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THE BUSINESS ROUNDTABLE

PRESS Release

FOR IMMEDIATE RELEASE

Contact: Laura Catalano
(202) 828-8867

BRT LAUNCHES PROGRAM TO SPEED CLIMATE CHANGE TECHNOLOGIES

Calls on government to clear a path for technology development, commercialization

Washington (July 21, 1999) – The Business Roundtable today launched two initiatives that seek to combine the power of government and business to accelerate development of technologies that will help address global climate concerns. BRT called on the government to clear a path for development and commercialization, emphasizing the vast potential of technologies and their role in addressing climate change.

"Fostering and accelerating the development and commercialization of new and breakthrough technologies is the most effective response to address concerns about climate change, even though it is clear there will be considerable time before we understand the range of potential impacts from greenhouse gases," said Robert N. Burt, chairman and CEO of FMC Corporation and chairman of BRT's Environment Task Force.

A new BRT report, *The Role of Technology in Responding to Concerns About Climate Change*, illustrates the enormous potential of fascinating technologies being developed in every sector of the economy. It also details the technological, cost, infrastructure, and market challenges that must be overcome before these technologies can be successfully brought to the marketplace.

"BRT believes the development, large-scale commercialization, and global dissemination of innovative long-term technologies will enable us to meet the world's growing environmental and energy needs," said Burt. "Breakthrough technologies that will make a real difference in climate change will not be ready overnight. We need to focus on the long-term technological developments that will enable us to realize such a difference."

The two BRT initiatives are designed to jump start this process, said Burt. The first initiative involves working with government to identify and eliminate regulatory, trade, informational, infrastructure, and other obstacles to rapid technological innovation, commercialization, and dissemination. BRT will prepare a report of its findings and offer concrete, practicable recommendations to clear the path for innovation.

Next, BRT plans to invite government, the national labs and other research institutions, as well as members of academia to partner with The Business Roundtable in hosting a summit on technology transfer in the 21st century.

The summit will serve as the kick-off to identify concrete proposals and goals. BRT will engage those in the public and private sectors to identify proposals for improving the process of technology transfer, with a focus on increasing the value and involvement of the private sector in commercializing new technologies. The goal of the summit is to reach consensus on actions to accelerate technology development and transfer. A business/government partnership can provide early input on research and technology transfer to accelerate the movement of new and emerging technologies into the market.

"It is my hope that these initiatives will chart a course that will enable the public and private sectors to harness the great potential of technology to help address our concerns about climate change," said Burt.

Senators Frank Murkowski and Chuck Hagel and Congressmen John Dingell and Ron Klink joined BRT today in releasing its study. Burt applauded work by the four distinguished legislators "who share our long-term vision for realizing the vast technological potential that exists in this country. They are working diligently here in Washington to create the strategic focus, the policy environment, the economic incentives, and the legislation necessary to realize this vision."

BRT pledged its full support for S 882, the Murkowski-Hagel-Byrd legislation that would fund a R&D program to spur development of energy-saving technologies. "We feel this legislation, if enacted, will go far in promoting and accelerating technology development," said Burt.

"The Business Roundtable is excited about the promise innovative technologies hold in helping solve our concerns about climate change, and we are deeply committed to turning this promise into reality – to make the 21st century the most environmentally conscious and prosperous we have ever seen."

For a copy of BRT's study, visit our web site at **www.brtable.org**

The Business Roundtable is an association of chief executive officers of leading corporations with a combined workforce of more than 10 million employees in the United States. The chief executives are committed to advocating public policies that foster vigorous economic growth and a dynamic global economy.

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THE BUSINESS ROUNDTABLE

FACTS-AT-A-GLANCE

BRT's Global Climate Program

Background

The Kyoto Protocol sets forth specific targets and timetables for the United States and other industrialized nations to reduce emissions of six greenhouse gases believed to cause changes in the global climate system. The agreement, which was signed by President Clinton in November 1998, calls for the United States to reduce its emissions seven percent below 1990 levels by 2008-2012, an unprecedented 41 percent reduction off projected emission levels. To place the magnitude of the United States' commitment into perspective, it is the equivalent of having to eliminate *all* current emissions from either the U.S. transportation sector, the utilities sector, both residential and commercial sources, or the industrial sector.

The seven percent reduction target will require painful choices and the timetable will give the United States little time to achieve the necessary reductions, given the constitutional obligations for ratifying the Kyoto Protocol and the subsequent lengthy domestic implementation process. The Business Roundtable opposes the agreement in its current form because it is filled with holes or "gaps" that would harm the U.S. economy without significant global environmental benefit.

In view of the potential implications of the Kyoto Protocol, BRT in early 1998 launched a series of efforts to take a thoughtful, independent view of the very complex problem of climate change. As outlined below, BRT's five-part Global Climate Program aims to help policy-makers and the public gain a better understanding of the environmental benefits and economic consequences of the Kyoto Protocol.

"The Kyoto Protocol – A Gap Analysis"

Published in June 1998, this 42-page report analyzes the Kyoto Protocol in terms of its binding restrictions on the United States, and the measures it contains to help industry meet the emission-reduction targets. The report finds the Kyoto Protocol contains major "gaps" or problems, including: immediate and significant cuts in energy use; lack of developing country participation; lack of specificity on definition of "carbon sinks;" no details on compliance and enforcement; and no details on emissions trading.

The Gap Analysis findings raise fundamental questions in the areas of science, economics, and the role of technology in responding to climate change. As a result, BRT launched the following initiatives to gain a better understanding of the issues in each of these areas.

Economic Project

This two-part project was designed to analyze the Kyoto Protocol and several issues identified in BRT's Gap Analysis that require further economic study, including a number of the "free market" mechanisms proposed by the Administration. With the aid of highly credible, independent economists and BRT member company experts, the Roundtable performed the following work.

- *Principles for the Design of an Emissions-Credit Trading System for Greenhouse Gases* – Released in June 1999, this white paper evaluates what is necessary to make the Kyoto Protocol's emissions trading mechanism work. The paper lays out three broad principles for the design of a viable trading system: confidence, liquidity, and economic viability.

- *Trade and Industry Impacts of the Kyoto Protocol* – Published in June 1999, this report by W. David Montgomery of Charles River Associates and James L. Sweeney of Stanford University analyzes the potential impacts on U.S. trade and competitiveness if industry is required to meet emission-reduction targets in the agreement.

  Key findings, which have been documented in peer-reviewed literature, include: U.S. agriculture, chemical, and other energy-intensive industries risk sales losses in the five to 10 percent range in 2010, unless developing countries are included in international emissions-permit trading; and U.S. GDP losses would exceed $60 billion per year from 2010 onward, unless full participation in global permit trading creates a level playing field.

Technology Project

This effort is a review of the role of new and emerging technologies in addressing global climate change. In June 1999, BRT released a white paper entitled *The Role of Technology in Responding to Concerns About Global Climate Change.* The paper shows that although technologies hold great promise, there is no evidence to support the belief that technologies can meet the kinds of energy and carbon-reduction goals inherent in the Kyoto Protocol. The paper examines the enormous potential of technology to improve energy and resource efficiency, points out several barriers to accelerating the emergence of new technologies, and identifies performance measures that can be applied to assure proper stewardship of taxpayer investments and subsidies. BRT makes recommendations to accelerate near-term technology and foster long-term technology development.

Scientific Forum

In October 1998, BRT sponsored the Conference on Global Climate Science to help participants and member companies better understand the scientific context in which the issue of potential climate change is being discussed. BRT issued a report earlier this year summarizing 12 global climate science presentations on the following topics: What Do We Know About Climate Science?; How Can Humans Influence Climate?; How Do We Forecast Climate?; What Limits Our Ability to Forecast Climate?; What Can We Say About the Impacts of Climate Change?; Have Humans Already Influenced Climate?; and The Link Between Policy and Science.

Education Project

BRT is in the process of developing a program to educate member company employees and the public at large about the findings of our combined initiatives to examine the Kyoto Protocol, its underlying science, and implications for the U.S. economy.

To obtain copies of these reports and white papers, visit BRT's web site at *www.brtable.org*

DRAFT

TO: Rosina, Mike, Jeff Seabright, David Gardiner
FROM: Sam Baldwin
RE: Possible Press Release per the Business Round Table Announcement
DATE: July 16, 1999

We are pleased to see the Business Round Table report, "The Role of Technology in Responding to Concerns About Global Climate Change."

We agree with the Business Round Table when they say:

- "In every sector of the economy, the long-term prospect for new and emerging technologies hol potential for greater productivity, safety, convenience, and greater energy and carbon efficiency
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- Transport: "electric drives, hybrid-electric and fuel-cell vehicles" "alternative fuels...such as et methanol, compressed natural gas, and even converting natural gas directly to ultraclean liquid Advances in biotechnology hold promise for converting biomass to fuel.
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- Fossil energy: integrated coal gasification combined cycle
- Renewables: wind, solar, geothermal, superconductors, power electronics
- Carbon sequestration, both geological and biological

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- **addressing local and regional environmental problems** such as urban air quality and region deposition.

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BUDGET	FY98 Actual	FY99 PCAST	FY99 Request	FY99 Actual	FY2000 PCAST	FY2000 Request	FY2000 Senate	F H	0
Energy Efficiency									
--Buildings R&D									
--Industry R&D									
--Transport R&D									
Energy Efficiency	430	615	617	502	690	615			
Renewable Energy R&D	294	475	389	336	585	398			
Prior Year Balances	-24		-17						
Office of Science									
Total Renewable Energy	270	475	372						
--State/local Grants									
--Other									
TOTAL Energy Efficiency and Renewable Energy									

THE BUSINESS ROUNDTABLE

Environment Task Force

The Role of Technology in Responding to Concerns About Global Climate Change

July 1999

The Business Roundtable
An Association of Chief Executive Officers Committed to Improving Public Policy

Table of Contents

EXECUTIVE SUMMARY

Technological progress is at the core of both the 20th century American success story and the 21st century's promise. American citizens and businesses have great faith in what technology can accomplish and have demonstrated the ability to realize technology's promise through imagination, hard work, and the enabling powers of a free and efficient market economy. It is vital that federal technology policy initiatives take into account the central role of the private sector in commercializing and making practical new and emerging technologies, as well as the underlying importance of a healthy economy.

In a preliminary review of the role of new and emerging technologies for addressing global climate change, The Business Roundtable (BRT) finds great promise and truly exciting opportunities. In every sector of the economy, the long-term prospect for new and emerging technologies holds the potential for greater productivity, safety, convenience, and greater energy and carbon efficiency.

Background

Essentially all proposals to address global climate change contain recommendations that address the role of new and emerging technologies that provide and use energy. The BRT believes that the deployment of more energy-efficient technologies and the development of new and breakthrough technologies constitutes the most effective response to concerns about possible changes in our climate. Nonetheless, this will not be a significant factor in meeting the targets set forth in the Kyoto Treaty.

The BRT has taken a firm position in opposition to the Kyoto Protocol in its current form because it does not include developing countries, it would have a negative impact on the U.S. economy and it would bring no significant global environmental benefit. This study identifies another major problem inherent in the Protocol's attempt to seek quick-fix solutions. In the short term, there are no technologies that make plausible the goals sought by the Kyoto Protocol. Technologies that may make a significant difference will not be commercial for a long time. The BRT believes that any effort to address climate change will need to be sustained, long-term *and* global. Further, we believe it will be some time before we understand whether the range of potential impacts from greenhouse gases will be severe or trivial. Accordingly, the BRT believes that this time should be used aggressively and sensibly to foster long-term technology advancement and commercialization.

Economic Underpinning

Technology progress depends on a healthy economy both at home and abroad. Without the financial ability to invest in R&D, undertake commercialization risks and purchase new equipment, technology progress will stall in industrial nations. Without economic growth, developing nations will not be able to purchase the preferred, new technologies. Thus, it is critical to ensure that all policies foster, not harm, the economy of the United States and all nations. A central policy tenet is that governments cannot foster private sector technology advancement by picking winners and losers. Instead, a central role for government is to ensure its policies are coordinated and consistent, and that unintended regulatory, policy and tax impediments to innovation are remedied.

The Document

The body of this paper is devoted to highlighting the kinds of dramatic changes in energy-related technologies that are on the horizon in every major sector of the U.S. economy. While important technology advancements can occur in relatively short time periods — say, just a few years — history and market realities show that it takes decades to make major changes in the infrastructure of the economy. This paper does not attempt an exhaustive list of all such possibilities in every sector of our $8 trillion economy. Rather, the paper provides a topical overview of the character and direction of progress, with an emphasis on the long term, in as much as the BRT (and others) have noted that short-term fixes are both unrealistic and economically disastrous. Not only is the future of technology at some level unknowable, especially in the long term, but an exhaustive treatment of every sector of the economy is far beyond our scope and intent. The BRT's goal is to illustrate the dramatic long-term potential that exists and to propose that this potential form the vision for any federal activities directed at reducing or changing energy use patterns in the United States. Following are some examples of emerging technologies that this paper identifies.

Technologies "On the Horizon"

- No exploration of technology progress in the 21st century would be complete without considering the impact of information technology. The "digital revolution" will likely bring pervasive and deep changes in how energy is managed and used in every sector. Not only are machines, motors, lights and equipment in general afforded "intelligence," but entire processes from design to fabrication, delivery and operation are improved by the rapidly emerging capabilities of the microprocessor and telecommunications.

- The automobile is one of the most visible technological achievements of the 20th century. Long-term research now is focused on lightweight materials, new manufacturing processes, electric drives, and hybrid-electric and fuel-cell vehicles. The fuel cell, which can convert chemical energy directly into electricity without combustion, has great long-term potential for reducing emissions from motor vehicles, including large trucks and railroad engines. In addition, new technologies may make alternative fuels viable, such as ethanol, methanol, compressed natural gas and even converting natural gas directly to ultraclean liquid fuel. Advances in biotechnology hold promise for converting biomass to fuel as well as low-cost ways to strip sulfur from diesel fuel.

- Aircraft will utilize the technology progress in ultra-strong and lightweight materials and advanced controls systems. Tantalizing prospects in emerging technologies point to the potential to reduce turbulence and wind resistance — "smart" wings — which could dramatically improve fuel efficiency. Aerodynamic technology will benefit the high-speed passenger trains of the future as well. Researchers have demonstrated that low-cost magnetic levitation brings the prospect of such superfast passenger trains nearer. Emerging technologies can reduce drag for ships through new hull designs and exotic or "smart" coatings that will boost speed and cut fuel use for the billions of tons of products shipped around the world each year.

- On the manufacturing front, the scope of emerging technologies is staggering — and highly promising — both for U.S. competitiveness and environmental progress. Logs may be cut with powerful lasers, furniture assembled with microwave dryers and coatings set with electron beams. A high-temperature plasma (18,000°F) can vaporize materials that can then be literally sprayed onto surfaces, directly depositing a coating with great efficiency and quality. Silicon wafers may be cleaned without water, using powerful ultraviolet laser light. Electron beams can sterilize food-product containers. Ion implantation can improve metal hardness so that equipment lasts longer. Superefficient chemical processes are emerging based on the use of microwaves and lasers rather than thermal energy. Laser "scissors" can marry computer-driven systems to efficiently make custom shapes for textiles and allow rapid, affordable made-to-order-and-fit clothing, saving money, inventory and materials. In the long term, the idea of "desktop manufacturing" could emerge for complex components based on successful pilot projects today that use computers integrated with powerful lasers and powder metals.

- The technology revolution embraces agriculture through developments in biotechnology, information technology and radically new technologies for fertilizing. Biotechnology holds the promise for increasing crop yield, reducing spoilage, and reducing both fertilizer and water with new generations of crops — all of which reduce energy use and emissions. Aquaculture is another emerging area and includes both ocean- and land-based "farming" of crops and fish.

- America's businesses, schools, governments, factories and hospitals are housed in millions of buildings. Emerging building technologies that first appear in the commercial sector frequently show up in residential building designs as costs drop. Already computer-aided design makes it far easier to achieve efficient designs. New "smart" windows that can match changing heating conditions are in the development phase. Practical, small, self-contained combined heat and power systems, both microturbines and fuel cells, are on the horizon. Advanced building control systems that use cybernetic systems (smart controllers and fuzzy logic) will enable optimal energy usage, storage, production, purchase and sale for buildings by responding to local climate and weather conditions as well as energy prices. Advances also continue in lighting systems, and new light "engines" combined with fiber optics may illuminate an entire building from a single ultraefficient light source.

- Conventional and unconventional electricity generating systems will benefit from emerging technologies. New materials will increase efficiencies for mines, wells, pipelines and power plants. Next generation nuclear plant designs could bring a renaissance to the nation's largest noncarbon energy source. Advanced coal technologies, such as pressurized fluidized bed combustion, advanced supercritical and integrated coal gasification combined cycle, will boost efficiencies. New chemical and biotechnologies promise ultraclean fossil fuels and can make the fuels needed for fuel cells, another emerging source of electricity. Advances in materials science and control systems will bring down costs for wind, solar and geothermal sources of electricity. And scientists will continue to move ever closer to unraveling the challenges of practical fusion energy. New materials and technologies in high-power electronics, neural networks and superconductors promise a virtual revolution in electricity distribution.

- Technology also will bring advances to mechanisms for "carbon sequestration" — removing carbon from the earth's atmosphere or the systems that produce carbon emissions. In the long term, carbon sequestration technologies in agricultural, geological and physical removal or "scrubbing" all hold potential. Biotechnology may play a particularly important long-term role by enhancing future biomass growth both on land and in the ocean, or by using engineering bacteria to directly convert combustion exhaust or atmospheric carbon dioxide into fertilizer or fuel.

Key Conclusions

Our conclusions are presented in the form of answers to four key questions.

1. Must technology be part of a solution to our concerns about global climate change?

Yes. Long-term technologies in every sector hold enormous potential to improve energy and resource efficiency while also bringing important gains in such key areas as productivity, safety, convenience and competitiveness. These opportunities can only be realized in the long term because of the nascent and unproven nature of new technologies, the inherent time-to-commercialization cycles for radically new technologies, the ability of businesses and consumers to adopt them, and the nature of capital formation and investment.

Fostering and accelerating the emergence of new and breakthrough technologies is the most effective response to those concerns. It requires a clear understanding of the appropriate roles for the government and private sector in basic research, technology demonstration and technology deployment.

