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TJ's Technology Paper

Global Climate Change

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The Honorable Janet Yellen
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Dear Dr. Yellen:

The Business Roundtable today released a report, *The Role of Technology in Responding to Concerns About Climate Change*, which calls for two initiatives intended to bring together government and business to accelerate development and use of innovative technologies that can address global climate concerns.

The first part of the global climate effort will involve working with government to identify and remove obstacles to the innovation, commercial assimilation and dissemination of new technologies with potential to address global climate concerns, including time-consuming processes involving infrastructure, trade, and regulation. The Business Roundtable intends to prepare a report on its findings on ways to streamline governmental processes to facilitate technology development on this important issue.

Secondly, the BRT intends to bring together leaders from government, the nation's science labs and major research institutions, and leading science academicians to co-host a national summit on technology transfer in the 21st century. The counsel of government, business, research and academic communities will be important to honing research targets and opportunities as well as facilitating technology transfer to the market. A national summit will serve as a kick-off to the process of developing concrete proposals and goals by reaching consensus on steps to accelerate new technologies that address global climate change.

The just-completed BRT report is enclosed as background on the approach recommended by the nation's major employers. The Business Roundtable 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.

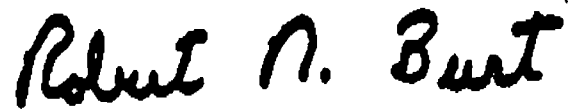
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Breakthrough technologies that will make a real difference in climate change will not be ready overnight. We need to focus on the long-term developments in technology that will enable us to realize such a difference.

One action already on the table that can be of substantial assistance is S 882, the Murkowski-Hagel-Byrd legislation that would fund an R&D program to spur development of energy-saving technologies. The BRT fully supports this bill, and was joined by Senators Frank Murkowski and Chuck Hagel and Congressman John Dingell in releasing the BRT study.

The BRT is excited about the promise of new technologies that can address concerns about climate change, and we are committed to turning this promise into reality. I am asking you to join with business, government, research and academic leaders to put this comprehensive approach to work on behalf of all Americans, and future generations.

Sincerely,

A handwritten signature in black ink that reads "Robert N. Burt". The signature is written in a cursive, slightly stylized font.

Robert N. Burt,
Chairman and Chief Executive
FMC Corporation
and Chairman of the Environment Task Force,
The Business Roundtable



ENVIRONMENT TASK FORCE

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

July 1999

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

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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.brttable.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

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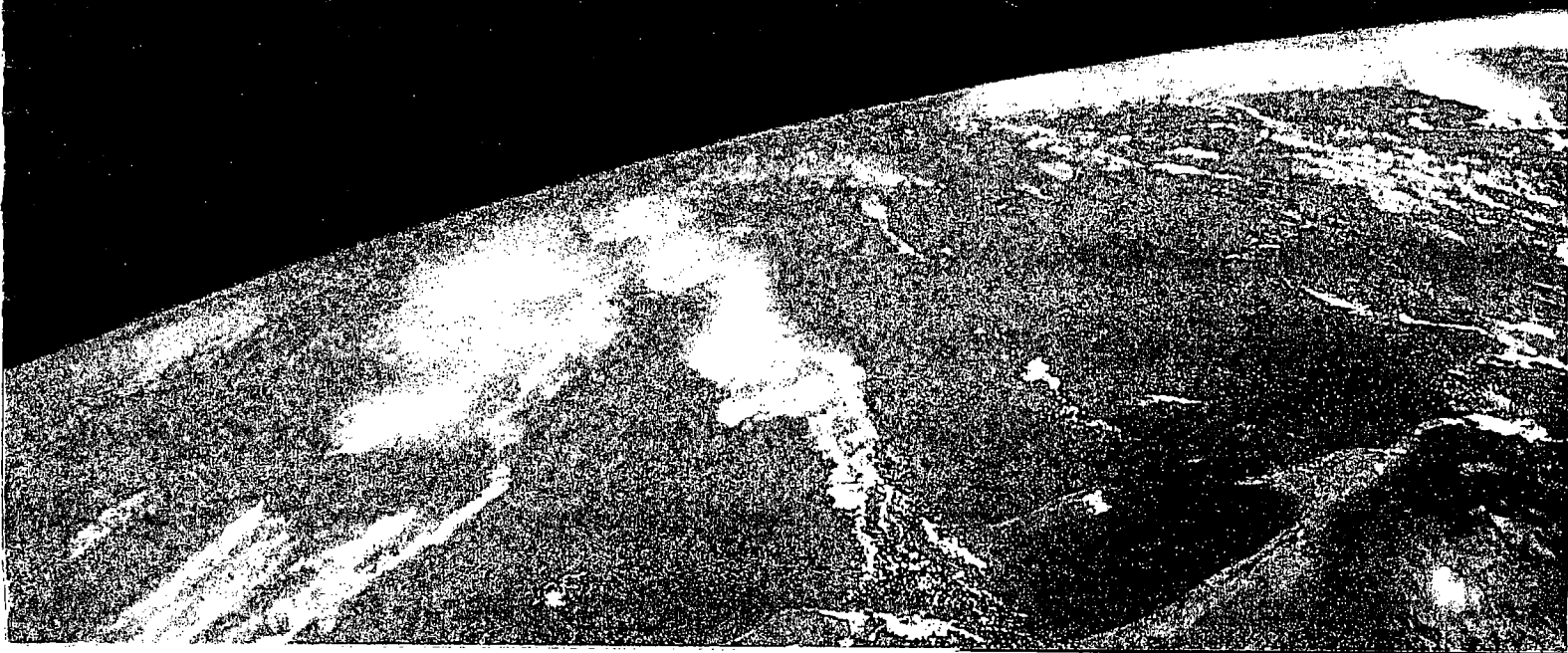
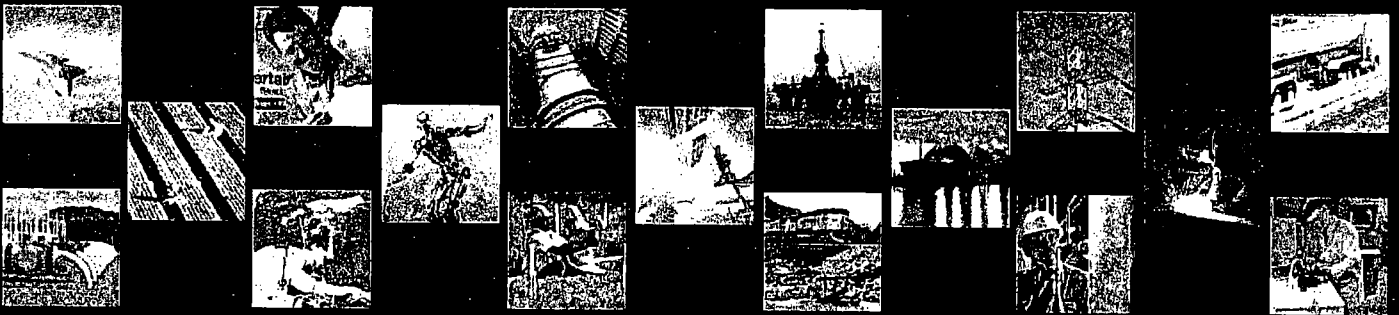


THE
BUSINESS
ROUNDTABLE

THE ROLE OF TECHNOLOGY IN RESPONDING TO CONCERNS ABOUT GLOBAL CLIMATE CHANGE

TECHNOLOGY

IN THE 21st CENTURY



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.

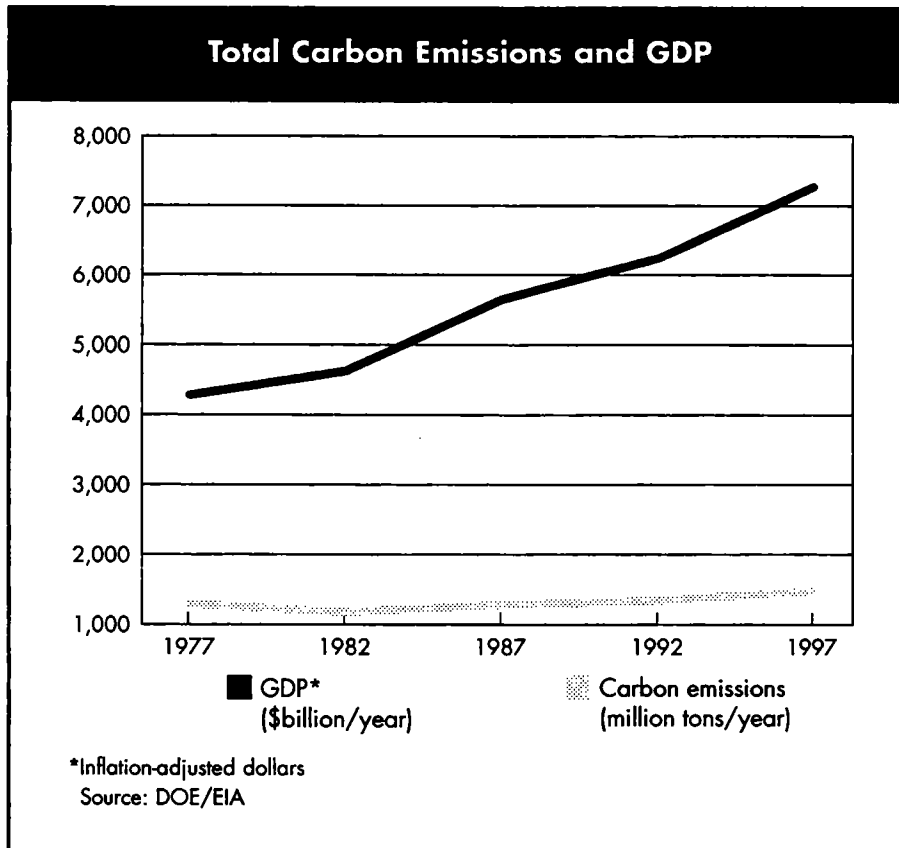
The technology progress, challenges and opportunities associated with effecting major changes in the energy infrastructure of the United States are best illustrated by considering the baseline facts visible in the trends of the past 20 years.

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

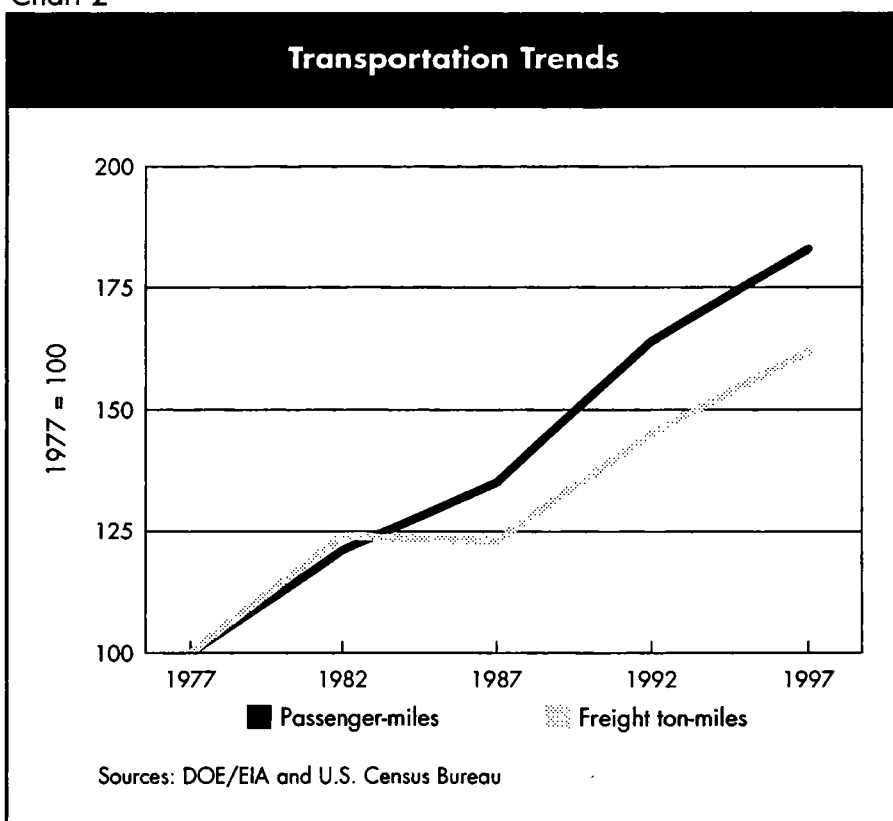
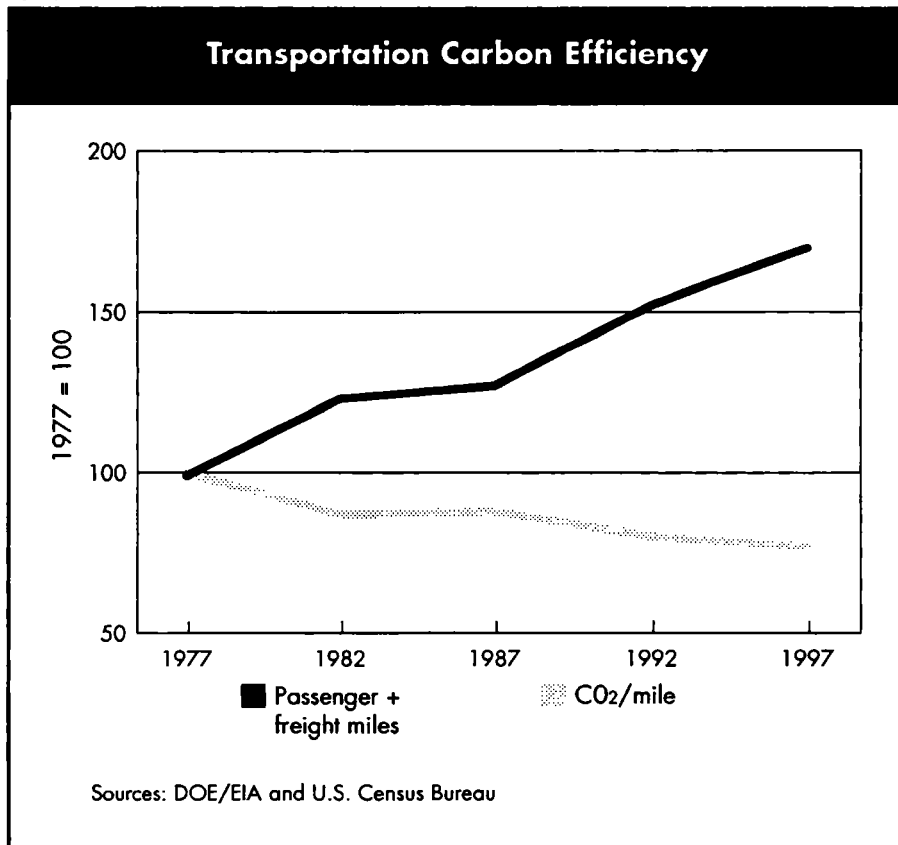


Chart 3



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, aero-

dynamic 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 light-weight 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 resis-

tance. 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 micro-sized flaps. Fabricated by borrowing the technologies used to make integrated circuits, micro-sized 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 “sempianning” 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

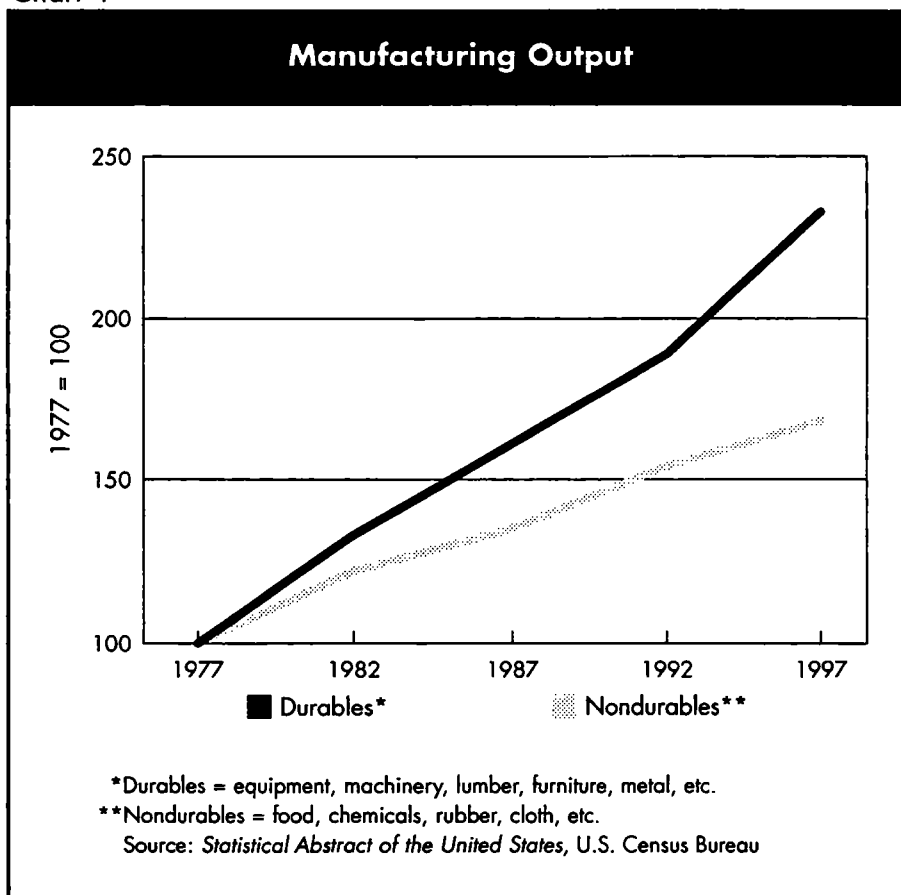
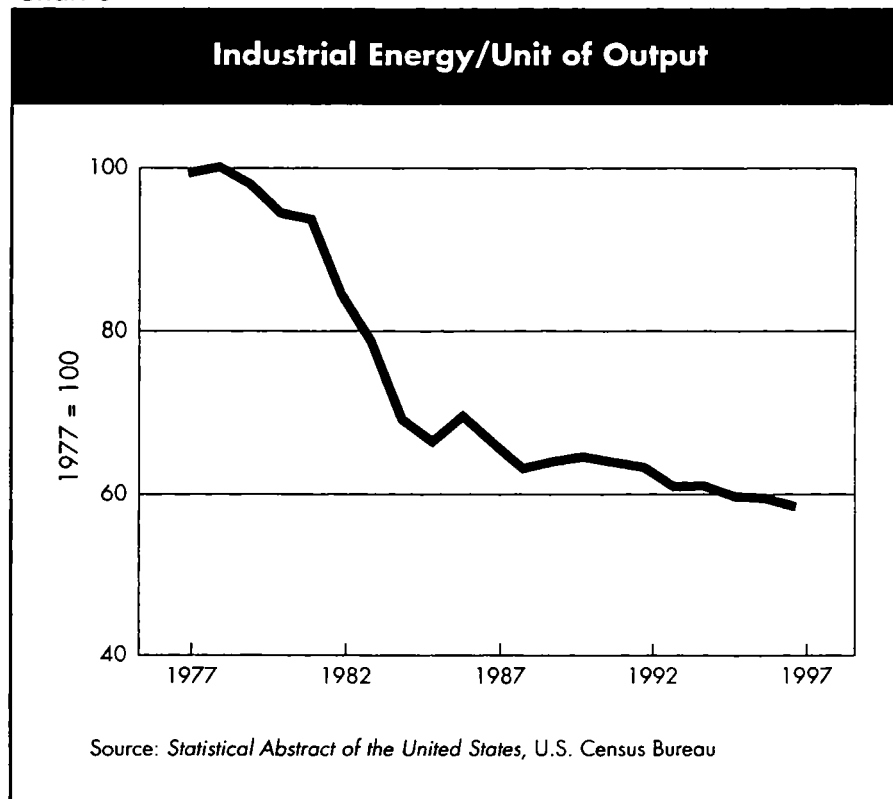


Chart 5



- 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.

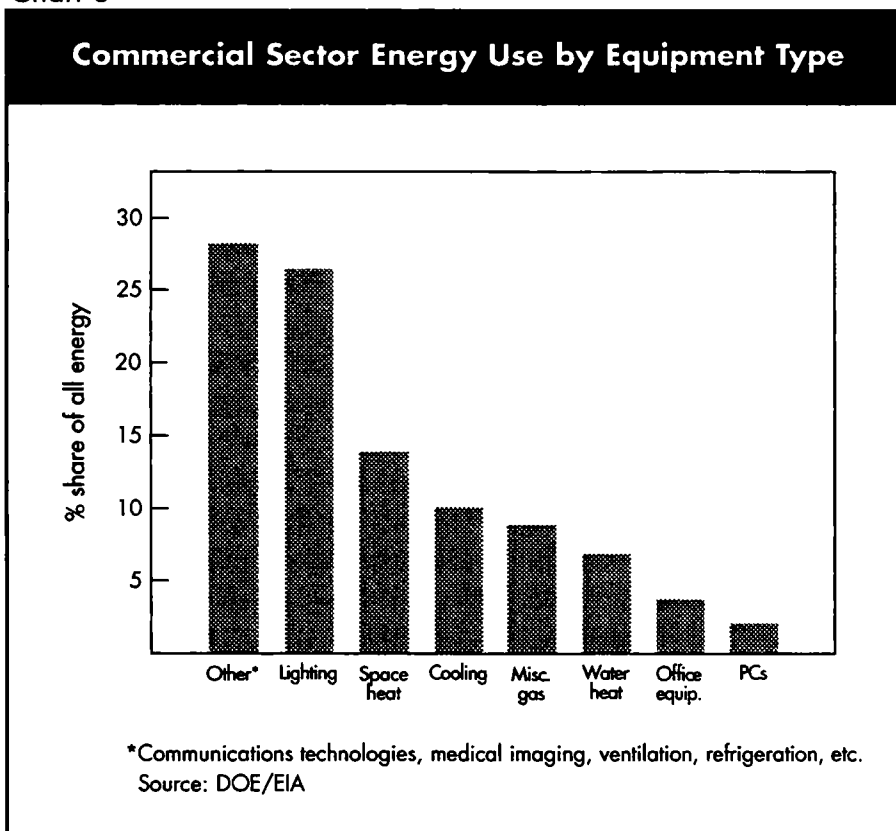
IV. TECHNOLOGY DEVELOPMENT IN THE COMMERCIAL SECTOR

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



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.”

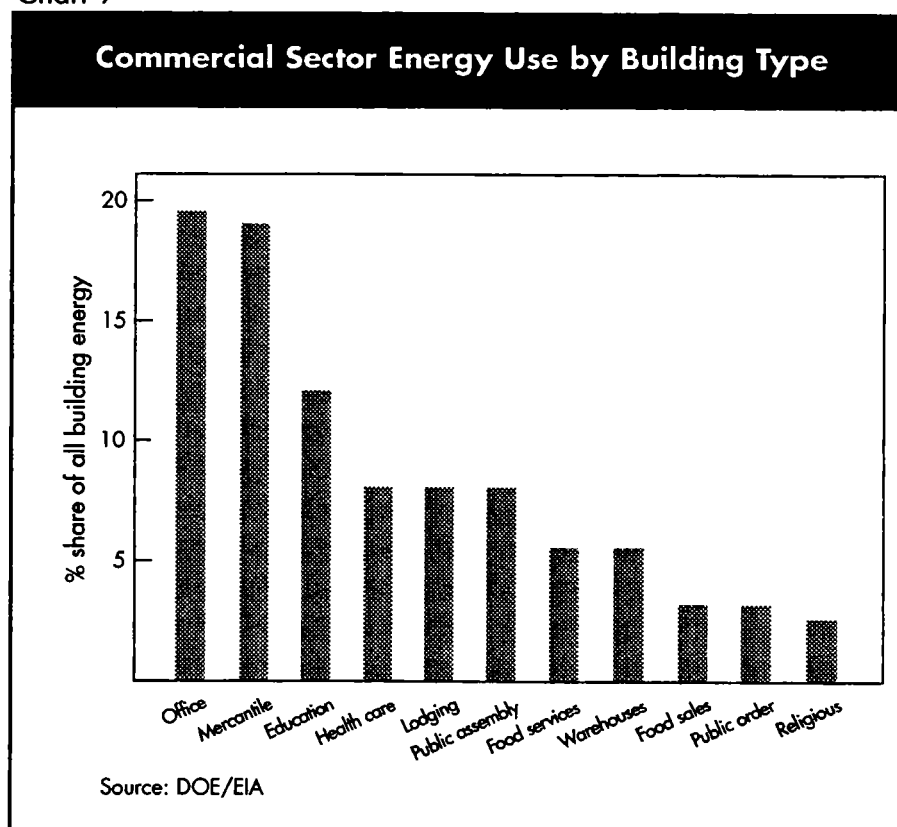
The commercial building sector is highly varied in terms of technology requirements, market pressures and economic priorities. Chart 9 illustrates the types of commercial buildings and each category’s share of total commercial building energy use.²⁰

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

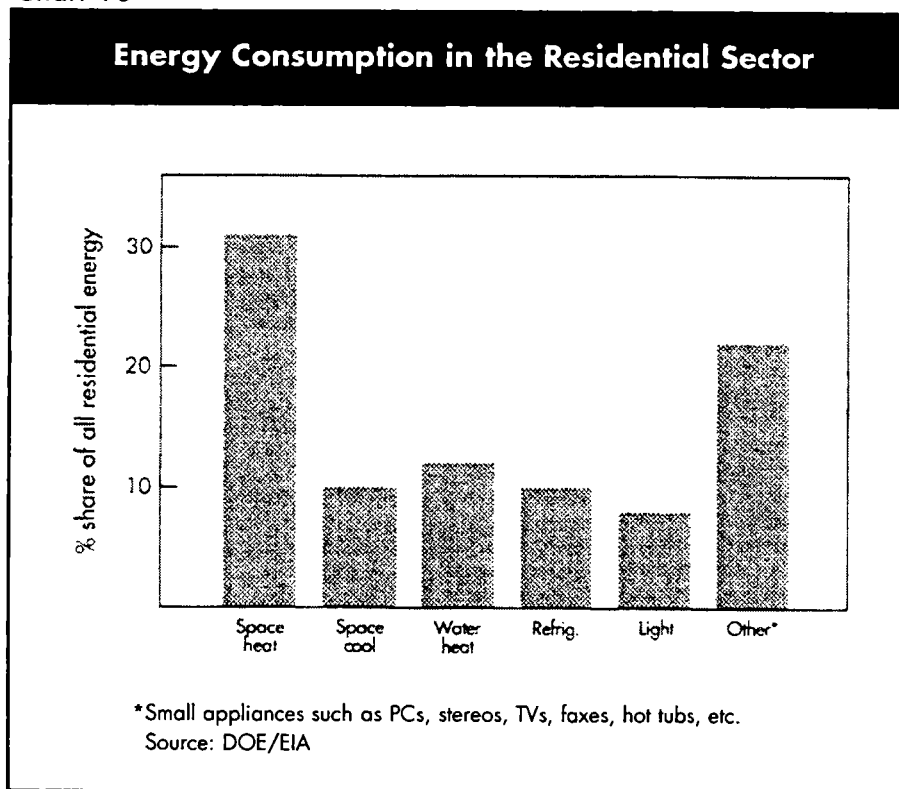
Ensuring that manufacturers are aware of the entire range of new technologies is important. A challenge — and opportunity — continues in the arena of engaging equipment developers in long-range technology transfer initiatives with private and federal research facilities, where important new — and even 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



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 envelopes 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

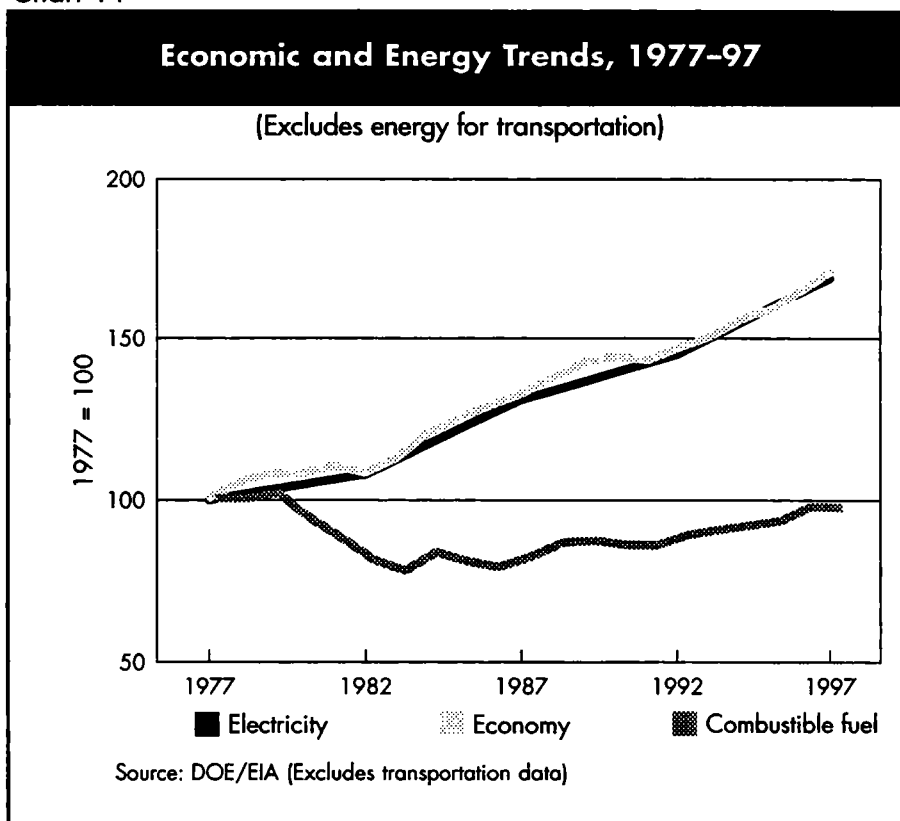


Chart 12

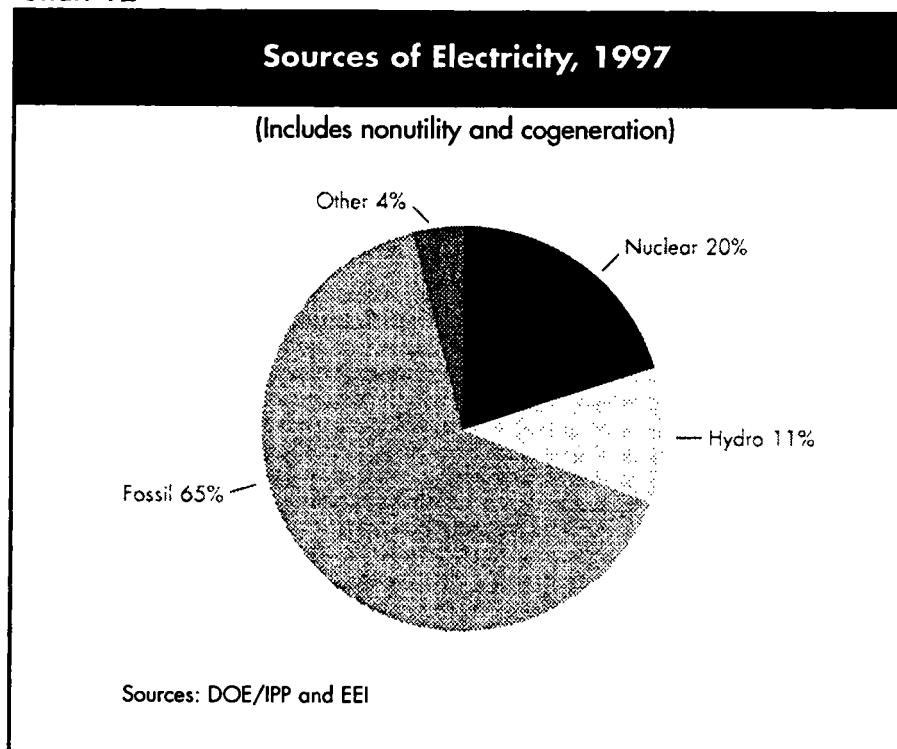


Chart 13 illustrates the *additions* to the nation's electric supply over the past two decades. Coal accounted for 56 percent and nuclear power for 32 percent of the increase in total electricity supplied.

