Fossil Fuels, the Hydrogen Economy, and Energy Policy

2004 Aspen Energy Policy Forum
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Published in the United States of America in 2004
by The Aspen Institute

Printed in the United States of America

04-070
ISBN: 0-89843-422-x

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Foreword

Each of the major fossil fuels - oil, natural gas, and coal - faces significant challenges and presents interesting opportunities. Concerns about climate change and supply security lead many to believe that a transition to a hydrogen economy will be necessary in the long term. The 28th annual Energy Policy Forum considered key variables affecting supply and demand for each of the fossil fuels, domestically and globally, including new technologies and the competition offered by alternatives such as renewables and nuclear. It then examined the problems and potential of hydrogen, including its primary fuel source. Finally, based on these discussions, it suggested guidance for the development of near-term government energy policy.

A consistent strength of the Forum is the interaction among people with diverse views trained in different disciplines. Although the participants are knowledgeable in their own businesses or disciplines, in wrestling with multidimensional challenges they are challenged to avoid easy responses that draw on a single area of expertise. The exchanges are enhanced by an informal atmosphere and a not-for-attribution rule that encourage creative thinking and candid speaking.

Red Cavaney, President and CEO of the American Petroleum Institute, and Susan Tomasky, Executive Vice President and CFO of American Electric Power Company, co-chaired this year's Forum. Their broad experience and insight helped guide the varied and timely contributions of the diverse expert participants, bringing focus and perspective to a broad topic. A highly qualified group of session chairs and speakers provided a wealth of information and contributed substantially to the richness of the dialogue. Their names are listed in the Forum Agenda that follows.

The Institute's Program on Energy, the Environment, and the Economy acknowledges and thanks our sponsors for their very important financial support. Without their generosity and commitment to our work, the Forum and other projects of the Program could not continue. Contributions were received during the past year from the following:

American Electric Power (AEP)	William and Julie Fulkerson
Alstom Power Inc.	Institute of Gas Technology (IGT)
American Petroleum Institute	PEPCO
Aramco Services Company	Ruhrgas AG
Areva Enterprises Inc.	Sempra Energy
The Boyd Foundation	Sullivan & Worcester LLP
Cinergy Corp.	Thelen Reid & Priest
ChevronTexaco Corporation	Van Ness Feldman
Edison Electric Institute	Wabash Valley Power

Paul Runci again served as rapporteur for the Forum, skillfully extracting the major themes and illustrative points from a wealth of excellent presentations and discussions and summarizing them in an interesting and readable text.

Administrative preparations and arrangements in Aspen were admirably handled by Katrin Thomas. Her hard work and attention to detail were responsible for a pleasant and smoothly run meeting. Along with the participants, I am grateful for her cheerful and efficient support.

This report is issued under the auspices of the Aspen Institute, and neither the Forum speakers, participants, nor sponsors are responsible for its contents. Although it is an attempt to represent views expressed during the Forum, all views expressed were not unanimous and participants were not asked to agree to the wording of the recommendations or of the report.

John A. Riggs
Executive Director
Program on Energy, the Environment,
and the Economy

Agenda

"Fossil Fuels, the Hydrogen Economy, and Energy Policy"

Aspen, Colorado
July 3-7, 2004

Co-chairs: **Red Cavaney,** President and CEO, American Petroleum Institute
Susan Tomasky, Executive Vice President and CFO, American Electric Power

Session I: Oil

Chair: **Red Cavaney,** President and CEO, American Petroleum Institute

Speakers: **Marianne Kah,** Chief Economist, ConocoPhillips
Overview - supply and demand

Fareed Mohamedi, Chief Economist, PFC Energy,
Geopolitical context and variables

James Ragland, Director, Aramco Services Company
Technology variables

Amory Lovins, CEO, Rocky Mountain Institute
Oil displacement

Session II: Gas

Chair: **John F. Riordan,** President and CEO,
Gas Technology Institute

Speakers: **Donald F. Santa,** President, INGAA
North America overview

Wilfried Czernie, Executive Vice President,
Ruhrgas AG
European overview

Audie Setters, Vice President, Chevron-Texaco
Worldwide LNG

Stephen A. Holditch, Department Head,
Texas A&M University
Potential for unconventional gas

Session III: Coal

Chair: **Susan Tomasky,** Executive Vice President and
CFO, American Electric Power

Speakers: **Nicholas P. Guarriello,** President and CEO,
R.W. Beck & Co
Economic overview

Kurt E. Yeager, President and CEO,
Electric Power Research Institute (EPRI)
Near-term technologies

Robert H. Socolow, Professor,
Princeton Environmental Institute
Carbon capture and sequestration

David G. Hawkins, Director, NRDC
Environmental constraints

Session IV: Hydrogen

Chair: **David Garman,** Assistant Secretary and
Acting Undersecretary
U.S. Department of Energy
Overview and potential

Speakers: **Robert W. Shaw,** President, Aretê Corporation
Infrastructure development

Daniel Sperling, Professor, UC Davis
Hydrogen in autos

Joseph J. Romm, Center for Energy & Climate Solutions
Obstacles

Session V: Policy Choices

Chair: **Ernest J. Moniz,** Professor, MIT

Breakout Group Moderators:

Melanie Kenderdine, Vice President,
Gas Technology Institute

William L. Massie, Covington & Burling

Ben Yamagata, Van Ness Feldman

Framework and Recommendations

In the final session of the 2004 Energy Policy Forum, participants proposed a series of recommendations for federal government policymakers based on the discussions during the previous days. These recommendations are listed below.* Among the conclusions that provided the framework for the recommendations were the following:

Framework

- Reliance on energy markets should remain a core principle guiding energy policy. However, public goods, such as energy security, environmental stewardship, or service to disadvantaged communities, are not fully reflected in market actions. Government should address such market failures by, for example, providing price signals that internalize the costs of such marketplace externalities. The marketplace should then be allowed to function efficiently.

- The risks of climate change require urgent action in order to preserve options for the decades ahead. "No regrets" and voluntary actions alone are inadequate.

* Not all of the participants at the Policy Forum were present for all deliberations including the final session where these recommendations were adopted.

- Fossil fuels are the dominant source of world primary energy today and will remain so for some time to come.

- The geographical distribution of oil and gas reserves poses supply and geopolitical challenges for the U.S. and other major consuming countries.

- Coal is plentiful and inexpensive in the U.S. and many other major consuming countries but presents significant environmental challenges.

- Climate change and the actions taken to avoid or mitigate its consequences are the potential game changer for continued dominance of fossil fuels and thus for the world's energy infrastructure.

- In a world that imposes constraints on greenhouse gas emissions at a meaningful level, the potential game changer for fossil fuels is the capability to sequester carbon on a large scale.

- One of the paradigm shifts from the fossil fuel dominated energy system that may be realized in this century is transition to a hydrogen economy. The benefits would include superior environmental performance at the point of end use. With carbon-free sources of hydrogen, it would address climate change. The challenges of economics, supply, distribution, and storage are considerable, but some small-scale applications are already on the market.

- Consensus among business, environmental groups and others is needed to move a policy agenda, and policies that address multiple goals (e.g. climate change, supply, efficiency, security, economic growth, pollution) are the most attractive choices.

- Greater public education on the interconnection of energy, environmental, and security issues is critical.

Recommendations:

1. ***The President and Congress should initiate a greenhouse gas emission control regime in 2005.***

   A major concern about the U.S. and global response to climate change is whether actions will be taken early and broadly enough to preserve the option of maintaining atmospheric CO_2 concentrations at or below double pre-industrial levels. The long residence time of atmospheric CO_2 (measured in centuries); the long life of power plants, buildings, vehicles, and other energy infrastructure; and the rapid increase in demand in developing countries conspire to demand a strong, early response. The large sunk costs in the energy infrastructure and the need for a global response conspire to impede such a response.

   A mandatory control regime should be based on a carbon cap and trade model and should provide modest emissions ceilings at first, becoming more stringent over time. It should allow emitters as much flexibility as possible with regard to timing and location of emissions, and choice of control technologies. The system should also incorporate "safety valves" to prevent unexpectedly rapid carbon price increases from slowing the economy. The regime should be economy-wide.

   In working toward an effective and resilient global regime, U.S. policymakers must earn both the support of the American public for a domestic program and the participation of developing countries. The U.S. role on the world stage is critical, and initiation of a domestic program in 2005 would be an important step toward global leadership on climate change and actions by developing countries.

2. ***The President and Congress should strengthen energy efficiency standards and institutionalize a process for evolving higher standards that link to technology evolution and drive innovation.***

The attainment of higher levels of energy efficiency is crucial to the nation's economic, environmental, and overall security. Establishment of a national commission on energy efficiency could help to educate consumers, inventory energy efficiency opportunities, and provide general guidance and information. Stronger, mandatory efficiency standards should be implemented in key economic sectors, including transportation, residential and commercial buildings, appliances, and industrial processes. In addition to standards for new buildings and processes, strong attention must be paid to existing energy use patterns. Mandatory standards should also evolve over time to reflect new technological possibilities and to stimulate technological innovation.

Major improvements in transportation efficiency are technologically possible and necessary to reduce U.S. dependence on oil in general, and to diminish political exposure to exporting nations of concern.. A variety of policy tools, including CAFE standards and feebates, could be used to spur both improvements in conventional internal combustion engines and the diffusion of hybrid and alternative-fuel vehicles.

In the buildings sector, the institution of real time price signals would be an effective means of influencing consumer behavior. Technologies for real-time metering now exist and could be deployed to give consumers greater choice and control over their energy use.