2. What are the barriers to accelerating the emergence of new technologies?

A set of relatively well-defined but complex barriers exist in four central areas:

- Market-oriented factors in setting priorities for basic federal research funding;
- Mechanisms to advance public/private applied research partnerships while protecting commercial interests;
- Issues relating to cost and risk sharing at the pre-commercial phase;
- Regulatory conflicts, hidden disincentives in such areas as the tax code and related issues that can discourage or impede commercialization.

3. What performance measures can be applied to ensure proper stewardship of taxpayer investments and subsidies?

Federal research and technology activities need to incorporate both long-term policy objectives and a framework that takes into account realistic characteristics of businesses, markets and consumers. A primary objective should be to incorporate a high degree of accountability for the use of taxpayer funds.

4. *Is technology a viable solution for meeting the emissions reductions mandated by the Kyoto Protocol?*

Not in the timeframe envisioned in the Kyoto Protocol. While often valuable for other reasons, there is no evidence to support the belief that technologies can meet the kinds of energy and carbon goals inherent in the Kyoto Protocol. Technology and innovation simply cannot be mandated. The Kyoto Protocol provides neither the time nor the appropriate policy environment to develop, commercialize on a large scale and disseminate worldwide the innovation energy technologies that would be needed to make such large reductions in greenhouse gas emissions without serious harm to the world's economy. (See also The American Society of Mechanical Engineers' February 1999 General Position Paper, "Technology Implications for the U.S. of the Kyoto Protocol Carbon Emissions Goals.")

Key Observations and Recommendations for Action

The BRT has identified two key premises relating to short- and long-term technology advancement as well as four related proposals for action.

Near-Term Technology Acceleration

The BRT believes that there may be potential for additional or more rapid implementation of near-term energy-efficient technologies, both domestically and internationally, that can modestly reduce carbon emissions. The BRT notes the following premise and proposes a related action item.

Premise #1

Government barriers can unintentionally impede efficient investment.

Proposal #1

The BRT will undertake a study to identify specific problems and opportunities to remove government barriers.

Long-Term Technology Fostering

Long-term technology progress is key to both public and private economic and environmental planning. The BRT believes there are refinements or additions to current initiatives that could play an important role in accelerating the emergence of technologies relevant to global climate change issues. The BRT notes the following premise and proposes a related action item.

Premise #2

Technology transfer and public/private partnerships can be improved, which will accelerate the movement of new and emerging technologies into the market.

Proposal #2

The BRT will create and host a national summit on technology transfer in the 21st century. The purpose of the summit will be to engage those in the public and private sectors to identify concrete proposals for improving the process of technology transfer with a focus on increasing the value and involvement of the private sector in commercializing new technologies.

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WEDNESDAY, JULY 21

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tionable calls prompted a chorus of complaints from fans, players and owners. Using less-experienced umpires could damp baseball's recent recovery from the 1994 player strike. "It's not a good time for baseball to have a confrontation," said Brandon Steiner, president of Steiner Sports Marketing in New York.

The umpires have been fighting with Major League Baseball over a series of disputes ranging from compensation to their authority in games. Many umpires were also upset when an umpire was suspended for bumping a player earlier this season. At present, 57 of the league's 68 umpires have faxed letters of resignation to the league, which are meant to take effect on Sept. 2.

But the league's tough stance may be having an impact. Since last week, several umpires have backtracked and tried to rescind their resignation letters, according to league officials.

NBC's Schiavone Quits Network After 26 Years

By a WALL STREET JOURNAL Staff Reporter

NEW YORK—Nicholas P. Schiavone, NBC's senior vice president of research, said he is leaving the television network after 26 years.

Mr. Schiavone, among the television industry's top numbers-crunchers, said he will be leaving the General Electric Co. unit in October. Mr. Schiavone, 50 years old, is credited with helping NBC shape its coverage of the Olympics to focus more on human-interest stories, and led the network's efforts to pursue an alternative to Nielsen Media Research.

In May, NBC reorganized its research division, bringing in a veteran of Walt Disney Co.'s ABC to run its research operations.

Business Roundtable Embraces Attempts To Curb Warming

* * *

CEOs Seek National Summit To Discuss Ways of Using Energy-Saving Devices

By JOHN J. FIALKA
Staff Reporter of THE WALL STREET JOURNAL

WASHINGTON — Citing "dramatic" changes in energy-related technology that can help U.S. industry curb global warming, the Business Roundtable is calling for a national summit on how business and government might speed the development and use of energy-efficient devices.

The Roundtable, which represents chief executives of more than 200 of the largest U.S. companies, will issue the results of a survey of its members today on Capitol Hill. It said "long term technologies in every sector hold enormous potential" to help combat climate change.

These include: automobiles able to travel 80 miles on a gallon of gas, fuel made from waste products, and special laser beams that cut logs and shape textiles. Most would lessen climatic change by generating less carbon dioxide and other gases. Such gases are thought to be artificially warming the earth's atmosphere by trapping more of the sun's heat—the so-called greenhouse effect.

Robert N. Burt, chairman of the FMC Corp. and head of a Roundtable task force on the environment, said the group believes many of the new technologies make good business sense because they will cut production costs. "The fact that it will help us prepare for reducing climate change is like frosting on the cake." Previously the group has stressed that moves to curb emissions might wreck the booming U.S. economy.

Mr. Burt said the group remains opposed to U.S. ratification of the Kyoto treaty on climate change because the survey indicates that most of the technology will take two decades or more to get into common use. The Kyoto treaty calls for industrial nations to begin cutting emissions between 2008 and 2012.

Roger S. Ballentine, who handles climate-change issues for the White House, said the Clinton administration regards the Roundtable survey as a positive step because it supports many aspects of the president's five-year, $6.5 billion budget request to accelerate government research into energy-efficient technology. "These are programs that just make sense. The fact that the Roundtable has just proposed this from a business perspective is heartening," he said.

Republicans on Capitol Hill have stymied the Clinton package, calling it a "backdoor attempt" to gain ratification for the Kyoto treaty. Mr. Burt said that while there may be some "similarities" with its new survey report, the Roundtable has taken no formal position on the Clinton proposals. Members of the group remain deeply split over emissions trading and other incentives offered by the treaty to help create markets for energy-saving technology, he said.

He said the Roundtable wants to help sponsor a national summit on ways to speed the transfer and use of new technology after the 2000 election. "We need a more stable, bipartisan environment on this. It may be a difficult thing to do."

Fred Krupp, president of the Environmental Defense Fund, a New York environmental group, called the Roundtable's latest stance "hypocritical" because it opposes the treaty while asking for government aid.

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Letters to the Editor

Biotech Products Are Rigidly Tested

The July 13 Letter to the Editor "Genetic Engineering is Not Crossbreeding" is accurate in only one respect: Biotechnology differs from crossbreeding in that one gene is inserted into an organism to achieve the desired effect. With traditional crossbreeding, every gene of an organism is potentially mixed with another. The one desirable trait that breeders want can be passed on, but so will some undesirable ones.

With biotechnology, scientists are able to focus on the desired gene and subject it to extensive testing before and after it is inserted into the new organism. Three federal agencies—the Environmental Protection Agency, the Food and Drug Administration and the Department of Agriculture—review a full battery of studies as the transgenic crop proceeds through development from field trial to full commercial release.

I serve as chair of an international panel of scientists formed by the Food and Agriculture Organization and the World Health Organization to construct model approaches to assess the safety of GMOs. The testing done by major U.S. biotech companies meets or exceeds those standards. Required testing, including allergy and toxicology studies, examines possible effects on human health. Other tests include examination of possible effects on mammals, birds, fish, beneficial insects, earthworms and lesser life forms. The potential to cross-pollinate with weedy relatives is also examined very closely. Potential to persist in the environment is also studied. Products are not approved for extensive test planting, much less commercial sale, unless they pass these tests.

Perhaps the writers of your July 13 Letter were not familiar with these procedures when they declared that biotech products are not adequately tested.

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and Technology
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Lincoln Neb.

Latest Moves Doom French Oil Industry

The French government's choice (article, July 7) to exercise its "golden share" to block takeovers of French oil firms by "Anglo-Saxon or American" companies effectively initiates the demise of French oil firms' economic significance in the future of oil. TotalFina SA's hostile bid for Elf Aquitaine may be the only chance for a French oil industry survival in the first half of the 21st century, but the deal as structured—or defended against—is the wrong tool aimed at the wrong target.

Elf spent "several hundred million dollars" in Kazakhistan oil reserves beginning in 1992. We noted in the Journal, Feb. 19, 1992, that a major economic impact would be to set up a top limit on oil prices by the mid-1990s, which it did for reasons the newly named four advisers to Elf don't understand. We noted in the Journal Jan. 22, 1986, that low oil prices would last "well into the future", and the 1990s saw oil @ $10 repeatedly. We are but 20% through "well into the future"; oil price wars of 1999-20... will make 1986-99 seem ... will be equally mis...

Elf's proble... its Ka...

Poverty Came to Call, Not Fame or Fortune

In regard to your June 25 page-one article on Microsoft's Encarta and its Italian edition: My father never forgave Don Ameche for playing the part of Alexander Graham Bell in the movie version of Bell's life. His strong feelings were aroused by this Italian-American actor's portrayal of an individual that he felt had cheated Antonio Meucci of his rightful honor as inventor of the telephone.

Meucci was born in Florence in 1808 and came to America in 1851. On Staten Island, he set up a candle factory. Among his workers for a time was Giuseppe Garibaldi, who later became the military head of the new republic of Italy.

In 1871, he tried to process a U.S. patent for his telephone, but lacked the funds to complete the filing process. He did succeed in filing a caveat for his "sound telegraph" on Dec. 9, 1872, which was renewed the following year.

Meucci led a hand-to-mouth existence and was in particularly dire straits when seriously injured in a Staten Island Ferry explosion that killed more than 100 passengers. His wife, Esterre, sold his experimental telephone equipment to a junk dealer for $6. Investors were nowhere to be found. Meucci turned to ... vice president of the American ... Telegraph ... of New York ...

What crime against the atmosphere could Toyota have committed worth $60 billion? That's how much the Justice Department was seeking in a lawsuit launched last week on behalf of it sister arm of the federal government, the Environmental Protection Agency.

Did Toyota dump a load of fluorocarbons into the ozone hole? Has it been feeding refried beans to the national cattle herd?

These might have been $6 million crimes or even $60 million crimes. But $60

Business World

By Holman W. Jenkins Jr.

billion? To incur that kind of sum, the offense was not against the environment but against environmentalists, namely those in charge of the California Air Resources Board, the EPA's stalking horse in matters of auto pollution.

There is no impact on clean air involved here, zero. The issue concerns what is known in common parlance as the "idiot light"—the light on the dash that from time to time mysteriously instructs the driver to "check engine" or "service engine soon."

Since 1996, when the standards known as On-board Diagnostics II were fully phased in, the American driving public has become mass-conditioned to ignore this light. What in an earlier model might have indicated a serious maintenance problem was now programmed to illuminate only on evidence of a potential problem with the emissions system.

But nobody told drivers this. That was part of the plan.

One estimate by GM suggests that 99% of new car owners can expect to see at least one false warning in their first 10,000

Environment Task Force

The Role of Technology in Responding to Concerns About Global Climate Change

A White Paper from The Business Roundtable
July 1999

Table of Contents

EXECUTIVE SUMMARY

Technological progress is at the core of both the 20th century American success story and the 21st century's promise. American citizens and businesses have great faith in what technology can accomplish and have demonstrated the ability to realize technology's promise through imagination, hard work, and the enabling powers of a free and efficient market economy. It is vital that federal technology policy initiatives take into account the central role of the private sector in commercializing and making practical new and emerging technologies, as well as the underlying importance of a healthy economy.

In a preliminary review of the role of new and emerging technologies for addressing global climate change, The Business Roundtable (BRT) finds great promise and truly exciting opportunities. In every sector of the economy, the long-term prospect for new and emerging technologies holds the potential for greater productivity, safety, convenience, and energy and carbon efficiency.

Background

Essentially all proposals to address global climate change contain recommendations that address the role of new and emerging technologies that provide and use energy. The BRT believes that the deployment of more energy-efficient technologies and the development of new and breakthrough technologies constitute the most effective responses to concerns about possible changes in our climate. Nonetheless, technology will not be a significant factor in meeting the targets set forth in the Kyoto Protocol.

The BRT has taken a firm position in opposition to the Kyoto Protocol in its current form because it does not include developing countries, would have a negative impact on the U.S. economy and would bring no significant global environmental benefit. This study identifies another major problem inherent in the Protocol's attempt to seek quick-fix solutions. In the short term, there are no technologies that make plausible the goals sought by the Kyoto Protocol. Technologies that may make a significant difference will not be commercial for a long time. The BRT believes that any effort to address climate change will need to be sustained, long-term *and* global. Further, we believe it will be some time before we understand whether the range of potential impacts from greenhouse gases will be severe or trivial. Accordingly, the

BRT believes that this time should be used aggressively and sensibly to foster long-term technology advancement and commercialization.

Economic Underpinning

Technology progress depends on a healthy economy both at home and abroad. Without the financial ability to invest in R&D, undertake commercialization risks and purchase new equipment, technology progress will stall in industrial nations. Without economic growth, developing nations will not be able to purchase the preferred, new technologies. Thus, it is critical to ensure that all policies foster, not harm, the economies of the United States and all nations. A central policy tenet is that governments cannot foster private sector technology advancement by picking winners and losers. Instead, a central role for government is to ensure its policies are coordinated and consistent and that unintended regulatory, policy and tax impediments to innovation are remedied.

The Document

The body of this paper is devoted to highlighting the kinds of dramatic changes in energy-related technologies that are on the horizon in every major sector of the U.S. economy. While important technology advancements can occur in relatively short time periods — say, in just a few years — history and market realities show that it takes decades to make major changes in the infrastructure of the economy. This paper does not attempt an exhaustive list of all such possibilities in every sector of our $8 trillion economy. Rather, the paper provides a topical overview of the character and direction of progress, with an emphasis on the long term, in as much as the BRT (and others) have noted that short-term fixes are both unrealistic and economically disastrous. Not only is the future of technology at some level unknowable, especially in the long term, but an exhaustive treatment of every sector of the economy is far beyond our scope and intent. The BRT's goal is to illustrate the dramatic long-term potential that exists and to propose that this potential form the vision for any federal activities directed at reducing or changing energy use patterns in the United States. Following are some examples of emerging technologies that this paper identifies.

Technologies "On the Horizon"

- No exploration of technology progress in the 21st century would be complete without considering the impact of information technology. The "digital revolution" likely will bring pervasive and deep changes in how energy is managed and used in every sector. Not only are machines, motors, lights and equipment in general afforded "intelligence," but entire processes from design to fabrication, delivery and operation are improved by the rapidly emerging capabilities of the microprocessor and telecommunications.
- The automobile is one of the most visible technological achievements of the 20th century. Long-term research now is focused on lightweight materials, new manufacturing processes, electric drives, and hybrid-electric and fuel-cell vehicles. The fuel cell, which can convert chemical energy directly into electricity without combustion, has great long-term potential for reducing emissions from motor vehicles, including large trucks and railroad engines. In addition, new technologies may make alternative fuels viable, such as ethanol, methanol, compressed natural gas and even natural gas that is converted directly to ultraclean liquid fuel. Advances in biotechnology hold promise for converting biomass to fuel as well as developing low-cost ways to strip sulfur from diesel fuel.
- Aircraft will utilize the technology progress in ultrastrong and lightweight materials and advanced controls systems. Tantalizing prospects in emerging technologies point to the potential to reduce turbulence and wind resistance — "smart" wings — which could improve fuel efficiency dramatically. Aerodynamic technology will benefit the high-speed passenger trains of the future as well. Researchers have demonstrated that low-cost magnetic levitation brings the prospect of such superfast passenger trains nearer. Emerging technologies can reduce drag for ships through new hull designs and exotic or "smart" coatings that will boost speed and cut fuel use for the billions of tons of products shipped around the world each year.
- On the manufacturing front, the scope of emerging technologies is staggering — and highly promising — both for U.S. competitiveness and environmental progress. Logs may be cut with powerful lasers, furniture assembled with microwave dryers and coatings set with electron beams. A high-temperature plasma (18,000°F) can vaporize materials that can then be sprayed literally onto surfaces, directly depositing a coating with great

efficiency and quality. Silicon wafers may be cleaned without water, using powerful ultraviolet laser light. Electron beams can sterilize food-product containers. Ion implantation can improve metal hardness so that equipment lasts longer. Superefficient chemical processes are emerging based on the use of microwaves and lasers rather than thermal energy. Laser "scissors" can marry computer-driven systems to make custom shapes for textiles efficiently and allow rapid, affordable, made-to-order-and-fit clothing, saving money, inventory and materials. In the long term, the idea of "desktop manufacturing" could emerge for complex components based on successful pilot projects today that use computers integrated with powerful lasers and powder metals.

- The technology revolution embraces agriculture through developments in biotechnology, information technology and radically new technologies for fertilizing. Biotechnology holds the promise for increasing crop yield, reducing spoilage, and reducing both fertilizer and water usage with new generations of crops — all of which reduce energy use and emissions. Aquaculture is another emerging area and includes both ocean- and land-based "farming" of crops and fish.
- America's businesses, schools, governments, factories and hospitals are housed in millions of buildings. Emerging building technologies that first appear in the commercial sector frequently show up in residential building designs as costs drop. Already, computer-aided design makes it far easier to achieve efficient designs. New "smart" windows that can match changing heating conditions are in the development phase. Practical, small, self-contained combined heat and power systems, both microturbines and fuel cells, are on the horizon. Advanced building control systems that use cybernetic systems (smart controllers and fuzzy logic) will enable optimal energy usage, storage, production, purchase and sale for buildings by responding to local climate and weather conditions as well as energy prices. Advances also continue in lighting systems, and new light "engines" combined with fiber optics may illuminate an entire building from a single ultraefficient light source.
- Conventional and unconventional electricity-generating systems will benefit from emerging technologies. New materials will increase efficiencies for mines, wells, pipelines and power plants. Next-generation nuclear plant designs could bring a renaissance to the nation's largest noncarbon energy

source. Advanced coal technologies, such as pressurized fluidized bed combustion, advanced supercritical and integrated coal gasification combined cycle, will boost efficiencies. New chemical and biotechnologies promise ultraclean fossil fuels and can make the fuels needed for fuel cells, another emerging source of electricity. Advances in materials science and control systems will bring down costs for wind, solar and geothermal sources of electricity. And scientists will continue to move ever closer to unraveling the challenges of practical fusion energy. New materials and technologies in high-power electronics, neural networks and superconductors promise a virtual revolution in electricity distribution.