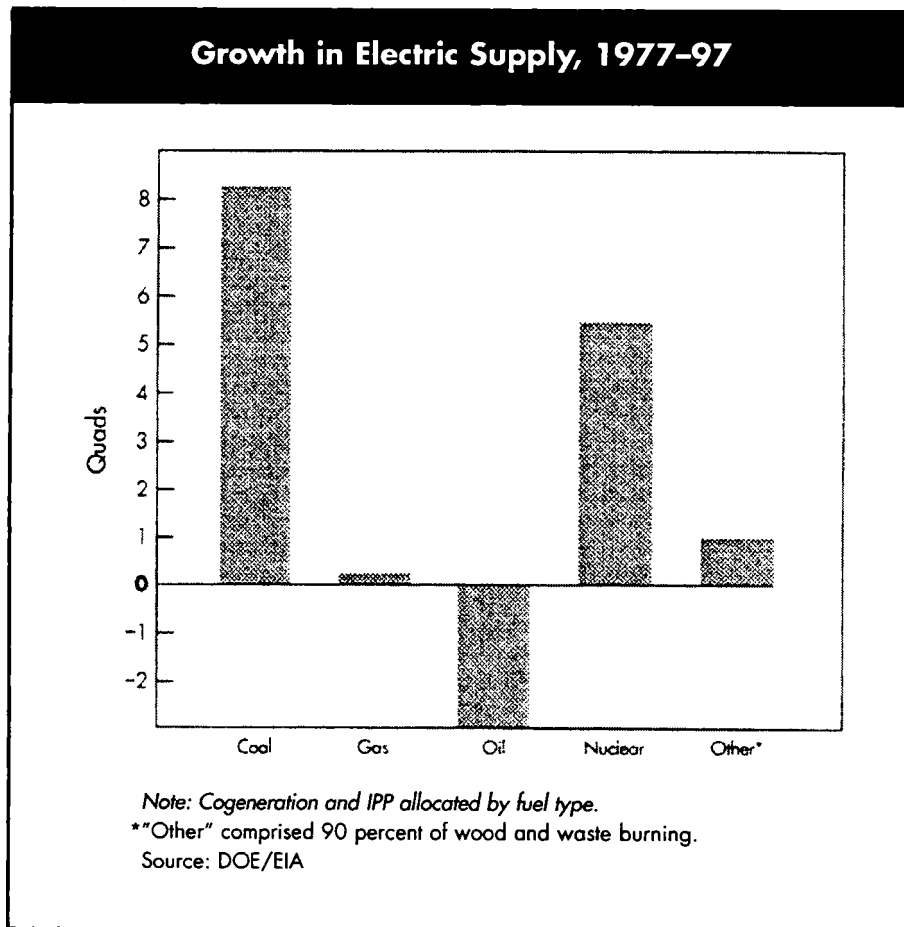
The central challenge for regulators and legislators who seek more efficient models for organizing the electricity industry will be the need to meet market-driven growth in demand for electricity without lowering quality.

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



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 CO₂ 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 CO₂ 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 CO₂ 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” CO₂ 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 — CO₂ 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

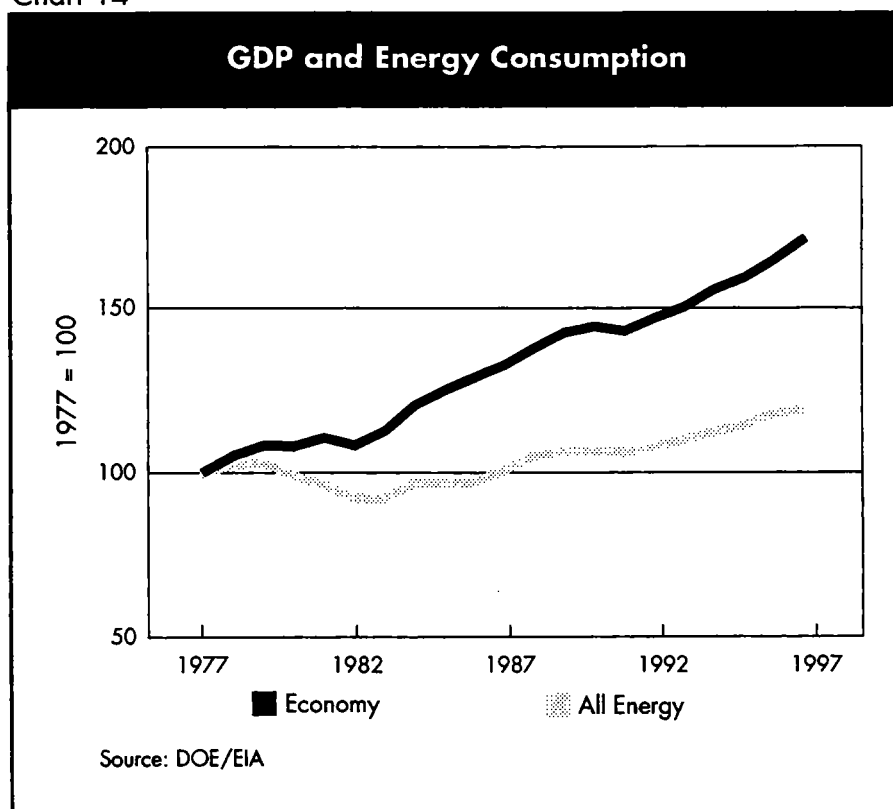


Chart 15

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 & refrigeration)	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.

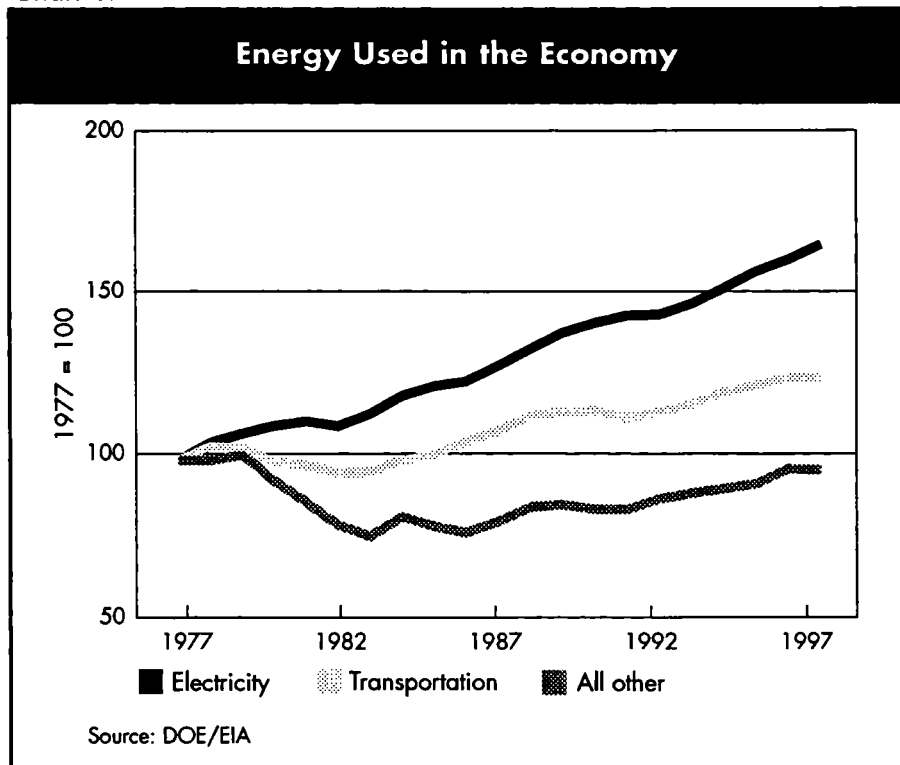
A useful way to view these trends is through the three primary ways that energy is delivered to the marketplace. Energy for transportation is essentially unrelated to the electric sector or to any of the specific energy technology choices in other sectors. In the balance of the economy (industrial, commercial 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

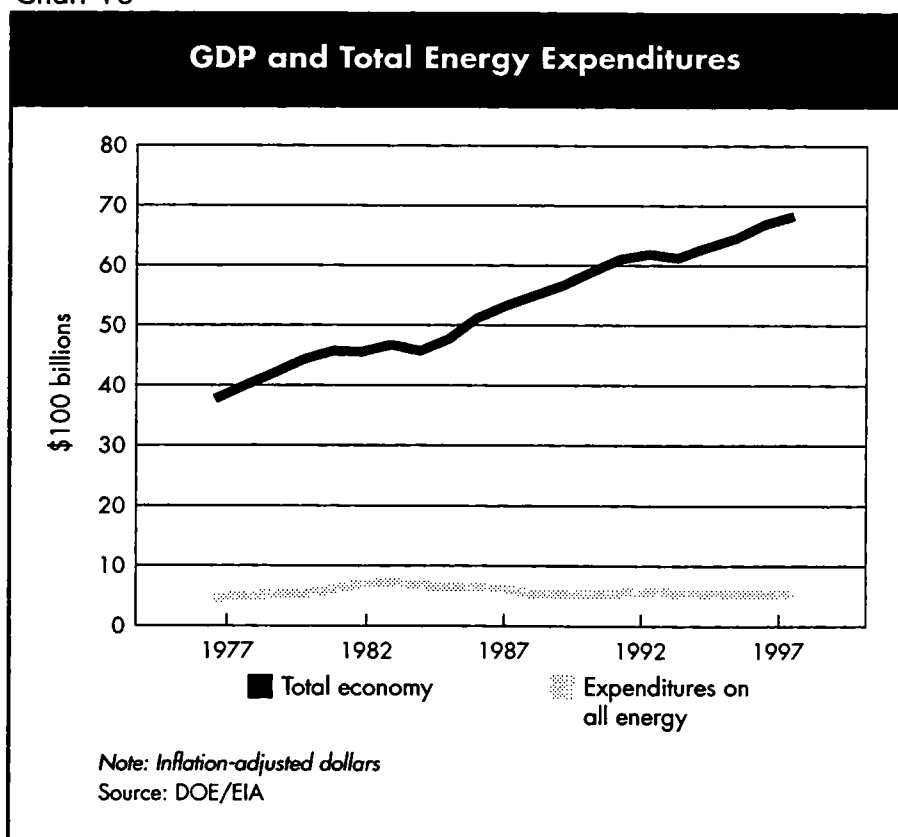
Chart 17



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



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- ³*Annual Energy Review 1998*, DOE/EIA.
- ⁴*Ibid.*
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- ¹²*Ibid.*, Tables 1032 and 1039.
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- ¹⁵*Statistical Abstract*, Table 1065.
- ¹⁶*Annual Energy Review*, DOE/EIA.
- ¹⁷*Fortune*, May 11, 1998.
- ¹⁸EPRI.
- 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.
- ²⁴National Automatic Merchandising Association.
- ²⁵*Annual Energy Outlook 1998*, DOE/EIA, p. 42.

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

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TOWARD A TECHNOLOGY GREENHOUSE STRATEGY

Jae Edmonds

The Framework Convention on Climate Change (FCCC) sets as its objective the stabilization of the **concentration** of greenhouse gases in the atmosphere at safe levels. No matter what level turns out to be "safe" this obligation requires that anthropogenic CO₂ **emissions** must, eventually, decline to zero. We will discuss the relationship between emissions and concentrations in detail below, however, since energy use is the most important present and anticipated future source of net CO₂ emissions, eventually declining emissions implies an eventual secession of coal fired power plant construction, and prohibition of coal gasification and liquefaction.

The Energy Background

We note here the anticipated contributions of fossil fuels to future CO₂ emissions are not all equal. The present understanding of the fossil fuel resource base indicates that conventional oil and gas resources are limited, and provide a limited pool from which emissions can be released. Coal and unconventional oils such as oil shales are available in vastly greater quantities (IPCC, 1996). It is the growing use of coal as a feedstock for synthetic fuels and as an input to electric power generation that drives the expansion of CO₂ emissions beginning in the first half of the next century. The limited resources of conventional oil and gas imply that while their use will continue to grow during the first half of the next century, production will be unable to keep pace with global energy demands and will experience production declines in the second half of the twenty-first century, unless the resource base has been grossly underestimated.

Stabilizing Fossil Fuel Emissions

Stabilizing CO₂ emissions is not the same as stabilizing CO₂ concentrations. While stabilizing fossil fuel emissions at any level reduces the rate of accumulation of CO₂ in the atmosphere, it does not stabilize the concentration of atmospheric CO₂. Table 1 shows the atmospheric concentrations of CO₂ under a scenario developed by the Intergovernmental Panel on Climate Change (IPCC), called IS92a (Leggett, et al., 1992) and then compares it to concentrations derived from similar scenarios, but which stabilize emissions at alternative emissions ceilings. Tracking IS92a until emissions reach 10 PgC/yr at which point emissions are stabilized, leads to a concentration of almost 600 ppmv by the year 2100, with the concentration continuing to rise. Even stabilizing at 1990 emissions rates implies a concentration that approach 500 ppmv by the year 2100. Stabilizing at 1990 emissions rates in turn would require great changes in the way the world uses energy. If as anticipated, the world's population doubles, stabilizing emissions requires that average global per capita emissions must fall from approximately 1 tonne/yr to 0.5 tonne/yr. We note that present United States per capita emissions are approximately 5 tonne/yr.

Table 1: Year 2100 Atmospheric CO₂ Concentrations for IS92a and Alternative Cases in Which Energy Related Emissions are Stabilized at Varying Levels ^a

Case	Rate at Which Emissions are Stabilized (PgC/yr)				
	IS92a	10	9	8	7
Concentration (ppmv)	725	592	569	545	520

^a Assumes that land-use and cement emissions follow IS92a.

Stabilizing Emissions Is Not Enough

Stabilizing CO₂ emissions will not stabilize the concentration of atmospheric CO₂. Stabilizing concentrations is more ambitious than stabilizing emissions. In fact ultimately stabilizing the concentration of CO₂ in the atmosphere means that net emissions must eventually go to zero. The Intergovernmental Panel on Climate Change (IPCC) has explored a variety of emissions paths consistent with alternative stabilization levels for CO₂. One path which stabilizes the atmospheric concentration of

CO₂ at a ceiling of 550 ppmv is shown in Figure 1, along with constant 1990 emissions and two business as usual scenarios based on the IPCC IS92a scenario.

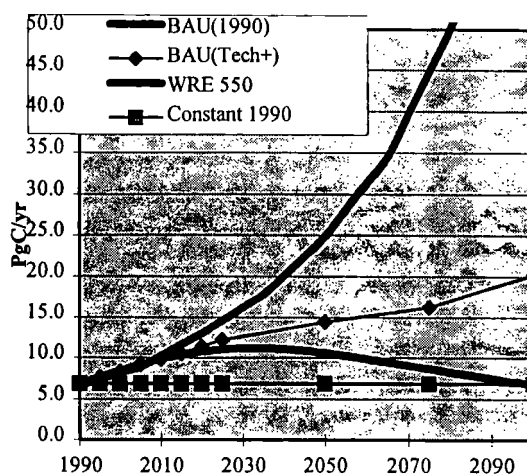


Figure 1: CO₂ Emissions for Alternative Scenarios

Both business as usual scenarios adopt the same economic and demographic assumptions as the IPCC. They differ only in their technology assumptions. Case IS92a(Tech+) adopts the IS92a technology development assumptions,¹ while IS92a(1990Tech) holds technology fixed at 1990 levels. While WRE550 was constructed to stabilize the concentration of CO₂ at 550 ppmv, Figure 2, neither IS92a(1990Tech) or IS92a(Tech+) achieve that goal. Further, even the constant 1990 emissions case fails to stabilize the concentration of atmospheric CO₂. The concentration continues to rise into the twenty-second century and ultimately exceeds the 550 ppmv ceiling.

Cumulative Emissions and the “Window of Opportunity”

There are two things to note about the IPCC calculations. First, emissions always ultimately decline to zero. And second, emissions always **rise** initially for ceilings 450 ppmv and higher. This may seem ironic; if emissions must eventually decline to zero, how can they rise initially? The answer is that

¹ For example the efficiency of the average fossil fuel powerplant is assumed increase at more than 1.0%/yr between 1990 and 2050, from 0.33 to 0.66. Exogenous end-use energy intensity proceeds at between 0.5%/yr (OECD nations) and 2.5%/yr (Eastern Europe and the Former Soviet Union). The cost of non-fossil fuel electric power generating technologies, other than nuclear and hydroelectric, declines at an average annual rate of 4.5%/yr between 1990 and 2025, and at 1.25%/yr from 2025 to the year 2100. And the cost of biomass energy production declines at an annual rate of one percent per year between 1990 and 2100 from 1990 values ranging from \$2.50/GJ to \$4.40/GJ, depending on the location and scale of production

the concentration of CO₂ depends, to a first approximation, on cumulative emissions. Any steady-state concentration higher than at present means some continued emissions.

The concentration target determines the allowable emission total. The higher the ceiling, the greater the allowable emission total. But the higher the ceiling, the greater the climate change which will ultimately be experienced. **This highlights the fundamental tradeoff – costs associated with emissions mitigation against benefits from reduced long-term climate change.**

If the “safe” ceiling for CO₂ concentration is sufficiently high, total allowable emissions may be great enough to provide the breathing space necessary for an orderly transition from existing carbon-intensive energy technologies to non-carbon energy technologies.

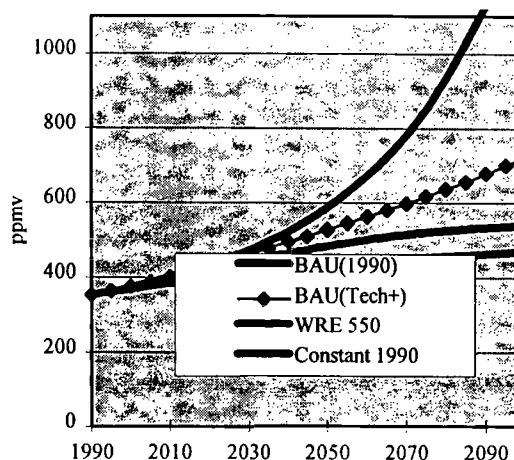


Figure 2: CO₂ Concentrations for Alternative Scenarios

In a future which must negotiate a transition from carbon-intensive energy technologies to non-carbon energy technologies, the fact that emissions can rise before ultimately declining is important. It provides the “window of opportunity” needed to establish the international mechanisms for emissions mitigation, to enlist those nations (both within and outside Annex I), which are responsible for the majority of present and anticipated future emissions, and to replace the existing energy system with a system which is non-carbon emitting. For example, in the case of a 550 ppmv ceiling, global fossil fuel carbon emissions could rise to 9.7 PgC/yr in 2033 (compared with the 1990 rate of 6.0 PgC/yr and a IS92a (Tech+) emissions rate of 11.5 PgC/yr in 2033) and would not be required to return to 1990 levels until the year 2100.

Replacing the existing energy system with a system which is non-carbon emitting will not be trivial. The present carbon-emitting, global, energy system works. It is relatively inexpensive and requires only a small fraction of society’s wealth to operate and maintain. It is supported by global infrastructure investments that have co-evolved and accumulated over long periods of time. Developing global, non-carbon, alternative energy technologies will require time, ingenuity, and investments of a similar magnitude to those which underpin the present system. The process must be so broadly articulated that it permeates both rich and poor societies. Because energy is ubiquitous, the transition will affect many aspects of human technology in ways that are both major and minor.

Ceilings and Floors

The higher the ceiling the higher the maximum fossil fuel emissions, and the longer emissions can rise before departing substantially from the reference case, and the higher the emissions can grow. These relationships are computed for the WRE scenarios and displayed in Table 2. The rate of emissions decline in the period subsequent to maximum emissions is also lower for higher concentration ceilings. This is contrast to steadily growing emissions in the IS92a (Tech+) scenario, Figure 1.

Table 2: The Relationship Between CO₂ Concentration Ceilings, Maximum Emissions, and the Subsequent Rate of Emissions Decline: WRE Cases

Steady-State Concentration →	350 ppmv	450 ppmv	550 ppmv	650 ppmv	750 ppmv
Deflection Date IS92a (Reference technology) ^a	2001	2007	2013	2018	2023
Deflection Date IS92a (1990technology) ^a	2001	2006	2007	2007	2007
IS92a (Reference technology) Growth Rate ^b	1.8%	1.4%	1.1%	0.9%	0.7%
IS92a (1990technology) Growth Rate ^b	1.6%	1.3%	1.0%	0.8%	0.6%
Maximum Date	2005	2011	2033	2049	2062
Maximum Emission ^d	6.0	8.0	9.7	11.4	12.5
Rate of Decline ^c		1.1%	0.8%	0.6%	0.5%
Emission in year 2100 ^d	4.0	3.7	6.9	10.0	12.5

^a The deflection date is the year in which emissions in the emissions stabilization trajectory first fall below IS92a emissions by more than 0.1 PgC/yr.

^b Average annual rate of growth (%/yr) of WRE fossil fuel carbon emissions between the "Deflection Date" and the "Maximum Date."

^c The rate of growth (%/yr) of fossil fuel carbon emissions between the "Deflection Date" and the "Maximum Date."

^d PgC/yr fossil fuel carbon emissions on the date of maximum total anthropogenic carbon emissions. 1990 fossil fuel emissions were 6.0 PgC/yr.

^e Rate of decline in fossil fuel carbon emissions, in percent per year, over the first 75 years following the date of maximum emissions. Note 350 ppmv not defined as it requires a negative net emission.

We have also computed the rate of emissions growth from the date at which significant emissions mitigations begin until the date of maximum emissions. There is relatively little difference among alternative WRE trajectories for rates of emissions growth between the date of deflection and the date of maximum emissions. But due to the fact that the rate of anticipated emissions growth declines over time in the IS92a (Tech+) scenario, the difference between the constrained WRE trajectory and the IS92a(Tech+) scenario is uniformly smaller the higher the ceiling chosen.

As time passes without emissions mitigation, the current CO₂ concentration grows ever larger. Returning the concentration of CO₂ to 350 ppmv requires negative emissions, because the concentration now exceeds 350 ppmv (358 ppmv in 1994). That is, not only would all CO₂ emissions from fossil fuel use and deforestation need to cease, but in add a program of net carbon sequestration, such as reforestation, would be required. It is difficult to imagine near-term stabilization of the atmosphere at any concentration that is lower than contemporary concentrations. Potential CO₂ ceilings are gradually transformed into CO₂ floors over time. The rate at which concentrations are rising is presently approximately 2 ppmv per year. At that rate emissions would not exceed 400 ppmv until the year 2013. Under the IS92a trajectory, the rate grows to about 2.5 ppmv per year toward the middle of the twenty-first century.

Costs Matter

A transition from the present carbon-emitting energy technology to an alternative non-carbon energy technology will entail costs. The degree of sacrifice, that is the cost of emissions mitigation, will depend primarily on four factors:

1. The ceiling,
2. The extent of participation among the world's nations,
3. The degree of flexibility as to where and when emissions mitigation can be undertaken, and
4. The non-carbon emitting technology alternatives to fossil fuel technologies.

Each of these factors can profoundly influence the cost to the world of stabilizing the atmosphere.

Minimizing costs is important. The higher the cost, the more resources must be diverted to emissions reductions. And the more resources which must be diverted to the emissions reductions, the fewer the resources available to pursue society's other goals such as improving health, providing education, reversing the effects of past pollution, and raising the material standard of living, as well as for reducing emissions.

The Coming Energy Transition

While replacing the present energy technology is a daunting task, it would eventually happen in any event. The supply of conventional oil and gas resources is limited, and during the first quarter of the twenty-first century most energy models suggest that ability of the energy system to expand supply at the same pace as global demand will become increasingly difficult. This is likely to lead to higher fossil fuel prices and inaugurate another energy system transition.

Coal appears poised to play an important role in the coming energy transition. In the absence of concerns related to climate change, coal could begin to be used as a feedstock for synthetic liquids and gases, and become an increasingly important fuel for electric power generation around the world. This in turn implies a increase in the scale of global CO₂ emissions. It is this transition to a coal based energy system which is responsible for the anticipated escalation in CO₂ emissions during the middle of the next century.

But the central role of coal in the future is not preordained. The relative importance of coal and other energy forms including non-carbon energy forms, will depend on many factors including the direction of technology developments over the next quarter century.

Technology and Cost

Technology is a major determinant of cost. Recent work (Edmonds et al., 1996) shows that, depending on the suite of technologies available at the end of the first quarter of the next century, the cost of stabilizing the atmosphere can vary by literally trillions of dollars.

In a modeling experiment, Edmonds et al. (1996) assumed different levels of technology development and coupled that with the assumption that beginning immediately, all nations of the world agreed to begin a program of emissions mitigation which would stabilize the atmosphere. Institutional arrangements which provided for full flexibility in where emissions reductions were undertaken were

assumed to be developed, so that the world met any emissions mitigation in any year at the lowest possible cost. The global emissions paths were taken from Wigley et al. (1996).

Three alternative energy technology regimes were considered:

- Technology Case 1: **IS92a (1990Tech)** -- Technologies are frozen at 1990 levels. No energy technology improvements of any kind were considered.
- Technology Case 2: **IS92a (Tech+)** -- IPCC Technologies from the IS92a scenario were assumed to become available. This case assumes significant energy technology improvements in both fossil and non-fossil energy technologies over the course of the next century. It is this set of technological change assumptions which is associated with the 1400 ppmv CO₂ concentration in Figure 1.
- Technology Case 3: **Advanced Technology** -- In addition to the technologies available in Technology Case 2, a suite of advanced, non-carbon emitting technologies are developed which are efficient and cost effective. These technologies have been described in for example Ishitani, et al. (1996).²

The cost estimates developed here must be viewed as a lower bound on the actual costs that would be experienced in reality. But the pattern they show is revealing. Figure 3 shows the costs for different CO₂ concentration ceilings. The difference between stabilizing the concentration at 550 ppmv with 1990 technologies and the technology advances in the IS92a scenario is staggering.

² The advanced technology case examines technologies which might be introduced in the future, but which are not presently available. These technologies include: advanced liquefied hydrogen fuel cells; hydrogen transformation from natural gas, biomass, or electrolysis; non-fossil fuel electric power generating technologies including solar photovoltaic, nuclear fusion, and wind, and commercial biomass energy production. Mean potential costs for the non-carbon electric technology set is assumed to decline to a cost of \$0.04/kWh by 2020 and decline 0.5%/yr thereafter. Biomass energy is assumed to be available at costs ranging from the \$1.40/GJ to \$2.40/GJ.

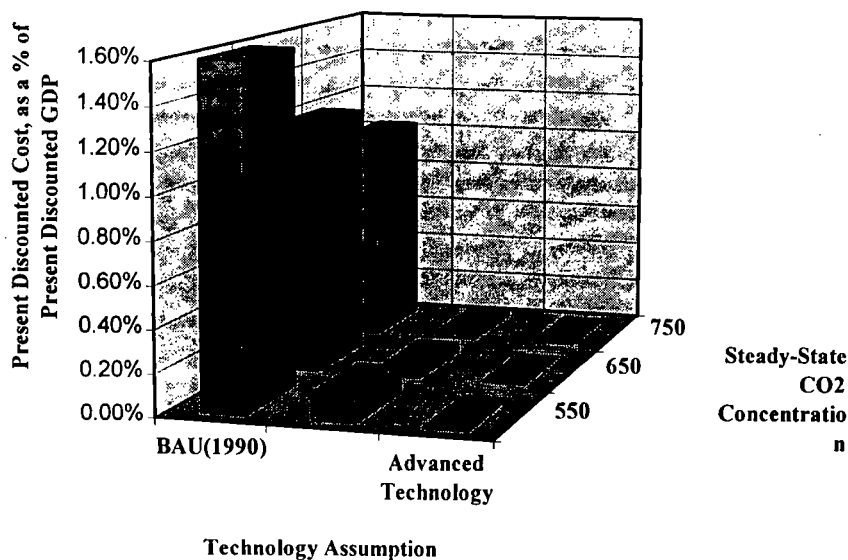


Figure 3: The Relationship Between Technology and Minimum Cost of Stabilizing the Atmosphere Below Various Ceilings

The cost of stabilizing the atmosphere at 550 ppmv with 1990 energy technologies exceeds \$12 trillion³ or more than 1.5 percent of GDP, even with full flexibility in where emissions are reduced. In contrast the introduction of IS92a assumptions lowers costs to approximately one trillion dollars or only 0.12% of GDP, and if advanced, non-carbon, energy technologies could be made widely available by the year 2020, these costs virtually disappear.

Technology reduces costs by lowering the required emissions mitigations. To stabilize the atmosphere at 550 ppmv the WRE analysis requires that global fossil fuel CO₂ emissions be reduced to 6.5 PgC/yr in the year 2100. With 1990 technology, global fossil fuel CO₂ emissions grow to more than 67 PgC/yr by the year 2100 in contrast to 20 PgC/yr in the IS92a scenario and only 9.5 PgC/yr with advanced technologies. While different models would yield different estimates of costs, even with the same technology assumptions, and the assumed complete flexibility in where emissions mitigations occur may not actually be achievable, the importance of energy technology in shaping the cost of achieving any climate goal is a robust qualitative result.

³ Costs are denominated in 1990 United States dollars, computed as the present discounted sum of all years costs discounted at 5%/yr.

Choosing a Technology for the Future

While 1990 technology is available, it is not well suited for a rapidly evolving future. Beyond the turn of the next century it leads to an even more rapidly increasing emissions trajectory than the IS92a (Tech+) case, Figure 1, and makes it increasingly costly to achieve alternative emissions goals. The technology scenario described in IS92a (Tech+) may or may not be realized. The real-world introduction and development of technology is a complex process. New technologies spring from research, growing out of a broad web of improvements in scientific understanding of basic and applied processes, are nurtured in niche market applications, and in some cases, ultimately improve to the point where they supplant older, less dynamic technologies.

If new technologies grow out of advances in research, then the scale of energy research and development (R&D) efforts is important. But, while technology appears to hold the promise of low cost atmospheric stabilization, recent energy R&D investment levels in the United States have been declining. Measured in almost any way United States investment in energy research and development (R&D) has declined substantially over the last decade. For example, total (public and private) United States expenditures for energy R&D declined from \$5.2 billion in 1985 to \$3.4 billion in 1994, a real decline of 42% (expressed in constant 1987 US dollars; Dooley 1996). Furthermore as a percent of GDP, United States investments in energy R&D have declined from 0.074% of GDP in 1985 to 0.035% of GDP in 1994 (Dooley 1996).

