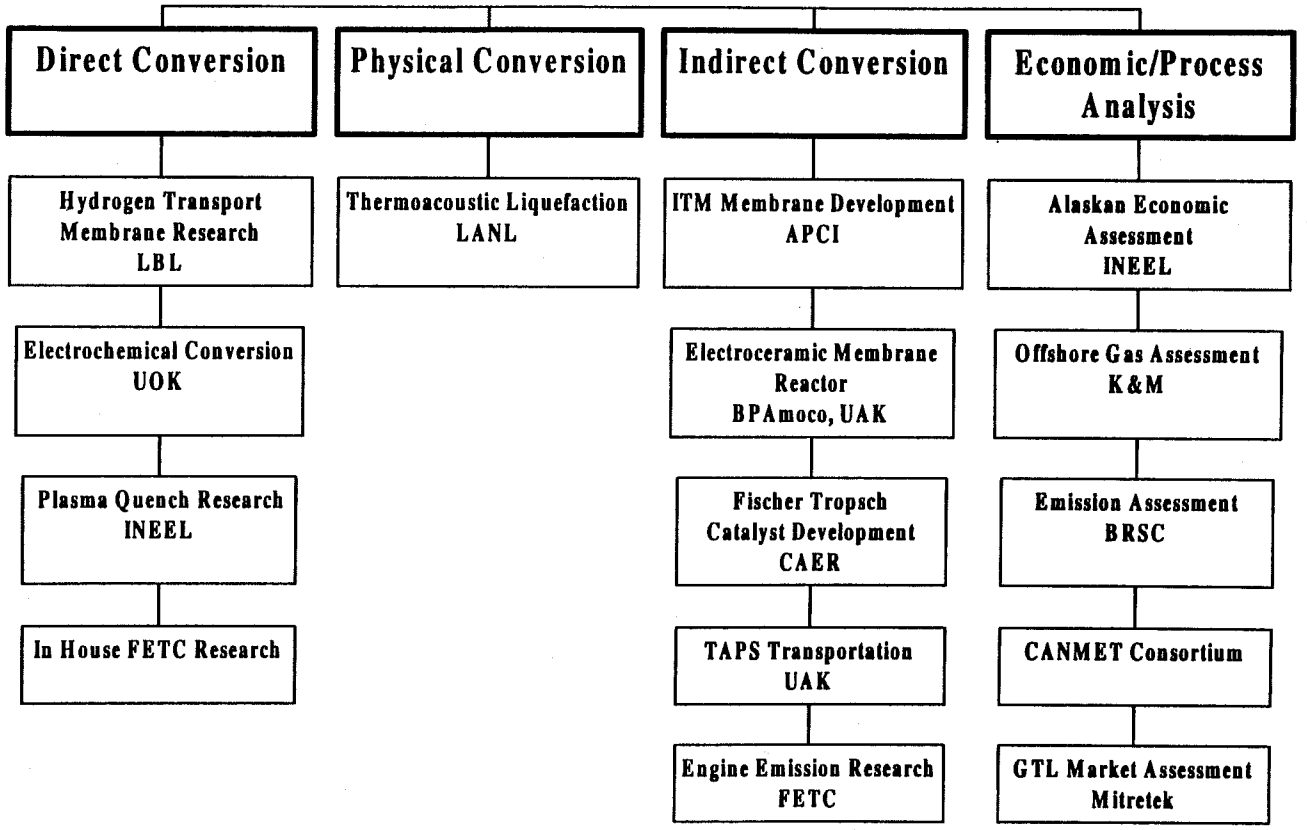
FETC

FETC Gas to Liquids Program



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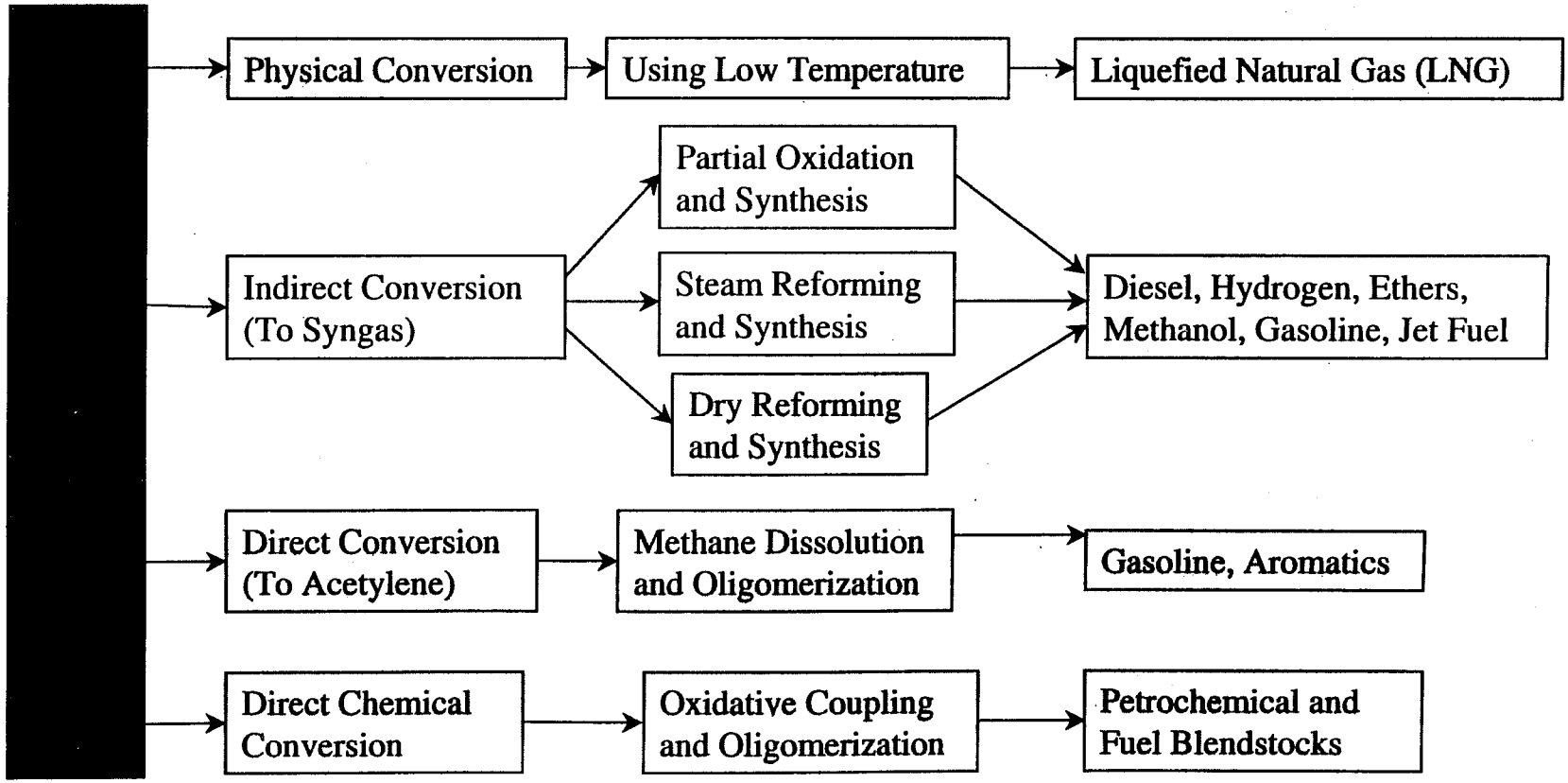
Natural Gas Conversion Processes



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Emissions Performance of Fischer-Tropsch (F-T) Diesel Fuels Is Superior to Petroleum Diesel Fuels

Emissions Reduction Relative to Low Sulfur Petroleum Diesel	
Hydrocarbons	41-46%
CO	45-47%
NOx	9%
Particulates	27-32%

Emissions Reduction Relative to Low Sulfur/Low Aromatics Petroleum Diesel	
Hydrocarbons	25-31%
CO	34-38%
NOx	5%
Particulates	23-29%

*Ranges based on three fuels, i.e., summer, winter, and California formulations, produced from natural gas and coal feedstocks.

M990786 PPT

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GTL Program Goal and Direction

