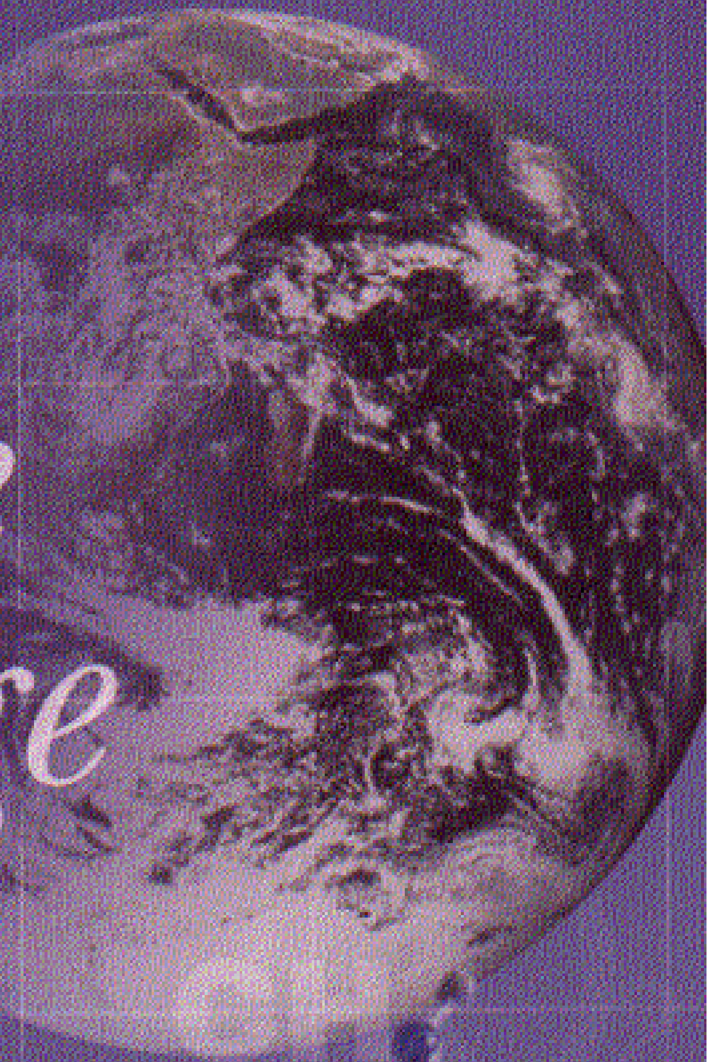
American Petroleum Institute

Voluntary Actions by the Oil and Gas Industry

Climate Change



VOLUNTARY ACTIONS BY THE OIL AND GAS INDUSTRY:

A Conference on Industry Best Practices to Improve Energy Efficiency and to Reduce Greenhouse Gas Emissions

Executive Summary

The American Petroleum Institute (API) conference on Voluntary Actions by the Oil and Gas Industry: A Conference on Industry Best Practices to Improve Energy Efficiency and to Reduce Greenhouse Gas Emissions, was held in Houston on December 1 - 2, 1999. It included 32 presentations from industry, academia, and government agencies on voluntary efforts undertaken by industry that reduce carbon dioxide and methane emissions. Because speakers were urged to be brief in their presentations to maximize the number of topics covered, attendees at the conference and readers of this report are encouraged to contact the presenters for more details on the initiatives they described. Attachment 1 contains contact information for speakers; and Attachment 2, a list of conference attendees.

Goal and Organization of the Conference

The goal of the API conference was to provide an introduction to the broad range of voluntary activities currently underway in the oil and gas industry that directly or indirectly address climate change issues. These activities include:

- efforts to better understand the sources and quantities of greenhouse gas (GHG) emissions generated by oil and gas industry operations;
- initiatives to reduce GHG emissions, including operational efficiencies and the sequestration of carbon emissions;
- support for fundamental climate change research;
- research and development programs on more energy efficient automotive systems; and
- development of renewable energy resources.

All of these efforts focused on carbon dioxide (CO_2) or methane (CH_4), the two GHGs associated with oil and gas industry operations and use of its products.

Many of these activities are "no-regrets" options, i.e., they can be justified at least partially by benefits other than GHG emissions reductions. Historically, some were undertaken solely because of these other benefits, such as the cost savings generated by energy efficiency programs. But all are examples of ways in which oil and gas companies can help address concerns about climate change.

The conference was opened with remarks by Red Cavaney, President and CEO of the API. During the luncheon on December 1, the conference was addressed by Jeff Seabright, Executive Director of the White House Task Force on Climate Change. On December 2, the conference heard a talk by Mark Mills, President of Mills-McCarthy & Associates, on the pit-falls of technology forecasting. These three talks comprised the "policy" discussion at the conference and will be summarized before the technical presentations.

The technical presentations were divided into seven sessions.

1. Emissions Estimating and Reporting
2. Operational Processing Techniques
3. Participation in Government Programs
4. Carbon Sequestration
5. Research and Development
6. Automotive Partnerships
7. Renewable Fuels and Alternative Energy Supplies

Conference Themes

While no attempt was made to develop a set of conference conclusions, several themes emerged from the presentations:

• Opposition to the Kyoto Protocol does not mean a "do nothing" attitude about climate change or the reduction of greenhouse gas (GHG) emissions. In his opening remarks, Red Cavaney, President and CEO of API, stated:

> ... it has never been a question of whether or not to take action. Rather it has been a question of what are the appropriate actions to take while so many issues remain unresolved … you will hear how many individual oil and gas companies are answering that question through their own voluntary actions.

These sentiments were echoed by Jeff Seabright, Executive Director of the White House Task Force on Climate Change:

> While we may have public policy differences on the merits of the Kyoto Protocol, Kyoto and climate are not synonyms in our vocabulary … if we can find ways to work together today to meet this challenge, we welcome the opportunity.

• Oil and gas industry operations provide many opportunities for "no regrets" approaches to GHG emissions reduction. A number of speakers presented case studies on emissions reduction projects that saved their companies money. Efforts by companies to conserve energy, which reduce carbon dioxide and methane emissions, began in response to price shocks in 1973 and 1974; these efforts have been ongoing ever since. Others presented examples of projects which provided ancillary benefits in terms of new business development, environmental conservation, or public recognition.

• Information exchange about best practices, not only between companies, but also between functions within the same company, can speed the identification and implementation of GHG emissions reduction approaches. There is no need to "reinvent the wheel."

• The adage "what gets measured gets managed" is particularly applicable to GHG emissions. Understanding the sources and quantities of GHG emissions in a company's operations is a critical first step in designing effective control strategies. An ongoing API project to recommend best practices for the development of GHG emissions inventories is one response to this need.

• Significant reductions in GHG emissions are possible using existing technology: co-generation, leak reduction in natural gas exploration and production, and careful attention to energy management in all operations. Each of these approaches has the potential to provide a positive return on investment in many oil and gas industry operations.

• Voluntary government programs that provide opportunities for companies to exchange information on methods for measuring and reducing GHG emissions provide many benefits. Company speakers praised two of these programs in particular: Natural Gas STAR and ENERGY STAR Buildings.

• New technology will be needed if GHG emissions are to be reduced to very low levels at an economically viable cost. Several technological needs were highlighted:

- improved gasification technology for refinery residuals and other high carbon fuels, including coal, to provide syngas for use in co-generation and as a feedstock for the production of fuels, chemicals and hydrogen -- this technology could be used in conjunction with CO_2 capture and sequestration to provide carbon-free power from fossil fuels;

- lower cost carbon separation technologies for use with CO_2 capture and sequestration approaches; and

- gasoline reformer technology for use with automotive fuel cells.

Opening Remarks

Red Cavaney, President and CEO, API

Mr. Cavaney welcomed conference attendees on behalf of API and its member companies, and presented the following summary of API's position on climate change:

• The U.S. oil and gas industry takes climate change seriously. It has never been a question of whether or not to take action. Rather, it has been a question of what are appropriate actions to take when so many issues remain unresolved. Although many aspects of climate science remain unsettled, API member companies are not waiting for answers before taking action.

• Climate change is an issue in flux. The science is evolving, and we cannot say precisely how it will turn out. Policy, too, is evolving and should, as we improve our understanding. Large uncertainties increase the importance of ensuring that policies are based on clear principles and the best technical foundation.

• API's view begins with the principle that facts should drive policy. The scientific evidence for assessing human impacts on climate is evolving and still uncertain. Understanding climate change, separating natural from human-induced change, and deciding on appropriate global policies are all extremely difficult undertakings. However, we do know enough to take the risk seriously and to rule out inaction as an option.

• We also know that the economic impact of the Kyoto Protocol on the United States -- as presently set forth -- would be very significant. Various studies predict dramatic increases in energy costs, millions of lost jobs and a major decline in U.S. economic growth -- if 30 percent cuts in carbon emissions from U.S. fossil fuel use are mandated within a decade.

• The CEOs of API member companies have directed API to place a special focus on voluntary actions our industry can take now to control GHG emissions.

• The oil and natural gas industry's agenda for the future will include:

- continued sharing of information on voluntary actions;
- additional climate-related research;
- reporting progress in controlling GHG emissions;
- pursuing partnerships with government and others in the private sector to further manage emissions; and
- being advocates for effective actions consistent with API's policy on climate change.

Mr. Cavaney concluded his remarks by discussing the critical role that innovative technology has played over the more than 100 year life of the oil and gas industry. API member companies, alone and in partnership with others, such as the automakers, are continuing their efforts to develop the new technology that will be needed to deal with climate change and the other environmental challenges of the 21st century.