3. ***The President and Congress should significantly increase spending on energy R&D programs and manage these programs through a disciplined portfolio process aligned with national strategic objectives.***

Federal resources devoted to energy R&D have declined substantially in real terms and must be increased commensurate with the central role of energy in the economy, environmental quality, and national security. New funding mechanisms, such as dedicated R&D trust funds, tax incentives, and mandatory checkoff programs, should be explored for their potential to increase and sustain a broad and robust energy R&D portfolio.

The nation's energy R&D portfolio must balance economic risks and time scales in pursuit of strategic policy objectives. Industry, national labs, and academia should be engaged actively in shaping the federal portfolio, ensuring that both short-and long-term programs, and basic and applied research efforts are well represented. While the private sector is well suited to the performance of short-term and applied R&D, government has a key role to play in sponsoring and performing long-term, high-risk, pre-competitive energy R&D, such as that associated with carbon sequestration science. In this regard, government should increase its sponsorship of university-based research, where the next generation of energy scientists and technologists will be formed. The numbers of U.S. scientists and engineers working in the energy field has been dwindling for several years, and rebuilding this intellectual workforce should be a high priority.

4. *The President and Congress should develop a strategy to ensure that technology is available to burn coal more cleanly.*

The abundance of coal and its attractive price relative to other fuels guarantee that it will be a major part of the U.S. and world energy picture for decades to come. Even acknowledging that it presents climate change and other environmental problems, it is not going away. Policy makers must provide funding for research into technologies that will allow greater emissions reductions at less cost. They must provide incentives, and regulations where necessary, for the commercial deployment of these technologies.

5. ***The President and Congress should act to facilitate the development of North American and global natural gas markets.***

Many energy analysts agree that the U.S. will have difficulties satisfying natural gas demand with domestic supplies for the next ten to fifteen years. Proposed solutions include the significant expansion of LNG imports, the construction of an Alaskan gas pipeline, and increased domestic production of gas from unconventional onshore and ultra-deep offshore reservoirs. While LNG holds the greatest near-term potential as a supply option, local opposition to the construction of new LNG facilities can be strong. The government should play an active role in educating the public regarding the relative safety, risks, and merits of LNG, and facilitate the permitting of LNG installations, both on- and off-shore.

Policy makers must also recognize that natural gas is becoming a globally traded commodity to a greater extent now than ever before. Since the U.S. will increasingly be part of this global gas market, the development of spot markets and North Atlantic arbitrage would facilitate a more efficient market for long-term U.S. gas supply. Full energy independence is an illusory goal. A more realistic policy focus would be the development of functioning global markets, with sufficient elasticity to preclude the concentration of market power in the hands of a few suppliers.

6. ***The President and Congress should formulate a comprehensive national policy to ensure the renewal and expansion of the nation's energy infrastructure. National energy infrastructure policy should focus on the key issues of electricity transmission and gas pipeline networks, oil refineries, and nuclear spent fuel disposal.***

Federal policy must recognize the national importance of energy infrastructure. While policy must be responsive to local interests and concerns, it must also recognize that energy delivery infrastructure and rules have national implications (e.g.

long distance electricity transmission, "balkanization" of fuels specifications). The reliability of energy supply can be severely affected by "seams" in the infrastructure and the primacy accorded state and local interests in some regulatory areas, as recent electricity blackouts and gasoline price spikes have shown. National policy must address the disadvantages associated with the regional nature of many U.S. energy supply systems. The federal government is uniquely able to establish national "rules of the road" to minimize regional and local system differences.

7. ***The President and Congress should elevate the role of energy as a foreign policy concern.***

Energy supply lies at the core of developing nations' efforts to improve living standards and quality of life. Yet, rapidly increasing energy use in such countries will exacerbate global problems of energy supply security and climate change. Thus, managing rising global energy needs and averting related tensions, conflicts, and environmental problems will require that energy play a more prominent role in U.S. foreign policy. A major policy initiative to work with other industrialized nations to bring electricity to the billions of people around the world who lack it could contribute significantly to a variety of U.S. foreign policy goals, including national security, environmental quality, and economic growth. Additionally, supply diversity enhances energy security, and relations with current and potential supplier nations are strategically important to the U.S.

Session I: Oil

Recent price increases and heightened volatility in oil markets have affected oil producers and consumers worldwide, prompting speculation about underlying causes and potential means of addressing them. The oil session's core question concerned the ability of industry and government leaders to plan the U.S. energy future under conditions of heightened uncertainty and price volatility. What key factors are shaping the future of world oil markets, and how might they influence decision makers' thinking with regard to long-term energy planning, environmental protection, geopolitics and national security?

Oil Market Volatility and the Future

The future stability or instability of the world oil market will be influenced by the expectations of oil industry executives and analysts. Persisting perceptions that the geopolitical environment is increasingly insecure are likely to result in lower levels of upstream investment in the oil industry, despite a "risk premium" currently putting upward pressure on prices. These views stem in part from the war in Iraq, recent terrorism in Saudi Arabia, U.S. foreign policy in the Middle East more broadly, and conditions in several producer nations outside the Middle East. Since some industry analysts have already called attention to the need for higher levels of investment to augment world oil production and refining capacity, declining future investment could help to make a self-fulfilling prophesy of market volatility and high petroleum prices.

According to one participant, market volatility also results from an apparent geopolitical realignment in the Persian Gulf region stemming from U.S. foreign policy in the Middle East. Gulf Cooperation Council (GCC) states were previously willing to take foreign policy cues from the U.S. and to go along with the U.S. in its efforts to isolate Iran and Iraq. Recently, however, the GCC countries have asserted greater foreign policy independence, perhaps to maintain their own legitimacy at home in the light of the unpopularity of the U.S. and the war in Iraq. Other key countries such as China and Russia have capitalized on the decline in U.S. prestige in the region, and have taken this opportunity to strengthen their own political ties with Saudi Arabia and other Gulf OPEC nations.

While perceptions may play an important part in shaping oil market conditions, several objective factors on both the supply and demand sides have combined to produce current high oil prices. Economic recovery in the U.S. and steady energy growth in China and other East Asian countries have augmented global demand, tightening the world oil market. In China, where automobiles are key aspirational goods for the emerging middle and upper classes, for example, economic growth is spurring unprecedented levels of vehicle ownership. Twenty new models of sport utility vehicle will be introduced to the Chinese market this year alone. Many analysts now point to China as a chief long-term global rival to the U.S. and other Western countries for world oil supplies, particularly those in the Persian Gulf. Some Forum participants view developing world demand growth as having inherent destabilizing effects on the world oil market.

Other participants questioned the assumption of U.S. demand inelasticity that, in their view, underlay the discussion of future supply and tightening markets. They noted, for instance, that consumers are demonstrating demand elasticity through increasing orders for hybrid vehicles such as the Toyota Prius, which now has a nine-month waiting list and sells above sticker price. Conversely, large sport utility vehicles, such as General Motors' Hummer, have experienced sales declines as gasoline prices have risen, prompting large manufacturer rebates to prospective buyers. Other participants noted that, in the longer term, industrial demand for oil is also somewhat elastic, and persistent high prices would prompt large industrial users to move operations offshore, as several have done already.

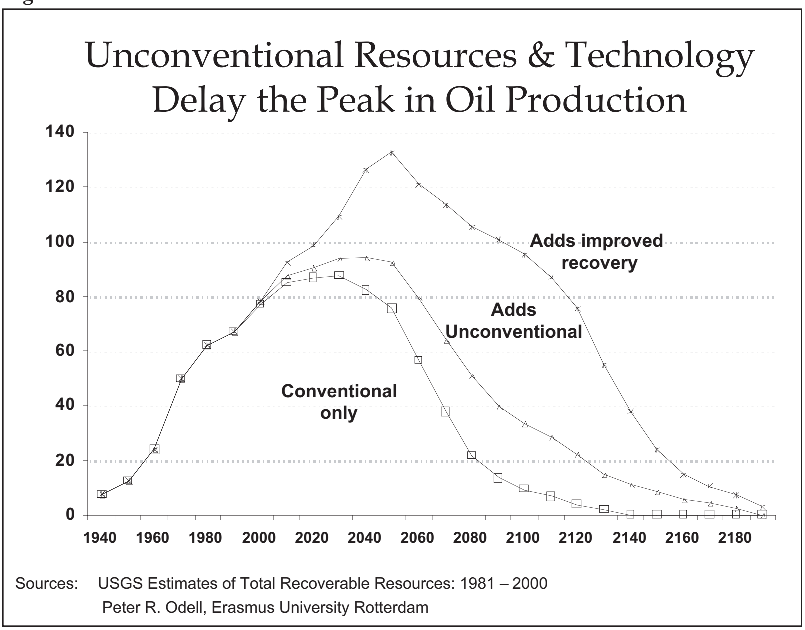
On the supply side, a shortfall of excess production capacity in the Organization of Petroleum Exporting Countries (OPEC) or elsewhere has put upward pressure on prices, as has the very high utilization rate of U.S. refining capacity. While U.S. refineries are now operating near full capacity, little investment capital is flowing to the refining industry. Also, the plausibility of an interruption to the output of Iraq and some other producer nations casts an additional pall over oil price projections, since substitute suppliers are unlikely to be found in the short- to medium-term.

The prospect of higher levels of Iraqi production and, over the longer term, carbon controls also contribute to price volatility. Saudi Arabia, currently the only OPEC producer with significant spare capacity, appears reluctant to use it now to reduce world market prices, in part due to concerns that the eventual return of Iraq to full production may one day put strong downward pressure on oil prices. Of even greater concern to major OPEC countries is the possibility - or, according to some analysts, likelihood - that a global carbon emissions control regime will be implemented. That eventuality could have devastating long-term consequences for the economies of oil exporting countries, many of which envision large wealth transfers to importing countries as a result. They may consider current high prices to be advance compensation for a carbon-constrained future.