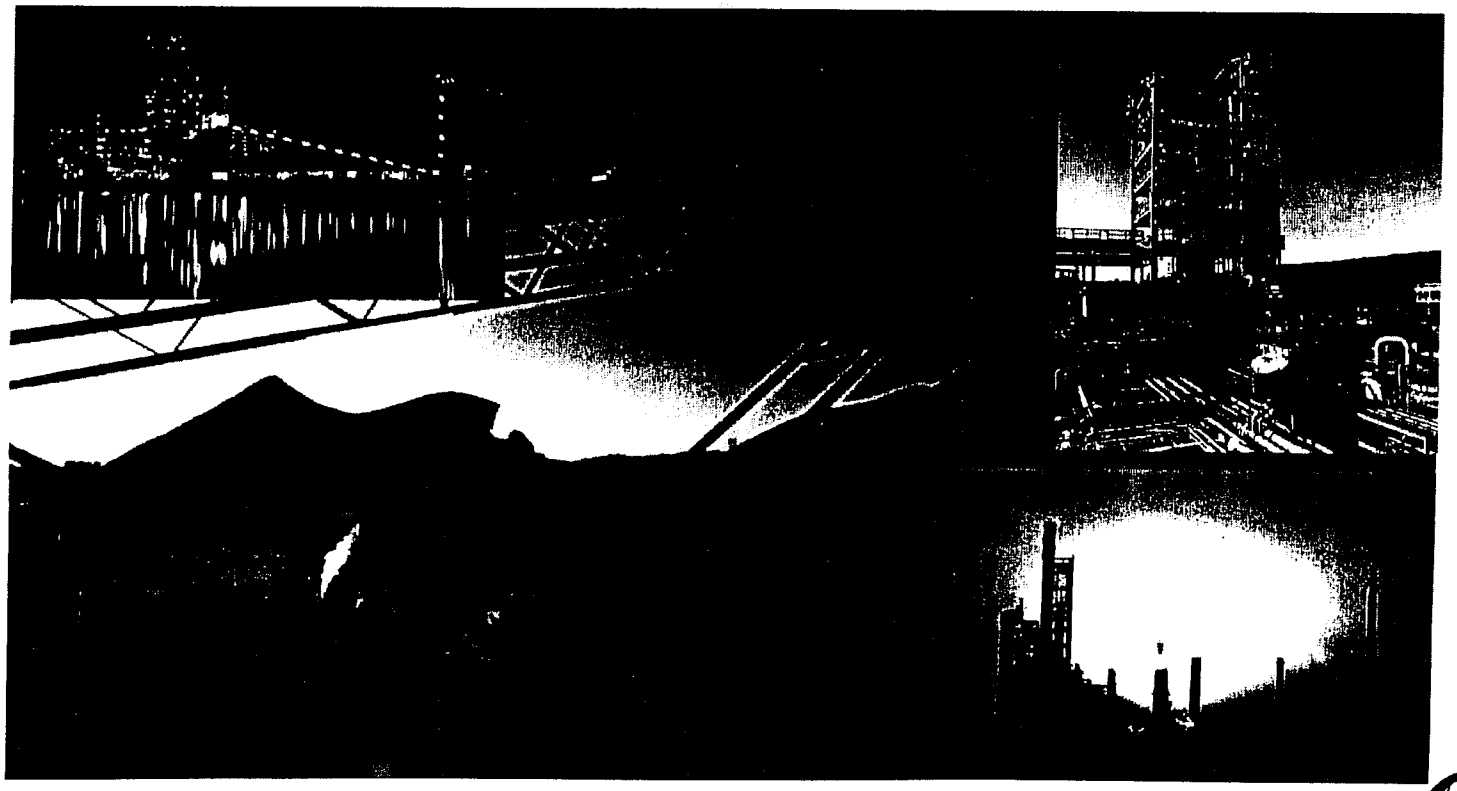
- Extend/expand/validate public database on GTL processes, products, and economics to aid in the inevitable private and public decision making necessary to best utilize our remote natural gas resources -- ANS, offshore
- Current Program Activity focus on process elements of established, but as yet non-commercial FT technology -- require incentives
- The program emphasis will continue, but may well be supplemented by fresh looks at how GTL technology can support attainment of new motor fuel performance demands that seem on the horizon

E. Presentation by:

JOHN WINSLOW

Product Manager, DOE-FETC

Early Entrance Coproduction Plant
A Joint IGCC/Transportation Fuels & Chemicals Program



FETC

Early Entrance Coproduction Plants: A Path to Commercializing Advanced Fossil Technology for Power and Fuels

A Joint DOE Fossil Energy IGCC/Transportation Fuels & Chemicals Program

FETC

Early Entrance Coproduction Plant - Vision/Goal

- **VISION**
  - by 2007 there will exist one or more fully integrated pioneer plants demonstrating the technical, economic, and environmental benefits of gasification-based coproduction technology

- **GOAL**
  - facilitate the coproduction of some combination of fossil based electricity (or heat), fuels and chemicals by partnering with industry and other key stakeholders in the deployment of coproduction plants

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Situation Analysis

- **Coal continues to be an important energy source well into the next century**
- **It is imperative coal be used in the most efficient and environmentally responsible manner**
- **There exist barriers to deployment of advanced clean coal technologies for power and fuels**
  - market forces do not favor deployment because of high capital costs and low natural gas prices
  - greater coal use spurns global climate concerns

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EIA U.S. Energy Projections

	1995	2020	% Growth
Quads			
Total Energy	90.9	118.6	30%
Total Coal	20.0	25.6	28%
Total Gas	22.2	33.1	49%
BkWh			
Total Power	3083	4459	45%
Coal	1671	2265	36%
Gas	322	1389	331%
MMBPD Petroleum	17.8	24.4	37%
Million Tons C Emissions	1411	1956	39%