Luncheon Comments

Jeff Seabright, Executive Director, White House Task Force on Climate Change

Mr. Seabright acknowledged the important role that the oil and gas industry had played in helping fuel the past century of human development and the role that it would have to play in the next century. He said that the many EPA and DOE participants in the conference were evidence of the Clinton Administration's dedication to working with the industry to advance solutions to the climate challenge, despite policy differences over the merits of the Kyoto Protocol.

The Administration believes:

- climate policy must be grounded in sound science, and that there is an ample scientific basis for taking action now; and
- climate change efforts should begin with win-win, no regrets actions, such as those embodied in the President's $6.3 billion, five-year Climate Change Technology Initiative.

The Administration perspective is that COP-5[1] was "a substantive meeting where the Parties achieved steady, solid progress towards building a truly global, cost-effective agreement on global warming." The Administration stressed that two issues were essential if the Kyoto Protocol was to be ratified by the U.S.:

1. The final agreement must be cost-effective, with

[1] COP-5, the Fifth Meeting of the Conference of Parties to the UN Framework Convention on Climate Change, was held in Bonn, November 13 - 24, 1999.

rules on trading, sinks, and compliance that get the most GHG emission reduction per dollar.

2. There must be more meaningful participation from key developing countries.

These positions were not popular with other nations.

An emerging area of consensus is the importance of technology development. Mr. Seabright highlighted efforts to improve energy efficiency in exploration, production, and refining, and to develop new technologies, many of which were discussed in more detail during the conference. Demand for natural gas is anticipated to grow by 80 percent over the next 30 years, which will create new challenges for transportation infrastructure and storage. DOE is refocusing its R&D efforts in response to this projection.

Mr. Seabright closed by reminding the conference of America's environmental achievements over the past 30 years, saying that we now have both cleaner air and water than we have had in generations and a vibrant economy. He acknowledged that climate change is in many ways more complex that any of the environmental challenges we have faced, but expressed confidence that, working together, we will meet this challenge as well.

Technology Forecasting

Mark Mills, President, Mills-McCarthy & Associates, Inc.

Since energy use accounts for the majority of human GHG emissions, and technology determines the amount of energy use, all climate policies include technology forecasts, either explicitly or implicitly. Therefore, it is critical that we examine our ability to make technology forecasts, particularly in the energy use area. A review of generally accepted technology forecasts made 100 and 25 years ago showed that they were all woefully inaccurate.

Mr. Mills drew the following lessons from the failure of the 25 year forecasts. They suffered from:

- an infusion of Malthusian beliefs;
- technical myopia;
- wishful thinking, i.e., they were agenda-driven; and
- overestimation of the rate of change; i.e., failure to take the inertia of human-systems into account.

His conclusion was that technology forecasting for a 50 or 100 year period is worthless -- too many big things happen. However, it should be possible to make reasonable forecasts for 25 years, provided that we differentiate between technologies that are technically feasible and technologies that are possible given the inertia of real systems.

He cited Peter Drucker, who said that while he doesn't make forecasts, it is possible to identify major events that have already happened and that will have predictable impacts in the next decade or two. Based on this approach and events of the last 25 years, Mr. Mills drew the following conclusions about the energy sector for the next 25 years:

1. Energy forecasters aren't -- their projections are wrong.
2. Markets aren't stupid -- there are no big market imperfections waiting to be corrected.
3. Cheap energy is good.
4. Fossil fuels aren't limited.
5. Alternative energy is not an alternative -- it won't account for any sizeable part of the market.
6. Efficiency increases demand by reducing prices.
7. Competition increases demand, again by reducing prices.
8. Fossil fuels drive the digital age -- by powering the businesses that information technology generates.
9. Cyberspace will increase oil demand -- higher economic activity will mean more demand for transportation which is fueled by oil.
10. Oil is the alternative fuel -- no alternative fuel can grow fast enough to replace the growth in demand for oil for transportation.

Mr. Mills concluded with two additional thoughts about the next 25 years:

- With or without climate change, the U.S. economy will grow to $25 trillion and the U.S. population will grow to 400 million.
- Transportation technology replaces time with energy. This has happened in industrialized countries and is starting to happen in developing nations.

Technical Session 1

Emission Estimating and Reporting

Understanding the sources and quantities of GHG emissions is a critical first step in their control. Five papers were included in the session:

Moderator: Tom Burns, Chevron Corporation

1. Industry Overview and Emission Sources
   Ajit Sapre, Mobil
2. GHG Emissions Methodology Comparison and Industry Best Practices Development
   Miriam Lev-On, ARCO
3. Government Reporting - National Emissions Inventory, Climate Wise - Voluntary GHG Reporting
   Wiley Barbour, EPA
4. Emissions Inventory Guidance Methodology
   Vern Schievelbein, Texaco
5. Emissions Inventory Verification
   Ralph Feeney, BP Amoco

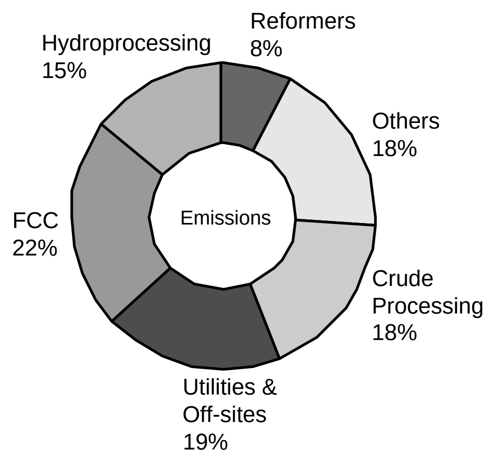
The industry papers provided an overview of the oil and gas industry's contribution to both the U.S. and global man-made GHG emissions inventories, the sources of the industry's emissions, and best practices for collecting and verifying emissions data. EPA's paper described the development of the U.S. Greenhouse Gas Inventory, and additional written information was provided on EPA's voluntary program for reporting GHG emissions reductions.

Industry Overview and Emission Sources

Ajit Sapre, Mobil

Oil and gas industry operations account for approximate 8 percent of man-made carbon dioxide (CO_2) and 15 percent of man-made methane (CH_4) emissions worldwide. Industry total CO_2 emissions are about 1200 million tonnes/year, of which 820 million are from refining and marketing operations, and 390 million from exploration and production operations. A breakdown of refining CO_2 emissions, which are directly related to energy consumption, is shown in Figure 1. More than half of exploration and production CO_2 emissions are the result of flaring. (Note: Approximately 500 million tonnes per year of CO_2 emissions from chemical operations are not included in this analysis.) Essentially all of the approximately 47 million tonnes of CH_4 emitted by the oil and gas industry is from exploration and production operations. A breakdown of these emissions is shown in Figure 2.

Figure 1 - Refinery CO_2 Emissions

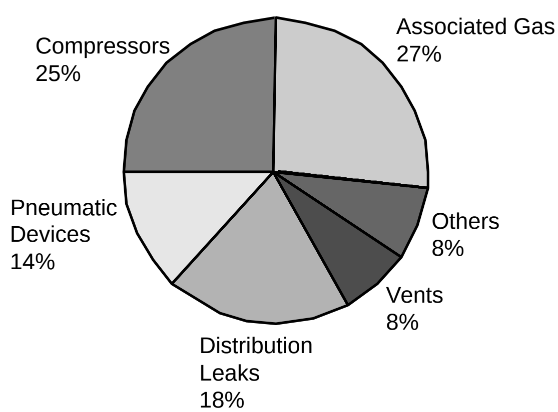


Typical U.S. refinery energy consumption is—600,000 Btu per Bbl

Energy Consumption

% of Crude Feed Stock	
Complex Refinery	8 - 10%
Topping/Cracking	6 - 8%
Simple Refinery	4 - 6%

Figure 2 - Upstream CH_4 Emissions By Source



Analysis of the CO_2 and CH_4 data indicates:

- CO_2 emissions from the combustion of petroleum products are ten times larger than emissions from refinery operations.
- Opportunities exist to reduce CO_2 and CH_4 emissions in oil and gas operations by applying best practices and new technology, (e.g., flare reduction, energy efficiency and equipment reliability, co-generation, CO_2 sequestration, etc.).
- Significant variability exists in accounting and reporting of emissions. Emissions from fuel combustion are reasonably accurate, whereas, fugitive emissions are less accurate. Variability also arises from "ownership" issues for off-site emissions, and for shared facilities (operator or equity share).

GHG Emissions Methodology Comparison and Development of Industry Best Practices

Miriam Lev-On, Arco

In early 1999, in response to findings that there were wide variations in the ways that API member companies accounted for and reported GHG emissions data, API established a Greenhouse Gas (GHG) Emissions Methodology Working Group to investigate the sources of the variability and develop a consistent industry methodology. The Working Group's charter included the following four tasks:

- recommend best methodology and technical tools,
- promote consistent estimation of petroleum company GHG inventories,
- facilitate the development of aggregation methods for industry emissions, and
- provide recommendations for consistent public reporting of aggregated emissions.

The Working Group has compiled and analyzed emissions reporting methodologies from member companies and government agencies. It has used this information to develop a framework for a draft measurement protocol. In the course of developing the draft protocol, a number of policy issues were discussed with API management and agreement reached on the approaches to be used.

Issue
- What emissions should be included?

Approach
- Focus on CO_2 and CH_4 first, other GHGs later if industry is a significant emitter.

Issue
- What industry sectors should be included?

Approach
- Common framework for all sectors -- exploration to the retail outlet -- with specific protocols for individual units.

Issue
- Should the reporting scope include all operations globally?

Approach
- Methodology will be consistent with international guidance, but near-term API reporting is likely to be limited to U.S. operations.

Issue
- How should we account for emissions from joint ventures, or other non-wholly owned enterprises?

Approach
- Two parallel methodologies: operated facilities only, and "equity" share. Currently exploring the appropriate definition of "equity" for emissions reporting purposes.