- Technology also will bring advances to mechanisms for "carbon sequestration" — removing carbon from the earth's atmosphere or the systems that produce carbon emissions. In the long term, carbon sequestration technologies in agricultural, geological and physical removal or "scrubbing" all hold potential. Biotechnology may play a particularly important long-term role by enhancing future biomass growth both on land and in the ocean or by using engineering bacteria to convert combustion exhaust or atmospheric carbon dioxide directly into fertilizer or fuel.

Key Conclusions

Our conclusions are presented in the form of answers to four key questions.

1. Must technology be part of a solution to our concerns about global climate change?

Yes. Long-term technologies in every sector hold enormous potential to improve energy and resource efficiency while also bringing important gains in such key areas as productivity, safety, convenience and competitiveness. These opportunities can only be realized in the long term because of the nascent and unproven nature of new technologies, the inherent time-to-commercialization cycles for radically new technologies, the ability of businesses and consumers to adopt them, and the nature of capital formation and investment.

Fostering and accelerating the emergence of new and breakthrough technologies is the most effective response to those concerns. It requires a clear understanding of the appropriate roles of the government and private sector in basic research, technology demonstration and technology deployment.

2. What are the barriers to accelerating the emergence of new technologies?

A set of relatively well-defined but complex barriers exist in four central areas:

- market-oriented factors in setting priorities for basic federal research funding;
- mechanisms to advance public/private applied research partnerships while protecting commercial interests;
- issues relating to cost and risk sharing at the precommercial phase; and
- regulatory conflicts, hidden disincentives in such areas as the tax code and related issues that can discourage or impede commercialization.

3. What performance measures can be applied to ensure proper stewardship of taxpayer investments and subsidies?

Federal research and technology activities need to incorporate both long-term policy objectives and a framework that takes into account realistic characteristics of businesses, markets and consumers. A primary objective should be to incorporate a high degree of accountability for the use of taxpayer funds.

4. Is technology a viable solution for meeting the emissions reductions mandated by the Kyoto Protocol?

Not in the timeframe envisioned in the Kyoto Protocol. While technology is often valuable for other reasons, there is no evidence to support the belief that technologies can meet the kinds of energy and carbon goals inherent in the Kyoto Protocol. Technology and innovation simply cannot be mandated. The Kyoto Protocol provides neither the time nor the appropriate policy environment to develop, commercialize on a large scale and disseminate worldwide the innovative energy technologies that would be needed to make such large reductions in greenhouse-gas emissions without serious harm to the world's economy. (See also The American Society of Mechanical Engineers' February 1999 General Position Paper, "Technology Implications for the U.S. of the Kyoto Protocol Carbon Emissions Goals.")

Key Observations and Recommendations for Action

The BRT has identified two key premises relating to short- and long-term technology advancement as well as two related proposals for action.

Near-Term Technology Acceleration

The BRT believes that there may be potential for additional or more rapid implementation of near-term energy-efficient technologies, both domestically and internationally, that can reduce carbon emissions modestly. The BRT notes the following premise and proposes a related action item.

Premise #1

Government barriers can unintentionally impede efficient investment.

Proposal #1

The BRT will undertake a study to identify specific problems and opportunities to remove government barriers.

Long-Term Technology Fostering

Long-term technology progress is key to both public and private economic and environmental planning. The BRT believes there are refinements or additions to current initiatives that could play an important role in accelerating the emergence of technologies relevant to global climate change issues. The BRT notes the following premise and proposes a related action item.

Premise #2

A business/government partnership can provide early input on research and technology transfer to accelerate the movement of new and emerging technologies into the market.

Proposal #2

The BRT will invite the government to take part in a national summit on technology transfer in the 21st century. The summit will serve as the kick-off to identify concrete proposals and goals. We will engage those in the public and private sectors to identify proposals for improving the process of technology transfer with a focus on increasing the value and involvement of the private sector in commercializing new technologies.

Overview

Introduction

"Every great advance in science has issued from a new audacity of imagination."

— *The Quest for Certainty,* John Dewey,
American philosopher and educator, 1929

"A good technology must by definition be useful. It must be able to survive fierce buffeting by market forces, economic and social conditions, governmental policies, quirky timing, whims of fashion and all the vagaries of human nature and custom."

— "The Uncertainties of Technological Innovation,"
Key Technologies for the 21st Century,
150th Anniversary Issue, *Scientific American,* September 1995

The Business Roundtable (BRT) has responded to the Kyoto Protocol and has taken a firm position in opposition to that treaty in its current form. Our concerns and observations have been published previously (and can be found at www.brtable.org). We oppose the Kyoto Protocol because it seeks a quick-fix solution that is technologically implausible in the short timeframe allotted under the agreement. The agreement is filled with holes or gaps that would harm the U.S. economy and have no significant global environmental benefit.

Essentially, all proposals to address global climate change contain recommendations for advancing technologies that provide and use energy. We agree that the deployment of more energy-efficient technologies and the development of new and breakthrough technologies constitute the most effective response to concerns about possible changes in our climate. BRT member companies are firm in their resolve to work with government leaders to advance the development and dissemination of new and emerging energy-efficient technologies that address concerns about possible changes in our global climate, without harming our economy.

The subject of this paper is a preliminary exploration of the role of new and emerging technologies in addressing global climate change.

In explorations regarding advancing technology, we believe it is critical to keep in mind the reality that a strong domestic and global economy is a prerequisite for achieving all technology growth goals as well as all environmental goals. Moreover, it is paramount that a strong U.S. and global economy be maintained to make it possible to tackle this issue successfully on a global basis. Thus, regardless of the starting point for pursuing policies to accelerate new and emerging technologies, this area of public/private partnership is a challenge that requires not only imagination, but also the leadership and appropriate cooperation of both industry and government.

It takes years and millions of dollars to bring investments in new technology from the lab to the marketplace. There are no quick fixes or easy solutions. Broad-based technology development in many fields is required. Industry has to play the leading role in developing and deploying the technologies that could enable us to reduce greenhouse-gas emissions while meeting the world's growing needs for energy. The successful development, commercialization and global dissemination of new technologies requires a stable public-policy environment to encourage industry to assume the financial risks necessary to develop and commercialize technologies on a global scale. Governments have a responsibility to provide a supportive and stable environment for innovation, consistent with economic development and public-policy objectives.

Government's Role in Technology Advancement

The government can help foster and supplement private sector research by providing broad-based economic incentives without picking winners and losers. Government has a clear role in ensuring that its policy goals are coordinated and consistent and that unintended regulatory, policy and tax impediments to innovation are remedied. Government support is most effective when it is focused on long-term fundamental research and on precompetitive R&D instead of commercialization, which must be driven by the marketplace. This reality is consistent with the concept that activities directed toward global climate issues necessarily entail an approach best characterized as a marathon rather than a sprint.

Most important, government must resist the temptation to mandate a quick fix to a long-term issue. New technology does not roll off the end of an assembly line. It cannot be scheduled like a production line. Attempts to do so only increase risks, raise costs, and deter the development and commercialization of technologies that are needed and acceptable to end users.

It is critical that any government policy be consistent with market demands, consumer behavior and existing infrastructure. Technology policies must be consistent with capital turnover rates, which vary from business to business and are particularly long in infrastructure-related businesses. While it is clear that government can devise policies that may, at least in the short term, encourage the use of energy-efficient technology, these opportunities will interfere with the efficient operation of the marketplace if pursued by prescription, inappropriate inducement or coercion.

The government's efforts with regard to short-term technology advancement should be focused largely on eliminating existing political, regulatory and tax obstacles that discourage productive investment in new energy-efficient equipment and technology.

The government's role in the long term should focus on stimulating advances in basic energy technologies that have broad benefits for society. Government also should focus on enhancing technology transfer, both from the federal laboratory system to the private sector and from developed to developing nations. While governments will always have a role in relevant world trade and related diplomatic issues, experience with global trade organizations suggests it will take years — if not decades — to develop effective institutions to fund and transfer new energy technologies for addressing concerns about climate change.

Summary

The array of technologies that underpin the U.S. economy requires the production and use of energy. Virtually all global climate change proposals thus are focused on how the technologies that drive our economy use and deliver energy and have as central tenets improved energy and carbon efficiency.

Over the past 20 years, the U.S. economy has grown by $4 trillion. At the same time, national energy efficiency has improved by 30 percent — 30 percent less energy used per dollar of Gross Domestic Product (GDP). Carbon emissions per dollar of GDP also have declined by about 30 percent. Without this impressive improvement in efficiency, the U.S. economy would be consuming the equivalent of 6 billion more barrels of oil and emitting 500 million more metric tons of carbon per year.

The progress in energy efficiency over the past 20 years has occurred primarily because of investments made by industry in new technology. In order to plan effectively how to maintain and accelerate these advances in technology, especially those that can occur without punitive energy prices, we need to understand clearly what has made these efficiency improvements possible, technically and economically.

The BRT believes that government has a vital role to play in the development of new and emerging energy technologies. However, we do not believe that role should be prescriptive or dominant. It is instructive to note that total industry investment in R&D is nearly double that of the federal government and is forecast to grow more rapidly. Total 1999 industry R&D spending is forecast to grow 9 percent to $157 billion, compared with total federal R&D spending, projected to stay essentially flat at $68 billion.[1]

We believe it is important for the government to recognize clearly the difference between stimulating short-term technology investment and long-term technological progress. We believe that there are actions that government and industry can undertake in the short term to accelerate new technology investment and that there are near-term activities that could be undertaken productively to accelerate the emergence of long-term technologies. Fundamental to both is the need for our leaders to create a stable public-policy environment to encourage technology development, innovation and commercialization on both national and global scales. Economic incentives, flexible market mechanisms and the elimination of regulatory obstacles are a necessary first step toward achieving our goals for a safe environment and a sound economy.

I. Introduction

"It is a great mistake to think that the bare scientific idea is the required invention, so that it has only to be picked up and used. An intense period of imaginative design lies between. One element in the new method is just the discovery of how to set about bridging the gap between the scientific ideas and the ultimate product. It is a process of disciplined attack upon one difficulty after another."

— Alfred North Whitehead, *Science and the Modern World,* 1925

Despite the many economic and political uncertainties, frequent lack of supportive public policy and often-low consumer demand, American industry is investing in developing new energy-efficient technologies that will lower carbon emissions significantly.

The potential of both short- and long-term invention, commercialization, and diffusion of new energy technologies in all major sectors of the U.S. economy are outlined below. This effort is intended to illustrate the types of technology development being undertaken by American industry, the great potential in new long-term technologies, the hurdles that must be overcome and opportunities for public/private partnerships. Our objective is not to identify a definitive list of new technologies nor to estimate the magnitude of the energy and emissions impacts of specific technologies. Such an effort is neither possible nor productive given the great uncertainties in technology forecasting. Our objective is to illustrate the framework necessary for understanding and improving the development and commercialization of technology that is central to policy proposals associated with global climate concerns.

The productivity growth that has occurred and continues to occur in the U.S. economy comes from the "intersectoral flow" of new technologies. No single technical improvement, invention or idea accounts for the incredible commercial success of the economy or an industry. Indeed, researchers have pointed to the intersectoral flow of technologies as one of the fundamental qualities and possibly the most important characteristic of 20th century innovation. This reality highlights the need for flexibility in approaching technology advancement.

The Timeframe Issue

Federal proposals directed at accelerating near-term investment in energy efficiency technology must take into account two overriding factors. First, in terms of national carbon emissions, climate change is a long-term issue and is unlikely to be affected significantly by modest short-term actions. In this respect, we agree with the basic concept that any policies considered by the federal government should be oriented towards the long term — the idea that this issue is analogous to a marathon, not a sprint. We note for the record that this approach does not imply that nothing can be done nor that business is complacent, but rather that whatever actions are proposed should take into account realistic timeframes and economic issues. Second, from the perspective of business growth and thus national economic growth, there are substantial risks in federal policies that mandate targets, assume technology and ignore market realities.

All that being said, we recognize that businesses can overlook potentially viable opportunities for near-term replacement of equipment with more efficient equipment — often characterized as an "information gap." While we believe that the gap is relatively small when it comes to truly commercially viable, near-term technologies, to the extent that some opportunities are indeed lost, the nation loses the opportunity for practical reductions in energy use, and businesses and consumers lose the potential for energy savings.

In every sector of the economy, there are new and emerging technologies with exciting long-term potential for improving business profitability, economic growth, energy efficiency and quality of life for people in all nations. This is the focus for federal technology policy that we believe holds the greatest potential for achieving our environmental and economic goals.

The body of this paper is devoted to highlighting the kinds of dramatic changes in energy technologies that already are appearing on the horizon. This approach is intended to point to the kinds of progress that appear possible — although one cannot create an exhaustive list of all possibilities. Not only is the future of technology at some level unknowable, especially in the longer term, but an exhaustive treatment of every sector of the economy is far beyond our scope and intent. Rather, our goal is to illustrate the dramatic technological potential that exists in the long term and to propose that promotion of these opportunities form the core of any federal activities directed at reducing greenhouse gases or changing energy use patterns in the United States.

Technology transfer to foreign nations is another development that is important to U.S. business prosperity and to addressing climate change concerns cost-effectively. As with the preceding discussion of long-term technology development, we believe there is a role for government in international technology transfer. Indeed, because of the nature of international trade and diplomacy, a federal role will continue to be important in the regulatory, legal and economic policy areas.

Energy Use and Carbon Emissions Baseline

Essentially, all major proposals regarding climate change mitigation relate to the use of energy — the types of fuels used by the economy; the technologies used to obtain, refine, convert and deliver fuels; and the energy requirements of the technologies that consumers and businesses use. The focus on energy arises from the simple fact that 85 percent of the entire U.S. energy supply comes from fossil fuels, all forms of which in varying degrees lead to carbon dioxide emissions.

Total U.S. energy consumption can be allocated by sector as follows (with energy used for electricity allocated to each sector):[2]

- 28 percent transportation;
- 36 percent industrial;
- 17 percent commercial sector; and
- 18 percent residential sector.

This sectoral breakdown is used in the following section to explore future energy technologies.

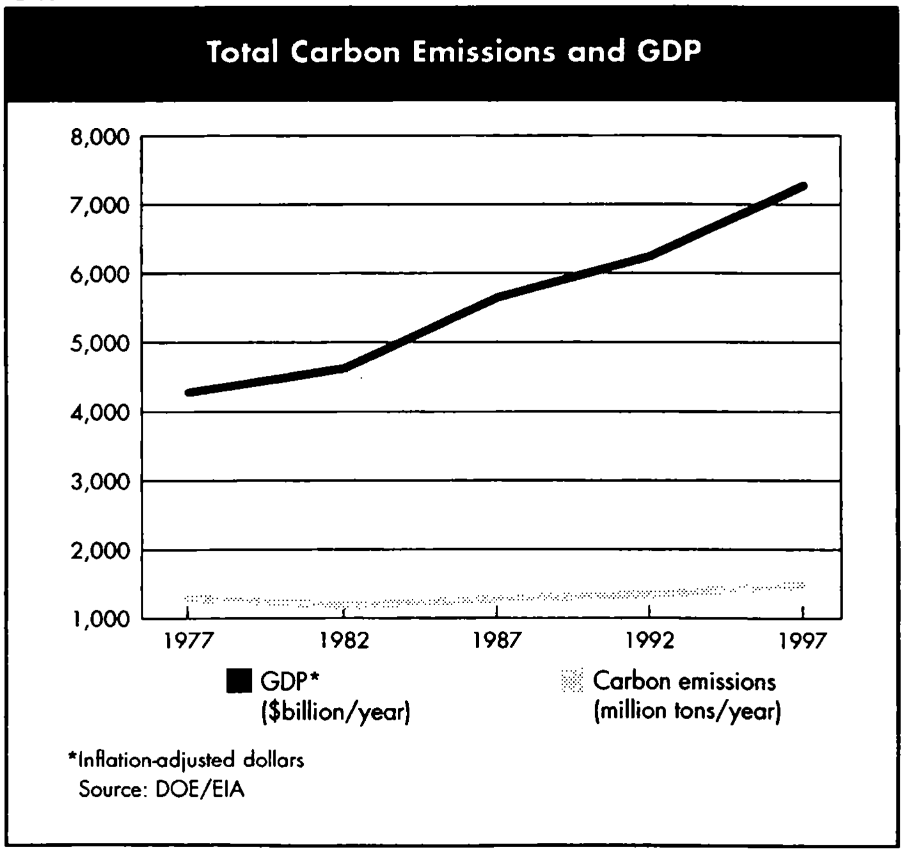
The technology progress, challenges and opportunities associated with effecting major changes in the energy infrastructure of the United States are best illustrated by considering the baseline facts visible in the trends of the past 20 years.

Over the past two decades:[3]

- The economy (GDP) grew 70 percent.
- Overall energy efficiency improved 30 percent (less energy per GDP dollar).
- Sixty-five percent of growth in energy supply came from fossil fuels: 43 percent coal and 22 percent natural gas.
- Twenty-seven percent of growth in the energy supply came from nuclear energy, accounting for essentially all nonfossil growth.
- Electricity supplied 100 percent of all net energy growth in services and manufacturing.
- Oil supplied 99 percent of all net growth in transportation energy use.
- Transport sector fuel efficiency improved 30 percent (less energy per passenger mile).

A central objective in energy efficiency and carbon reduction strategies is to improve overall carbon emissions efficiency. This allows economic growth and moderated or possibly reduced total carbon emissions growth. The trends of

Chart 1



the past two decades represent the character of trends that are desirable for the next two. Over the past two decades:

- Total carbon emissions have risen only 15 percent.
- Carbon emissions per GDP dollar have declined 34 percent.

The Role of Information Technology

Advances in information technology will impact every sector of the economy. No exploration of technology progress in the 21st century would be complete without considering the role and impact of information technology. The long-term impacts of innovation in information technology are difficult to forecast, but based on early indicators, we believe information technology likely will bring pervasive and dramatic changes in how energy can be managed and used.

Some of the information technology-related efficiencies already are visible in businesses ranging from services and manufacturing to health care, mining, paper, agriculture and transportation. Information technology's impact on energy use is manifested primarily as improvements in efficiency and reductions in waste. Not only are machines, motors, lights and equipment in general afforded "intelligence," but entire processes from design to fabrication, delivery and operation can be improved.