Conclusions

Implementing the goal of the FCCC requires that anthropogenic CO₂ emissions must ultimately decline toward zero even though emissions may rise for some years before peaking. This, in turn, requires a global transition from the present suite of carbon-intensive energy technologies and its supporting infrastructure to a new suite of global non-carbon emitting energy technologies. The magnitude of this undertaking should not be underestimated. The global transition must involve rich and poor nations and has implications for the entire fabric of society's infrastructure. The cost of this transition is not entirely outside our control. If new, non-carbon energy technologies can be developed and deployed over the course of the next quarter century, costs can be dramatically reduced from levels that would be required with present technology. But if R&D is the source bed of new technology, present trends are not promising. Both public and private sector R&D are declining both as a fraction of GNP and absolutely, despite the fact that energy R&D is a minor component of overall economic activity. An important component of an effective overall greenhouse emissions mitigation strategy must be a set of policies which encourage a reversal in present trends of both public and private sector R&D.

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9/29/97 Tech mtg

D. Commerce paper

Purpose: tech by specific category
interactive effects

\$500m level $\approx$ efficiency scenario in 566 study
everything "possible" w/o C taxes

blogs

equip efficiency - "almost" all from appliance stds

$\rightarrow$ "vast majority"; all if you wanted to
bc a political question

Eric Petersen

8/4

trying to pull all of the relevant cost #s

-TS asked him + Skip to look at

-hope to have investment costs + ROI by tomorrow

M-M

(?)

1990

152 bldgs

2010 base

176 bldgs

2010 tech

139-154

↖ not
electrifying
fuels component
only

? primary by end-use - does M.M. do it

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Jim Turner

8/4

Climate Δ Policy Analysis (dated 8/17)

- designates lead authors - dom, intl

Sent Trucillo info @ price + revenue Δ s in electric sector last week

- delivered prices, electric utility revenues

See tables in 2 pager

Fig 1: based on DOE info

Danny Ellerman (MIT) - first did this (~95)

Jim replicated

10 yr rolling forecast

retirements poorly acted for in models

→ can do it (over next couple of days)

Howard G - in NEMS - "hardwired" @ plant life

extension - did offline analysis to find that it's economic

Will send July 18 version

Don't know @ renewables - don't know how they got them

FASOM (Texas A&M) - to est. biomass as an energy crop to compete w/ other crops

- fuel supply curves for biomass

- sent them to EIA

- Alternative - what comes out of Oak Ridge NL

(acreage * a penetration rate)

poplar, willow, switchgrass - common biomass fuels

Ship Laitner - EPA

8/4

very crude based on energy consumption

base 90

440 - trans - M-M

257 - cars, lt trucks

183 - freight

base 2010

611 - trans - M-M

373 - cars,

278 - freight

efficiency (1.75)

M-M

permit price: \$63.86
(1995)

495 trans

242 cars + lt trucks

253 freight

→ 924 in 2020

Industry

CCAP is not industry-focused

- mainly bldgs technology, some utilities
- 1/2 possible savings in industry is from fuels

Slab study

generated cost curves - (4-14) plugged in Marshall

used LIEF model - independent of slab study, but consistent w/ slab study

industry didn't stabilize at 1990 levels in 2010, but later

1.25, 1.75 are economy-wide

didn't like 1.75

case 3 - tech investment case

not shooting for 1.75

but trying to see what is a reasonable upper limit
in M-M - see if we get close

LIEF - hybrid model (econometric/bottom-up) - price elasticity response by sector
18 sectors, fuel type
electrification, non-

NEMS-parametric estimates based on Δ in efficiency
efficiency gap - est. based on time series
data: current practice vs.
cost effectiveness

eff gap + elasticities $\rightarrow$ how much is
available - cost curves mapped into
M-M

Prob of adoption

- combined heat + power - ind. - envl permitting issues may affect adoption
do small electricity generators have to go thru FERC
uncertainty & envl permitting

- expect normal efficiency annually 1-1.2%; think 2%/yr is sus
but need targeted ~~incentives~~ incentives to retire capital faster
 $\rightarrow$ need signal

- feedstock in chemicals - opportunities to Δ ; recycling needs to be treated
better (in taxes than virgin materials)

- extent to which we can bring in other envl issues - need flexibility
for AQs + GW

L34 duty vehicles

no annualized value of costs
on basis of DOE study, can't do
\$800-1200/vehicle but we can do

↓ best derived from cost curves mapped into M.M.
energy innovations study

- Energy Innovations - consortium of groups

update of 90/91 study (America's Energy Choice)

- Am Council for Energy Efficient Economy

John DeCicco 429-8873

transportation contact

Neil Elliott

industry contact

talks regularly w/ industry (CMA, Steel Institute, etc)

→ different approaches
than lab study

- fuel savings: took AEO97 forecast in 2010 as starting point

new vehicles: 14,000 mi/y.

28 mpg → 45 mpg

used AEO97 fuel price

↳ carbon cost applied to gasoline(?) : carbon price + AEO97 2010 price

simple payback

↳ cost of C
case 3 in M.M.
X

13,000 VMT

\$1.23/gal 2010 (95¢)

- no carbon added

energy eff should be seen as a larger productivity issue
needs to be seen as a productivity benefit → need to
highlight for administration

→ energy savings just part of the story

2010 baseline - AE097

w/ efficiency (advanced tech) 244-266 from Slabs study
eff w/ low carbon low end to hi end efficiency

#25-406 from Slabs study - not documented

Dan Green @ Oak Ridge

Steve Plotkin @ Argonne, but in DC

488-2403

> ~~could discuss methodology~~
+ cost savings estimate

costs - all trans sector, not just heavy duty

↑ finding makes it much more likely - probably in millions \$

Bob Truillo has PAVV finding data

will email into on cost figures

BLSS

- ranging #s b/t
1.25 - 1.75

1.75 w/ + w/o trading
are very close - shouldn't be,
but M-M implements it that way
DRI have a 1.75 w/trading
1.75 cases are very close

1990
460

2010 base
AEO97: 575
M-M
DRI

2010
M-M: 30-~~40~~ 40
1.25 - 1.25 reduction
w/trading

2020
30-45

in lab study

EIA



will check
from Marshall
Considers M-M is most reliable representing technology

2 sets of #s

2010 w/o trading - Phil deVos, he will have
to check

1.25 in M-M by Δig behavior
regulations
manufacturing incentives

not autonomous to emit signals
but auto to price signal

fully funded CCAP, PNGV, other industry activities
could get close to 1.25

can't get

can't separate w/ + w/o trading w/in model

DRI: E/GDP one all ^{else} sectors except electricity
same b/t 1.25 → 1.75 DRI
→ all out of electricity

probability

understanding CCAP
+ climate tech efforts
(diffusion)

funding would help

do we have budget roadmap to 1.25-1.75.
→ No, but working on it

PCAST also working on it

hoping to answering ~~that~~ by October

Source of electric sector costs

IPM - EPA's electric sector model
breaks out capital from operating

NEMS may yield
different
→ consult w/ Howard

Jim Turner
7/23/97

Share of
Kwhr terms
Chart 2: DRI 1.25 stabilization
case

	1990 ^{AEI}	2010	2020
coal base	53	52	60
policy	53	45	43
gas base	13	20	24
policy	13	22	32

What @ gas response → key

g↑ p→ ?

DRI not as aggressive w/ fuel switching

definitely more gas in electric

but gas may ↓ ↑ in end use sectors

→ in end use, has competing fuels, + energy
efficiency

emissions reductions:

end use efficiency ↓ demand
↓ fuel supply

efficiency of 1.25 case - DRI efficiency

AEI w/o price signal

	2010	2020
1.25 w/o price signal:	590.2	628.8
1.25 w/ price signal: stabilization 1990	475.8	469.1

Sector	1990 Emissions	2010 Base Emissions	Emissions Reduction in 2010 with CCP	Cost Estimates (billions)	Probability of Achieving Reductions
Freight, Aircraft, and Rail	185	295	29	\$25-\$40/year	?
Autos and Light Trucks	432	598 <i>DOE's 1-b: 616</i>	90-120 ¹		
Industry	471		10-15% of 2010 baseline	\$2-\$4/year	
Buildings			26-80 ²	\$7-\$14/year	
Electric	481.4 AEO	AEO97 forecast 626.4		\$8-\$10/yr	

which is base case is important

Emissions metric: millions of metric tons of carbon equivalence (MMTCE)

2010 Base Emissions:

Emissions Change in 2010 with CCP: These are the estimated reductions in emissions under climate change policy modeled through IAT effort and, in some cases, the DOE Five-Labs Study.

Baseline Electricity:

AEO96

2010: 610.2

2020: n/a in AEO96

DRI

2010: 643.4

2020: 705

¹ Paper notes that carbon emissions can be reduced by 15-20% over 2010 baseline forecast.

² Paper notes the potential emissions reductions of 13-40 MMT separately in both the residential sector and the commercial sector.

7/16 mtg

7/24: POTUS meets w/ scientific experts + press briefing

Series of efforts to ↑ public attn.

Weekly mtgs of principals - tech discussion next week (Friday)

ID all phrases in sectoral papers, draft memo w/ these, attach barriers paper, + fax to OMB, have OMB send paper out

e. tech principals mtg - R+D policy, mkt-based policies to encourage development + adoption

need papers by middle of next week for next Friday's mtg

See outline handout

goal is to send paper out on Wed

multiple purposes: 1) explain modeling - what does it tell us

2) can price get tech out there, what about policy stimulus

Joe Rohm - this is a tech paper, ignore the econ modeling + focus on tech

Jeffrey Huber - not a tech-econ dichotomy

How do we allocate emissions - it really matters → accounting issue
does bldg sector or electricity sector get bens for end use
DSM reductions in energy use?

call authors - ask e incorporating our comments
need copy of renewable energy paper

David
Doniger

Mary Beth

need marginal technology explicitly stated

need implied discount rates + MC in addition to avg costs

need overview of model approaches + lab study

Eric Peterson

inconsistencies in style + content

- treatment of costs is one significant inconsistency

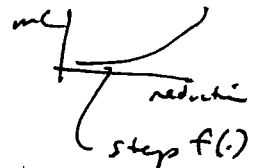
need guidance on key problems in bringing papers together

how do we cost

- rate of return for CO_2 reduction

- MC for abatement w/in sector

→ want function



what's the most efficient way to spend \$/B?

Ray's question @ payback period - check w/ Jay what he asked

should we do savings benefits estimates for next week?

- a caveat, qualitative statement in paper

→ Isn't there a spatially specific issue here?

Can M-M or DRI estimate the geographic

locations of ↓ in CO_2 + associated ↓ in

VOCs , NO_x , PM - Does ↑ in nat. gas have negative benefits

paper comments, cc Bob Trucillo

talk to authors @ costs, develop a template of costs

7/10 mtg - 324 OEOB, IATsh group

R&D investment + long-term opportunities

investment (\$100m $\rightarrow$ 1 year savings in efficiency in 20 years)

A layman's guide to the difference between
mkt failures & barriers, &
why this matters to policy.

$\rightarrow$ ~ 3 pager

get a couple of papers from Jay

Buildings

what are actions necessary to achieve these 35%, 65% levels
- these are replacement decisions only, under normal retirement
separate discussion b/t bldg shells + bldg appliances/etc equipment

Electric

needs discussion on $\textcircled{N}$ power

needs 2 sections 1) demand effects from other sectors

2) what's possible w/in electricity sector

Climate Change + Technology

7/9 mtg - 324 OEOB, IATish group

what are specific implications for each sector

series of mtgs of principles over next month

11-12 Th mtg after asst secy's mtg

Cross-cutting papers will be done (leakage, competitiveness, etc.)

need for analysis on minimizing impacts by sector

- possible dialogue w/ industry, NAOs to get information on minimizing impacts (throw out several options)

Freight, Aircraft + Rail Paper

baseline projection on efficiency ↑ is conservative (almost zero improvements)

Market only gives small eff ↑ bc only least efficient mpg falls out - only looks at trucks

major DOE R&D effort to ↑ eff of diesel engines

intermodal shift to rail has caused ↑ emissions while rail eff ↑ (per ton shipped by rail, emissions ↓ but total tons shipped ↑ significantly)

NASA's goals appear too ambitious - no one thinks they can meet all of these for subsonic travel

★ Do we have rate of return for R&D investment opportunities?

- trucks yes; aircraft it would be difficult

Are opportunities actually cost-effective or just theoretical?

small opps (short-term) - diesel engine improvements

big opps (long-term) - fuel cell engine

Can we verify info we receive from tech producers

e.g., compare assumptions w/ public statements or buy-in by industry

Lesson from models - not much of reductions, may need to

get from other sectors

Discussions w/ private sector will likely focus on rates of return

Industry wants these papers - need to refine them first

3 kinds of mtgs: CEOs + principals

low-levels (technical folks)

advisory council mtgs

Vision papers by 7 most energy-intensive sectors (DOE)

- future of tech in their sectors

Will papers be leaked? Should we include policy options?

embargoed until 2/2/98

Climate Change Technology Initiative (CCTI)

Last fall, the President announced a nine-point plan to begin addressing climate change, including a five-year, \$5 billion package of tax incentives and research and development spending to spur energy efficiency and help develop low-carbon energy sources. With the historic agreement in Kyoto in December 1997 to reduce greenhouse gas emissions, the President is now proposing a \$6.3 billion initiative over 5 years -- \$2.7 billion in increased spending and \$3.6 billion in tax incentives. (See Table 1.) For FY 1999, the budget shows \$473 million in increased spending on climate-change related technologies (\$1.292 billion vs. \$819 million in FY 1998) and \$421 million in tax incentives, for a total first-year initiative of \$894 million.

TABLE 1

Direct Programs & Tax Incentives	Dollars in Millions				
	1997 Actual	1998 Estimate	1999 Proposed	Dollar Change: 1998 to 1999	Total Increase 1999-2003
BY AGENCY					
Energy	657	729	1060	+331	+1,899
Environmental Protection Agency	86	90	205	+115	+677
Housing and Urban Development	--	--	10	+10	+10
Commerce	--	--	7	+7	+38
Agriculture	--	--	10	+10	+86
R&D Program Total	743	819	1,292	+473	+2,710
Tax Incentives	--	--	421	+421	+3,635
Climate Change Technology Total	743	819	1,713	+894	+6,345

TABLE 2

Direct Programs	Dollars in Millions		
	1998 Estimate	1999 Proposed	Dollar Change: 1998 to 1999
BY AREA OF EFFORT			
Buildings	146	264	+118
Industry	156	216	+60
Transportation	246	356	+110
Electricity	220	332	+112
Carbon Sequestration and Cross-Cutting Research	0	42	+42
Policy Analysis, Market Incentives	6	26	+20
Program Direction	45	57	+12
Climate Change Technology			
Direct R&D Total	819	1,292	+473

Columns may not add due to rounding.

Copied

The principal focus of the initiative is an R&D portfolio that covers the four major carbon-emitting sectors of the economy (buildings, industry, transportation, and electricity), plus carbon removal and sequestration, Federal facilities, and crossing cutting analyses and research. (In Table 2, Federal Facilities are included under Buildings.)

BUILDINGS

- ***Accelerate the deployment of existing technologies.*** Major improvements in the energy efficiency of both residential and commercial buildings can be obtained through better labeling of highly efficient technologies and appliances (such as the easily identified Energy Star label), through demonstrations and partnerships with builders and developers, and through two related tax credits:
 - one that encourages the purchase of certain highly efficient building equipment (electric heat pumps, natural gas heat pumps, advanced central air conditioners, and fuel cells for power generation); and,
 - one that provides a credit for the purchase of highly-efficient new homes.
- ***Partnerships for Advanced Technologies in Housing (PATH).*** HUD will lead a team that includes DOE and EPA to work with the building industry to develop, demonstrate, and deploy housing technologies and practices that are inexpensive, highly efficient, and attractive to consumers. This effort will also focus on streamlining Federal, state, and local codes and regulations, education outreach, and creating local markets for PATH housing using pilot sites and demonstrations.
- ***Million Solar Roofs.*** In June of 1997, the President announced an initiative to encourage the installation of one million solar hot water and solar photovoltaic (PV) installations on buildings over the next 10 years. DOE will fund cost-reduction R&D for solar thermal and rooftop PV systems, and will establish partnerships with communities, builders, and other Federal agencies to promote the use of building-mounted solar systems.
 - In addition, a tax credit is proposed to encourage the purchase of rooftop solar thermal and PV systems.
- ***Increased R&D.*** In addition to encouraging the deployment of the best available technologies, DOE is also increasing its research on building systems modeling, to help architectural engineers, and on major components such as next-generation heat-pumps, cooling systems, furnaces, and lighting.

INDUSTRY

- ***Partnerships with industry.*** DOE works closely with industry on technology roadmaps and plans to reduce energy consumption and secure early reductions in greenhouse gas emissions. Industries already engaged in this effort include aluminum, steel, glass, paper and forest products, metal casting, and chemicals. These technology roadmaps form the basis for cost-shared R&D with industry teams and consortia.
 - This work will be enhanced within DOE, and complementary efforts will be undertaken by EPA, USDA, and DOC (NIST), which will lead to voluntary greenhouse gas reduction programs within industry.
- ***Combined heat and power.*** This is an advanced form of cogeneration that integrates power generation with the provision of useful thermal energy in a factory or building.
 - R&D will be accelerated on advanced turbines, fuel cells, and other technologies, and new approaches to capturing useful work or heat through several temperature stages (e.g. electric generation, industrial process steam, steam building heat) in factories or commercial buildings will be demonstrated. When commercially accepted, these systems will allow us to capture the waste heat the Nation now throws away.
 - A 10 percent tax credit is also proposed for investments in combined heat and power systems that have depreciation recovery periods of 15 years or longer.
 - Tax credits are also proposed for certain investments to remove or recycle fluorine and fluorocarbon compounds that act as highly-potent greenhouse gases.

TRANSPORTATION

- ***Partnership for a New Generation of Vehicles (PNGV).*** A government-industry effort to develop an attractive, affordable car that meets all applicable safety and environmental standards and gets up to three times the fuel efficiency of today's cars, or roughly 80 miles per gallon. Five agencies participate in PNGV -- DOE is the largest player, followed by EPA, DOC, NSF, and DOT.
 - The program will lead to "concept cars" in the year 2000 and production prototypes in 2004.
 - This winter, industry and the government have announced the designs that they will pursue -- hybrid vehicles that combine a power source (a piston engine or fuel cell) with battery storage and electric motors.

- In FY99, the combined request for PNGV-related work in those agencies is \$277 million, up from \$227 appropriated in FY98.
- Tax credits are proposed to encourage the purchase of this type of highly-efficient vehicle, and to help make them more affordable. A \$3,000 credit will be available starting January 1, 2000 for vehicles that are twice as efficient as the norm for their class, and a \$4,000 credit will become available January 1, 2003 for vehicles that are three times as efficient as the norm. (The \$3,000 credit would phase out by 2006, and the \$4,000 credit would phase out by 2010.)
- ***Partnerships for Light and Heavy Trucks.*** Similar government-industry efforts are proposed to develop more efficient diesel engines for both light trucks and heavy trucks.
 - DOE has been engaged in R&D on more efficient large truck engines for several years, and that effort will be stepped up in FY99, in coordination with increased work on large diesel engines at EPA and DOD.
 - A government-industry partnership is currently being formed for R&D on smaller diesel engines suitable for light trucks and sport-utility vehicles (SUVs), which are the fastest-growing class of passenger vehicles. A clean, efficient diesel engine could improve the fuel-economy of light trucks and SUVs by 50 percent.
- ***Sustainable Transportation.*** This initiative would promote alternatives to single-occupancy vehicle travel using pilot projects in selected communities modeled after the highly successful approach adopted by the Portland, Oregon metropolitan region.
 - The sustainable transportation programs in EPA and DOE will be coordinated with existing and planned DOT programs. (DOT is not funded within the Climate Change Technology Initiative, however.)
 - An amendment is proposed to current tax law to equalize treatment of parking and transit benefits. To encourage public transportation and vanpools, employers would be allowed to provide tax free transit and vanpool benefits in lieu of compensation, up to the same amount that they can provide for parking.

ELECTRICITY

- ***Renewable energy.*** Expand research partnerships for key renewable technologies such as wind, photovoltaics, geothermal, biomass, and hydropower to accelerate price reductions and improve performance. The same programs will also be supporting increased R&D in hydrogen production and storage and in superconductivity.
 - The FY99 budget proposes a \$100 million increase in DOE for solar and renewable energy R&D -- a 37 percent increase over FY98.

- A 5-year extension is proposed for the tax credit for electricity produced from wind and biomass.
- The photovoltaic (solar electric) component of the Million Solar Roofs initiative (described above under "Buildings") also can be described as an electricity-sector initiative, providing "distributed generation."
- ***Electricity Restructuring.*** DOE and EPA will work with States and utilities on the restructuring of the electricity sector, to ensure that the restructuring does not create barriers to the adoption of renewable and low-carbon generating technologies.
- ***Nuclear power-plant life extension.*** DOE will initiate an R&D effort addressing the critical technology needs to allow currently-operating nuclear power plants to safely extend their operating lifetimes by 10 to 20 years.
 - Under current NRC licences, approximately 60 gigawatts of electric generating capacity would have to be retired between now and 2015. (Most of that comes between 2005 and 2015.)
 - Providing the technologies necessary to safely operate these plants for another 10 to 20 years will make the transition to other low-carbon energy sources, such as solar and renewable energy, much easier.
 - (NRC has indicated that they would probably not grant any plant more than one life extension.)
- ***Innovative coal combustion technologies.*** In FY99, DOE will initiate a research program on innovative new approaches to coal combustion that offer the possibility of much lower carbon emissions than existing technologies.

CARBON REMOVAL AND SEQUESTRATION.

- ***Sequestration R&D.*** Research initiatives are being funded in both basic and applied research to find ways to remove carbon dioxide (CO₂) from combustion gases and sequester (store) the carbon so that it does not enter the atmosphere.
 - DOE's basic science office will engage in biochemical and microbial research.
 - DOE's fossil energy office will conduct an applied sequestration R&D program, jointly managed with the basic science office.
 - USDA will initiate research on enhancing the carbon-sequestering capabilities of agricultural species. NIST will support complementary biotechnology work on plant metabolism and carbon use.

CROSSCUTTING ANALYSIS AND RESEARCH

- ***Emissions credits, incentives, and trading.*** EPA will lead an effort, assisted by DOE, to evaluate options for a domestic trading system and early reduction program in industry. The Federal government will work with stakeholders to understand their views and interests, and to build the institutional capacity needed to implement a carbon emissions credit and trading system.
- ***Program and science assessments.*** DOE will lead efforts to assess the implications of new research results produced by the Global Change Research Program, in order to determine what geographic and technological responses may be appropriate.

Comments on \$500 million/year Technology Proposal

DOE's response does not appear to have answered the request of the Principals for a detailed description of the "technology option" in terms of specific policies (dollars spent on R&D, dollars spent on diffusion, imposition of standards, price measures, and moral suasion) and their best-guess estimated effects. At first DOE seems to say that the predicted effects are pure R&D, and then it turns out that there are hidden assumptions about public awareness changing or standards being changed. We continue to believe that much, if not all, of the R&D is probably worth doing, particularly along the lines of the PCAST report. But we also continue to believe in a pessimistic bottom line for the odds of incremental payoffs in terms of carbon reductions by 2010. As John Holdren said in his 9/28 presentation, the time lag for the payoff, even to applied R&D, is simply too long to expect that by 2010 we would get more than "diddly" from new spending.

DOE stated that this proposal is based on the efficiency case in the 5 Labs Study. In a review of the proposal presented on 9/29, it appears that there are numerous divergences from the 5 Labs Study efficiency case. In light of the inconsistencies apparent in the proposal, and the substantial methodological flaws in the 5 Labs Study, it seems imprudent to base significant policy decisions on information received thus far. The point was raised at the 8/19/97 meeting on the 5 Labs Study that this study should not go to or be used by principals. To date, there appears to be insufficient justification to modify this view.

General Comments

- The 5 Labs Study indicates that government programs, utility programs, and state programs cost 15% of technology costs (p. 1.13). Since DOE apportions all carbon savings in their proposal to the federal programs listed in the summary chart, we assume that all costs accrue to the federal government. In the "optimistic" assessment of the costs and benefits, DOE claims that government programs will likely only cost about 7% of technology costs, because half of emissions reductions occur through standards (see below). Assuming that this is true, and that the technology costs of the efficiency case range between \$26 - \$49 billion/year in the optimistic assessment (p. 1.14), then government programs should cost between \$1.82 - \$3.49 billion/year. However, using a 13.5% government cost stipulation (based on a 15% government program cost, minus 10% [instead of 50%] of these costs because of standards), the costs of government programs would range between \$3.51 - \$6.62 billion/year. The proposal presented on 9/29 costs 3 to 13 times less than projected by the 5 Labs Study, and yet generates greater carbon savings.
- The proposal employs standards to a much lesser extent than the 5 Labs Study. In the Study, "at least half of the efficiency occurs as a result of federal policies (e.g., standards and carbon permit charges)" (p. 1.13). Since the efficiency case does not include a carbon permit system, we assume that half of the carbon savings in the efficiency case result from standards. However, in this proposal, only about 10% of the emissions reductions occur due to standards (on the high ends of the ranges, 20 MMTCE out of 206 MMTCE).

- The projected carbon savings for 2010, while indicated as approximately 155 MMTCE, has a range of 127-206 MMTCE. Note that this large range does not overlap with the 5 Labs Study projection of 126 MMTCE (p. 1.12).
- The efficiency case is portrayed in the 5 Labs Study as carbon savings that occur because of already available and cost-effective technologies. In effect, government policies are only necessary to overcome market barriers. However, this proposal appears to be more reliant on R&D than on deployment and diffusion of existing technologies. Using the upper bounds of the ranges of carbon savings, we find that more than half of emissions reductions (104 of 206 MMTCE) result from R&D programs.

Specific Comments

Buildings Sector

Two programs claim to achieve 17-29 MMTCE. Note that under the 5 Labs efficiency case, 25 MMTCE of potential reductions were identified (p. 1.12), with a different penetration assumption than the one provided in the summary chart. The Study employed a 35% penetration rate assumption (p. 3.3), while this summary chart claims to be based on a 15-25% assumption for equipment efficiency and a 25% assumption for 21st Century Housing. With the lower penetration rate assumed in this proposal, we would assume that the carbon savings would be less than those found in the 5 Labs Study -- instead, they are greater. Based on these assumptions and the information provided by the 5 Labs Study, we would expect carbon savings to range between 11-18 MMTCE.

Equipment Efficiency: The 5 Labs Study indicates that a total of 25 MMTCE can be reduced in residential and commercial buildings under the efficiency case. The 9/26 memo describes this set of programs to include fuel cells, even though fuel cells are not in the 5 Labs efficiency case (they only come into play in high efficiency case, although the text is very unclear about whether fuel cells actually generate any benefits prior to 2020).

21st Century Housing: There is insufficient detail provided in the 9/26 memo to identify the appropriate carbon savings in the 5 Labs Study.

Transportation Sector

The 5 Labs Study projects 73 MMTCE reductions in emissions under the efficiency case (p. 1.12), while this proposal estimates carbon savings ranging between 65 - 87 MMTCE. Note that this upper bound is almost equivalent to the high efficiency case with a \$25/ton permit fee in the Study (88 MMTCE).

Two PNGV Categories: The 5 Labs Study indicates that annual PNGV funding is approximately \$250 million/year (p. 5.2). The two categories of increased PNGV programs would sum to \$140 million/year in FY99 and \$260 million/year in FY03. This increase is much less than believed necessary to achieve the goals of the PNGV program. The authors of the 5 Labs Study note that for PNGV to be successful, "substantial additional funding for R&D will be required, perhaps two to

ten times what is presently being spent” (p. 5.7). The proposal increases funding to just the lower end of this required spending level.

Industry Sector

The 5 Labs Study projects 28 MMTCE of carbon emissions reductions under its efficiency case (p. 1.12). This proposal estimates carbon savings under three categories of programs ranging between 30 - 65 MMTCE. Note that the upper end of this range is 11 MMTCE more than the high efficiency case with a \$25/ton permit fee in the 5 Labs Study.

Industries of the Future: In the 5 Labs Study, the list of heavy manufacturing industries in table 4.6 (p. 4.10) corresponds to the list of the Industries of the Future on the DOE webpage (<http://www.oit.doe.gov/iof/industry.html>). In this table, these industries account for only 9 MMTCE in the efficiency case and 21 MMTCE in the high efficiency case (\$50/ton permit system). However, the proposal notes that Industries of the Future programs can achieve carbon reductions ranging between 10 - 20 MMTCE.

Utilities Sector

Three categories of programs claim to generate carbon savings of 15-25 MMTCE. However, the efficiency case in the 5 Labs Study does not project any reductions in carbon emissions in this sector (p. 1.12). Further, the carbon sequestration R&D category of programs is not described in the 9/26 memo.

For additional review of the methodological flaws in the sectoral analyses, refer to earlier memos that provide comments on the 5 Labs Study.

MEMORANDUM

TO: Rosina Bierbaum

FROM: Jeff Frankel and Joe Aldy

DATE: 10/1/97

RE: Comments on *Sources of Greenhouse Gases*

We appreciate the opportunity to look over *Sources of Greenhouse Gases*. The document provides a very important service of specifying the sources of the nation's carbon dioxide emissions. In four pages, a substantial amount of useful information is provided in easy to understand figures and bullets. However, the document could be improved by addressing three issues: 1) remove the ambiguous "options" listed by the sectoral breakdowns of carbon dioxide emissions; 2) clarify and refine carbon dioxide emissions numbers; and 3) include sources of non-carbon dioxide greenhouse gas emissions.

- The list of "options" should be removed. In a document on sources of emissions, they appear to be out of place. Further, the document provides no context for the options -- are these options for consumers? producers? local and state governments? the federal government? They appear to be a list of goals without any specification of how they are to be achieved, the likelihood they will be achieved, the costs of attempting to achieve them, and the cost-effectiveness. Many resemble the unspecified visions in the DOE 5 Labs Study. Visions are not programs, and without specific and credible information on how these goals could be achieved, they can only serve to confuse the intended audience.
- Several of the references to carbon dioxide emissions and energy use need to be clarified. First, bullet two on the first page appears to represent the trend in greenhouse gas emissions, although the numbers represent energy-related carbon dioxide emissions. The statement about 1997 emissions is the projection for energy-related CO₂, not for greenhouse gas emissions. We do not have the projection for 1997 for all greenhouse gases, but given that in 1994, total U.S. GHG emissions summed to 1,672 MMTCE (EIA, U.S. Emissions of Greenhouse Gases, table ES2), it is difficult to imagine that 1997 emissions would be nearly 200 MMTCE below this. We know that the percentage increases above 1990 reflect EIA's Annual Energy Outlook 1997 projections for energy-related CO₂ emissions, but we do not know if the trend holds for the remaining ~15% of greenhouse gas emissions.