Issue
- Should the inventory account for emissions attributable to imported and/or exported utilities?

Approach
- Methodology will include both direct and indirect emissions associated with electricity use.

Issue
- How should the industry handle emissions attributable to the use of its products?

Approach
- Methodology will consider only emissions from operations. Development of generic carbon factors for petroleum products to allow calculation of emissions associated with product use may follow.

The draft measurement protocol framework considers four sources of emissions:

1. combustion devices,

2. non-point (fugitive) sources,

3. specialized process vents (e.g. CO_2 emissions from enhanced oil recovery operations), and

4. maintenance and turnaround operations.

The Working Group's target is to have a final industry guidance document available during summer 2000. It has begun outreach to other trade associations for broader consistency in the development of the methodology and for cooperation and resource leveraging. Opportunities for discussions with government agencies and international bodies are also being considered.

Government Reporting: National Emissions Inventory

Wiley Barbour, EPA

The UN Framework Convention on Climate Change (UNFCCC) requires the U.S. to annually report its emissions inventory of six GHGs and the net effect of sinks on that inventory. EPA is the lead agency in this effort, but many other government agencies and laboratories participate in the effort. The Energy Information Administration (EIA) is the primary source of energy use data, and the Department of Agriculture, and particularly the U.S. Forest Service (USFS), are the primary sources of data on land use change and forestry used to calculate the sinks component of the inventory.

The official title of the report is "Inventory of U.S. Greenhouse Gas Emissions and Sinks." Copies are available both on EPA's web-site[2] and from the National Center for Environmental Publications (1-800-490-9198).

Production of the U.S. inventory is a continuous cycle, with work beginning on a new report as the finalized report is being submitted. The report is submitted to the UNFCCC in mid-April for the year ending 16 months earlier, i.e., the report submitted on April 15, 2000 will cover 1998. A first draft for agency review is available in October, and a draft for a 45-day public review is typically made available in late December. The public review period is announced in the Federal Register and the review draft made available on EPA's web-site.

In addition to the information required by the UNFCCC, EPA's report contains a wealth of information about the sources of emissions, trends in emissions growth, and ozone precursors. Some of the interesting points from these analyses include:

• Total carbon-weighted U.S. GHG emissions grew by about 1.5% per year between 1991 and 1997. The rate of growth appears to be slowing - 1997's increase was 1.3% and a preliminary estimate of 1998's increase is 0.5%. The small increase in 1998 may be due to a warmer than normal winter, but summer 1998 was also warmer than usual without any apparent effect on emissions.

• CO_2 accounts for 82% of total U.S. GHG emissions; 99% of CO_2 is generated by fossil fuel combustion -- 41% from petroleum and 22% from natural gas. CO_2 emissions are growing faster than population, but slower than GDP.

• From 1990 to 1998, CO_2 from fossil fuels grew 10%, 3/4 of the total increase in U.S. GHG emissions. Industrial emissions of PFCs, HFCs and SF_6 grew 40%, while emissions from agricultural sources grew 11%.

• CH_4 emissions account for 10% of the U.S. GHG inventory. Oil and natural gas systems are the third most important source of these emissions; landfills, and enteric fermentation and manure management, are the first two. Control of CH_4 emissions offers some of the most cost-effective options for reducing GHG emissions.

• U.S. forests represent a net sink for carbon, but the annual reduction attributable to this sink is decreasing. EPA is working with USFS to better define the sink including soil carbon contributions.

• EPA is also working with states to assist them in developing their own GHG emissions inventories. So far 35 states have developed GHG emissions inventories.

• Characterizing the uncertainty distribution around

[2] The easiest way to find the reports, including drafts, when they are available for public comment, is to access EPA's home page (www.epa.gov) and search for all of the words "Greenhouse Gas Inventory" as the part of the title of a document. Searching for the individual words or not specifying that the phrase is part of a title will generate an unmanageable list of hits.

specific data inputs is a major difficulty. Typically, EPA gets a single estimate of a value with no indication of its error band.

• EPA's experience on developing a national inventory suggests the following for corporate inventories:

- Since we don't know what the ultimate rules for inventories will require, be flexible on the boundaries of the inventory.

- Decide whether you are tracking emissions or emissions reductions; if you are tracking emissions reductions, more information will be needed.

- Keep the books clean and open; record all information so that you can adjust the inventory if the rules change.

- Share the wealth; this is a learning experience for everyone.

Emissions Inventory Guidance Methodolog y

Vern Schievelbein, Texaco

Texaco developed an emissions inventory methodology to allow its business units to generate comprehensive, accurate and defensible GHG emissions data at a relatively low cost. The methodology, which is available on request from Texaco, was the basis for 1990, 1997 and 1998 company-wide GHG emissions inventories. It is also used to assess GHG emissions from potential new business ventures, to screen process designs, and to increase understanding and awareness of GHG emissions among Texaco business units.

In addition to the six GHGs covered by the Kyoto Protocol, Texaco's methodology includes CO, NOx, and VOCs. It includes all operations except service stations and indirect emissions (and credits) from import or export of electricity and steam. The methodology uses a tiered approach, using emission factors based on through-put when more detailed data are not available.

The lessons Texaco has learned from the use of its methodology include:

- Industry methods for performing GHG inventories must be standardized before company comparisons are meaningful.
- The tiered approach allows:
  - generation of GHG emissions when little data is available,
  - generation of facility specific data to provide a more detailed understanding of existing operations, and
  - meaningful comparisons of new facility design options.
- The methodology has given business units an understanding and appreciation of GHG emissions and actions that can be taken to reduce them.

Emissions Inventor y Verification

Ralph Feeney, BP Amoco

In 1998, Sir John Browne, CEO of BP Amoco, committed to reduce BP Amoco's GHG emissions by 10% below their 1990 baseline by 2010. He also pledged to do it in a transparent way so that the reduction could be measured and verified by external observers. This talk outlined BP Amoco's efforts to create a GHG emissions audit and verification process that meets the commitment to transparency.

In spring 1999, BP Amoco, in partnership with Den Norsk Veritas, KPMG, and, ICF Consulting, established a GHG Audit Project with three objectives:

- to review and evaluate the protocols used by their business units to estimate CO_2 and CH_4 emissions, and the way these protocols are implemented;
- to develop a process for carrying out an audit of GHG emissions; and
- to provide an independent audit opinion of BP Amoco's GHG emission data for the 1990 baseline and for 1998.

To date the project team has developed audit criteria, which approach the level of a financial audit; assessed the risks to the quality of the GHG data, and carried out some preliminary audits. The biggest areas of risk appear to be quality of data from non-operated sites and data uncertainty, especially for methane emissions. Other issues include boundary definition and potential for double counting. Ultimately, the project will carry out up to 30 on-site audits and desk reviews of all reporting units. An Expert Panel will issue Audit Opinions on the 1990 and 1998 data BP Amoco have published, and that opinion will form the basis for a statement in the company's external report.

Technical Session 2

Operational Processing Techniques

Improving industry's own operations is an obvious way of achieving GHG emissions reductions. In this session five papers were presented describing specific improvements.

Moderator: Walt Retzsch, API

1. Upstream GHG Reduction: Good Business, Environmental Gain
   Gordon Reid Smith, BP Amoco

2. Hydrocarbons to Liquids: An Alternative to Flaring
   Jeffery Harrison, Texaco

3. Improving Energy Efficiency
   Tim Nelson, Chevron

4. Co-generation in Industrial Sites
   Edward Markowski, Exxon

5. Gasification for Refinery Processing
   Richard Weissman, Texaco

Upstream GHG Reduction: Good Business, Environmental Gain

Gordon Reid Smith, BP Amoco

BP Amoco's annual assessment of GHG emissions reduction opportunities has identified many opportunities to increase profitability by reducing emissions. The process involves the following steps:

Identifying Sources
↓
Quantifying Emissions
↓
Identifying and Costing Emission Reductions Opportunities
↓
Implementing Projects
↓
Identifying Changes - What Really Happened?
↓
Measuring Emission Reductions
↓
Verifying and Auditing Emission Reductions

Principal upstream GHG emission sources are:

- CO_2 from combustion, including flaring; energy efficiency techniques developed in downstream operations can help reduce these emissions;
- CO_2 from venting, mostly from amine acid gas separation plants; and
- CH_4 emissions from venting and leaks.

Two factors raised CH_4 emissions. First, many small upstream operating sites have no external source of power. Gas pressure powers instrumentation and pumps, then is vented. Second, the paradigm has been "gas is free," and therefore can be vented without significant concern. Competitive pressures are changing both approaches. Vented gas is lost revenue, which must be minimized.

BP Amoco is a Natural Gas STAR partner and is implementing the approaches promoted in that program. It is currently replacing about 4000 high-bleed controllers and will avoid emitting about 800 SCF CH_4/day/controller, for a total of nearly 25,000 tons CH_4/year. Revenue from the sale of this gas creates a payback period of less than three years, which meets BP Amoco's internal investment criteria. Optimization of glycol dehydrators is providing similar benefits. BP Amoco found that it was operating these units at three to four times the required circulation rate, and could save 30,000 tons CH_4/year by optimizing the units.

Note: Technical Session 3 contains two papers on the Natural Gas STAR Program, one from an EPA perspective, the other from a company (Spirit 76) perspective.

Hydrocarbons to Liquids: An Alternative to Flaring

Jeffery Harrison, Texaco

Currently large quantities of associated natural gas are produced for which there is no economically attractive market. In some cases this gas can be reinjected. Alternatively, it can be vented, flared or converted into liquids.