Modern computer-aided design and manufacturing systems (CAD/CAM) made it possible to reduce development time and cost and optimize equipment design for efficiencies in ways previously considered either too time consuming or impossible. Microprocessors embedded in smart equipment allow it to operate more efficiently and thus use less energy (or materials). Similarly, the emergence of "just-in-time" delivery of products to factories is more than a reduction in inventory expense; it also reduces the energy and materials cost associated with the production, stockpiling and often waste in inventory-based systems. The operation of motor vehicle fleets and aircraft already has been greatly enhanced by practical information systems optimizing routing, minimizing idle time and, consequently, reducing energy waste. It is also possible that the concept of future "smart" highways will lead not only to reduced congestion and greater safety but also to reductions in energy use. In every sector of business, designers and managers are finding new opportunities for efficiencies because of information technology.

While we believe the energy impacts of information technology may be significant and even revolutionary, for the purposes of this paper's exploration, we note only that this topic should be afforded additional attention and likely holds important long-term opportunities both in terms of energy use and economic prosperity.

II. Technology Development in the Transportation Sector

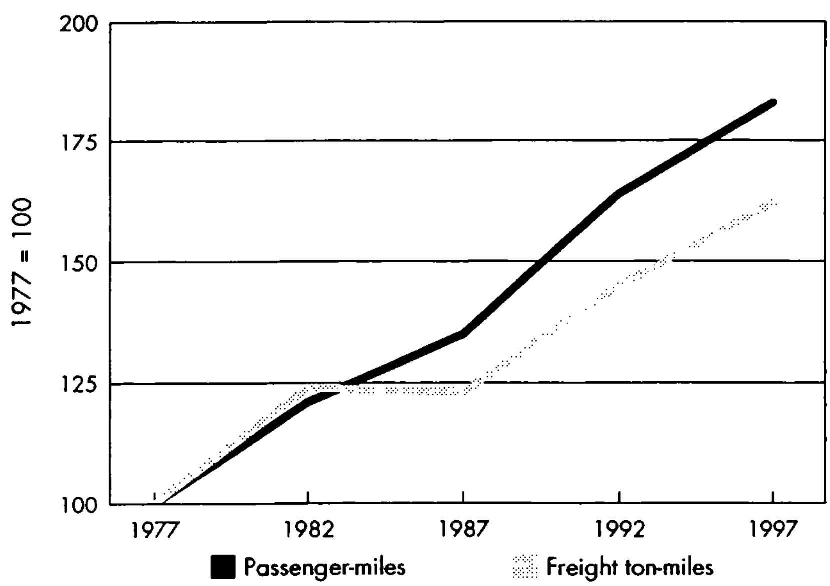
Energy Background

The transportation sector consumes 27 percent of the U.S. energy supply, of which 97 percent is delivered to market as an oil-derived product, 2.8 percent comes from natural gas (essentially all of which is used to compress and "transport" natural gas in pipelines), and 0.2 percent comes as electricity.

Because of economically driven growth in transportation use, energy demand has grown 25 percent over the past two decades even though overall fuel efficiency (energy per passenger and freight mile) has improved about 30 percent (i.e., the emissions of carbon per mile of passenger and freight traffic has declined continuously).

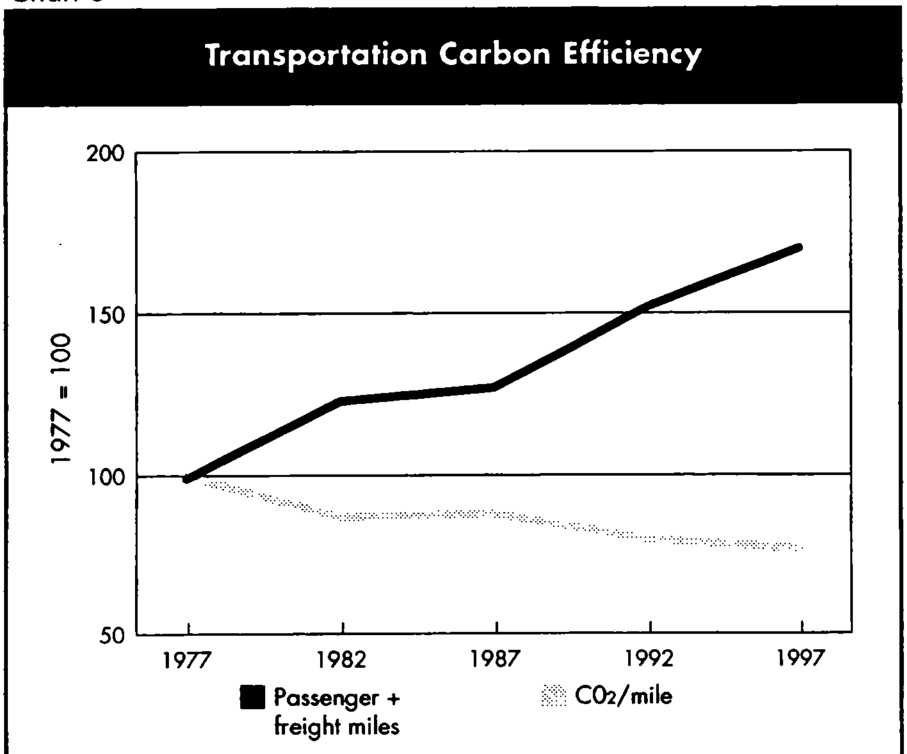
Chart 2

Transportation Trends



Sources: DOE/EIA and U.S. Census Bureau

Chart 3



Sources: DOE/EIA and U.S. Census Bureau

Motor Vehicles — Automobiles

Overview

Automobiles account for 54 percent of all transportation energy use.[4] The automobile is one of the technological developments that has defined the 20th century. In addition to serving as a force driving the development of new manufacturing techniques and industrial growth, the automobile has come to occupy a major role in both the modern economy and culture. The automobile has provided unprecedented mobility and freedom to enormous numbers of people. The combined forces of rising consumer expectations and competition have driven technology progress so that the modern automobile has achieved remarkable levels of efficiency, comfort and safety.

Today, consumer demands for affordable vehicles also include an expectation that their transportation needs are met while minimizing potential harm to the environment. Auto makers and fuel manufacturers seek to meet this challenge in the face of increasing global competition. Because of technical uncertainties, the diversity of transportation needs and driving conditions, and the heterogeneity that characterizes vehicle markets around the globe, research in the United States, Europe, Canada and Japan is proceeding on a broad array of vehicle technologies, with companion activities under way to address fuel issues.

It takes decades to develop and prove new vehicle technologies. These technologies then are assessed for costs, manufacturability, serviceability and customer acceptance. Favorable assessments lead to a production prototype that goes through several years of additional testing to ensure compliance with all safety, health and environmental standards. It then may take 10–20 years to replace a significant proportion of the 200 million vehicles on the road. Because the average life of new vehicles is around 15 years, more than half of the vehicles sold today still will be on the road in 2010.

Near-Term Technology Opportunities

Vehicle manufacturers have responded to past periods of rising fuel prices and consumer demands for improved fuel efficiency with a variety of conventional vehicle technologies. The effect has been an increase in the average fuel economy of new American cars from 14 miles per gallon in the early 1970s to 28 miles per gallon today.

Among the most important conventional vehicle technologies that have been introduced are front-wheel drive; electronic fuel injection; multivalve engines; reduced rolling resistance with the advent of radial tires; more aerodynamic designs; and electronically controlled, four-speed automatic transmissions with lockup. Reductions in weight and greater use of plastics; aluminum; and high-strength, low-alloy steel also have contributed to improved fuel economy. Further reductions in vehicle mass, improvements in aerodynamic drag, and reductions in tire rolling resistance and engine friction provide opportunities for additional gains in fuel economy.

Manufacturers face a variety of technical and economic obstacles when commercializing new vehicle technologies. Low gasoline prices in the United States limit the value of fuel savings to consumers. Indeed, low energy prices have contributed to the trend for consumers to purchase larger, heavier (and therefore safer) and more powerful vehicles with added safety, convenience and performance features that offset some of the fuel efficiency gains. Some conventional technologies also are nearing physical limits. For example, aerodynamic drag coefficients cannot be reduced much further for most vehicles without impairing serviceability.

New and Emerging Technologies

Promising advanced-conventional vehicle technologies include such technologies as direct injection, stratified-charge gasoline engines, direct-injection compression-ignition engines and continuously variable transmissions. The industry also is developing technically feasible but, to date, more costly lightweight vehicle structures using aluminum and polymer composites.

Direct-injection gasoline engines are more fuel efficient than conventional gasoline engines, but they also are more costly and have difficulty meeting nitrogen oxide (NO_x) emissions standards. Compression-ignition engines also can improve efficiency, but they too cannot meet more stringent standards for NO_x and particulate matter in the United States without the development of new fuels.

Partnership for a New Generation of Vehicles

The Partnership for a New Generation of Vehicles (PNGV) is a major basic research initiative in the U.S. motor vehicle industry. The European Union Council for Automotive Research (EUCAR) also is conducting motor vehicle research in Europe. PNGV is a joint effort of the U.S. government's national laboratories, Ford, DaimlerChrysler and General Motors to develop vehicles that achieve up to 80 miles per gallon, are mostly recyclable, accelerate from zero to 60 miles per hour in 12 seconds, accommodate six passengers, meet all safety and emissions requirements, and cost about the same as comparably sized cars today. PNGV research includes lightweight materials, manufacturing processes, electric drives, and hybrid-electric and fuel-cell vehicles. The consortium plans to unveil a concept vehicle in 2000 and a production prototype in 2004. The most promising PNGV technologies are fuel cells and hybrid-electric drive vehicles with compression-ignition, direct-injection engines.

Electric Vehicles

The first specifically designed electric car in modern times was introduced in the United States in December 1996. Manufacturers also have introduced a variety of electric vans and pickup trucks in the United States and abroad. While these vehicles represent impressive technological achievements, their high cost, limited driving range and lack of refueling infrastructure have limited sales of electric cars and trucks to about 1,000 vehicles since their introduction two years ago.

More efficient electric motors and batteries with higher specific-energy and power storage, greater longevity, and increased driving range are major technological obstacles to expanding the application of electric vehicles beyond limited niche markets. The successful development of nickel-metal hydride batteries and, in the future, lithium batteries to replace current lead-acid batteries would double the driving range of electric vehicles, but manufacturers will have to overcome significant cost and infrastructure obstacles.

Hybrid-Electric Vehicles

Technology is advancing rapidly on hybrid vehicles that combine two energy sources (e.g., a battery and an internal-combustion engine) with an electric drive train and motor. Hybrid vehicles are more efficient than conventional gasoline engines, but they also are more complex and costly with their added electric motors and drive, electronic controls, and batteries. It is technically feasible to achieve fuel economy in the 60–70 miles-per-gallon range with a hybrid using a battery and a compression-ignition, direct-injection engine. Hybrid vehicles are in limited production in some markets overseas, and some manufacturers have announced plans for limited sales in the United States next year. As with electric vehicles, the development of low-cost, high-specific power energy batteries is critical for commercialization.

Fuel-Cell Vehicles

In the long term, no technology has greater potential for reducing all emissions from motor vehicles than the fuel cell. These electrochemical devices convert chemical energy directly into electricity without combustion. With hydrogen as a stored fuel, they emit only water, and with hydrogen produced from renewable or nuclear energy sources, they could become exceptionally low-emissions vehicles.

Coupled with mass reductions and improved aerodynamics, a fuel-cell vehicle with hydrogen produced from an on-board reformer could achieve fuel economies in the 60–80 miles-per-gallon range, while vehicles using hydrogen as a stored fuel could achieve 70–85 miles per gallon. The direct use of hydrogen as a stored fuel also would avoid the added cost and weight of an on-board fuel processor, and the vehicle could operate with a smaller fuel cell. On-board storage is complicated, however, by the low density of hydrogen fuel, a number of complex safety issues, and the cost and availability of hydrogen.

Important recent advances in fuel-cell technology include improved catalysts for gasoline, methanol and ethanol, as well as nonpolluting Proton Exchange Membrane (PEM) fuel cell that can operate directly on methanol, which is the easiest on-board fuel to reform into hydrogen. Major advances in technology, huge cost reductions and new fueling infrastructure (if the hydrogen is not reformed from gasoline) are needed for widespread commercialization of fuel-cell vehicles.

Alternative Fuels

Other long-term opportunities are associated with the combined impact of new engine and fuel technologies. Alternative fuel vehicles that run on ethanol, methanol, compressed natural gas, liquefied petroleum gas or hydrogen have the potential to reduce carbon dioxide emissions compared to gasoline-driven vehicles. These vehicles are in the market today in limited production, mainly as bi-fuel vehicles that run on both alternative fuels and gasoline to overcome the current lack of refueling infrastructure for alternative fuels. The higher cost of these vehicles, limited feed stock production and lack of delivery infrastructure are major obstacles to broad commercialization.

Advances in biotechnology may hold promise for improving yields of biomass crops and enhancing chemical processes to convert biomass to fuel, thus lowering the costs of such fuels.

Another promising advance in biotechnology is biodesulfurization, which reduces the sulfur content of diesel fuel. The advantage of this technique over conventional desulfurization is in the over fourfold reduction in energy it requires.

Scientists already have conducted considerable research in converting currently wasted or flared natural gas into transportation fuels. While the basic technology for conversion has existed since World War II, recent developments and pilot projects have yielded promising results. The advantage of natural-gas-to-liquid fuels is that they convert an available, underused energy source (which is also a potent greenhouse gas) into an exceptionally clean fuel that can be burned with a high level of efficiency. The central challenge, other than cost, will be to reduce the energy required for the conversion process.

Motor Vehicles — Commercial Trucks

Overview

Trucking accounts for 17 percent of all transportation energy.[5] Heavy trucks account for 60 percent of all freight volume moved in the United States. The more than 400,000 companies operating 4 million medium- and heavy-duty trucks play an important role in the economy. The overall fuel efficiency of heavy trucks has improved more than 30 percent since 1982.[6] In addition, trucking companies have achieved energy and resource savings by using retreaded tires (approximately 1 million per year), avoiding the energy and costs associated with new tire replacement.

Near-Term Technology Opportunities

Truck manufacturers face a variety of technical and economic obstacles in commercializing improved conventional vehicle technologies. The primary areas for continued, incremental efficiency improvements will come from reduced aerodynamic drag (especially as older trucks are replaced at the end of their useful life), lower rolling resistance as tire technology advances and additional gains in basic diesel engine design. Weight reductions are possible through new materials and design techniques, but ultimately are limited by load carrying requirements.

New and Emerging Technologies

In the long term, the primary major technology change in trucking may be associated with radical new propulsion technology, especially fuel cells. The emerging practical size for early fuel cells is suitable for use in large vehicles, such as trucks and buses. The use of a fuel cell would result in large trucks becoming hybrid vehicles, in which the fuel cell's output is used to drive electric motors. Other possibilities exist regarding highly efficient microturbines that, when coupled with electric drive, permit improvements in efficiency. (Many large off-road and mining trucks and similar equipment already are hybrid, but they use diesel engines as electric generators.)

Aircraft

Overview

Commercial aviation accounts for 13 percent of all transportation energy.[7] In 1998, commercial aircraft transported approximately 1.3 billion passengers globally. Commercial aviation fuel efficiency has improved dramatically, with energy needed per passenger-mile dropping more than 50 percent from 1970 levels.[8] At the same time, commercial passenger travel (total passenger miles) has increased 50 percent in the past 10 years alone. The aviation industry continues to improve its safety record while striving to improve both passenger comfort and efficiency continuously. It is notable that some commercial aircraft are kept in service for 40 years. Thus, the overall effect of technology change incorporated into new aircraft will take many years to affect both domestic and global fleets.

Near-Term Technology Opportunities

In commercializing new technologies, the aviation industry faces exceptionally stringent entry criteria pertaining to reliability and safety. In the near-term, the most significant improvements in fuel efficiency are likely to come from operational efficiencies such as those generated by the Communication Navigation Surveillance-Air Traffic Management System (CNS-ATM). While modest weight reductions may be possible with new materials and design techniques, modern aircraft already use available, reliable, cost-effective, lightweight materials that meet regulatory requirements.

New and Emerging Technologies

The two primary areas of long-term technology improvement are new engine technologies with improved combustion efficiencies and improved materials technology. Other areas for improvements are changes in the mechanical and hydraulic systems and new ways to reduce turbulence and wind resistance. The implementation of any technology changes in aviation are held to high standards with regard to safety issues and other critical aircraft goals.

Emerging technologies include the use of lower-weight electric and information control systems to replace mechanical and hydraulic systems.[9] Long-term research points to the intriguing potential, for example, of reduced turbulence and wind resistance from the emerging field of nanotechnology, which could produce microsized flaps. Fabricated by borrowing the technologies used to make integrated circuits, microsized flaps on a wing's surface combined with turbulence sensing and control may be able to reduce wing-to-air turbulence. NASA also has explored the potential for microengineered holes on wing surfaces that could alter airflow and reduce turbulence.

Rail

Overview

Railroads account for 2 percent of all transportation energy.[10] While the transport of goods by railroad cars has not grown significantly in the past two decades, the rail system still forms a backbone in the freight system and accounts for 1.5 billion tons of goods moved each year.[11] Similarly, passenger miles by rail have remained almost unchanged for years and total only 1 percent of air passenger miles.[12]

Near-Term Technology Opportunities

Locomotives are essentially small electric power plants that drive 4,000 hp electric motors using sophisticated computer-control systems. Technology progress in motor-generator systems and electric controls in general will confer on the rail industry continued, although marginal, efficiency improvements.

Improvements in tracks and more modern, faster locomotives may prove helpful in moving people from air to rail for intercity travel of 400 miles or less, which brings the energy benefit arising from the inherent efficiency advantage of rail over aircraft.

New and Emerging Technologies

Because their size is suited ideally to the probable scale for near-term fuel cells, rail locomotives may prove the most practical test beds and early commercial adopters of fuel-cell power systems.