The Global Petroleum Resource Base

While there may be many causes for concern regarding future volatility and high prices in world oil markets, many analysts point to the fact that estimated global recoverable oil resources continue to increase. Future resource adequacy is likely to be sustained in the long run through the combined forces of technological innovation and enormous unconventional fossil reserves worldwide. (See Figure 1.) High prices and political risks associated with conventional petroleum supplies, particularly those in the Middle East, may serve to enhance the economic and political attractiveness of North American unconventional resources such as oil shales and tar sands. However, some industry experts assert the inexorability of the "Hubbert curve" and contend that mainstream assessments of oil reserves and resource abundance are overly optimistic.

Figure 1



Notwithstanding such optimism regarding global petroleum resources, rates of global reserve growth have fallen steadily in recent years, principally due to chronic underinvestment in new production infrastructure. The largest remaining conventional reserves are still located in the region of highest political risk (i.e., the Middle East), while the costs of finding and developing new conventional supplies have risen by approximately $4 per barrel since 1999. Similarly, supply replacement costs have risen from the mid-$20 range to the mid-$30s because of the infrastructure investment gap. Several OPEC members now need $30/barrel oil to break even, partly due to the weaker dollar, suggesting that today's high oil prices are likely to persist for several years and may even constitute a new market equilibrium price level.

Technology and the Global Oil Future

Technology is one of the most powerful variables determining the global oil outlook. The oil industry historically has adopted many of its transformational technologies (e.g., three-dimensional seismic imaging) from other industries, and the prospects for further technology spinoff in the future appear strong. In the estimation of some oil industry professionals, emerging innovations in several fields, including biotechnology, nanotechnology, and genetic engineering, all have promising potential applications in petroleum production, processing, and end use.

The application of new technologies to the oil industry has played a central role in the continual revisions of estimated resources and reserves in key areas. For example, one participant noted that technological advances over the past twenty years have led Saudi Arabia to increase its estimate of oil initially in place (its aggregate resource endowment) from 550 billion barrels to more than 700 billion barrels today. Similarly, state-of-the-art imaging technologies combined with real-time data analysis and supercomputing capability are enabling dramatic extensions of life cycle reserve assessments. More accurate imaging and data facilitate more efficient reservoir management and production. These techniques combined with evolutionary improvements in established technologies such as horizontal drilling have allowed some of the world's best-endowed oil provinces, such as Saudi Arabia, to protract their estimated development and production plateaus significantly. Saudi Arabian oil fields now plateau after fifty years on average, in contrast to the ten-year industry norm. As a result, Saudi Aramco projects daily production of 12 million barrels and production costs of $0.50 per barrel for at least fifty years - even with no future additions to proven reserves.

Supply shortfalls stemming from political instability and terrorism in Middle Eastern OPEC nations are more likely to pose immediate threats to world energy supply than resource limitations will for the foreseeable future. Even though major exporters such as Saudi Arabia have extensive security in place and have some redundant and mothballed facilities that could be brought on line quickly in the event of a major accident or terrorist incident, the fact remains that oil and gas production infrastructure is extensive and challenging to safeguard. This ease of disruption helps to explain the chronic underinvestment in technology and infrastructure that slows the development of the petroleum industry in key producing areas.

While the oil industry's technological future provides many reasons for optimism among producers and consumers alike, there are also significant uncertainties that cloud the technological future. For example, even though OPEC still has the world's largest and lowest-cost oil resources, deploying the new technologies needed to produce them will require major new investments. Considering the political and economic risks associated with Gulf OPEC countries, these investments are far from guaranteed. Likewise, while non-OPEC countries and regions such as the Arctic hold significant promise for additions to future reserves, uncertainties exist regarding production possibilities in these areas, even with high rates of technological advance.

In the light of these uncertainties and the significant environmental risks incumbent in a fossil-fueled future, some analysts now argue that it is prudent and may even be profitable to make a swift and total transition from oil to non-carbon fuels. For several analysts, the mounting evidence of linkages between energy-related emissions and global climate change makes the case for rapid energy system change particularly compelling.

The accelerated development and deployment of biofuels for transportation, such as lignocellulosic ethanol, for example, could help to offset the 70% of annual global oil demand growth spurred by increasing light and heavy truck travel. The combination of new fuels with strong, super-light advanced materials could facilitate a progression - relatively rapid, in one participant's view - from today's petroleum-based motor vehicles to super-efficient, zero net emissions ones. Considering that the U.S. has reduced the energy-intensity of its economy by some 43% since the first oil supply shock of the 1970s, this participant argued that an even more dramatic energy transition might be achieved today. Catalyzing such change is as much a question of political will as technical feasibility.

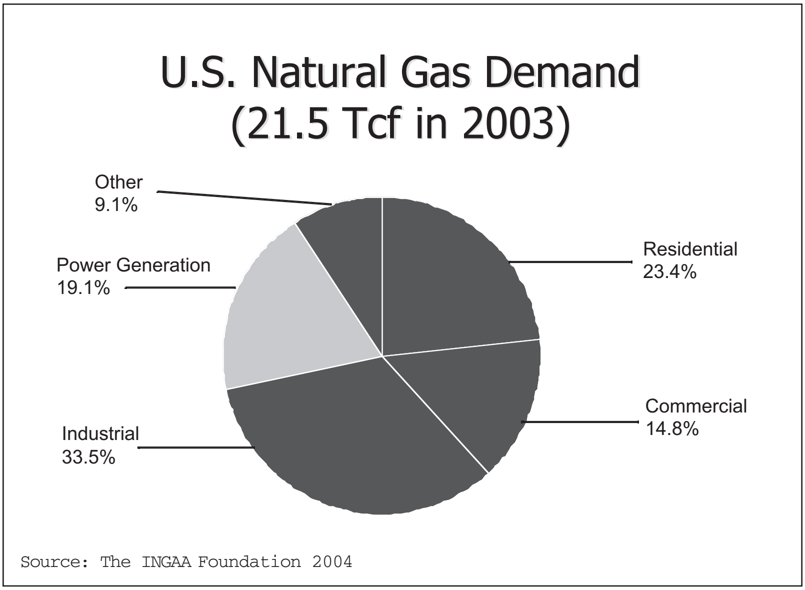
Session II: Natural Gas

Gas supply now presents a series of problems for major consuming countries, not least the United States. Gas supplies have been tightening for several years, driving up prices and heightening market volatility. No apparent relief is on the visible horizon, and some analysts estimate that current trends are likely to continue for at least three to five years, if not a decade or more. The natural gas session of the Forum addressed many of the factors that have worked together to create today's gas markets and considered a variety of short- and longer-term developments that might alleviate tight supplies, high prices, and market volatility.

Regional Overviews: North American and European Gas Markets

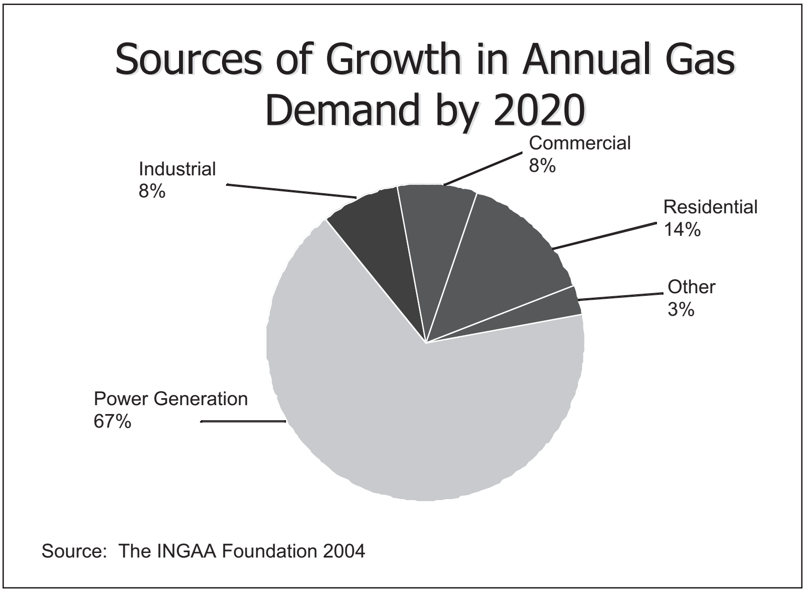
Natural gas now constitutes approximately 25% of U.S. primary energy consumption. Demand for gas grew by more than 30% during the 1990s, when market and regulatory forces combined to make gas the fuel of choice for new power generation and for many industrial facilities. North American suppliers are now struggling to meet the explosion in gas demand and coping with a chronic shortfall of investment capital for infrastructure development. As a result, gas demand has become increasingly unstable as some industrial consumers have switched fuels or closed facilities or moved abroad in search of price relief. Industrial demand fell by approximately 1 trillion cubic feet (tcf) between 1998 and 2002. Yet, recent scenarios now project aggregate demand growth; one low growth scenario estimates that annual U.S. gas demand will climb by more than 25% by 2020, from 21 tcf in 2003 to 29 tcf. This growth corresponds with an estimated wholesale gas price of $4.40/million cubic feet in 2020. The power generation industry is a principal driver of current trends. Although only responsible for 19% of current gas demand, the sector accounts for two-thirds of anticipated demand growth. (See Figures 2 and 3.)

Figure 2



Changes in the U.S. regulatory environment could play a definitive role in the future of North American gas. Gas industry representatives estimate that if the industry is permitted to make the infrastructure and technology investments necessary to serve a growing market, gas demand in the U.S. could climb as high as 34.2 tcf in 2020. Key variables in this scenario include the permitting and construction of new liquefied natural gas (LNG) facilities, construction of an Alaskan gas pipeline, additions to transmission pipeline

Figure 3



infrastructure in the lower 48 states, and access to gas resources in the Rocky Mountains and elsewhere in the continental U.S.

