National Energy Modeling System/*Annual Energy Outlook* Conference Summary - March 21, 2000

This paper presents a summary of the eighth annual National Energy Modeling System/Annual Energy Outlook conference held on March 21, 2000. The remarks for each speaker were summarized by the session moderators and are not intended to serve as transcripts of the sessions. The comments and opinions of speakers outside the Energy Information Administration (EIA) are their own and do not necessarily reflect the views of EIA. Sessions are planned to have a balanced range of opinions and discussion in order that both EIA and the public be better informed on the issues associated with the current energy debates.

Introduction

On March 21, 2000, the Office of Integrated Analysis and Forecasting, Energy Information Administration (EIA), hosted the eighth annual National Energy Modeling System/*Annual Energy Outlook* Conference. These conferences are open to the general public and attract a wide range of participants from other Federal and State government agencies, trade associations, energy industries, private corporations, consulting firms, and academia.

Earlier National Energy Modeling System/*Annual Energy Outlook* conferences concentrated on the initial development of the National Energy Modeling System (NEMS) and the underlying model methodologies and on the results of the first *Annual Energy Outlook* developed using NEMS. Recent conferences have focussed less on specific projections and model developments and more on energy issues, key analytical assumptions, and their potential impacts on energy markets.

Keynote Address: Microeconomic Analysis of Technological Change: Implications for Climate Change Assessment Models

Robert N. Stavins
Albert Pratt Professor of Business and Government and Faculty Chair, Environment and Natural Resources Program, John F. Kennedy School of Government, Harvard University

Integrated assessment models are used to simulate policy-economy-environment interfaces, such as those associated with the efficacy and cost of reducing anthropogenic sources of greenhouse gas emissions. The interactions among government policies, the level of emissions, and the resultant economic impacts occur over a long time horizon—on the order of 50 years. Therefore, it is crucial that the integrated assessment models that are used to inform policymakers on climate issues incorporate the cumulative impact of technological change on the path of future energy-efficiency improvements and the patterns of energy use.

Frequently, integrated assessment models use an exogenous autonomous energy efficiency index (AEEI) to capture the time path of efficiency improvement. When combined with a capital stock vintaging algorithm, this approach provides some approximation to future stock characteristics. However, empirical estimates are needed of the rates of both endogenous and exogenous changes in energy efficiency that will determine the menu of technologies that will be available over time and the likely responses to policy changes. To understand the potential for public policy to affect energy efficiency, the process through which technology evolves must be considered: invention, innovation, diffusion, and product use. Both economic incentives and conventional regulations can be targeted to any of these stages but with greatly varying likelihood of success.

Jaffe and Stavins investigated technology diffusion in the context of energy efficiency by carrying out econometric analyses of the dynamic effects of energy prices and technology adoption costs on the adoption of thermal insulation technologies in new residential construction. They found that equivalent percentage cost technology adoption subsidies were consistently more effective than energy price changes in encouraging adoption. Command-and-control regulations, in the form of State building codes, appear to have little effect on technology diffusion if they are set below existing standards of practice.

The innovation process affects improvements in the characteristics of products. A curve that traces the cost versus the energy intensity of a product can be used to indicate the tradeoff between equipment cost and energy efficiency. Constructing a series of simulations makes it possible to examine the effects of energy price changes and efficiency standards on the menu of products over time. In the case of room air conditioners, it was found that a substantial amount of improvement would be described as autonomous, but significant amounts of improvement are the result of changes in energy prices and changes in standards.

The implications of these findings for integrated assessment modeling are that econometric estimates can be used to carry out dynamic simulations of the cumulative impacts of changes in relative prices and other factors on future technology invention, innovation, and diffusion, to estimate business-as-usual baselines, and to forecast the impacts of various policies. It appears that econometrically-estimated micro models of technological change can be employed within large-scale integrated assessment models, combining elasticities of energy efficiency improvement with empirical estimates of sector-specific AEEIs. However, it is left to the builders of integrated assessment models to decide.

International Energy and Carbon Trends

Moderator: Perry Lindstrom
Energy Information Administration

More than 80 percent of worldwide greenhouse gas emissions result from the burning of fossil fuels to meet global energy needs. As the world economy expands, the demand for energy will continue to rise, and increasing fossil fuel consumption to meet this demand will lead to higher emissions of greenhouse gases. This session presented an overview of the projections for energy demand and carbon emissions. Efforts to mitigate these trends through carbon sequestration in world forests were discussed as well as approaches to allow for international trading in carbon credits based on binding carbon limits in industrialized countries. Finally, a new modeling framework that would allow for analysis of various carbon policies was discussed.

Worldwide Projections of Energy Consumption and Carbon Emissions from the *International Energy Outlook*
Linda Doman, Energy Information Administration

This presentation summarized the projections in the *International Energy Outlook 2000* and highlighted the changes since the *International Energy Outlook 1999*. Much of the growth in energy consumption will come from the developing countries of the world, particularly developing Asia. Because of this growth, carbon emissions from developing countries will equal those of the industrialized world by 2010.

In 1997, world energy consumption totaled 380 quadrillion British thermal units (Btu). By 2010, it is projected to reach 500 quadrillion Btu and 608 quadrillion Btu by 2020, an increase of 60 percent relative to 1997. Increasing energy demand results in carbon emissions increasing from 6.2 billion metric tons of carbon in 1997 to 8.1 billion metric tons of carbon in 2010 and 10.0 billion metric tons of carbon by 2020. The increase in carbon emissions is slightly more than the total increase in energy consumption because coal, a high-carbon fuel, plays an important role in providing for the energy needs of developing Asia.

Land Use and Climate Change Outside the United States
Michael J. Coda, Nature Conservancy

This presentation emphasized the role of land use in climate change. According to estimates by the Nature Conservancy, deforestation contributes to about one-fourth of carbon dioxide emissions worldwide. This organization is conducting several major projects to protect forests and thereby encourage continued carbon sequestration in these forest ecosystems.

There are six principles that should be followed regarding forest sequestration projects and credits that may result from those projects. These principles include 1) measurability and verification, 2) additionality to projects that would have occurred otherwise, 3) leakage, or increased emissions elsewhere, 4) duration, a long-term net positive reduction, 5)ecosystem protection, and 6) sustainable development in the host country.

Institutional Requirements for a World Price of Carbon
Arthur Rypinski, U.S. Department of Energy, Office of Policy

In order to structure a world market for carbon credits, there is a need for a consistent set of principles. These would be embodied in an institutional framework that would allow for the exchange of credits between countries and private entities within those countries.

Article 17 of the Kyoto Protocol allows for emissions trading for the purposes of reaching the commitments under Article 3, which includes binding limits on greenhouse gas emissions. Such a trading regime would require that government-to-government transactions make or confirm those trades in the private sector. Not all governments would necessarily trade carbon credits. Within those countries that did trade, not all sources would be involved in a cap and credit scheme. Those sources that lend themselves to trading would be the "large" point sources, such as electricity generators. Other sources, perhaps the majority of the sources, would lend themselves to regulatory controls rather than market-based approaches. Most likely a mix of policies will emerge that combine emissions credits with other approaches such as fuel economy standards.

Bridging the Gap Between Top-Down and Bottom-Up Energy Models: The System for Analysis of Global Energy Markets
Ronald Earley, Energy Information Administration

EIA is developing a new international energy model to better characterize carbon policy measures and their impacts on the world economy. Such a model will need to combine top-down drivers of energy services such as gross domestic product (GDP) and population with bottom-up models that have details on energy technologies.

The goals of the new model are to develop a baseline for energy consumption and carbon emissions, determine the cost of reducing carbon emissions, and estimate the impacts of these policies on nations and regions of the world. The model will be required to support the needs of the *International Energy Outlook*, and to calibrate with NEMS to model energy markets for the United States. The model must allow for accessible policy levers and ease in using partial results from other energy and economic models.