For passenger traffic in the future, the primary promise continues to be the potential for very high-speed, magnetically levitated rail systems. Researchers recently have demonstrated noncryogenic alternatives for magnetic levitation, which create the potential for lower costs and nearer-term implementation. With speeds approaching slow aircraft, "maglev," as the technology is known, if proven practical and economically feasible, offers the greatest potential competition for medium- and short-distance air travel in terms of time and convenience. A maglev train can achieve a per-passenger fuel efficiency that is nearly three times better than the best current passenger aircraft.[13]

Shipping

Overview

Marine fuel uses account for 6 percent of all U.S. transportation energy.[14] Ships offer enormous advantages in terms of moving large quantities of bulk materials over long distances. More than 1 billion tons of freight are moved within the domestic United States by ships on intracoastal waterways and rivers. However, the bulk of shipping is associated with international trade, and the majority of ships are foreign-owned. Thus, while ships constitute a significant source of global energy use, their use does not fall under the purview of domestic industry — except to the extent that advanced U.S. technology can be exported to nations building and operating ships. Of the 25,000 merchant ships worldwide, fewer than 500 are U.S.-registered.[15] There are another 55,000 nonmilitary ships in the world, most of which are outside of the United States, and all of which burn oil.

Near-Term Technology Opportunities

Commercializing improved combustion technologies for ship propulsion constitutes the primary area for reduced fuel use. To the extent that such technologies can be made cost-effective and are applicable as retrofits, shippers will implement them to reduce costs. Otherwise, the slow turnover rate in ships will make energy-efficiency progress slow in this area.

New and Emerging Technologies

Energy efficiency for ships is limited inherently by water resistance. Research into turbulence, one of the most challenging areas of basic science, may yet yield insights that will permit the development of coatings, materials or technology-related fixes in hull design that could improve efficiency dramatically. Entirely new designs also may be feasible. Such designs would follow on the concept for a waterjet-propelled freighter using a "semiplanning" hull that could afford large ships some of the speed and efficiency advantages of small pleasure craft. A variety of advances in chemical engineering promise new coatings for ship hulls that would reduce friction and turbulence and thus increase efficiency. Similarly, advances in chemical coatings as antifouling agents promise to reduce the inherent problem of marine life buildup on ship hulls, which increases drag.

In the long term, the primary technology changes for shipping may come from radical new propulsion technology, including advanced turbines (instead of diesel engines) and possibly fuel cells. As with the aviation industry, the shipping industry's future likely will follow important technology advancements stimulated by the needs of the military. The U.S. Navy's long-term R&D goals are directed towards exploring the "all electric" ship because of important tactical military benefits, which include greater fuel efficiency.

III. TECHNOLOGY DEVELOPMENT IN THE INDUSTRIAL SECTOR

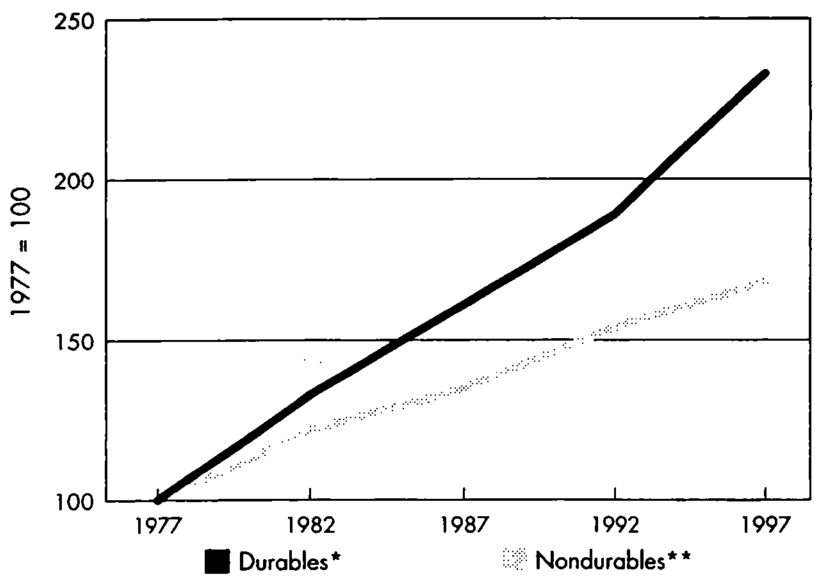
Energy Background

The industrial sector consumes 36 percent of the U.S. energy supply, of which 66 percent is combustible fuel (roughly equal shares of natural gas and oil), and 33 percent comes from electricity. Over the past two decades, overall industrial sector energy use has risen a modest 4 percent, even as total output has grown dramatically. The net effect has been a continued reduction in energy used (and emissions produced) per unit of industrial output.

The relative shares of energy used in the industrial sector are as follows.[16] The energy shares generally correlate with carbon emissions.

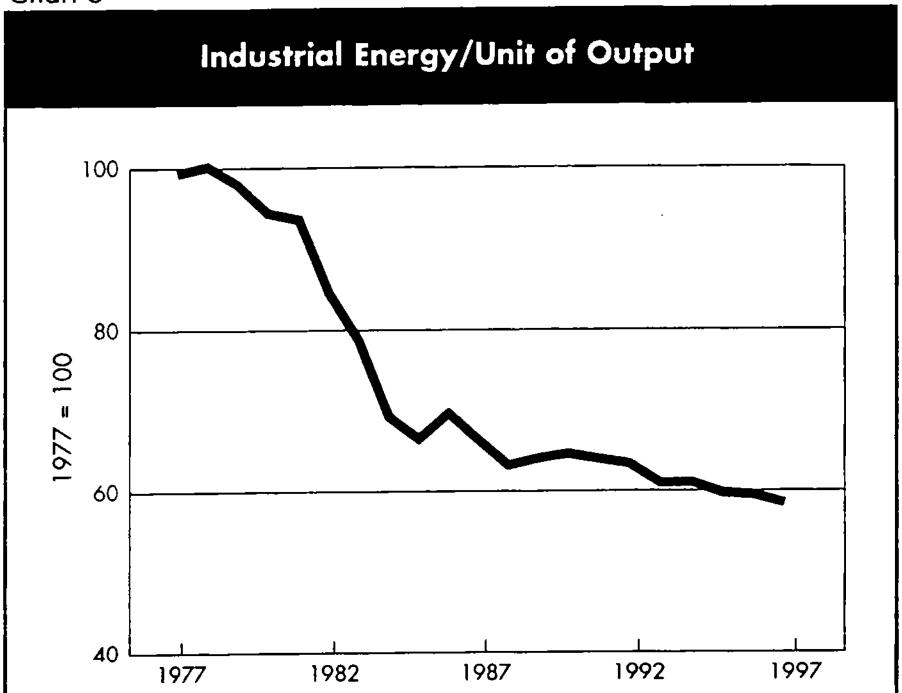
Chart 4

Manufacturing Output



*Durables = equipment, machinery, lumber, furniture, metal, etc.
**Nondurables = food, chemicals, rubber, cloth, etc.
Source: *Statistical Abstract of the United States*, U.S. Census Bureau

Chart 5



Source: *Statistical Abstract of the United States*, U.S. Census Bureau

- 82 percent manufacturing;
- 8 percent mining;
- 5 percent agriculture;
- 1 percent water; and
- 4 percent construction.

These shares of energy use more or less reflect the extent of this preliminary analysis of technology opportunities, but they are not intended to reflect the relative economic or societal importance of any sector.

Industrial Overview

The industrial sector is by far the most complex of the major sectors of the economy and, consequently, creates enormous challenges for evaluating technology trends without exhaustively detailing dozens of highly varied subcategories.

Chart 6

Overall Changes in Manufacturing Energy Use

Fuels used	1977–97
Total energy	+4%
Combustible fuels	-3%
Coal	-43%
Natural gas	+24%
Oil	-3%
Use of Electricity	+25%

Source: DOE/EIA

Continued growth in manufacturing and industrial activities is forecast to continue the historic trend of reduced overall growth in total energy use. This trend likely will be realized because of industry's strong inherent interest in seeking and employing every practical means and technology to reduce costs and increase productivity. It is important to note, nonetheless, that while continuing the industrial energy-efficiency trends of the past would be remarkable in itself, it would *not* be sufficient to meet any federal policies directed at an absolute reduction in industrial energy use.

While manufacturing's dominance of total energy use suggests a reason to focus on that subsector of industry, it is important to note that energy and technology policies directed at one area could have a spillover effect that negatively affects other lower energy-consuming subsectors. While some industries may not consume as much energy or emit as much carbon, policies affecting energy prices and availability may have a disproportionately large effect on them. Some of these smaller energy users can be significant players in economic terms. Thus, well-meaning energy policies with potentially modest economic impacts in one industrial area could have unintended devastating economic impacts in another. The potential for cross-sectoral problems and the difficulty in easily identifying them is inherent in the complexity of the industrial sector.

An additional complication for federal policy lies in the confluence of two issues. First is the increased dependence of industry on electricity to meet growth (as seen in the trends summarized in Chart 6). This trend emphasizes the value of reducing electric costs and is manifested in the widely recognized interest in increasing competition in the electric sector. As federal and state legislators wrestle with the complexities of utility deregulation, they also will be faced with the conflicting imperatives of the second issue. Second, federal climate-change policy concepts are directed at reducing the use of coal-fired electricity, which almost certainly will increase electricity costs because coal generation provides 55 percent of the entire electric supply. (See Chapter VI on electric utilities.)

Manufacturing

Overview

The range and diversity of the types of businesses in manufacturing are beyond the scope of this overview. Instead, we explore the character of technology progress in manufacturing collectively.

The shares of energy used in the manufacturing subsectors are:

- 77 percent conversion industries and
- 23 percent materials fabrication.

These two broad classifications of the manufacturing subsector encompass the industries in Chart 7.

Chart 7

Conversion Industries	
Process	**Materials production**
Chemical and allied products	Primary metals
Paper and allied products	Stone, clay, glass
Food and kindred products	
Petroleum and coal products	
Textile mill products	
Tobacco products	

Fabrication Industries	
Metals	**Nonmetals**
Transportation equipment	Rubber and miscellaneous plastics
Machinery (except electrical)	Lumber and wood products
Electrical equipment	Printing and publishing
Fabricated metal products	Furniture and fixtures
Instruments, related products	Apparel, textile products
Miscellaneous industries	Leather products

Technology evaluations and policy measures in particular need to be considered within the context of fundamental changes in the very nature of manufacturing. The dominant manufacturing model in the second half of the 20th century was based on mass production characterized by a relatively narrow range of standardized products in each sector, maintenance of inventory systems and a high degree of "old style" management organization. This "old" model has served the nation well and was substantially responsible for the United States' ascendance as an economic leader following World War II.

The later part of the 20th century has seen the emergence of a new 21st century manufacturing model. The new model is based on the concepts of "lean" and "agile" manufacturing techniques, great flexibility, rapid product development, diverse product mix, rapid and real-time customer feedback, and the primacy of quality and quality control, along with organizational trends toward distributed decisionmaking. One of the most dramatic examples of the new manufacturing model can be found in one of the older U.S. industries: steel making. The U.S. steel industry has embraced 21st century technology, agile technologies and reached new levels of efficiency (driven by fierce competitive pressures) characterized by the now-dominant "mini-mills."

Near-Term Technologies

Near-term technology changes in virtually all areas of manufacturing fall into two broad categories: more efficient conventional equipment and the potential for cogeneration.

Virtually all aspects of manufacturing depend on one or more of the conventional technologies grouped under motors, lights, chillers and boilers. In general, standard technology progress leads to continuous improvements in the efficiency of conventional equipment. According to a recent survey, one-third of all U.S. manufacturers are "seriously scrutinizing energy usage."[17] The primary issue for businesses to consider is the cost-effectiveness of accelerating the replacement of older equipment with new, more efficient equipment.

A frequently cited near-term technology opportunity lies in increasing the use of cogenerated electricity, wherein a manufacturer can provide both heat and electricity to a facility. Cogeneration can increase dramatically the combined overall efficiency of obtaining electricity and heat separately. The viability for cogeneration depends on a wide variety of business-specific factors in terms of the nature and mix of a facility's energy needs, practicalities relating to operation, maintenance and access to fuel, and regulatory issues.

New and Emerging Technologies

Manufacturers can improve energy efficiency both directly and indirectly. Many emerging energy-using technologies are fundamentally more efficient, such as advanced materials that allow higher temperatures and combustion efficiency or lower friction. In addition, many important improvements in energy and materials efficiency occur because of emerging technologies that bring profound gains in productivity, usually by requiring fewer inputs of all kinds per unit of output, by permitting entirely new and more efficient ways of executing fabrication tasks, or by fundamentally improving the entire supply chain of a process or industry.

This report does not provide a detailed list of new technology opportunities for every subsector. Instead, we illustrate the character of future technology opportunities and the nature of progress by way of a few representative examples. It is clear from even a preliminary assessment of emerging areas that remarkable technology opportunities exist and wait only for further advancement, validation and commercialization.

- The push to increase yields in the timber industry may come from the use of a technology developed for medical purposes. Computer tomography can scan logs for internal defects and use software to optimize how a log should be cut to yield the greatest amount of product. These decisions themselves which can be modified in real-time based on market demand for specific product. In addition, sawing can be replaced with powerful lasers that have great flexibility in creating specific and even complex shapes. Further downstream in the wood industry is the potential for such highly efficient alternatives as radio-frequency drying (more efficient and rapid than thermal drying) and low-emissions, low-waste techniques for coating wood products using ultraviolet light or electron beams.
- Plasma spray technology offers revolutionary ways to put coatings on materials, a ubiquitous activity in manufacturing. A high temperature plasma (18,000°F) vaporizes materials that then literally are sprayed onto surfaces, thus directly depositing a coating with high efficiency and quality. This process is not just efficient but also may create revolutionary new materials,

including thin diamond coatings for mechanical parts in engines. The low friction and high durability of such coatings radically improves equipment's fuel efficiency and operational life. Such technology also holds promise in depositing superconducting films.

- A major source of water and energy use in the semiconductor industry is associated with the simple but vital process of washing silicon wafers. One emerging technology may clean wafers without water using powerful ultra-violet lasers that in effect "unglue" contaminants from silicon surfaces, allowing them to be simply blown off with an inert gas without harming the silicon surface.
- Researchers are exploring the use of electron beam systems for sterilizing food-product containers, such as juice cartons. The technology not only offers lower cost and greater food-product safety, but also lower energy use than conventional steam sterilization.
- Ion implantation is emerging as a method for improving the surface hardness of metals. Improved hardness leads to greater longevity for equipment and associated economic and energy savings from extended lifespans. In the auto industry alone, experts forecast enormous savings from reduced replacement of machine tools.
- A significant expense and indirect source of material and energy waste arises from metal tools that simply wear out and must be replaced regularly, especially in manufacturing operations. New materials-hardening techniques now are nearing commercialization. In these techniques, metal surfaces are treated by ion implantation that results in a substantial increase in the hardness and durability of metal surfaces. The technology can boost metal tool life up to 10-fold and is expected to create substantial savings in avoided tool replacements.
- Microwave rather than thermal energy may open up entirely new avenues for efficient chemical processes. Researchers see opportunities not only to speed up processing and reduce waste, but also to increase the flexibility and precision of the processes and even create entirely new processes. Applications cut across many sectors. For example, preliminary experiments have shown that microwave energy can improve radically the production of a wide variety of products, ranging from drugs to polyethylene.

- Research and development into the various uses of ultraintense visible light already has produced promising results and even some new products. Intense visible light (based on superbright flash lamps) can be used to cook or sterilize food and even strip paint.
- Power lasers offer new and emerging opportunities across many sectors, ranging from welding (already commercial in some areas) to recently demonstrated textile "scissors." Laser scissors can marry computer-driven systems to make custom shapes efficiently, making manufacturing more agile in responding to consumer needs, greatly reducing inventories and reducing waste in the manufacturing process.
- Prototypes for so-called "desktop manufacturing" now exist for bringing profound changes to manufacturing complex components. The basic concept that has been demonstrated successfully involves the use of computers integrated with powerful lasers and powder metals. Rather than manufacturing a complex metal object comprised of multiple alloys, machining steps, castings and so on, in the new approach, a computer-designed part can be fabricated directly "out of thin air" by the powerful laser using a continuous feed of the various powdered metals. Not only does this afford potential for phenomenal advances in control and dramatic reductions in design and production lead times and costs, but there also will be attendant reductions in material and energy waste.

Mining

Overview

The mining industry, while accounting for only 8 percent of industrial sector energy use, provides the fundamental materials for all primary inputs to a modern economy, whether exotic metals or basic products such as coal and limestone. The major challenges faced by miners in a commodity-driven business are cost efficiencies and environmental regulations.

Near-Term Technologies

Because mining is highly capital intensive and equipment lifespans are long, equipment turnover is relatively slow. As a result, near-term technology opportunities are — compared with those of many other industries — "long term."

Nonetheless, engineers are making important advances in the energy-intensive heavy equipment basic engines and motor drives and the drive systems for ore processing. As with all industries, investment in more efficient equipment must be balanced by payback periods based on realistic forecast prices and savings.

New and Emerging Technologies

The three areas in which emerging technologies may hold promise in the long term include basic changes in motive systems for driving heavy machinery, potentially radical changes in actual mining technology (lasers and even cryogenic cooling technologies hold some promise), and techniques and equipment for ore processing. For some aspects of mining, biotechnology has potential for extracting critical materials from low-grade ores by taking advantage of the affinity of genetically engineered bacteria for specific elements. Intriguing possibilities also are being explored in which certain plants' affinity for specific elements such as gold may make it feasible to use plants as a way to collect low-concentration elements from the soil. In addition, more powerful underground imaging capabilities, combined with information technology, holds the promise of improving the finding and mapping of deep underground resources and thus reducing the cost, waste and energy by efficiently targeting mining activities.

Agriculture

Overview

The agricultural sector accounts for only 5 percent of industrial sector energy use, but it holds a self-evidently critical role for any economy. This sector also is extremely (and perhaps uniquely) sensitive to minor changes in the costs of inputs such as energy and the combined uncertainties of weather and world markets. In addition, farming businesses face continually rising constraints and costs associated with existing and emerging environmental regulations.

Near-Term Technologies

Near-term technology opportunities fall into three areas: vehicles, processing equipment and fertilizers. Farmers will invest in near-term efficiency advances in vehicles, engine drives, lighting and motor, and such related equipment efficiencies provided the investments represent significant, realistic near-term cost paybacks. The cost of capital, thin profit margins and substantial near-term uncertainties in uncontrollable areas (e.g., weather and global competition) will be the issues dominating near-term decisionmaking for farmers. Computer-controlled and satellite-linked systems hold near-term potential for reducing irrigation water use and associated energy for water pumping. In addition, substantial improvements in pumping efficiency are on the near-term horizon.