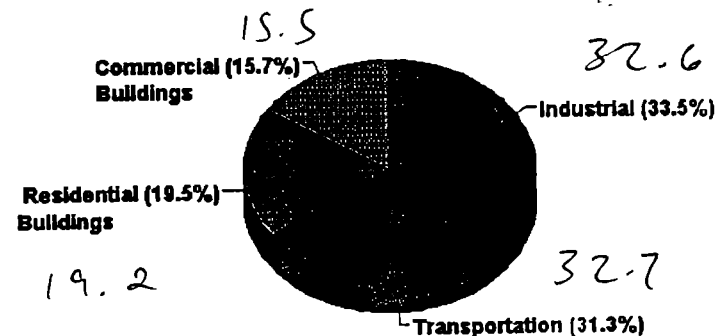
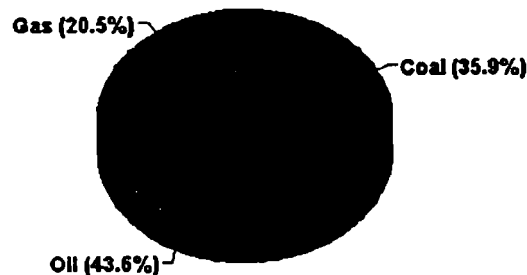
Second, the estimates of carbon emissions per unit energy in the fourth bullet do not conform with comparisons using the EIA's Emissions of Greenhouse Gases in the United States 1995 (table B1) carbon emissions coefficients for coal (electricity), gasoline (as an example of oil), and natural gas. Coal should have a slighter higher estimate of carbon emissions, while oil should have a much higher carbon emissions estimate (almost double of the estimate in the document).

Third, the projections regarding energy prices do not conform with EIA's Annual Energy Outlook 1997 estimates for 2010. Between 1995 and 2010, minemouth coal prices fall from \$18.83/short ton to \$16.92/short ton (greater than 2% decline), gasoline prices increase from \$1.148 to \$1.218 (instead of falling 5%), and world oil prices increase from \$17.26/barrel to \$20.41/barrel (not nearly constant).

- While the document identifies specific emissions of carbon dioxide, it virtually omits any discussion of non-carbon dioxide greenhouse gas emissions. A complete survey of the sources of all greenhouse gases could better inform policy makers.

Sources of Greenhouse Gases

- 1994: 83.6%, assuming all energy related CO₂
about 85% of U.S. greenhouse gases
- ♦ CO₂ released by consumption of coal, oil, and gas is responsible for ^{about} 85% of U.S. greenhouse gases
- ♦ U.S. greenhouse gas emissions are now 10% above 1990 levels and are projected to be 28% above 1990 levels by 2010 because of growing demand for energy. 1997 production was 1,480 Million Metric Tons (MMT)
DOE projection - only energy related
1996: 1463.0 CO₂, not total
CO₂, not total
GHG
- ♦ Transportation, Industry, and buildings are each responsible for about a third of US greenhouse gases. Residential buildings are responsible for slightly more than half of the total contribution buildings.
20% (Horowitz conversion); 78-80% EIA (Emissions of GHG 95) 38% (Horowitz); 34% for gas (EIA)
- ♦ Coal produces 72% more greenhouse gases than natural gas per unit of energy delivered; oil 22% more.
10% AIG AEO97 (95-2010)
- ♦ Coal prices are expected to fall 2% by 2010 and gas prices 5%. Oil prices will be nearly constant. oil jumps 17.26 → 20.41 1/2
increase 6% AIG AEO97 (95-2010) AEO97 (A12)
- ♦ Oil remains the single largest source of CO₂ and 73% of oil is used in transportation. Coal burning produces 36% of CO₂ and 85% of coal is used to generate electricity.
- ♦ In these accounts, the CO₂ produced to generate electricity is charged to the sector using the electricity. Taken together, emissions of electric production sold to all sectors is 36% of U.S. CO₂.



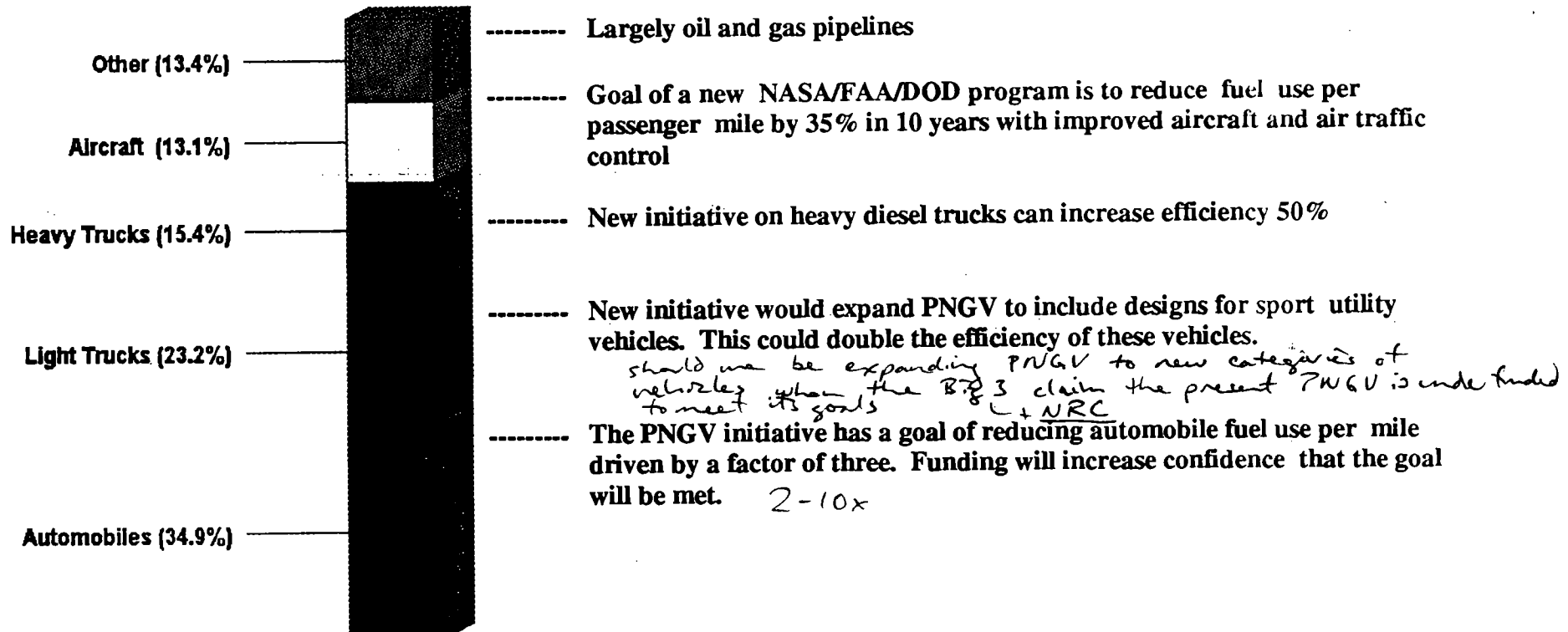
Transportation

- ♦ Transportation contributes ^{32%} 31% of U.S. CO2 and output is growing ^{1.4% in AEO97} 1.8% per year (10 million tons per year) – twice as fast as industry and buildings -- because vehicle miles traveled have been increasing by nearly 3%/year and because nearly half (44.5%) of all passenger vehicles sold are now sport-utility vehicles and other “light trucks” which get, on average, 25% fewer miles per gallon than automobiles.
- ♦ More than 98% of all transportation energy comes from petroleum

Percent of all U.S. CO2
Production

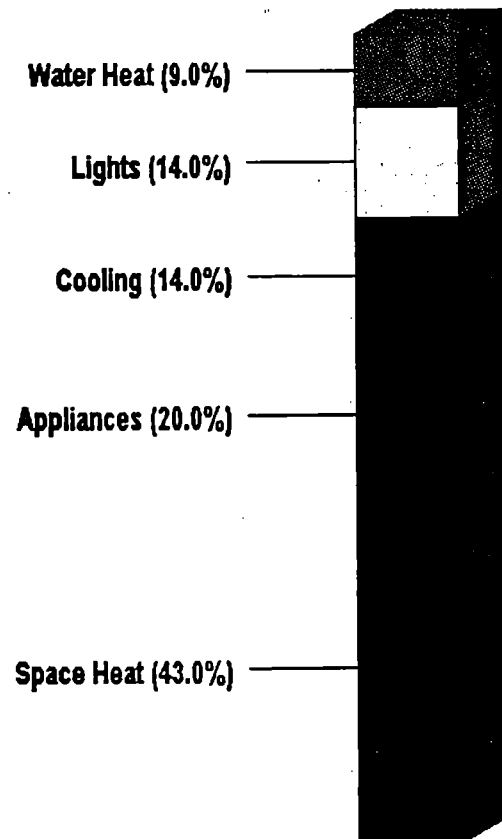
Options

*What are these options?
What about costs + cost-effectiveness*



Buildings

- ♦ Residential buildings produce 19% of U.S. CO2 and emissions are expected to grow 1% annually (2.6 MMT/year). Energy demand is greatest for heating, electrical appliances (refrigerators, clothes dryers), and air conditioning.
- ♦ Commercial buildings produce 15% of U.S. CO2 and emissions are expected to grow 1% annually (2.1 million metric tons per year). Energy demand is greatest for lighting, electric equipment (computers, fax machines, copiers), and air conditioning.



----- Best available appliance technology can increase efficiency 25-30%

----- Energy for residential lighting can be cut by 50% and commercial lighting by 25% using existing technology. Advances in bulbs, controls, and daylighting will lead to greater savings. *at what costs?*

----- Existing technology can reduce commercial air conditioning and ventilation 48%. With improved building designs can lead to greater savings

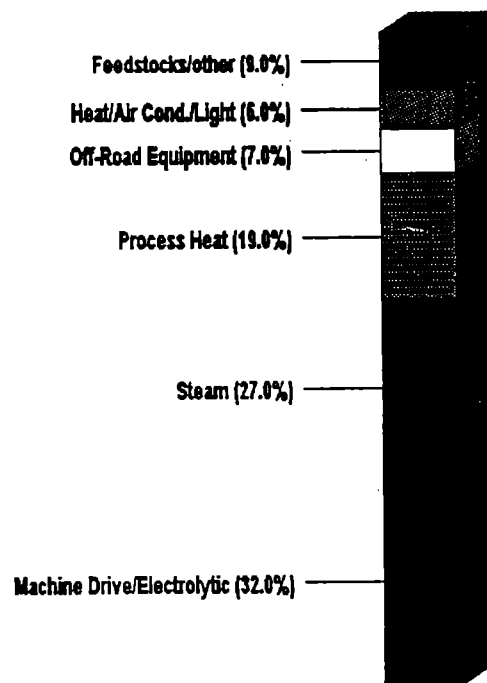
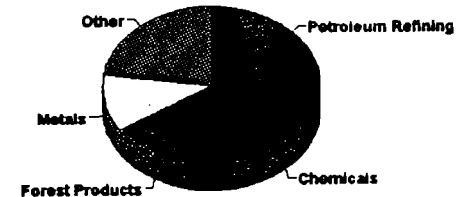
----- Refrigerator and freezer efficiency can be increased 25-30% using available technology. Growing energy use in electronic equipment at home and in offices (TVs, computers, fax and copiers) need attention. Labeling is key

----- With improved building designs (such as PATH homes), new buildings can be much more efficient. In the future, fuel cells and gas turbines for buildings will be able to provide heat, hot-water, and electricity. Residential heating units can be made 10-25% more efficient and commercial heating 48%. Energy star labels are critical.

*these are visions,
not programs
if they are available, then
why aren't people buying them*

Industry

- ◆ Manufacturing industries produce a third of all CO₂ – an amount which is expected to 4 million metric tons per year. ? > 4 mmt/y - in AE097
- ◆ 80% of all industrial CO₂ comes from petroleum refining, Chemicals, Paper, lumber and other forest products, and metals (dominated by steelmaking).
- ◆ While overall growth of industries is expected to average 2.1% during the next 15 years, output from the energy intensive industries responsible for most of CO₂ production is expected to be 1.3%. Growth is much faster in information-intensive industries



- In the future, some biomass products could be substituted for oil/gas ?
- Savings much like those available for commercial buildings
- New diesel technology can be applied to many of these uses
- Steam and process heat dominate the energy use chemical manufacturing, paper production, and many other energy-intensive operations. Available industrial natural gas turbines produce electricity and process heat and produce 1/3 to 1/2 as much CO₂ as conventional systems. Regulatory changes are needed to encourage high-efficiency, new units. New chemical processing techniques and use of biomass instead of fossil fuel can lead to further gains.
- Motors, compressed air, and other machines providing mechanical power can be improved significantly using improved control strategies, more efficient designs and components.



Jeffrey A. Frankel
09/26/97 06:40:56 PM

Record Type: Record

To: Adele C. Morris/CEA/EOP, Randall W. Lutter/CEA/EOP, Joseph E. Aldy/CEA/EOP

cc: Janet L. Yellen/CEA/EOP

Subject: mtg. Mon. to discuss current DOE technology policy statement

2:30, at TJ's, rm 248. I plan on going, but would like to bring Joe and maybe Adele or Randy. DOE has finally been given serious marching orders by the Principals that they must re-cast their claims in terms of predicted effects from a breakdown of:

- ① govt. spending on R&D
- ② govt. spending on diffusion
- ③ standards
- ④ price
- ⑤ moral suasion

*separate out by each of these
esp. tech, R&D*



cc: *AM*
JFA
PL

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
AIR AND RADIATION

FAX MEMORANDUM: 10 Total Pages

TO: Jeff Frankel, CEA, (202) 395-5046

FROM: Skip Laitner, EPA/OAP *Skip Laitner*

SUBJECT: An EPA Working Paper on Technology and Climate Change

DATE: September 15, 1997

Attached is a copy of the draft paper I gave last week to the North American Conference of the International Association of Energy Economics. Since I referenced Janet Yellen's recent testimony, I thought CEA should have a copy of it for internal review. Please let me know if you have any questions or comments.

WYMIWYG (What You Measure is What You Get): The Benefits of Technology Investment as a Climate Change Policy¹

Skip Laitner
Environmental Protection Agency
Office of Atmospheric Programs, MS 6201J
401 M Street, SW
Washington, D.C. 20460
(202) 233-9833/9589

INTRODUCTION

In a June 26, 1997 speech to a United Nations environmental conference, President Clinton acknowledged that "concentrations of greenhouse gases in the atmosphere are at their highest levels in more than 200,000 years and climbing sharply." If that trend does not change, the President noted that the resulting climate changes would "disrupt agriculture, cause severe droughts and floods and the spread of infectious diseases." In underscoring the fact that no nation can escape the danger of climate change, the President stated that: "We must create new technologies and develop new strategies like emissions trading that will both curtail pollution and support continued economic growth. We owe that in the developed world to ourselves, and equally to those in the developing nations. Many of the technologies that will help us to meet the new air quality standards in America can also help address climate change. This is a challenge we must undertake immediately."

Drawing on the guidance of the President's statement to the United Nations, it is clear that any future climate change policies adopted by the United States should be anchored by a technology-based investment strategy. Recent modeling efforts by an Interagency Analytical Team (IAT) found that the accelerated use and development of energy efficient and low-carbon technologies can substantially reduce the costs of U.S. greenhouse gas reductions. Indeed, a number of the modeling results suggest that with the right mix of technologies, the economy can actually be strengthened by a technology-based strategy. This is

because the right mix of technologies can convert wasted resources into productive assets. As Janet Yellen, Chair of the Council of Economic Advisers, recently commented, "if we do it dumb, [climate change policy] could cost a lot, but if we do it smart, it will cost much less and indeed could produce net benefits in the long run." (Yellen 1997). This opportunity is also underscored by a June 1997 NGO study entitled, *Energy Innovations*. A detailed analysis of the technology opportunities within the United States indicated that an innovative path could reduce U.S. carbon emissions 10 percent below 1990 by the year 2010. At the same time, consumers would save \$530 per household, and the economy would support 800,000 more jobs by 2010 compared to present path projections (Energy Innovations 1997).

Despite the opportunity inherent to an investment-led climate strategy, a number of studies continue to find that the economy will be the real loser should the United States make any attempt to cap carbon emissions at or below anything close to 1990 levels. A study for the American Petroleum Institute, for example, found that carbon abatement strategies could lead to GDP losses by 3.0 percent or more. (Bernstein 1997). Yet, a close review of such studies suggests that a WYMIWYG phenomenon may be at work — "What You Measure is What You Get." In a different context this point was dramatically made by a WRI review of 16 of the more widely accepted economic models which have been used to evaluate different climate change policies. (Repetto and Austin, 1997). In their landmark review, the WRI researchers found that the macroeconomic impacts of stabilizing greenhouse gas emissions are likely to be

1. A draft paper given to the 18th Annual North American Conference of the USAEE/IAEE, September 7-10, 1997, San Francisco, CA, USA.

modest, and if improved technology assumptions and environmental benefits are factored into the modeling runs, the results are likely to be positive. Focusing more on the technology perspective, Greening (1997) suggests that if a policy or set of policies reduces per unit factor prices of capital and energy, the marginal product of those factor inputs will increase. "Provided that this policy has sufficiently low transaction costs associated with it," she notes, "then an energy efficiency policy should increase rates of economic output."

BACKGROUND AND CONTEXT

In June 1996, the Department of Energy (DOE) and the Environmental Protection Agency (EPA) sponsored a joint workshop where more than 50 experts from inside and outside the government made presentations on technical issues associated with our capability to reduce those greenhouse gas emissions in the next century. As part of that workshop, the Interagency Analytical Team (IAT) released what were then preliminary results on the economic effects of emission reduction proposals.

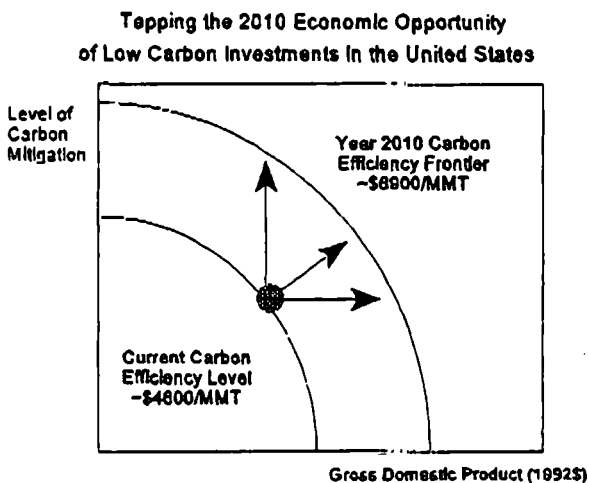
Since that June 1996 workshop, the IAT has more fully explored the "technology option" as a climate change strategy. As part of the review, the IAT developed a better set of assumptions about the opportunity for technology improvements, and then developed a new set of modeling runs that lead to a better understanding of the economic dimensions of the climate change policy problem. Preliminary results of the IAT effort were released in mid-July by Yellen (1997) in remarks before the House Commerce Subcommittee on Energy and Power. Unfortunately, the complete sets of modeling runs were not yet integrated within the IAT reports. As a result, the public received only the "best" of the bad news, with the good news yet to come.

This paper describes those missing technology assessments. It first discusses the opportunity for technology to both reduce greenhouse gas emissions and strengthen overall economic activity within the United States. Second, it reviews the IAT model selection and, in particular, the use of Markal-Macro which is an integrated energy supply and demand modeling system (Markal) and a macroeconomic model (Macro). Markal-Macro is especially useful for translating technology assumptions into economic impacts.

The development of the technology assumptions was done primarily by staff members from DOE and EPA — the agencies that have the primary responsibility for the Administration's energy and environmental policies. The IAT also included members from the Departments of Commerce, Treasury, Labor, and State, as well as members of the White House staff. The author was one of several co-chairs of the various IAT task forces.

What is the technology opportunity?

The common perception among policy makers and industry leaders is that the twin objectives of protecting the environment and encouraging continued economic



growth are inherently contradictory. Because of the "unavoidable tradeoff" between the environment and the economy, a battle is constantly being waged between industry, government and interest groups regarding how much of the environment should be sacrificed for the benefit of the economy — or vice versa. From a technology perspective, however, it becomes increasingly clear that these two goals are not necessarily contradictory. The reason is that the U.S. economy is not operating at its optimal level of energy efficiency. In economic jargon, this means that the country is operating well "within" rather than "on" its production possibilities frontier (PPF). This is illustrated in the figure above.

Based upon a set of IAT runs from the Markal-Macro model, the data suggest that the U.S. economy now obtains about \$4,600 dollars of value-added (measured as GDP in constant 1992 dollars) for every

million metric tons (MMT) of carbon emitted to the atmosphere. Using a reasonable set of technology assumptions (described later in this paper), it appears that by the year 2010, the economy could be obtaining at least \$6,900 of GDP for every million metric tons of carbon emitted. As it turns out, the base case forecast suggests that the normal rate of efficiency improvement will obtain about 30 percent of this "carbon gap." Perhaps more important, implementing a set of policies which encourage the development and deployment of energy efficient and low-carbon technologies can close this gap to the benefit of both the climate and the economy (DOE 1997, Energy Innovations 1997, Krause 1996, Laitner, et al., 1995, OTA 1991).

How have other studies approached the problem?

Typical of many analytical perspectives is a recent policy brief published by the Brookings Institution (McKribbin and Wilcoxen 1997). In explaining the value of tradable permits, the authors ask us to suppose that a particular firm has an abatement cost of \$100 per ton of carbon while a second firm has a higher cost of \$200 per ton. If greenhouse gas emissions are to be reduced by a total of 20 tons, with each firm sharing the responsibility to reduce emissions equally, the total abatement cost is estimated to be \$3,000. Yet, in continuing their discussion, the authors offer no information about the possible production savings made possible by the \$3,000 investment. In effect, this and many other such analyses examine only the cost side of the ledger. By definition, then, any analysis that evaluates only the abatement cost of a given climate policy would tend to show a loss in the overall level of economic activity.

How does Markal-Macro Improve the Analysis?

As described in other documentation, the IAT process relied on three primary models and a number of other analytical tools and models to feed information into the modeling runs. The three major economic models were the DRI Macroeconomic Model, the Second Generation Model, and the Markal-Macro Model already referenced.

The DRI Macroeconomic Model is a macroeconomic and energy-end use model maintained by

DRI/McGraw-Hill. It has a strong representation of U.S. energy supply and consumption, and it contains a reasonable level of detail for approximately a dozen industrial sectors. The Second Generation Model (SGM) is a computable general equilibrium (CGE) model maintained by Battelle's Pacific Northwest Laboratory. Its strength lies in its ability to model the long-term path of climate change policies including key aspects of international trade. It also has a strong representation of energy supply technologies but has very little industry detail. The model contains 8 energy-related sectors, two economic sectors, and the household and government sectors.

Finally, the Markal-Macro model is a dynamic linear optimization model that contains a technology rich, "bottom-up" perspective. Markal-Macro is a domestic model which is maintained by DOE's Office of Policy and International Affairs and EPA's Office of Planning and Program Evaluation. It was this model that was used to examine the question of whether an investment-led technology policy might lower the cost associated with climate change mitigation.

The Markal-Macro model was used to establish a Base Case, and then to simulate the effects of a carbon constraint on energy service demand, choice of fuels, substitution of capital/labor for energy, and the penetration of energy-efficient and low-carbon technologies. The model has two parts to its modeling system. The first part is Markal (short for Market Allocation) which is an energy model that contains the dynamic linear programming routine that is run over time in five-year intervals, from the period 1990 through 2025. The second is Macro which is a macroeconomic model with an aggregated view of long-term economic growth. While maintaining the technological richness and flexibility of Markal, Markal-Macro adds price elasticity on demands for energy services and links changes in the energy system to the level of economic activity. The Markal-Macro solution maximizes consumer welfare over the solution period, optimizes aggregate investment, and provides a least-cost energy system that will meet the endogenously determined demand for energy services (Markal-Macro, 1997).

The advantage, then, of Markal-Macro is that it: (a) allows both a "bottom-up" and a "top-down" perspective within an economic and accounting framework, and (b) allows the user to explore and

compare different assumptions about the cost and energy bill savings of technology and technology choices. As an example, in a set of runs referenced as a "Technology Investment Case," Markal-Macro shows the level of investment increasing by an average of 0.8 percent over the period of analysis compared to a reference case. It also shows that — despite a carbon constraint and, therefore, higher energy prices — the cost of energy services (including both the incremental cost of investment and the annual energy bill) actually declining by an average of 1.7 percent compared to a reference case. At the same time, Markal-Macro shows GDP (measured in constant 1992 dollars) increasing by an average 0.32 percent over the study period.

THE MODEL SCENARIOS

The Reference Case

The domestic energy and emissions baseline forecasts for all three IAT models were benchmarked to the Energy Information Administration's *Annual Energy Outlook 1997* (AEO97). Adapting the AEO97 base case assumptions, Markal-Macro forecasts an average U.S. economic growth rate of 2.1 percent annually in the years 1995 through 2010, tapering off to 1.4 percent in the period 2010 through 2020. A slower population growth, coupled with only very modest productivity improvements, is the reason for the decline in the economic growth rate.

At the same time, the nation's energy intensity is expected to decline 0.9 percent and 0.7 percent annually in those same two periods. This is because of technology assumptions that parallel those in AEO97 and the expected rates of efficiency improvement given normal capital stock turnover in the absence of either a carbon constraint or other energy price signals. The net result is a projected growth in the nation's total energy use that rises from 90.9 quads in 1995 to 107.9 quads in 2010 and 115.2 quads in 2020.

Carbon emissions are expected to rise to 1,767 million metric tons (MMT) in 2010 and 1,940 MMT in 2020. By 2020, baseline emissions will be an estimated 600 MMT above the 1990 levels — a level of reduction that is commonly discussed as an interim target to help achieve overall climate stabilization. These results are

summarized in Table 1 that follows at the end of this paper.

The Behavioral and Technology Cases

While there were many different model runs within the IAT process, in Markal-Macro the alternative scenarios generally focused on two separate cases. The first was a largely behavioral response to a carbon constraint capped at the 1990 levels of carbon emissions (1,340 MMT). The second was a technology investment case that assumed both the existence of presently cost-effective but underutilized technologies, and the development and deployment of cost-effective but advanced technologies. This scenario was also capped at the 1990 level of carbon emissions.

With some differences, the behavioral case assumes the same set of technology assumptions as found in AEO97. Before the emissions cap is imposed, it is assumed that energy intensity will decline 1.0 percent in the year 2000, and decrease linearly to 1.25 percent between 2000 and 2010, and remain at 1.25 percent per year between 2000 and 2020. This modest improvement is based upon the assumed policy announcement effect: the actions that take place because of an international agreement on climate change will generate an increased willingness to invest in energy efficient technologies. In Markal-Macro, this response is generated by lowering hurdle rates to 80 percent of the base case assumptions.

The technology investment case adopts the same hurdle rate assumptions as in the behavioral case, but in this scenario, both consumers and businesses have a richer and deeper mix of technologies from which to choose. The technology choices parallel those generally found in the DOE Interlaboratory Study and the *Energy Innovations* Study previously cited.

RESULTS OF TECHNOLOGY ASSUMPTIONS

The behavioral case and the technology investment case offer an important comparison of economic impacts resulting from climate policies that stabilize at 1990 levels of greenhouse gas emissions. Again, Table 1 provides this comparison.

Perhaps the most immediate result is the cost of carbon between the two alternative scenarios. In the behavior case the carbon price in 2010 rises to \$145 per metric ton (in 1995 dollars), falling to only \$129 in 2020. As might be expected, the impact on GDP is small but negative. In 2010 GDP is 0.05% lower in the behavioral case compared to the base case, or \$9,150 billion compared to \$9,205 billion (measured in constant 1992 dollars). On the other hand, carbon prices in the technology case start in 2010 at \$87 per metric ton, falling to as little as \$24 per ton by 2020. At the same time, the net gains in GDP are positive throughout the period of analysis. In 2010, the level of GDP is 0.23% above the base case, increasing from \$9,205 billion to \$9,226 billion.

The reason for the net positive impact on GDP needs to be seen from several perspectives. First, the carbon constraint, in the absence of better technology choices, increases the cost of carbon. This, in turn, increases overall energy prices. Second, the higher energy prices coupled with a limited set of cost-effective technologies decrease the demand for energy services which tends to weaken economic activity. In the year 2010, for example, energy service demand is down by about 8 percent in the behavior case compared to the reference case. As a result, both investment and the cost of energy services are down, 2.80 percent and 3.61 percent, respectively. Hence, GDP declines in the behavioral case compared to the base case.

On the other hand, the improved assumptions about technology choices in the technology investment case allow businesses and consumers to respond to the price signal by investing in more cost-effective technology. This pattern decreases the cost of carbon since more tons of carbon are removed as a result of both energy-efficient and low-carbon technologies. This can be seen in two ways. First, energy service demand for the year 2010 is down only 0.8 percent in the technology case compared to the base case. Second, while total investment is down slightly in the year 2010 (-0.15 percent), total capital is up as a result of higher investment levels in earlier years (0.58 and 1.75 percent for the years 2000 and 2005, respectively). These conditions nudge economic activity to 0.23 percent above the base case forecast for 2010.

POLICY IMPLICATIONS

Under the United Nations Framework Convention on Climate Change (UNFCCC), 153 countries are working in a combined effort to draft an international treaty aimed at reducing atmospheric greenhouse gases to help prevent global climate change. Initial efforts to reduce emissions to 1990 levels by 2000 have not been successful. For this reason the United States and other negotiators have agreed that a new legally binding target should be set which is both "real and achievable." In so doing the United States has also made it clear that while the *targets* must be binding in order to achieve results, *individual measures* should not be binding to give each country maximum flexibility in the implementation of the treaty. Through a differentiated approach, policy makers will have the freedom to develop national strategies which meet treaty obligations without jeopardizing economic growth and prosperity.

For the United States, a national climate change mitigation policy should be anchored by a productivity-led investment strategy — one that is focused on the promotion and diffusion of cost-effective energy-efficient and emerging renewable energy technologies that are now widely available but underutilized. This type of policy will provide the market with a clear and unambiguous signal about the importance of a climate change mitigation policy. At the same time, a productivity-led strategy will allow innovators from all economic sectors to take advantage of emerging investment opportunities resulting from increased demand for energy efficient technologies.

An effective climate policy needs to ask: (1) how much "underutilized technology" is now available; (2) how much near-term technology can be reasonably made available; and (3) how much long-term technology needs to be developed through research and development programs? Models such as Markal-Macro cannot answer that question since they can only choose from among the technologies that are previously entered into their respective databases. Indeed, there is evidence that the base case assumptions of Markal-Macro itself do not adequately capture the full set of currently available technologies now on the market (Laitner 1997). Moreover, there is no ability for Markal-Macro and other models to incorporate endogenous technological change in response to either price or policy signals.

Estimates of Existing Potential

Several major studies have already established the existence of an efficiency gap which can contribute to an investment-led climate policy major. The *Energy Innovations* study shows, for example, that through 2010 the technology generally exists to reduce the nation's energy intensity (measured as the number of Btus of primary energy per dollar of GDP) at a rate consistent with the technology investment case evaluated by the Markal-Macro model (see, Table 1). In addition, there is strong evidence that the potential may be understated, especially in the industrial sector, since efficiency technology investments also lead to other production cost savings not captured by such models (Elliott, et al, 1997).