EIA Annual Energy Outlook 1998

- Natural gas use grows dramatically over the next 20 years
- Coal continues to be a substantial portion of the total energy mix

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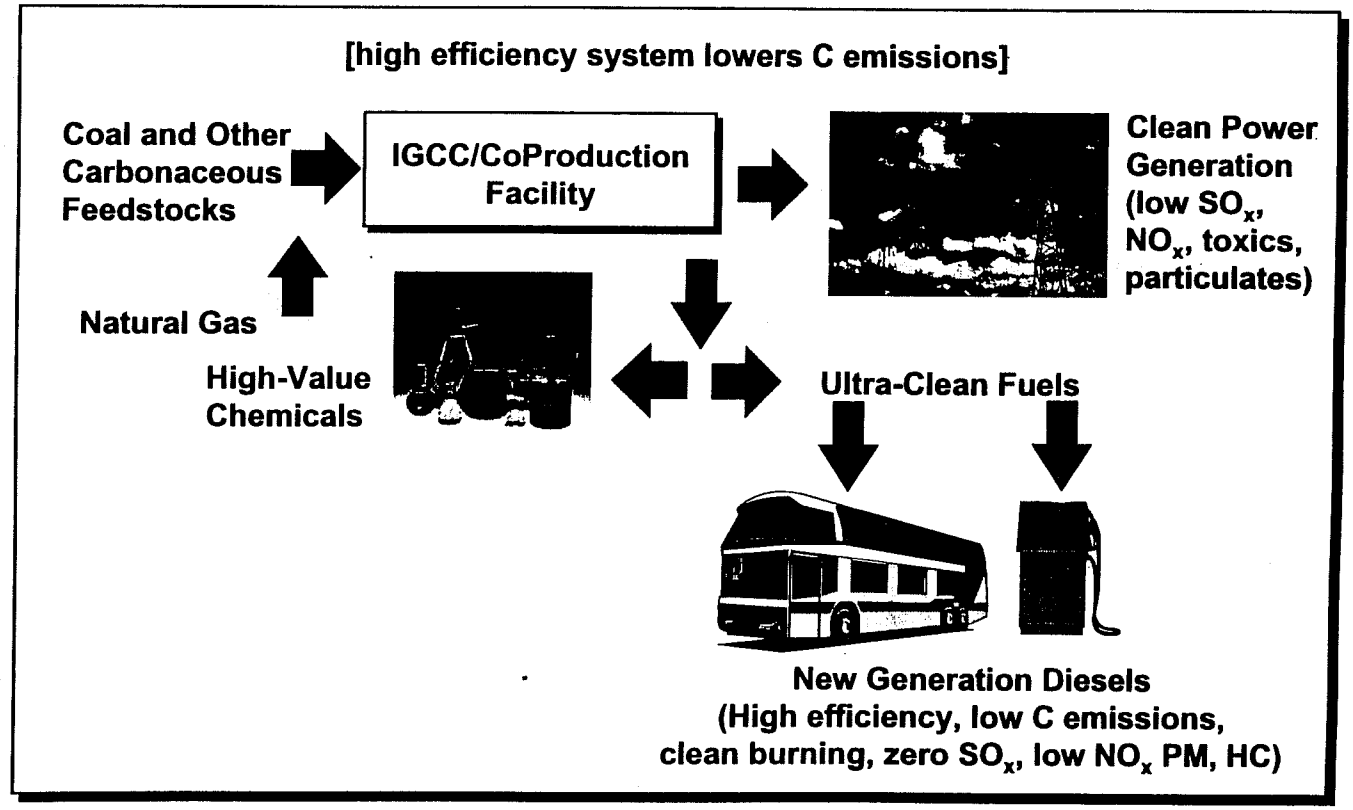
Coproduction Integrated into a Power/Fuels/End-Use System