With demand projected to rise under almost any scenario, supply is a key question. Already, North America consumes 29% of world gas output, but has less than 5% of world gas reserves. Many analysts believe that U.S. and Canadian natural gas production from traditional basins is already in decline. Even though additional gas reservoirs exist in the U.S., many are located on Federal lands that remain off limits to exploration and production.

With North America's current conventional resources projected to meet only 60% of demand by 2020, unconventional gas resources and LNG imports will become even more important. Yet, infrastructure investment challenges abound and will need to be addressed to ensure the availability of supplies from these sources. For example, industry analysts claim that as much as $42 billion is now needed for new pipeline infrastructure, and $25 billion will be needed for gas storage over the next decade. Investors have thus far been unwilling to finance new capacity in the absence of new long-term transmission contracts, while buyers have hesitated to sign contracts without new transmission capacity. Compounding the problem, the financial collapse of merchant gas-fired generators and gas marketers has left a gap with regard to backstopping pipeline and storage capacity. Moreover, as the need for new infrastructure grows, so does the strength of opposition by community and environmental groups, since permitting decisions are frequently made at the local level, where such groups have their greatest leverage.

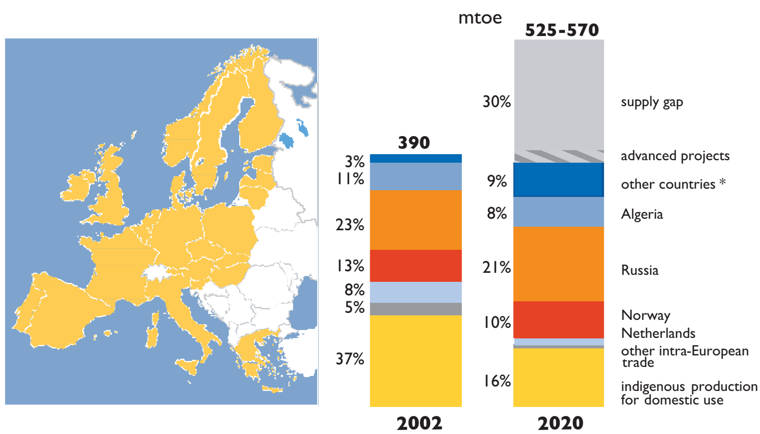
There are high economic costs associated with delayed infrastructure expansion in North America. As one Forum participant noted, for every two-year delay in the construction of major new infrastructure projects the cost to U.S. consumers is likely to exceed $200 billion by 2020. While long construction lead times raise the levels of risk and cost associated with gas infrastructure, for the economy as a whole the risks and costs of postponement are apparently far greater

Gas markets in Europe face many challenges similar to those in North America. As in the U.S. and Canada, for example, gas demand growth in the European Union (EU) is increasingly driven by the needs of the electric power industry and is contributing to higher levels of energy import dependency (mainly on Russia and Algeria). The expansion of the European Union and the liberalization of its energy industries have both played key parts in the acceleration of import dependence. The EU is already over 50% dependent on gas imports, and both the percentage of imports and transmission distances of European gas imports are rising. (See Figure 4.) In conjunction with environmental policies and regulations favoring gas over other fossil fuels, European gas demand and foreign dependence are likely to continue growing.

Considering these features of the European gas market, supply security is one of the most pressing concerns facing the EU. Industrial gas consumers, like their U.S. counterparts, continue to rely on long-term contracts with foreign producers to ensure adequate supply in the long-term. Long-term contacts are the mainstay of supply security, since equity financing of projects within Europe has proven largely infeasible and since the capital market usually demands long-term sales guarantees. Industrial gas consumers are

Figure 4

Natural Gas Supplies EU 25



*2020: Nigeria 3%, Katar 2%
Basis for imports: Contracted volumes and probable contract prolongation

Source: Ruhrgas

seeking to have a more direct influence in supply security by seeking a stronger presence in the upstream outside the EU. European firms are acquiring shares in exploration and production companies to secure their long-term supply base, minimize risks, and have a greater influence in the shaping of future upstream projects.

Since many analysts project that gas is likely to remain the most attractive fossil fuel in Europe for the foreseeable future, the main challenges for the EU will be on the supply side. Key challenges will include the procurement of additional gas at competitive prices from more distant suppliers, and the balancing of security risks with ever-higher levels of import dependence and gas-to-gas competition.

Meeting Future Gas Needs: The Outlook for LNG and Unconventional Gas Resources

Global demand for gas is expected to rise for the foreseeable future because of its economic, environmental, and efficiency advantages over other fuels. Today, world consumption is 251 billion cubic feet per day (bcf/d) - 84 tcf annually - and analysts anticipate global demand growth of 2.2% annually through 2025. While the world has vast gas resources available in principle to satisfy continually rising demand, both the location and the physical properties of the resource base are likely to present major problems. Indigenous production in the U.S., Canada, EU, and Asia-Pacific will not meet demand growth in those markets over the next 15 years, and the resulting supply shortfall will create a need for inter-regional gas transportation.

Transport of gas resources from wellhead to market presents one of the most significant challenges. Moving the large gas resources of the Middle East, Russia, and North Africa, for example, will require major infrastructure investments in both producing and consuming countries, mainly for LNG liquefaction and regasification facilities and new pipeline capacity. Global LNG demand is rising faster than demand for any other fossil fuel, and continued growth is limited primarily by a global shortage of LNG terminals. Many analysts view the anticipated expansion of global LNG as creating an integrated global gas market like that for oil, a development that could have valuable stabilizing effects on energy markets. In their view, gas and oil are already trending toward an equalized global price per btu. Several new LNG terminals have been proposed around the world (including some 30 in the U.S.), but the best candidate sites are likely to be in Mexico and other Latin American countries, Africa, and Indonesia. Political and regulatory barriers to new LNG facilities appear likely to stall most construction in the U.S. indefinitely.

Controversy surrounding the siting of new LNG facilities presents less formidable obstacles in Japan and the European Union, where both the regulatory environment and public perceptions are more favorable to LNG facilities. In Japan, for example, there are now 20 regasification plants, compared with four in the U.S. The U.S. is regarded as a particularly high cost and high risk environment by potential LNG investors; investors are aware not only of potential siting difficulties but of the myriad agreements necessary to pull together the various stakeholders and to integrate the components of the value chain needed to bring a new terminal to fruition. Thus, of the many proposed U.S. LNG facilities, most are unlikely to be built.

Much of the controversy in the U.S. concerns the safety of LNG. While many policymakers and members of the general public regard

LNG as a particularly volatile and dangerous fuel, proponents contend that LNG is actually less dangerous than other fossil fuels. They argue that LNG is a well-established global business that has not had a major accident globally in 45 years, nor an incident of any kind in the U.S. in more than 25 years. Contrary to widespread belief, LNG is transported in unpressurized, sealed vessels in which no oxygen is present, rendering the fuel not flammable. The lack of pressurization helps to ensure that a major explosion would be less likely, in the event that a fire were to occur.

Should LNG prove less feasible as a supply option in North America or elsewhere, there is no shortage of domestic hydrocarbons, as vast quantities of unconventional gas resources exist and could be produced, economics and technology permitting. As the gap widens between global demand and conventional production capacity, industry analysts believe that unconventional resources will play an increasingly prominent role in the supply mix along with heavy oil and tar sands, nuclear power, and renewable energy sources. In North America alone, these resources include large deposits of tight gas sands, coal bed methane, gas hydrates, and gas shales. In the U.S., production of coalbed methane has grown by more than three orders of magnitude since the mid-1980s, to more than 1.1 tcf in 2004, and tight gas sands production has also more than doubled since 1990 to more than 3,000 bcf annually. U.S. gas hydrate resources alone may exceed 300,000 tcf, although most are likely to remain inaccessible. Technological progress and high gas prices are facilitating the development of domestic unconventional resources. Even at a price as low as $3.50/mcf, many unconventional resources become economically viable.

Globally, quantities of unconventional resources far exceed those of higher-value resources with regard to gas and virtually all other commodities. Tight gas and coalbed methane resources are now being produced in several countries including Venezuela, Canada, China, and Egypt. However, the necessary investment and technological inputs rise steadily as production progresses along a continuum from conventional to unconventional resources.

Conventional gas appears likely to continue its dominance of world gas markets for at least twenty years, as reserves continue to grow in key producing regions. Russia's proved conventional reserves now exceed 1,700 tcf, while those of Iran and Saudi Arabia now stand at approximately 800 tcf and 200 tcf, respectively. Vast unconventional reserves exist in each of these areas as well, although production from each will remain more expensive than conventional resources for decades to come. Some Aspen participants cautioned, however, that increasing reliance on major OPEC producers for gas in addition to a deepening OPEC oil dependence would only broaden Western exposure to Middle Eastern political risks. Better alternatives, they suggested, may be found in heightened end-use efficiency, development of renewable resources, and production of domestic unconventional resources; a portfolio approach would offer the highest level of energy and environmental security. In fact, some analysts point to a strong demand response to prices on the part of gas consumers, particularly in the industrial sector, and note that high future prices could have the mixed effect of spurring higher efficiency as well as increased demand for coal, oil, and renewables.