Technology: Keeping Natural Gas Competitive

Moderator: James M. Kendell
Energy Information Administration

Over the last 20 years, remarkable technological advances have been realized in the natural gas supply industry that have significantly reduced costs and increased finding and success rates. The extent to which these advances could have been foreseen is questionable. The potential for such technological advances to continue at the same pace for the next 20 years remains to be seen. Will future research and development budgets be sufficient to fund such continued advancements? Are there other impediments to continued growth in the industry? Are gas producers chasing a moving target that is outpacing them due to depletion effects? One thing that is certain is that the technological advances that are made, or are not made, will have a significant impact on natural gas prices in the future.

The Impacts of Technological Progress on Oil and Natural Gas Exploration and Development
Dana Van Wagener, Energy Information Administration

The *Annual Energy Outlook 2000* (*AEO2000*) reference case assumptions for technological advancement in the oil and gas supply module (OGSM) of NEMS are based on historical trends from the late 1970s through 1998, with no specific technologies represented. To provide a range around these assumptions, rapid and slow technology cases were generated. Technology affects the drilling, lease equipment, and operating costs associated with getting the natural gas out of the ground, which are assumed to decline roughly 0.5 to 2 percent per year. Exploratory drilling success rates have also improved and are assumed to continue to improve at a rate of 0.5 percent per year because of technological advances. However, technology has had the most impact on new reserve discoveries, particularly in the offshore Gulf of Mexico and some deep onshore resources. Within the unconventional gas submodule of OGSM, numerous research and technology initiatives are combined into eleven specific technology groups. Variations in potential technological impacts in this segment are reflected by changing the time that hypothetical plays in currently unassessed areas become available for exploitation and their subsequent impact. For conventional sources, variations in potential technological impacts are represented by adjusting the technological parameters for the rapid and slow cases up or down by one-third of their reference case values, with no variation imposed on the associated resource base.

Drilling costs are estimated at the regional level, taking into account the separate impacts of drilling to greater depths, rig availability, the level of drilling activity, and technological progress. Technological improvement must offset the upward pressure on costs due to drilling to deeper depths, increased drilling activity, and rig constraints. More recently, average drilling costs per well have actually increased as the use of relatively new, more expensive techniques, such as horizontal drilling technology, has increased. The early part of the forecast continues this trend but, as the impact of technology compounds, the average cost eventually declines. Success rates have also improved significantly from two decades ago, resulting in fewer wells to find a given target. Since the rate of improvement has slowed over the last few years, a relatively conservative rate of improvement was incorporated. As a result, exploratory success rates do not vary much across the cases nor do they improve much throughout the projection period. The finding rate, or discoveries per well, captures the impact of technological improvement, as well as price and declining resources or depletion. In the absence of technology and price impacts, the finding rate declines reflect the natural progression of the discovery process from larger, more profitable fields to smaller, less economical ones. The more mature the region, the faster the decline. Technological improvement can offset these declines as has occurred in the past, but, given the finite resource base, technology cannot continue to completely offset the impact of declining resources.

The slow technology case, with higher costs, lower finding rates, lower success rates, and fewer available unconventional resources, results in a wellhead price that is 33 percent higher than the reference case price by 2020; however, the wellhead price is 21 percent below the reference case in the rapid technology case. Fewer wells are required to achieve the same reserve additions in the rapid technology case as in the reference case, allowing more production at lower prices. By contrast, more drilling is required in the slow technology case to achieve the reference case level of reserves, resulting in a marked increase in prices and thus decreased demand and lower production. In the slow technology case, there is a significant impact on natural gas production from unconventional sources; however, in the rapid technology case, average prices are so low that development in this area is still not economical, despite decreases in costs and increases in available resources. The analysis shows that the degree which technologies advance over the next 20 years has the potential of significantly affecting the price and production of natural gas.

Importance of Technology to Natural Gas Supply
Robert S. Boswell, Forest Oil Corporation

Forest Oil Corporation is an independent oil and gas production company with sales of $357 million in 1999, with operations in the Rocky Mountains, the Gulf offshore and onshore, and in Canada, including the Northwest Territories. The share of U.S. onshore natural gas production from independent producers has increased from 54 percent in 1993 to 65 percent in 1998. Quite a number of technological advances have been particularly beneficial in recent years, including 3-D seismic imaging, directional drilling, and subsea production systems. Future technologies that may emerge are micro-drilling technology, smart drill pipe technologies, customized 3-D processing algorithms, and neural net interpretation technology. The Gas Research Institute estimates that by 2015 technology improvements will account for about 35 percent of natural gas production and that their research and development spending for nonconventional production has paid back more than fourfold, particularly for coalbed methane. However, total spending by Government and the private sector on research and development has steadily declined since 1978 from nearly $10 billion (1996 dollars) to around $2 billion in 1998. Since the innovation and defusion period can be close to ten years, producers are currently benefitting from dollars spent in the 1970s and 1980s. While technology is extremely important to independents, they do not have research departments and must rely on collaborative research and development efforts.

Technology is only one part of the equation. Although the resource base in North America is adequate, access to the offshore and Rockies is critical. The National Petroleum Council (NPC) projects that the major contributing areas for natural gas will be the deepwater and nonconventional sources, the more challenging resources. Impediments to resource development include: generating the necessary capital investments, which is particularly difficult for independents; pipeline access to more remote areas; public policy; land access; and regulatory burdens, as well as adequate spending for research and development. Annual capital expenditures for development and drilling alone will need to increase by close to 45 percent for the industry to produce 30 trillion cubic feet by 2010, a huge jump to an industry that domestically comprises less than 1.2 percent of the economy. Limited cash flow has contributed to difficulties in generating capital outlays. While 95 percent of undiscovered oil and 40 percent of undiscovered natural gas is located on land owned by the Federal and State governments, much of this land is restricted. Not only is direct access denied, but regulatory burdens can effectively impede development. In the future, development of indigenous resources must be encouraged by opening up promising areas for exploration and development and decreasing regulatory burdens. At the same time, the economics of exploration and development must be enhanced by providing incentives for investments and access to capital, as well as providing incentives and funding for research and development expenditures, particularly for Government-administered collaborative research.

The Technology of Wishful Thinking: "A Tree Cannot Grow to the Sky"
Michael G. Webb, Kerr-McGee Corporation

Kerr-McGee is a major oil and gas producing company, with oil and gas revenues close to $1.8 billion in 1999, mainly operating in the United States and the United Kingdom. For the most part, domestic natural gas production has been flat for the last six years. The major energy forecasters have predicted an increase in natural gas demand from between 20 to 40 billion cubic feet per day above existing U.S. production by 2015. Growth is expected in all sectors, with the largest increase for electricity generation. According to the NPC, demand in the electricity generation sector is expected to more than double by 2015. Satisfying this demand will present quite a challenge to the natural gas industry.

There are five critical factors affecting U.S. natural gas supply:

- *New customers*, most significantly new combined-cycle, natural gas turbines. Those coming on line in 1999 and 2000 use natural gas at the rate of 5 to 6 billion cubic feet per day. These volumes come from a pipeline system generally not designed to throttle from 0 to 5 billion cubic feet per day in only 30 minutes.

- *Financial requirements*. Historically, the business has returned 6 to 7 percent. To attract capital, the business must provide a return that is greater than the cost of capital, 10 to 12 percent. If the return on investment is satisfactory, the workers and rigs will follow.

- *Lead-time*. If access is available, the time from drilling to production for onshore and shallow offshore wells can be up to two years and from two to fifteen years for deepwater wells. Onshore natural gas production, which is more than 70 percent of domestic supply, has been declining in most areas, and Gulf of Mexico shelf production has declined steadily since 1997. However, production in deepwater Gulf of Mexico is increasing sharply, mitigating the decline in overall Gulf production. Other factors include the rate of technology development and the issue of access to public lands and restricted areas.

- *Depletion rates*. Depletion rates have been increasing and, from 1998 to 1999 on the Gulf of Mexico shelf, were 33 percent overall and 47 percent for new wells in their first year.