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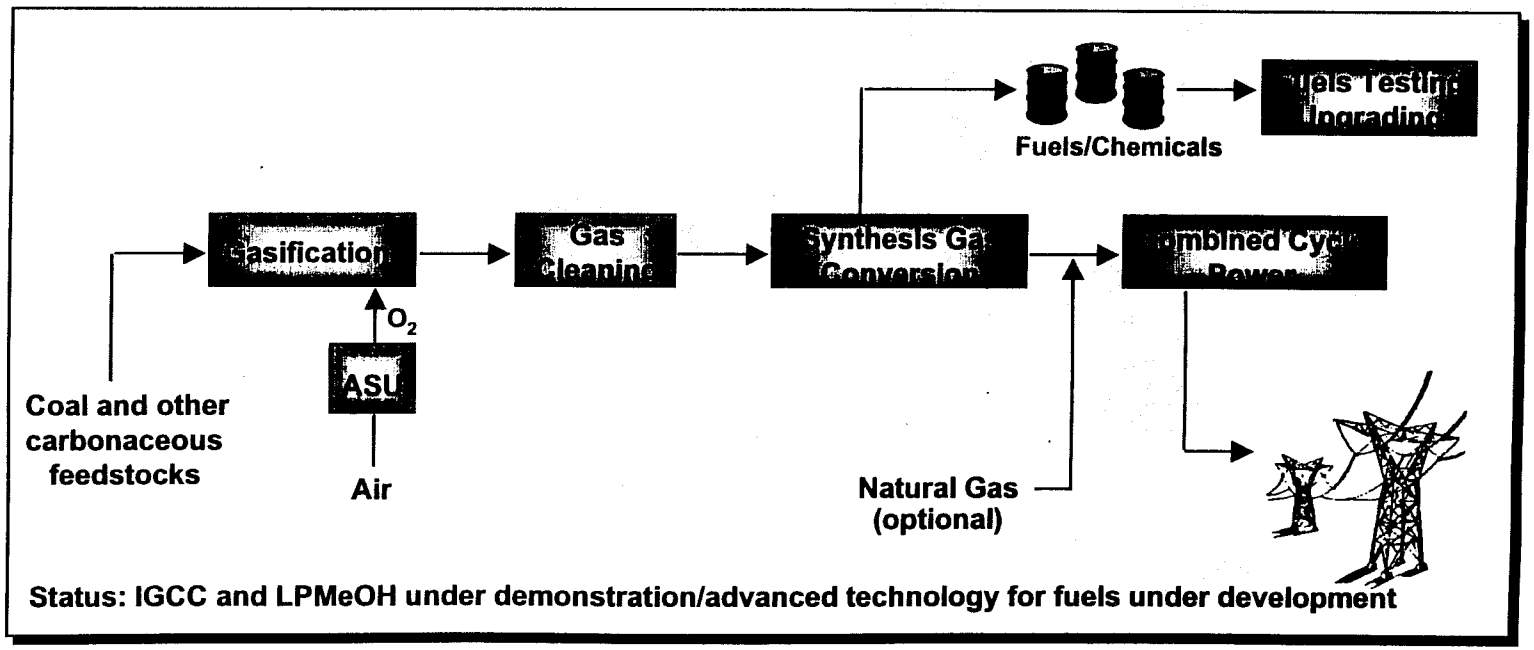
Coproduction Cofeed Concept Schematic (Co Co)



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Coproduction Plant - Environmental Benefits

- **Coproduction reduces carbon emissions by 400,000 tons annually for each pulverized coal plant replaced**
- **High quality F-T fuels will meet or exceed future emissions regulations**
  - high cetane diesel in high efficiency engines reduce CO_2
  - zero sulfur, nitrogen, aromatics reduce NOx, SOx, PM
- **Coproduced IGCC power decreases the environmental impact associated with coal utilization**

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Coproduction Plant - Economic Benefits

- Versatility of coproducing power and fuels accelerates deployment of both IGCC and F-T technologies, increases plant capacity, and reduces risks
- With advanced technology, coproduction increases ROE 15 percent and is competitive with ~ $18 crude and power in the range 25-30 mils

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Coproduction Plant - Energy Security Benefits

Coproduction facilities, in combination with stand-alone coal fuel plants, will be needed to meet the goal of 5MM BPD of ultra-clean transportation fuels from domestic resources of coal, natural gas and petroleum

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Coproduction Plant - Barriers to Deployment

- **Barriers:**
  - technical risks
    - scale-up, RAM
  - economic risks
    - capital/feed cost, product value
  - system integration risks
    - coupling technology modules with existing infrastructure

The Early Entrance Coproduction Plant Strategy can mitigate these risks

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Coproduction Plant - Concept

- Single-train commercial scaleable size
- Constructed adjacent to existing infrastructures
- Capable of processing multiple feedstocks and producing more than one product
- Undertaken by industrial consortia with assistance from State and Federal Government
- Risk reduction permits future plants to be deployed with no government assistance

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Coproduction Plant - Government Role

- **Government role is to mitigate risk by:**
  - supporting R&D
  - promoting formation of industrial/stakeholder teams, and
  - sharing in cost of pre-detailed design studies (i.e. feasibility studies)

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Coproduction Plant - Industry Response

- **Project economics will be site specific**
- **Feedstock and product flexibility are essential**
- **Incentives are likely needed to counteract project risks**
  - front-end incentives preferred
- **Government to cost share project feasibility studies, supporting R&D, and preliminary site specific design**
- **Government to assist in**
  - incentive search
  - environmental permitting