It is important to note that climate change is a critical variable that will have a major impact on future gas demand and the economics of both LNG and unconventional resources. If a price is placed on carbon, either via taxes or an emissions cap-and-trade system, then gas could become an even more popular fuel choice globally. Yet European participants warned that the architecture of such a pricing mechanism would have to be carefully designed in the U.S. and other countries to avoid some of the perverse effects associated with carbon management regimes now in place in the EU. In Europe, as much as 70 billion Euros raised annually via carbon taxes are often deposited in countries' general funds, distorting incentives for emissions reductions and disillusioning consumers with regard to ecotaxes. Nonetheless, carbon emissions and climate change are regarded more seriously in Europe than in the U.S. and contribute to Europe's growing preference for gas both for power generation and industrial processes. To the extent that this preference displaces coal, gas will contribute to falling carbon emissions. However, growing preferences for gas may be a double-edged sword; to the extent that gas competes and wins against renewable energy sources, it has the potential to increase net carbon emissions in the long term.

Session III: Coal

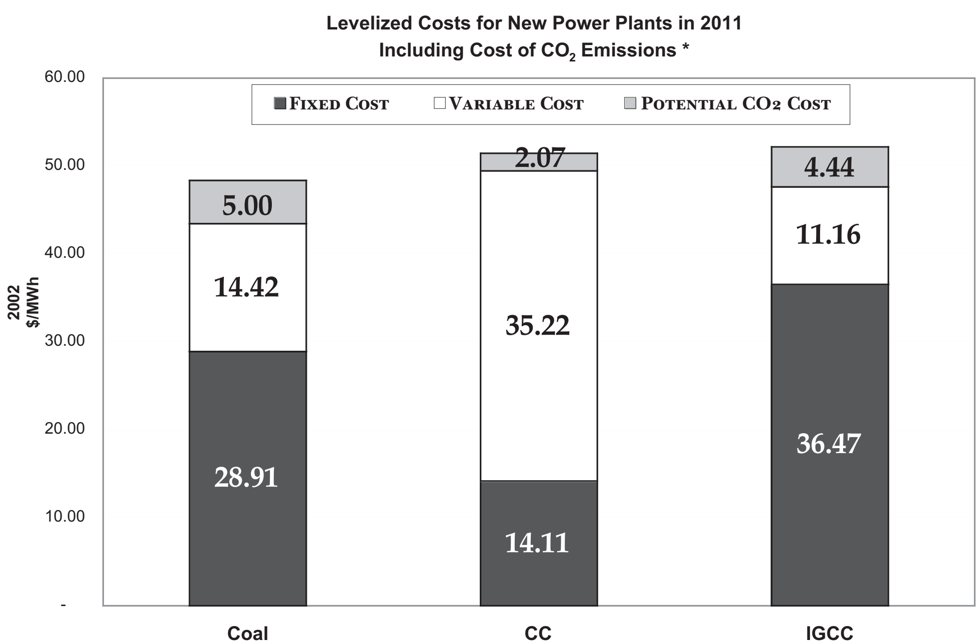
While natural gas has recently been the fuel of choice for new power production, coal has proven itself a resilient and survivable competitor. Both in the U.S. and globally, coal remains a mainstay of electric power production and other major industries, even as environmental regulations have grown more stringent. On economic grounds, coal has remained a strong competitor with gas and other fuels, and is increasingly attractive in the U.S. as gas prices continue to climb. In both the industrialized and developing worlds, the sheer magnitude of the resource appears to guarantee a prominent position for coal in the global fuel mix for the next century. Session III of the Forum addressed the global and domestic prospects for coal, considering the future impacts of emerging technologies, foreseeable developments in energy economics, and the potential consequences of carbon controls in response to climate change concerns.

Economic and Technological Perspectives on U.S. Coal

Coal has been the backbone of the U.S. electric power industry since its beginning. While other fuels have ebbed and flowed in their contributions to U.S. electricity generation, coal has remained remarkably constant, fueling 50% or more of power consumption since 1950. Given the growth of the industry, the constant share of coal in the fuel mix amounts to a doubling of coal consumption since 1970. Today the U.S. has some 900,000 MW of installed coal-fired capacity, constituting about 34% of the nation's total.

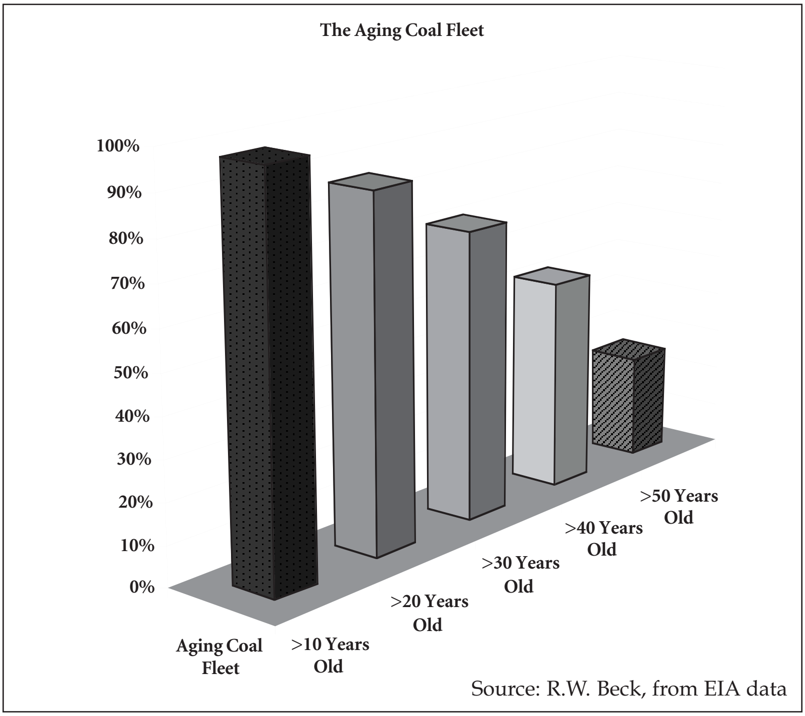
Coal's low cost dramatically influences the price of electricity in the U.S. Even with increasingly stringent environmental regulations, coal-fired plants have managed to maintain their competitive footing while decreasing their regulated emissions steadily. Absent government imposition of a cost on carbon dioxide emissions, coal is also likely to remain the lowest cost option for future power generation, with an average levelized operating cost of $43.33/MWh for plants coming on line in 2011 (in 2002 dollars). Coal's attractiveness is also enhanced by its vast domestic availability - the U.S. has some 250 years of reserves at current rates of use-and its price stability relative to other fossil fuels. As Figure 5 shows, coal industry analysts estimate that even the addition of modest carbon controls ($5/ton CO_2) would add only about $5.00/MWh to the levelized cost of new coal plants, enabling coal to maintain its economic advantage over combined cycle gas plants.

Figure 5



Source: R.W. Beck, based on EIA projected costs and fuel prices.
Cost of CO2 emissions assumed to be $5 per ton for this analysis.

Figure 6



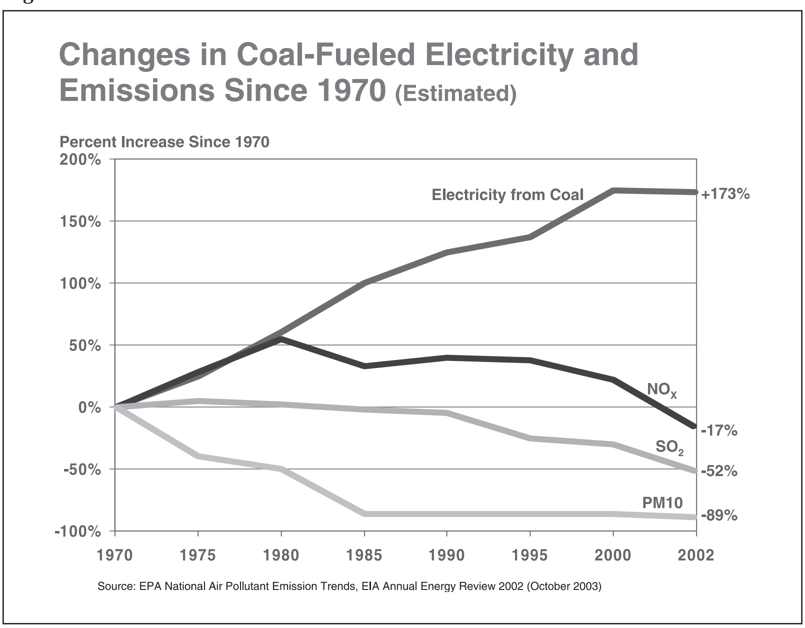
Yet, it is also important to note that the U.S. coal fleet is an aging one. Over 80% of U.S. coal-fired power plants are more than 20 years old, nearly 50% of the fleet is over 40 years old, and 25% is over 50 years old. (See Figure 6.) Analysts warn of the need for as much as 256 GW of new capacity, including 112 GW of coal-fired capacity, to meet surging U.S. demand between now and 2025. However, the difficulties associated with siting and permitting new plants are likely to hamper the industry's future development in the U.S. The long lead times, higher costs, and many uncertainties surrounding the construction of new coal plants are major obstacles, especially when compared with the quicker and easier process of building new gas plants.

The properties of coal resources vary considerably from region to region within and across countries. Thus coal-fired power plants have significant technological requirements. Since many analysts believe that technology will provide the basis for continued coal use, coal technology must be approached on the basis of several key performance criteria, including capital cost, efficiency, sulfur dioxide control, and carbon dioxide emissions.

Mercury control will be a new frontier in environmental control technology with significant cost implications for coal consumers. By one estimate, removing one ton of mercury could have a cost range of $15-55 million, depending on coal resource quality and technology choice. To a large extent, future regulations establishing mercury control guidelines will determine technology options, some of which are expected to be commercially available in 4-5 years. Technologies currently being developed include pre-combustion scrubbers, sorbent injection, polishing filters, and stack catalysts. Since the mercury content of coal varies by shipment, each plant will have to be equipped to capture mercury in multiple ways.