New and Emerging Technologies

Over the long term, the entire agricultural sector may benefit both financially and in energy efficiency from advances in biotechnology, information technology and radically new fertilizing technologies. Biotechnology holds the promise for increasing crop yield, reducing spoilage, and reducing both fertilizer and water with new generations of crops — all of which reduce energy use and emissions. Similarly, advancing information technology systems can improve management of facilities, buildings, animals and equipment in ways previously inconceivable or prohibitively expensive. Future research also may yield such unusual opportunities as using electric fields to cause the selective migration of key nutrients to target crops. Other emerging areas include aquaculture in two forms. One is the potential for ocean-based farming of both crops and fish with greater yields of food product at lower costs. The other is land-based aquaculture, where pilot systems already have achieved very high yields of fish raised in controlled watertank environments.

Water

Overview

Providing for a reliable and safe supply of drinking water and safely managing the waste water produced by society are core industrial activities. While water-related activities account for only 1 percent of total industrial energy use, because of increasing environmental and safety regulations, the trend is toward rapid increases, not decreases, in the energy that may be required to provide the water-related services demanded by our society. Both drinking and waste-water systems are highly dependent on energy in the form of electricity and, in fact, collectively account for 3 percent of industrial electricity use.[18]

Near-Term Technologies

Water systems, like other infrastructure systems, are highly capital intensive and, thus, have an inherently slow turnover rate in terms of the penetration of new, more efficient equipment. The dominant near-term opportunities in water-related systems are associated with improving the efficiency and control of motor/pump systems.

New and Emerging Technologies

There exist a wide variety of potentially interesting technologies for cleaning and purifying water, including ozonation (to replace or reduce chlorination), advanced membrane systems, electron beams, ultraviolet light and even acoustic cavitation. Efficiency and cost improvements also can come with improved rapid and real-time detection of pathogens, micro-organisms and contaminants. This in turn would permit precise and appropriate treatment of water as required, thereby potentially reducing energy and chemical use as well as enhancing water quality.

Construction

Overview

The construction industry consumes 4 percent of the energy used by the industrial sector and is characterized by the types of heavy energy-consuming equipment needed to build the infrastructure, buildings and highways that house and enable any economy. This industry, like all infrastructure industries, also is characterized by capital-intensive equipment with a slow turnover rate.

Near-Term Technologies

The dominance of heavy equipment with engine and motor drive suggests that incremental energy gains will emerge based on the same advances in these areas as previously noted for other industries. And, as with all industries, investment in more efficient equipment must be balanced by payback periods based on realistically forecast prices and savings.

New and Emerging Technologies

Over the long term, radically new types of building materials may improve efficiencies in the operation, speed and flexibility of construction. Researchers also are exploring the potential of nontraditional building materials such as composites. In addition, research suggests that new materials technologies hold promise in both concrete and asphalt. New materials, new application techniques and real-time monitoring of deterioration of physical structures can increase the useful lifespan of energy-intensive infrastructure. "Smart" bridges, with imbedded sensors that detect early corrosion and weakness, can permit early remediation and, thus, ultimately longer lifespan for such structures.

IV. Technology Development in the Commercial Sector

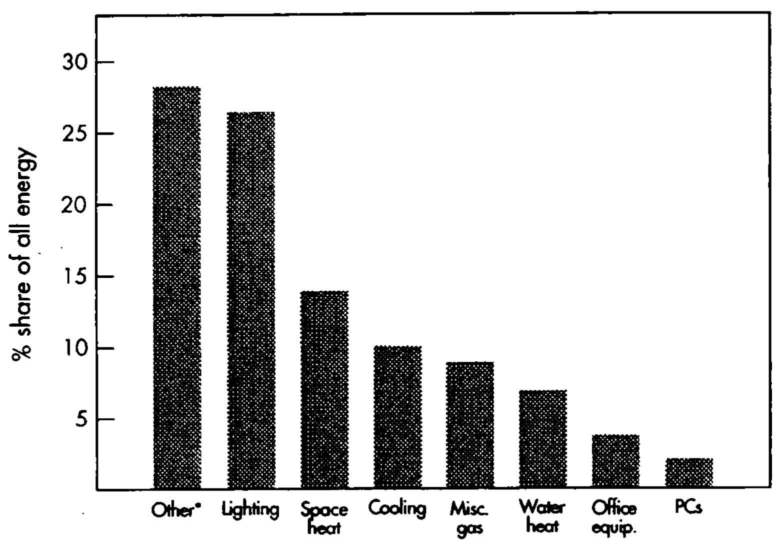
Energy Background

The commercial sector consumes 17 percent of the U.S. energy supply, of which nearly 75 percent is delivered as electricity and the remaining 25 percent as a combustible fuel (primarily natural gas).

Energy used to operate buildings dominates the commercial sector, accounting for more than 70 percent of all energy use. Historic trends show two important technology-related changes. First, efficiency gains have been significant, with energy use per square foot of commercial building declining more than 30 percent since 1979.[19] An underlying trend is the increased use of electric end-use technologies, as electricity's share of energy per square foot in commercial buildings has risen from 38 percent in 1979 to more than 50 percent today.

Chart 8

Commercial Sector Energy Use by Equipment Type



*Communications technologies, medical imaging, ventilation, refrigeration, etc.
Source: DOE/EIA

The primary energy uses in the commercial sector are illustrated in Chart 8. They point to areas where technology progress has driven and can drive efficiency and where new sources of demand are appearing — notably for PCs and the broad category titled "other."

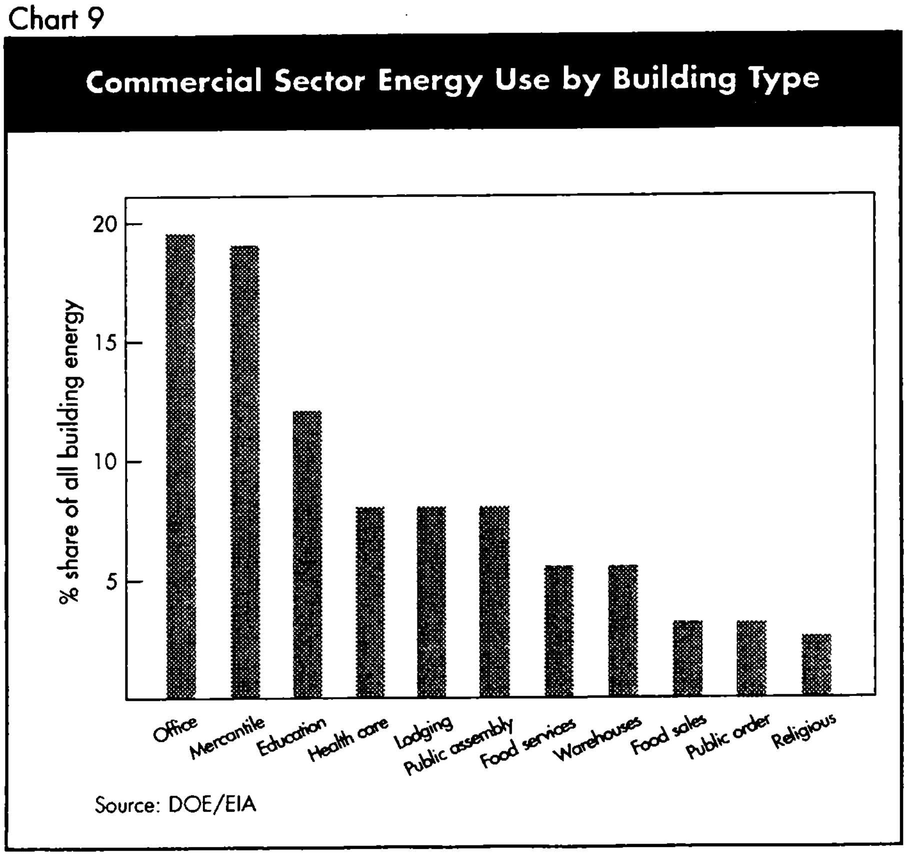
The commercial building sector is highly varied in terms of technology requirements, market pressures and economic priorities. Chart 9 illustrates the types of commercial buildings and each category's share of total commercial building energy use.[20]

Buildings

Overview

Operators of commercial buildings face the same array of environmental, regulatory and financial constraints as any business, in addition to issues related to safety, air quality and flexibility to accommodate changing market conditions. As the data in Chart 9 show, three building categories account for

Chart 9



50 percent of all commercial building energy use: offices, mercantile buildings and education-related buildings. The various functions of these buildings create substantial differences for the practical implementation of technology. For all buildings, achieving high levels of indoor air quality is a major area of concern. Energy savings initiatives driven by the energy crises of the 1970s gave insufficient consideration to the air quality problems created by "tight" buildings. Great strides in understanding and improving air quality have been made since then and will continue to be central driving forces in all technology development in this sector.

Potential incentives for reducing energy use probably will be associated with buildings that use the most energy per square foot. The three building types that are the most energy intensive are food service, health care and food sales. These three building types have diverse market and operational driving forces and use over twice as much energy per square foot as an office building.[21] As with the industrial sector, these variations point to important differences in the specifics of technology implementation, particularly with regard to near-term financial issues.

Near-Term Technologies

Reducing the total consumption of energy for commercial buildings is highly dependent on the existing installed base. Buildings have a predictably long lifetime; the mean life for commercial and institutional buildings is assumed to be 50 years. Thus, building-related energy consumption is projected to rise with growth in total commercial floor space driven by an expanding economy.[22] This growth is due primarily to new construction, mitigated only marginally by the slow turnover (retirement) of existing buildings and limited (economically and technologically) means to improve the current building systems. Even the most optimistic (and intrusive) projections for reducing energy growth still only would slow growth without achieving any absolute reductions in energy use. While building lighting continues to be one of the dominant uses of energy, businesses are well aware of the existence of practical and more efficient lighting technologies that can be retrofitted realistically, and many forecasters believe that most of the "cream" has been skimmed in this area.

New and Emerging Technologies

A key, underlying aspect of technology development will occur in the area of new, computer-based design tools that will allow architects and engineers to effectively achieve an "integrated design" approach to buildings. Improved energy efficiency, higher air quality, lower first cost and operational gains will arise from a holistic approach to the complex design of buildings. Continued advances in computing power and software bring this goal within sight.

The three main areas of long-term technology affecting building energy consumption are: envelop systems (building material and architectural design), self-contained energy systems (such as microturbine generators and fuel cells), and advanced control systems.

Building envelop technologies already have contributed to significant reductions in new construction energy costs and have the potential to reduce energy consumption per square foot by 50 percent. The opportunities include architectural designs for orientation and layout that take advantage of solar heating, natural lighting, etc., and improved materials such as insulation, glazing and wall construction. As an example, a new hospital can be designed to achieve reductions in energy per square foot of more than 35 percent.

Advanced insulation technologies such as gas-filled and evacuated panels have the potential for increasing the R-value per unit of thickness by an order of magnitude over that of conventional technology. Other promising technologies are electrochromatic coatings that change the optical characteristics of windows to match environmental conditions. Entire buildings may be designed with adaptive thermal characteristics to minimize energy consumption.

New developments in building energy systems could see widespread deployment. These include small, captive, combined heat and power systems for self-contained building service that have the potential to provide self-sufficient or even net energy production by increasing power-generation efficiencies, heat recovery, solar heat gain and thermal distribution. For these systems to be viable, engineers must develop market-viable microturbines, heat pumps, fuel cells, building-integrated photovoltaic systems and advanced materials. Fuel cells can provide the same services, operate on different fuels and perform extremely quietly at an efficiency of 80 percent or better. Fuel-cell developers still face substantial hurdles, including maintenance issues, manufacturing costs and long-term reliability. Early research also shows the potential for fabricating glass windows that can double as photovoltaic cells.

Advanced building control systems may have the potential for earlier implementation than building envelop technologies because they can be retrofitted in existing buildings. Advanced building control systems using cybernetic (smart controllers and fuzzy logic) systems also are key to future energy-use reductions. These systems will enable optimal energy usage, storage, production, purchase and sale for buildings. This will allow real-time responses to local climate and weather conditions as well as energy market conditions. The industry must develop standard protocols for operating controls and the mechanical equipment and instrumentation (sensors, controls and communications) required to perform optimizing functions.

Building lighting is the second-largest energy user, representing 28 percent of all commercial energy usage. Advances in high-efficiency bulbs and smart occupancy-based and voice-activated controls have demonstrated the potential for practical applications. Researchers must focus on the development of new sources, improved technologies for existing sources, materials development, fiber optics, photonics, system engineering and modeling, thin film coatings technology, more efficient and dimmable power supplies, and fixtures with highly reflective and efficient optical designs.

Equipment

Overview

The four generic categories of energy-using equipment placed inside commercial buildings that are not central to building operation are office computers, other office equipment, miscellaneous gas equipment and "other." Natural gas uses are primarily for cooking, some district heating and electricity self-generation. The "other" category encompasses new and emerging telecommunications technologies, ventilation (driven by air quality concerns), and such varied end uses as service station equipment and vending machines. The growth in the "other" category is forecast to be the highest and will assume the dominant energy-consuming position in the hierarchy of commercial equipment. In fact, the *growth* in energy used by equipment in the "other" category by itself will exceed by twofold the total current energy used by all office equipment.[23] It is important to note that much of the growth in technologies in the "other" category is associated with new and emerging technologies that bring new productivity to businesses (such as telecommunications) as well as safety and convenience. Vending machines, for example, fit into the "other" category and provide convenient access to food and other products. New vending machine technologies are moving increasingly in the direction of mini, full-service food stations with both chilling and cooking capabilities. There are already 5–7 million vending machines in use.[24]

Near-Term Technologies

Significant efficiency gains are possible in the near term, for example, with the reduced consumption of electricity for Energy Star computer monitors. However, the overall growth in demand for basic equipment (again driven by economic opportunity and need) likely will more than offset efficiency gains, leading to continuing but moderated growth in energy use. The challenge for implementing efficiency improvements in commercial equipment arises from very short paybacks required by rapid obsolescence. At the same time, this presents nearer-term opportunities for the introduction of new, more efficient equipment, provided that the energy efficiency does not place the equipment at a competitive cost disadvantage or impair its operational characteristics.

New and Emerging Technologies

Ensuring that manufacturers are aware of the entire range of new technologies is important. A challenge — and opportunity — continues in the arena of engaging equipment developers in long-range technology transfer initiatives with private and federal research facilities, where important new — and even revolutionary — changes in materials, design or operation may be nascent and not visible in the commercial domain.

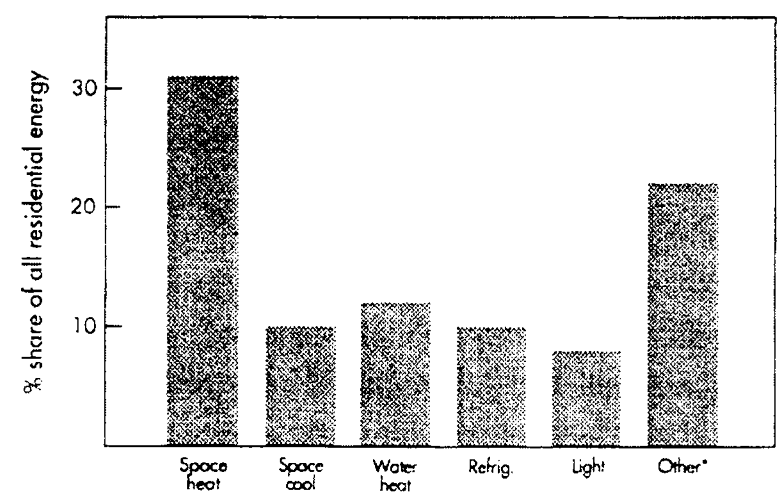
V. Technology Development in the Residential Sector

Energy Background

The residential sector consumes 19 percent of the U.S. energy supply, of which 65 percent is delivered as electricity and 35 percent as a combustible fuel (primarily natural gas). Residential forecasts and policies present the greatest challenge because of the highly diverse, eclectic and comparatively unpredictable nature of residential sector behavior.

Chart 10

Energy Consumption in the Residential Sector



*Small appliances such as PCs, stereos, TVs, faxes, hot tubs, etc.
Source: DOE/EIA

Buildings

Overview

Reducing total residential building energy consumption is dependent on the existing installed base. Homes have a long lifetime, generally longer than commercial buildings, ranging from 50 years to 100 years. Thus, major changes in efficiency arising from basic and dramatic improvements in fundamental design, material and construction techniques will take place only over very long time periods. Hurdles for implementing near-term technologies that improve energy efficiency in the residential sector include end-user awareness, availability of capital, willingness to allocate capital to energy efficiency and consumer tolerance for long-term payback on investment.

Near-Term Technologies

Efficiency improvements from 20 percent to 50 percent are available with the new generation of natural-gas furnaces, heat pumps, central air conditioning systems and refrigerators.[25] The normal turnover rate for home appliances leads to forecasts of continual decline in the amount of energy needed for refrigeration and no growth in residential space-cooling energy use, even as the nation's housing stock grows. However, lighting energy use is forecast to grow slightly, as is energy for space heating. Accelerating early adoption of the most efficient technology in any residential application requires a balance of consumer, market, behavioral and economic factors.

New and Emerging Technologies

The three main areas of long-term technology impact for residential buildings are the same as for commercial buildings: envelop systems (building material and architectural design), self-contained energy systems (such as microturbine generators and fuel cells) and advanced control systems. There are two primary differences between commercial and residential applications: Residential scales are smaller and present technical or engineering challenges, and residential first costs need to be lower in order to achieve shorter payback periods. Both of these realities mean that most building technology improvements will be implemented first in the commercial sector, then in the residential sector as costs and scale decrease.

Building envelop technologies include architectural designs for orientation and layout, which take advantage of solar heating, natural lighting, etc., and improved materials such as insulation, fenestration, glazing and wall construction. Advanced insulation technologies such as gas-filled and evacuated panels have the potential for increasing the R-value per unit of thickness by an order of magnitude compared to that of conventional technology. Other promising technologies are electrochromatic coatings that can change the optical characteristics of windows passively to match changing environmental conditions and whole-building envelops with thermal characteristics that can change as needed to minimize the building loads.

As in the commercial sector, building energy systems and advanced building control systems can be retrofitted to existing buildings. It may be feasible to develop small, captive, combined heat and power systems for self-contained service. Some systems are already viable but are only competitive where energy costs are high. Such systems have the potential of being self-sufficient or even energy producers by increasing power-generation efficiencies, heat recovery, solar heat gain, thermal distribution, etc. Researchers will need to develop market-viable microturbines, heat pumps, fuel cells, building-integrated photovoltaic systems and advanced materials.