Texaco's study explored the effect on Global Warming Potential (GWP) of the various options for gas disposal. GWP compares the contribution to the enhanced greenhouse effect of GHGs to that of CO_2, which is assigned a GWP of 1. CH_4 has had a GWP of 21 (though recent studies indicate the value should be lower). The study compared emissions profiles for venting, flaring, and reinjection of natural gas with the profile for a hydrocarbons-to-liquid (HTL) plant. For the HTL plant, emissions from the combustion of the conventional liquids that would be displaced were also considered. Results were reported in terms of millions of GWP tons/year.

Option	**GWP,** *million tons/year*	**Comment**
Basis: Natural Gas Feed to a 25,000 B/D HTL Plant		
Venting	25.0	Emitted as CH_4
Flaring	6.6	Assume 95% conversion to CO_2
Conversion to liquids (HTL)	5.0	Assume 100% conversion to CO_2 and lower GWP vehicle emissions
Reinjection	0.3	Power requirement for reinjection

From this analysis Texaco concluded that substantial reductions in GHG emissions are possible through reinjection or HTL.

Improving Energy Efficiency

Tim Nelson, Chevron

This talk presented the seven tenets of Chevron's successful energy management program.

1. Corporate Leadership with Local Execution
2. Energy Measurement
3. Empowered Energy Coordinators
4. Best Practice Leverage
5. Energy Champions for Projects
6. Commitment
7. Celebrate and Share Success

Specifics were provided for each tenet, and the following results reported for Chevron Refining:

- About 18% reduction in energy consumption rate since 1991, which translates into a cumulative savings of $500 million in energy costs.
- The Refinery Energy Team has the confidence of their management to set the energy goal and implement best practices to meet the goals.
- The Refinery Energy Team is being challenged by teams in other business units (Chemicals, E&P, etc.) for supremacy.

Lessons learned from this effort include:

- Energy initiatives have dual benefits for operating costs and climate change.
- An organized approach can yield significant benefits but cultural changes are critical.
- Leverage learnings corporate-wide.
- Measurements are critical.
- Use measurements and data to continually prove to yourself that you are as good as you think you are.
- Get the basics right and win with practice and performance.

Note: Mobil's experience with a similar energy efficiency program is reported in Technical Session 3.

Co-generation in Industrial Sites

Edward Markowski, Exxon

Traditionally, refineries and other industrial sites have generated steam and electricity separately, with both processes having losses. Using a gas turbine to generate electricity and the exhaust from that turbine to generate steam (co-generation) can improve overall efficiency in the order of 20 percent. This presentation reported on Exxon's application of co-generation at 30 sites with 1490 MW generating capacity. Key conclusions were:

- Co-generation offers an economic approach to improve competitiveness, reduce overall emissions, and reduce natural resource consumption.
- Co-generation makes good business and environmental sense in suitable locations.
- Through better energy efficiency Exxon's refineries and chemical plants have become 38 percent more energy efficient since 1973, representing a savings of 1.3 billion barrels of oil and a cleaner environment.

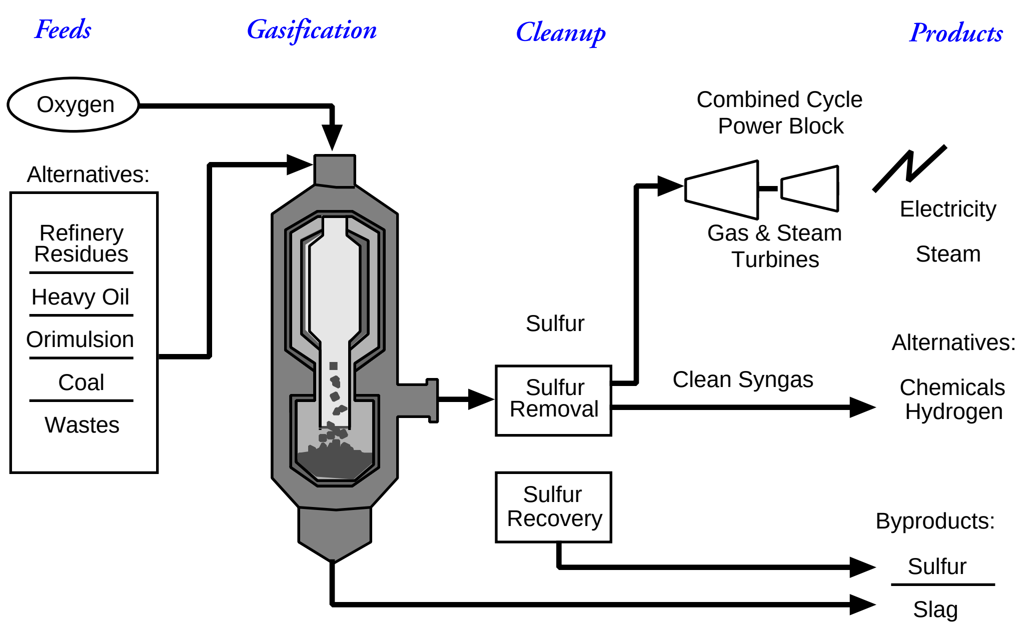
Gasification for Refinery P rocessing

Richard Weissman, Texaco

Gasification combined with co-generation offers the opportunity to use refinery residues and other high carbon fuels in an energy efficient, low GHG emissions process.

Texaco's gasification process is non-catalytic and operates at 1500°C and 85 atmospheres pressure. CO_2 can be captured from the syngas stream and sequestered prior to power generation to provide a process which, at least theoretically, can provide power from carbon-based fuels with no CO_2 emissions. Current IGCC (Integrated Gasification - Combined Cycle) technology achieves 40-43 percent efficiencies; the next generation will achieve 44-49 percent efficiency. SOx and NOx emissions are lower than other technologies for coal and heavy ends.

Texaco Gasification Process



Superior Environmental Performance

Technical Session 3
Participation in Government Programs

Two types of *voluntary* government programs are important in the oil and gas industry's effort to respond to climate change: R&D programs, which promote the development of new technology; and technology diffusion programs, which encourage the application of existing, low GHG emission technology. This session included five talks, two on R&D programs and three on technology diffusion programs.

Moderator: Arthur Lee, Texaco

1. Early Entrance Co-Production Plant -- DOE Project
   Ronald Skarbek, Texaco

2. Partnership for a New Generation of Vehicles
   Edward Wall, DOE

3. Natural Gas STAR Partnership, ENERGY STAR Buildings Partnership - An EPA Perspective
   Paul Grunning, EPA

4. Natural Gas STAR Partnership - A Company Perspective
   James Frederick, Spirit 76 Energy

5. Mobil's Energy Management Network & ENERGY
   Fred Schoeneborn, Mobil STAR Buildings Program

A question that arises whenever voluntary government programs are discussed is: "If these programs offer so many benefits, why not make them mandatory?" The session offered an answer to this question, which may best be summarized by quoting Jeffrey Westhoven, Deputy Director of the Ohio Office of Energy Services:

Voluntary vs. Mandator y

- Voluntary is **easier** to create; no legislation, rulemaking, public comment.
- Voluntary is better when enforcement is **difficult** or **cumbersome**.
- Voluntary is better for **popular** programs; mandates are better to force compliance.
- Mandates force cooperation with the **letter** of the law; voluntary with the **spirit** of the law.

Early Entrance Co-P roduction Plant: DOE P roject
Ronald Skarbek, Texaco

Vision 21 is a DOE program to develop the technology basis for ultra-clean integrated energy plants that will be deployed early in the 21st century. Many of these plants will be co-production plants, in that they will be designed to produce both power and products such as fuels and chemicals. Texaco is participating in this program with a $15 million, 4 year project to develop a plant based on Texaco gasification technology that will produce power, fuels and chemicals from coal and/or other high carbon fuels. Other participants in the project include General Electric (co-generation technology), Rentech (Fischer -Tropsch technology) and Praxair (air separation technology). DOE will provide $9 million of the project costs.

The project will proceed in three phases:

- Phase I - Concept definition and planning
- Phase II - Research, development and testing
- Phase III - Engineering design for a specific site

The specific site for the design has yet to be chosen, but both Tampa Electric and Texaco's Port Arthur Refinery have expressed interest in the project.

Partnership for a New Generation of Vehicles
Edward J. Wall, DOE

The challenges facing the transportation sector are: growing petroleum consumption, urban pollution and climate change. During the next 50 years, the number of light duty vehicles worldwide is expected to increase five-fold, from approximately 700 million to roughly 3.5 billion. A "sustainable development" approach is required to deal with this growing vehicle population. Government and industry share responsibility for developing this approach.

The Partnership for a New Generation of Vehicles (PNGV) was started in 1993 as a collaboration between seven government agencies, and their 20 laboratories, and the three U.S. car manufacturers. It has three goals:

1. improving the productivity of the U.S. automotive manufacturing base,
2. achieving near term vehicle improvements, and

3. developing a mid-sized car with triple current fuel economy.

The third goal is the one that the program is best known for, and the talk focused on this goal. The first milestone was selection of technology for three concept cars. The target was met in 1997 when the program focused on: (1) parallel hybrid-electric vehicles, (2) direct injection diesels, and (3) fuel cells as the technology approaches. Future goals of the program are the development of three concept vehicles by 2000 and development of production prototypes by 2004.

PNGV started out as "fuel neutral", but power plants being considered by the program may require extensively modified fuels. DOE is addressing this issue with the Advanced Petroleum-Based Fuels Program (APBF)[3].

DOE is also looking at the effect of diesel fuel composition on emissions from the improved diesel engines to be marketed in 2002 - 2004. Results obtained in this program show that a 50% reduction in particulate emissions for a 10 ppm sulfur fuel containing 15% DMM (di-methoxy methane), and 35% reduction for 100% Fischer-Tropsch liquids. Details of the diesel fuel study are available on DOE's web site (www.ott.doe.gov/decse).