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Pioneer Plant - Strategy

- **Multi-phase program for deployment of coproduction plant**
  - Phase 1: Feasibility Study
  - Phase 2: Supporting R&D
  - Phase 3: Preliminary Site Specific Design
  - Phase 4: Detailed Engineering Design
  - Phase 5: Construction and Operation
    - government to cost-share phases 1-3

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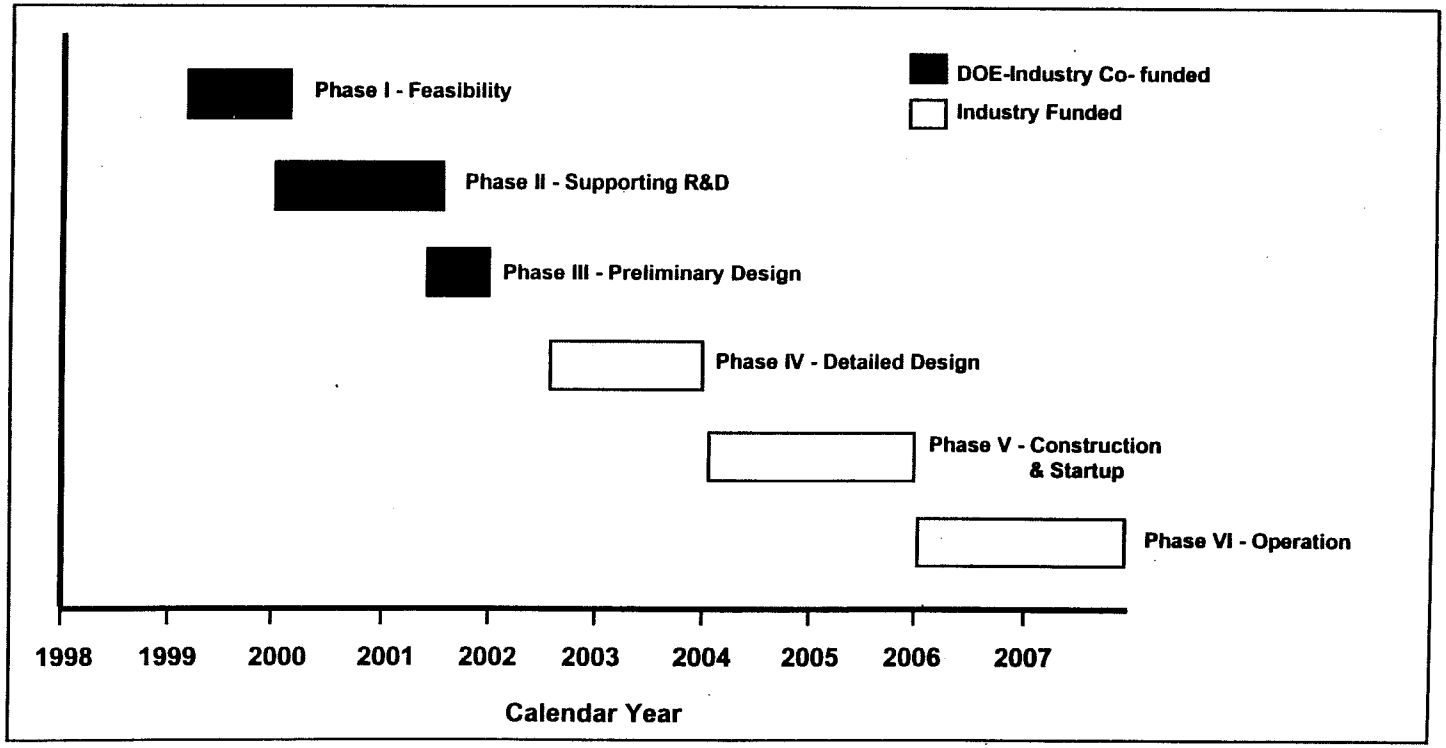
Coproduction Plant - Strategy Roadmap



FETC

Fuel Life-Cycle Greenhouse Gas Emissions (g CO_2eq./mile)

	Production/ Extraction	Conversion/ Refining	Transportation	Fuel Combustion	Total
ANS Crude	28	101	25	378	533
Mild Continent Crude	23	87	9	371	489
Arab Light Crude	35	81	26	367	509
Venezuelan Syncrude	32	143	10	390	574

FETC

Fuel Life-Cycle Greenhouse Gas Emissions (g CO_2eq./mile)

	Production/ Extraction	Conversion/ Refining	Transportation	Fuel Combustion	Total
FT from IL#6 Coal	37	537	3	343	919
with sequestration					428
with coproduction					656
GTL - ANS	0	165	25	360	550
with sequestration					431
and flaring credit					-60
GTL - offshore USGC	47	109	5	360	520
with sequestration					456
FT from Biomass		-252	3	343	93
with sequestration					-397

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APPENDIX A. GAME PLAN

A. PURPOSE

The DOE Office of Fossil Energy (FE) plans to sponsor research to develop advanced technologies for producing premium transportation fuels from domestic feedstocks. The DOE's intent is to facilitate the establishment of an industrial base in the U.S. that will produce the next generation of high-performance, low-emission fuels from our domestic fossil resources of coal, natural gas, and oil.