Pulverized coal and fluidized bed combustion systems currently serve as the technological backbone of the coal-fired power industry. Using these established technologies, the industry has made steady strides in its performance, improving efficiency and reducing emissions substantially over the past thirty years. (See Figure 7.) A key technolog-

Figure 7



ical wildcard for the coal industry, however, will be the integrated gasification combined cycle (IGCC) plant, which some in the industry regard as the "philosopher's stone" of coal technologies. IGCC systems may become the coal technology of choice in the future, considering their superior environmental performance and high efficiency. Moreover, the compatibility of IGCC systems with both carbon capture and hydrogen co-production technologies opens a broad range of future possibilities. In fact, the U.S. Department of Energy's FutureGen program is a large-scale effort to demonstrate the commercial potential of carbon capture and hydrogen production in conjunction with power production. Yet, widespread commercial deployment is likely to hinge on continued system improvement in terms of cost and reliability if IGCC plants are to compete with pulverized coal and fluidized bed systems. Carbon controls could have a major impact in this regard, since estimated carbon capture costs are significantly lower for IGCC than other coal technologies.

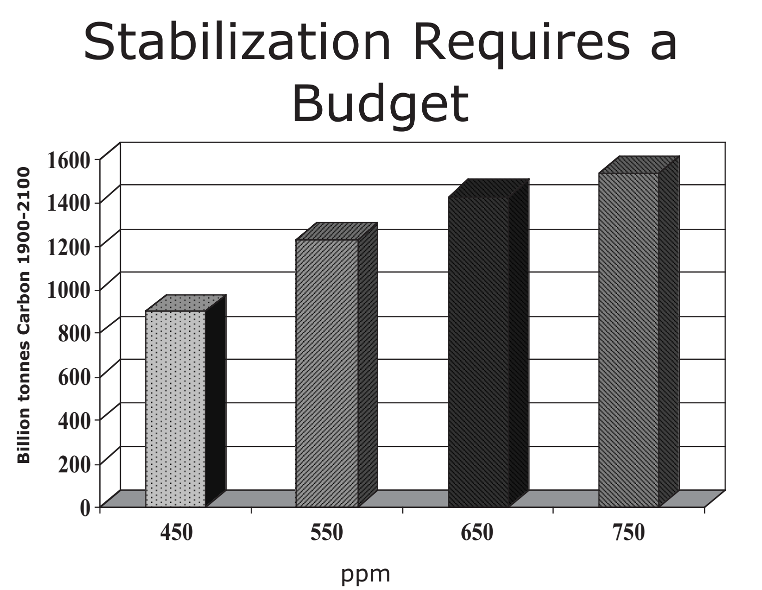
Coal in a Climate-Constrained Future

There is broad scientific agreement that anthropogenic emissions of carbon dioxide and other greenhouse gases are contributing to observed rises in global mean temperature. Over the coming century, these changes could have irreversible and potentially cataclysmic effects on the natural and built environments including widespread flooding of coastal areas, species extinctions, major shifts in weather and temperature patterns, and increased severity and frequency of extreme weather events.

Since the use of fossil fuels is the largest source of man-made carbon emissions, coal, as the most-carbon-intensive fossil fuel, is under particular scrutiny. Coal presents a great dilemma; its global abundance holds out the possibility of access to electricity for nearly three billion people who now enjoy no energy services. At the same time, the prospect of indefinite expansion of coal use to meet the world's unsatisfied energy needs raises obvious environmental concerns. Balancing this tension between near-term quality of life improvements and the possibility of long-term planetary disaster will be a key challenge for leaders over the course of the next century.

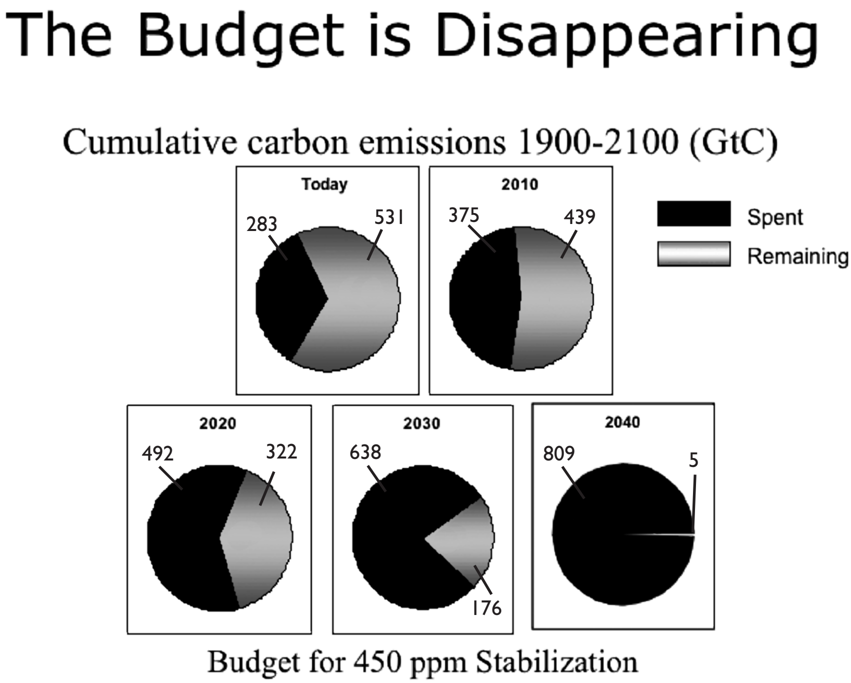
One participant cautioned that the urgency of the climate-energy challenge is greater than most industry executives and policy makers appreciate. Because carbon emissions are long-lived in the atmosphere, there is a cumulative carbon emissions budget for any given level of atmospheric concentration. Regardless of the target concentration level, the reality of carbon budgets necessitates an eventual transition from today's carbon-intensive global energy system. If, for example, carbon emissions of 2.1 gigatons correspond with a 1 ppmv rise in atmospheric concentration, as scientists now suggest, then stabilization at 450 ppmv will require cumulative global emissions of no more than 900 billion tons carbon between 1900 and 2100. (See Figure 8.) While more than half of that budget may remain today, the growth of fossil energy use worldwide is likely to consume the remainder by 2040 as additions to coal-fired capacity in the U.S., China, India, and Europe accelerate in the next decade. (See Figure 9.)

Figure 8



Source: NRDC, from IPPC Third Assessment Report (2001)

Figure 9



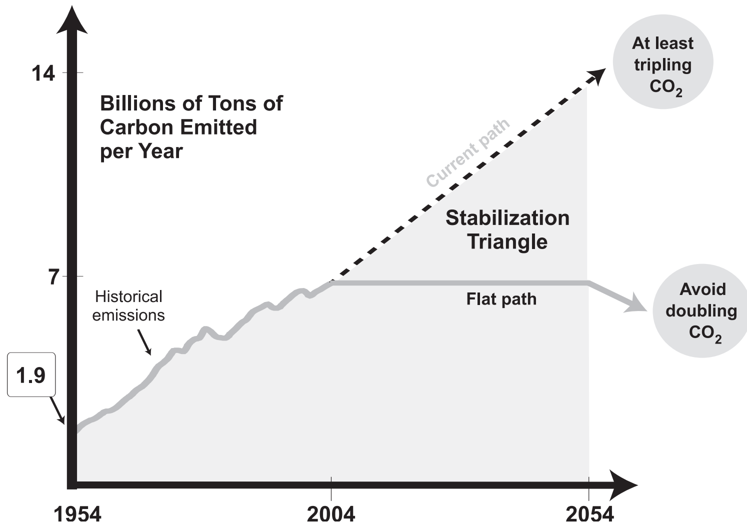
Source: NRDC, from IPPC Third Assessment Report (2001)

As many analysts now contend, carbon emissions reductions need not be incompatible with continued use of coal and other fossil fuels. In fact, they argue that the robustness of the global fossil energy system demands that carbon management tools - systems for the capture and sequestration of large amounts of waste carbon - play a vital role to ensure a reconciliation of global economic and environmental necessities. Thus, an environmentally proactive coal industry could transform itself to become an asset rather than a liability in global efforts to reduce carbon emissions.

The magnitude of the carbon emissions stabilization challenge and the urgency surrounding it is illustrated in Figure 10, which shows two hypothetical atmospheric stabilization paths for the next fifty years. The "stabilization triangle" represents 175 billion tons of carbon emissions that could be avoided by holding global emissions to the current average of 7 gigatons of carbon per year (GtC/y) until

2054. Carbon reduction beginning today holds open the option of stabilization at less than twice pre-industrial levels of atmospheric carbon concentration, while delayed action (shown here beginning in 2054) precludes that option.

Figure 10



Source: Carbon Mitigation Initiative, Princeton University

No single action can achieve the emission reductions implied by the full stabilization triangle. For considering policy options, however, the stabilization triangle may be disaggregated into a series of seven more manageable wedges, each representing 1 GtC/y average emissions reduction. The triangle could then be realized through a portfolio of emissions reduction technologies and options, each representing one wedge, for example: renewable electricity and fuels, energy efficiency and conservation, forests and soils, nuclear fission, fuel switching, and carbon dioxide capture and storage.

For carbon capture and storage to play a prominent role in atmospheric stabilization, a concerted effort would be needed immediately to demonstrate its safety and effectiveness, to gain public acceptance, and to begin permitting storage sites. Carbon storage technology is still nascent, and important uncertainties (for instance, regarding the likelihood and consequences of leakage) have not yet been addressed adequately. Only one such site is currently operating, Norway's offshore Sleipner gas field. For carbon capture and storage to contribute a full wedge to emissions reduction as discussed above, the equivalent of 70 Sleipner Fields' storage capacity would have to be added annually and maintained through 2054 at least. As this estimate shows, the use of carbon capture and sequestration as a climate change mitigation tool is a massive proposition, considering the quantities of materials that would have to be handled globally to make it work. Managing such quantities of carbon would require many different storage media such as deep saline aquifers, deep ocean sequestration, the creation of carbonate compounds, and biomass sequestration. Each of these options entails its own limitations and uncertainties and needs additional research.