Lighting technologies that are developed for commercial applications also may find eventual use in the residential sector, although at less than 10 percent of total residential energy use, lighting efficiency will not be a major economic motivator for home savings. Advances in high-efficiency bulbs and smart occupancy-based and voice-activated controls have demonstrated potential.

The use of advanced building control systems (smart controllers and fuzzy logic systems) also are key to future reductions. These systems will enable optimal energy usage and allow real-time response to local climate and weather conditions as well as market conditions. They also will offer homeowners new services, convenience, and even integrated safety and environmental monitoring. However, such technologies will need to make great strides in cost, ease of use and ease of retrofit installation to make significant penetration in residential markets.

Equipment

Overview

The categories of energy-using equipment used inside residences encompasses a broad and growing class of appliances, devices and equipment for comfort, safety, entertainment and convenience. Two decades ago, a few appliances characterized residential equipment: refrigerators, ovens, heaters, lights, radios and television sets. Today, the list is long: personal computers, other office equipment such as fax machines, second and third television sets, second and third computers, microwave ovens, dehumidifiers, security systems, security lighting, architectural lighting, fans, pumps, heaters, water beds, VCRs, cordless telephones, chargers for cell phones, and chargers for cordless weed trimmers and lawn mowers. Virtually all of the growth forecast for residential energy use is expected to occur in the "other" category. By 2010, the "other" category will consume more energy than space heating, becoming the leading source of residential energy demand.[26]

Electricity is forecast to slightly increase its share of overall residential sector energy needs, with overall consumption of energy rising about 20 percent by 2020. Demand for electricity is forecast to account for 87 percent of that growth.[27]

Near-Term Technologies

While significant efficiency gains are possible in the near term (for example, in the reduced electricity consumption of Energy Star computer monitors), the overall growth in demand for a wide array of consumer products is forecast to lead to continuing growth in electricity used for in-residence equipment. The challenge for implementing efficiency improvements in consumer equipment arises from short paybacks required by rapid obsolescence. At the same time, this presents near-term opportunities for the introduction of new, more efficient equipment, provided that the efficiency does not place the equipment at a competitive disadvantage or impair its consumer appeal.

New and Emerging Technologies

Opportunities for ensuring that new residential and consumer equipment, especially in the "other" category, is as efficient as possible generally will pertain to spreading awareness of new technologies among manufacturers and engaging equipment developers in technology awareness initiatives.

VI. Technology Development in the Electric Sector

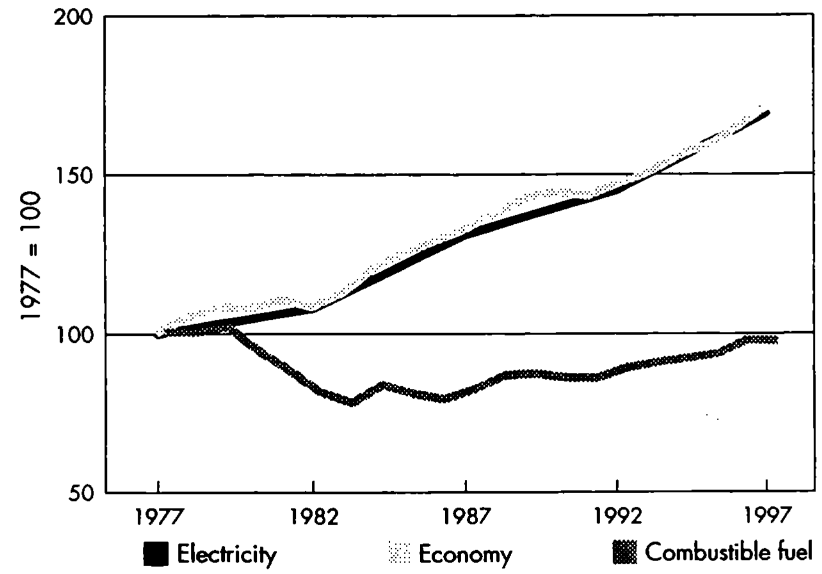
Energy Background

The U.S. economy spends more on electricity than on any other energy commodity: \$230 billion a year for kilowatt hours and about \$200 billion a year for oil in all forms.[28] Over the past two decades, electricity demand has continued to grow with the economy, even as the use of combustible fuels for all nontransportation purposes has changed little. While these trends have driven interest toward the electric sector as a target for future carbon emissions reductions and efficiency gains, it is important to note that these trends have occurred as a consequence of technology decisions in the marketplace. The trends of the past two decades illustrate the role of electricity as the fuel of the information economy.

Chart 11

Economic and Energy Trends, 1977–97

(Excludes energy for transportation)

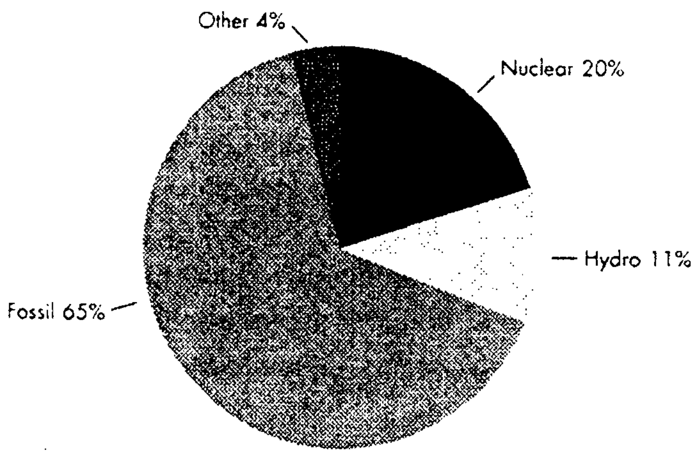


Source: DOE/EIA (Excludes transportation data)

Chart 12

Sources of Electricity, 1997

(Includes nonutility and cogeneration)



Sources: DOE/IPP and EEI

Chart 13 illustrates the *additions* to the nation's electric supply over the past two decades. Coal accounted for 56 percent and nuclear power for 32 percent of the increase in total electricity supplied.

The central challenge for regulators and legislators who seek more efficient models for organizing the electricity industry will be the need to meet market-driven growth in demand for electricity without lowering quality.

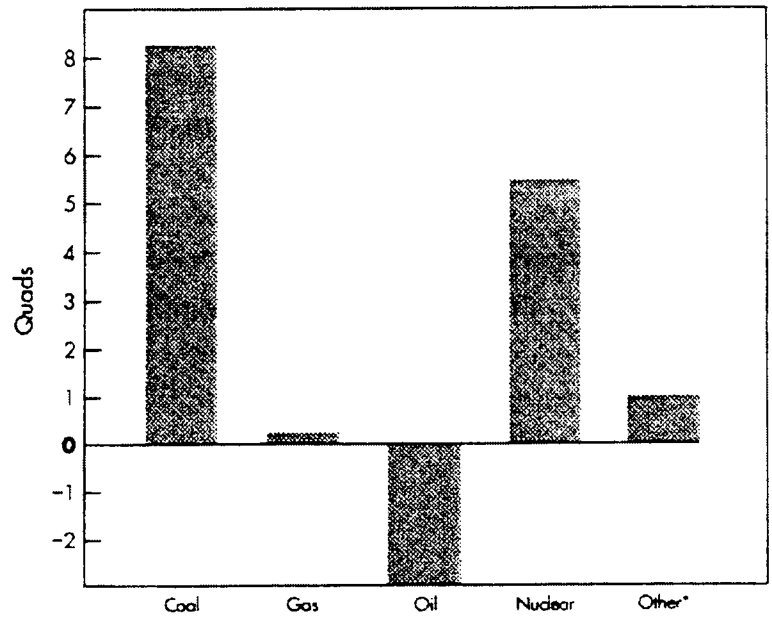
Conventional Generation

Overview

Today's existing electricity generating capacity is primarily fossil-fuel based, with a heavy dependence on coal (56 percent of all generation; oil-fired units account for less than 3 percent). With today's technology, it is unlikely the electric utility industry could reduce its greenhouse-gas (GHG) emissions to the levels called for in the Kyoto Protocol within the 2008–12 time frame without jeopardizing the electric supply system. And, as the baseline data above have shown, the long-standing linkage between electric use and economic growth has continued.[29]

Chart 13

Growth in Electric Supply, 1977-97



Note: Cogeneration and IPP allocated by fuel type.
*"Other" comprised 90 percent of wood and waste burning.
Source: DOE/EIA

Future electric supply considerations need to take into account that additional nuclear capacity is neither forecast nor anticipated by most analysts. This will create a substantial challenge for other sources (likely natural gas) to provide as much growth in energy supply for the next 20 years as nuclear energy did for the past 20 years. Providing this much future supply will require the construction of 500 large-scale (200 MW) natural gas-fired power plants and additional major investment in natural gas production and delivery.[30]

Near-Term Technologies

Fossil

Through the normal course of engineering and market pressures for reduced costs, conventional coal and natural gas power plants experience continuous improvements in efficiency that reduce fuel consumption and emissions. Improvements occur in a multitude of areas. However, confusion and uncertainty arising from flux in the regulatory and policy environment can create substantial practical impediments to any business undertaking major new capital investments. The electric sector is in a prolonged transition from the old monopoly system (that is still largely in place across the country) to a new system of regulations and laws that are far from clear in scope, form and timing.

Rapid advancements in information technology could contribute in the short term to higher efficiencies and lower costs as sensing, control, software and even virtual reality systems improve O&M and real-time operations. In addition, recent advances point to near-term potential for biotechnology to produce engineering bacteria that may be able to reduce scaling in cooling pipes dramatically. This, in turn, would lead to significant improvements in thermal efficiency.

Nuclear

Today, this large-scale, zero-emission generation source provides approximately 20 percent of the country's electricity. Nuclear power should continue to play a strong role in reducing all forms of emissions and contribute to a diverse national energy supply. A key issue for this energy source will be the extent to which operating licenses are renewed. Without relicensing, most nuclear units will shut down by 2020, and their substantial electricity supply will have to be replaced. Securing additional operating life for well-managed plants will assist in the attainment of any federal carbon-emission mitigation goals. Carbon emissions surely will increase if these nuclear plants are not relicensed because there is no other zero-emissions generation source that could supply as much electricity as nuclear power supplies today. A contributing factor for continuing nuclear energy's contribution will be the status of federal programs to manage nuclear waste. A license renewal and nuclear waste management process that proves to be generic, timely and predictable will encourage a decision to continue the nuclear option. Government and industry must continue to work together to refine the process in the upcoming years.

Hydro

The Department of the Interior has plans to eliminate a share of existing dams. In our judgment, under a best-case scenario, conventional hydro is not expected to grow and may even face some of the same relicensing problems as nuclear energy. Thus, a best-case scenario for the second-largest source of zero-emissions electricity (less than 10 percent of the national supply) would be to maintain the status quo for the next several decades.

Distributed Generation

Emerging near-term distributed generation technologies — natural gas- and oil-fired microturbines and advanced diesel generators — have come closer to economic practicality due to continuous improvements in basic engineering and materials. Distributed generation — whether sized in the 10 kWh range (household), the 70–100 kWh range (small business) or the 1 MW range (large business) — may offer important economic, reliability and competitive advantages as the electric sector is restructured. However, to the extent that these technologies use fossil fuels and have thermal efficiencies comparable to central station power plants, the net efficiency implications are modest and potentially nonexistent. Industry analysts expect the combination of deregulation and technology improvements in conventional engine generators to create new demand for distributed equipment that uses both diesel fuel and natural gas.[31]

Only in applications where cogeneration of electricity and heat are practical do gains in overall energy efficiency occur. These efficiency gains also are reflected in cost savings for relatively large-scale cogeneration. Already, cogeneration — an important form of distributed generation — accounts for 6 percent of the total electric supply system of the United States and has increased more than 25 percent in the past four years alone.[32] To the extent that tax, regulatory and policy impediments are removed, cogeneration can be expected to continue to grow as an efficient form of distributed generation. The magnitude of the total contribution from cogeneration will depend on the practical limits of the number of viable applications in industry, where both scale and thermal needs create economic advantages over purchased power.

New and Emerging Technologies

Advanced coal and gas-cycle technologies currently under development are projected to achieve significant efficiency improvements, thereby reducing energy use and carbon emissions as well as the cost of electricity. Experts expect advanced natural gas-based combined cycles to reach very high efficiencies (on the order of 60 percent) based on progress made in materials technology. Advanced coal technologies, such as pressurized fluidized bed combustion, advanced supercritical and integrated coal gasification combined cycle, also will see increased efficiencies, projected to be up to one-third more efficient than today's coal-fired units. These advanced coal- and gas-fired technologies can replace existing plants as old ones are retired, but the technologies are not expected to be commercially viable prior to scheduled or practical retirement of most of the existing fossil-based stock.

The Department of Energy's Vision 21 includes a coal gasification plant with hydrogen separation, chemical production and carbon dioxide sequestration. However, this type of concept requires considerable advances in basic technology in a wide variety of areas.

Just as technology can create a new generation of fossil-based electricity sources, so too could technology bring a new generation of nuclear fission reactors over the long term. New designs for nuclear reactors already are available, with a wide range of technologies promising ongoing efficiency and cost improvements.

Distributed Generation

Fuel cells constitute the most interesting long-term form of distributed generation. However, the industry must overcome substantial technical and practical hurdles to make this technology economically viable at scales that are useful for small businesses and homes. Early applications are most likely to appear in larger businesses. In such applications, distributed generation will have to compete on a cost basis with very low-cost conventional generation and cogeneration.

Renewable Generation

Overview

Nonconventional and/or renewable electricity generation, including wood, wind, solar thermal, solar photovoltaic, municipal waste and geothermal (excluding large-scale conventional hydro), contributes about 0.5 percent of the nation's electric supply. Of this mix, geothermal accounts for 80 percent of the total. Current forecasts assume a growth in supply from nonconventional renewables ranging from 200 percent to 10,000 percent by 2015. These high forecast growth rates would allow renewables to account for about 5 percent of the increase in electric supply required by 2015.[33] It is notable that of the total growth in renewable supply forecast, 41 percent is assumed to come from the conversion of municipal trash to electricity, 29 percent from geothermal expansion and 27 percent from burning wood and related biomass — collectively, 91 percent of all forecast renewable growth.

Near-Term Technologies

Even under the most optimistic scenario, nonhydro renewables cannot contribute a major share of either the growth in supply or the absolute supply of electricity for the next several decades. Currently, the average generation cost from nonhydro renewables is two to three times that of electric generation from conventional sources.

Biomass requires the use of large amounts of land. It is estimated that a 2600 MW plant operating at 65 percent capacity would require one half of the state of Ohio's available farmland and forests. According to the latest estimates by the Department of Agriculture, the maximum available farmland in the United States is equivalent to 78 million acres, of which only 35–40 percent could be used (due to many constraints, one of which is the lack of water supply) for growing trees, biomass, etc. This translates to a maximum generation of 210 billion kWh per year from biomass, which represents only 3 percent of the total electric energy demand projected in 2010. This maximum generation capability does not account for the high cost of developing new biomass generation technology or the infrastructure that would be needed.

Although wind energy is the least expensive of all nonhydro renewables, it is limited by available sites. The maximum contribution from wind energy is not expected to exceed 2–3 percent of total electricity needs. Furthermore, wind energy, like all other renewables (with the exception of biomass), cannot be utilized to its maximum potential in the absence of a cost-effective energy storage technology. Therefore, wind energy may not play any major significant role in the nation's total electricity needs for the foreseeable future.

New and Emerging Technologies

Fusion

The long-term prospects for fusion energy continue to remain the most significant and challenging. It is an appropriate area for continued federal R&D.

Transmission and Distribution

Overview

The transmission and distribution of 3 trillion kilowatt-hours of electricity each year in a fashion that provides instant availability and high quality has been and will continue to be one of the most challenging technical aspects of the electricity system. Because there is only one transmission system bringing power to every business and home, enormously important issues attend electric reliability as the states and federal government explore — or in a few cases initiate — "retail" access to alternative suppliers.

While some energy inevitably is lost in an electric transmission system, there are opportunities for improving energy efficiency from technology advances in both the near and long term. Reducing national transmission losses by two percentage points would yield a comparable reduction in total utility carbon emissions. This level of efficiency gain could yield energy savings equivalent to 100 million barrels of oil per year and make available the electric output of 20 power plants of 500 MW each with no new construction.[34]

It is important to note that it is possible to unintentionally create disincentives for businesses to pursue technology investment in this area because of new policies relating to the regulation and use of the transmission system. To the extent that efficient electric transmission is considered an important national priority, this issue should be explored carefully in the context of regulatory policies in the restructuring of the utility industry.

Near-Term Technologies

The primary near-term opportunities will arise from the use of new high-power semiconductors for switching power, replacing electro-mechanical switches, and providing substantial improvements in efficiency and control. Pilot systems already have been installed to evaluate performance of these new systems.

New and Emerging Technologies

Over the long term, advances in three areas promise efficiency gains: high-power electronics, neural networks and superconductors. Basic research is needed to continue to advance the capabilities of semiconductor devices to handle the high power levels of electric transmission and distribution systems. Advances in this area, along with neural networks, hold the potential for greater real-time monitoring, control and switching of high power loads, with attendant improvements in efficiency.

The industry has long viewed high-temperature superconducting wire (zero-resistance wire) as holding major potential for dramatic reductions in losses in all forms of power transmission. Basic materials research must continue in this area to yield practical and economical products.

VII. Technology Development in Carbon Sequestration

Overview

The planet's total carbon cycle involves both sources (natural and anthropogenic) and sinks. While annual emissions of carbon from natural sources are substantially greater than from human sources, it is clear from the record that anthropogenic carbon emissions have been rising with industrialization. A major issue in both the science of climate change and in proposals to address carbon emissions is the extent and role of sinks. It is vital that scientific research advance the state of knowledge regarding the extent to which natural sinks play a role in the planet's carbon cycle and in the ambient concentration of carbon dioxide in the atmosphere. It is noteworthy, for example, that recent research suggests that natural processes create a condition in which North America acts as a net sink, absorbing more carbon than is emitted from fuel combustion.[35] Clearly, understanding this aspect of the carbon cycle will be essential both from scientific and policy perspectives.