- *Average discovery sizes*. Discovery size on the Gulf of Mexico shelf has dropped from 225 billion cubic feet equivalent in the 1970s to 30 billion cubic feet equivalent in the 1990s. Advances in information technology fostered the transformational technologies of 3-D seismic and horizontal drilling. All offshore fields have been shot with 3-D seismic, and visualization technologies are commonplace. All offshore exploration on the shelf and most of the deepwater play is based on 3-D seismic. Time-lapse 3-D, i.e., 4-D seismic, is being used in some new fields to monitor reservoir performance. Directional, extended-reach, and horizontal drilling have been employed everywhere economics dictate. About 60 percent of onshore fields have been shot with 3-D seismic and drilled on that data. The finding and development costs of U.S.-based independents have more than tripled over the past ten years, from about $4 to $13 per barrel of oil equivalent between 1988 and 1998, and reserves replacement costs are growing sharply from less than $2 to nearly $10 per barrel of oil equivalent between the early 1970s and 1998, in nominal dollars.

To date, technology has failed to increase domestic production and has not generally reduced finding and development costs. Technology works at the margin—reserves that were formerly found for $6 per barrel are *not* being found for $3 per barrel. Most offshore development targets down to 5 billion cubic feet have been drilled, and smaller targets with high rates yield increasingly rapid depletion. There is a unifying concern about responsible development in land access for all energy service providers. Thus, although North America has an enviable resource base, the scale of its use and the degree to which significant technologies have already been deployed place expectation ahead of supply. Technology can help but, given the extent to which it has already advanced, will be limited by the geology.

Transportation Fuels: Reduced Sulfur and Oxygenates

Moderator: Bruce Bawks
Energy Information Administration

Gasoline and diesel fuel have long dominated the highway transportation fuel market but the quality and characteristics of those fuels have been and are continuing to change. Over the next few years, reduction in sulfur content is expected for both gasoline and diesel fuel. In addition, restrictions on the use of methyl tertiary butyl ether (MTBE) have been mandated for California and are proposed for other areas of the country. This session reviewed the Environmental Protection Agency (EPA) sulfur regulations and discussed the impact of reduced sulfur and MTBE on fuel cost and supply availability.

Cleaner Cars, Cleaner Fuel, Cleaner Air: An Overview of the Tier 2/Gasoline Sulfur Final Rulemaking

Mary T. Manners, Environmental Protection Agency

The Tier 2/gasoline sulfur rule covers both vehicles and fuels and is projected to substantially lower nitrogen oxide emissions. EPA promulgated this final rule in December 1999. The corporate pool average sulfur content for all types of gasoline falls to 120 parts per million by 2004, with a refinery average of 30 parts per million starting in 2005. Gasoline produced for sale in several Western states and Alaska can be as high as 150 parts per million sulfur starting in 2004. In addition, temporary, less stringent standards are provided for small refiners, defined as refiners with fewer than 1,500 employees and a corporate crude oil capacity of less than 155,000 barrels per day. EPA's estimates of the additional cost of low-sulfur gasoline range from 1.5 cents per gallon in Petroleum Administration for Defense District (PADD) III to 2.6 cents per gallon in PADD V (excluding California), with a national average increase of 1.7 cents per gallon. The estimates are highest in PADDs I, IV, and V.

The diesel fuel proposed rulemaking should be published by late spring or early summer 2000. The current standard is 500 parts per million, and EPA is evaluating very low sulfur levels. The American Petroleum Institute (API) supports a 30-parts-per-million average with a 50-parts-per-million cap. Cost estimates for diesel desulfurization, based on a MathPro study, range from 2.7 to 6.1 cents per gallon.

EPA announced a plan to restrict or eliminate MTBE use in gasoline. The Blue Ribbon Panel had recommended that MTBE should be reduced substantially, that Congress should act to remove the oxygenate requirement for reformulated gasoline, and that EPA should seek mechanisms to ensure that no loss of current air quality benefits occurs. EPA is also studying the need for and feasibility of controlling emissions of air toxic pollutants from motor vehicles and their fuels.

Modeling Transportation Fuels Product Quality Requirements within the National Energy Modeling System
Thomas White, Energy Information Administration

The petroleum market module of NEMS is a refinery linear programming model of the U. S. market, with import supply curves to represent foreign supplies. Major inputs include product demands, the world oil price and related import supply curves, and distribution and transportation costs. Major outputs are the product prices, crude and product import levels, and refinery capacity, utilization, and investment. Gasoline is blended in a traditional gasoline pool and a reformulated gasoline pool, with specifications based on EPA's complex model but not explicitly optimized.

The *AEO2000* reference case includes the ban on MTBE in California but the Tier 2 sulfur reduction in gasoline and possible restrictions on MTBE use throughout the United States were analyzed in sensitivity cases. The sulfur reduction case assumed a decrease in sulfur content to 30 parts per million in reformulated gasoline by 2004 and 30 parts per million in traditional gasoline by 2007. New desulfurization technologies were also included in the refinery structure. The results indicated that domestic gasoline production increased initially but then declined when the full impact of the sulfur reduction began to be felt in 2006. The cost differentials amounted to about 3 to 4 cents per gallon for traditional gasoline and 5 to 6 cents per gallon for reformulated gasoline.

The MTBE restriction case assumed a limit on MTBE use of 3 percent of gasoline volume by 2003. Gasoline imports were higher than in the reference case starting in 2001 with an equivalent drop in domestic gasoline production. Traditional gasoline prices increased by nearly 2 cents per gallon in the 2005 to 2007 timeframe, and reformulated gasoline prices increased nearly 3 cents per gallon by 2003 then declined to around 2 cents per gallon in the 2005 to 2009 timeframe.

Premises Matter, Nothing but Premises Matter, and It's a Nickel a Gallon. What was the Question?
Barry D. McNutt, U. S. Department of Energy

Consumers are concerned about supply and price. Supply affects price, and price is what is important. Cost is reflected in price only in an equilibrium market. Most of the studies analyzing the impacts of sulfur restrictions assume that refiners will make the necessary investments. What if they don't? A key premise of the studies is that refiners will behave as we assume, for example, investing in the latest technologies, which may not be a reasonable assumption. The reports must be read to understand what these analyses do, not what is said about them, and the premises must be read before accepting the results.

The MathPro analysis indicated that it was more economic *not* to make up the lost volume of MTBE and investigated what level of MTBE and other oxygenates would be used in gasoline without the oxygenate standard but with a reduced sulfur requirement. It found that the model balanced at today's levels in PADDs I, II, and III. The position of the Department of Energy (DOE) is that MTBE is not overused; however, the water problems must be addressed.

One premise of many studies estimating the cost of low-sulfur gasoline is that undemonstrated technology will perform according to the manufacturer's specifications and that all refiners will use it. DOE does not agree with this premise. In the NPC study, half of the refiners use the new technologies and half use older technologies. As a result, the NPC study showed a 4.5-cents-per-gallon differential compared to 1.7 cents per gallon in the EPA study. The results depend on industry behavior. Another issue relates to the distribution systems. We are heading toward "no-sulfur" fuel. How will this be distributed? Will we need to desulfurize the other products in the distribution system to prevent contamination?

DOE estimated that it would cost 3 to 4 cents per gallon to eliminate MTBE but, if we allow some MTBE use, the cost would be cut in half. The estimates of various studies range from 0.8 cents per gallon to 4 to 6 cents per gallon. Important premises concern how the lost volume is made up and what ethanol price is assumed. Our study assumed that a higher price for ethanol, an additional 33 cents per gallon, would be needed to bring on more production. The cost differential is due entirely to the cost estimate of the price of ethanol.

Fuels: Major Changes and New Directions
Marc Meteyer, American Petroleum Institute

The industry continues to produce cleaner and cleaner fuels that, coupled with vehicle technology gains, have resulted in significant environmental gains. But major challenges are ahead in dealing with simultaneous reductions in gasoline and diesel sulfur levels, MTBE phasedown, and more stringent toxics regulations. The major challenge will be to maintain reliable and adequate supplies and to contain costs. The cost for the gasoline sulfur standards is projected to be about 5 cents per gallon; however, the most advanced desulfurization technology is not commercially proven, and costs could be higher if there are problems with the latest technology.