Estimates of the R&D Potential

Numerous studies show a very high private and social rate of return to investment in research and development (R&D) programs. Mansfield (1991) notes, for example, that "[d]ozens of economists working independently with quite different sorts of models and entirely different kinds of data have found that the social rate of return from industrial innovations and R&D has been very high, frequently 40 percent or more. This is a remarkable fact, and one that policy-makers should recognize." DeCanio (1997) provides a table of almost two dozen studies showing an average social rate of return to R&D of 60 percent. The Council on Economic Advisors (1994) reports estimated social rates of return on R&D range as high as 50 to 100 percent. CEA suggests that the high rates of return are a strong indication that both firms and society as a whole are underinvesting in R&D.

Such evidence indicates a significant potential to improve both the economic and environmental welfare by increasing aggregate R&D, including R&D in energy efficient technologies. We know that it is possible to increase aggregate R&D substantially; this is a policy decision having mainly to do with the funding of graduate education for scientists and engineers, and with the availability of jobs and equipment for those researchers upon completion of their degrees. DeCanio notes that we have the historical experience of the post-Sputnik push that demonstrates the feasibility (and benefits) of an increase in society-wide R&D. The time

lag for beginning to see the effects of such an effort would be three years at the most. Brøgger (1997) found that after 20 years, 1.3 Quads of energy could be saved for each \$100 million of R&D devoted to energy efficiency technologies.

Some analyses have suggested that if the current pattern of R&D programs are changed to emphasize the development of technologies which can help mitigate the problems of global climate change, the opportunity costs may be substantial. However, there is no evidence that the present allocation of R&D monies is optimal. Even if it were known that the social rate of return to energy-efficiency R&D were lower than the return to some other kinds of R&D, it would still be justified to increase energy-efficiency R&D if: (1) the environmental benefits augment the other economic benefits sufficiently; or (2) it is not possible (perhaps for political reasons) to increase R&D in the other sectors. A social rate of return of 40 percent is still quite attractive, even if some other (unobtainable) opportunity offers 50 percent.

Estimates of the Economic Costs of Promoting Technology

There are two categories of costs which must be accounted for within any modeling exercise. The first is the actual level of technology investment. The second is the R&D and program costs associated with delivering the technologies to the market and in making both consumers and businesses aware of those investment opportunities. Similarly, there are at least three categories of benefits that should be included within an economic analysis. These include: (1) the direct energy bill savings driven by the investments made necessary with a proposed climate policy; (2) the environmental benefits created by the investments and not captured within the usual modeling framework; and (3) the spillovers created by either the investment or the R&D and program costs. The latter benefit generally stems from the nonenergy productivity gains made possible by the energy-efficient technologies (Elliott, et al., 1997) and the social rates of return referenced by DeCanio (1997) and others. The results from the Markal-Macro technology investment case captures only the direct investment costs and the energy bill savings. Hence, this tends to make the results highly conservative since: (a) the nonenergy benefits are not captured in the analysis; and (b) the R&D and program costs are quite small in

comparison to the actual level of direct investment. Still, it is helpful to provide at least a working estimate of the costs and benefits associated with stabilizing greenhouse gas emissions to 1990 levels. For this we turn to the DOE Interlaboratory Study and the *Energy Innovation Study*.

The DOE analysis suggests a cumulative investment on the order of \$400 billion would be necessary to stabilize carbon emissions with a \$50 per ton cost of carbon in the years 1997-2010. This will generate a cumulative savings of about \$700 billion within the same period (in 1995 dollars). The *Energy Innovation Study* suggests a \$333 billion investment that would yield a \$550 billion savings (in 1993 dollars). Both studies, then, suggest a net positive gain for the economy.

The DOE analysis then suggests that the noninvestment costs would be about 7.0 percent of the cumulative investment, or about \$28 billion. In a separate estimate, Laitner (1997b) estimates the combined R&D and program costs to be on the order of \$21 billion (in 1995 dollars) over the period 1997 through 2010. This is about 5.0 percent of the total technology investment estimated by the DOE study.

CONCLUSION

The emerging evidence suggests that the United States is in a strong position to reduce carbon and other greenhouse gas emissions through a technology-led investment strategy. While the total investment appears to hover around \$400 billion, it is worth noting that in the period 1998 through 2010, the AEO97 forecast indicates the United States will generate a total investment of \$17.2 trillion (in 1992 dollars). If the Lab Study numbers are right, the roughly \$400 billion investment (in 1995 dollars, or ~\$375 billion in 1992 dollars) is about 2.2 percent of the total investment otherwise anticipated by AEO97 (Laitner 1997b). In other words, we are talking about diverting only 2 to 3 percent of the typical investment pattern away from less-efficient and more carbon-intensive technologies into a more productive mix of technologies. Moreover, the associated transaction costs appear to be quite low, on the order of 5-7 percent of the total investment required to stabilize emissions by 1990. In keeping with Greening's comments about the marginal product of

capital and energy (Greening 1997), then an energy efficiency and low-carbon policy "should increase rates of economic output." This is now supported by the analysis generated within the IAT process using the Markal-Macro model.

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Table 1. Summary of Markal-Macro Simulation Results

	1995	2000	2005	2010	2015	2020
GDP (Billion 1992 Dollars)						
Base Case	6,739	7,554	8,387	9,205	9,884	10,569
Behavioral Case	6,739	7,540	8,380	9,150	9,813	10,481
Technology Case	6,739	7,559	8,428	9,226	9,907	10,614
Total Primary Energy Consumption (Quads)						
Base Case	90.9	97.6	103.5	107.9	110.4	115.2
Behavioral Case	90.9	95.4	98.4	91.9	94.9	97.5
Technology Case	90.9	91.9	92.8	91.2	93.7	96.6
E/GDP (Thousand Btu's Per 1992\$ of GDP)						
Base Case	13.49	12.92	12.34	11.72	11.17	10.90
Behavioral Case	13.49	12.65	11.74	10.04	9.67	9.30
Technology Case	13.49	12.16	11.01	9.89	9.46	9.10
Carbon (Million Metric Tons)						
Base Case	1,424	1,583	1,691	1,767	1,824	1,940
Behavioral Case	1,424	1,526	1,579	1,340	1,340	1,340
Technology Case	1,424	1,448	1,457	1,340	1,340	1,340
Cost of Energy Services (Percent Change from Base Case)						
Behavioral Case	0.00%	-0.55%	-1.03%	-3.61%	-4.10%	-2.72%
Technology Case	0.00%	-2.11%	-1.34%	-2.63%	-1.49%	-0.97%
Level of Technology Investment (Percent Change from Base Case)						
Behavioral Case	0.00%	0.00%	-0.79%	-2.80%	-2.09%	-3.91%
Technology Case	0.00%	0.58%	1.75%	-0.15%	0.49%	1.50%
Marginal Cost of Carbon (\$1995 Per Ton)						
Behavioral Case	NA	NA	NA	145	134	129
Technology Case	NA	NA	NA	87	52	24

Summary of Greenhouse Gas Emissions-Reduction Actions

Million Metric Tons of Carbon Equivalent

Source: U.S. Climate Action Report—1997

Action Number	Action Title	1993 Action Plan Estimate for 2000	1997 U.S. CAR Revised Estimate for 2000	Actual Reductions to Date
Residential & Commercial Sector Actions		26.9	10.3	--
New	Rebuild America	2.0	1.6	--
1 and 2	Expanded Green Lights and Energy Star Buildings	3.6	3.3	1.5
3	State Revolving Fund for Public Buildings	1.1	Terminated	
4	Cost-Shared Demonstrations of Emerging Technologies			
5	Operation and Maintenance Training for Commercial Building Facility Managers and Operators	3.8	0.0	--
6	Energy Star Products	5.0	4.3	1.9
7	Residential Appliance Standards	6.8	0.2	--
8 and 11	Energy Partnerships for Affordable Housing			
9	Cool Communities	4.4	0.4	--
10	Update State Building Codes			
New	Construction of Energy-Efficient Commercial and Industrial Buildings		0.1	--
New	Superwindow Collaborative		0.0	--
New	Expand Markets for Next-Generation Lighting Products		0.2	--
New	Fuel Cells Initiative		0.0	--
Industrial Sector Actions		19.0	4.8	--
12	Motor Challenge	8.8	1.8	--
13	Industrial Golden Carrot Programs	2.9	Merged into Action 12	
14	Accelerate the Adoption of Energy-Efficient Process Technologies		Terminated	
15	Industrial Assessment Centers	0.5	CCAP Component Terminated	
16	Waste Minimization	4.2	2.1	--
17	Improve Efficiency of Fertilizer Nitrogen Use	2.7	0.8	--
18	Reduce the Use of Pesticides		Terminated	
Transportation Sector Actions		8.1	5.3	--
19	Cash Value of Parking			
20	Innovative Transportation Strategies	6.6	4.6	--
21	Telecommuting Program			
22	Fuel Economy Labels for Tires	1.5	0.7	--
Energy Supply Actions		10.8	1.3	--
23	Increase Natural Gas Share of Energy Use Though Federal Regulatory Reform	2.2	Terminated	

Action Number	Action Title	1993 Action Plan Estimate for 2000	1997 U.S. CAR Revised Estimate for 2000	Actual Reductions to Date
24	Promote Seasonal Gas Use for Control of Nitrogen Oxides	2.8	0.5	--
25	High-Efficiency Gas Technologies	0.6	Terminated	
26	Renewable-Energy Commercialization	0.8	0.3	--
27	Expand Utility Integrated Resource Planning	1.4	Terminated	
28	Profitable Hydroelectric Efficiency Upgrades	2.0	0.0	--
29	Energy-Efficient Distribution Transformer Standards	0.8	0.5	0.0
30	Energy Star Distribution Transformers			
31	Transmission Pricing Reform	0.8	Terminated	
New	Green Power Network	Not included	0.0	--
Land-Use Change & Forestry Actions		10.0	2.4	--
43	Private Depletion of Nonindustrial Private Forests	4.0	Terminated	
44	Accelerate Tree Planting in Nonindustrial Private Forests	0.5	0.4	--
16	Waste Minimization	4.2	2.0	--
9	Expand Cool Communities	0.5	To be determined	
Methane Actions		16.3	15.5	--
32	Expand Natural Gas STAR	3.0	3.4	1.6
33	Increase Stringency of Landfill Rule	4.2	6.3	0.0
34	Landfill Methane Outreach Program	1.1	1.9	0.1
35	Coalbed Methane Outreach Program	2.2	2.6	1.9
36	RD&D for Coal Mine Methane	1.5	Terminated	
37	RD&D for Landfill Methane	1.0	Terminated	
38	AgSTAR Program	1.5	0.3	0.0
39	Ruminant Livestock Efficiency Program	1.8	1.0	0.0
Actions to Address Other Greenhouse Gases		16.3	25.4	--
17	Improved Fertilizer Management	4.5	5.3	--
40	Significant New Alternatives Program	5.0	6.4	--
41	HFC-23 Partnerships	5.0	5.0	--
42	Voluntary Aluminum Partnership	1.8	2.2	2.9
New	Environmental Stewardship Initiative	Not included	6.5	--
Foundation Actions			11.3	--
	Climate Wise	Not estimated	1.8	--
	Climate Challenge	Not estimated	7.6	--
	State and Local Outreach Programs	Not estimated	1.9	--
Total GHG Emission Reductions From CCAP		108.6	76.0	15.0

Data are not immediately available for cumulative emissions reductions for many CCAP programs. Cumulative emissions reductions of about 5 MMTCE can be attributed to DOE's CCAP programs, but are not available at the program level. EPA's Office of Air and Radiation (OAR) is responsible for cumulative emissions reductions of about 10 MMTCE through their CCAP programs. OAR's HFC programs are currently verifying emission reduction achievements, and are expected to affect cumulative totals.

The Role of Technology

There are three ways to reduce greenhouse emissions:

- Energy Efficiency (i.e. reduce the energy intensity of the economy)
- Clean Energy (i.e. reduce the carbon intensity of the economy)
- Carbon Sequestration (i.e. remove carbon from the economy)

Emission reductions need to occur in four areas:

- Buildings
- Transportation
- Industries
- Utilities

Substantial new investment is needed in three areas:

- Basic Research
- Applied Research and Development
- Deployment

Current Technology Reports

- Report of the President's Committee of Advisors on Science and Technology
- "Technology Opportunities to Reduce U.S. Greenhouse Gas Emissions" (Draft) (Report of Eleven National Lab Directors)
- "Scenarios of U.S. Carbon Reductions" (Report of Five National Labs)

SCENARIOS OF U.S. CARBON REDUCTIONS:

Potential Impacts of Energy-Efficient and Low-Carbon Technologies by 2010 and Beyond

CONCLUSIONS

A vigorous national commitment to develop and deploy energy-efficient and low-carbon technologies has the potential to reduce U.S. carbon emissions to 1990 levels in the medium term (i.e. 2010) and produce energy savings that are roughly equal to or exceed costs. International trading or flexibility in meeting a stabilization target, considered by other studies, could increase those savings further. Beyond the medium term, the next generation of these technologies promises to enable a continuation of aggressive carbon emissions reductions over the next quarter century. The study assumes penetration of technologies from expanding Clinton Administration initiatives, such as the Partnership for a New Generation of Vehicles, natural gas technologies, the Climate Change Action Plan and renewable energy such as wind and biomass.

BACKGROUND

Five Department of Energy national laboratories led by Oak Ridge and Lawrence Berkeley National Laboratories have conducted a comprehensive, peer-reviewed, one year "bottom-up" analysis of the role technology can play in stabilizing U.S. carbon emissions. It is the most authoritative and documented study of this subject since the National Academy of Sciences and the Office of Technology Assessment reports in 1991. The study documents in detail how four key sectors of the economy - buildings, transportation, industry, and electric utilities - could respond to a climate treaty launched in the year 2000 with a goal of stabilizing emissions in 2010 and a U.S. cap and trade system is phased in. This study examines the potential effect of an aggressive program of clean technology research, development, and deployment combined with alternative marginal permit prices of \$25/ton and \$50/ton of carbon.

RESULTS

The study concludes that energy efficiency and low-carbon technologies have a very large potential to reduce U.S. carbon emissions while meeting the full energy needs of U.S. businesses and families and providing a positive return on investment for the nation. Many consumers and businesses would save money through reduced energy use and lower overall energy bills. Current projections suggest that a carbon emissions reduction of 390 million metric tons (MMT) is required to stabilize U.S. emissions in 2010 at 1990 levels. A combination of energy efficiency, low-carbon technologies and relatively inexpensive coal power plant conversions to natural gas - motivated by a vigorous national program and a \$25/ton carbon permit price - can reduce 2010 emissions by a total of 230 MMT. Under a \$50/ton carbon permit price, technology investments are estimated to reduce 2010 emissions by a total of 390 MMT. The analysis also suggests that substantial additional savings are available if permit prices were to begin to rise above the \$50/ton level. Annual investment costs of such reductions are estimated to be \$50 to \$90 billion per year, but result in substantial energy bill savings in the range of \$70 to \$90 billion in 2010.

In the long term, these climate change mitigation actions will provide additional benefits not considered in the study - reductions in criteria air pollutants (i.e. ozone and fine particles), decreased dependence on imported oil, greater industrial productivity, and U.S. leadership in technologies likely to be a major source of international trade and jobs in the next century.

METHODOLOGY

In contrast to previous studies that use top-down economic modeling, the five laboratory study uses a bottom-up technology-by-technology assessment as well as a top-down engineering-economic modeling approach. It uses a wide variety of technology cost and performance information to assess potential impacts. Detailed analyses of the buildings, industry and transportation sectors quantify the impacts of end-use energy efficiency improvements and low-carbon technologies on carbon emissions, while a utility sector analysis estimates the impacts of low-carbon technologies, changes in operations and conversion of some coal power plants to natural gas.

A Technology Portfolio for Reducing Carbon Emissions: \$500 Million Level

It is clear that no single strategy, whether economic or technological, will ensure that the U.S. can reduce and stabilize carbon emissions while maintaining a robust and healthy economy. The US however can develop technologies that if deployed, will be able to reduce emissions in the U.S. with little impact on economic productivity or consumer preferences. A multi-pronged approach to technology investment would include three kinds of actions: R&D investments; public-private partnerships; and implementation initiatives.

If successful, the set of technologies and initiatives proposed here could help reduce potential emissions by more than 175 MMT by 2010 at an annual incremental investment above the FY1997 appropriation of about \$500 million.

	Federal Costs (\$millions above FY97 appropriated)		2010 Potential Carbon Savings	2020 Potential Carbon Savings
	FY99	FY03	MMT	MMT
Equipment Efficiency	50	150	15-20	30-75
21 st century housing	35	60	3-5	15-20
Expanded PNGV (including expansion to light trucks)	100	160	30-60	100-150
PNGV for heavy trucks	40	100	10-20	30-50
Advanced Aircraft	40	40	10-20	30-40
Biofuels	25	55	5-10	20-40
Combined Heat and Power	30	60	15-35	30-70
Industries of the Future	20	60	10-20	20-40
Motors and other systems efficiency	15	25	5-10	10-30
Renewables R&D	95	140	5-10	40-60
Renewables Deployment	25	50	15-30	40-50
Carbon Sequestration R&D	50	100	0	50-75
TOTAL	500	1,000	123-240	

916
FY99-FY10: 8106

Buildings

Energy Efficient Equipment: Improve equipment efficiency including lighting, commercial air conditioning loads and demonstrating fuel-cell systems. This will be accomplished with increased federal research partnerships to develop advanced building equipment and appliances; a public service campaign to attract increased attention to the "Energy Star" label; and accelerated work on energy efficiency standards for appliances under existing authority.

21st Century Housing: Create a partnership with builders, suppliers, insurance companies and state

and local governments that will undertake a program to accelerate development and demonstration of inexpensive, efficient, attractive housing and streamline federal, state, and local building and utility regulations in ways that encourage innovation in construction.

Transportation

Expanded Partnership for the Next Generation Vehicle (PNGV): Increase the probability of meeting the original PNGV goals by increased funding; expand work on the next generation vehicle technologies including fuel cells; and expand PNGV to include light trucks/sport-utility vehicles.

PNGV for Heavy Trucks: Expand partnership with engine manufacturers to double the efficiency of heavy-duty trucks for civilian and military applications, which produce about 15% of CO₂ in transportation.

Advanced Air Traffic Control, Advanced Aircraft: Create technologies and practices to produce a 35% reduction in greenhouse gases per passenger miles traveled by 2020.

Biofuels: Accelerate R&D on the number of crop species under development, crop harvest, handling and storage systems and crop to fuel conversion processes to significantly expand use of biomass fuels as new automobile technologies are developed.

Industry

Combined Heat and Power: Accelerate the development and widespread use of combined heat and power systems in industry. Widespread use of these very efficient technologies can be accomplished largely through regulatory reform and streamlined permitting.

Industries of the Future: Enhance industry/government research partnerships in areas such as chemicals, aluminum, forest products and steel manufacturing technologies that can lead to large emissions savings.

Motors and Related Systems: Accelerate the use of market-ready industrial motor systems, steam systems and compressed air storage to improve efficiency and productivity across industry.

Renewable Energy

Renewables R&D: Expand research partnerships in key renewable technologies such as wind, photovoltaics, geothermal, biomass and hydropower to accelerate cost reductions.

Renewables Markets: Support early demonstrations of renewable technologies through federal procurement of solar rooftops, cost-shared demonstrations of early biomass cofiring, expanded field verification of wind energy and other actions.

what basis for this?

A Technology Portfolio for Reducing Carbon Emissions: \$1 Billion Level

The next \$500 million increment would have two basic components. The first is mid- to long-term basic and applied research and development and carbon sequestration R&D described in the draft DOE report *Technology Opportunities to Reduce U.S. Greenhouse Gas Emissions* prepared by the directors of eleven National Laboratories. This investment will create the foundation for substantial reductions in U.S. emissions below 1990 levels in the long term. The second component is tax incentives to accelerate the use of current energy efficient and clean energy technologies. These incentives will reduce the direct cost to consumers and businesses of near-term emissions reductions.

If successful, the initiatives proposed here could result in additional emissions reductions by 2010 and substantially higher reductions in the post-2010 period.

	Federal Costs (\$millions above FY97 appropriated)		2010 Savings in	2020 Savings in
	FY99	FY03	MMT Carbon	MMT Carbon
\$500 Million Technology Increment	500	1000		
Basic Research:	100	150	TBD	TBD
Materials Science				
Chemical Sciences				
Biotechnology				
Geosciences, Computation, etc.				
Cross-Cutting Technology Research	100	100	TBD	TBD
Fuel Cells				
Hydrogen energy				
Sensors and Controls				
Electricity Transmission				
Energy Storage				
Carbon Sequestration	50	50	TBD	TBD
Tax Incentives to Accelerate PNGV Introduction	n/a	100	TBD	TBD
Renewable Energy Tax Credits	100	100	TBD	TBD
Accelerated Depreciation for Efficient Industrial Equipment	150	100	TBD	TBD
SUBTOTAL	500	600		
TOTAL (at \$1,000 Million Level)	1000	1600		

\$16.85 - FY99 - FY00

Basic Research

Materials Science: Conduct research and development to create advanced materials for critical components in a variety of advanced energy systems - including lightweight vehicles, high temperature turbines, fuel cells, advanced engines and a variety of new smart systems.

Chemical Sciences: Accelerate research in a variety of chemical processes vital to an array of energy technologies. Such processes include materials separations in industry, chemical catalysts and combustion.

Biotechnology: Expand R&D in a range of areas including bioprocessing, energy crops, photosynthesis, and genetic engineering to increase the carbon fixation of some plant species.

Geosciences, Computation, Environmental and Ecological Sciences and Nuclear Sciences: Expand and create public/private partnerships to pursue a variety of breakthrough science and technologies including atmospheric and ocean carbon cycles, geophysics for CO₂ injection into underground aquifers, response of ecosystems to increased CO₂, advanced nuclear systems, advanced computation for energy systems component design, and computational techniques to increase understanding of a wide variety of natural and artificial processes.

Cross-Cutting Technology Research

Fuel Cells: Accelerate research and development on fuel cells, highly efficient devices which produce electricity and hot water with virtually zero emissions and have broad potential applications in power generation, buildings, industry and transportation vehicles.

Hydrogen Energy: Expand R&D on hydrogen production, storage and use. This clean burning fuel has wide potential in transportation, industry and power generation.

Sensors and Controls: Accelerate R&D on a wide array of sensors and controls. These technologies play a critical role in clean energy production, efficient industrial processes and carbon sequestration through ensuring maximum process efficiency at minimum cost.

Electricity Transmission and Distribution: Develop new materials and technologies to reduce electrical transmission losses - including superconducting cables, sophisticated control systems, and superconducting transformers.

Energy Storage: Expand R&D on energy storage technologies such as advanced batteries, ultracapacitors and superconducting storage to efficiently and inexpensively store energy.

Carbon Sequestration

Given the huge global resources of fossil fuels, the world economy will likely continue to use large quantities of fossil energy for the foreseeable future. A variety of technologies have the potential to separate out carbon and sequester that carbon. This initiative will establish a substantial R&D effort to develop technologies such as decarbonization of fuels, ocean storage, injection of underground aquifers and increased biological absorption of atmospheric CO₂.

Tax Incentives

Tax Incentives to Accelerate PNGV Introduction: A tax credit could be provided for early purchasers of PNGV vehicles. This credit could partially defray the additional capital cost of these vehicles and would end when initial higher purchase prices fall.

Renewable Energy Tax Credits: Tax credits and other financial incentives could be provided to investors in renewable power systems. These incentives could be performance based and also be available to municipal utilities. These incentives would phase out as renewable energy system costs decrease.

Accelerated Depreciation for Efficient Industrial Equipment: Investments in energy efficient and low-carbon industrial technologies could be eligible for accelerated depreciation. Eligibility would be based on improvements in performance.

A Technology Portfolio for Reducing Carbon Emissions: \$2 Billion Level

An additional federal budget expenditure of \$1 billion would focus largely on a long term objective of further reducing emissions in the 2020-2030 period. The science and technologies developed would have large global market potential - putting the U.S. in the position of leadership in the technologies and science needed to reduce global atmospheric concentrations of greenhouse gases.

The portfolio of initiatives at this level focus on rapid acceleration of breakthrough energy efficiency and clean energy technologies, critical basic research and cross-cutting technology development, advanced carbon sequestration and selected tax incentives to accelerate use of not only current advanced technologies but also more advanced technologies as they become available.

The breakthrough R&D on energy efficiency, clean energy, basic research, cross-cutting technologies and carbon sequestration are described in the draft DOE report *Technology Opportunities to Reduce U.S. Greenhouse Gas Emissions* prepared by the directors of eleven National Laboratories. These investments will further establish a solid foundation not only for substantial reductions in U.S. emissions in the long term, but also expanded U.S. leadership in energy and environmental technologies in the coming decades.

	Federal Costs (\$millions above FY97 appropriated)	
	FY99	FY03
\$1000 Million Technology Increment	1000	1600
Energy Efficiency R&D	150	150
Advanced Buildings Technologies		
Advanced Industrial Technologies		
Advanced Transportation Technologies		
Advanced Agriculture and Forestry		
Clean Energy R&D	150	150
Fossil Resource Development		
Fossil Power Generation		
Nuclear Energy		
Renewable Energy		
Basic Research:	200	200
Materials Science		
Chemical Sciences		
Biotechnology		
Geosciences, Computation, etc.		
Cross-Cutting Technology Research	100	100
Fuel Cells		
Hydrogen energy		
Sensors and Controls		
Electricity Transmission		
Energy Storage		
Carbon Sequestration	100	100
Tax Incentives	300	300
Accelerated PNGV Introduction		
Renewable Energy		
Accelerated Depreciation for Efficient Industrial Equipment		
Biofuels Production		
Accelerated Depreciation for Low Carbon Industrial Technologies		
SUBTOTAL	1000	1000
TOTAL (at \$1,000 Million Level)	2000	2600

\$ 28.85 - FY99-FY10

Powering America for the 21st Century

As we prepare for the 21st century, one of the greatest challenges our nation faces is addressing the problem of global climate change without sacrificing our economic prosperity and quality of life. Scientific evidence is mounting that atmospheric concentrations of greenhouse gases--including carbon dioxide, methane, and nitrous oxide--have increased dramatically during the past fifty years, and that these increased concentrations are causing a change in global temperature and precipitation.

Greenhouse gas emissions are largely caused by the burning of fossil fuels --oil, coal and natural gas--which are used to supply three quarters of the world's energy needs, and eighty five percent of U.S. energy needs. Atmospheric greenhouse gas concentrations can be expected to increase even more dramatically during the next few decades given projected economic growth in the developed and developing world. The President's Council of Advisors on Science and Technology has warned, "There is considerable doubt whether the world... can continue to rely on these fossil fuels to this degree through the expected economic growth of the next few decades without encountering intolerably disruptive climatic change caused by the resulting greenhouse gas emissions."

To ensure our economic prosperity, food supply, environmental quality and quality of life, the U.S. must, over the next few decades, substantially reduce our reliance on fossil fuels, produce adequate and reliable supplies of affordable energy in environmentally sustainable ways, and find other solutions to the climate change problem. The key to meeting these challenges lies in America's technological strength and our tremendous innovative capacity.

Developing technologies to reduce concentrations of greenhouse gases and a new generation of energy technologies is perhaps the greatest technological challenge our nation has ever faced. It is even more difficult and important to our nation than President Kennedy's challenge, "to put a man on the moon in ten years," which spawned the Apollo program. Our nation invested more than \$111 billion (in 1997 dollars) over an eleven year period in our manned space program (representing 1.4 percent of *total* federal spending during this period). To solve the problem of climate change, we must make the same kind of bold, serious, sustained commitment to R&D that we made during the Apollo program.

The Clinton Administration proposes to increase our investment in energy and climate change R&D by \$6 billion annually, over a twenty year period, through the **"Powering America for the 21st Century Program."** The Powering America Program would establish a variety of innovative, cooperative R&D partnerships among all sectors of American industry, academia and the federal government, as well as among our international trading partners.

The program would focus on two critical aspects of the climate change problem. The first is meeting the U.S. projected energy needs in the 21st century with highly efficient energy technologies which produce no or low greenhouse gas emissions. The second is aggressively pursuing innovative techniques for reducing the atmospheric concentration of greenhouse gases.

The Powering America Program would operate as follows:

- The federal government would invest \$3 billion annually, leveraging a \$ 3 billion annual investment by U.S. industry, in a variety of government-university-industry partnerships to accelerate research, development and deployment of a new generation of energy technologies which 1) cause no or low greenhouse gas emissions, 2) are vastly more energy efficient than today's technologies, and 3) provide the same performance and cost effectiveness as today's technologies ("next generation energy technologies").
- This funding also would support studies and cost-shared R&D projects to reduce atmospheric concentrations of greenhouse gases, including exploring sequestration techniques, underground storage of greenhouse gases, and ecological solutions such as re-forestation and ocean management ("concentration reduction technologies").
- The federal government would invest an additional \$3 billion annually--over twenty years-- in R&D on next generation energy technologies and concentration reduction technologies in cooperation with our industrialized trading partners. This \$ 3 billion investment would leverage a \$___ billion annual investment by our international partners. This funding also would support joint implementation and deployment, where appropriate.
- All sectors of U.S. industry would be involved in this cooperative R&D effort, including the transportation sector (autos, light trucks, freight, aircraft and rail), residential and commercial buildings sector, electric power generators, and energy and waste intensive industries (including chemicals, steel, glass products and agriculture).
- Each industry sector would set voluntary targets for greenhouse gas emissions reductions by a date certain, and define the technological challenges that industry faces in order to meet its emissions targets. This will enable each industry sector to identify next generation energy technologies and concentration reduction technologies applicable to that industry, and to prepare an initial technology road map. That road map will be revised over time as the state of knowledge improves. In setting emissions reduction targets and technological goals, establishing a dialogue and cooperation across industry sectors would be emphasized. The development of multi-industry road maps would be encouraged.
- Funding decisions with respect to both domestic and international partnerships will be made, based on technical and business merit, by an Energy Advisory Board composed of senior level representatives from each of the participating industry sectors (with appropriate technical and business experience), leading academic experts on next generation energy technologies and concentration reduction technologies, the Secretaries of Energy and Commerce, and the President's Science Advisor.
- In addition to the \$6 billion in new funding, to ensure the coordination of federal climate change efforts, the government will consolidate all of its existing research and development activities relating to climate change, including monitoring and assessment, and research on next generation energy technologies and concentration reduction technologies, within a single federal laboratory within the Department of Energy system. All other current functions of the designated laboratory will be moved to other facilities, and the laboratory will be given the sole mission of research, development and deployment activities related to climate change. The research agenda of this laboratory will be determined by the Energy Advisory Board.
- The Energy Advisory Board will be directed to consider all relevant research areas, including clean power generation, renewables, energy efficiency, fission, advanced fossil fuel, sequestration and fusion technologies. Attached is a paper prepared in consultation NIST's industry advisory committee, outlining a few possible promising research areas.

Federal R&D Recommendations for Climate-Change Technologies

Summary

September 17, 1997

Based on our broad based outline of recommended research topics, we have focused, prioritized, and expanded the outline. The result is a summary of selected R&D recommendations for mitigating CO₂ and other harmful atmospheric emissions, and the development of a global modeling infrastructure, which is vital to our ability to objectively assess the climactic impacts of policy decisions.