Work is beginning on fuels for fuel cell vehicles. DOE expects to have a draft program plan available for comment in March 2000. The program will focus on the effects of fuel composition, including additives and contaminants, on fuel cell performance.

Natural Gas STAR Partnership, ENERGY STAR Buildings Partnership: An EPA Perspectiv e

Paul M. Grunning, EPA

Natural Gas STAR is a flexible, voluntary partnership between EPA and the oil and natural gas industry designed to cost-effectively reduce methane emissions from the production, transmission, and distribution of natural gas. It was launched in 1993 as a partnership with natural gas transmission and distribution companies; extended in 1995 to natural gas producers; and extended again in 1999 to natural gas gatherers and processors.

[3] An overview of the program is available in a report titled: "Progress Report for Advanced Automotive Fuels, FY 1999." An overview of the program is available in a report titled: "Progress Report for Advanced Automotive Fuels, FY 1999."

The program uses existing technology, Best Management Practices (BMPs), and Partner Reported Opportunities (PROs). The two BMPs initially identified were the replacement or retrofit of high bleed pneumatic devices and the installation of flash tank separators on glycol dehydrators. Since then over 45 PROs have been identified.

Companies joining the program are responsible for considering which BMPs and PROs are cost-effective for their operations, developing a plan to implement those techniques within three years, and reporting annually on their progress. EPA assists this effort by addressing regulatory barriers, facilitating technology transfer, working with vendors, and developing technical and implementation tools. Cumulatively, the Natural Gas STAR Program has reduced CH_4 emissions by 50 billion cubic feet; 64 percent of this saving has resulted from PROs, the remainder, from the initial two BMPs.

The ENERGY STAR Buildings Program addresses inefficient energy practices in commercial buildings, which EPA estimates will cost building owners $130 billion by 2010. The program is a five-phase effort:

1. installation of energy-efficient lighting (Green Lights);
2. a building tune-up, i.e., checking the efficiency of heating and cooling systems components;
3. installation of window films, reflective roof covers, and energy-efficient office equipment;
4. upgrading air handling equipment; and
5. re-sizing the heating and cooling plant to service the reduced load efficiently.

Companies joining the program commit to upgrading, where profitable, 60 percent of their building space within seven years, and to tracking and reporting success. EPA supports the program with training, tools, recognition and public relations support. Examples of success included Boeing, which was able to achieve annual savings of $7 million on electricity bills and avoided emissions of 40 million pounds of CO_2 by upgrading their lighting.

Natural Gas STAR Partnership: A Company Perspectiv e

James Frederick, Spirit 76 Energy

Initial management response to voluntary government programs is often skeptical: "What's in it for us?" and "How much is it going to cost?" Spirit 76 Energy's experience with Natural Gas STAR is that its costs were low, and limited to transaction costs for joining the program and preparing annual progress reports, but that its benefits, in terms of recovered CH_4 that could be sold as product, were large.

The main function of Natural Gas STAR is information sharing -- through information exchange meetings, lessons learned publications, newsletters, case studies, etc. These sources provide detailed information needed to evaluate specific best practices so operators can decide which are economically attractive for a company's specific circumstances. Many solutions are site specific and will not work equally well in all locations. The program is flexible and allows operators to decide which practices to pursue.

Participation in Natural Gas STAR has generated extra revenue. It has also generated positive publicity and reduced CH_4 emissions. Overall it has been a major benefit to Spirit 76 Energy and to the natural gas industry.

Note: BP Amoco's experience with Natural Gas STAR was discussed in their presentation in Technical Session 2.

Mobil's Energy Management Network and ENERGY STAR Buildings

Fred Schoeneborn, Mobil

Mobil's Energy Management Network is composed of 155 site energy specialists and 3 corporate staff. To date it has conducted 44 site energy surveys. These are voluntary efforts within the corporation; surveys are only conducted when requested by a site. They focus on the management of energy utilities: how they are procured or generated, how they are distributed, how they are used, and whether there are areas for improvement. Each energy sur vey generates a list of recommendations for one-time and repeatable savings, and the implementation of these recommendations is tracked on an annual basis. As of the end of 1998, energy management has lowered Mobil's energy costs by $103 million/year compared with 1992. It has also avoided the generation of 435 million lbs. of CO_2, 3.3 million lbs. of SOx, and 1.5 million lbs. of NOx.

Lessons learned and other information are exchanged through the network by means of monthly newsletters and an annual conference. One lesson learned in this effort is that compressed air is the most expensive utility and one which is often ignored because "air is free." However, it takes five units of electrical power to generate one unit of compressed air power.

Mobil's program has also yielded significant public relations benefits including "Partner of the Year Awards" from EPA, recognition as Corporate Energy Manager of the Year from the Association of Energy Engineers, and recognition in New Zealand, Japan, and Nigeria.

Mobil was a charter member of ENERGY STAR Buildings. As with other STAR programs, the key benefit is information exchange, the ability to talk to peers in a "non-sell" environment. Mobil has completed its ENERGY STAR revamp at four buildings, with annual savings of $507,000 for an investment of $3,630,000. It also has avoided emissions of 10.7 million lbs. CO_2/yr.

Note: Chevron's experience with a similar approach to energy efficiency was reported in Technical Session 2.

Technical Session 4

Carbon Sequestration

Only a small portion of the carbon in the environment is in the atmosphere. Far larger quantities are sequestered (stored) for periods ranging from months to centuries in biomass (living plants and animals), soil, and the oceans. Large quantities of carbon also are stored for very long times in geological formations. One approach to dealing with GHG emissions is to enhance the sequestration of carbon in these reservoirs.

Mr. Skip Mick, moderator of the session, introduced the topic by quoting the Executive Summary of a recently released DOE Draft Report: *Carbon Sequestration: State of the Science*[4]:

> The development of today's fossil fuel energy based system is rooted in the industrial revolution. … we have developed an intricate, tightly coupled energy system that has been optimized over 200 years for economy, efficiency and environmental performance, but not for the capture and sequestration of its largest material effluent, CO_2.

Five papers were presented in this session on different methods to store carbon.

Moderator: Skip Mick, Marathon

1. State of the Science
   David Beecy, DOE
2. Sleipner Field CO_2 Storage Project
   David Thomas, BP Amoco
3. Capture of CO_2 from Coal Gasification and its Utilization for Enhanced Oil Recovery
   Ray Hatterbach, Dakota Gasification
4. Overview of Ocean CO_2 Sequestration
   Howard Herzog, MIT
5. Climate Change, Forests, and Conservation
   Michael Coda, TNC

[4] The DOE Draft Report, *Carbon Sequestration: State of the Science* can be found on DOE's web site at www.fetc.doe.gov/products/gcc/index.html

State of the Science

David Beecy, DOE

The objective of the UN Framework Convention on Climate Change reads, in part:

> … stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

Wigley, Richels and Edmonds[5] showed that that there is a period of time, varying from a few years to several decades, in which to develop the technology to stabilize atmospheric concentrations of CO_2. Three types of technology would be needed:

- decarbonization - i.e. use of lower carbon energy sources including nuclear and renewables;
- improved efficiency to lower carbon emissions per unit of energy consumed; and
- sequestration, either the capture of CO_2 before it is emitted or its removal from the atmosphere.

DOE's presentation was a summary of its program on carbon sequestration, starting with the following representation of the available pathways for carbon and CO_2 sequestration.

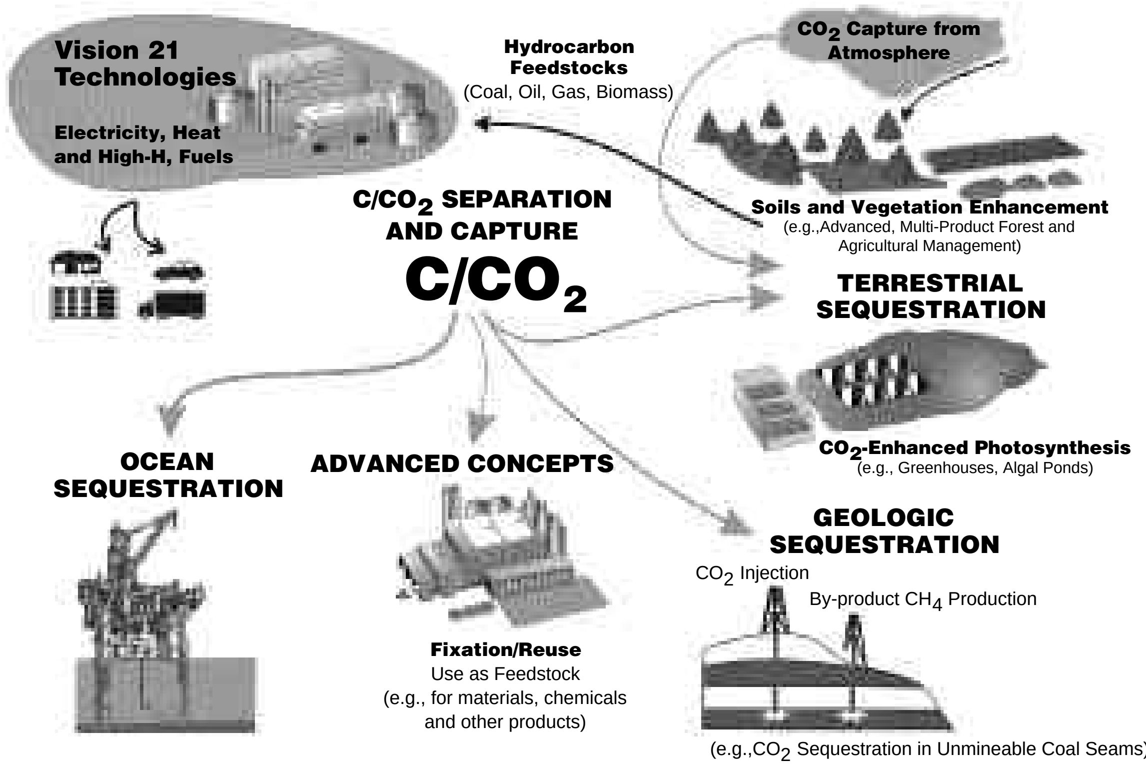
The major pathways for carbon/CO_2 sequestration are:

- terrestrial, in living plants and the soil;
- ocean, either by increasing the growth of plankton or as liquid CO_2 stored in the deep ocean; and
- geological, in saline aquifers or depleted oil and gas reservoirs.