Sulfur levels in diesel fuel can be reduced in a cost-effective way from 500 parts per million to 50 parts per million by 2007, but more stringent reductions are not justified on a benefit/cost basis and could lead to fuel supply problems. EPA wants a 15-parts-per-million cap, but this is too difficult to attain and could cause problems such as those that happened this winter.

The root cause of the MTBE problem is the Federal mandate for oxygen content. The debate concerns the use of too much oxygenates. All oxygenates, including ethanol, are soluble in water. API is not anti-ethanol but doesn't want mandates. Repeal of the oxygen mandate, as recommended by the Blue Ribbon Panel, gives the refiners maximum flexibility in fuel production and allows for the most rapid removal of MTBE from the fuel supply. All reformulated gasoline environmental performance requirements can be met without oxygenates. API is partnering with environmental and State organizations to support Federal legislation related to the phasedown of MTBE.

Refiners are committed to producing cleaner fuels, but the industry is under intense pressure to meet numerous significant challenges at the same time. The changes will provide environmental benefits, but it is not clear what the net effect will be on cost and ability to supply the market.

Challenges in Competitive Electricity Markets

Moderator: Robert T. Eynon
Energy Information Administration

In competitive electricity markets, the pricing of electricity will be based on marginal costs. The formation of prices and the allocation of costs to customer classes is of interest to industry analysts. There is also considerable interest in the methods used to allocate transmission services in a restructured environment including mechanisms to evaluate how well electricity markets are functioning. This session explored proposed methods to characterize electricity prices. It reported on the design and operational experience of the New York independent system operator (ISO) dealing with transmission issues. The session also provided a proposed guide for monitoring market performance to determine the existence and extent of market power.

Competitive Pricing in the National Energy Modeling System

Peter C. Whitman, Energy Information Administration

As restructuring of the electricity market continues, NEMS has been modified to reflect changes in markets, including the emergence of marginal cost pricing of electricity and the changes in the relationship in the end-use sectoral prices. This has resulted in modifications to both the capacity planning and the pricing submodules of NEMS. The primary goal of the competitive pricing methodology is to reach economic equilibrium. That is, each new generator must receive sufficient revenue to cover its costs, and the older generating units that cannot recover their going-forward costs must retire. This is accomplished through a marginal cost pricing mechanism and adjustment of reserve margins to equate marginal outage costs and the marginal cost of capacity. Because the price of natural gas is the predominant factor in setting the marginal costs, three scenarios were analyzed showing the effect of three distinct natural gas price paths on electricity prices.

End-use electricity price ratios among sectors—residential, commercial, and industrial—will most likely change with competition and unbundling of the generation services. Factors in causing such a change include the responsiveness of each sector to prices, overall price levels, and the ability to reduce electricity demand through self-generation or other means. As markets mature, NEMS will be enhanced to reflect additional information that becomes available.

Market Design in the NY ISO: Issues and Performance

Paul M. Sotkiewicz, Federal Energy Regulatory Commission

The design of the New York ISO includes day-ahead and real-time energy markets with simultaneous bidding and clearing of markets for energy and ancillary services. Demand-side bidding is included in the design. Congestion is managed using nodal prices for generators and zonal prices for loads. The design provides no compensation for uninstructed excess generation. Experience from actual system operations over several months reveals increasing price inversions for ancillary services, increasing general level of prices, and substitutions of faster-response services for slower-response services. These results suggest both strategic behavior and market power problems. Congestion on the system appears to be increasing over time as well. Although there have been no price corrections in day-ahead markets, there have been numerous revisions in real-time markets due to data problems, characteristics of bid curves, and dispatching of natural gas turbines.

Market Monitoring: Approaches and Issues to Analyzing Market Performance
Russell J. Tucker, Edison Electric Institute

Federal Energy Regulatory Commission (FERC) Order 2000 requires regional transmission organizations (RTOs) to perform market monitoring. Mechanisms are needed to provide information about market performance. The information will be used to evaluate behavior of participants and to provide reports to FERC. It will also provide a framework to propose efficiency improvements, to detect design flaws, and to access market power abuses. The information would include market-clearing prices and quantities, transmission congestion, price comparisons, supply curves, and analysis of price setting, market structure, and concentration. Behavior of participants will be evaluated using information on bidding strategies, company supply curves, bidding strategy comparisons, bid changes or deviations in actual generation, and outages. A balance is needed to preclude either overly aggressive monitoring or lack of monitoring.

The Impact of Advanced Technologies on Fuel Economy and Vehicle Emissions

Moderator: Susan H. Holte
Energy Information Administration

The transportation sector is a major focus for emissions regulations, from both the vehicle and fuel perspective. While fuel economy standards have not been changed in a number of years and are unlikely to be revised in the near future, increased fuel economy, combined with advanced emission control technologies, will be key to future reductions in emissions, particularly as travel continues to grow. This session looks at the progress that has been made in advanced vehicle and emissions technologies, the prospect for future developments, the marketability of the advanced vehicles, and the barriers to their penetration.

Emerging Transportation Technologies and Advanced Technology Vehicles: The State of the Art
David M. Chien, Energy Information Administration

A number of current energy policies encourage the development and penetration of advanced and alternative-fueled vehicles, including the Energy Policy Act of 1992, low-emissions vehicle programs in New York, Massachusetts, and California, Corporate Average Fuel Economy standards, and Tier 2 emissions regulations on gasoline. In the future, regulations on diesel fuel and MTBE, programs such as the Partnership for a New Generation of Vehicles (PNGV), and policies to limit greenhouse gas emissions may also have an impact. There are significant barriers to the development and deployment of advanced technology vehicles. A number of vehicle attributes, such as acceleration, interior space, and driving range, may be less than consumers desire. Prospects for low gasoline prices and high initial costs for the advanced technology vehicles make them less attractive economically. There are also issues with infrastructure development and technical issues with some of the technologies. On the other hand, some significant cost reductions and breakthroughs have been achieved, partly driven by the programs and regulations already mentioned, and partly the result of competition from foreign markets where higher fuel prices are helping to encourage technology development.

In *AEO2000*, turbo direct injection, hybrid electric, and fuel cell vehicles are all projected to have fuel economy substantially above that of conventional gasoline vehicles. However, gasoline will remain lower in cost than most of the fuels for the advanced technologies. Other vehicle attributes are also likely to slow the penetration of the advanced vehicles. Although the initial cost of fuel cell vehicles declines significantly over the forecast horizon, all the advanced vehicle prices are considerably higher than those of conventional vehicles, with the exception of turbo direct injection vehicles. Availability of methanol and hydrogen fuels is expected to be very limited, and electric, hybrid electric, and fuel cell vehicles are likely to have reduced luggage space. Commercial availability, availability in certain size classes, and reduced vehicle range for some technologies may also present barriers to penetration. In the *AEO2000* reference case, gasoline-electric hybrid and turbo direct injection vehicles are expected to significantly gain sales for both automobiles and light trucks. In the high technology sensitivity case, which assumes further cost and performance advances for the advanced technologies relative to the reference case, diesel-electric hybrid and hydrogen fuel cell vehicles also begin to penetrate.

Tier 2 Emission Standards and Future Engine Development
David E. Foster, Engine Research Center, University of Wisconsin

The PNGV program has three major goals: 1) improve national competitiveness in manufacturing future generations of vehicles, 2) implement commercially viable innovations from research on conventional vehicles, and 3) develop vehicles by 2004 with utility comparable to conventional vehicles that achieve up to three times the efficiency of comparable family sedans, or about 80 miles per gallon, while meeting safety and emissions standards. Constraints on the successful penetration of advanced vehicles include emissions standards, consumer cost and performance requirements, and fuel economy. In the near term, advances in internal combustion engines will be used to meet the PNGV goals; however, fuel cells have the greatest potential beyond 2004. Progress is being made on direct injection engines for both gasoline and diesel fuel vehicles, as well as the technologies for the removal of emissions and particulates.