A. Commercial & Residential Buildings

- **Blended Cements**

Background: Concrete is composed of about 10-15% cement, with the balance being crushed stone, sand, gravel, water, and other materials. Cement production is extremely energy intensive, resulting in about 1 ton of CO₂ emissions per ton of cement produced. In 1997, approximately 80 million tons of cement will be produced in the U. S., resulting in approximately 80 million tons of CO₂ emissions.

Recommendation: Replace a portion of the portland cement with waste byproducts such as flyash (from coal-fired utilities), granulated blast-furnace slag (from iron-ore production), or with limestone interground with clinker and gypsum. A 5% replacement of portland cement with flyash, slag, limestone or other mineral admixtures yields about a five million ton reduction in CO₂ emissions. Ten percent yields ten million tons, etc. Allowable percentages in Europe range up to 35%, although 5% is typical. Research is required to develop test methods and data which can become the technical basis for the improved specifications needed to assure adequate and reliable performance. The problem is complex because of the number of variables involved, and progress is likely to be slow unless a strong government-industry partnership can be established. R&D is needed to develop chemical and physical methods for evaluating raw materials and for use in quality control and assurance of the final product, and for assuring the adequacy of the many aspects of the performance of concretes made from the cements using different mixture proportions and different processing conditions.

Benefits: This is a relatively well understood process. Use of waste byproducts in cement, which would otherwise be landfilled benefits the environment, reduces CO₂ emissions, improves productivity of cement companies and increases their global competitiveness. Concrete producers would benefit from increased availability of cement, and end users of cement and concrete would benefit by reduced costs of construction materials.

Barriers: U. S. standards do not encourage use, or specifically prohibit use of extenders. Consensus standard-setting organizations are composed of some organizations that have a financial interest in preserving the use of unblended cements. Specification of construction materials in the U. S. is very fragmented, and there are currently no substantial incentives for customers or standard-setting organizations to change material specifications. It will be important to work to get new standards adopted and work with states and localities to implement the new standards.

- **Improved Energy Efficiency of Buildings, Appliances and Electrical Devices**

Background: Most of the energy for residences and commercial buildings is consumed by major electrical appliances, HVAC, and lighting systems that operate much below theoretically achievable limits.

Recommendations: Many scientists agree that a substantial increase in the efficiency of current appliances and lighting systems is not unreasonable, and could be achieved, not by incremental improvements, but by substantial redesign, use of new materials, and development of new technologies. For example, replacement of fluorescent or incandescent light fixtures by of solid-state devices for lighting could result in much brighter illumination, substantial efficiency improvements, and increased durability and longevity. Improved insulation and space-conditioning systems (e. g., alternative refrigerants), as well as passive and active reflective coatings for buildings and structures would provide make substantial energy-saving gains and benefit by their ease of retrofit.

Benefits: Because residential and commercial buildings consume so much energy, even modest improvements would have enormous impacts on CO2 emissions.

B. Biotechnology/Forestry/Agriculture/Food Production

- **Biotechnology for Atmospheric CO2 Mitigation**

Background: Approximately 40% of all photosynthesis occurs in the seas. In this process, oceanic plants take up CO2 and with light energy from the sun, convert it into organic carbon and oxygen. The oceans contain 50 times as much CO2 as does the atmosphere, and it is estimated that primary production incorporates 35 gigatons of carbon into marine biomass annually. This abundant source of fuel for energy has not been tapped commercially because it is not competitive with soybean meal and other easily harvested, traditional sources of biomass, and also because, regardless of the source, biomass is not competitive with other types of fuels.

Recommendations: The federal government should continue to support research on the use of biotechnology to enhance biomass production and utility, as well as manipulate cellular metabolic pathways for optimized CO₂ consumption. The enzyme that captures CO₂ for photosynthesis, ribulose biphosphate carboxylase/oxygenase is relatively inefficient so it is important to determine its structure in order to redesign the enzyme to make it more efficient. Next, the chemical composition of biomass can be altered to make it more suitable for particular applications. For example, marine microalgae can be genetically engineered to boost their lipid content with the aim of providing an economic source of alternative fuels. It is vital to develop tools to elucidate the biogeochemical cycles that determine the fate of all life-supporting elements on Earth. Work must be conducted to understand and manipulate the molecular genetics and biology of esoteric metabolic pathways associated with the carbon, sulfur, phosphorous, iron and other biogeochemical cycles. For example, iron induced algae blooms in the open water off the Galapagos Islands demonstrated significant photosynthetic energy production with a concomitant increase in CO₂ elimination from the atmosphere. In another example, genetically-enhanced microorganisms represent a low-energy, high-conversion pathway of vegetable matter to ethanol. The results of genetic manipulation need not be restricted to marine applications, but would have substantial impact on terrestrial plants and trees as well.

Benefits: The oceans represent an immense and virtually untapped source of biomass-derived products, a substantial commercial opportunity, and an unoptimized sink of CO₂. A minute increase in the uptake of CO₂ by the oceans, whether due to increased harvesting of biomass materials or introduction of CO₂-loving algae would have tremendous commercial impact and exert tremendous leverage on mitigating terrestrial CO₂ levels. Further, applications to terrestrial plants and vegetation could increase sequestration of CO₂.

C. *Energy Production*

- **Solar Energy Production**

Background: Solar energy conversion makes more sense now than ever before. In the last few years, there have been dramatic improvements in the semiconductor and thin-film technologies which enable solar energy conversion, and very importantly, the new materials and manufacturing methods are increasingly efficient and inexpensive.

Recommendations: We propose a government-wide program to exploit the new developments in solar conversion to develop this technology as a truly viable alternative to fossil fuel. The program would involve research, technology development, and infrastructural support for industry.

Examples of work to be done include development and characterization of advanced materials such as photoconductive polymers, "buckyballs," and dye-sensitized semiconductor films, which have considerable potential to revolutionize the technology. Needed measurements for new developments include characterization of the key photophysical processes and failure mechanisms. Measurements and standards will be essential for a successful solar energy conversion industry, providing developers, suppliers, and users with a framework for assessing properties which must be specified. These include energy conversion efficiency, longevity, and the optical properties of materials and coatings. New and existing solar conversion technologies will benefit from recent advances in measurement methods, such as optical microscopy and imaging, light scattering, and ultrafast time-resolved laser spectroscopy, which can characterize the light-conversion process, map composition of photovoltaic films, and assess quality in manufacturing. Measurements of optical properties of materials, such as thin-film absorption and reflectance, as well as measurements of the spectral efficiencies of solar energy conversion devices will be essential for optimizing performance.

Benefits: Solar energy offers an inexhaustible power generation alternative that is clean, free of greenhouse gas emissions, is inexpensive and reliable in operation, and is readily accessible to all countries and economies throughout the world. Solar power generation is also amenable to rapid retrofit, and can be used by existing power distribution infrastructures.

- **Fusion Energy**

Background: The benefits of fusion energy production are well known (cleaner source of energy without the radioactive disposal problems of current fission systems, abundant supply of "fuel"). However, the fusion energy research community has been somewhat disjointed and projections for working systems keep getting delayed beyond the 25 year horizon, thus losing the attention of many policy makers.

Recommendations: We must demonstrate plasma ignition without significant degradation of critical plasma parameters, impurity control, fueling and ash removal, long pulse or steady state operation; we must find acceptable new materials for plasma facing components and first wall, develop hot blankets for breeding tritium, demonstrate reliability, high duty cycle and safety and so on. Many experts believe that the above problems can be addressed and solved in 2-4 tokamak systems, built partly in parallel, over the coming 15 to 25 years. In principle, we could have a demonstration power plant as early as the year 2015. This must be a goal of a world-wide fusion program - because of the enormous costs, no single country can afford or risk to go it alone. A fusion demonstration facility, generating electricity in an environmentally acceptable manner, should be built as rapidly as technically feasible, by the year 2015. This calls for an aggressive development of a number of parallel systems which solve the various problems of

physics, technology, safety, environmental acceptability etc. Some pruned version of ITER could be one of the required parallel systems needed for overall development.

Benefits: The benefits of fusion energy are well documented. A virtually limitless supply of fusion energy would revolutionize mankind in unimagined ways. Greenhouse gas emissions would drop precipitously, industrial and economic growth would explode world-wide, and direct benefits would be reaped by every person on the planet.

- **Fossil Fuel Decarbonization, Direct CO₂ Removal and Sequestration**

Background: Combustion of fossil fuels is the largest man-made source of CO₂ emissions. Fuel decarbonization, direct CO₂ removal and sequestration would allow continued use of fossil fuels and their infrastructure while releasing far less carbon dioxide to the atmosphere. Fuel decarbonization involves using a reformer or gasifier and shift reactors to produce a gaseous mixture of hydrogen and CO₂ from the fossil feedstock. The hydrogen is then separated and relatively pure CO₂, accounting for a large fraction of the carbon in the original feedstock, is obtained as a byproduct.

In direct CO₂ removal, industrial effluent streams which typically contain vast amounts of CO₂, would be "scrubbed", not only to remove the typical pollutants such as NO_x, SO_x, and HCl, but innovative technologies would remove the CO₂ as well, thus preventing its release into the environment altogether. In direct CO₂ sequestration, the collected CO₂ is sequestered in deep saline aquifers under the land or under the ocean floor, or in abandoned oil and gas wells. There is currently underground space available in the European Union and Norway alone, mostly in deep aquifers under the North Sea, to store about 280 billion tons of carbon (as CO₂). For comparison, world-wide emissions from fossil-fuel burning are about 6 billion tons annually.

Recommendation: Research into the scale-up of the fuel decarbonization process, direct CO₂ removal technologies, and the long term fate of CO₂ sequestration is needed. The fuel decarbonization technique is well known, although an economic means of large-scale hydrogen production, and an insufficient infrastructure for hydrogen distribution remain significant problems that must be addressed. In addition, hydrogen storage is problematic and new high-density or solid state storage technologies must be promoted and developed. Recent advances in hydrogen fuel cells must continue. For example, the proton-exchange membrane fuel cell runs at low temperatures, has a high power density, and is small enough for mobile applications, but can also be used for residential and commercial buildings. For direct CO₂ removal from stack gases, research is needed to develop innovative membranes and cryogenic processes to efficiently remove CO₂ with minimal energy requirements. Questions that must be answered in CO₂

sequestration include what effect CO₂ would have on sea life near the point of injection, how much CO₂ would become mixed with the ocean over time, what happens in the event of an earthquake and a sudden uncontrolled release of CO₂, and what effects it would have on life near the ocean bottom?

Benefits: If decarbonization were combined with the use of hydrogen fuel cells, direct CO₂ removal and carbon sequestration, the resulting energy regime would utilize fossil fuels efficiently, yet greatly reduce the amount of CO₂ emitted to the atmosphere. This would allow much of the world, which is primarily fossil-based, to continue using much of their fossil infrastructure while they are transitioning to a non-fossil or reduced-fossil mode of energy production.

D. Geoengineering

- **Repairing the Earth's Atmosphere**

Background: Global time scales for natural absorption, dissolution, destruction, or transformation of atmospheric pollutants and greenhouse gases is on the decadal and century level. Thus, even if the most draconian global reductions in pollutants and greenhouse gases are immediately implemented, substantive changes or improvements in the climate and eco-system will not be observed within the many people's lifetime, and certainly not within the political lifetime of many policy makers. However, if an active means of remediating or repairing the present atmospheric conditions can be developed, global changes can be substantially accelerated.

Recommendations: Active physical remediation of the upper atmosphere via directed energy beams (electromagnetic or particle beams) could have tremendous and rapid benefit. Although economic and safety issues would require careful study and creative design, it may in principle be possible to actively dissociate and remove greenhouse gases using energy beams directed into the atmosphere from land, air, or space borne sources. It may even be possible to redirect and utilize Strategic Defense Initiative technology for peaceful purposes in this way. It might also be possible to utilize the natural bombardment of the upper atmosphere which occurs during solar flares--when the sun hurls energetic particles toward the earth. Now that it is possible to predict somewhat in advance when these solar events occur, perhaps the atmosphere could be seeded with a sensitizing agent just prior to the solar event. The sensitizing agent would then react to bombardment by the solar flare to effect a desirable change in the greenhouse gas content of the upper atmosphere. The idea is analogous to that in medicine where the body is injected with a particular chemical prior to bombardment with energy beams for diagnostic or therapeutic purposes--only in this case the goal would be to "heal the earth" rather than a single patient.

Benefits: Directed energy beams can be tailored in wavelength and intensity to target the destruction, transformation, or generation of specific atmospheric species. Impacts would be substantial and much more rapid than natural global time scales. Used in tandem with ongoing emission reduction programs around the world, atmospheric remediation can provide the option of a slower phase-in of emission reduction targets. In addition, this represents an excellent defense conversion program where much of the technology developed for the Strategic Defense Initiative would have direct application here.

E. Environmental Assessment and Evaluation

- **Understanding the Global Climate System**

Background: The global climate system consists of exist extremely complex interactions and feedback among energy inputs (from space to/from the earth), energy transport and transformations, human and natural chemical cycles, regional and global circulation (atmosphere and oceans), model building, metrology, and global (current and paleo-) monitoring. The most vital thrusts of a large global climate program should look at the system as a whole, and to identify weak points in our understanding, modeling, data, monitoring, and metrological capabilities. An especially pernicious aspect is that extremely small and apparently insignificant imbalances (or model errors or data inadequacies) can have profound impacts on the accuracy of our forecasts.

Recommendations: There are four major thrust areas that must be addressed in order to advance our understanding of the global climate system and begin to develop confidence in our modeling capabilities: 1) *Energy inputs as a function of time and space*, which involves satellite and ground-based monitoring and model-based forecasting (retrospective and prospective) of geo- and solar-based energy input changes, 2) *Energy transformations and redistribution*, which requires that the life cycles of greenhouse and ozone-harming species be understood and monitored, 3) *Circulation and modeling*, typified by activities like the World Ocean Circulation Experiment where unique input functions of human-made chemicals (SF₆, CFCs) and isotope injections (Kr-85, C-14, H-3) have been critical to the success tracer monitoring in establishing global circulation patterns and the hydrological cycle, and 4) *Metrological Aspects* are at the core of our understanding and forecasting of global climate. Measurements of radiation and chemical and isotopic species are central input data for climate (and circulation) models, as well as being indicators of sometimes unsuspected climate change. What is missing, or under-represented, are sufficient interactions linking the *quantitative* needs of the modelers with the fundamental measurement capabilities, and availability and accuracy of physical and chemical parameters.

- **Measurement of Whole-Spectrum Radiation Load on Global Climate**

Background: Solar radiation is the primary source of the energy needed for the development and sustenance of terrestrial and aquatic life on Earth. Solar radiation from the far infrared to the deep ultraviolet impinges on the Earth's atmosphere, penetrates to different depths in the atmosphere, depending on the wavelength of the light, and ultimately induces innumerable forms of physical, chemical, and biological transformations. However, our knowledge of the amount of solar radiation throughout the electromagnetic spectrum and throughout the atmosphere is too fragmentary and of insufficient quality to account for the ultimate environmental effects of our most important environmental component.

Recommendations: By building on emerging optical technology in the long and short wavelength regions of the spectrum, an opportunity exists for a national effort to quantify the whole-spectrum radiation forcing needed to model and mitigate the effects of human activity on global climate change. An important aspect is to quantify the radiation dosage and absorption at all levels within the atmosphere, by terrestrial features, bodies of water.

Benefits: This information is vital for understanding the a key component of the global energy balance, as well as understanding how environmental contaminants are can be affected or transformed throughout the ecosystem.

F. International R&D

- **Fusion Energy Development**

Programs in many countries, especially some of the developing ones, have now started to mature and must establish linkages with each other and with mainstream activities like ITER etc. Considering the importance of fusion for developing nations, it should be possible to raise resources for a joint mature experiment which can then address an important set of questions for the mainstream fusion program. This can also be treated as an insurance so that at some point of time in the future, if the developed nations feel that they would prefer to wait, the developing nations can take off on their own and solve their energy problems themselves.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20502

September 16, 1997

MEMORANDUM FOR

TODD STERN
KATIE McGINTY
GENE SPERLING
DAN TARULLO

JLY
JAF
RL-329
AM-328 1/2
JA-317

FROM: ROSINA M. BIERBAUM

RE: FYI

cc: TJ Glauthier
Peter Orszag
David Sandalow
Janet Yellen -

Attached, please find a memo I received from the Staff
Director of the joint NAS/NAE/IOM report, "Policy Implications of
Greenhouse Warming..."

Note: potential for a 25% reduction of US greenhouse gases at
less than \$10/T.

Call me at 6-6077, if you have any questions.

German-American Academic Council Foundation
Stiftung Deutsch-Amerikanisches Akademisches Konzil
Washington Office



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Washington, DC 20007

Fax: (202) 833-8514

8 October, 1996

MEMORANDUM

Via Fax: 202-456-6025
Two Pages Total

To: Rosina Bierbaum, OSTP
From: Rob Coppock, Deputy Director **RL**
Subject: Greenhouse gas emissions reduction potential

The NAS report "Policy Implications of Greenhouse Warming: Mitigation, Adaptation and the Science Base" states on p. 493:

"[A review of Figures 29.2 to 29.5 indicates that] it would not be unreasonable to expect that a roughly 25 percent reduction in U.S. greenhouse gas emissions (i.e., 2 Gt CO₂ equivalent) might be achieved at a cost of less than \$10/t CO₂ equivalent. This is, in more commonly used terms, roughly an additional \$22 per short ton of coal, \$4.75 per barrel of oil, \$0.60 per million cubic feet of natural gas, \$0.11 per gallon of gasoline, or 0.7 cents /kWh for the current U.S. electricity mix."

These costs were estimated using available technologies in a variety of sectors (residential and commercial energy management, industrial energy management, transportation, electricity and fuel supply, and nonenergy emissions reductions).

Tef. Frank
315

C: Hm
JA
RL

FAX MEMORANDUM

TO: Gene Sperling
Todd Stern
Katie McGinty

6 pages, including this one

Call if problems,
703/354-1588

CC: Jack Lew
Josh Gotbaum

FROM: T.J. Glauthier

DATE: September 14, 1997

RE: Technology Strategy for Climate Change Mitigation

Here is a draft of a program-type description for a U.S. Technology Strategy. This is the strategic formulation that would be supported by the types of detailed individual technology write ups that I shared with you yesterday. It will be useful to get your reactions to this overall approach, and especially to deal with the issues that I've identified at the end of the paper.

We still need to plough ahead with the agencies to get more complete development of the individual technology options, especially realistic estimates of emissions reduction potential and funding requirements, both near- and long-term. As we get those, we can put together overall program options at different funding levels in the context of our overall climate change strategy.

I look forward to talking to you further about this tomorrow.

(Hope you're watching the game now.....Redskins ahead at this point, 10-7)

A U.S. TECHNOLOGY STRATEGY FOR CLIMATE CHANGE MITIGATION

GOAL To join forces with the nation's leading corporate, university and other research centers to develop, demonstrate and encourage the market adoption of technologies in key sectors of the economy that will enable the U.S. to stop the growth of the country's greenhouse gas emissions in the future and, at some point, to return them to 1990 levels and lower, while maintaining or increasing overall economic performance and consumer satisfaction. In addition, to foster the development of these and related technologies for export to, or joint venture with, developing countries also working to minimize greenhouse gas emissions.

LONG-TERM TECHNOLOGIES

For the long-term, the strategy focuses on basic energy technologies, where breakthroughs are needed to provide radically different paradigms capable of providing high performance services with zero or very low emissions of greenhouse gases. An example of this type of program is the present "Partnership for a Next Generation of Vehicles" (PNGV) in which the auto manufacturers and the government are collaborating to develop a production prototype vehicle by 2004 that will achieve three times the fuel economy of a standard passenger car, 80 mpg, with the same performance and passenger amenities. The long-term technology strategy will phase up to a level of \$..... per year of federal funds. Because of the very long-term nature of this basic research, non-federal funding is expected to be limited. Examples of the research that are included in this area are:

- Small, light hydrogen fuel cells for automobiles and light-duty trucks, that can meet the weight, size, performance and maintenance requirements of these vehicles
- Biofuels research that can produce liquid fuels from agricultural products and waste materials at a price equivalent to 75 cents per gallon of gasoline or less
- Aircraft engines and design innovations that will reduce the combination of CO₂ and NO_x emissions (both greenhouse gases at high altitudes) by a factor of five
- Expanded "Industries for the Future" program to focus on topics jointly-identified with the industries, such as biological process for catalytic reactions and chemical separation to achieve.....
- Bulk energy storage, such as advanced batteries, that can
- Carbon sequestration, including injection of CO₂ into aquifers and other geological or oceanic formations

MEDIUM-TERM TECHNOLOGIES

For medium-term technologies, the strategy focuses on refining and proving

technologies that have already been demonstrated in the laboratory, but may need critical incremental improvements, such as to achieve key threshold performance levels, and which need to be proven under real-world operating and use conditions. The strategy, when fully implemented, will reach a level of \$..... per year of federal funding, which should leverage an equal or greater level of private sector funding of these technologies. These projects should be cost-shared at least 50% by the private sector to ensure that they will respond to true market needs. Examples of the types of medium-term technologies that are included in the strategy are:

- Hydrogen fuel cells for buildings and heavy-duty transportation, that are able to operate for over 5,000 hours per year for 10 years or more with outputs of that can power a school, shopping center, or long-haul truck or train
- Advanced turbine systems for use in combined heat and power systems at industrial facilities, which can meet new air quality standards and achieve twice the energy efficiency levels of conventional electricity generation and separate process heating systems
- Biomass production and processing for electric powerplant use on a scale to support a commercial powerplant of 300 megawatts on a sustainable, long-term basis
- A PNGV program for heavy trucks, as a partnership between the truck engine manufacturers and the Defense Department which purchases commercial truck engines for its trucks and heavy combat equipment, to demonstrate a medium/heavy duty diesel engine that will achieve

NEAR-TERM TECHNOLOGIES

For near-term technologies, the strategy focuses on actions to encourage market adoption of improved technologies that have been proven in pilot tests to be superior technologically and economically, but are not being used widely by end users. The reasons for that may include market barriers, lack of information and demonstrations, and initial investment cost. The federal role will be one of supporting the private sector, consumer groups, and others in funding demonstrations, supplying consumer information, streamlining regulations, and encouraging the development of innovative financing programs. [?? tax credits, accelerated depreciation, emissions limits/allowances, financing, efficiency standards and regulations??] These incentives will be particularly focused on encouraging investment in more efficient technologies when capital equipment stock is replaced. This program will reach a level of \$..... when fully phased in, and should leverage a much larger amount of private sector funding, since these products are close to full market status. Examples in this area are:

- Solar power, where the "Million Solar Roofs Initiative" is a partnership with businesses and government to develop and encourage voluntary programs to deploy one million solar

photovoltaic and hot water systems on residential, business, and government rooftops by the year 2010

- New residential housing construction, where our new "Partnership for Advanced Technologies in Housing" (PATH) program is starting to work with builders, suppliers, insurance companies, and local regulators to develop and use building designs and production methods that can lower costs, improve safety, and also reduce greenhouse gas emissions by 50%
- A cities partnership with the nation's mayors to stimulate the improvement of energy efficiency and reduction of energy costs and air pollution in major cities through the use of alternative fuel buses and other municipal vehicles, more efficient street and other lighting, and energy-saving investments in municipal buildings
- A Federal government initiative to use the government's purchasing power and its 500,000 buildings and 000 vehicles to demonstrate advanced energy efficient technologies while also saving money for the public. Since 1990, the Federal government has reduced its total energy usage by 18% and reduced its energy bill from over \$11 billion to just \$8 billion in 1995. This will also include actions in locations where large numbers of the public will experience them, such as the National Parks, which are visited by over 200 million people per year.

PRINCIPLES

- Partner with the private sector to the maximum extent feasible, including cost-sharing and joint agreement on plans and goals
- Include the nation's universities and other research institutions along with the federal government's research laboratories and centers
- Evaluate specific areas of research on their potential for both cost-effective and absolute levels of reduction in future greenhouse gas emissions, and for maintaining high levels of performance and user satisfaction
- Develop specific, peer-reviewed performance goals
- Maximize market-based approaches and minimize the government's attempt to pick "winners" and "losers", especially by focusing on target performance levels needed in various applications, rather than on specific technologies

EMISSIONS REDUCTIONS

This strategy is designed to provide both long-term and near-term benefits in reducing greenhouse gas emissions. The very long-term research initiatives are, of course, quite uncertain with respect to the technological performance they will achieve in emissions reduction. Their goals, however, are very ambitious and are aimed at the step function improvements that are needed to deal with the climate change issue in the long run. The shorter-term elements of the strategy are, of

course, also uncertain, but primarily as a result of uncertainty about customer and market acceptance of the technologies, rather than about their underlying technical capabilities.

Acknowledging those uncertainties, this technology strategy is estimated to achieve carbon dioxide reductions in about years reaching approximately to million tons per year from the projected levels under a business as usual set of technology assumptions.

In the longer term, by 2030 and beyond, this strategy should lead to advances that would reduce emissions on the order of to per year, and could potentially be much higher.

FUNDING

When fully phased in, the Climate Change Technology Strategy should be funded at an annual level of \$ per year from the federal government. That should leverage an additional amount of at least \$ in private sector funding for the development and demonstration of these technologies.

The full phasing in of this strategy will depend upon the availability of funds from the sale of emissions allowance auctions or other new sources of revenue. By reinvesting a portion of such revenues in this technology strategy, these funds are being put back into the economy in a manner that creates jobs, improves the competitive standing of U.S. industry, and will provide long-term benefits to the country.

In the meantime, to initiate the technology strategy, the Federal Government will seek an increase in funding from the Congress beginning in the next Budget, to be submitted in February.

MANAGEMENT

The Federal implementation of this technology strategy will be led by It will involve practically every Federal department and agency, and, of course, the whole system of national laboratories and research centers throughout the country. Every effort will be made to work closely with the Congress to enlist their advice and support for this important national initiative.

In order to ensure a high quality, independent oversight and review of the strategy over time, the President's Council on Science and Technology is being asked to establish a standing committee to provide an annual review of the program. As with other such PCAST committees, it is expected that this one will include leaders from the private sector, universities, independent research centers, and public interest groups.

ISSUES

- Funding — the use of auction or other climate-related revenues for funding, and the concept of delaying the full phase in of the strategy in until such funds are available
- Funding levels and emissions reductions, including the allocation among long-, medium-, and near-term technologies
- Incentives — what are we willing to include, especially to stimulate the near-term adoption and use of these technologies: direct funding, information, streamlining regulations, financing or preferential financing in government programs, tax credits, accelerated depreciation, emissions trading, efficiency standards and regulations?
- Management — who will run it? Should we have a formal outside review group, like the PCAST committee described above?

I. BUILDINGS

A. PATH

1. *Background*

This initiative would; develop a challenge goal through discussions with industry; build on existing initiatives - National Construction Goals, Buildings for the 21st Century, National Homeownership Strategy, and Energy Star Buildings, with added focus and coordination; map out a coordinated strategy based on an evaluation of the technology R&D process and needed resources in government and private sector; significantly reduce the economic, legal and regulatory barriers to systematic use of technological innovation; help implement regulatory streamlining models and procedures.

Included would be three pilots to initiative PATH. These might include (1) Colorado — using the Stapleton Airport Redevelopment as a major site for these homes, (2) Florida — the current insurance and housing crisis makes this a good starting place (3) Los Angeles — urban housing issues are a critical issue.

This is more than a climate change initiative as it includes disaster mitigation, occupation health and safety and home ownership. Final budget numbers and carbon estimates not yet available. Vice President has discussed his interest in this partnership independent of climate change issues.

2. *Actions*

A partnership designed to streamline federal, state, and local regulations and create markets for building designs that achieve major energy savings while reducing costs. Partners will seek expedited permitting and reciprocity from participating communities. Insurance companies will play a key role by encouraging construction quality.

- Large procurements for new housing units meeting ambitious performance specifications will be made in Colorado, Florida, and Los Angeles.

Federal agencies will participate by streamlining federal regulations, helping communities craft performance-based procurement instruments, helping review and certify structures claiming to meet performance specifications, forming research partnerships to develop pre-commercial components and design concepts (not costed here, see long-term section) and providing overall national leadership and an infrastructure for communication between participating communities

3. *Analysis of Impact*

This initiative has the potential of making housing affordable to 5 million families in the U.S. who don't own homes today and at the same time reduce carbon emissions. To help the industry grow, and to meet the policy goals we need to introduce new technologies and practices - but introducing new technologies has been a slow and difficult process. We have the opportunity to create a partnership between government and industry that will challenge the industry to create and apply advanced and innovative technologies and practices in the residential building marketplace.

The residential and commercial buildings sector produces over 30 million tons of waste and energy use in buildings account for more than one-third of air emissions.

B. RATINGS FOR EXISTING HOMES

1. *Background*

A new program under consideration would recognize homeowners for making comprehensive energy efficiency improvements by providing Energy Star certification to highly efficient existing homes. This certification will provide reliable information in the market place that will be useful to buyers and sellers of homes, enabling purchasers to identify energy-efficient homes and providing asset value to home energy efficiency improvements.

The energy used in a typical home causes more greenhouse gas pollution in a year than does an average car. These greenhouse gas emissions can be reduced by 1/3 in many homes while maintaining or improving home comfort. At the same time, homeowners can reduce their annual energy bills by 1/3, saving hundreds of dollars per year.

The Energy Star Homes program compliments the Energy Star New Homes program, which is working hand-in-hand with home builders to construct homes that exceed the Model Energy Code by 30%. Certified homes will receive an "Energy Star Home" plaque. DOE and EPA have joined forces with industry to provide consumers with energy-efficient, lower-pollution home products that are easily identified by the Energy Star label. In addition to launching an Energy Star Homes program, the President could "challenge" consumers to invest in energy efficiency, turning their homes into Energy Star Homes. This message would reinforce the national Energy Star campaign currently underway, and provide additional motivation to consumers to consider energy efficiency in their investment decisions.

Thousands of products currently carry the Energy Star label, including heating and cooling equipment, refrigerators, dishwashers, computers, and others. Measurement techniques have already been established by DOE through the proposed Home Energy Rating System guidelines, which are widely used in the homes industry. A Public Service Announcement campaign has been launched in August to facilitate the national Energy Star campaign. The print, television, and radio announcements draw the link between energy use and pollution and encourage Energy Star purchases. Initial roll-out has focused on the West Coast and has received significant media attention. The campaign will spread to target cities across the country in the coming months.

2. *Actions*

- Develop a national, voluntary rating system for existing homes which would be available to potential purchasers.
- Widely advertise the value and use of the rating system

3. *Analysis of Impact*

C. ENERGY STAR CUSTOMER SERVICE PROGRAM

1. *Background*

2. *Actions*

- Provide national leadership to encourage partnership with utilities, energy service companies, and others interested in offering improved service to their residential and commercial customers by helping them reduce their energy usage and energy bills. For commercial customers, including

schools, hospitals, and shopping malls, this could also include installing, financing, and maintaining on-site electricity generation systems that would reduce overall energy usage. Goals would include:

- increase the installation rate of high efficiency equipment for routine replacements of key building equipment and appliances

increase the market penetration rates of intelligent building management systems

3. Analysis of Impact

D. MILLION SOLAR ROOFS

1. Background

Government and industry to install 1 million buildings applications of photovoltaics, solar water heating and energy efficient design.