It may also be possible to use CO_2 as a feedstock in chemical processing. DOE's program includes activities on all of these pathways.

[5] Wigley, T.M.L., R.G. Richels, and J.A. Edmonds. 1996: Economic and environmental choices in the stabilization of atmospheric CO_2 concentrations. *Nature*, 379: 240-243.

Carbon/CO_2 Sequestration Pathways



CO_2 storage capacity is uncertain, but it is orders of magnitude larger than current or projected emission rates. Many of these pathways depend on separating and capturing CO_2 before it is released to the atmosphere. A key need for these pathways is a lower cost method of CO_2 separation. DOE's program is investigating both evolutionary improvements in existing technology and "revolutionary" technologies such as integrated combustion and CO_2 separation schemes.

Carbon sequestration is also attracting international attention, particularly through the International Energy Agency (IEA) GHG R&D Programme, which is supported by 17 IEA member countries, as well as industrial sponsors, including API member companies. In addition, China and India participate in this program as observers.

Sleipner Field CO_2 Storage Project

David Thomas, BP Amoco

The Sleipner Field in the Norwegian sector of the North Sea produces a gas that contains about 8 percent CO_2. The CO_2 content must be lowered to produce pipeline quality gas. Since the CO_2 was already separated, Norway's CO_2 tax of $50 per tonne of CO_2 made sequestration rather than venting of CO_2 an attractive option. Of the various sequestration options, disposal in a geologic formation was the most viable.

Statoil has been injecting CO_2 into the Utsira formation, a saline aquifer, for 2 1/2 years. Current injection rate is 1 million tonnes/year, with no problems to date. This project has attracted a great deal of international interest because:

- it is the first time, other than in enhanced oil recovery operations, that CO_2 has been injected underground; and
- underground disposal of CO_2 is one of the components of a vision for the carbon-free use of fossil fuels.

However, two significant questions have been raised about the approach:

- can we be sure that the CO_2 injected in Utsira will stay there; and
- the Utsira formation is huge, will the technique work in smaller saline aquifers?

To explore these issues the Saline Aquifer Capture and Storage (SACS) Project, led by Statoil and supported by BP Amoco, Mobil, Norsk Hydro, Saga Petroleum, Vattenfall (a Swedish electric utility) and a number of research foundations in the European Union, was formed. The project is funded at 5 million Euros; its goals are to:

- verify under what circumstances CO_2 storage in an aquifer is safe and reliable;
- validate geology, geochemistry, and geophysics models, and reservoir tools;
- initiate new R&D related to the above topics; and
- start development of a "Manual of Good Practice."

IEA has developed a broader cooperative effort between the SACS Project and the governments of the U.S., Canada, Japan and Australia.

Capture of CO_2 from Coal Gasification and its Utilization for Enhanced Oil Reco very

Roy Hatterbach, Dakota Gasification

The Dakota Gasification Company produces 240 billion SCF CO_2 /day as a by-product of its production of synthetic natural gas from lignite at Beulah, North Dakota. Some of this CO_2 will be pipelined to the Weyburn Field, 200 miles away in Saskatchewan, for enhanced oil recovery. The $1 billion (Canadian) project will pipeline 27 million tons of CO_2 over 15 years, all of which will be sequestered. Oil production will be increased by 138 million barrels.

Overview of Ocean CO_2 Sequestration

Howard Herzog, MIT

Oceans are the largest sink in the carbon cycle. They currently hold 40,000 GtC (billion tonnes of carbon) compared with 750 GtC in the atmosphere and 2200 GtC in the terrestrial biosphere. Most (about 90%) of the CO_2 emitted today will end up naturally in the oceans over the next 1000 years. Additional CO_2 can be sequestered in the oceans either by direct injection of relatively pure CO_2, or by enhancing uptake of CO_2 by marine organisms, for example, with iron fertilization. From a physical standpoint the oceans can absorb all of the 5,000 - 10,000 GtC contained in fossil fuel reserves. However, the environmental impacts of such a change are uncertain -- sequestering 1300 GtC would lower ocean pH by 0.3 units.

CO_2 is denser than saturated sea water at depths below 3700 meters, which had led to suggestions that it could be piped to the deep ocean and stored there for long periods of time. However, both local and global environmental impacts would have to be evaluated, as well as the cost and effectiveness of storage. Injection of a pool of CO_2 would lower the local pH of sea water, which could kill some marine organisms. An international collaboration project involving the U.S., Japan, Norway, Canada, Switzerland, and Australia, started in 1997 with the goal of understanding the environmental effects of direct injection of CO_2 into the deep ocean. Experimental work is scheduled for summer 2001.

A second approach to ocean sequestration is enhancing the growth of marine organisms. When these organisms die, some of the carbon they absorbed is transferred to the ocean floor. Studies have shown that in nutrient rich portions of the ocean, growth of marine organisms is iron-limited. Two experiments have shown that under these conditions, the addition of soluble iron to the ocean increases marine organism growth over the short term. However, many questions remain:

- What is the effect of iron fertilization on the rest of the marine ecosystem?
- How much of the carbon taken up by marine organisms is actually sequestered?
- What is the relationship between iron and other nutrients; do they become limiting?

In July 1999, DOE formed a Center for Ocean Carbon Sequestration to study these and other questions about the feasibility of this approach.

Climate Change, Forests, and Conser vation

Michael Coda, The Nature Conservancy

Forests are a major sink for carbon, and deforestation is a major source of anthropogenic CO_2 emissions. Globally, deforestation contributes as much to CO_2 emissions as coal combustion. Protecting existing forests offers a way to prevent these emissions.

The Nature Conservancy (TNC), whose mission is "to preserve plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive," presented its experience with two forest conservation projects.

- The Noel Kempff Project in Bolivia involves adding 300,000 hectares of land, which was previously a logging concession, to a national park in Bolivia. The $9.5 million, 30 year project includes funding for local economic and community development, and will generate 15 million tons of carbon offsets over 30 years. Fifty percent of these offsets are available to the projects industrial sponsors (including BP Amoco), the remainder will go to the Bolivian government.

- The Rio Bravo Project in Belize involves protecting 14,000 hectares of rainforest that were slated for agricultural development. The $5.6 million, 40 year project will generate 2.4 million tons of carbon offsets, again 50 percent of which are available to industrial sponsors.

Both of these projects have been approved under the U. S. Interim Joint Implementation (USIJI) Program and have had to demonstrate their suitability. Critical criteria and their fulfillment for the Noel Kempff Project are:

- Additionally - the projects would not have occurred without sequestration funding from outside sponsors -- the parcel was slated for deforestation.

- Leakage - Sustainable development activities are being undertaken providing alternatives to forest clearing.

- Baseline - Extensive trend data on deforestation activities in the area are available.

- Permanence - the land is now part of a national park; the project has a permanent endowment.

Similar information is available for the Rio Bravo Project from TNC.

Technical Session 5

Research and Development

R&D has a critical role to play in any climate change response strategy. We need fundamental research to better explain the climate system, and applied R&D to develop lower GHG emissions technology. Two technical papers were presented in this session.

Moderator: Gary Ehlig, Exxon

1. Industry Support for Fundamental Climate Change Research
   A. Denny Ellerman, MIT

2. Technology to Separate CO_2 from Gas Turbine Exhaust
   Gardiner Hill, BP Amoco

Note: A third presentation in this session - Technology Forecasting by Mark Mills - is described at the beginning of this report.

Industry Support for Fundamental Climate Change Research

A. Denny Ellerman, MIT

Better understanding of climate science and better analyses of policy options are critical to the development of more effective climate change policies. To help provide that understanding and analyses, a number of API-member companies are sponsors of the MIT Joint Program on the Science and Policy of Global Change. Industry provided some seed money to get the program started and continues to support MIT's research.

The Joint Program brings together MIT's Center for Global Change Science, MIT's Center for Energy and Environmental Policy Research, other MIT researchers, and outside research groups such as the Ecosystems Center of the Marine Biological Laboratory. Its core effort is the development of an integrated climate change model, which is comprised of four major components:

1. a coupled atmospheric chemistry and climate module that calculates the impact of changes in emissions (both natural and anthropogenic) on climate;

2. an anthropogenic emissions prediction and policy analysis module that calculates the effect of economic and policy changes on anthropogenic emissions;

3. a natural emissions module that calculates the effect of climate and other changes on natural emissions; and

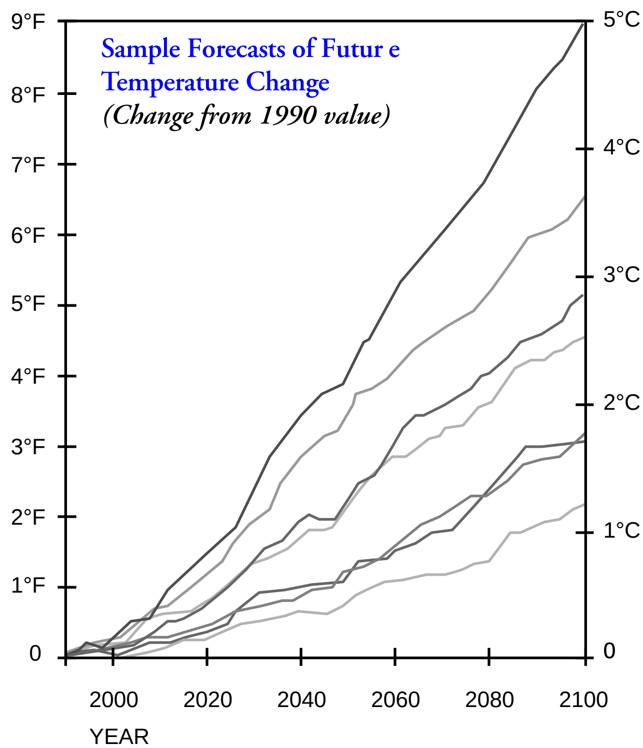
4. a terrestrial ecosystems module that calculates the effect of climate and other changes on ecosystems and their productivity.