Meeting the PNGV goals is a huge challenge. Alternative energy converters are not sufficiently developed to meet the PNGV timeframe. In the near term, internal combustion engines are the candidate technology, but all will need extensive exhaust gas aftertreatment to meet the new emissions standards and will have an attendant fuel economy penalty. Even when new energy converters are developed, the total energy conversion efficiency will not be very different from a good internal combustion engine. The area of emissions reductions for high-efficiency engines is an area of very intensive research and good collaboration among government agencies, national laboratories, and industry.

Ultra-clean Vehicles: Technology Options and Emissions and Fuel Economy Policy Considerations
Andrew F. Burke, Institute of Transportation Studies, University of California, Davis

There are a number of factors driving the development of advanced technology vehicles including the California low-emissions vehicle standards, worldwide competition, the PNGV program, and concerns about greenhouse gas emissions. Significant progress has been made in achieving large reductions in emissions for internal combustion engines. For electric vehicles, there have been developments in advanced batteries, both nickel metal hydride and lithium ion. There are now some limited production and prototype hybrid electric vehicles. For fuel cell vehicles, there have been advances in the stack size, but not so much progress in fuel reformers; however, there have been some vehicle demonstrations.

Marketing issues for advanced vehicles include driving range for electric vehicles, fuel economy, cost, refueling infrastructure, consumer education, and regulations on fuel economy and emissions. In order to make the vehicles more competitive, there needs to be changes in the structure for weight reduction, in the drive line, and in the size and power of the energy storage. The various technologies have different relative marketability. Some of the more significant factors in consumer decisions are initial cost, driveability, consumer adaptability, refueling infrastructure, and financial incentives. Ranking hybrid electric, electric, hydrogen fuel cell, and reformer fuel cell vehicles, hybrid electric vehicles are the best in a cost or refueling ranking and electric vehicles in a driveability ranking. The projected marketability over the next five to ten years is hybrid electric vehicles first, followed by electric, reformer fuel cell, and hydrogen fuel cell vehicles.

In summary, there are several technology options for ultra-clean vehicles and several for improvements in fuel economy in excess of 50 percent. Emission standards remain a strong consideration, and it is possible that future standards may be structured differently than current standards, for example, looking at full fuel-cycle emissions or total greenhouse gas emissions. The selection of technology will primarily be based on efficiency, not emissions. Vehicle cost and the refueling infrastructure are the key issues for advanced vehicle marketability.

Market Potential and Market Barriers to Distributed Power Growth in the United States

Moderator: Andy S. Kydes
Energy Information Administration

Estimates of the market potential for distributed energy for heat, power, and mechanical drive vary widely as well as the estimated costs of the associated equipment, the proposed market size and attributes, and market barriers. Typically, distributed power is power generation that is located near demand centers, owned and operated either by the electric utilities or other independent operators or by end users. Utilities and independent operators of the transmission grid may install distributed generation to manage the electricity load, to increase or maintain adequate reliability, and to substitute for additional long-distance transmission lines. In this case, power generation is usually the only product. Alternatively, distributed power can be entirely owned by end users or by third parties operating the system for end users primarily to satisfy their needs using technologies such as microturbines, diesel engines, fuel cells, and combined heat, power, and mechanical drives. This session identified the market opportunities and market barriers to distributed heat, power, and mechanical drive.

Documenting Barriers to Distributed Power
R. Brent Alderfer, Competitive Utility Strategies

The barriers to the growth of distributed power can be categorized as technical interconnection, business practices, and regulatory policy. Technical interconnection barriers include the lack of interconnect standards, which the Institute of Electronic and Electrical Engineers (IEEE) is currently working to correct, and operational barriers that relate to safety and reliability. As an example of a safety issue, linemen performing repairs and maintenance of the main distribution system and working with downed power lines must be certain that the lines are really dead and not carrying distributed power. Business practice barriers include contractual requirements, such as assigning liability for damages, selective discounting to avoid bypass, other stringent business performance conditions, and utility interconnect fees. Regulatory barriers include direct utility prohibition, high exit fees, selective discounting to discourage distributed power generation, ISO procedures and costs, and tariffs, for example, high demand charges, low buy-back tariffs, and high uplift tariffs.

Although these regulatory, institutional, and market barriers are significant, the market is evolving in ways that will encourage distributed generation. For example, barriers such as the IEEE interconnect standard and some changes to regulatory practices are being resolved. It is expected that distributed generation will ultimately find a significant place in a restructured U.S. electricity market when the regulatory playing field and tariff issues have been satisfactorily resolved.

Industrial Cogeneration: ***Annual Energy Outlook 2000***
Daniel H. Skelly, Energy Information Administration

This presentation discussed EIA's projections of combined heat and power (CHP), emphasizing the outlook in the industrial sector where a new forecasting methodology was developed for *AEO2000*. EIA projects slow growth in CHP in its reference case from 2000 to 2020. Most of those additions occur in the industrial sector with about 4 gigawatts of capacity added over that period, excluding the refining sector. Slow growth in cogeneration in recent years and in the forecast is attributed to, among other factors, declining electricity prices and rising natural gas prices. These energy price trends would reduce the economic incentive for cogeneration over time because purchased electricity prices are declining, while the price of natural gas delivered to industrial users is increasing. An alternative case examined the impact of 20 percent lower installation costs and higher efficiency for cogeneration technologies. In that case, the cogeneration capacity additions from 2000 to 2020 in the industrial sector are estimated at 12 gigawatts, compared to 4 gigawatts in the reference case, excluding the refining sector. Looking at estimates of industrial CHP by major industry group, the largest projected additions occur in the paper and chemical industries. For the next version of the model, data underlying the technical potential will be updated and cost and technology improvements over time will be incorporated.

District Heating Systems: Combining Heating, Cooling, and Power to Improve Efficiency and Reduced Emissions
Mark Spurr, International District Energy Association and F.V.B. District Energy, Inc.

District energy is defined as the combination of heating, cooling, and power to improve efficiency and reduce emissions. Currently, the U.S. market includes 5,800 systems, with more than one quadrillion Btu of end-use energy served. Approximately, 16 percent of the market serves utilities, 17 percent hospitals, 16 percent military, 24 percent colleges, 8 percent industrial, and 19 percent in other facilities.

District energy systems have a competitive advantage for office/industrial parks and downtown areas. They can also be used to optimize energy use and minimize costs in new building complexes and to reduce peak power demand. The new market potential for district energy systems is estimated at 19 gigawatts by 2010 and 50 gigawatts by 2020, with almost 22 gigawatts of new electricity capacity avoided by 2010 and 57.5 gigawatts avoided by 2020. Compared to new natural gas, combined-cycle power plants, the projected energy savings are 0.3 quadrillion Btu in 2010 and 0.8 quadrillion Btu in 2020, with associated reductions in carbon emissions of 5.0 million metric tons in 2010 and 13.3 million metric tons in 2020. There are a number of structural, utility-related, and regulatory barriers to the market diffusion of district energy systems although solutions exist. Structural barriers include lack of awareness, integrated planning, high initial capital cost, and uncertainty and risk. Utility-related barriers include high exit fees, onerous interconnect standards, and high backup fees. Regulatory barriers include the fact that emissions avoided are not credited from displaced generation, the lack of output-based environmental standards, and complex and costly permitting.

Market Opportunities for CHP and Rationalized Regulations
R. Neal Elliott, American Council for an Energy Efficient Economy

Drawing a distinction between distributed generation and CHP, distributed generation is at or near the point of use. Not all CHP is distributed generation. All CHP is inherently efficient while not all distributed generation is efficient. CHP does not always include electricity because sometimes heating and cooling are provided directly through drives without the intermediate electricity generation. The CHP technologies are boilers, steam turbines, combustion turbines, reciprocating engines, and fuel cells. The current size of the CHP market is estimated at 50 gigawatts equivalent. Data not collected from most surveys on CHP include micro and small systems less than 1 megawatt, direct drive applications, systems not connected to the grid, and some new market-driven nontraditional systems. Nonelectric data are not collected. Under a new market paradigm aimed at developing integrated energy systems that emphasize low energy use, energy reliability, and low environmental impacts, the CHP potential could reach over 200 gigawatts equivalent. Some analytical issues need to be resolved, and a more complete representation of CHP is needed in integrated models, particularly in end-use markets.