The chief competitors of the US industry, Germany and Japan, have already established national initiatives to enhance their native industries' market and lower system costs. Germany is expecting to spend over \$100 million on research and domestic PV rooftop programs and Japan plans to spend \$120 million to subsidize the purchase of 10,000 rooftop PV systems. Those countries have realized that to be a world-leader in PV requires a strong domestic market

2. Actions

The program would have a number of components, some related to other activities. The key to the program would be the partnership with communities, states and companies with the federal government providing information resources to help develop voluntary deployment programs. The program could also include potential government purchases of rooftop systems for government facilities (related to the proposed executive order in part 2); low cost financing options - a variety of federal loan programs (SBA, FEMA, FmHA, RUS, Fannie Mae among others) already in existence could be utilized to provide low cost financing - approximately 20 years at 5% below bank rates; promotion by the White House and DoE will be invaluable in this process.

3. Analysis of Impact

The US can achieve a critical mass for domestic sales without spending the type of money that Japan and Germany will be spending. The greenhouse gas impacts of the program are important. While rooftop solar systems will contribute only a little to reducing greenhouse gas emissions before 2010 (200,000 metric tons) the key to the program is that the technology and market will be strong and viable to accelerate after 2010 and be the cornerstone to maintaining a stabilized level of carbon emissions. Renewables will be critical after 2010 in keeping emissions stable through 2020 and beyond and this program will ensure that the domestic industry is ready to meet the challenge at a cost of \$10M per year.

A) ADVANCED BUILDING R&D

i) *Background*

ii) *Actions*

- lighting
- advanced appliances
- sensors and controls
- tools for integrated building design/analysis
- advanced appliances

iii) *Analysis of Impact*

E. NEW APPLIANCE STANDARDS

1. *Background*

DOE suggests that high priority be given to new standards for clothes washers, cooking products, distribution transformers, fluorescent lamp ballasts, residential water heaters and room air conditioners. Medium priority would be given to residential central air conditioners and heat pumps

2. *Actions*

- Enforce existing appliance standards and promote benefits
- Develop aggressive standards for: central air conditioning, ballasts, washing machines

3. *Analysis of Impact*

II. TRANSPORTATION

B) PNGV

i) *Background*

ii) *Actions*

- Increased funding in bottleneck technologies may be needed to increase the probability of meeting the 80mpg goal. These include:
 - ⇒ lithium ion batteries (key bottleneck is electric storage)
 - ⇒ low-cost electric power controls in small volume (see electric controls below)
 - innovative hydraulic storage and pump/motor hybrids low-cost composite materials

iii) Analysis of Impact

C) NEW TECH FOR AIR TRAVEL

i) Background

Current emissions of CO₂ from aircraft are 2.5% of the total global emissions from fossil fuel use. Over the past 30 years, aircraft have contributed about 1.5% of the industrial increase in atmospheric carbon dioxide. Current emissions of NO_x from aircraft are estimated to have an effect on climate that is comparable to CO₂.

Operational efficiencies that will be achieved through a global transition to advanced technology Communications, Navigation, Surveillance/Air Traffic Management include:

- Increased user-preferred routing
- Reduced horizontal aircraft separation
- More efficient climb/descent procedures
- More efficient approach procedures
- More efficient ground movement procedures

A joint research venture between NASA and industry pursuing innovative engine technologies that will lead to cleaner-burning and higher-efficiency engines can meet these challenges.

Today, over 11,000 airplanes are in commercial service worldwide. In the next two decades 12,000 new commercial airplanes will be necessary to both meet projected growth in air travel and replace the older aircraft. New technologies must be adopted to ensure that these airplanes meet the highest safety and environmental standards. There are technological solutions that will significantly reduce aircraft emissions that contribute to global climate change

ii) Actions

Continue planned funding for aeronautics and air traffic control in NASA, FAA, and DoD. Ensure effective coordination and that adequate priority is given to improved fuel efficiency.

iii) Analysis of Impact

NASA's test facilities and core expertise in materials, structures, aerodynamics, propulsion, analytical methods, and computational tools will be key elements in helping to revolutionize aircraft design and manufacturing. NASA's research efforts will focus on innovative design techniques and structural concepts to enable the U.S. aviation industry to significantly advance today's aircraft and engines. NASA's Advanced Subsonic Technology (AST) program seeks to reduce emissions of future aircraft by a factor of three within 10 years and by a factor of five within 20 years. The stretch goals are to reduce NO_x by 70 percent and improve fuel efficiency by at least 8-10 percent. Could achieve 10 mmtc savings.

Additional savings can be achieved by improved air traffic control. efficiencies is a 12% reduction in the annual amount of fuel burned, leading to the following reductions in annual emissions (MLbs/yr):

- CO2 79.10
- NOx .37
- H2O 29.20
- HC .05

D) PNGV FOR HEAVY (>8500LB) TRUCKS

i) *Background*

The Partnership for a New Generation of Trucks (PNGT) would be a joint public/private automotive technology research program focused on the objective of increasing the fuel economy, and reducing carbon emissions, of heavy trucks.

This program would be modeled after the existing Partnership for a New Generation of Vehicles (PNGV) program. The preliminary fuel economy improvement goals would be 25 to 50 percent improvement for long haul trucks and 100 to 200 percent improvement (note that 200 percent is equivalent to the "3X" level of improvement in PNGV) for urban delivery vehicles. One could achieve 10-20 mmtc reduction post 2010 with a government investment of \$25-30M per year.

i) *Actions*

- ii) The timetable would be to develop production prototype vehicles by 2005 that meet levels of fuel economy improvement given above while also maintaining other important attributes: 1) particulate and nitrogen oxides emission levels of 0.05 and 1.0 grams per horsepower-hour, respectively, 2) applicable safety standards, 3) total life-cycle cost no higher than baseline vehicles, and 4) engine performance at least as good as baseline vehicles. An important constraint would be that the fuel economy improvement must be achieved through improved technology rather than through the use of increasing gross vehicle weight loadings or decreasing empty backhauls
- 25 to 50 percent improvement in fuel economy for long haul trucks and 100 to 200 percent improvement for urban delivery vehicles.

⇒ *focus on improved diesels, hybrid drive-trains Analysis of Impact*

Heavy trucks, defined as trucks with gross vehicle weight ratings over 8500 pounds, account for about 16 percent of the carbon emissions from the transportation sector or about 5 percent of the total national carbon emissions (or about one-quarter of the carbon emissions from cars, pickup trucks, minivans, and sport utility vehicles). About 70 percent of the carbon emissions from heavy trucks are from long haul trucks (semi-tractor trailers). The diesel engines used in long haul trucks are the most efficient engines used in any vehicle application and are generally operated under steady-state, high-power conditions which are optimal for high fuel economy (for example, on an energy per ton-mile basis, a 7 mpg long haul truck is equivalent to a car that gets 140 mpg). Urban delivery vehicles account for most of the remaining 30 percent of carbon emissions from heavy

trucks. Urban delivery vehicles use both diesel and gasoline (with the recent trend being increasing use of diesel) and are generally operated under low-speed, stop-and-go conditions which offer greater opportunities for fuel economy improvement.

A. STIMULATE MARKETS FOR EFFICIENT VEHICLES

III. INDUSTRY

A. ACCELERATE COMBINED HEAT AND POWER

1. Background

Advanced turbines, utilizing natural gas or biofuels, when operated as part of a combined heat and power (C.P.) system at industrial facilities, can generate electricity while meeting thermal loads. Systems can achieve nearly doubling the energy efficiency over conventional electricity generation and separate process heating systems. Recent developments in combustion turbine technology present an opportunity for major improvements in competitiveness and reduction in emissions as well and represent a potential major new international market for U.S. industry. In addition to accelerating coordinated industry and government research, development and demonstrations, the amelioration of several market barriers or impediments would radically enhance the entry and expansion of these systems in the industrial market.

Air Quality Permitting barriers: To site a new C.P. facility or repower an existing industrial boiler can require an extensive and several year application process, driving up costs. A standardized and accelerated permitting process could be developed.

Utility Open Access barriers: Current and potential future utility regulations can impose burdens on independent facilities generating electricity in terms of cost of stand-by power, artificially high access fees and artificially low electricity purchase rates.

Equitable Financial Treatment: Depending upon the ownership of the C.P. facility, current depreciation schedules can impose higher rates than for comparable electric utility generation.

2. Actions

- establishment of expedited and standardized environmental permitting processes for advanced turbine-based industrial Combined Heat and Power systems;
- performance-based emissions standards as for utility generator emissions in the new EPA rules on SO_x and NO_x;
- credits for efficient C.P. systems that displace utility generation emissions in emissions permit applications;
- strong encouragement by the Federal Government that unencumbered, open access to the electricity distribution system by efficient C.P. and on-site generation be included in state and national utility restructuring legislation;
- common depreciation schedules for all on-site and utility-generation assets.
- ensure focus on near-term opportunities in forest product industries including paper processing's supply of "black liquor" and "hog fuels"

develop information, tools, best practices, and training.

3. *Analysis of Impact*

B. EXPAND INDUSTRIES OF THE FUTURE RESEARCH PARTNERSHIPS

1. *Background*

ii) *Actions*

- Biocatalysis and other methods for achieving high productivity chemical production and separations at low cost and with low emissions
- Use of biomass feedstocks as substitutes for petrochemical feedstocks

[Other long-term research projects from "industries of the future" roadmaps?]

- Biocatalysis and other methods for achieving high productivity chemical production and separations at low cost and with low emissions
- Use of biomass feedstocks as substitutes for petrochemical feedstocks

[Other long-term research projects from "industries of the future" roadmaps?]

iii) *Analysis of Impact*

C.

D. INDUSTRIAL POWER

1. *Background*

The Motor Challenge program has had remarkable success in partnering with industry; moving the market to more efficient industrial motor-driven systems. Working off this success, and expanded partnership activities will seek greater participation in Motor Challenge. Expanded activities will provide information on best practices, and training to assist industries in managing, upgrading, and engineering their motor-driven, steam and compressed air system technology that is pervasive throughout manufacturing facilities.

The principal market barriers to be overcome are to: 1) move the market from a first cost to a life cycle cost focus, 2) fill the void of unbiased and reliable technical information and training; make it easily obtainable, and 3) overcome a lack of awareness of benefits available from a "system focus" and energy efficiency overall throughout all levels of manufacturing firms -from the CEO to the person on the shop floor. Expanded activities will promote a message that cost reduction and increased productivity can be achieved simultaneous to improving energy efficiency. That is, energy efficiency and improved productivity go hand and hand.

Implementation will pattern the steam system and compressed air system initiative program designs after the Motor Challenge partnership activities which are industry-driven, and relies heavily on market participants to deliver information and training to the industrial end-user customers (i.e., the existing Motor Challenge Allied Partner network).

2. Actions

- Enforce existing appliance standards and promote benefits

Develop aggressive standards for: central air conditioning, ballasts, washing machines

3. Analysis of Impact

Motor driven systems, steam systems and compressed air systems comprised over 60 percent of all industrial energy - over 300 MMT per year. Therefore, the near-term opportunity would be to mitigate about two to three times more carbon than the Motor Challenge program will accomplish, along, almost 30-45 mmtc.

IV. CITIES

A. CLEAN CITIES

1. Background

10 regional pilot projects to overcome institutional and analytic barriers to better integration of transportation and land use planning as proposed in the President's budget.

STI is modeled after the success that has been achieved in Portland, Oregon. The Portland region avoided construction of a costly western by-pass by implementing policies that focused on in-fill development and developments near a new light rail system. Portland combined a program of aggressive public outreach with new methodologies that enabled planners to explore alternatives to highway construction. Portland has stabilized growth in per-capita VMT over the last 5 years.

Goals are to increase transportation efficiency, decrease VMT and congestion, maintain or improve regional mobility, promote brownfields redevelopment, and reduce environmental impacts of transportation. Funding for collaborative planning, public participation, modeling, pre-construction engineering, and project evaluation. \$30 million in DOT funding over 6 years; \$4.25 requested for FY98. Builds on EPA's existing CCAP program Transportation Partners and DOT's Sustainable Communities Initiative. Complements EPA's Urban Initiative, Brownfields Initiative and Sustainable Development Challenge Grants

The House Appropriations Committee has zeroed the line item for this initiative from DOT's budget ISTEA-2 as proposed by Moynihan and Chafee authorizes a similar program for \$50 million annually over the next six years. This is substantially more than the administration's budget request.

2. Actions

- Support Urban Initiative, Brownfields Initiative and Sustainable Development Challenge Grants
- ten regional pilot projects to overcome institutional and analytic barriers to better integration of transportation and land use planning as proposed in the President's budget

Using a similar program, Portland stabilized growth in per-capita VMT over the last 5 years

3. *Analysis of Impact*

Extrapolating from the Portland experience to the nation, it is estimated that the \$30 million proposed for this initiative could support annual national air pollution reductions of approximately: 0.9% for HC; 1.4% for NOx; 0.9% for CO; and 1.2% for CO₂, or approximately 18 MMTC

B. NATIONAL LEADERSHIP FOR STATE TRANSPORTATION PROGRAMS

V. AGRICULTURE

A. BIOFUELS

1. *Background*

2. *Actions*

- Solicit bids for a large-scale facility for converting biomass to a liquid fuel (ethanol, ethanol, synthetic diesel)

a) AND/OR

Restructure ISTEA proposal for extension of ethanol tax credit so that it will apply to all biomass-derived fuels on an equitable basis

3. *Analysis of Impact*

B. FARM-BILL FOR BIOMASS

1. *Background*

2. *Actions*

Review use of Conservation Reserve , Rural Economic Development, Flood Control and Drainage, riparian control, and other programs to encourage experiments with sustainable biomass crops

3. *Analysis of Impact*

E) NEW CROPS FOR BIOMASS

i) *Background*

ii) *Actions*

- Apply advanced genetic techniques to create drought/disease/pest-resistant biomass crops capable of being delivered for less than \$20/dry ton/ha
- Develop production/harvesting methods compatible with sound conservation/wildlife management plans
- Develop low-cost harvesting, drying, transport methods

- Apply advanced genetic techniques to create drought/disease/pest-resistant biomass crops capable of being delivered for less than \$20/dry ton/ha
- Develop production/harvesting methods compatible with sound conservation/wildlife management plans

(1) Develop low-cost harvesting, drying, transport methods

iii) Analysis of Impact

F) LOW INPUT AG.

i) Background

ii) Actions

Launch an ambitious program to achieve the yields of "green revolution" hybrid grains without use of nitrogen fertilizers. This means either fixing nitrogen in microorganisms associated with the plant root structure or developing nitrogen-fixing cyanobacteria capable of reproducing in the soil.

Launch an ambitious program to achieve the yields of "green revolution" hybrid grains without use of nitrogen fertilizers. This means either fixing nitrogen in microorganisms associated with the plant root structure or developing nitrogen-fixing cyanobacteria capable of reproducing in the soil.

iii) Analysis of Impact

VI. UTILITIES

A. PUBLIC BENEFITS CHARGE

1. Background

The Systems Benefit Charge, also known as the Universal System Benefits Charge, is a simple non-bypassable charge that appears on all customer electric bills. The charge is commonly thought of as based on a user's kWh consumption, but it can also be a flat fee, similar to the long-distance access charge that appears on all telephone bills. The System Benefits Charge is commonly proposed in restructuring proceedings as a means of raising a pool of funds to maintain investments in public programs such as R&D, support for low-income consumers, energy efficiency programs and investments, and in some cases, renewable energy technologies. This fund would be disbursed to states on a matching basis, if a state had one or more of the public purpose programs in place. This proposal is being considered in three Congressional bills (Jeffords, DeFazio and Markey), nine states and the Pacific Northwest, and the proposed legislation being discussed within the Administration. A potential model for this fund is the Telecommunication Act, which has a surcharge collection and disbursement to states on matching basis.

(i) Consumer Information Disclosure

Actions would be taken to provide consumers with information so they can participate in an educated fashion in the competitive deregulated electricity market to their full advantage. Information about prices should be provided so they understand the competitive advantage of one seller over another, and this should be provided consistently across state lines, as sellers will be able to sell across state lines. Also, consistent and accurate information should be provided on renewable technologies, as the interest in "green" electricity develops, as is expected, based on experience gained in retail pilot programs in the northeast and other regions. Two Congressional bills have

mandatory disclosure requirements (Markey and Jeffords). Ten states have disclosure requirements in their state restructuring legislation. It is also included in the DOE utility restructuring legislation being discussed within the Administration.

2. Actions:

- Submit legislation
- A fund similar to the Universal Service Fund for telecommunications would be established to cover poor and rural customers as well as to provide state resources to fund efficiency and renewable programs which would be eliminated under deregulation.

Federal service charge of a tenth of a cent per kWh (1 mill/kWh) would be collected and given to states which charge an additional tenth of a cent for state operations.

3. Analysis of Impact:

B. LOW CARBON ELECTRICITY

1. Background

Actions would be taken to provide consumers with information so they can participate in an educated fashion in the competitive deregulated electricity market to their full advantage. Information about prices should be provided so they understand the competitive advantage of one seller over another, and this should be provided consistently across state lines, as sellers will be able to sell across state lines. Also, consistent and accurate information should be provided on renewable technologies, as the interest in "green" electricity develops, as is expected, based on experience gained in retail pilot programs in the northeast and other regions. Two Congressional bills have mandatory disclosure requirements (Markey and Jeffords). Ten states have disclosure requirements in their state restructuring legislation. It is also included in the DOE utility restructuring legislation being discussed within the Administration.

(i) Renewable Portfolio Standards

A renewable portfolio standard would require either every generator or every retail power supplier to have a certain percentage of renewable energy credits in their resource mix, equal to some percentage of its total annual electricity sales. A retail seller can earn credits by owning renewable electric plants and generating credits, purchasing renewable electric power and receiving credits, purchasing credits from a renewables generator, or perhaps from a specialized REC market. A credit is earned for every MWh of renewable power. Such standards are being proposed in four Congressional bills (Bumpers, Jeffords, Schaefer, and Markey), in restructuring legislation in four states (Arizona, Maine, Nevada, and Vermont), and in restructuring legislation currently being discussed within the Administration. Percentage requirements for purchase would begin at very modest levels and gradually increase over a set time period, with most proposals going through 2010. The requirements on levels, which technologies and other issues would be set at the State level within broad Federal guidelines.

2. Actions

- As a part of utility restructuring, require either every generator or every retail power supplier to have a certain percentage of renewable energy credits in their resource mix, equal to some percentage of its total annual electricity sales. A retail seller can earn credits by owning

renewable electric plants and generating credits, purchasing renewable electric power and receiving credits, purchasing credits from a renewables generator, or perhaps from a specialized REC market.

(i) AND/OR

require that information be made available to facilitate state programs whereby customers could voluntarily indicate a willingness to pay a premium for electricity generated from low-pollution (low CO₂) generating facilities. Technical assistance (information infrastructure) could be provided for state green energy programs

3. *Analysis of Impact*

C. RENEWABLES PORTFOLIO STANDARD

D. ENCOURAGE GREEN PROCUREMENT

VII. CROSS-CUTTING AND BASIC RESEARCH

G) FUEL CELLS FOR CARS AND OTHER LIGHT-DUTY

i) *Background*

ii) *Actions*

- 20-40 \$/kW fuel cells capable of meeting the weight/volume/maintenance requirements of an automobile
 - low-cost/volume gasifiers for converting liquid fuels to hydrogen low-cost/efficient on-board hydrogen storage

iii) *Analysis of Impact*

H) FUEL CELLS FOR BUILDINGS, TRUCKS, AND OTHER HEAVY DUTY VEHICLES

i) *Background*

If successful, a new or retrofit building in 2010 using efficient technologies with electricity and hot water provided by an 80% to 90% efficient fuel cell could have no first-cost penalty with well under half the energy costs of a typical 1990 building and one-quarter the greenhouse gas emissions. The fuel cell is a unique technology that can revolutionize the way buildings acquire power, heating, cooling and hot water - with low emissions, low noise and high efficiency. This accelerated funding will result in prototype introduction of the PEM technology by 2004. This prototype introduction will be followed by cost-shared demonstrations in buildings that illustrate how installation of PEM fuel cells and energy efficient equipment can reduce buildings air emissions to extremely low levels.

ii) *Actions*

- 100-300 \$/kW fuel cells compatible with heavy vehicles (trucks, rail) and buildings (cogeneration units producing electricity and power).
 - low-cost/high-reliability reformers for converting natural gas emphasis on range of technologies: PEM, molten carbonate, solid oxide

iii) Analysis of Impact

I) BIOFUELS RESEARCH

J) BASIC ENERGY RESEARCH

K) SEQUESTRATION

i) Background

ii) Actions

- lightweight materials for vehicles and other applications
- advanced nuclear cycles [safe, proliferation-resistant, environmentally benign, cost-effective]
- bulk energy storage
- hydrogen production, storage, transportation, and use
- semiconductor research for advanced photovoltaics
 - inexpensive devices capable of switching large electric currents rapidly
 - molecular biology for bioprocessing, biofuels, and low-input agriculture

iii) Analysis of Impact

EP4's 33/50 Program -
 • Customize goals across facilities & industries

Draft

Draft

*draft
by end of this
week*

*will become a decision making document
(the earlier tech paper is ground
document)*
 September 13, 1997 Page - 1 -

Climate Change Technology Options

- PCAST

The Options outlined below include both options which will accelerate deployment of technologies at or near commercial readiness as well as options for stimulating research which can achieve breakthroughs that will provide benefits in the long-term.

1. Buildings:

1/2 residential, 1/2 commercial
 Buildings produce 35% of US CO₂ and consume over 2/3 of all US electricity. Energy use in buildings has increased 2.5%/year since 1986. The construction industry has not gone through the transformation that has reshaped most American manufacturing because of fragmented local regulation and no tradition of research or systems engineering. It appears possible to cut greenhouse emissions in buildings by a factor of 2 or more (and in some cases make buildings net energy producers) using methods that both improve building quality and lower cost. Leaders in the industry, its suppliers, the companies that insure and finance buildings, and state and local regulators are willing to join us in capturing the potential of making sharp reductions in building energy by improving products and production methods and streamlining regulation. Our strategy involves near-term actions to reinvent federal, state, and local regulations to create a near-term demand for the many technologies already available and a research partnership with builders and suppliers aimed at dramatically new building designs and appliances.

	Actions	Federal Cost	Savings (MMT)	
		\$ millions (per year)	2010	2030
PATH	The Partnership for Advanced Technologies in Housing (PATH) aims to develop building designs and production methods which can lower costs while reducing greenhouse emissions by 50% and meet ambitious goals in wind and seismic resistance and other areas. The partnership includes builders, building suppliers (windows, appliances, etc.), insurance companies and federal/state/local officials. It will: - streamline federal, state, and local regulations and create markets for building designs that achieve major energy savings while reducing costs. Partners will seek expedited permitting and reciprocity from participating communities. Insurance companies will play a key role by encouraging construction quality. - organize large, locally funded, procurements (tens of thousands of units) for new housing units meeting performance goals in partnership with states and cities (Colorado, Florida, and Los Angeles appear to be the most likely in the near term)	\$10 HUD \$10 NIST \$5 DOE		

should have performance targets

*industry says "don't forget current technologies."
 today's mty to get participating agencies to
 fill in blanks (fed costs, emissions reductions,
 maybe private costs)*

*Program evaluation designed from ground up
 choosing programs from Benefit/cost high to low
 regulatory cost*

	Federal agencies will participate by streamlining federal regulations, helping craft performance-based procurement instruments, helping review and certify structures, supporting forming research partnerships to develop pre-commercial components and design concepts (not costed here, see long-term section) and providing overall national leadership and communication infrastructure for participants.			
Home Energy Ratings	Widely advertise the value and use of a voluntary rating system for new and existing homes which would assist homebuyers make choices based on sound information about energy/environmental characteristics of the building			
Energy Star Customer Service Program	- Provide national leadership to encourage partnership with utilities, energy service companies, and others interested in offering improved service to their residential and commercial customers by helping them reduce their energy usage and energy bills. For commercial customers, including schools, hospitals, and shopping malls, this could also include installing, financing, and maintaining on-site electricity generation systems that would reduce overall energy usage. Goals would include: - increase the installation rate of high efficiency equipment for routine replacements of key building equipment and appliances - increase the market penetration rates of intelligent building management systems	? EPA/DOE		
Million Solar Roofs	- partnership combining businesses, federal, state, and local governments to develop and communicate approaches to voluntary deployment programs for photovoltaic and hot water systems on one million US rooftops by 2010. - government purchases of rooftop systems for government facilities develop special programs for federal loan programs (SBA, FEMA, FmHA, RUS, Fannie Mae among others) already authorized to provide low-cost financing (20year loans 5% below bank rates are possible) - promotion by federal agencies	\$10 DoE	0.2	30-50
Advanced Building R&D	- Expand competitive, cost-shared research partnerships on integrated building design research using the Building America framework - Expand research on advanced appliances, consumer electronics, lighting, sensors, controls, and tools for integrated building design/analysis			
New Appliance Standards	Continue developing appliance standards using existing authority for energy-intensive appliances.			

600 + 50

Need
costsHenry
hkelley@ostp.eas.gov

2. Transportation

Cars, trucks, aircraft, and other transportation produces 33% of US CO₂ and has grown an average of 2.3% annually since 1986. Low fuel prices and constant increases in vehicle miles traveled make this the fastest growing source of US greenhouse gases. The average efficiency of new US cars and light trucks has been declining since 1985. All attempts to affect the industry through fuel taxes or fuel economy regulation face fierce opposition. Research may produce radically new technologies capable of delivering large gains in efficiency without increasing the cost of vehicles or travel. This program focuses entirely on research designed to reduce fuel consumption of cars, trucks, and aircraft by factors ranging from 50-200%.

	Actions	Federal Cost \$ millions	Savings (MMT)	
		(per year)	2010	2030
PNGV	- Increased funding in bottleneck technologies may be needed to increase the probability of meeting the 80mpg goal. These include: ⇒ lithium ion batteries (key bottleneck is electric storage) ⇒ low-cost electric power controls in small volume (see electric controls below) ⇒ innovative hydraulic storage and pump/motor hybrids ⇒ low-cost composite materials	0-100 [above \$261M in FY97]	up to (70)	
New Tech for Air Travel	- Reduce energy consumption per passenger mile of air travel by []% - Next generation air-frames and high-bypass engines increase efficiency 10-15% - Use of advanced air-traffic control systems can reduce fuel requirements by []% by avoiding delays and permitting optimized routes	[100 in FY98 NASA budget]	10	
PNGV for Heavy (>8500lb) Trucks	25 to 50 percent improvement in fuel economy for long haul trucks and 100 to 200 percent improvement for urban delivery vehicles. - focus on improved diesels, hybrid drive-trains	25-30	10-15	

DOE
thinks
this is
high

3. Industry

Industry produces 33% of US greenhouse gases — 78% of it in six industrial sectors: pulp and paper, chemicals, petroleum refining, glass, aluminum, iron and steel, and metal casting. Our strategy is to focus on accelerating the adoption of technologies which could have a major impact in a few areas where the payoff is high and regulatory or other barriers appear to be blocking adoption. Over the long-term, research partnerships can achieve efficiency gains with biotechnologies and other methods.

	Actions	Federal Cost \$ millions	Savings (MMT)	
		(per year)	2010	2030
Accelerate Combined Heat and Power (use waste biomass or natural gas)	- establishment of expedited and standardized environmental permitting processes for advanced turbine-based industrial Combined Heat and Power systems; - performance-based emissions standards as for utility generator emissions in the new EPA rules on SOx and NOx; - credits for efficient C.P. systems that displace utility generation emissions in emissions permit applications; - strong encouragement by the Federal Government that unencumbered, open access to the electricity distribution system by efficient C.P. and on-site generation be included in state and national utility restructuring legislation; - common depreciation schedules for all on-site and utility-generation assets. - ensure focus on near-term opportunities in forest product industries including paper processing's supply of "black liquor" and "hog fuels" - develop information, tools, best practices, and training.		10-30	
Expand Industries of the Future Research Partnerships	- Establish priorities in long-term research identified in the roadmaps already developed by industry groups and increase federal investment - Topics would include such things as biocatalysis and other methods for achieving high productivity chemical production and separations at low cost and with low emissions, inert anodes for aluminum production, and electromagnetic metal casting.	30-50 DOE		
Industrial Power	Expand existing Motor Challenge Allied Partner network capture energy efficiency opportunities employing market-ready industrial steam system and compressed air	\$10 DOE	30-45	

	system technology. - Partnership will develop and communicate improved designs for efficient air and steam systems in addition to electric motor control - Provide training programs for industrial designers and expand programs in engineering schools.			
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4. Cities

The local transportation policies, urban design, and other urban policies have a profound influence on carbon production. []% of vehicle miles driven occur in metropolitan regions. Portland Oregon demonstrated that a growing economy did not need to translate into growing amounts of travel and urban congestion given sensible programs in highway construction, parking policies, mass transit, and zoning. Using a similar program, Portland stabilized growth in per-capita VMT over the last 5 years. Some of the programs considered (building retrofits and increased use of non-auto transportation) could have impacts in the near term. Programs to encourage changes in urban structure that minimize travel needs are important but will have influence only over the long-term.

	Actions	Federal Cost \$ millions	Savings (MMT)	
		(per year)	2010	2030
Clean Cities	- Develop a partnership with the nation's mayors to strengthen and focus existing programs in DoT, EPA, and DoE to encourage efficient urban transportation planning and improve the energy efficiency of public buildings including schools and hospitals. - Support Urban Initiative, Sustainable Development Challenge Grants - Support regional pilot projects to overcome institutional and analytic barriers to better integration of transportation and land use planning	\$30 in NEXTEA \$? EPA ? DOE	18	
National Leadership for State Transport programs	- The administration's NEXTEA bill proposes a 25% increase (to \$1.3 billion annually) for the Congestion Mitigation and Air Quality Improvement Program . While states have authority to spend the funds in many areas, federal leadership could help focus programs on carbon emissions and provide information and analysis not available to many states. - Help states consider greenhouse emission goals as they develop plans for responding to the New National Ambient Air Quality standards..	325 (increase included in NEXTEA budget)		

5. Agriculture

Programs in agriculture aim to develop production methods that achieve large reductions in inputs of agricultural chemicals and create new economic opportunities for rural communities through crops that can produce an energy source which can be used with zero net contribution of greenhouse gases. The strategy relies on using authorities available in the farm bill to encourage early experiments in areas where niche-markets can be identified for biomass energy crops and a research program designed to achieve much larger markets in the future.