Supporting research in the program develops the scientific and policy understanding necessary to continually improve the model. Results from the Joint Program are published in the peer-reviewed literature, but are also made public through a wide variety of other channels including: popular articles, Global Change Forums (hosted by MIT every nine months), meetings, conferences, briefings for governments, Congressional testimony, etc.

MIT provided one example of results obtained with the model, the chart shown below giving the plausible range of temperature increase from 1990 to 2100. These projections were developed by asking researchers to estimate plausible high and low ranges for the key variables in the model and to provide estimates of their probability. The estimates were then used to generate seven model projections. They show a range of temperature increases from 1 - 5°C. Two conclusions were drawn from this exercise:

1. scientific uncertainty had a greater impact on projected temperature rise than economic uncertainty; and

2. if we are on a high temperature rise path, it should be obvious within a few decades; if we are on a low temperature rise path, we may not know it for many decades.



Technology to Separate CO_2 from Gas Turbine Exhaust

Gardiner Hill, BP Amoco

BP Amoco's corporate target for reducing CO_2 emissions translates to a 30 million tonne reduction from projected 2010 emission levels. A review of options for achieving these reductions indicates that capture and sequestration of CO_2 will play a key role. Successful CO_2 capture and sequestration projects require three things:

1. a source of CO_2,
2. a sink for the CO_2, preferably one which is fairly local to the CO_2 source to reduce costs, and
3. materiality - the source must be large enough to make a difference.

BP Amoco's review indicated that its operations on the Alaskan North Slope met these criteria. There were several large sources -- gas turbine exhaust from power generation facilities -- and near-by oil reservoirs that could act as sinks.

CO_2 capture from turbine exhaust is technically challenging. Corrosion inhibition and mitigation is expensive, and the project requires a large capital investment. To address these problems, BP Amoco is proposing a Joint Industry Project (JIP) involving industry, technology suppliers and government, with the goal of reducing the cost of CO_2 capture and sequestration by a factor of four. Three technology routes are being considered:

1. Post combustion technology, i.e., separate the CO_2 from conventional turbine exhaust. This technology exists and at a cost of $400/ton CO_2, represents the base case. Cost reductions are likely through technology development and process integration.
2. Pre-combustion decarbonization, i.e., reform the fuel and separate CO_2 before combustion in the turbine. This is an emerging technology that might offer greater cost reductions.
3. Oxygen-fuel options, i.e., use oxygen for combustion to generate an exhaust that contains only CO_2 and water. This is a longer term option that requires both developments in gas turbine technology and lower-cost air separation for oxygen.

The goal of the JIP is to operate a demonstration project by mid-2005. None of the three technology options are considered the favorite; the choice is likely to be project specific.

Technical Session 6

Automotive Partnerships

The oil and gas industry generates and can control only a small fraction of the GHG emissions that ultimately result from the use of our products. Most of these emissions are generated when our customers burn the fuels we sell. Thus it is imperative that we work with equipment manufacturers to minimize the emissions associated with using our products. Automobiles represent the largest user of petroleum fuels, and as shown in the figure below, conventional automobiles convert only a small fraction of the energy in the fuel they use into useful work.

Four papers were presented in this session covering automotive partnerships on programs to reduce GHG emissions.

Moderator: Jim Katzer, Mobil

1. Fuel Choices for Fuel Cell Powered Vehicles
   Charles Darnell, Exxon

2. Assessment of Future Vehicle and Transportation Technology Options
   Malcolm Weiss, MIT

3. California Fuel Cell Partnership
   Catherine Lentz, CARB

4. Ford/Mobil Fuel Cell and Direct-Injection Diesel Research
   Jim Katzer, Mobil

Fuel Choices for Fuel Cell Powered Vehicles

Charles Darnell, Exxon

Fuel cell technology offers the potential for greater increases in automotive energy efficiency than any of the other new automotive concepts being developed. However, since the fuel cells under consideration operate on hydrogen, fuel supply is a critical issue. Currently three fuels are under consideration: hydrogen, methanol, and a liquid hydrocarbon like gasoline. If either methanol or a gasoline were used, it would have to be reformed on-board to generate hydrogen. The following table summarizes the advantages and disadvantages of each of these three fuels.

Advantages	*Disadvantages*
Gasoline	
Existing capacity and infrastructure	Reformer complexity
Fuel flexibility	Heat integration
Vehicles range	
Fuel price	
Methanol	
Development head start	Start-up time
Simpler reformer design	Safety, health and environmental implications for new fuel
	Additive impact on reformer
	New capital required
Hydrogen	
No on-board reformer	Infrastructure cost
No vehicle emissions	Safety implications
	Vehicle range

Key conclusions from the evaluation of these fuel options were:

- Fuel cell vehicles must compete with other emerging powertrain technologies.
- Auto and fuel issues need to be considered jointly.
- Both gasoline and methanol engines should be pursued prior to commercialization decisions.
- Gasoline offers the best utilization of the existing infrastructure.
- Hydrogen appears to be significantly disadvantaged as a fuel for personal vehicles.
- Efficiency and emission comparisons should be made on a well-to-wheels basis.
- Safety, health and environment aspects of new fuels need to be carefully assessed.
- Ample reserves are available for all fuel options.
- Taxation should be fuel neutral.

Details of this assessment are available in an API Report titled *Fuel Choices for Fuel Cell Powered Vehicles.*

Assessment of Futur e Vehicle and Transportation: Technology Options

Malcolm Wiess, MIT

This presentation reported on a study at MIT's Energy Laboratory, initiated in fall 1998 and partially funded by API member companies. The study will provide a comprehensive comparison of the fuel and vehicle technologies that could be developed and used by 2020. Only those technologies with potential to capture 5 percent of the market in 2020 are being considered, but, thus far, market entry problems have not been evaluated. A report on the study should be available during spring or summer 2000.

The technologies considered are:

Fuels: gasoline, diesel, Fischer-Tropsch diesel, methanol, hydrogen

Powertrains: gasoline internal combustion engine (ICE), diesel ICE, hybrid drives, fuel cells

Bodies: evolutionary, advanced

The baseline vehicle is an evolutionary gasoline ICE about the size of a Toyota Camry. It's characteristics, compared with its 1996 counterpart, are:

	1996	*2020*	*% Change*
Weight, kg.	1460	1135	- 22
Fuel use, mpg	28	54	- 48
Cost ($1996)	19,300	20,300	+ 5

Interior and trunk space, performance and range would remain constant.

Preliminary findings from the study are:

- The fuel cycle can consume a significant amount of energy. Thus, comparisons must be made on a "well-to-wheels" basis. Considering vehicle energy use only gives inflated values of energy efficiency and may distort the ranking of technologies.
- Fuel costs (ex-tax) will be under 4 percent of the total cost of operation for new U.S. cars; vehicle purchase costs will be 70-75 percent. Efficiency will go up faster than fuel cost.
- ICE hybrid cars are likely to have the highest well-to-wheels efficiency and therefore the lowest CO_2 emissions. Questions remain about the ability of ICE hybrids, particularly diesel hybrids, to meet standards for non-CO_2 emissions.
- No new technology looks like an across the board winner for 2020.
- Hydrogen fuel cell or battery cars may be attractive in the long run, but the technical and economic obstacles to their introduction are formidable.
- A shift to electric drive trains would serve both intermediate- and long-term goals.

California Fuel Cell Partnership

Catherine Lentz, CARB

California has made substantial progress in improving air quality. Between 1980 and 1997, population grew 39 percent, vehicle miles traveled grew 78 per cent, but peak ozone levels declined 49 percent. Los Angeles has now gone through a full year without a smog alert; Houston now has the country's "dirtiest" air. However, millions of people in California still are exposed to air quality that exceeds National Ambient Air Quality Standards. To continue reducing automotive emissions, in 1990, California adopted its Zero Emissions Vehicle (ZEV) program, which currently calls for these vehicles to be marketed in 2003.

The California Fuel Cell Partnership was announced in April 1999. It includes auto manufacturers, fuel cell manufacturers, API member companies, and the California government agencies. Its goals are to:

1. demonstrate fuel cell vehicle technology in "real world" conditions;
2. demonstrate alternative fuel infrastructure, hydrogen and methanol fueling,
3. develop fuel standards and specifications;
4. explore the path to commercialization: consumer research, safety codes and standards, and emergency response training; and
5. increase public awareness.