Despite the large uncertainties surrounding the viability of these technologies, accelerated deployment of IGCC coal plants would be a valuable step in the direction of commercial carbon capture and storage. In addition to their other merits, these facilities could be useful tools for the development of data and experience with coal gasification and carbon capture. Most industry analysts believe, however, that accelerated deployment of IGCC coal systems is unlikely in the near term in the absence of government subsidies and incentives to catalyze the construction and operation of several "first mover" facilities. One Forum participant estimated that a U.S. government investment of $1 billion per year for ten years could develop 30 mid-sized coal gasification combined cycle plants with carbon capture and storage. Such an investment of public capital, he argued, would be relatively modest relative to other strategic investments made in the nation's vital interest, such as the Marshall Plan or the space program.

Regulation, not technology alone, will be the lynchpin of effective carbon management, in the opinion of many Forum participants. Expectations regarding the regulatory environment, and its economic implications, are what is likely to move companies to begin thinking about carbon constraints and prompting them to act in preparation for them by investing in new technologies. While some coal-dependent companies now regard carbon constraints as inevitable and are proceeding accordingly, many others still maintain a "wait and see" attitude.

Despite the general technological optimism of many Forum participants, this sentiment was counterbalanced by a sense of pessimism concerning the likely adoption of well-designed and timely policies and regulations. In fact, some experts expect no meaningful policy action in the short term that might bring about effective climate change responses domestically or internationally.

Session IV: Hydrogen

Many people have great expectations that hydrogen will become the future foundation of the global energy system, facilitating a transition from fossil fuels in the long term. Echoing this intent, the Bush Administration recently stated its commitment to U.S. technological leadership in a global transition to a hydrogen-based economy beyond 2020 as a matter of environmental, economic, and national security. Yet, realizing this vision will require the elimination of several obstacles to a hydrogen economy, including advances in reforming technologies, improvement in fuel cell performance, and the need for major infrastructure investments. Since hydrogen is an energy carrier rather than a primary energy source, its relative energy security and environmental benefits will be a function of the methods used to produce it. Hydrogen may be produced from a variety of other fuels including gasoline, natural gas, methanol, and coal, and through the electrolysis of water. Most analysts believe that fossil fuels will remain the primary feedstock for hydrogen production for the foreseeable future.

Critics fault the hydrogen vision from various angles. Some analysts fault the current structure of tax incentives, R&D incentives and investments in hydrogen as lacking the level of commitment needed to catalyze large-scale change. Other analysts argue that by focusing attention on hydrogen as a long-term solution, many promising short-term opportunities, including energy efficiency and renewable energy systems, may be neglected. The fourth session of the Forum considered ongoing and prospective developments related to hydrogen energy technologies and addressed the challenges of balancing today's and tomorrow's energy and environmental needs.

Building a Hydrogen Infrastructure

A maxim shared by many professionals involved in the development of hydrogen technologies is “don't let those who say something cannot be done stand in the way of those who are doing it.” Those already working in the industry recognize that huge amounts of hydrogen are made and used every day in the industrial economy, testifying that reliable and time-tested ways of producing hydrogen from hydrocarbons exist. These methods include electrolysis, steam reforming of light hydrocarbons, and partial oxidation of heavy hydrocarbons among others. Several vendors already offer commercial hydrogen fuel cells for stationary applications, and many of these units have been deployed to provide backup and auxiliary power to hospitals, manufacturing plants, and other industrial facilities.

Hydrogen systems for transportation are at an earlier stage of development and commercial acceptance than those for stationary uses. Due to the high costs associated with hydrogen transport, some industry participants, including major firms, now advocate the development of distributed hydrogen production systems. Small scale electrolyzers already available commercially could be set up at service stations or garages, for example, and used to service hydrogen-fueled vehicles at reasonable cost today, even without scale economies from mass manufacturing. The estimated infrastructure cost for a distributed network of hydrogen production facilities is approximately $1 million per fueling station. Hydrogen produced in this manner could theoretically be used in any application where natural gas or gasoline is used today, and could power fuel cells or hydrogen-burning internal combustion engines.

There are still important technological hurdles that industry must overcome along the way to a hydrogen-fueled future. The unit cost of a transportation fuel cell, now approximately $500/kW, must be reduced to $50/kW according to industry analysts before they will gain substantial market share. While major auto manufacturers including GM, Toyota, and Honda are confident that these targets will be met, it is unlikely to occur prior to 2010 at the earliest. However, large-scale market penetration of hydrogen vehicles, e.g. displacement of 10% of gasoline sales, is unlikely to occur earlier than 2030 by current estimates. The lifetime of key system components such as membranes is another technological hurdle that must be overcome before fuel cells deploy widely.

Yet, major auto makers are now spending approximately $500 million per year on fuel cell and hydrogen-related R&D to push the technology forward. The fact that both public and private R&D investment is incremental suggests that the development and diffusion of hydrogen technologies might also be gradual and incremental.

The Future of Hydrogen : Key Policy Questions

Many analysts and policymakers appear confident that the advent of a hydrogen-fueled future is inevitable. Yet others question both the likelihood of a hydrogen future and the wisdom of policy efforts in the near-term to accelerate a transition to hydrogen. They note that other fuels and energy technologies have enjoyed similar favor in the past (e.g., solar power), and have failed to emerge on the scale envisioned by their proponents. Will hydrogen be different in this regard? Should it be different?

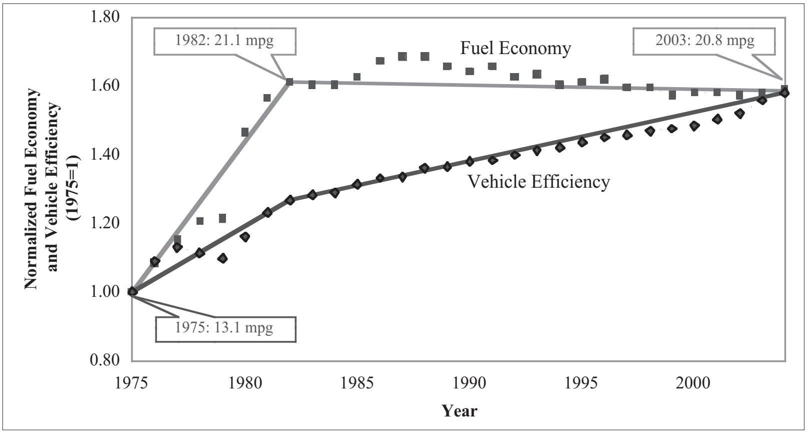
As one participant noted, the success of any non-fossil fuel alternative hinges on two key policy and economic criteria. First, public support depends on the degree to which fuels demonstrate societal benefits and public goods that are greater than those of fossil fuels. Second, market success depends on the extent to which an alternative is cheaper and/or better for consumers and producers than fossil fuels. To date, no alternative fuel has satisfied the latter set of criteria.

With regard to societal benefits, hydrogen is not a clear-cut winner. For example, since conventionally-fueled cars (particularly hybrids) are becoming cleaner and more efficient, hydrogen powered vehicles may offer only marginal advantages over gasoline and diesel powered cars in terms of air pollutants regulated under the Clean Air Act. However, depending on the energy source used to produce it, hydrogen can have significant potential advantages in terms of carbon emissions reduction and climate change mitigation. Given its global abundance, hydrogen also could be very attractive from an energy security perspective. The feedstocks, reforming methods and the availability of related systems such as carbon dioxide capture and storage technologies used to produce hydrogen will be determining factors with regard to the environmental and security benefits of a hydrogen economy.

The transition to a hydrogen economy becomes less urgent if major fuel efficiency improvements are gained from hybrid and conventionally fueled vehicles. However, even with those improvements, there might still be compelling policy reasons to accelerate the transition to a hydrogen economy. If climate stabilization is a real policy goal, for instance, efficiency improvements and hybrid vehicles alone will not be sufficient in the long term. While these technologies have helped to bring about an annual improvement of about 1-2% in internal combustion engine efficiency, consumers have been purchasing larger and more powerful vehicles, roughly offsetting efficiency gains.

Figure 11 illustrates this relationship. Despite continuous automotive efficiency improvements since 1975, the fuel economy of the U.S. fleet has remained essentially flat since 1981. Given that vehicle miles traveled have also been increasing, by 2% annually in the U.S., the net effect is a large increase in fuel use. Rapid introduction of hybrid vehicles and significant improvements in conventional vehicle fuel economy would at best flatten greenhouse gas emissions growth from the U.S. transportation sector, and only for 2-3 decades. Stabilizing global emissions of greenhouse gases for the long term will require the global adoption of alternative fuels and alternative transportation systems that make possible real reductions in CO_2 emissions and not simply a reduction in the growth rate of CO_2 emissions from the transport sector.

Figure 11



Source: Lutsey and Sperling, based on EPA data.