In this workshop you will help identify the current and potential barriers to achieving this goal and the technology approaches to overcoming them. While participants will help define the major technical challenges facing the production of "ultra-clean" fuels, the development of a comprehensive technology plan is not the focus of this workshop. However, the workshop results will be used to develop a *technology roadmap,* which will provide the R&D framework—the research strategies, pathways, and timing—to achieve the goals.

B. EXPECTED OUTCOMES

Through the workshop, we will:

- Identify the key barriers (scientific, technology, engineering, market, regulatory, and business) to achieving an ultra-clean fuels capability using domestic resources
- Identify the R&D topics that can help overcome these barriers
- Assess the near-, mid-, and long-term nature of this R&D
- Examine the respective industry and government roles in this R&D
- Identify opportunities for industry-government collaboration

The workshop is expected to begin a dialog within the fuels community on how to develop strategic alliances among industry and government to achieve the goals of ultra-clean fuels from domestic resources.

C. GENERAL FORMAT

The workshop will be a 1½ day facilitated meeting that will take place June 30-July 1, 1999 at the Adam's Mark Hotel in Dallas, Texas. The workshop will bring together about 40 senior managers and technology experts from various segments of the fuels industry. Invited participants represent a cross-section of companies that produce fuels and chemicals, industry trade and research organizations, and government research managers. The workshop will include a plenary session, facilitated working sessions, and a summary session.

The following guidance will help prepare you for the workshop:

> ***Prior to the Workshop*** — Participants should consider the major competitive issues and market drivers that will shape the fuels industry in the next 20 years and how and where advanced technology can play a role in matching regulatory requirements to market development.

Thursday, July 1

Breakout Group Sessions: Based on the "top 5" high-priority barriers from the previous day, the same groups as the previous day will examine the R&D opportunities to overcome these barriers. The groups will brainstorm to identify a set of R&D topics that can help overcome the barriers. The group will assess the near-, mid-, and long-term nature of the R&D and vote on priority topics. The potential DOE and industry roles in the R&D will be examined, along with the opportunities for and possible structure of industry-government collaboratives.

Summary Session: This session will bring the breakout groups together to present concise summaries of their group deliberations. Participants will be encouraged to engage in a discussion of the findings of each group and the common technical challenges. Participants will also have an opportunity to give concluding remarks and suggest next steps.

F. WORKSHOP PRODUCTS

The registrants will receive a copy of the workshop proceedings, which will contain all the
A draft report incorporating the raw materials (the "storyboards") developed during the facilitated sessions will be prepared and distributed to participants for review and comment within one week of the workshop. Any consensus results of the workshop will not be changed. Comments received will be incorporated into a workshop proceedings document that will be distributed to participants within one month.

These products will then be used by the department in the planning and analysis of a program initiative for ultra-clean fuels, as outlined in the draft strategy paper *Fossil-Derived Ultra-Clean Transportation Fuels for the 21st Century*. The workshop will not result in any decisions to fund specific R&D projects. It is intended to gather opinions on critical R&D drivers based on judgements of technical and market needs.

The mechanisms by which FE subsequently implements research activities will, in large part, depend on the guidance it receives from you and other industry leaders. Examples of recent FETC procurement strategies that may be applicable include: a) the Early Entrance Coproduction Plant (EECP) solicitation; and b) the Premium Carbon Products Consortium. These two approaches are very different. The EECP initiative required the formation of industry-led teams, with each team comprising all the organizations that are needed to deploy the technology. The Premium Carbon Products Consortium is comprised of companies that contribute funds, which are then leveraged with DOE's to sponsor industry solicited and selected research. Whether one of these approaches, or another is selected, DOE's long term goal is to assist industry in developing the technologies necessary to produce the next generation of clean, ultra-low emission, premium fuels. Through this public/private sector partnership we envision the development of a suite of technologies that will enable the U.S. to draw upon its domestic resources (coal, oil, and gas) to help meet the anticipated and more stringent environmental regulations that are being imposed on the transportation sector.