Three project phases are planned:

- 1999: project development
- 2000 - 2001: hydrogen fuel cell vehicle demonstration,>15 car and up to 5 buses
- 2002 - 2003: other technologies, if available, >30 cars and 10 buses

Ford/Mobil Fuel Cell and Direct-Injection Diesel Research

Jim Katzer, Mobil

Simultaneous drives for "zero" tailpipe emissions and significantly improved fuel economy to reduce CO_2 emissions is leading to the development of new vehicle-power plant technologies, which will drive changes in fuel types and specifications. Cooperative technology development is required if the fuel and vehicle are to be developed into an optimized system. One such cooperative approach is the Ford/Mobil Diesel and Fuel Processor Strategic Alliance. Its goals are to develop and demonstrate systematic approaches to meeting diesel emissions limits and to develop an effective hydrocarbon fuel processor for fuel cell vehicles.

At the present time, diesel engines are 35 - 40 percent more efficient than gasoline engines. However, to meet Tier 2 emissions standards in 2004, diesels require a 95 percent reduction in NOx emissions and a 90 percent reduction in particulate matter emissions. Additionally, there is growing concern about the toxicity of diesel emissions.

Particulate traps can reduce particulate emissions to very low levels, but they will require low sulfur fuel. Mobil showed test data indicating over 90 percent particulate removal. Preliminary vehicle test data shows that particulates can be controlled to 0.001 g/mi., one-tenth the Tier 2 standard, on a 30 ppm sulfur refinery prototype fuel. The durability of such systems needs to be demonstrated.

At least two technologies can control NOx. Selective catalytic reduction, using urea as a reductant, can control over 90% of NOx. NOx can also be stored on a catalyst during lean operation, then reduced during periods of rich operation. This approach requires ultra-low sulfur fuel. Durability has not been established for either approach.

The objectives of the hydrocarbon processor for fuel cells program are to:

- deliver at least 65 kw,
- improve fuel economy by 50 percent compared with a gasoline engine base,
- start as quickly as a gasoline engine,
- be light weight (110 lbs.), and
- have a 10-year life.

Methanol is simpler to reform than gasoline, which has pushed developers toward methanol. However, the Ford/Mobil position is that if vehicle requirements can be met with methanol reformers, hydrocarbon reformer technology can be developed to meet the same requirements.

Technical Session 7

Renewable Fuels and Alternative Energy Supplies

Net carbon emissions can be expressed:

Net C = C/E x E/GDP x GDP - S

where:

Net C = net carbon emissions to the atmosphere

C/E = the "carbon intensity" of the energy system, i.e. the average amount of carbon emitted per unit of energy

E/GDP = the "energy intensity" of the economy, i.e., the average amount of energy used per unit of GDP

S = the amount of carbon sequestered

Use of renewable energy sources reduces the carbon intensity term in this relationship.

This session had three papers on renewable energy.

Moderator: Ralph Feeney, BP Amoco

1. Renewable Energy Overview
   Stanley Bull, DOE

2. Role of Solar Energy
   Tom Vonderhaar, BP Amoco

3. Role of Geothermal Energy
   Andrew Whittome, Amoseas Indonesia

Renewable Energy Overview

Stanley Bull, DOE

The National Renewable Energy Laboratory (NREL) is DOE's focal point for research on renewable energy. Its program includes research on wind, solar, biomass, geothermal, and hydro power. In 1998, these sources accounted for 10 percent of U.S. energy supply, 5 percent from hydro power and 5 percent for all other renewables. Use of these resources avoids emission of 70 million tonnes carbon/year.

All parts of the U.S. have renewable energy resources.

- The developable, windy land in 5 states (Montana, Wyoming, North and South Dakota, and Minnesota) could produce electricity equivalent to the annual demand for the contiguous 48 states.
- A circle 100 miles across in the Nevada desert covered with solar arrays could satisfy America's entire electricity demand.

Use of renewables is increasing and the cost of power from these sources is decreasing:

- 2500 MW of wind power is installed in the U.S. Current cost is 4 - 7¢/kwh. Projected cost in 2010 is 2 - 3¢/kwh.
- About 500 MW of photovoltaics are installed worldwide, most in remote locations. Capacity is growing at 15-20%/year. Best laboratory performance for photovoltaics has increased from 6% efficiency in 1977 to 19% in 1999.
- 350 MW of solar thermal is installed in the U.S., largely for hot water heating.
- Installed capacity for biomass electricity is 7500 MW. Biomass is also converted into ethanol for transportation fuels. Current production cost is $1.22/gal. Projected 2010 cost is $0.67/gal.
- 2700 MW of geothermal energy is produced in the U.S. at a cost of 7 - 10¢/kwh, which is marginally competitive with natural gas.
- By 2030, emissions of 135 - 260 million tonnes carbon/year could be avoided by additional use of renewables in the U.S.

Role of Solar Energ y

Tom Vonderhaar, BP Amoco

Solar energy is a key component of BP Amoco's response to climate change, both to sell to customers and to use in their own operations. Solar has several enduring advantages. It requires no fuel; generates no emissions, waste or noise; has no moving parts; is safe; is easy to scale to customer requirements. The basic solar power module is 75 - 100 watts, and there is little economy of scale. The technology works today and has widespread customer appeal.

The price of photovoltaics (PV) has come down steadily. In 1980 the cost was $20 - 25/watt, which limited its use to special circumstances. Today the cost is about $3/watt and it is beginning to become competitive in some urban markets. Total current annual sales of PV modules are about 150 MW valued at $500 million. Total cost of the installed PV systems is about $1.2 billion/year, and the market is growing at a rate of 15 - 20%/year.

In polls, solar has the highest customer appeal of any power source. Also, 40-70 percent of consumers say that they would be willing to pay a premium for "green" electricity, and when actually given the opportunity, 40 percent of customers in California and 30 percent in Pennsylvania chose "green" electricity.

BP Amoco's program to use solar power in their own operations is called Plug In The Sun, which involves a $50 million investment to install 3.5 MW of PV on about 200 service stations in 11 countries. This will avoid emission of about 3500 tonnes of CO_2/year, and will make BP Amoco one of the largest users of solar power in the world. PV will supply about 40-50 per cent of the stations' energy.

BP Amoco is also installing 1.5 kw PV systems on 180 houses in a new sub-division in Southern California. These systems are part of an energy efficiency package and will supply about 90 percent of the home's energy need. The systems cost about $20,000/house and will payback in terms of reduced electricity bills. Finally, BP Amoco is installing 1 kw PV systems on the athlete housing for the Sydney Olympic Village.

Several conditions are necessary for PV to become successful on a large scale in the U.S.:

1. the electricity industry must be restructured to make the transmission infrastructure available to solar and other renewables,

2. customers must have the option to choose renewable energy,

3. there must be uniform standards for distributed power interconnection, and

4. there must be net metering so that customers get credit for the electricity they provide to the grid.

Recognition of the economic value of CO_2 would improve economics but is not a precondition.

The economics of PV use in the U.S. depend on the amount of sunshine, the cost of power from the grid, and the support available from government programs. Based on these factors, Hawaii and California are the most attractive locations -- PV is breakeven at a cost of $7/watt. New York, Massachusetts and Connecticut are the next most attractive locations -- PV is breakeven at $4-5/watt. In all cases, the high cost of electricity from the grid is a major driver.

Role of Geothermal Energ y

Andrew Whittome - Amoseas Indonesia

Most geothermal energy resources are located in zones of high volcanic activity. Worldwide there are about 9000 MW of geothermal energy available, about 1 percent of the world's electricity need. The resource is more important in some local areas, such as the Western U.S., Japan and Indonesia.

The technology to find and exploit geothermal resources is similar to that needed for petroleum exploration and development, and oil companies are active participants in the industry. Geothermal plants are usually located at the resource. Hot fluid from the geothermal resources is piped into a generating plant where it is used to generate electricity. Two approaches are used:

1. "flash" plants (about 95 percent of existing capacity) use direct contact condensers and vent any gases associated with the geothermal fluid to the atmosphere, and

2. binary cycle plants that heat exchange the geothermal fluid to produce steam, then reinject the fluid and any associated gases.

Geothermal fluids typically contain some GHGs; but CO_2 emissions from geothermal power generation are much lower than for fossil fuel power generation.

Source	lb. CO_2/kwh
Geothermal	0.18
Natural gas	1.03
Petroleum	1.56
Coal	2.13

Amoseas Indonesia, an affiliate of Chevron and Texaco, operates the Darajat Geothermal field in Indonesia, which is currently generating 135 MW of power and avoiding over 1 million tonnes of CO_2 emissions/year compared with a coal-fired alternative. Amoseas is constructing a co-generation plant at North Duri which will generate 300 MW/year at an overall efficiency of 91 per cent, avoiding 2.7 million tonnes of CO_2 emissions/year.

ATTACHMENT 1

Speaker List

Voluntary Actions by the Oil & Gas Industries:
A Conference on Industry Best Practices to Improve Energy Efficiency and to Reduce Greenhouse Gas Emissions

December 1-2, 1999,
Houston, TX

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Hydrocarbons to Liquids: An Alternative to Flaring
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Refining Processes and Improvements
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CARBON SEQUESTRATION

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Carbon Dioxide Re-injection

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Carbon Dioxide Disposal

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Tree Planting & Forestry Practices

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Climate Change, Forests, and Conservation: The Nature Conservancy's Work in Carbon Sequestration
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SESSION VI
RESEARCH & DEVELOPMENT – SECOND DAY

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Industry Support for Fundamental Climate Change Research

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VI. B
Advanced Technologies and the Role They Can Play Over Time

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Partnerships

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Technology to Separate CO_2 from Gas-Turbine Exhaust

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SESSION VII
AUTOMOTIVE PARTNERSHIPS

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Fuel Choices for Fuel Cell Powered Vehicles

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Automotive Partnership Project Examples

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SESSION VIII
RENEWABLE FUELS & ALTERNATIVE ENERGY SUPPLIES

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CONFERENCE SUMMARY DISCUSSION

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