Near-Term Technologies

The two immediate and straightforward technologies for carbon sequestration relate to forests and modified soil-tilling techniques. Both preservation of existing forests and reforestation serve as substantial "sinks" because carbon dioxide in the atmosphere is a primary nutrient for plant growth. A variety of conventional near-term and existing technologies and equipment are relevant to the industries associated with both forestry and farming. As with other technologies discussed previously, carbon sequestration must have inherent economic value for the associated businesses.

New and Emerging Technologies

Long-term technology development relating to carbon sequestration can be divided into three basic categories: agricultural or enhanced biomass-related sequestration, geological sequestration, and physical carbon removal or "scrubbing."

The field of biotechnology may dominate the long-term potential associated with enhancing future biomass growth rates and carbon absorption. The extent to which bioengineered plants may be capable of growing in soils with lower levels of nutrients and/or water would provide the dual benefit of greater carbon sequestration and enhanced global food supply. Scientists also have proposed advanced technologies associated with the ocean-based farming of phytoplankton. Preliminary estimates suggest that ocean farming could be comparatively inexpensive and have the side benefit of increasing fish yields. Research into the technologies and infrastructure as well as basic ecosystem impacts will be valuable, regardless of the ultimate utility of this sequestration technique. Various specific technologies also may hold promise with regard to the areas of restoring degraded soils.

Geological sequestration may offer additional potential. The concept is simple in principle but costly in execution, absent substantial advances in technology: It involves capturing CO_2 from oil and gas wells and potentially even from combustion processes and injecting it into the deep earth. Oil and gas companies are exploring enhanced CO_2 stripping and reinjection in deep wells or below the ocean floor, an activity already in use for pressurizing oil and gas wells. It is possible to pump exhaust CO_2 directly into the ocean depths, where it becomes a liquid and may remain on the bottom indefinitely. Among the key areas scientists will explore are the stability and longevity of such disposal as well as potential disruptions to natural ecosystems.

A variety of technologies are theoretically possible for physically removing or "scrubbing" CO_2 from the atmosphere or combustion flue gases. Here, technology research will be focused on new or better chemical processes. And finally, here too biotechnology may hold potential for using engineering bacteria to convert combustion exhaust — or atmospheric — CO_2 directly into fertilizer or fuel.

VIII. Observations and Recommendations

Technological progress is at the core of both the 20th century American success story and the 21st century's promise. American citizens and businesses have great faith in what technology can accomplish and have demonstrated the ability to realize technology's promise through imagination, hard work, and the enabling powers of a free and efficient market economy. Thus, it is vital that any federal technology policy initiatives take into account the central role of the private sector in commercializing and making practical new and emerging technologies as well as the underlying importance of a healthy economy. In accordance with these basic beliefs and the review of technological opportunities and challenges that follows, the BRT proposes the following guiding principles for public policies and for actions it can take to promote technologies that impact energy use, energy efficiency and carbon emissions.

Near-Term Technology Acceleration

As the BRT has articulated previously (*The Kyoto Protocol: A Gap Analysis,* June 1998), near-term government mandates to direct or control technology choices to meet Kyoto-style emissions targets are not feasible and have the potential to create enormous damage to the efficient functioning of virtually all businesses and thereby do serious damage to the U.S. economy. Nonetheless, the BRT believes that there may be potential for additional or more rapid implementation of more energy-efficient technologies to reduce carbon emissions in the near term. The BRT believes the following core premises and related action items would help realize this near-term potential.

Premise #1: Government barriers unintentionally impede efficient investment.

Businesses frequently are aware of and interested in purchasing, deploying or producing important energy-efficient technologies, but they face obstacles unrelated to the inherent merits of the technologies. Thus, market penetration is slowed or halted, so businesses lose economic opportunities and the nation fails to benefit from reduced energy use and emissions. Similarly, businesses here and abroad are aware of lost opportunities (due to regulatory, tax or similar barriers) to export advanced and energy-efficient technologies that would bring efficiency and emissions-reduction gains to both U.S. and foreign firms.

Proposal #1: Identify specific opportunities to remove government barriers.

The BRT will undertake a study involving (but not limited to) a survey of BRT members to determine the types of issues, policies, regulations and tax rules that impede early adoption and export of energy-efficient or carbon-reducing technologies that are otherwise practical or proven, and it will provide specific recommendations for improving or eliminating those barriers.

Long-Term Technology Progress

Long-term technology progress is a core objective of public and private planning for both economic and environmental goals. Because of the inherent uncertainties in investing in long-term technology development, the government must avoid picking "winners and losers." Nonetheless, the BRT believes that there are additional initiatives, or refinements to existing initiatives, in the areas of long-term technology development and public/private partnership that could play an important role in accelerating the emergence of technologies relevant to global climate change issues. In order to assist in this area, the BRT notes the following core premise and proposes a related action item.

Premise #2: Technology transfer and public/private partnership can be improved, thus accelerating the movement of new and emerging technologies into the marketplace.

Technology transfer has long been one of the most challenging areas for public/private partnership. The BRT is aware of the potential for energy efficiency and emissions-reduction gains that may be realized from using technologies that are under development or already have been developed in the national federal laboratory system. To the extent that businesses can be made aware of opportunities and the federal laboratory system made more responsive or accommodating to business realities, the time to market for new and emerging technologies can be shortened, benefiting business interests, the nation's economy and climate change goals.

Proposal #2: A summit meeting on technology transfer in the 21st century.

The BRT will invite the government to a national summit meeting on technology transfer with two specific goals:

a) Identify mechanisms to increase the involvement of business and private interests and perspectives in research earlier in the process to increase the likelihood that a greater portion of R&D work will be useful in the free market.

b) Determine a specific framework to establish a business-driven national or international partnership on technology transfer, based on the ideas and proposals explored at the summit.

To the extent that solid and productive ideas for engagement emerge from the summit, the BRT will implement some form of new partnership on technology transfer between industry and the research community. The BRT believes, for example, that it may be possible to create a single, user-friendly "portal" to help the private sector navigate through the entire array of government and university technology transfer programs. The BRT will form a working group to explore other concepts to bring to the summit.

While the BRT will approach the concept of technology transfer from a "market pull" perspective, we recognize that extensive effort and knowledge exist in the technology transfer community and will seek guidance, ideas and cooperation from all relevant players. Specifically, the BRT will begin the process of informal discussions with key leaders in national and university-based laboratories and invite key individuals to participate in the summit.

Other Initiatives

As a result of the lessons learned from this study and from the continuing interests of the BRT, we are conducting an ongoing evaluation to explore additional initiatives, ideas and projects that relate to the core technology issues explored here. For example, the BRT will explore the potential for creating or using Internet-based tools to enhance the flow of information about new technologies and accelerating their commercialization. We also will explore the relevance of employing business-to-business e-commerce in technology transfer.

Appendix — Energy Background

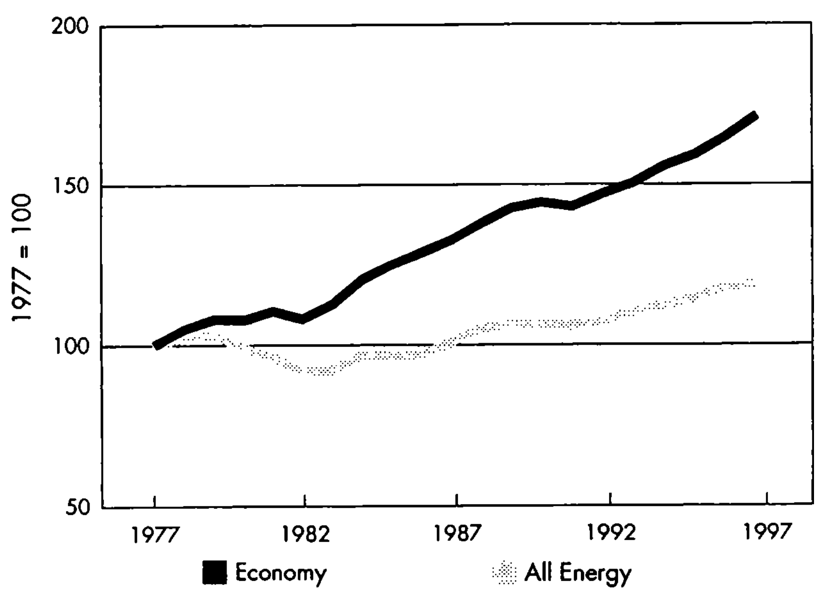
The economy has grown faster than overall energy use (see Chart 14). This is a reflection of continuous improvements in energy efficiency that have derived primarily from technology progress. The improved efficiency means that energy demand today is the equivalent of 6 billion barrels of oil per year less than it would otherwise have been at the 1977 level of efficiency. This important economic and resource gain consequently has reduced carbon emissions.

The relative importance of energy in the various parts of the economy is visible in the two baseline data sets: the current uses of energy by sector and the changes, or growth, in overall energy uses over the past two decades. Chart 15 summarizes current national energy use by major sectors and primary subsectors (or sector major uses).

Chart 16 summarizes the changes in primary energy supply over the past two decades. The recent history has three implications for the near future. First, the substantial historic and continuing role of the nation's nuclear power

Chart 14

GDP and Energy Consumption



Source: DOE/EIA

Chart 15

Allocation by Sector of Total Overall U.S. Energy Consumption

Primary sector	Primary sector share of all U.S. energy	Subsector share of sector energy*
Transportation*	28%	
Automobiles		*54%*
Commercial truck		*17%*
Commercial aviation		*13%*
Railroads		*2%*
Marine transportation		*6%*
Industrial	36%	
Manufacturing		*82%*
Mining		*8%*
Agriculture		*5%*
Water		*1%*
Construction		*4%*
Commercial	17%	
Office, mercantile, education-related buildings		*50%*
All other buildings		*50%*
Residential	18%	
Heat (space & water), cool (space & refrig.)	*65%*	
All other uses		*35%*

*Subsector totals do not equal 100 percent because transportation energy also includes energy used to transport liquid fuels and natural gas pipelines and similar transportation uses not included in the table.
Source: DOE/EIA

plants points to the importance of their continued safe and efficient operation. Second, the near certainty that a comparable amount of nuclear capacity will *not* be ordered and built in the near future presents a major challenge to other nonfossil sources to provide as much energy in the next 20 years as nuclear did in the past 20 years. Third, improved energy efficiency and carbon efficiency in the U.S. economy occurred even as fossil fuel use rose.

A useful way to view these trends is through the three primary ways that energy is delivered to the marketplace. Energy for transportation is essentially unrelated to the electric sector or to any of the specific energy technology choices in other sectors. In the balance of the economy (industrial, commercial and residential), the types of energy-using equipment can be divided into

Chart 16

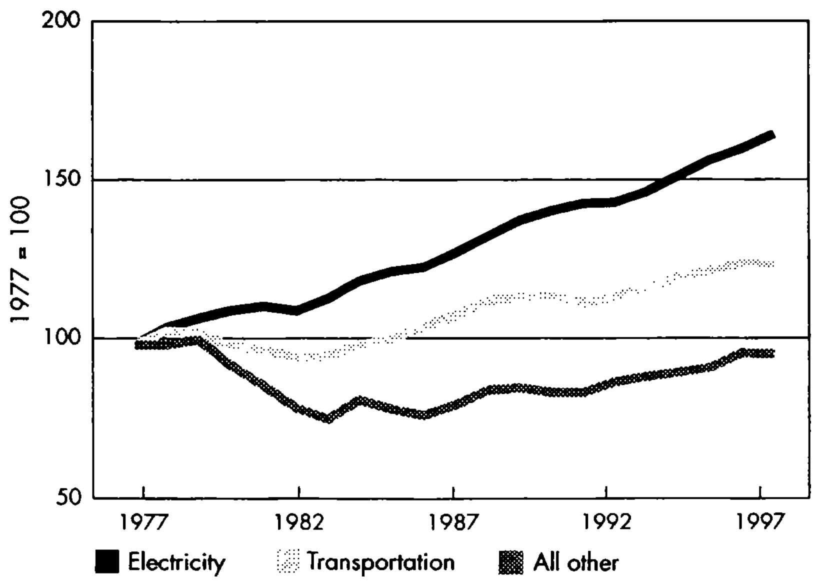
Changes in U.S. Energy Supply

Energy source	Share of growth, 1977–97
Overall changes	
Fossil energy	*65%*
Nonfossil energy	*35%*
Fossil shares of all growth in U.S. energy	
Coal	*43%*
Natural gas	*21%*
Oil	*-8%*
Nonfossil shares of all growth in U.S. energy	
Nuclear	*27%*
Other	*8%*
Hydro	*8%*
Geothermal	*0.2%*
Wind, solar	*0.2%*

Source: DOE/EIA

Chart 17

Energy Used in the Economy

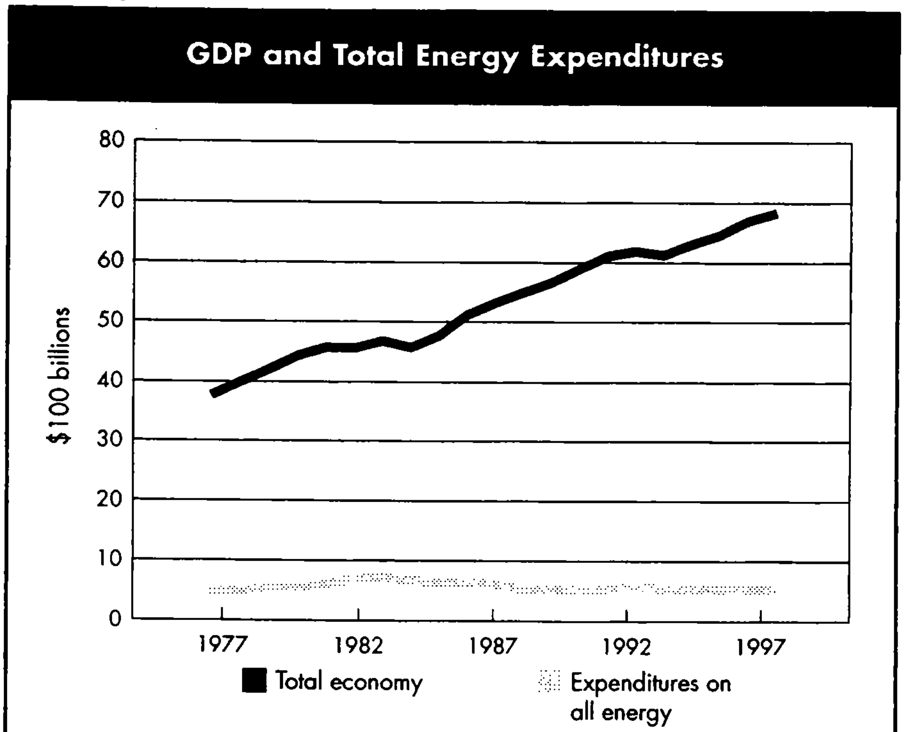


Source: DOE/EIA

two simple categories: electric and nonelectric. Chart 17 illustrates the historic trends for these three primary uses of energy.

The cost of fuels will continue to be a key factor in all energy proposals. The problems created by very high energy prices in the late 1970s are well documented. Low energy prices are vital not only from the individual consumer and business perspectives, but also in terms of national economic inputs. Energy is a primary commodity or resource, and its price directly affects inflation. Chart 18 shows total energy purchases over the past two decades, which have remained remarkably constant at about $500 billion per year (inflation-adjusted) even as the GDP and energy use have grown. (Energy use did decline briefly during the late-1970s recession that was created primarily by energy price shocks. Declining use thus moderated total energy spending, but at the expense of economic growth.)

Chart 18



Note: Inflation-adjusted dollars
Source: DOE/EIA

ENDNOTES

[1]Jules J. Duga, *Battelle-R&D Magazine,* Jan. 4, 1999.

[2]DOE/EIA.

[3]*Annual Energy Review 1998,* DOE/EIA.

[4]Ibid.

[5]*Trucking Facts & Industry Issues,* American Trucking Association: 41 billion gallons of gasoline and diesel fuel.

[6]*Trucking Facts & Industry Issues,* American Trucking Association.

[7]"Scenarios of U.S. Carbon Reductions," Interlaboratory Working Group on Energy-Efficient and Low-Carbon Technologies, Office of Energy Efficiency and Renewable Energy, U.S. DOE, Sept. 22, 1997, p. 5.41.

[8]Ibid: 1970 10,351 Btu/pm to 1987 4,753.

[9]*Technology for the United States Navy and Marine Corps, 2000-2035: Becoming a 21st-Century Force,* National Academy of Sciences, 1997.

[10]"Scenarios of U.S. Carbon Reductions," p. 5.41.

[11]*Statistical Abstract of the United States,* U.S. Census Bureau, Table 1034.

[12]Ibid, Tables 1032 and 1039.

[13]M. Mills, "Transportation Fuels — Electricity," *Encyclopedia of Energy Technology and the Environment,* 1995, p. 2698.

[14]"Scenarios of U.S. Carbon Reductions," p. 5.41.

[15]*Statistical Abstract,* Table 1065.

[16]*Annual Energy Review,* DOE/EIA.

[17]*Fortune,* May 11, 1998.

[18]EPRI.

[19]*Annual Energy Review,* DOE/EIA, Table 2:20.

[20]*Survey of Commercial Buildings Energy Consumption and Expenditures, 1995,* DOE/EIA.

[21]*Survey of Commercial Buildings Energy Consumption and Expenditures, 1995,* DOE/EIA: office at 100,000 Btu/sq. ft. and health care 230,000.

[22]*Annual Energy Outlook 1998,* DOE/EIA, p. 43: 1996 70 billion sq. ft. and 2020 reaches 87 billion.

[23]*Annual Energy Outlook 1998,* DOE/EIA, p. 43.

[24]National Automatic Merchandising Association.

[25]*Annual Energy Outlook 1998,* DOE/EIA, p. 42.

[26]*Annual Energy Outlook 1998,* DOE/EIA.

[27]EIA & GRI.

[28]*Annual Energy Expenditures,* DOE/EIA.

[29]"Electricity in Economic Growth," National Academy of Sciences, 1986.

[30]*Annual Energy Outlook 1998,* DOE/EIA: currently 100,000 MW nuclear capacity.

[31]"Venerable engine/generator repositioned for on-site, distributed power," Special Report, *Power,* February 1999.

[32]EEI Non-Utility Sources of Energy, 1998.

[33]*Annual Forecast 98,* DOE/EIA.

[34]Calculation from EIA data.

[35]Gloor et al., "A Large Terrestrial Carbon Sink in North America ... ," *Science*, 16 October, 1998.