Electricity Generating Technologies: Impact on Emissions Reductions

Moderator: Scott B. Sitzer
Energy Information Administration

An important factor affecting greenhouse gas and other emissions resulting from energy consumption is the characteristics of energy-consuming equipment. In the electricity sector, generating plants–which both consume and produce energy–can be fueled by a variety of sources, including fossil, nuclear, and renewables. Each type of plant has a unique set of characteristics–efficiency, fuel type, utilization rate, typical size–that determines expected emissions. The stock of generating plants, together with the demand for electricity, determines total emissions from the electricity sector. The choice of new capacity and the pattern of retirements are crucial for assessing whether or not emissions from this sector can be reduced. This session provided an overview of the major new generating technologies currently on the horizon and the prospects for market penetration. In addition, EIA speakers provided summaries of future capacity projections from *AEO2000*.

Increasing Dependence on Fossil Fuel Drives Electricity Sector Emissions

J. Alan Beamon, Energy Information Administration

Over the next 20 years the demand for electricity is expected to continue to grow. As it has over the last 20 years, the rate of growth is expected to slow relative to economic growth but grow more rapidly than other energy sources. In the *AEO2000* reference case, electricity use grows 1.4 percent annually on average, while in the high demand case it grows 2.0 percent annually. To meet consumers' needs, power companies are expected to add nearly 300 gigawatts of new capacity, or 1,000 plants, in the reference case and over 400 gigawatts, or 1,300 plants, in the high demand case. Nearly 90 percent of the new plants will be fueled by natural gas. Natural gas turbine and combined-cycle plants are the most economical options available for most uses. New coal plants play an increasing role in the latter half of the 20-year forecast period, while only a small number of new renewable facilities are expected.

Emissions from power generators, especially nitrogen oxides and carbon, will grow with the increasing dependence on fossil fuels. Sulfur dioxide emissions are expected to decline as the year 2000 cap from the Clean Air Act Amendments of 1990 (CAAA90) becomes effective although emissions will exceed the 9-million-ton cap through 2010 as companies use allowances they have banked in the first phase of the program. Nitrogen oxide emissions are also expected to decline in 2000 as a result of CAAA90; however, the decline is temporary because they are not capped. Without other action, they are expected to rebound to the current level by 2020. Carbon emissions from electricity generation are expected to rise continuously over the next 20 years. The increased use of coal in existing plants and natural gas in new plants will drive carbon emissions up as the demand for electricity grows. By 2020, they are expected to be 208 million metric tons higher than the 1998 level of 550 million metric tons, a 38-percent increase.

Central Station Renewables in the *Annual Energy Outlook 2000*
Thomas W. Petersik, Energy Information Administration

The United States is expected to maintain its reliance on fossil fuels for U.S. electricity supply through 2020, with coal, natural gas, and petroleum providing more than 80 percent of all domestic electric power. The share of renewable energy sources—conventional hydroelectricity, biomass (including biomass co-fired with coal), geothermal, landfill gas, solar photovoltaics and solar thermal, and wind—will likely remain similar to today, less than 10 percent of U.S. electricity supply. However, the mix and relative contributions of individual renewable technologies will change.

Conventional hydroelectricity will remain the dominant renewable source of U.S. electric power, but its share of all renewables will decline from 80 percent today to about 67 percent in 2020. In *AEO2000* for the first time, EIA projects a slight, about 1-percent, decline in generation from the current stock of hydroelectric capacity in response to growing environmental concerns and other water use preferences. If laws and regulations were to change to permit removal of the Snake River and other dams, hydroelectric declines could be greater than shown in the *AEO2000* reference case. Other renewables, particularly biomass (for cogeneration, landfill gas generation, and co-firing with coal), geothermal in the West, and wind, should grow more rapidly. The factors favoring these increases include the Federal production tax credit, State mandates, including renewable portfolio standards, customer and utility green power initiatives, and other programs which subsidize renewables. Solar photovoltaics, while remaining too expensive for most grid-connected electric power applications, are expected to continue to experience lower costs and expanding usage but remain very small contributors to U.S. electric power supply. By 2020, the combination of nonhydroelectric renewables is expected to provide about 3 percent of all U.S. electric power requirements.

Perspective for a Zero Emissions Coal Plant
Robert J. Wright, U.S. Department of Energy, Office of Fossil Energy

Global greenhouse gas emissions, even with carbon mitigation efforts such as the Kyoto Protocol, will continue to increase about 0.5 percent annually. There is no commitment yet from the largest of the Annex II countries to reduce their carbon emissions. Coal will continue to supply 23 percent of total energy requirements and 34 percent of total electricity generation worldwide, through 2020. In the United States, 21 gigawatts of additional coal-fired generating capacity are projected over the next 20 years. The question is how to manage carbon emissions given this background.

The Vision 21 program has as its goal reducing carbon emission rates from coal-fired technologies to about the same level as today's natural gas, combined-cycle plants. Current combined-cycle plants emit about 700 pounds of carbon dioxide (CO_2) per megawatthour of electricity. With research and development, it is believed that coal-based plants could be built that would emit between 800 and 1200 pounds of CO_2 per megawatthour, which would retain coal's competitive position even under carbon constraints. The overall goals of the program are to clean up existing power plant emissions, boost the efficiencies of new coal- and natural gas-fired plants by more than 50 percent, reduce costs, and develop a safe, economical sequestration option.

There is a large worldwide capacity potential for CO_2 sequestration–deep ocean, deep aquifers, depleted oil and gas reservoirs, and coal seams. Sequestration is already being deployed in a number of projects, including the North Sea and U.S. enhanced oil recovery sites. The cost of sequestration is currently high, more than $100 per ton of carbon equivalent. Midterm sequestration options appear to be about $50 per ton, with a long-term goal about $10 per ton, or less than 0.2 cents per kilowatthour.

The DOE sequestration research program has resulted in twelve awards in Phase I for innovative concepts, including carbon separation, ocean sequestration, and geological sequestration. Six projects have been selected for Phase II. There are also multinational projects being sponsored by the International Energy Agency. While a zero-emissions coal plant is technically feasible, there are considerable uncertainties about cost and timing. The Vision 21 goal is to find the best sequestration technology and bring down costs to make the zero-emissions plant commercially viable.

U.S. Nuclear Options and Potential
Edward Rodwell, Electric Power Research Institute

Nuclear power has significant positive elements. It is a zero-emission technology, and U.S. emissions would be reduced by choosing the nuclear option for new generating plants. It is also highly reliable, with a median U.S. capacity factor of 88 percent. Three new light-water-reactor plant designs have been certified by the Nuclear Regulatory Commission and are available for deployment. On the negative side, nuclear capacity costs 0.5 to 1.0 cents per kilowatthour more than natural gas-fired plants for new orders today. Thus, cost will constrain the extent to which nuclear power is deployed and emissions reduced. Either natural gas costs must rise or nuclear costs must fall for the technology to penetrate.

The Electric Power Research Institute's research and development program includes projects to reduce the costs of the latest light-water-reactor designs and to explore helium gas-turbine reactor technology and economic potential for commercial orders after 2010. Cost reductions for the light-water-reactor program are estimated to be 0.35 to 0.7 cents per kilowatthour, with additional research undertaken by vendors expected to drive costs down further. Thus, in the short term, the 0.5- to 1.0-cents-per-kilowatthour cost disadvantage of nuclear power can be resolved. In the longer term, the helium gas-turbine technology could reap the benefits of the additional research, as well as benefits from substantial replication cost reduction due to global nuclear deployment.

The Potential for Renewable Power Technologies to Reduce Greenhouse Gas Emissions
Eldon Boes, National Renewable Energy Laboratory

Historically, renewable energy costs have declined and renewable capacity has steadily increased. Projections from the National Renewable Energy Laboratory (NREL) show that geothermal and wind costs will become competitive with those of natural gas by 2020.