Of course, hydrogen fuel cell powered vehicles are not the only potential alternative to fossil fuels. Cellulosic ethanol and battery electric vehicles using grid electricity may also be promising contenders. It is not clear, however, whether or when these technologies are likely to be able to compete with fossil fuels on cost, considering the current high costs of growing, transporting, and processing cellulosic ethanol, and the weight and high cost of batteries for electric vehicles. For electric vehicles, as with fuel cell vehicles, the source of the electricity is a key determinant of the degree of environmental benefit conferred by the technology. Currently, the majority of electricity in the US is from conventional, pulverized, coal power plants. Many believe that hydrogen fuel cells have the best chance, among today's potential alternatives, of competing with fossil fuels on cost. Under the most optimistic scenarios, however, it will be decades before this occurs. The long-term societal benefits associated with fuel cells may be their greatest attraction. In this regard, policy will have an important role to play for the foreseeable future in promoting hydrogen by leveling the playing field and enabling fuel cells to penetrate the market.

Hydrogen's supporters and skeptics both acknowledge that there are important drawbacks to the use of hydrogen, and that these must be addressed. Safety is a key issue that will make fuel handling and storage more costly and more difficult. Some analyses suggest that hydrogen is a much more dangerous fuel than natural gas, while others indicate the opposite; the ensuing controversy over hydrogen and public safety complicates the process of technology choice. In addition, as the previous section discussed, the need for major changes and additions to infrastructure also presents a high hurdle that will require large commitments from policy makers and private investors. As a hydrogen-based transportation system also implies a transformation of the oil and automotive industries, the prospects for change in the foreseeable future may appear dim. Even though several major auto makers are now investing large sums in the development of hydrogen fuel cell vehicles, none appears ready to bet its future on a complete transition from fossil fuels.

For some, the bottom line is that betting too heavily on hydrogen would be a policy misstep and that government efforts to pick technological winners are likely to be unsuccessful, as they have often been historically. In the light of the many uncertainties associated with hydrogen safety, storage, infrastructure, and cost, plunging swiftly down a hydrogen path, as some analysts advocate, would close off other technology options and risk locking in to a suboptimal system in the long term. Perhaps even more dangerous, concentrating on a hydrogen transition could provide a rationale for avoiding near-term policy action on climate change. In the view of some Aspen participants, climate change cannot wait for a transition to hydrogen which, under the best of circumstances, would be unlikely before 2035. Advocates of this position urge policymakers to focus their attention on steadily climbing greenhouse gas emissions and act to curb them starting in the near term.

From this perspective, one participant contended that policy makers would be wiser to focus on averting an impending global explosion of coal-fired power plant construction. Some two-thirds of the world's anticipated 2030 coal-fired capacity has not yet been built, indicating that significant opportunities for greenhouse gas emissions reduction exist through fuel switching, efficiency, and other measures that could obviate the need for many of these new coal plants. Natural gas is widely expected to be the initial energy source for producing hydrogen, and some observers contend that this natural resource would yield greater environmental benefits if used as an alternative to coal in power production rather than as a feedstock for hydrogen as a transportation fuel.

However, as one participant countered, there is a difference between a transition phase to hydrogen vehicles and a long-term strategy. Using natural gas to fuel 10 million hydrogen-powered vehicles in the U.S., just over 5% of the fleet, would result in just a 2% increase in natural gas demand. Thus, the tradeoff between gas for power production and gas for hydrogen reforming may not be the most important consideration in the next few decades. To ensure adequate energy supply and environmental quality in the long run, it may be most important to start the transition to hydrogen, which can eventually be produced from renewable energy or nuclear sources and used for both power production and transportation.

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Conserving Biodiversity

Co-chaired by Bruce Babbitt, former U.S. Secretary of Interior, and José Sarukhán, Professor of Ecology and former President of the National University of Mexico (UNAM), the dialogue was based on commissioned discussion papers and focused primarily on the policy drivers of ecosystem degradation and biodiversity loss. With this report, the group seeks to educate policy makers and opinion leaders on the loss of critical ecosystems and biodiversity and to recommend specific changes in policies that may affect biodiversity, such as trade, aid, and lending policies.

2005. ISBN#0-89843-421-1 $12 per copy

A Climate Policy Framework: Balancing Policy and Politics

The Aspen Institute, in association with the Pew Center on Global Climate Change, convened a diverse group of leaders to develop a politically feasible framework for a mandatory U.S. climate change policy. Co-chaired by Eileen Claussen and Robert W. Fri, the group did not discuss whether mandatory action is now warranted. It did, however, reach consensus on several fundamental elements of a national policy, if one is adopted.

2004. 100 pages, ISBN# 0-89843-397-5, $12 per copy

Tackling the Critical Conundrum: How Do Business, Government and Media Balance Economic Growth and a Healthy Environment?

Former EPA Administrator Christine Todd Whitman and former Undersecretary of State Frank Loy co-chaired a Forum in Aspen on balancing economic growth and a healthy environment. This report includes their conclusions and discussion papers exploring the tradeoffs from the perspectives of business leaders, elected officials, investment firms, journalists, and economists.

2004. 102 pages, ISBN# 0-89843-435-1, $12 per copy.

Electricity Restructuring

The 2003 Energy Policy Forum focused on electricity restructuring. Chaired by former Director of Central Intelligence and Undersecretary of Energy John Deutch, participants discussed the advantages and disadvantages of national rules governing transmission, economic and market power issues affecting ownership, whether the market's choice of fuel is in the national interest, whether natural gas supplies are adequate, and how restructuring will affect the future of nuclear power, renewables, efficiency, and distributed generation. A series of Electricity Recommendations were sent to Congressional and Administration leaders following the Forum.

2003. 55 pages, ISBN#: 0-89843-389-4, $8 per copy.

U.S. Policy on Climate Change: What Next?

Following U.S. withdrawal from the Kyoto Protocol, the Aspen Institute invited a distinguished group of scientists, business leaders, and environmental experts to discuss what the U.S. should do next. The non-technical discussion papers provide useful background and innovative policy suggestions. Forum co-chairs Frank Loy, Undersecretary of State under President Clinton, and Bruce Smart, Undersecretary of Commerce under President Reagan, summarize the discussion and the Forum's conclusions in a compelling introductory essay. The group concluded that the U.S. government needs to send a signal now that carbon emissions will have a cost in the future. Editor, John A. Riggs.

2002. 200 pages, ISBN# 0-89843-344-4, $16 per copy.

Vulnerability and Resilience

The 2002 Aspen Energy Policy Forum convened at a time of heightened urgency regarding energy vulnerability and resilience. The recent California crisis, the increasing volatility of oil and gas prices, and the sudden collapse of Enron and other energy companies focused attention on the nation's enduring energy problems. In addition, the events of September 11, 2001, raised a host of new questions about the vulnerability of energy systems and moved the threat of terrorism to the top of the list of energy challenges. The Forum, chaired by former Senator J. Bennett Johnston, addressed the question of energy vulnerability and resilience in the context of four key issues: the development of the energy systems of the future; the evolving geopolitics of energy; the reduction of America's reliance on oil; and the creation of a resilient electricity industry. Rapporteur, Paul Runci.

2002. 51 pages, ISBN# 0-89843-366-5, $8 per copy.

Dam Removal: A New Option for a New Century

This report offers a series of recommendations and practical advice to make it easier to integrate the consideration of dam removal into river management decisions, and zto evaluate fairly and, if appropriate, to implement dam removal effectively. It is the product of a two-year dialogue among a group of people who represent a wide range of interests and disciplines. The imprimatur of this diverse group, with interests that are often at odds, lends a unique weight to the wide-ranging and practical recommendations.

2002. 68 pages, ISBN# 0-89843-360-6, $12 per copy.

U.S. Policy and the Global Environment: Memos to the President

Prior to the 2000 election the Aspen Institute convened a distinguished group of leaders as a hypothetical committee to advise the new President on global environmental policy. Experts prepared this set of policy memos to tell the President, concisely and in understandable language, "what he should know" and "what he should do" about climate change, biodiversity, population, oceans, water, food and agriculture, and other problems. A thematic summary of the group's conclusions, written by co-chairs Donald Kennedy of Stanford University and Roger Sant of the AES Corporation, communicates the urgency of the challenges, the complexity of the interrelated issues, and the optimism necessary to tackle them. Editors, Donald Kennedy and John A. Riggs.

2000. 220 pages, ISBN#0-89843-303-7, $16 per copy.

The Mexico-US Border Environment and Economy: A Call to Action to Make the Mexico-US Border Region a Model of Bi-National Cooperation for Sustainability

Co-sponsored by the Aspen Institute Program on Energy, the Environment and the Economy, and the Leadership for Environment and Development (LEAD), Mexico, participants in the Mexico-US Border Dialogue convened in Aspen in October 1999. In this report, available in English or Spanish, the group calls on then-Presidents Zedillo and Clinton as well as the 2000 presidential candidates in both Mexico and the U.S. to take major bi-national action necessary to ensure the environmental and economic health of the border region.

2000. 159 pages, ISBN# 0-89843-287-3, $8 per copy.

With All Deliberate Speed: Electricity Restructuring in Asia

The 1999 Pacific Rim Energy Workshop was held in Kanagawa, Japan, co-sponsored and hosted by The Asia-Pacific Energy

Research Centre (APERC), the energy research arm of the Asia Pacific Economic Council (APEC). Representatives of 17 countries or economies discussed electricity restructuring and fuels trade in the region. This report of the meeting concludes that the theoretical and observed benefits or deregulation are quite powerful, but there are concerns about the impacts of making the transition from national monopoly systems to deregulated or privatized systems. Moderator and rapporteur, Loren Cox.

1999. 23 pages, ISBN#0-89843-278-2, $8 per copy.

Uncovering Value: Integrating Environmental and Financial Performance

A potentially powerful trend is developing in the business and financial world. By learning to "value the environment," companies and financial institutions are uncovering another competitive edge. As communication of the business value of environmental considerations improves in quality and quantity, market forces will increasingly drive environmental progress and environmental opportunities will more directly drive strategic business planning.

1998. 37 pages, ISBN# 0-89843-254-5, $8 per copy.

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