AGENDA

ULTRA CLEAN FUELS WORKSHOP
June 30-July 1, 1999

Time	Activity	Presenter
	WEDNESDAY, JUNE 30	
7:00-8:00 AM	**Registration/Continental Breakfast**	
	Plenary Session	
8:00-8:30 AM	Opening and Welcome Remarks	Thomas Torkos, Associate Director, Fuels & Specialty Markets, DOE- FETC William Lawson, Director, DOE-NPTO Lowell Miller, Director, DOE - HQ Coal Fuels & Industrial Systems Pandit Patil, Director, DOE Advanced Automotive Technologies
8:30-9:00 AM	Collaboration Models and Opportunities for Ultra-Clean Fuels R&D	Gregory Kawalkin, Senior Advisor, DOE-FETC
9:00-9:30 AM	Regulatory Developments: Tier II and Beyond	Glenn Passavant, Senior Program Manager, EPA
9:30-10:00 AM	Industry Perspectives on the Challenges of Tier II	Open Discussion
10:15-11:45 AM	DOE Fossil Energy Fuels Programs	Dexter Sutterfield, Technology Manager, DOE-NPTO Venkat Venkataraman, Product Manager, DOE-FETC John Winslow, Product Manager, DOE-FETC
11:45-12:00 PM	Instructions for Breakout Sessions	Rich Scheer, Energetics, Inc.
12:00-1:00 PM	**Lunch**	
1:00-5:00 PM	**Breakout Sessions on Barriers**	
	Group 1. Roadmapping for Fuel products A Group 2. Roadmapping for Fuel Products B Group 3. Roadmapping for Fuel products C	Rich Scheer, Energetics, Inc. Melissa Eichner, Energetics, Inc. Chris Caperton, Energetics, Inc.

Time	Activity	Presenter
	THURSDAY, JULY 1	
7:15-8:00 AM	**Continental Breakfast**	
8:00-12:00 PM	**Facilitated Breakout Sessions on R&D Topics, Strategies, and Collaboration**	
	Group 1. Roadmapping for Fuel Products A Group 2. Roadmapping for Fuel Products B Group 3. Roadmapping for Fuel products C	Rich Scheer, Energetics, Inc. Melissa Eichner, Energetics, Inc. Chris Caperton, Energetics, Inc.
12:00-1:00 PM	**Lunch**	
1:00-2:00 PM	**Summary Session**	
	Group Reports	Group Representatives
	Common Themes	Rich Scheer, Energetics, Inc.
2:00-2:30 PM	**Next Steps and Action Items**	
2:30 PM	**Adjourn**	

During the Workshop — Participants will actively share ideas through facilitated sessions. Structured brainstorming and focused analysis will be used to identify critical issues and build consensus on strategic paths. Participants should come prepared to work. Bring your ideas and wear comfortable clothes — all materials you need will be provided to you.

After the Workshop — A draft report will be prepared and circulated to participants for review and comment. Additional information may be sought to clarify points and provide technical insight, although any consensus results of the workshop will not be changed. After all comments are received and integrated, a final report will be issued.

D. BACKGROUND

Major automobile and truck manufacturers have expressed concern over the availability of fuels to meet forthcoming EPA Tier II emissions standards for light-duty vehicles. Three FE programs, the petroleum Oil Processing Program (OPP), the natural gas Gas-to-Liquids (GTL) program, and the Coal Transportation Fuels and Chemicals (CTF) programs are targeting the development of a suite of advanced fuels intended to meet EPA's Tier II standards without a major impact on the transportation infrastructure by collaborating in a jointly-sponsored Advanced Transportation Fuels Development Program.

The mission of the joint GTL/OPP/CTP Program is to partner with industry to ensure a stable, affordable supply of energy for the U.S. by fostering the development and deployment of technologies to produce ultra-clean burning, high-performance transportation fuels from domestic resources by the year 2010.

E. WORKSHOP STRUCTURE

The workshop is designed as a product-oriented meeting in which participants have active roles. The workshop will consist of four separate sessions spread over 1½ days. Each session is described below.

<u>Wednesday, June 30</u>

Plenary Session: The objective of this session is to provide perspectives on the technical, regulatory, and market drivers for ultra-clean fuels. You will hear a variety of perspectives on market opportunities and needs and an overview of the current status and future direction of fuels technologies. EPA Tier II requirements for fuel products will be discussed, and FE perspectives on requirements beyond Tier II—for diesels, gasolines, and fuels for fuel cells—will be presented and discussed to gain general consensus on a product goal set for the year 2010. The session will also include instructions for the facilitated groups and a description of the workshop process.

Breakout Sessions: These will be facilitated breakout sessions involving all participants. Participants will be assigned to one of three smaller groups, which will meet separately. The three groups will address the same topics: DOE's vision and goals; Barriers; and R&D and other actions. The purpose is to provide guidance to DOE on the technical strategy and appropriate government-industry partnership for developing ultraclean fuels. The separate breakout groups will discuss, then rank the items that were listed for each of the three topics.

APPENDIX B: PARTICIPANT LIST

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