	Actions	Federal Cost \$ millions	Savings (MMT)	
		(per year)	2010	2030
Biofuels	- Restructure ISTEA proposal for extension of ethanol tax credit so that it will apply to all biomass-derived fuels on an equitable basis <i>And/OR</i> - Provide funding to share the cost of a large-scale facility for converting biomass to a liquid fuel (ethanol, ethanol, synthetic diesel)			
Farm-Bill for Biomass	Review use of Conservation Reserve , Rural Economic Development, Flood Control and Drainage, riparian control, and other programs to encourage experiments with sustainable biomass crops	2 USDA		
New Crops for Biomass	- Apply advanced genetic techniques to create drought/disease/pest-resistant biomass crops capable of being delivered for less than \$20/dry ton/ha - Develop production/harvesting methods compatible with sound conservation/wildlife management plans - Develop low-cost harvesting, drying, transport methods	20 USDA		
Low Input Agriculture	Launch an ambitious program to achieve the yields of "green revolution" hybrid grains without use of pesticides or nitrogen fertilizers. (fixing nitrogen in microorganisms associated with the plant root structure, nitrogen-fixing cyanobacteria capable of reproducing in the soil, and other concepts)			

USDA

6. Utilities

Electric utilities produce about a third of all US greenhouse gases 88% of which results from coal-fired power plants. Emissions have grown about 3.5% annually since 1990. Our strategy here focuses on using the opportunities presented as states and the federal government consider sweeping deregulation of electric generation. The goal is, at a minimum, to maintain incentives for efficiency and renewable energy that are at least as powerful as those available under existing regulation. Several options would increase incentives. In addition, we suggest options for accelerating development and adoption of renewable energy technologies such as wind which may be able to provide competitive power in some parts of the country.

	Actions	Federal Cost \$ millions	Savings (MMT)	
		(per year)	2010	2030
Public Benefits Charge	• A ^{fund}would be established to cover poor and rural customers as well as to provide state resources to fund <u>efficiency and renewable programs</u> which would be eliminated under deregulation. <i>↳ don't double count</i> • Federal service charge of up to a tenth of a cent per kWh (1 mill/kWh) would be collected and given to states which charge an additional tenth of a cent for state operations.	\$1,000-3,000 (scoring?)		
Renewable Portfolio Standard	• As a part of utility restructuring, require either every generator or every retail power supplier to have a certain percentage of renewable energy credits in their resource mix, equal to some percentage of its total annual electricity sales. A retail seller can earn credits by owning renewable electric plants and generating credits, purchasing renewable electric power and receiving credits, purchasing credits from a renewables generator, or perhaps from a specialized REC market.			
Encourage Green Procurement	• Help states experiment with methods for encouraging programs in which individual utility customers would be given the option of paying somewhat higher bills to cover the cost of purchasing low-carbon energy. • Require that information be made available to facilitate state programs whereby customers could voluntarily indicate a willingness to pay a premium for electricity generated from low-pollution (low CO₂) generating facilities. Technical assistance (information infrastructure) could be provided for state green energy programs			

Renewable Procurements	Help utilities and other potential buyers of renewable energy purchase equipment (possibly through purchasing consortium such as the "green carrot" procurements) that provides the lowest-cost to customers while creating a market that can encourage innovative technologies. This might, for example, permit a firm to develop a large wind field including construction of required transmission to connect the field to a suitable grid and possibly use of underground compressed air energy storage (CAES) to increase capacity factor and load-following characteristics of the and therefore the value of the power.			
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7. Cross-Cutting and Basic Research

Stabilizing global greenhouse gas concentrations over the next few decades will require major changes in the way energy is produced and consumed. Achieving these goals requires investment in long-range, high-risk technologies which do not meet the investment objectives of private firms. The programs proposed here would provide federal investment for basic science and basic engineering in key areas. Most of the technologies supported here would benefit many different business sectors.

	Actions	Federal Cost \$ millions	Savings (MMT)	
		(per year)	2010	2030
Fuel Cells for Cars and Other Light-Duty	20-40 \$/kW fuel cells capable of meeting the weight/volume/maintenance requirements of an automobile - low-cost/volume gasifiers for converting liquid fuels to hydrogen - low-cost/efficient on-board hydrogen storage			
Heavy Duty Fuel Cells	100-300 \$/kW fuel cells capable of providing cogeneration or onsite power for buildings and other applications (including coproduction of electricity and liquid fuels using biomass) and for use in heavy vehicles (trucks, buses, rail) - low-cost/high-reliability reformers for converting natural gas to hydrogen - balanced investment in PEM, molten carbonate, solid oxide			
Biofuels Research	next generation technology capable of producing liquid fuels for less than 75 cents/gallon gasoline equivalent including options for cogeneration systems yielding electricity.			

Basic Energy Research	• lightweight materials for vehicles and other applications • advanced nuclear cycles [safe, proliferation-resistant, environmentally benign, cost-effective] • bulk energy storage • hydrogen production, storage, transportation, and use • semiconductor research for advanced photovoltaics • inexpensive devices capable of switching large electric currents rapidly • molecular biology for bioprocessing, biofuels, and low-input agriculture			
Sequestration of Carbon	• injection of CO₂ in aquifers and in other mechanisms • production of hydrogen at wellheads • advanced concepts			

plasma switches?

8. Federal Procurement Policy

Various Options being prepared by a separate policy group

9. International

Export Promotion	Many energy technologies will have larger, earlier markets abroad than they do in the US. These international markets provide large export potential for US producers and could result in worldwide savings much higher than those shown in estimates which only indicate carbon savings in the US. Large export opportunities include: • PNGV and other automobile technology • aircraft technology • photovoltaic and wind • high-technology components of biomass systems (turbines, gasifiers, harvesting equipment) • fuel cells • advanced industrial technologies • building controls and appliances
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Natural Resource side

> forestry

• 33/50 for GHG - Non-CO₂
reporting for methane, etc.



EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL OF ECONOMIC ADVISERS
WASHINGTON, D.C. 20500

SENIOR ECONOMIST

MEMORANDUM

TO: Bob Tuccillo

FROM: Jay Shogren and Joe Aldy *[Signature]*

DATE: August 5, 1997

RE: Comments on 7/30/97 Discussion Paper: The Role of Technological Change to Address Global Climate Change

We continue to be concerned about two issues in this paper: 1) the need for a common method to measure emission reductions and costs; and 2) the provision of cost estimates.

Common Method: In the current version of the role of technology paper, the set of sector papers use more than one method to present emissions and costs: Markal 1.25, Markal 1.75, DRI 1.25, and the DOE Labs Study. These methods use different sets of assumptions, and generate different results for both emissions reductions and costs by sector. Also, the methods all impute a different permit price to achieve 1990 levels stabilization. Given these differences, comparing one sector's potential for emissions reduction to another sector's potential is like comparing apples and oranges. Comparing sectors to determine the biggest bang for the buck would be more useful if the numbers for each sector were comparable.

In addition, the same method should be used to estimate the costs to achieve the projected emission reductions. The costs reflect the emissions reductions by sector -- the models should generate emissions reductions based on the marginal costs of new technologies and fuel switching. The final ton of emission reduction within each sector should cost the same across sectors given that a domestic trading system is implied throughout the analysis. Applying cost estimates from other sources generates inappropriate estimates.

Cost Estimates: The papers should provide reliable estimates of annual costs over a specific period of time. Several papers provide annual costs, but do not specify the period of time: through 2010, 2020, or perpetuity. Further, some of the costs estimates are inadequate: an annual cost estimate is necessary for light duty vehicles; and the range of costs in the buildings paper reflect two different scenarios (efficiency and high efficiency in the DOE Labs Study), while the carbon emissions reductions provided in the first chart reflect only one scenario. The costs of achieving these reductions is one of the range's endpoints, not a value somewhere within the range.



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COUNCIL OF ECONOMIC ADVISERS
WASHINGTON, D.C. 20500

SENIOR ECONOMIST

MEMORANDUM

TO: Bob Tuccillo

FROM: Jay Shogren and Joe Aldy *JS*

DATE: July 28, 1997

RE: Comments on 7/28/97 Discussion Paper: A Technology Approach to Addressing Global Climate Change

We provide comments on the discussion paper below. The first set of comments reflects several issues that we believe need to be emphasized. The second set reflects specific edits and necessary clarifications in the paper. Also, we have compiled a draft chart describing the emissions and costs across sectors.

Set 1:

p. 2: The two fundamental changes imply the need to influence firm and consumer behavior through price signals. The importance of pricing carbon should be stated explicitly.

p. 5: DOE's Labs Study: The discussion of this study should reflect the following assumptions that are noted in the report:

- The model runs for the 3 end-use sectors were not integrated and may overstate the effects of technology penetration (6/11/97 draft, p. 1.2).
- The analysis of costs is confined to technology costs, and does not assess policies or programs necessary to achieve market acceptance (p. xvi).
- The assessment of cost-effectiveness ignored implementation costs (p. xvi).
- The high efficiency/low carbon case invokes the announcement effect, but does not specify a numeric change in the rate of energy efficiency improvement (p. 1.6).
- The high efficiency/low carbon case requires technology breakthroughs, not just accelerated diffusion, to achieve emissions reductions in the transportation sector (p. 1.7).
- Emissions reductions under both scenarios require additional public sector programs and funding (p. x).

p. 6: The discussion of prices in the economy should note that the total costs to society of a cap and trade program should be lower than the costs of the subsidies listed in the second and third bullets.

Sectors Papers:

Need for a common emissions reductions methodology: The papers use several different models to estimate the reductions within each sector. Autos and Light Trucks, Buildings, and Industry use Markal-Macro; Freight, Aircraft, and Rail use the DOE Labs Study; and Electric uses DRI 1.25 w/o carbon price (assumes announcement effect with E/GDP of -1.25/year but no cap and trade program). This creates two problems. First, an assessment to determine the cost-effectiveness of achieving 1990 levels in 2010 should be integrated. Since these models employ different assumptions, they will yield different sectoral targets for achieving the 1990 goal. A goal for a sector in Markal is dependent on the goals for other sectors (and the costs of reaching those goals) in Markal. Providing estimates from Markal, DRI, and the 5 Labs Study ignores the dependence of the sectoral estimates. A range of estimates representing these different modeling efforts could better illustrate sectoral responses. Second, since the costs of achieving goals are dependent on the costs in other sectors, estimates of the cost-effectiveness of technology adoption will likely be skewed under a non-integrated approach. Again, a range of costs could better describe the state of knowledge on technology adoption.

Cars and Light Trucks Costs: This paper still needs an annualized cost of technology adoption. Based on the information provided in the paper, we estimate the cost to be \$18 billion to \$28 billion per year starting in 2010. For the lower bound, we multiplied the cost of a new car at 30% of the PNGV goal, \$1,200 per car¹, times the number of cars and light duty trucks sold in a year, which we estimate to be 15 million². For the upper bound, we used the cost estimates in the Labs Study for cars (\$2,000 per car) and light trucks (\$1,650 per truck) under the high efficiency/low carbon case and multiplied them by the approximate number of cars (9 million) and trucks (6 million) sold this past year. We readily admit that this is a gross representation of the cost, and we would obviously prefer a more precise estimate, but given the information in the paper, this is the best we could do.

Buildings

Costs: How are the energy savings calculated? What is the assumed electricity price? Did the analysis carefully ensure that no double-counting occurred (e.g., estimating energy savings from installing fluorescent lights, that increase the efficiency of energy, and "smart" lighting systems, that decrease the use of energy).

¹ This is the Markal-based estimate of the cost. The lower range in the paper reflects an analysis in the report "Energy Innovations" by a consortium of energy efficiency organizations. We employ \$1,200 because we believe it is appropriate to use the cost figure from the same analysis that generated the emissions reductions estimate.

² In 1994, 8.99 million passenger cars and 5.7 million light duty trucks were sold in the U.S. (1996 Statistical Abstract). The National Association of Business Economists estimate that 1997 vehicle sales will total 15.1 million (NABE Outlook and Policy Survey, 2/97, summary provided in AAMA webpage, <http://www.aama.com>). Given uncertainties about the demand for passenger cars and light trucks, we conservatively assume 15 million cars and light trucks will be sold in 2010.

Set 2:

p. 1: Transportation emissions growth projection is the DOE 5 Labs Study modification of the EIA AEO97 projection. Technically, it is not an EIA projection.

p. 3: The DOE Study indicates that emissions growth will be 380 million tons (not 377).

p. 3: The chart indicates that in the 3 major sectors, the growth in emissions is merely slowed, while utilities appear to be the only sector with negative growth in emissions. This implies the significance of an effective carbon tax. Without the price signal of a carbon permit, these reductions cannot be achieved. The tax ought to more explicitly reflect this.

p. 4: The projection of natural gas tripling under climate policy does not reflect the modeling results in the IAT report (5/19/97 draft, p. 14). The DRI-DRI Energy run in table 4 of the IAT report actually indicates a decrease in natural gas relative to the base case. The more appropriate comparison may be natural gas use under climate policy in 2010 to natural gas use under baseline conditions in 2010.

Autos and Light Trucks

Upper Chart: These carbon emissions are for the entire transportation sector, not just the autos and light trucks sector.

Key Trends, Second Bullet: This bullet notes that fuel economy is projected to grow to 31 mpg in 2010. The DOE Labs Study rejects this estimate given projected low fuel prices and an assumption of no change in CAFE standards. The argument provided by the Labs Study appears plausible. This would affect the content of this bullet and the lower chart.

Freight, Aircraft, and Rail

Costs: We need to obtain the details on the cost estimates from DOE: \$25 to \$40 billion is a large range.

Electric Power

Upper Chart: Estimates of carbon emissions under the "technology case" do not conform with the emissions reductions noted on p. 3. Does the case in this chart represent a DRI 1.25 case without climate policy? Doesn't 1.25 assume the announcement effect associated with adopting a policy?

Lower Chart: See above discussion on increase in gas use under climate policy.

Renewable Energy

Needed Technological Improvements: The electric power paper indicates that renewables as a share of electricity supply increase from 1.5% to 1.8% through 2010. This paper indicates a substantially higher growth rate. An explanation of this could clarify any potential confusion.



EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL OF ECONOMIC ADVISERS
WASHINGTON, D.C. 20500

SENIOR ECONOMIST

MEMORANDUM

TO: Bob Tuccillo

FROM: Jay Shogren and Joe Aldy *JS*

DATE: July 23, 1997

RE: Comments on technology sector one-pagers

Below are our comments on the one-pagers. The first set of comments reflects issues that are relevant to all of the papers, and the second set addresses specific statements within the papers. Given the short turn-around necessary for these papers, we understand that some of our comments cannot be incorporated. However, we submit them to stimulate a discussion on these issues and to anticipate some of the questions that may be asked by the users of these papers.

General Comments

1) **Summary Chart:** A summary chart of all of the sector papers could be beneficial to the users. For example, such a chart could include the following categories: sector, energy use (quads or percentage of total use), 1990 emissions, 2010 baseline emissions, 2010 1.25 case emissions, cost of achieving reductions under 2010 1.25 case, and the likelihood of achieving 2010 1.25 case reductions. The papers already include most of this information, except for an explicit discussion of the probability of meeting the 2010 1.25 case reductions. For this category, a listing of issues that positively or negatively affect the probability would be as valuable as a quantified estimate of the probability. For example, the probability of success depends on, among other issues, the funding of federal R&D programs and CCAP programs, necessary R&D innovation, fuel price trends, etc. This one page chart could effectively tell the story embedded in the remaining ten pages and serve a purpose analogous to an executive summary. In addition, a chart with the breakdown of emissions by sector would be beneficial, because as the papers read now, someone who simply adds up the sectors' shares would find a value greater than one because of the accounting issue associated with electric power. Without appropriately accounting for the electric sector emissions, one could risk double counting emissions.

2) **Order of Papers:** Papers that address related sectors or issues should be paired together. For example, the freight, aircraft and rail paper should be paired with the autos and light trucks. Also, the electric power and renewable energy papers should be paired.

3) **Conformity of Charts:** The charts should all employ the same format and terminology. For example, we should decide on graphing trends through a line graph (e.g., freight paper) or bar

chart (e.g., industrial emissions). In addition, we should consider whether we want two trends (base and 1.25, as most of the bar charts have it), or one trend (as in the freight paper). The papers should all use the same term for the 2010 1.25 case (this case is referred to as 1.25, technology, and efficiency in different papers).

4) Reductions Potential: The papers should all explicitly state the emissions reduction potential within an industry -- this is implicit in the graphs, but it could be beneficial to have the numbers specified for each sector.

Specific Comments

Freight, Aircraft, and Rail Paper:

- 1) Are the costs and cost savings specified in the estimates present values?
- 2) Needs the funding value for PNGV. At present funding level (and administration's requested level, if it is different), what is the likelihood of achieving the PNGV goal in 2010?

Industrial Emissions Paper:

- 1) In the third bullet, the second sentence notes the GWP of non-carbon GHG. Since the carbon equivalence in MMTCE estimates captures GWP, do we need to also include the GWP measure? Multiple metrics may confuse some users.
- 2) Some of the statements on costs imply that these technologies are win-win. If that is the case, then why is government policy necessary to stimulate investment?
- 3) In the discussion on investment costs, it could benefit users to state the expected cost savings of these investments (in a similar fashion to most of the other papers).
- 4) How much will the necessary policies cost government to implement and spur the required investment?

Sector-Specific Section:

- 1) Estimates of expected emissions reductions in 2010 under 1.25 case for all of these technologies would be beneficial. In addition, costs of creating and adopting these technologies and anticipated cost savings would also be useful.
- 2) The Aluminum section notes that 4 MMT of PFCs are emitted annually. Are these 4 MMT or 4 MMTCE? If it is the latter, then we should note that, and ensure that MMTCE is used consistently through all of the papers.

Buildings Paper:

1) Do emissions, even under 1.25 case, still go up in 2010 relative to 1990? The chart gives that impression.

2) In the cost estimates, are the net savings \$10-\$19 billion or \$11-\$19 billion?

3) What is the likelihood of doubling the budget for federal programs?

4) Is the second chart necessary?

Renewable Energy:

1) To give some context to the prices of renewable energy sources, the price per kilowatt-hour for coal, hydro, and nuclear source electricity would be beneficial.

2) Third bullet ends awkwardly. The sentence could be rewritten as "...and as manufacturing achieves greater efficiencies."

3) The author may want to add a bullet on the effect of consumer choice in the electricity markets and the opportunity for "green" price premiums. (FYI, see today's WSJ, second section, front page.)

4) What are the returns or the cost-savings of the investments noted in the costs section?

Autos and Light Trucks:

1) In the fourth bullet, improved fuel economy will not maintain desired levels of VMT. Rather, improved fuel economy will maintain levels of emissions given an increase in VMT.

2) Authors of this and the freight paper should ensure that discussions on PNGV conform.

3) The two bullets under costs imply that PNGV will not be met. If so, should that be stated explicitly?

Electric Power:

1) Is the second chart necessary?



EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL OF ECONOMIC ADVISERS
WASHINGTON, D.C. 20500

SENIOR ECONOMIST

MEMORANDUM

TO: Bob Tuccillo

FROM: Jay Shogren and Joe Aldy

DATE: July 16, 1997

RE: Comments on climate change policy sectoral papers

The comments we have provided to the authors focus on the cost estimates and the issue of market barriers. To give you a sense of our thoughts on policy approaches to market barriers, we have drafted a short discussion of the differences between market failures and market barriers. If any of the authors talk to you with questions about policy discussions in their papers, feel free to share this with them. To provide you with some context for this issue, we have quoted passages from several papers below. If you have any questions about this, you can contact Joe at 395-1455.

Statements about Policies and Market Barriers

Transportation Policy: Light Duty Vehicles and Carbon Emissions, p. 2, second paragraph:

"Many of these technologies have already emerged in the market, lacking only appropriate policy signals to accelerate their diffusion, or to redirect their use toward fuel economy instead of improving other vehicle attributes."

Freight, Aircraft, and Rail Emissions Projections and Potential for Reduction, p. 2, second bullet:

"The DOE five-lab study stipulates that carbon emissions reduction at the low end of the ranges in the last column of the table above are likely, so long as the government institutes appropriate policies and research efforts are intensified."

The Carbon Reduction Potential in the U.S. Buildings Sector, p. 3, second full paragraph:

"The probability of realizing the potential savings estimated thus is largely dependent upon the effectiveness of policies in removing the barriers to these investments."

Industrial Emissions and Economic Impacts, p. 1, fifth bullet:

"These energy savings and reduction in carbon emissions are unlikely to happen without policy measures driving the improvement in the industrial capital stock."

Market Failure Versus Market Barriers: Why the Distinction Matters for Policy

Throughout the discussions on the development and adoption of technology in the climate change context, people often use the phrases “market failure” and “market barrier” interchangeably. While both market failures and market barriers can slow the diffusion of technology, there are important distinctions that extend beyond semantics. Policy intervention to eliminate a market failure may make society better off, depending on the costs of the intervention. Policy intervention to eliminate a market barrier cannot make society better off and usually makes society worse off, regardless of the implementation mechanism. In cases that consider the potential carbon emissions savings for various technologies, one should not expect to achieve that potential by pricing carbon (attempting to correct a market failure) because market barriers still affect the adoption of these technologies. This paper explains the distinction between market failures and market barriers and why the distinction matters for policy.

Definitions

Market Failures: Market failures represent flaws in private markets to transmit information fully to people in the market. For example, when supplying a public good, a person ignores some real costs. Thus, his or her private costs diverge from true social costs, resulting in an inefficient allocation of resources.

Market Barriers: Market barriers represent well-functioning, but occasionally complex, private markets. Information is fully transmitted among all those in the market, although some information may seem incomplete to non-participants (read: policy/market analysts). A person address all real costs, but these costs can go undetected by analysts, hence the term “hidden costs”. For market barriers, private costs match social costs, and resource allocation is efficient.

Examples

Market Failures: Economists have identified three major market failures in the climate change context: 1) information (public attributes); 2) moral hazard; and 3) pollution externalities.

Information has both public and private attributes. Market failure occurs because once information becomes public, (a) it is too costly to exclude others from using it, and (b) one person’s use of information does not preclude another person’s use. These characteristics lead to an undersupply of information on technology, because the information supplier can not gain benefits from the information users. The public good nature of information results in the undersupply of R&D investment and low adoption rates.

Moral hazard exists when one person imposes a cost on another person, and has insufficient incentive to stop. For example, with rented housing, the owner of the housing could pay for an energy efficiency investment, but since the renters benefit because they pay the utility bill, the owner has no incentive to invest.

Pollution externalities can cause the private marginal cost faced by individuals to be lower than the social marginal cost, resulting in an oversupply of pollution. For electricity, people do not pay for environmental costs from carbon when they buy coal-based electricity. This makes coal-based electricity more attractive than non-carbon energy sources (e.g., renewable energy).

Market Barriers: The literature has identified several barriers that explain the slow rate of technology adoption: 1) qualitative attributes differ across technologies; 2) private attributes of information; 3) private discount rate diverges from social rate; and 4) heterogeneous usage levels.

Qualitative attributes of technologies can affect adoption. Consumers of technology prefer technologies because of a set of characteristics, not just energy efficiency. For example, some technology consumers may purchase a product with a lower efficiency than another product because the former is more reliable than the efficiency-superior product.

Private attributes of information include the tasks of learning how a new technology works with one's existing suite of technologies and identifying technology suppliers. Transaction costs exist with these tasks. If opportunities for economic gains in supplying this information exist, one would expect arbitrage to occur where middlemen consultants would assess the needs of potential adopters and match them with the appropriate suppliers.

The social discount rates to evaluate new technologies may not fully capture the uncertainty and risks faced by individuals and firms. These private actors may use a much higher discount rate reflecting the uncertainty of future energy prices, the reliability of the technology, the irreversibility of a technology investment, and the constraints on their ability to borrow capital.

Heterogeneous use of energy-intensive technology can affect who benefits from efficiency investments and who does not. If a technology is cost-effective on average, it may not be cost-effective for individuals who do not use much energy.

Policy Implications

These examples illustrate the primary distinction between failures and barriers. Failures occur because people do not face all of the net benefits of adopting a technology, and so they underadopt--a socially inefficient resource allocation. Barriers occur because private actors do face all of the net benefits of adopting a technology, and because these net benefits are negative, they do not adopt--a socially optimal resource allocation.

This has two related implications for policy. First, estimates of technology adoption in response to climate policy must recognize that market barriers will prevent adoption to the levels predicted by engineering studies. High adoption rates will be realized once prices go high enough to eliminate the barrier, e.g., high carbon prices can provide the stimulus for some technologies to clear the barrier. Second, policies could be designed to try and eliminate barriers, but firms have found that these technologies are not cost-effective for them. Subsidies that increase their adoption will generate benefits less than the policies' costs.

Additional Reading

Cameron, Lisa J., Harry L. Foster, and W. David Montgomery. 1997. The economics of strategies to reduce greenhouse gas emissions. Charles River Associates, January 11, draft.

Jaffe, Adam B. and Robert N. Stavins. 1994. Energy-efficiency investments and public policy. *Energy Journal* 15(2): 43-65.

Jaffe, Adam B. and Robert N. Stavins. 1994. The energy-efficiency gap: What does it mean? *Energy Policy* 22(10): 804-810.

Nichols, Albert L. 1994. Demand-side management: Overcoming market barriers or obscuring real costs? *Energy Policy* 22(10): 840-847.

EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL OF ECONOMIC ADVISERS
WASHINGTON, D.C. 20502

MEMORANDUM

TO: Eric Petersen and Jim Turner
FROM: Jay Shogren and Joe Aldy
DATE: July 11, 1997
RE: Comments on Electric Power and Renewable Energy Papers

Below we have provided several comments on your papers. If you have any questions, please feel free to contact Joe at 395-1455.

Given that these two papers address many similar issues, we provide one set of comments. It could be beneficial to coordinate these papers, and consider integrating them into one paper. For example, coordinating the presentation of data is of paramount importance. On our first read through of these papers, it appears that the Markal-Macro and DRI models forecast either a 35% increase in non-hydro renewables in 2010 under GHG stabilization (electric power paper) or a more than threefold increase in renewables in 2010 under GHG stabilization (for M-M only in renewables paper). Given the potential uses of these papers, the same set of analytical results should be employed in all discussions.

Electric Power Sector

1) Changing the rate of retirement: Coal plants are, for the most part, fully depreciated. Therefore, the costs of coal-based electricity result from variable cost factors only. Switching to new forms of power requires significant capital investments. This situation puts renewables at a competitive disadvantage with coal, but this situation reflects a market barrier, not a market failure. Since effective policy should focus on failures and not barriers, policy should only affect the rate of retirement by getting the "price right" for carbon emissions.

2) Comparing renewable energy sources to coal-based energy: The modeling efforts anticipate significant decreases in the costs of renewable sources of energy with more R&D investment in the near future. How does the increase in carbon prices affect the investment in cost-reducing technologies for coal power? Do the higher prices stimulate investment in technologies that improve the efficiency of coal-fired power plants? Is there the possibility that utilities could adopt post-combustion carbon sequestration technologies, possibly analogous, in function if not in form, to SO₂ scrubbers?

Renewable Energy Sector

1) Note on biomass fuels: While they may not emit any net carbon, chemical intensive crops for ethanol still have a net positive effect on atmospheric loadings of greenhouse gases through fertilizer applications and escape of nitrous oxides. In addition, growing crops does require the consumption of fossil fuel energy. Further, there is the issue of transporting the biomass. For biomass fuels in cogeneration, which I understand could be scrub grown on marginal agricultural lands, this may not be as serious of an issue. This isn't to say that relative to coal, biomass is a loser, but just to point out that calling biomass a net zero contributor ignores several effects.

Also, the debate on biomass fuels tends to neglect the fact that it reallocates environmental bads from carbon dioxide emissions to chemical runoff and habitat modification.

2) Wind and solar power vary spatially: It would be interesting to know where wind power and solar power are most cost-effective. Some regions can definitely support one or the other better than other regions. However, is this an issue with deregulation of the utility industry? How could state rules on the use of renewable sources of energy by utilities affect allocation of wind- and solar-based electricity from regions with significant wind- and solar-generation to regions with less generation?

3) Factors that accelerate use of renewable energy: The author identifies four factors. Actually, the first two factors are the same: consumer choice and the opportunity to pay a price premium for "green" energy. The third factor is that states may require utilities to pass some renewable energy portfolio standards -- such standards eliminate the likelihood of a green energy premium, since consumers could not differentiate between utilities if they all provide green energy. The fourth factor is that lower renewable energy costs will spur more investments, especially relative to rising fossil fuel costs. Note that firms might invest in renewables even more under deregulation if the price premium effect becomes apparent.

EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL OF ECONOMIC ADVISERS
WASHINGTON, D.C. 20502

MEMORANDUM

TO: Eric Petersen
FROM: Jay Shogren and Joe Aldy *JS*
DATE: July 11, 1997
RE: Comments on Buildings Sector Paper

Below we have provided several comments on your paper. If you have any questions, please feel free to contact Joe at 395-1455.

1) Barriers to adoption: The author notes that there "is clear evidence that many of the potential reductions are not being realized in the current market system because of a number of institutional, organizational, and other barriers that work against the diffusion of energy-efficient technologies." The list of barriers include: insufficient information, lack of expertise for design, lack of low cost sources of capital, and inability for efficiency purchasers to fully capture rents. Barriers are not an indication of market failure. Market barriers reflect the real costs of adopting a technology that may not be included in the explicit price for the technology. For example, this could include the transaction costs of determining how well a new technology works with the building's existing technology. This inadequate information is a private good, not a public good, problem. Therefore, it represents a market barrier, not a market failure. While it is an explanation for why a technology has not been adopted, it is not rationale for policy intervention. Further, without an analysis of these barriers, it is impossible to determine how adoption rates will change under different carbon prices. We shouldn't just assume away the barriers.

2) Cost savings of technologies: The author notes that an array of technologies can have an annualized cost of \$14-\$24 billion/year with an annual energy bill savings of \$33 billion. We would like to see this broken down by each technology, or technology class (some may be big winners and others could be losers). Also, we would like to know the cost assumptions in estimating energy bills (since the modeling efforts presume significant increases in electricity prices). Have there been sensitivity analyses done to estimate if there is some floor price on carbon that would make the technology adoption more costly than the energy bill savings?

EXECUTIVE OFFICE OF THE PRESIDENT
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WASHINGTON, D.C. 20502

MEMORANDUM

TO: Skip Laitner
FROM: Jay Shogren and Joe Aldy *JS*
DATE: July 11, 1997
RE: Comments on Industrial Emissions and Economic Impacts Paper

Below we have provided several comments on your paper. If you have any questions, please feel free to contact Joe at 395-1455.

1) Win-win claim: The author argues that "since these new technologies tend to lower the overall cost of doing business, investments in energy efficient technologies may actually improve the competitive position of many industries." Then why haven't private firms already adopted these technologies? If a private benefit-cost analysis on an energy efficient technology is positive, then there is no need for policy to stimulate the adoption of the technology. Perhaps the slow rate of adoption reflects unaccounted costs in this analysis, such as high costs of capital or high costs of private information.

2) Rates of return: Heat recovery and cogeneration systems can "save 10% of energy use with an internal rate of return of 30-60%." This may be the case, but the omission in this discussion highlights what is probably the case: high capital costs, even with good returns, can serve as a barrier to action.

3) Understated benefits: The author notes that efficiency technologies "often" yield reduced labor and other material costs that are not captured in a discussion of the benefits. On the other hand, assessments of these technologies may not account for firms' opportunity costs for investing capital. If a firm has a fixed pool of investment capital in any period, even if an efficiency technology has a positive benefit-cost analysis relative to doing nothing, it may not be positive relative to the option of improving the quality of the product manufactured.