According to these projections, approximate displacement of direct energy requirements by renewable resources in 2020 include 150 billion kilowatthours for wind, 90 billion kilowatthours for biomass, 35 billion kilowatthours for geothermal, and 10 billion kilowatthours for solar photovoltaics. These levels of generation save approximately 46 million metric tons of carbon equivalent.

Deployment policies for renewables have recently emerged. Seven States currently have renewable portfolio standards, mandating a share of new generating capacity to be renewable-based. Twelve States have system benefit charge policies, which support development of renewable technologies through a fee charged to electricity consumers. Finally, the Energy Policy Act of 1992 mandated a production tax credit for wind and new closed-loop biomass capacity through June 1999, since extended through 2001, of 1.7 cents per kilowatthour. Internationally, other countries have enacted similar laws and regulations. Long-term trends, such as those envisioned in a Shell scenario through 2060, would indicate that renewable energy must eventually supply the majority of our energy requirements as traditional fossil fuels are depleted and their costs become prohibitive.

Technology Characterizations and Penetration in the Buildings Sector

Moderator: Steven H. Wade
Energy Information Administration

This session discussed some of the technology-related results for the buildings sector in NEMS for *AEO2000* and issues involved in quantifying the both historical and projected effects of building technologies on energy consumption. The three main themes for this session included: modeling technology change and the effects of technology penetration on buildings energy consumption and carbon emissions, estimating baseline energy by end use and technology, and projecting the impacts of advanced and renewable technologies.

Technology in the Residential Sector: A National Energy Modeling System Perspective
John H. Cymbalsky, Energy Information Administration

Technology in the Commercial Sector: A National Energy Modeling System Perspective
Erin E. Boedecker, Energy Information Administration

The *AEO2000* reference case includes energy savings from future technology improvements, and three sensitivity cases analyze the impacts of different technology assumptions. Delivered energy consumption in the buildings sector is about 0.9 quadrillion Btu lower in 2020 in the reference case than in a case in which future technology choices are frozen at 2000 levels. In a high technology case, which includes additional improvements in technology performance and costs as well as building shell improvements, energy consumption is reduced by 1.5 quadrillion Btu in 2020 relative to the reference case. If only the most efficient technologies within a class were selected from the high technology case regardless of cost, for example, the most efficient central air conditioner or natural gas water heater, then delivered energy consumption in 2020 would be reduced by 3.5 quadrillion Btu from the reference case. In this case, the savings nearly negate all of the energy growth in the buildings sector projected between 2000 and 2020 in the reference case. These cases illustrate the dramatic effects that technology can have on buildings energy consumption.

In the residential sector, the growth in demand from 2000 through 2020 for space heating and electronics is very similar although the average annual growth for heating is very small while electronics average more than 3.2 percent growth annually. Although the average annual growth in energy demand for personal computers is about 2 percent, the actual growth from 2000 to 2020 is relatively modest. In the commercial sector, personal computers, other office equipment (for example, copiers, faxes, and point-of-sale terminals), and other end uses (for example, telecommunications equipment, automated teller machines, and medical equipment) are the fastest growing end uses, all with average annual growth of about 2 percent, more than twice the growth rate as commercial floor space. Lighting is the biggest electricity end use in the commercial sector but has an average growth rate about one-fourth that of floor space, due to continued efficiency gains from standards and the penetration of efficient technologies such as electronic ballasts for fluorescent lighting, which is targeted by the EPA's Green Lights program and the Federal Energy Management Program.

In order to illustrate the potential impacts of equipment standards on buildings energy consumption, *AEO2000* includes cases in which it is assumed that standards are revised every eight years and the efficiency levels increased by 10 and 20 percent, when technologically feasible. Assuming the 10-percent increase in standards increases the stock efficiency of residential central air conditioners by about 20 percent by 2020. These assumed standards save more than 3 quadrillion Btu of delivered energy in the residential sector, or nearly 6.5 quadrillion Btu of primary energy, and more than 100 million metric tons of carbon emissions cumulatively through 2020. In the commercial sector, the cumulative savings from the assumed standards are about 2 quadrillion Btu of delivered energy, or nearly 5 quadrillion Btu of primary energy, and about 80 million metric tons of carbon emissions. Most of the commercial savings come from lighting, with standards for other products coming at least five years after lighting based on the assumed schedule; however, the lighting standard in *AEO2000* is about two years earlier than the now-likely implementation date.

Assessing the Wider Impacts of Federal Appliance Efficiency Standards
James E. McMahon and Julie Osborn (presenter), Lawrence Berkeley National Laboratory

Federal efficiency standards for buildings are by set by the U.S. Congress to achieve maximum energy efficiency improvements that are "technologically feasible and economically justified." Cumulatively from 1990 through 1999, these standards are estimated to have saved 3.2 quadrillion Btu of primary energy and 56 million metric tons of carbon. In addition to saving energy, the standards are estimated to have saved about $14 billion in energy, compared to about $4 billion of incremental equipment costs, for a net savings to consumers of $10 billion. The cost of the government programs over this period is estimated at about $0.2 billion.

Since technologies and their markets are dynamic, the mandated requirements include periodic updates to the standards. Currently there are six product categories under analysis for updating: commercial fluorescent lamp ballasts; heating, ventilation, and air conditioning (HVAC) and water heating equipment; residential clothes washers; water heaters; central air conditioners and heat pumps; and utility distribution transformers. The current process is designed to be as transparent as possible to interested parties with analytical tools in spreadsheets that are readily available for download from the Internet.

Issues recently aired during the proceedings include: 1) the choice of the baseline for commercial electronic ballasts since the more rapidly the market shifts toward electronic ballasts, the less the impact from the standard, 2) the wide variation in life-cycle costs for residential water heaters due to variations in energy prices and usage intensity, 3) the effects of standards on the competition between water heating fuels and equipment types, and 4) the somewhat controversial concept of a standard requiring horizontal-axis clothes washers, which save both energy and water but are unfamiliar and may not be readily accepted by consumers.

Standards have achieved significant reductions in energy and pollution, without undue burden, and the mandated updates will build on these results. Data are central to the standards-setting process, and there is a continued need for high quality data development. Finally, the use of models is also central to the process, and the use of NEMS has facilitated addressing the broader energy market effects of proposed standards.

National Energy Consumption Estimates for End Use Groups from Measured Data
James R. Brodrick, D&R International, and John D. Ryan, U.S. Department of Energy

In order to guide DOE's research, development, and deployment investment decisions in energy-efficient equipment for the buildings sector, detailed evaluations of the current, best available, and future technologies and market characteristics are necessary. Key results include an estimation of the national energy consumption for a particular end use group and suggested options to affect research, development, and deployment that will save energy.

As examples, two analyses with different approaches were presented, commercial HVAC auxiliary equipment, such as fans and pumps,[1] and televisions and videocassette recorders (VCRs) in households.[2] To estimate HVAC auxiliary equipment energy consumption, the HVAC report integrated data from a variety of sources, including field-measured energy use intensities, building simulation models, and EIA's commercial sector energy survey. The results indicate that auxiliary HVAC equipment is a significant consumer of energy, about 1.5 quadrillion Btu, larger than previously estimated. At this level, auxiliary equipment is of equal importance to energy consumption as the main HVAC equipment, indicating that opportunities for technology research, development, and deployment in this overlooked area should be evaluated.

The television and VCR study also integrated a variety of sources. This study used a sample of products with measured watt draw obtained from equipment sampled in repair shops, shipment vintaging, estimates of the stock of televisions and VCRs from EIA's residential energy survey, and hours of operation from survey data. One of the surprising findings was that televisions and

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[1] U.S. Department of Energy, *Energy Consumption Characteristics of Commercial Building HVAC Systems*, Volume II: Thermal Distribution, Auxiliary Equipment, and Ventilation, prepared by Arthur D. Little, Inc., under contract number DE-AC01-96CE23798, October 1999.

[2] Lawrence Berkeley National Laboratory, *Energy Use of Televisions and Videocassette Recorders in the U.S.*, March 1999.

VCRs consume 23 percent and 54 percent of their energy, respectively, in the "off" mode, supporting clocks and remote control powering. This also represents an opportunity to examine the costs of reducing energy consumption.

Grid-Connected Photovoltaics: Market Policies, Value and Deployment
Christy Herig, National Renewable Energy Laboratory

Photovoltaics (PV) is not a particularly new technology, and domestic commercial shipments have been tracked by EIA since 1982. Due to its current high cost relative to grid-based power from electric utilities, it has been most widely used to date in remote areas where grid extensions are costly. The Federal government, through DOE's Million Solar Roofs program, and the U.S. photovoltaic industry in its technology roadmap both have goals to increase the use of PV in domestic grid-connected applications. The roadmap goals for 2020 include domestic installations of 3.2 gigawatt peak capacity, of which about one-half is expected to be grid-connected distributed generation, one-third will be off-grid value applications, and the remaining one-sixth will be wholesale generation sold to the grid. Under the roadmap goals, projected costs to the end user are $3 per watt in 2010 and half that amount by 2020, compared to current retail costs in the range of $6 to $8 per watt.

Stimulation of PV installations will occur from funds made available from system benefit monies collected by utilities in 13 States currently and from renewable portfolio standards in eight States. There are also several other policies either in place or under consideration that should help to foster PV penetration, including net metering, or receiving the retail electricity rate for any sales to the grid, State tax incentives, low interest financing, manufacturing production incentives, green energy pricing, and municipal partnerships. A geographical analysis of breakeven turnkey costs was based on electricity rates, insolation estimates, and the package of State incentives. The top 15 States with the highest breakeven turnkey costs for PV had costs that ranged from $4 to $10 per watt. There were eight States with breakeven turnkey costs in the range of $6 to $10 per watt, indicating that if all incentives were included, PV is close to competing with traditional utility-supplied electricity in some locales today.

The Impact of Advanced Technologies on Efficiencies and Emissions in Air and Freight Transportation
Moderator: David M. Chien
Energy Information Administration

Freight trucks and aircraft accounted for approximately 10 percent of total energy consumption and 36 percent of transportation energy consumption in 1998. In 1997, almost 12 percent of carbon monoxide, 43 percent of nitrogen oxide, and 14 percent of volatile organic compounds from transportation were the result of freight trucks and aircraft. With the projected 1.4 percent annual growth rate in freight travel and 3.9 percent annual growth in aircraft travel that is projected in *AEO2000*, emissions of these criteria pollutants will only continue to grow rapidly. Advanced technologies may be able to reduce fuel consumption and emissions in the future. This session explored the state-of-the-art technologies, their potential to reduce fuel consumption and emissions, and the factors which contribute to the penetration of these technologies.

Aircraft Technology and Its Relation To Fuel Consumption and Emissions
Duc H. Le, Energy Information Administration

Options to reduce fuel use and emissions from aircraft include reduction of air travel, improvement of air traffic management and operational practices, substitution of alternative-fuels or advanced reformulated jet fuels, and efficiency improvements for both aircraft and engine technologies. Among the potential aircraft and engine technology options, increasing propulsion efficiency, reducing aerodynamics, and reducing airframe and engine weight are the most promising. However, strong market incentives in the form of high fuel prices will be necessary for the technologies to be adopted because of the high capital costs.

Compared to a frozen technology case in which new fuel efficiencies are held constant at the 2000 levels through 2020, the *AEO2000* reference case includes incremental fuel savings of approximately 310 trillion Btu in 2020. The high technology case, with more rapid technology improvement, includes incremental fuel savings of 673 trillion Btu in 2020 relative to the frozen technology case. Although both the reference and high technology cases have considerable fuel savings compared to the frozen technology case, total jet fuel consumption rises at an average annual rate of 3.2 percent in the reference case due to rapid growth in air travel as a result of higher levels of personal income, merchandise exports, and gross domestic product.

Potential for Emissions Reductions through Aircraft Technology Advances
Mark D. Guynn, NASA Langley Research Center

The National Science and Technology Council has stated that environmental concerns are of the utmost importance to the continued growth in future aircraft travel. Aircraft emissions will have an escalating effect on local air quality. The share of total regional nitrogen oxide emissions from aircraft is expected to almost quadruple by 2010 from current levels in Atlanta and Charlotte. Aviation is also a small but growing contributor to global carbon dioxide emissions. One of the goals of the Office of Aero-Space Technology within the National Aeronautics and Space Administration (NASA) is to reduce carbon dioxide emissions by 25 percent within 10 years (by 2007), 50 percent within 25 years (by 2022), and perhaps totally within 30 to 40 years. NASA also would like to reach the goals of reducing nitrogen oxide emissions by a factor of three within 10 years, by a factor of five within 25 years, and perhaps totally within 30 to 40 years.

The elements of NASA's technology advances concentrate on both the propulsion system and the airframe. Within the 2007 time period, propulsion advances, including a low nitrogen oxide combustor and advanced turbomachinery aerodynamics, are anticipated to reach the market. Airframe aerodynamic design methods and stitched composite wing design will assist in achieving the NASA emission goals by 2007. In order to reach the 2050 goals, fleet average efficiency would be required to more than double by 2050, which would reduce carbon dioxide emissions to 150 percent higher than 1990 level carbon emissions and nitrogen oxide emissions to 87 percent higher than the 1996 level. Therefore, near-term impacts of current research are minimal because it requires decades for these technologies to fully penetrate into the fleet. Substantial resources will be needed to convert NASA technologies into commercial products for use in new aircraft. Emissions reductions from current state-of-the-art technology are not sufficient to offset or reverse the expected growth in emissions due to rapid growth in travel demand.

Freight Truck Technology and Its Relation to Fuel Consumption and Emissions
Mark B. Friedman, Energy Information Administration

Several factors determine the rate of technology adoption in freight trucks, including the cost-effectiveness of the technology, the time the technology becomes available, and the applicability of the technology in combination with other vehicle technologies. Market penetration of advanced freight truck technologies is also based on several technology and market-related conditions that impact the level of cost-effectiveness. For example, fuel prices contribute to the value of the fuel savings from the technology and may also increase the speed of technology adoption. Certain technologies may be limited in their application to vehicle types, and therefore may only reach a maximum market share that is less than the entire market. For example, most advanced diesel engine technologies can not be applied to gasoline or gaseous engines. The magnitude of the fuel efficiency improvement from the technology also affects the level of fuel savings. One of the most important purchase criteria is the initial capital cost of the technology.

Three of the most cost-effective technologies in the *AEO2000* reference case are advanced low resistance tires, advanced heavy-duty diesel engines, and electronic engine controls. In the frozen technology case, new efficiency levels are held constant at the 2000 level of 5.7 miles per gallon through 2020; however, in the reference case the efficiency of new heavy-duty diesel freight trucks reaches 6.7 miles per gallon in 2020. An efficiency of 7.5 miles per gallon is reached in 2020 in the high technology case, which assumes that the Department of Energy, Office of Transportation Technologies achieves their program goals. Relative to the frozen technology case, reductions in fuel use are about 400 trillion Btu in the reference case and 777 trillion Btu in the high technology case in 2020.

Mack's Low Emission Engine Programs
John B. Bartel and Kenneth Murphy (presenter), Mack Trucks, Inc.

In their research and development programs, Mack Trucks, Inc., is currently developing a number of advanced technologies for freight trucks. Mack Trucks, Inc., has a comprehensive program to reduce vehicle emissions on diesel vehicles with particulate traps and advanced urea catalysts. The urea catalyst emits a fine mist of urea into the exhaust which converts the nitrogen oxides into pure nitrogen. Particulate traps are also effective at reducing emissions of large particulates but must be regenerated for continued use on the vehicle. Both technologies have the potential to significantly reduce nitrogen oxides and particulates but capital costs are high and the catalyst units very large.